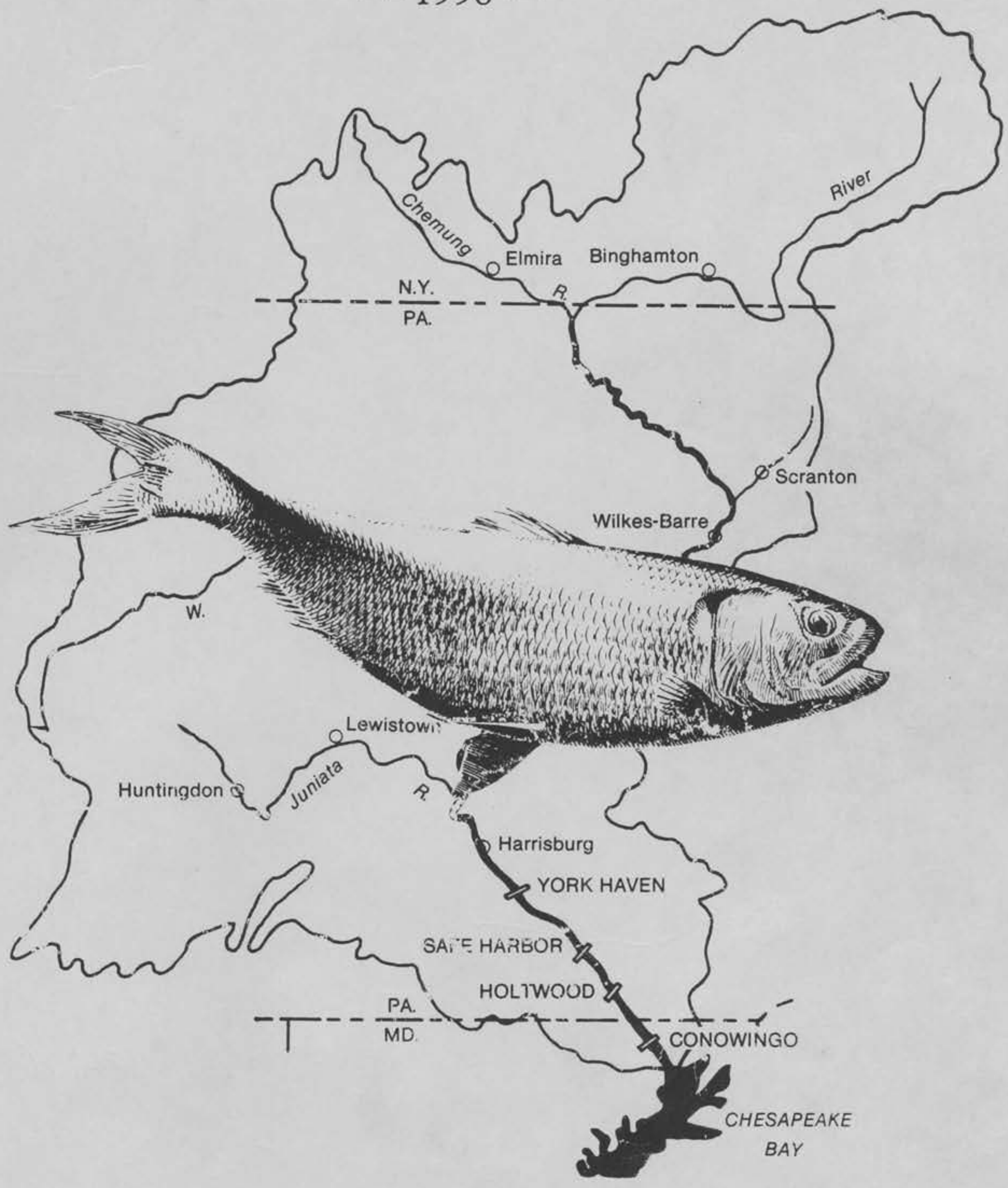
Restoration of American Shad to the Susquehanna River

ANNUAL PROGRESS REPORT

— 1990 —



SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

FEBRUARY 1991

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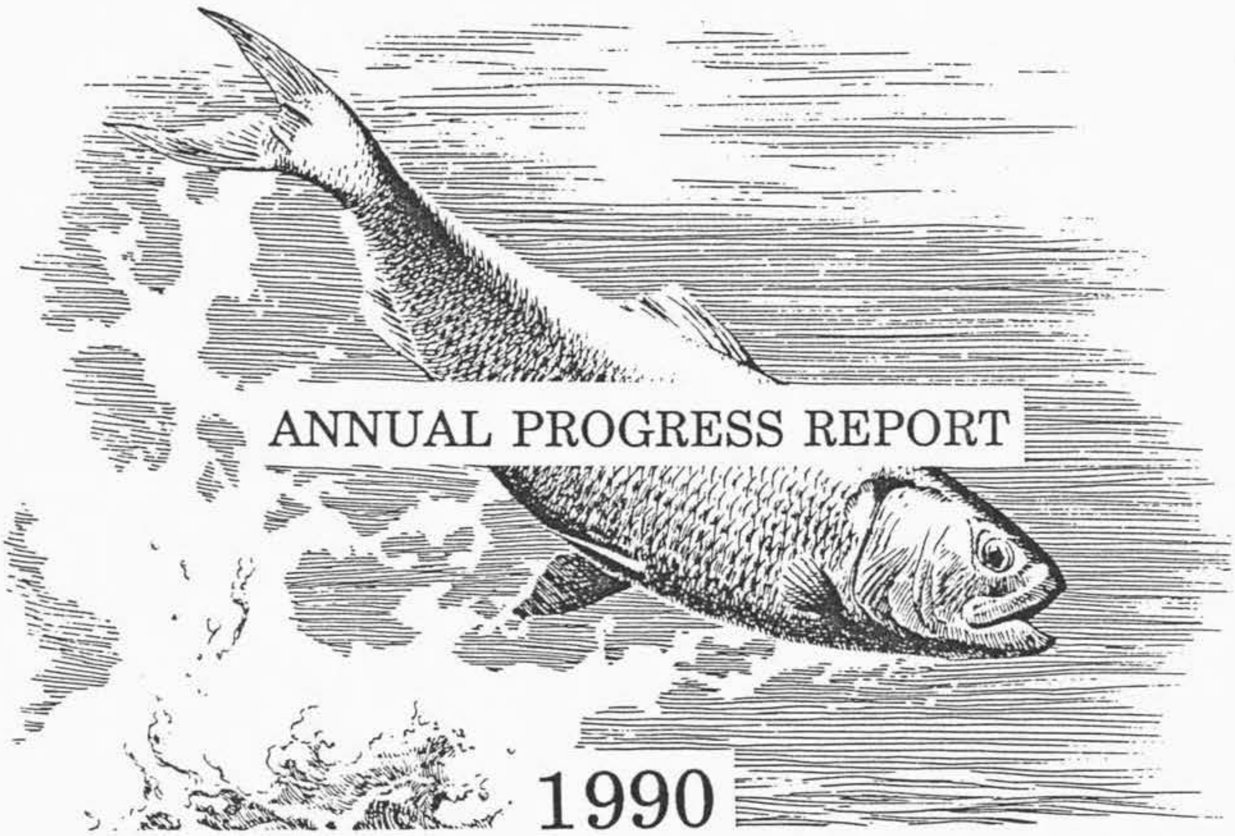

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

MARYLAND DEPARTMENT OF NATURAL RESOURCES
UNITED STATES FISH AND WILDLIFE SERVICE
NEW YORK DIVISION OF FISH AND WILDLIFE
PENNSYLVANIA POWER AND LIGHT COMPANY
SAFE HARBOR WATER POWER CORPORATION
SUSQUEHANNA RIVER BASIN COMMISSION
PHILADELPHIA ELECTRIC COMPANY
PENNSYLVANIA FISH COMMISSION
YORK HAVEN POWER COMPANY

FEBRUARY 1991

EXECUTIVE SUMMARY

The 1990 Annual Report of the Susquehanna River Anadromous Fish Restoration Committee presents results from numerous studies and activities aimed at demonstrating that American shad can be restored to the river. This is the sixth year of a 10-year program to rebuild stocks based on hatchery releases and natural reproduction of adult shad collected at the Conowingo fish lift and transferred upstream to spawn. Considerable efforts are also dedicated to evaluating and improving downstream migration of juvenile shad from the river. The restoration program represents a continuing commitment of state and federal fishery resource agencies and private utility companies to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1990 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 125,574 fish (Petersen Index). This was based on recapture of 70 shad from a tagged population of 581 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay (286 shad) and angling in the Conowingo tailrace (295 fish). Sixty-seven of the recaptures came from the lift at Conowingo. Estimated stock size in 1990 was 66% larger than in 1989 and 16 times greater than that of 1984. The shad population in the Conowingo tailrace was estimated to be 60,541, a 35% increase over that of 1989.

The trap and lift at Conowingo Dam (rm 10) operated for 72 days during the period 2 April through 23 June, 1990. A total of 1.19 million fish representing 44 taxa were handled. The great majority of the catch (94.6%) was comprised of gizzard shad and white perch. Alosa species included 15,964 American shad, 9,658 blueback herring, 426 alewives, and 77 hickory shad. American shad catch in 1990 was 7,653 more than in 1989 and represented a new record high for the Conowingo fish lift since it began operating in 1972. Catch per unit effort of shad at the lift in 1990 was the highest ever at 26.6 fish/trap hour.

Most American shad (9,915) were collected during 24 April to 11 May when river flow was less than 50,000 cfs and Units 1 and 2 were shut down to avoid flow competition with the lift. The largest single day shad catch ever recorded (1,517) occurred on 26 April. Overall sex ratio of shad in lift collections was 3.2 to 1 favoring males. Males ranged in age from II to VII (76% @ IV-V), and females were III to VIII (84% @ V-VI). Based on scale analysis, 50 of 725 (6.9%) shad examined were repeat spawners and 9 of these had two spawning checks.

A total of 15,075 American shad was transported to potential upstream spawning areas with less than 2% observed mortality. Of that total, 1,869 shad were stocked at the PA Fish Commission access at Swatara Creek, 11,269 were placed directly into the river at Tri-County Boat Club above York Haven Dam, and 1,937 were placed into a holding pen at Tri-County Marina. Of the 10,083 river herring taken at the trap in 1990, 5,408 were stocked into five upper Chesapeake Bay tributaries to support restoration efforts by the Maryland DNR, and 1,034 were hauled upstream in the Susquehanna River with mixed loads of shad.

A net pen measuring approximately 8.5' x 18' x 4.5' deep was deployed and stocked with shad at Tri-County Marina to assess hauling and delayed mortality, to enhance schooling and to attempt to relieve handling stress. A total of 1,937 shad were stocked in 16 trials (range 42-170 fish) during 30 April through 15 June. Of this number, transport mortality amounted to 2.8% and delayed mortality was another 3%, excluding 75 shad which died on 6 May when the pen filled with debris from the flooding Swatara Creek. Most of the 1,751 shad released from the pen after 15-22 hours holding appeared healthy and schooled normally.

In a special study by Maryland DNR and University of Maryland researchers stress response in adult shad was evaluated using serochemical analysis for electrolytes, kidney and liver function and reproductive potential. Blood and egg samples were removed from females immediately after capture at the fish lift, after holding, hauling and penning at Middletown. The greatest stress effect on these fish was noted in alteration in liver enzymes and elevation of blood carbon dioxide levels probably caused by handling-induced hypoxia.

A total of 196 adult shad from the Conowingo lift were transported to the RMC Muddy Run laboratory in 7 shipments between 16 May and 11 June. These were used in a special study to artificially induce spawning in shad using hormone injections. Human chorionic gonadotropin (HCG) and luteinizing hormone-releasing hormone ethylamide (LHRH-alpha) were both effective in inducing ovulation in shad. Over 300,000 eggs were stripped, fertilized and sent to the Van Dyke hatchery but only 31,000 viable eggs resulted.

The Pennsylvania Fish Commission operated the intensive culture facility at Van Dyke and rearing ponds at Thompsontown and Upper Spring Creek. During the period 17 April to 13 June, 28.6 million shad eggs were delivered to Van Dyke from the Savannah River (123,000), the Pamunkey River (477,700), the Delaware River (13.15 M), the Hudson River (14.53 M), and the Susquehanna River (327,200). Overall viability of eggs was 56.7% resulting in production of 13.06 million fry.

All fry produced at Van Dyke were distinctively marked with two to four separate 6-hour immersions in 200 ppm tetracycline (TC). About 5.62 million 16-29 day old fry were stocked in the Juniata River at Thompsontown, 3.94 million were stocked in the lower Susquehanna River at Lapidum, MD, and 2.37 million were placed in the Lehigh and Schuylkill rivers. The PA Fish Commission also reared 90,000 fingerlings from about 450,000 fry. Most of these were stocked at Thompsontown in early November. Maryland DNR received 530,000 fry and produced 163,000 fingerlings which were stocked at Havre de Grace and Elkton, MD in early October. In addition to immersion tags put on fish at Van Dyke, pond reared fish in PA and MD were also marked with TC-laced feed.

Cultural research conducted by the PFC in 1990 included egg viability testing with new bottom screens for Van Dyke jars and feed trials to determine effectiveness of AP-100 dry diet as a sole source of starter feed. PFC also continued a special study to evaluate the use of otolith microstructure to distinguish between wild and hatchery-reared shad in the Susquehanna River. They concluded that random selection of adult shad from the Conowingo fish lift provided a more accurate subsample of the return stock than use of handling and trucking mortalities. Based on microstructure of otoliths, hatchery shad comprised 81% of the trap catch in 1989 and 73% in 1990. Also, in a blind study, 89% of juvenile shad evaluated from several year-classes were correctly classified as to hatchery or wild source based solely on otolith microstructure. Mean daily increment spacing (first 15 days) was found to be significantly larger on otoliths of wild shad than those of hatchery origin.

As in past years, a considerable effort was devoted to assessing relative abundance, growth, timing of migration and source of juvenile shad during summer nursery and autumn outmigration from the river. In 1990, shad were sampled with seines at several sites above and below York Haven Dam; with cast nets in the York Haven forebay; with lift nets at Holtwood; from cooling water intake strainers and screens at Safe Harbor, Conowingo and Peach Bottom; and by netting and electrofishing in the upper Chesapeake Bay.

Shad were plentiful in free-flowing waters above Columbia, PA in August and September. Outmigration from the river occurred during the last two weeks in October and was closely correlated with high flows and rapidly declining water temperature. Juvenile shad grew well in the Susquehanna from a mean total length of about 70 mm in early August to 140 mm by November. Pond-reared fingerlings in collections were significantly smaller than similar aged shad released as fry. They demonstrated rapid downstream movements in early November. Relative abundance of shad appeared substantially greater than in prior years.

Almost 1,000 shad from collections at York Haven Dam and pool, New Cumberland, Highspire, Columbia, Wrightsville, Marietta, and Holtwood were returned to Benner Spring for tetracycline mark analysis. A total of 765 otoliths were examined from these collections and only 14 (1.8%) were unmarked and displayed wild microstructure. Hudson River fish showed highest relative survival based on numbers of fry stocked and comprised 97% of all marked fry-release shad analyzed from collections above Conowingo Dam. Delaware River fish constituted 29% of all fry stocked but less than 3% of recoveries. Pamunkey River fish made up less than 1%

of juveniles analyzed. Maryland DNR personnel collected 61 juvenile shad with various gear in the upper Chesapeake Bay during July through October. Of 57 age-0 fish analyzed for tags on otoliths, 54% were double-marked fish stocked at Lapidum and 46% were determined to be wild.

The Electric Power Research Institute, Metropolitan Edison Company and SRAFRC co-funded a continuation of the study at York Haven Dam to assess the effectiveness of underwater strobe lights to repel juvenile shad away from turbines and through an open trash sluice. Fish gathered at York Haven by late September and 117 tests were run through mid-October. Shad exhibited avoidance response to the strobe lights as expected, but with relatively high temperatures and low flows, large numbers of fish were not repelled through the open sluice as was noted in 1988. A trammel net fished in front of Unit 1 showed that few shad were startled into the turbine intake flow and most moved out to mid-forebay. High river flows in mid-October forced premature conclusion of the study - prior to shad outmigration.

The log chute immediately outside the forebay skimmer wall at Holtwood Dam was evaluated for effectiveness as a downstream passage route. Thirty juvenile shad were radiotagged and released above the chute in three lots of 10 fish each to examine behavior under different plant operating conditions. In two tests when spilling did not occur at the dam, 4 fish used the log chute, 5 went through turbines and 11 either did not pass the project or their passage route was undetermined. In the third test with spill at the dam, 4 fish went through turbines and 3 used the spillway. An additional 10 shad were released into flow at the open log chute and 9 were recovered downstream. All died within 24-hours and exhibited extensive descaling. Thermal mapping of the Holtwood forebay during project shutdown showed that discharge from the adjacent steam station increased surface and near-surface water temperature by about 6°C. Ambient conditions returned quickly when generation resumed.

American shad egg collection, hatchery culture, research and marking, juvenile recovery and mark analysis, adult shad net pen investigations, stress analysis, artificially induced spawning trials, juvenile shad telemetry and thermal mapping at Holtwood were funded from the 1985 settlement agreement with upstream utilities. The strobe light demonstration study at York Haven was co-funded by SRAFRC, EPRI and Met Ed. Philadelphia Electric Company paid for operation of the trap and lift at Conowingo, transfer of adult shad upstream, and strainer and screen checks at Conowingo Dam and Peach Bottom. Maryland DNR funded the adult shad population assessment, juvenile shad netting and electrofishing in the upper Chesapeake Bay, and fingerling pond culture at Havre de Grace and Elkton.

Additional information on activities discussed in this Annual Report can be obtained from individual Job authors or by contacting the Susquehanna River Coordinator, U. S. Fish and Wildlife Service, 1721 N. Front Street, Harrisburg, PA 17102.

Richard St. Pierre
Susquehanna River Coordinator

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INTRODUCTION

The Conowingo Dam Fish Passage Facility (hereafter Lift) has been in operation since 1972. It is part of a cooperative private, state, and federal effort to restore American shad to the upper Susquehanna River. In accordance with the restoration plan, the operational goal of the Lift has been to monitor fish populations below Conowingo Dam and transport as many migratory fishes (American eel, river herrings, American shad, and striped bass) upriver as possible. Funding for the operation and maintenance of the Lift is provided by subsidiaries of Philadelphia Electric Power Company (PECO).

The Conowingo Hydroelectric Station is operated as a run of the river peaking power station. The maximum rated peak discharge from its eleven units is 85,000 cfs. Natural river flow in excess of 85,000 cfs is released over the spillway. Generally, under efficient operation conditions, total discharge from the seven (1-7) small (5,000 cfs each) and four (8-11) large units (10,000 cfs each) is 75,000 cfs.

Objectives of the 1990 operation were to: (1) contribute to restoration efforts by the trap and transfer of prespawned American shad to pre-determined upstream localities, (2) monitor relative abundance of Alosa species, (3) obtain life history information from selected migratory fishes, (4) monitor species composition, (5) assist the Maryland Department of Natural Resources (MD DNR) in assessing the American shad population in the upper Chesapeake Bay, (6) obtain sagital otoliths from American shad for stock identification, (7) provide American shad for special studies and (8) as feasible contribute to river herring (alewife and blueback herring) restoration efforts by the trap and transfer of pre-spawned adults to pre-determined upstream locations and upper Chesapeake Bay tributaries.

METHODS

Prior to the operation of the Lift, surveys were initiated in mid-March 1990 to detect the arrival of alosids into the lower river system. Surveys were conducted at Stafford Bridge, at the mouth of Deer Creek, and in Octorara Creek. Eight surveys were conducted between 14 and 30 March. Two river herring were observed. Water temperature during these surveys varied from 42.8 to 60.0 F.

Preparations for the operation of the Lift began in early March and included a series of steps to make the Lift reliable and operable at 120,000 cfs in accordance with the Federal Energy Regulatory Commission (FERC) order issued on 7 January 1987 and outlined in the settlement agreement of 24 January 1989. The steps taken, and agreed to by the Susquehanna River Technical Committee (SRTC), are presented in Table 1.1. Lift operation was consistent with the 1990 SRTC Work Plan. As a result of the settlement agreement between PECO and resource agencies turbine Units 1 and 2 were shutdown when river flows were less than 65,000 cfs.

Lift operation commenced on 2 April and occurred on a alternate half day (0700-1300 hrs) basis through 20 April. The increased collection of shad on 20 April resulted in daily (0700 to approximately 1900 hrs) operation of the Lift on 20 and 21 April. Since no shad were collected on 22 April the Lift was operated for a half day. Lift operation resumed on 24 April and was operated daily through 31 May. The operation was canceled at 1535 hrs on 1 June because of mechanical problems (hopper was slipping). Operation resumed at 1140 hrs on 2 June after repairs were completed. Failure of a worm gear in the crowder swing mechanism at 1535 hrs on 2 June resulted in another shutdown. Lift operation resumed on 4 June and continued daily through 15 June. Although the Lift was operated daily from 16 to 23 June, operation was based on the shad catch. Generally, if no shad were collected during the last scheduled hour of operation (1200-1300 hrs) the Lift was shutdown. However, if a shad was collected between 1200 to 1300 hrs operation continued until no shad were collected in a one hour period. The spring trapping season ended on 23 June due to the limited number and the advanced spawning condition of shad collected.

The mechanical aspect of Lift operation in 1990 was similar to that described in RMC (1983). Fishing time and/or Lift frequency was determined by fish abundance and the time required to process the catch. However, due to large numbers of gizzard shad in the tailrace, two modifications implemented in 1985 to maximize collection of American shad were utilized (RMC 1986). Operation "Fast Fish"* (RMC 1986) was employed on an as needed basis and resulted in increased fishing time during periods of heavy fish activity by reducing mechanical delays associated with normal Lift operation. On several occasions, as a result of changes in water level and turbine discharge in the tailrace, large numbers of gizzard shad were attracted to the Lift. In an effort to maximize the collection of American shad, either weir gate 1 or 2, (Figure 1.1) was closed and fish that had accumulated were lifted rapidly

*Operation "Fast Fish" is leaving crowder in normal fishing position and raising hopper as necessary to remove fish that accumulated in the holding channel.

within minutes. Normal operation of the Lift was resumed after most fish had been removed. Attraction velocity and flow at the Lift were similar to those maintained since 1982 (RMC 1983). Based on the 1982 data, hydraulic conditions were maintained in the area of the Lift between the crowder and weir gate entrances similar to that reported in RMC (1983). Modifications to weir gates and house service unit settings were made during periods of heavy fish concentration and were similar to those maintained in 1985 (RMC 1986).

Minimum flow releases followed the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500, and 5,000 cfs were maintained from 1 to 30 April, 1 to 31 May, and 1 to 18 June, respectively. Generally, Unit Nos. 5 and 6 were used to meet minimum flow releases during April and May. Unit No. 5 was used to release the minimum flow in June. The minimum release from Unit Nos. 5 and 6 was based on results of 1982 and experience at other fish passage facilities which showed that passage effectiveness increased when competition was reduced between the attraction flow from the passage devices and the flow releases from other sources.

Fishes were processed as reported earlier (RMC 1983). Fishes were either counted or estimated (when large numbers were present) and released back to the tailrace. Length, weight, sex, and scale samples were taken from blueback herring, hickory shad, and alewife. The use of scientific and common names of fishes collected (Table 1.2) followed Bailey et al. (1970). Life history information (i.e. length, weight, sex, spawning condition, scales and otoliths) were taken from American shad that were sacrificed or released back to the tailrace and those that died in handling and transport. Per the 1990 work plan every 100th shad collected was sacrificed so otoliths could be removed and utilized in a stock identification study by the Pennsylvania Fish Commission. In addition, ovarian tissue, scale samples, lengths and weights from female American shad were provided to researchers from Johns Hopkins University for mitochondrial DNA analysis.

American shad scales were cleaned, mounted, and aged according to Cating (1953). The procedures employed to determine age structure and spawning history of shad were similar to those used by MD DNR, and had been validated through an exchange of scale samples in 1982 and 1983.

Holding and Transport of Shad and River Herring

The trap and transport of American shad is the primary purpose of Lift operation. Generally, transport occurred whenever 100 or more green or gravid shad were collected in a day, or at operators discretion. As feasible, up to 5,000 river herring were scheduled to be transported to Upper

Chesapeake Bay tributaries to assist MD DNR with restoration activities. Additional river herring collected and transported were scheduled to be released upriver. American shad and river herring transported upriver were released at the Tri-County Boat Club Marina located on the east shore of the river above York Haven Dam.

Based on results of holding experiments conducted in 1986, shad were held until a sufficient number was collected in order to increase the efficiency of the transport program. Four black circular tanks (2-800 gal., 2-1000 gal.), continually supplied with river water, were used as holding tanks. The aeration system utilized bottled oxygen and/or compressed air. Also, each tank was fitted with a cover to prevent escape and to reduce stress. Fish were transported in 1,100 gallon circular transfer units. All transfer units were equipped similarly to the system used in 1985 (RMC 1986). The holding and handling procedures employed during transport were similar to those used in previous years.

RESULTS

The relative abundance of fishes has fluctuated since 1972 (Table 1.3). Fluctuations have resulted primarily from changes in species abundance and modification to Lift and turbine operation. Prior to 1980, alosids (primarily blueback herring) and white perch dominated the catch.

Generally, from 1980 to 1990 the catch has been dominated by gizzard shad and white perch.

In 72 days of Lift operation in 1990 (2 April through 23 June) 1,187,889 fish of 44 taxa were caught (Tables 1.3 and 1.4). Predominant species in order of numerical abundance were gizzard shad, white perch, and American shad. Alosids (blueback herring, alewife, hickory shad, and American shad) comprised less than 2.2% of the total catch. Although the catch of gizzard shad was higher than that observed in 1989 it was lower than the catch recorded between 1984 and 1988 (Table 1.3). Gizzard shad dominated the catch daily from 2 April to 18 June and comprised over 92.5% of the total catch. The daily catch of fish ranged from 1,407 on 6 April to 71,459 on 13 May (Table 1.4).

Although large numbers of gizzard shad were observed in the tailrace and they dominated the catch almost daily it appeared that shutdown of Unit Nos. 1 and 2 when river flows were <65,000 cfs may have been the primary reason that the catch of gizzard shad at the Lift was minimized. Operation "Fast Fish" was utilized more frequently in 1990 than 1989. However, it was not utilized as frequently in 1990 as it was between 1985 and 1988.

American Shad

Catch

The 1990 catch of American shad (15,964) at the lift was the highest ever recorded since Lift operation began in

1972 (Table 1.4). Over 95% (15,282) of the shad collected were transported. Three hundred three shad were released back to the tailrace. The remainder of the fish consisted of Maryland DNR recaptures, handling and holding mortalities, and fish that were sacrificed.

A total of 185 shad (1.2%) died during daily operation of the Lift. Mortalities resulted from mechanical operation of the Lift, handling, and holding procedures. This mortality was within the range of mortality (1-3%) normally observed at the Holyoke Fish Lift where handling is generally non-existent; shad swim through a flume to gain access to the area upstream of the dam.

American shad were first observed at the Lift on 14 April (Table 1.4 and Figure 1.2). Most shad (9,915) were collected from 24 April through 11 May (Units No. 1 and 2 off). Some 2,313 American shad were collected from 12 May to 1 June. During this period the majority of lift operation coincided with full peak station operation and/or spills. A total of 4,334 shad was collected from 2 to 15 June (Units No. 1 and 2 off).

Modified weir gate openings in combination with operation "Fast Fish" was employed based on operators experience to decrease the gizzard shad catch and increase the American shad catch. This mode of operation was utilized for varying amounts of time on twenty-two days and resulted in an increased shad catch on fifteen days (Table 1.5).

As in the past, the catch per effort (CPE) of American shad varied by station generation and time of day (Table 1.6). The total catch of shad was much lower on weekends (3,807) than on weekdays (12,157). The CPE was 21.8 and 27.3 on weekends and weekdays, respectively. Generally, during both periods catches were greatest between 1100 and 1900 hrs with the highest catches occurring from 1500 to 1900 hrs.

The CPE was greatest during periods of minimum flow at 2 unit generation (7,500 and 10,000 cfs) (Table 1.7). The CPE was over 4 fold higher during periods of minimum flow at 2 unit generation than at 1 unit generation (5,000 cfs) and almost 2 fold higher than at higher levels of generation.

The largest daily catch (1,517 shad) ever recorded at the Lift occurred on 26 April (Table 1.4). Combined with the catch (1,283 shad) on 27 April it represented 17.5% of the 1990 shad catch.

American shad were collected at water temperatures of 49.6 to 77.5 F and at natural river flows of 18,200 to 96,700 cfs (Table 1.4 and Figure 1.2). Over 79% (12,689 shad) of the catch occurred at river flows less than 50,000 cfs. Some 9,708 shad were collected from 24 April to 10 May when flows were less than 36,100 cfs.

Over 58% of the shad were collected at water temperatures ≤65 F (Table 1.8). Water temperatures during the period of peak shad abundance (24 April to 11 May) ranged from 55.0 to 68.0 F. Water temperatures from 12 May to 3 June a period of increased river flow and decreased shad catch, ranged from 60.8 to 63.7 F. Generally, from 4 June to 23 June water temperatures increased and ranged from 67.6 to 77.5 F.

Transport

Pre-spawned American shad were transported from 24 April through 23 June. Most American shad were transported to the Tri-County Boat Club Marina access located above the York Haven Dam. A total of 1,869 shad was transported to the Pennsylvania Fish Commission (PFC) access at Swatara Creek (upstream of Tri-County) when access to the Tri-County facility was blocked due to Conrail construction activities. Eleven shad were transported by USF&WS personnel to their laboratory at Wellsboro, and 196 shad were transported to the Muddy Run Ecological Laboratory (MREL) at Drumore for artificial spawning studies.

Some 14,889 (93% of 1990 catch) American shad were transported to upstream spawning areas with an overall observed stocking survival of 98.1% (Table 1.9). Some 11,269 and 1,869 American shad were stocked directly to the river above York Haven Dam at Tri-County and Swatara Creek, respectively. In addition, 1,751 shad were successfully released from a net pen at Tri-County.

Transportation of shad occurred on 46 days and was accomplished in 86 trips. Generally, individual trips to Tri-County averaged 2.5 hours. The number of trips per day ranged from one to four; load size varied from 10 to 350 individuals per trip. Trip survival varied between 90.3 to 100%. Shad were transported at water temperatures of 54.7 to 77.5 F.

A total of 1,937 American shad was transported to an instream net pen located at Tri-County. The results of the net pen study are presented in Section 1A. In general, the results indicated that mortality (short term and delayed) associated with trap and transport appeared to be low.

The transportation of a large number of shad afforded the opportunity to estimate the potential contribution of these fish to the restoration program. The potential egg deposition of shad was calculated assuming an average fecundity of 200,000 eggs/female. Some 5,488 females were transported to upstream spawning areas, assuming that the percentage of females transported was the same as that of total fish collected. Estimated egg disposition of these 5,488 fish was 109×10^7 eggs.

Based on the 1987 results, holding facilities were utilized to allow shad collected on a given day to be held overnight or for several days to maximize transport operations and release larger schools of fish. Some 2,888 shad were held over at the Lift. The number of shad held varied from 1 to 387. A total of 104 shad died in the holding tanks.

Sex Ratios

Visual macroscopic inspection of shad was made to determine daily and seasonal sex ratios. Generally, when the daily catch exceeded 100 shad a minimum subsample of 100 fish was examined; when the daily catch was less than 100 shad all fish were sexed. Five thousand one hundred sixty-eight American shad were sexed in 1990. The daily sex ratio of shad collected at the Lift is given in Table 1.10. Males dominated the catch accounting for an overall male/female ratio of 3.2:1. Males outnumbered females from 14 April to 9 June; 5 May excluded. The number of females contributing to the catch increased in late May and peaked from 10 June to 20 June. Generally, the distribution of males to females in relation to the catch in 1990 was similar to that observed in past years.

Age Composition

Seven hundred twenty-five scale samples were collected in 1990. Scale samples were obtained from fish sacrificed for otoliths and DNA analysis, transport and handling mortalities, and from fish released back to the tailrace.

Therefore, this information is provided only to observe general trends.

Over 94% (688) of the scale samples collected were aged successfully in 1990. Males ranged from II to VII years old while females aged were III to VIII years old (Table 1.11). Most males (75.9%) were IV and V year olds while most females (83.9%) were V and VI year olds. Twenty-four males were repeat spawners; four were double repeat spawners. Twenty-six females were repeat spawners; five were double repeat spawners.

Tag-Recapture

RMC recaptured 70 MD DNR tagged American shad at the Lift in 1990, two were captured twice and one was tagged in the tailrace in 1989 (Table 1.12). The MD DNR tagged 581 shad in 1990;286 from pound nets in the upper bay and 295 by hook and line in the Conowingo tailrace. Of the 67 MD DNR recaptures 52 and 15 were tagged in the tailrace and in the upper bay, respectively. The fifteen tagged in the upper bay averaged 30.6 days free before capture at the Lift, while those tagged in the tailrace and recaptured at the Lift averaged 16.9 days free.

River Herring

Catch

The combined catch of river herring increased from that observed in 1989, but was much lower than historic levels (Table 1.3). The catch of blueback herring was over 2.5 fold higher than that observed in 1989. However, the catch of alewife was about 77% less than that observed in 1989.

A total of 9,658 blueback herring was collected (Table 1.4). Blueback herring typically arrive later than alewife and were first collected on 25 April. Over 40% of the catch occurred on 5 May and 99% of the total catch was collected from 26 April to 22 May at water temperatures of 59.0 to 62.6 F.

A total of 425 alewife was collected, with the first capture on 14 April (Table 1.4). Over 93% of the catch occurred between 21 April and 6 May at water temperatures of 52.7 to 66.2 F.

Transport

During the spring a total of 6,442 river herring (64% of total catch) was transported and included 175 alewife and 6,267 blueback (Table 1.13). Fishes were transported between 24 April and 25 May.

A total of 5,408 river herring (5,240 blueback herring and 168 alewife) were transported to five Chesapeake Bay tributaries for the MD DNR. The overall stocking survival was 98.5%. The Patapsco River, Winters Run, Little Patuxent River, Big Elk Creek, and Tuckahoe Creek received stockings that totaled 94, 3,750, 196, 300 and 1,068 river herring, respectively. Over 69% (3,750 fish) of the river herring transported were stocked in Winter Run on 5 May. Transport was accomplished in 7 trips. Load size transported varied from 300 to 1,500 fish per trip. Trip survival varied from 93.2 to 100 %.

A total of 1,034 river herring (7 alewife, 1,027 blueback herring) was transported and released into the Susquehanna River at the Tri-County Boat Club Marina (Table 1.13). Five of six loads transported were mixed loads that contained American shad. No transport mortalities were observed.

Hickory Shad

The hickory shad catch (77) continued to be low (Table 1.3). The first hickory shad was captured on 16 April (Table 1.4). Ninety-six percent of the total catch was collected from 25 April to 3 May at water temperatures of 57.7 to 67.6 F.

DISCUSSION

The run of shad is primarily dictated by natural river flows and water temperatures. The catch at the Lift is primarily dictated by variations in station discharge (peak load vs reduced generation), natural river flows, and the size and nature of the shad run (it occurs in waves). Station discharge is dictated by natural river flows, peak power demand, and minimum flow requirements.

A combination of several factors resulted in the record catch of 15,964 shad at the Lift. However, it appeared that the primary reasons were an increased shad population, and modification of station operation (Unit Nos. 1 and 2 off when river flows were less than 65,000 cfs) combined with an increase in the hours that the Lift was operated.

The settlement agreement of 1989 required the shutdown of Unit Nos. 1 and 2 (adjacent to the Lift) when river flows were less than 65,000 cfs. This increases Lift efficiency since the attraction flow from the Lift is not competing with the discharge from the adjacent units (RMC 1990). In 1990, 85.0% (13,505 shad) of the catch occurred when Unit Nos. 1 and 2 were off. Some 11,563 shad were collected at discharges of 10,000 to 6,500 cfs when Unit Nos. 1 and 2 were off.

The CPE in 1990 was the highest observed since Lift operation began (Table 1.14). The total CPE from 1985 to 1990, years of increased collections, was 4.6, 11.9, 15.1, 9.8, 17.3, and 26.6, respectively. However, since numerous factors affect the catch of shad at the Lift these data denote only general trends. The CPE in 1987 and 1989 was similar and higher than that observed in 1986 and 1988.

Catch rates in 1985 were much lower. In contrast, the estimated shad population in the upper Chesapeake Bay has been increasing since 1985 (Job VI).

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TABLE 1.1

The status of steps taken prior to 29 March 1990 to make the Conowingo Dam Fish Lift reliable and operable at 120,000 cfs.

STEPS
1. Inspect above and below water line and perform repairs as required. STATUS: Completed. Resulted in repair of valves 4 and 5.
2. Perform preventive maintenance including: a) Check out entire electrical system and replace any worn or corroded contacts; b) Clean out holding channel of any trash which may have accumulated over the fall and winter seasons; c) Calibrate weir gates to assure proper attraction flow; d) Recondition and install pumps which provide water to the fish sorting areas; STATUS: Items a through d completed.
3. Provide as required a crane or block and tackle system so that the weir and crowder motors can be removed when the station discharge flow goes above 120,000 cfs and subsequently reinstalled before the flow drops back down to 120,000 cfs. Additionally, the conduit to these motors will be checked for water tightness prior to operation, cracks will be sealed, and any worn junction box gaskets will be replaced. When water levels approach the level of the conduit, the conduit will be pressurized to further assure that the conduit will remain dry and that the crowder and weir gates can operate up to and including 120,000 cfs. STATUS: Completed. During spring a crane was made available on site as needed to install and remove the crowder and weir gate motors.
4. The licensees will also maintain on hand at the Dam various spare components and hoses. These will enable rapid repair in the event of an unforeseen breakdown of the lift. STATUS: Completed. Spare hoses, electrical components and a water supply pump were on hand.

TABLE 1.2

List of scientific and common names of fishes collected at the Conowingo Dam Fish Lift, 1972 through 1990.

Scientific Name	Common Name
Family - Petromyzontidae	Lampreys
Petromyzon marinus	Sea lamprey
Family - Anguillidae	Freshwater eels
Anguilla rostrata	American eel
Family - Clupeidae	Herrings
Alosa aestivalis	Blueback herring
Alosa mediocris	Hickory shad
Alosa pseudoharengus	Alewife
Alosa sapidissima	American shad
Brevoortia tyrannus	Atlantic menhaden
Dorosoma cepedianum	Gizzard shad
Family - Salmonidae	Trouts
Coregonus artedii	Lake herring
Oncorhynchus gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
S. fontinalis x S. namaycush	Splake
Family - Esocidae	Pikes
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Esox niger	Chain pickerel
E. masquinongy x E. lucius	Tiger muskie
Family - Cyprinidae	Minnows and carps
Carassius auratus	Goldfish
Cyprinus carpio	Carp
Nocomis micropogon	River chub
Notemigonus crysoleucas	Golden shiner

TABLE 1.2

Continued.

Scientific Name	Common Name
Family - Cyprinidae (continued)	
Notropis amoenus	Comely shiner
Notropis hudsonius	Spottail shiner
Notropis procne	Swallowtail shiner
Notropis rubellus	Rosyface shiner
Notropis spilopterus	Spotfin shiner
Notropis spp.	Minnows
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Rhinichthys cataractae	Longnose dace
Family - Catostomidae	Suckers
Carpiodes cyprinus	Quillback
Catostomus commersoni	White sucker
Erimyzon oblongus	Creek chubsucker
Hypentelium nigricans	Northern hog sucker
Moxostoma macrolepidotum	Shorthead redhorse
Ictiobus cyprinellus	Bigmouth buffalo
Family - Ictaluridae	Freshwater catfishes
Ictalurus catus	White catfish
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Noturus insignus	Margined madtom
Noturus spp.	Madtoms
Family - Belonidae	Needlefishes
Strongylura marina	Atlantic needlefish
Family - Cyprinodontidae	Killifishes
Fundulus heteroclitus	Mummichog
Family - Percichthyidae	Temperate basses
Morone americana	White perch
Morone saxatilis	Striped bass
M. saxatilis x M. chrysops	Striped bass x White bass

TABLE 1.2

Continued.

Scientific Name	Common Name
Family - Centrarchidae	Sunfishes
<u>Ambloplites</u> <u>rupestris</u>	Rock bass
<u>Lepomis</u> <u>auritus</u>	Redbreast sunfish
<u>Lepomis</u> <u>cyanellus</u>	Green sunfish
<u>Lepomis</u> <u>gibbosus</u>	Pumpkinseed
<u>Lepomis</u> <u>macrochirus</u>	Bluegill
<u>Micropterus</u> <u>dolomieui</u>	Smallmouth bass
<u>Micropterus</u> <u>salmoides</u>	Largemouth bass
<u>Pomoxis</u> <u>annularis</u>	White crappie
<u>Pomoxis</u> <u>nigromaculatus</u>	Black crappie
Family - Percidae	Perches
<u>Etheostoma</u> <u>olmstedi</u>	Tessellated darter
<u>Etheostoma</u> <u>zonale</u>	Banded darter
<u>Perca</u> <u>flavescens</u>	Yellow perch
<u>Percina</u> <u>caprodes</u>	Logperch
<u>Percina</u> <u>peltata</u>	Shield darter
<u>Stizostedion</u> <u>vitreum</u>	Walleye
Family - Osmeridae	Smelts
<u>Osmerus</u> <u>mordax</u>	Rainbow smelt
Family - Mugilidae	Mullets
<u>Mugil</u> <u>cephalus</u>	Striped mullet

TABLE 1.3

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1990.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
NO. DAYS	54	62	58	55	63	61	35	29	30	37
LIFTS	817	1,527	819	514	684	707	358	301	403	490
EST. OPER. TIME(HR.)	608	996	500	307	375	413	212	187	221	275
FISHING TIME(HR)	313	623	222	189	252	245	136	123	117	178
# SPECIES	40	43	42	41	38	40	44	37	42	48
AMERICAN EEL	805	2050	91937	64375	60409	14601	5878	1602	377	11329
BLUEBACK HERRING	58198	330341	340084	69916	35519	24395	13098	2282	502	618
HICKORY SHAD	429	739	219	20	-	1	-	-	1	1
ALEWIFE	10345	144727	16675	4311	235	188	5	9	9	129
AMERICAN SHAD	182	65	121	87	82	165	54	50	139	328
GIZZARD SHAD	24849	45668	119672	139222	382275	742056	55104	75553	278738	1156662
ATLANTIC MENHADEN	-	-	112	-	506	1596	-	-	16	42
TROUTS	1	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	34	67	20	24	54	291	70	15	23	219
BROWN TROUT	172	286	483	219	427	700	261	324	258	207
BROOK TROUT	1	3	4	1	-	2	23	-	4	3
TROUT	-	-	-	-	-	-	-	-	-	2
RAINBOW SMELT	-	-	-	-	-	-	-	-	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-		-	-
CHAIN PICKEREL	-	1	10	-	-	1	-	-	-	1
NORTHERN PIKE	-	2	2	-	-	2	2	4	3	-
MUSKELLUNGE	20	104	9	7	12	48	14	5	27	1
REDFIN PICKEREL	-	-	-	-	-	-	-	-	-	-
CARPS AND MINNOWS	-	-	-	-	-	-	-	-	-	-
GOLDFISH	-	27	1	9	4	1	-	-	-	1
COMMON CARP	4370	16362	34383	15114	6755	16256	11842	14946	8879	16313
RIVER CHUB	-	-	-	-	-	-	-	-	1	-
GOLDEN SHINER	165	430	437	751	1622	652	221	304	35	155
COMELY SHINER	5	252	3870	2079	740	769	1152	1707	781	281
SPOTTAIL SHINER	34	137	2036	268	1743	8107	8506	1533	849	31
SWALLOWTAIL SHINER	-	-	-	-	-	-	-	-	-	3
ROSYFACE SHINER	1	-	-	1	-	-	-	-	-	-
SPOTFIN SHINER	103	40	3011	1231	45879	7960	3751	41	314	524
BLUNTNOSE MINNOW	-	-	-	-	-	-	4	-	-	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	1	-	-	-	4	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-	-	-
SHINERS	264	3	-	-	-	-	-	-	-	-
QUILLBACK	7119	27780	14565	8388	9882	6734	2361	5134	2929	3622
WHITE SUCKER	363	1034	286	152	444	282	189	906	1145	1394
CREEK CHUBSUCKER	3	3	1	-	-	-	-	-	-	4
NORTHERN HOG SUCKER	-	2	-	1	5	-	3	6	13	1
SHORTHEAD REDHORSE	1097	4420	434	445	1276	1724	697	2163	1394	8533
WHITE CATFISH	3070	6394	2200	6178	1451	3081	982	515	605	2199
YELLOW BULLHEAD	7	45	1	32	2	47	25	13	18	36
BROWN BULLHEAD	510	5328	1612	740	451	2416	125	284	675	531
CHANNEL CATFISH	61042	55084	75663	74042	41506	90442	48575	38251	38929	55528
MARGINED MADTOM	-	-	-	-	-	-	-	.-	-	-
MADTOMS	-	-	-	-	-	-	-	-	-	-
TADPOLE MADTOM	-	-	-	-	-	-	-	-	-	-
MUMMICHOG	-	-	-	-	1	-	-	-	-	-
WHITE PERCH	50991	647493	897113	511699	568018	224843	113164	43103	26971	83363
STRIPED BASS	3142	495	1150	174	13	1196	934	260	904	3277
ROCK BASS	66	32	31	46	227	128	50	46	88	381
REDBREAST SUNFISH	707	2056	1398	3040	3772	8377	4187	3466	1524	1007
GREEN SUNFISH	3	-	4	39	81	168	25	-	16	28
PUMPKINSEED	229	2578	2579	1000	878	1687	512	323	446	306
BLUEGILL	567	1423	927	3058	2712	5442	1361	813	942	1299
SMALLMOUTH BASS	182	298	119	153	327	701	262	374	455	881
LARGEMOUTH BASS	82	80	23	19	33	14	22	22	41	13
WHITE CRAPPIE	4457	664	4371	9290	2987	1003	673	384	100	231
BLACK CRAPPIE	8	4	25	45	86	199	103	53	15	20
SUNFISHES	-	-	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	1	4	1	-	-	1	-	-	2
YELLOW PERCH	5955	1090	682	494	2904	735	526	379	373	1007
LOGPERCH	-	-	-	-	-	-	27	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-	-	1
WALLEYE	1840	2734	1613	369	2267	2140	967	2491	4153	2645
BANDED DARTER	-	-	-	-	-	-	1	-	-	-
ATLANTIC NEEDLEFISH	1	-	-	1	-	-	-	-	-	2
LAMPREYS	-	-	-	-	-	-	-	-	-	-
SEA LAMPREY	-	2	-	2	29	11	1	3	1	55
LAKE HERRING	-	1	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	-	-	-	-	-	270	273	2874	39
TIGER MUSKIE	-	-	-	-	-	-	13	132	34	53
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-	-	-
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	241419	1300345	1617888	917043	1175616	1169161	276045	197769	372379	1353308

TABLE 1.3 (CONTINUED)

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1990.

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990
NO. DAYS	44	29	34	55	59	60	63	51	64
LIFTS	725	648	519	1,118	831	1,414	1,339	1,117	1,363
EST. OPER. TIME(HR.)	502	299	251	542	546	639	637	539	664
FISHING TIME(HR)	336	224	192	421	449	532	513	457	571
# SPECIES	48	41	35	41	43	46	49	45	43
AMERICAN EEL	3961	1080	155	550	364	1662	103	157	224
BLUEBACK HERRING	25249	517	311	6763	6327	5861	14570	3598	9658
HICKORY SHAD	15	5	6	9	45	35	64	28	77
ALEWIFE	3433	50	26	379	2822	357	674	1902	425
AMERICAN SHAD	2039	413	167	1546	5195	7667	5146	8218	15719
GIZZARD SHAD	1226374	950252	912666	2182888	1714441	2488618	1402565	926213	1084073
ATLANTIC MENHADEN	-	1	-	1	-	-	-	-	-
TROUTS	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	20	2	5	70	9	14	10	4	14
BROWN TROUT	219	225	141	175	65	83	85	110	63
BROOK TROUT	5	2	-	1	-	-	1	1	-
TROUT	-	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	1	1	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	1	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	1	-
NORTHERN PIKE	5	1	-	-	2	-	-	-	-
MUSKELLUNGE	4	-	-	15	-	-	1	-	2
REDFIN PICKEREL	-	-	-	-	-	1	-	-	-
CARPS AND MINNOWS	1	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	1	1	-
COMMON CARP	15362	16273	8012	6729	2930	4607	8535	875	2761
RIVER CHUB	-	-	-	-	-	-	-	-	-
GOLDEN SHINER	92	216	8	292	23	40	28	5	2
COMELY SHINER	14214	3176	871	5141	582	21199	11734	35239	5798
SPOTTAIL SHINER	315	2132	-	3525	6247	155	55	282	112
SWALLOWTAIL SHINER	-	-	-	-	1	-	-	-	-
ROSYFACE SHINER	8	-	-	-	-	-	-	-	-
SPOTFIN SHINER	622	501	-	2695	695	796	65	5381	135
BLUNTNOSE MINNOW	-	-	-	-	-	-	65	-	-
BLACKNOSE DACE	2	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	1	-	-
SHINERS	6	-	-	-	-	-	-	-	-
QUILLBACK	1617	4679	1942	957	2327	1881	1578	170	1270
WHITE SUCKER	582	412	109	776	853	263	540	410	161
CREEK CHUBSUCKER	2	-	-	-	-	5	1	-	1
NORTHERN HOG SUCKER	-	-	-	-	2	4	1	1	3
SHORTHEAD REDHORSE	6974	7558	3467	3362	2057	3583	4782	2735	4228
WHITE CATFISH	565	224	77	1094	284	917	3849	1740	560
YELLOW BULLHEAD	61	10	7	21	35	41	80	445	32
BROWN BULLHEAD	338	179	69	461	134	163	345	402	108
CHANNEL CATFISH	40941	12559	20479	15200	18698	11699	36212	21692	8689
MARGINED MADTOM	6	-	-	-	3	-	1	-	-
MADTOMS	1	-	-	-	-	-	-	-	-
TADPOLE MADTOM	1	-	-	-	-	-	-	1	-
MUMMICHOG	1	-	-	-	-	-	-	-	-
WHITE PERCH	53527	23151	6402	68344	56977	29995	90651	15713	24581
STRIPED BASS	60	23	181	213	194	1337	874	357	1068
ROCK BASS	138	269	158	122	200	231	110	352	39
REDBREAST SUNFISH	1335	401	465	3366	1433	1471	730	443	187
GREEN SUNFISH	91	16	7	133	15	64	19	33	17
PUMPKINSEED	848	228	104	1013	402	490	135	115	46
BLUEGILL	1184	587	284	6048	1654	2436	1107	1561	446
SMALLMOUTH BASS	1095	1003	608	1081	666	536	548	491	424
LARGEMOUTH BASS	20	17	8	67	75	69	117	164	48
WHITE CRAPPIE	303	450	59	345	199	272	125	230	33
BLACK CRAPPIE	39	46	6	45	51	19	42	45	22
SUNFISHES	-	-	-	-	-	-	-	-	2
TESSELLATED DARTER	-	-	-	1	-	1	1	-	-
YELLOW PERCH	724	387	487	2146	2267	632	815	310	124
LOGPERCH	-	-	-	1	1	1	2	-	2
SHIELD DARTER	-	-	-	-	-	-	-	-	-
WALLEYE	504	683	236	609	380	267	311	319	460
BANDED DARTER	-	-	-	-	-	1	-	-	2
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	2	-	5
LAMPREYS	-	2	-	-	-	-	-	-	-
SEA LAMPREY	56	8	4	164	28	21	59	94	38
LAKE HERRING	-	1	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	2	-
STRIPED BASS X WHITE BASS	160	355	282	1377	1713	5895	6203	5243	1172
TIGER MUSKIE	56	16	10	73	35	30	20	33	10
BROOK TROUT X LAKE TROUT	-	-	2	-	2	5	-	1	-
STRIPED BASS X WHT PERCH	-	-	-	-	10	19	1	3	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	1	-
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	1403175	1028090	957821	2317797	1830641	2593445	1592965	1035121	1162841

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.

DATE	02 APRIL	04 APRIL	06 APRIL	08 APRIL	10 APRIL	12 APRIL	14 APRIL	16 APRIL
# OF LIFTS	6	9	8	7	7	10	7	16
FIRST LIFT	620	605	613	600	605	607	615	600
LAST LIFT	1200	1200	1145	1200	1200	1200	1200	1200
OPERATING TIME (HR)	5.67	5.92	5.53	6.00	5.92	5.88	5.75	6.00
FISHING TIME (HR)	4.83	4.83	5.00	5.25	4.82	4.37	5.13	5.08
AVE RIVER FLOW	32400	45200	68400	78100	62200	55700	98700	68000
AVE WATER TEMP (F)	47.3	47.3	48.7	48.7	48.2	50.0	49.6	50.9
AMERICAN EEL	-	1	-	1	1	1	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	-	-	-	-	1
ALEWIFE	-	-	-	-	-	-	1	21
AMERICAN SHAD	-	-	-	-	-	-	1	-
GIZZARD SHAD	1187	6030	1357	1285	2400	1746	6875	35250
RAINBOW TROUT	-	3	1	-	-	-	-	-
BROWN TROUT	-	-	-	-	-	1	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	-	1	-	1	-	2	2	4
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	2	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	-	-	-	-
WHITE SUCKER	-	1	1	2	1	1	2	4
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	1	3	6	7	6
WHITE CATFISH	1	-	1	1	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	1	2	-	-	1	-	2
CHANNEL CATFISH	323	34	39	27	14	44	12	16
WHITE PERCH	-	-	-	-	-	-	-	-
STRIPED BASS	-	-	-	-	-	-	-	-
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	-	1	-	-
SMALLMOUTH BASS	-	-	1	-	-	-	-	-
LARGEMOUTH BASS	-	-	-	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	10	9	2	3	-	6	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	-	-	1	1	-	2	1
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	2
STRIPED BASS X WHITE BASS	-	5	3	9	7	4	15	34
TIGER MUSKIE	-	-	-	-	-	-	-	-
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	1523	6085	1407	1331	2427	1813	6917	35341

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	18 APRIL	20 APRIL	21 APRIL	22 APRIL	24 APRIL	25 APRIL	26 APRIL	27 APRIL
# OF LIFTS	11	15	15	15	24	22	22	35
FIRST LIFT	553	700	600	605	605	1010	615	620
LAST LIFT	1208	1750	1740	1200	1735	1700	1555	1740
OPERATING TIME (HR)	6.25	10.83	11.67	5.92	11.50	6.83	9.67	11.33
FISHING TIME (HR)	5.47	9.50	10.42	4.63	10.17	5.83	6.63	9.58
AVE RIVER FLOW	50500	41300	36400	36500	33300	32700	31300	28300
AVE WATER TEMP (F)	50.5	51.8	52.7	53.2	55.0	57.7	59.0	59.4
AMERICAN EEL	1	-	1	-	1	1	-	2
BLUEBACK HERRING	-	-	-	-	-	1	12	8
HICKORY SHAD	-	-	1	-	-	4	11	8
ALEWIFE	-	1	7	1	3	70	16	2
AMERICAN SHAD	-	45	28	-	289	436	1517	1283
GIZZARD SHAD	11350	5925	6590	18015	27125	29785	15470	30175
RAINBOW TROUT	-	1	-	-	2	-	-	-
BROWN TROUT	-	-	1	-	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	1	2	3	2	4	3	2	1
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	25	5	31
SPOTFIN SHINER	-	-	-	-	-	-	25	-
QUILLBACK	-	-	-	-	-	-	-	3
WHITE SUCKER	2	4	8	-	3	13	44	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	1	122	144	20	423	430	276	169
WHITE CATFISH	-	-	-	-	5	-	-	1
YELLOW BULLHEAD	-	-	-	-	-	-	1	-
BROWN BULLHEAD	-	-	-	-	3	-	2	1
CHANNEL CATFISH	17	21	117	111	132	50	88	25
WHITE PERCH	-	-	-	-	-	30	153	511
STRIPED BASS	-	-	-	-	2	2	1	5
ROCK BASS	-	-	-	-	-	-	1	3
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	1	-	-	-	-	1
PUMPKINSEED	-	-	-	-	1	2	-	1
BLUEGILL	-	-	1	-	2	5	3	6
SMALLMOUTH BASS	-	2	-	11	9	14	13	26
LARGEMOUTH BASS	-	-	1	2	3	2	1	5
WHITE CRAPPIE	-	-	-	2	-	1	1	2
BLACK CRAPPIE	-	-	-	-	1	-	1	1
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	6	3	4	3
LOGPERCH	-	-	-	-	-	1	1	-
WALLEYE	-	3	7	-	1	7	12	14
BANDED DARTER	-	-	-	-	-	-	-	1
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	-	1	-	1	1	2
STRIPED BASS X WHITE BASS	9	32	51	32	28	24	42	12
TIGER MUSKIE	-	1	-	-	-	-	-	-
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	11382	6159	6961	18197	28043	30910	17703	32303

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	28 APRIL	29 APRIL	30 APRIL	01 MAY	02 MAY	03 MAY	04 MAY	05 MAY
# OF LIFTS	28	28	28	43	27	27	22	20
FIRST LIFT	600	605	620	605	605	610	610	603
LAST LIFT	1800	1755	1700	1750	1805	1755	1735	1755
OPERATING TIME (HR)	12.00	11.83	10.67	11.75	12.00	11.75	11.42	11.87
FISHING TIME (HR)	10.67	10.17	9.42	10.25	10.00	10.00	9.67	10.87
AVE RIVER FLOW	27700	29900	26500	27200	23000	22300	23000	25100
AVE WATER TEMP (F)	60.8	64.0	66.6	68.0	65.7	67.6	66.9	65.8
AMERICAN EEL	3	-	10	30	33	5	8	5
BLUEBACK HERRING	19	4	-	47	861	71	614	3897
HICKORY SHAD	3	8	3	6	8	23	-	1
ALEWIFE	5	2	12	36	156	40	6	1
AMERICAN SHAD	932	561	240	1018	750	357	89	396
GIZZARD SHAD	18695	30600	34960	47400	42125	18985	5520	19805
RAINBOW TROUT	-	-	-	-	-	-	1	-
BROWN TROUT	2	-	-	4	-	-	2	2
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	1	-	1	-	-	-	-	-
COMMON CARP	-	-	18	130	71	82	12	1
GOLDEN SHINER	-	-	1	-	-	1	-	-
COMELY SHINER	3	-	-	20	512	-	-	1
SPOTTAIL SHINER	30	-	3	-	2	-	6	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	2	-	-	4	16	1	-	1
WHITE SUCKER	3	2	3	4	9	4	2	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	1
NORTHERN HOG SUCKER	3	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	152	139	72	158	277	88	57	2
WHITE CATFISH	-	-	10	5	13	5	11	-
YELLOW BULLHEAD	-	-	5	1	6	15	1	1
BROWN BULLHEAD	-	2	11	5	5	2	5	-
CHANNEL CATFISH	156	224	347	163	560	303	373	86
WHITE PERCH	1798	1080	3795	3110	2390	1520	1130	528
STRIPED BASS	-	1	18	23	25	23	30	12
ROCK BASS	-	1	4	7	7	2	-	-
REDBREAST SUNFISH	1	1	6	16	16	23	11	4
GREEN SUNFISH	5	-	-	-	-	-	3	-
PUMPKINSEED	1	4	4	2	4	2	5	4
BLUEGILL	7	3	20	27	51	34	16	17
SMALLMOUTH BASS	18	24	30	39	52	18	10	6
LARGEMOUTH BASS	2	1	1	-	2	3	3	-
WHITE CRAPPIE	1	1	3	10	2	-	2	-
BLACK CRAPPIE	-	-	4	7	3	1	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	3	-	15	10	14	3	3	2
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	9	9	14	21	21	13	19	11
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	2	-	2	3	1	2	2	-
STRIPED BASS X WHITE BASS	4	1	2	23	18	11	5	3
TIGER MUSKIE	-	3	-	3	-	-	-	-
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	21860	32671	39614	52332	48010	21637	7946	24789

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	06 MAY	07 MAY	08 MAY	09 MAY	10 MAY	11 MAY	12 MAY	13 MAY
# OF LIFTS	39	32	14	16	14	18	45	36
FIRST LIFT	605	600	620	600	600	553	603	600
LAST LIFT	1745	1755	1755	1720	1745	1755	1755	1625
OPERATING TIME (HR)	11.67	11.92	11.58	11.33	11.75	12.03	11.87	10.42
FISHING TIME (HR)	10.17	9.92	10.42	10.22	10.78	10.92	10.97	9.72
AVE RIVER FLOW	29200	32100	34900	34700	36100	53100	62000	59600
AVE WATER TEMP (F)	66.2	63.9	65.3	61.7	64.4	64.0	62.6	62.6
AMERICAN EEL	3	4	6	-	8	3	4	-
BLUEBACK HERRING	1655	689	344	333	471	96	22	-
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	40	1	1	-	-	-	-	-
AMERICAN SHAD	979	498	192	109	59	210	129	5
GIZZARD SHAD	37655	34930	5895	10200	2622	19200	54895	70270
RAINBOW TROUT	1	-	-	-	-	-	2	-
BROWN TROUT	2	1	-	4	-	-	1	1
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	5	3	2	1	2	1	66	16
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	10	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	1	-	-	-	-	3	-
WHITE SUCKER	5	4	-	-	-	2	2	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	8	43	7	5	3	22	95	18
WHITE CATFISH	3	1	3	5	-	-	12	4
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	2	8	-	-	1	1	1	1
CHANNEL CATFISH	78	210	79	79	58	53	226	78
WHITE PERCH	402	793	350	437	450	602	1835	991
STRIPED BASS	11	39	19	12	14	15	53	35
ROCK BASS	-	2	-	1	4	-	1	1
REDBREAST SUNFISH	3	11	2	5	19	10	3	2
GREEN SUNFISH	1	1	-	1	2	-	1	-
PUMPKINSEED	1	1	-	2	8	-	2	-
BLUEGILL	22	25	20	8	26	49	14	3
SMALLMOUTH BASS	23	8	1	1	4	4	7	6
LARGEMOUTH BASS	2	-	1	3	1	1	1	-
WHITE CRAPPIE	-	1	-	1	3	-	-	-
BLACK CRAPPIE	1	2	-	-	-	-	1	-
SUNFISHES	-	1	-	1	-	-	-	-
YELLOW PERCH	1	3	-	-	3	3	15	1
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	4	8	6	4	9	9	9	5
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	3	1	-	-	1	2	1	5
STRIPED BASS X WHITE BASS	4	60	18	124	15	11	43	16
TIGER MUSKIE	1	-	-	-	-	-	-	-
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	40925	37349	6946	11336	3783	20294	57444	71459

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	14 MAY	15 MAY	16 MAY	17 MAY	18 MAY	19 MAY	20 MAY	21 MAY
# OF LIFTS	23	20	39	39	22	20	24	23
FIRST LIFT	558	600	602	603	610	600	613	610
LAST LIFT	1321	1755	1800	1730	1720	1745	1720	1745
OPERATING TIME (HR)	7.38	11.92	11.97	11.45	11.17	11.75	11.12	11.58
FISHING TIME (HR)	6.38	10.17	11.13	10.25	9.25	10.25	10.50	9.75
AVE RIVER FLOW	59200	61400	64100	73400	96700	95200	91100	86000
AVE WATER TEMP (F)	61.9	60.8	61.5	63.9	63.5	62.6	63.0	62.2
AMERICAN EEL	-	3	5	2	1	4	5	1
BLUEBACK HERRING	12	37	141	9	33	1	39	203
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	14	33	78	618	180	222	16	23
GIZZARD SHAD	32725	10730	58575	48665	6800	11175	27550	20716
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	3	3	-	-	2	1	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	4	1	20	132	71	7	14	17
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	-	1	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	8	72	-	-	1
WHITE SUCKER	1	-	3	-	4	8	1	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	8	3	20	86	97	53	23	167
WHITE CATFISH	6	16	2	30	-	10	9	7
YELLOW BULLHEAD	-	-	2	-	-	-	-	-
BROWN BULLHEAD	5	1	1	-	-	-	-	-
CHANNEL CATFISH	139	107	157	237	131	155	101	101
WHITE PERCH	940	485	155	245	168	53	20	84
STRIPED BASS	18	27	24	17	33	31	6	26
ROCK BASS	2	-	1	-	-	2	-	-
REDBREAST SUNFISH	1	9	1	1	1	1	-	-
GREEN SUNFISH	-	1	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	1
BLUEGILL	1	27	2	-	2	3	-	6
SMALLMOUTH BASS	1	1	3	6	10	4	2	3
LARGEMOUTH BASS	-	-	-	-	-	-	-	-
WHITE CRAPPIE	-	3	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	1	-	-	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	3	-	9	6	8	2	-	6
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	2	-	1	1	-	1	-	-
STRIPED BASS X WHITE BASS	12	52	17	69	35	45	14	30
TIGER MUSKIE	-	-	-	-	-	-	-	-
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	33898	11539	59217	50132	7649	11778	27800	21394

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	22 MAY	23 MAY	24 MAY	25 MAY	26 MAY	27 MAY	28 MAY	29 MAY
# OF LIFTS	22	24	27	23	14	15	17	20
FIRST LIFT	615	610	605	610	604	606	609	610
LAST LIFT	1745	1730	1800	1750	1755	1747	1950	1745
OPERATING TIME (HR)	11.50	11.33	11.92	11.67	11.85	11.68	13.68	11.58
FISHING TIME (HR)	9.00	8.75	9.00	9.42	11.17	10.53	10.62	10.08
AVE RIVER FLOW	70600	62300	65600	60400	60400	53000	50100	47400
AVE WATER TEMP (F)	62.6	61.5	61.0	62.4	62.6	60.8	63.0	63.5
AMERICAN EEL	2	1	1	6	1	1	-	2
BLUEBACK HERRING	5	1	3	1	-	-	2	1
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	98	105	152	339	77	50	302	293
GIZZARD SHAD	17575	14590	29351	7036	7896	6228	12485	1658
RAINBOW TROUT	1	-	-	1	-	1	-	-
BROWN TROUT	1	1	3	5	-	5	-	3
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	67	17	21	31	-	-	3	1
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	33	-	100	175	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	5	-	-
QUILLBACK	30	14	12	11	-	1	-	1
WHITE SUCKER	-	1	-	-	-	1	1	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	53	85	82	118	64	33	72	93
WHITE CATFISH	-	17	-	15	-	-	-	15
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	5	-	-	-	-	-	1
CHANNEL CATFISH	58	196	16	142	21	10	12	38
WHITE PERCH	14	30	3	44	72	6	16	109
STRIPED BASS	25	14	24	38	14	8	14	10
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	1	-	1	6	-	2	2	2
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	16	9	4	2	2
SMALLMOUTH BASS	3	3	4	4	-	5	2	3
LARGEMOUTH BASS	-	-	1	1	1	-	1	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	1	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	4	9	8	7	5	5	9	8
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	49	24	15	-	7	5	14	9
TIGER MUSKIE	-	-	-	-	-	-	1	-
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	17986	15113	29697	7854	8167	6471	13113	2250

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	30 MAY	31 MAY	01 JUNE	02 JUNE	04 JUNE	05 JUNE	06 JUNE	07 JUNE
# OF LIFTS	20	20	17	5	26	22	24	27
FIRST LIFT	645	606	608	1040	615	610	605	605
LAST LIFT	1755	1745	1435	1430	1750	1750	1750	1755
OPERATING TIME (HR)	11.17	11.65	8.45	3.83	11.58	11.67	11.75	11.83
FISHING TIME (HR)	8.45	9.83	8.22	3.50	10.42	9.67	9.67	9.67
AVE RIVER FLOW	66000	63600	60000	59800	40200	33400	30600	29400
AVE WATER TEMP (F)	62.2	63.7	62.6	63.7	67.6	69.4	69.8	68.9
AMERICAN EEL	2	1	2	2	3	4	7	2
BLUEBACK HERRING	3	1	-	-	-	-	2	5
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	178	346	80	19	272	143	796	279
GIZZARD SHAD	13650	8300	5035	2045	15910	5660	9040	20575
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	2	1	2	-	3	1	1	2
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	6	126	37	13	71	11	182	458
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	-	200	-	-	630
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	100	36	2	149	13	98	96
WHITE SUCKER	1	1	1	-	-	-	2	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	65	235	36	12	52	2	6	5
WHITE CATFISH	3	19	66	3	23	2	1	3
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	1	-	-	4	-	-	6
CHANNEL CATFISH	317	326	350	40	275	92	46	119
WHITE PERCH	57	60	66	16	13	3	4	10
STRIPED BASS	48	35	20	10	31	18	20	31
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	1	15	1	1	1
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	1	-	-	-
BLUEGILL	1	1	-	1	4	1	1	-
SMALLMOUTH BASS	4	7	4	-	9	4	1	5
LARGEMOUTH BASS	1	2	-	1	-	-	2	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	8	10	3	2	17	1	4	7
BANDED DARTER	-	-	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	1	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	10	7	11	1	8	2	4	17
TIGER MUSKIE	-	-	-	-	-	-	-	1
	======	======	======	======	======	======	======	======
	14356	9579	5749	2168	17060	5958	10229	22253

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	08 JUNE	09 JUNE	10 JUNE	11 JUNE	12 JUNE	13 JUNE	14 JUNE	15 JUNE
# OF LIFTS	19	18	20	23	21	21	22	20
FIRST LIFT	610	605	615	610	610	603	600	605
LAST LIFT	1645	1750	1755	1755	1755	1750	1750	1755
OPERATING TIME (HR)	10.58	11.75	11.67	11.75	11.75	11.78	11.83	11.83
FISHING TIME (HR)	8.92	10.33	10.17	10.00	10.08	10.13	10.17	10.25
AVE RIVER FLOW	32600	30000	31800	31600	33300	35600	24700	26900
AVE WATER TEMP (F)	71.6	70.7	71.2	72.3	75.2	73.4	71.6	71.6
AMERICAN EEL	2	7	3	5	5	3	5	4
BLUEBACK HERRING	-	3	2	-	8	-	1	1
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	1	-	-	-	-	2	-	-
AMERICAN SHAD	178	155	147	75	97	167	47	17
GIZZARD SHAD	6175	6886	9737	3595	3735	1787	2730	1136
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	1	1	1	-	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	174	69	413	136	30	81	77	23
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	100	542	333	300	310	-	2535	1
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	105	-
QUILLBACK	94	7	67	222	95	56	38	16
WHITE SUCKER	1	1	-	-	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	1	-	2	-	-	-	1	-
WHITE CATFISH	4	10	1	12	20	65	61	59
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	7	4	2	3	3	9	-
CHANNEL CATFISH	96	102	75	243	155	214	245	230
WHITE PERCH	-	-	-	-	2	1	-	-
STRIPED BASS	14	27	11	34	36	25	22	17
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	2	1	2	1	1
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	1	1	-	1	-	-	-
SMALLMOUTH BASS	1	2	2	3	1	-	-	-
LARGEMOUTH BASS	-	1	-	1	-	1	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
SUNFISHES	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	4	22	12	13	13	11	15	9
BANDED DARTER	-	1	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	1	1	-	-	-	-	2	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	5	8	4	12	4	4	6	7
TIGER MUSKIE	-	-	-	-	-	-	-	-
	======	======	======	======	======	======	======	======
	6852	7853	10815	4655	4516	2422	5900	1521

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1990.
(CONTINUED)

DATE	16 JUNE	17 JUNE	18 JUNE	19 JUNE	20 JUNE	21 JUNE	22 JUNE	23 JUNE	TOTALS
# OF LIFTS	13	16	11	14	13	11	12	8	1461
FIRST LIFT	603	600	605	600	600	600	605	610	
LAST LIFT	1315	1615	1145	1225	1205	1200	1200	1145	
OPERATING TIME (HR)	7.20	10.25	5.67	6.42	6.08	6.00	5.92	5.58	718.07
FISHING TIME (HR)	6.13	8.67	4.58	6.33	4.77	5.17	5.08	5.00	617.17
AVE RIVER FLOW	24900	22000	26300	29700	28700	28200	23200	21100	
AVE WATER TEMP (F)	72.5	70.7	71.6	73.4	74.8	75.6	75.2	77.5	
AMERICAN EEL	-	-	-	2	-	2	1	1	230
BLUEBACK HERRING	-	-	-	-	-	-	-	-	9,658
HICKORY SHAD	-	-	-	-	-	-	-	-	77
ALEWIFE	-	-	-	-	-	-	-	1	426
AMERICAN SHAD	26	59	21	72	14	24	24	5	15,964
GIZZARD SHAD	3793	3015	3992	1415	2313	346	425	216	1,099,588
RAINBOW TROUT	-	1	-	-	-	-	-	-	15
BROWN TROUT	-	-	-	-	-	-	-	-	63
BROOK TROUT	-	-	-	-	-	-	1	-	1
MUSKELLUNGE	-	-	-	-	-	-	-	-	2
COMMON CARP	24	578	42	9	278	53	135	8	3,888
GOLDEN SHINER	-	-	-	-	-	-	-	-	2
COMELY SHINER	215	80	-	2201	745	650	900	395	10,984
SPOTTAIL SHINER	-	75	-	-	200	-	-	30	417
SPOTFIN SHINER	165	-	-	12	75	35	65	70	557
QUILLBACK	11	57	5	26	133	25	127	3	1,657
WHITE SUCKER	-	-	-	-	-	-	-	-	161
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-	1
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-	3
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	-	4,228
WHITE CATFISH	31	1	21	42	55	53	60	68	891
YELLOW BULLHEAD	-	-	-	-	-	-	3	-	35
BROWN BULLHEAD	-	-	-	1	3	1	1	10	124
CHANNEL CATFISH	90	6	83	174	299	222	217	215	9,995
WHITE PERCH	-	2	2	-	2	-	-	-	24,587
STRIPED BASS	18	11	22	8	33	14	8	11	1,193
ROCK BASS	-	-	-	-	-	-	-	-	39
REDBREAST SUNFISH	-	-	-	1	-	1	1	1	191
GREEN SUNFISH	-	-	-	-	-	-	-	-	17
PUMPKINSEED	-	-	-	-	-	-	-	-	46
BLUEGILL	-	-	-	-	-	-	-	-	446
SMALLMOUTH BASS	-	1	-	-	-	-	-	-	425
LARGEMOUTH BASS	-	-	-	-	-	-	-	-	48
WHITE CRAPPIE	-	-	-	-	-	-	-	-	33
BLACK CRAPPIE	-	-	-	-	-	-	-	-	22
SUNFISHES	-	-	-	-	-	-	-	-	2
YELLOW PERCH	-	-	-	-	-	-	-	-	124
LOGPERCH	-	-	-	-	-	-	-	-	2
WALLEYE	4	1	4	10	3	5	5	2	494
BANDED DARTER	-	1	-	-	-	-	-	-	3
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-	5
SEA LAMPREY	-	-	-	-	-	-	-	-	38
STRIPED BASS X WHITE BASS	3	4	4	7	4	3	2	7	1,206
TIGER MUSKIE	-	-	1	-	-	-	-	-	11
	======	======	======	======	======	======	======	======	=========
	4380	3892	4197	3980	4157	1434	1975	1043	1,187,899

... shad by date and weir gate setting
... at Conowingo Dam Fish Lift, 1990.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	Total
24 Apr	# Shad		30	259	289
	Hrs Fishing	0.0	1.2	9.0	10.2
	Catch/Hr Fishing	-	25.00	28.78	28.33
25 Apr	# Shad		328	108	436
	Hrs Fishing	0.0	4.9	0.9	5.8
	Catch/Hr Fishing	-	66.94	120.00	75.17
26 Apr	# Shad		5	1,505	1,510
	Hrs Fishing	0.0	1.3	5.4	6.6
	Catch/Hr Fishing	-	3.85	278.70	228.79
27 Apr	# Shad		13	1,234	1,247
	Hrs Fishing	0.0	2.1	7.5	9.6
	Catch/hr Fishing	-	6.19	164.53	129.90
2 May	# Shad		234	512	746
	Hrs Fishing	0.0	1.8	8.2	10.0
	Catch/Hr Fishing	-	130.00	62.44	74.60
3 May	# Shad		146	211	357
	Hrs Fishing	0.0	2.4	7.6	10.0
	Catch/Hr Fishing	-	60.83	27.76	35.70
5 May	# Shad		288	107	395
	Hrs Fishing	0.0	3.5	7.4	10.9
	Catch/Hr Fishing	-	82.29	14.46	36.24
6 May	# Shad		687	291	978
	Hrs Fishing	0.0	5.0	5.2	10.2
	Catch/Hr Fishing	-	137.40	55.96	95.88

TABLE 1.5

Continued

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	Total
7 May	# Shad		161	337	498
	Hrs Fishing	0.0	4.5	5.4	9.9
	Catch/Hr Fishing	-	35.78	62.41	50.30
13 May	# Shad	2	2	1	5
	Hrs Fishing	2.4	1.9	5.4	9.7
	Catch/Hr Fishing	0.83	1.05	0.19	0.52
17 May	# Shad	614	-	3	617
	Hrs Fishing	6.5	1.3	2.5	10.3
	Catch/Hr Fishing	94.46	-	1.20	59.90
18 May	# Shad	176			176
	Hrs Fishing	9.3	0.0	0.0	9.3
	Catch/Hr Fishing	18.92	-	-	18.92
19 May	# Shad	222			222
	Hrs Fishing	10.3	0.0	0.0	10.3
	Catch/Hr Fishing	21.55	-	-	21.55
20 May	# Shad	3		13	16
	Hrs Fishing	1.8	0.0	8.7	10.5
	Catch/Hr Fishing	1.67	-	1.49	1.52
22 May	# Shad	88		10	98
	Hrs Fishing	7.1	0.0	1.9	9.0
	Catch/Hr Fishing	12.39	-	5.26	10.89
23 May	# Shad	105		-	105
	Hrs Fishing	8.5	0.0	0.3	8.8
	Catch/Hr Fishing	12.35	-	-	11.93

TABLE 1.5

Continued

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	Total
24 May	# Shad	6		146	152
	Hrs Fishing	1.2	0.0	7.8	9.0
	Catch/Hr Fishing	5.00	-	18.72	16.89
27 May	# Shad		-	50	50
	Hrs Fishing	0.0	0.3	10.2	10.5
	Catch/Hr Fishing	-	-	4.90	4.76
7 Jun	# Shad		95	172	267
	Hrs Fishing	0.0	2.3	7.3	9.7
	Catch/Hr Fishing	-	41.30	23.56	27.53
8 Jun	# Shad		80	98	178
	Hrs Fishing	0.0	1.8	7.1	8.9
	Catch/Hr Fishing	-	44.44	13.80	20.00
10 Jun	# Shad		20	127	147
	Hrs Fishing	0.0	0.5	9.7	10.2
	Catch/Hr Fishing	-	40.00	13.09	14.41
20 Jun	# Shad	2		12	14
	Hrs Fishing	0.2	0.0	4.6	4.8
	Catch/Hr Fishing	10.00	-	2.61	2.92
Total	# Shad	1,218	2,089	5,196	8,053
	Hrs Fishing	47.3	34.8	122.1	204.2
	Catch/Hr Fishing	25.75	60.03	42.56	41.64

TABLE 1.6

Comparison of catch per effort (hr) of American shad on weekdays vs weekend days by generation (cfs) at the Conowingo Dam Fish Lift, 2 April - 23 June, 1990.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	MORNING 5-9	14.5	31.0	2.8	10.2	22.9	10.5	13.9
	MID-AM 9-11	21.6	-	-	7.9	26.1	15.0	16.7
	MID-DAY 11-3	43.9	-	-	16.0	33.5	28.0	29.8
	LATE PM 3-7	98.9	-	87.8	40.4	51.4	39.9	48.4
	MEAN WEEKDAY	37.0	31.0	70.3	21.8	31.8	24.3	27.3
WEEKEND	MORNING 5-9	7.5	6.1	18.6	3.2	7.0	2.9	8.5
	MID-AM 9-11	7.2	-	2.1	10.0	6.3	3.5	6.0
	MID-DAY 11-3	23.8	-	85.9	33.6	15.6	15.2	21.9
	LATE PM 3-7	123.0	-	127.9	55.9	27.0	29.5	51.6
	MEAN WEEKEND	18.7	6.1	54.2	27.7	17.4	14.3	21.8

TABLE 1.7

Comparison of the American shad catch and catch per effort between discharges with one or two Francis units generating and high discharges (three or more unit generation) at the Conowingo Dam Fish Lift, 2 April to 23 June 1990.

Generation Status	No. Shad Caught	Total Minutes Fished	Number of Lifts	Shad Catch per Hour
One Unit	89	385	16	13.87
Two Units	1685	1741	93	58.07
High	14190	34902	1352	24.39
TOTAL	15964	37028	1461	25.87

TABLE 1.8

Catch of American shad in the Conowingo Fish Lift by water temperatures, 2 April to 23 June 1990.

Water Temp. (F)	Hours Fishing	CATCH		
		Number	Catch/ Effort	Percent
LE 65	371.15	9325	25.12	58.4
GT 65	245.98	6639	26.99	41.6
TOTAL	617.13	15964	25.87	100.0

TABLE 1.9

Summary of transportation of American Shad from Conowingo Dam Fish Lift, 02 April TO 23 June, 1990.

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
24 APR	289	54.7	191	TRI-CO MARINA	1	99.5	14.7	12.7	62.6
25 APR	436	57.2	255	SWATARA CR.	13	94.9	15.5	11.8	56.3
			199	SWATARA CR.	2	99.0	13.8	13.0	63.0
			120	SWATARA CR.	2	98.3	19.2	12.4	58.1
26 APR	1517	57.4	305	SWATARA CR.	0	100.0	9.2	12.4	67.1
			343	SWATARA CR.	11	96.8	12.0	13.4	67.6
			350	SWATARA CR.	14	96.0	13.4	13.0	67.1
			297	SWATARA CR.	1	99.7	11.8	14.0	68.0
27 APR	1283	-	339	TRI-CO MARINA	19	94.4	9.4	13.8	75.2
			298	TRI-CO MARINA	15	95.0	8.5	12.0	72.0
			342	TRI-CO MARINA	18	94.7	11.4	12.6	71.6
28 APR	932	60.6	264	TRI-CO MARINA	0	100.0	17.2	15.0	66.2
			292	TRI-CO MARINA	2	99.3	16.4	15.6	73.4
			268	TRI-CO MARINA	26	90.3	16.0	12.2	72.7
			313	TRI-CO MARINA	30	90.4	13.1	6.4	71.6
29 APR	561	63.9	171	TRI-CO MARINA	0	100.0	14.4	13.2	75.2
			230	TRI-CO MARINA	12	94.8	17.0	13.6	67.1
			174	TRI-CO MARINA	11	93.7	18.8	13.3	71.2
			134	TRI-CO MARINA	0	100.0	16.6	14.2	69.8
30 APR	240	65.3	110	TRI-CO MARINA	0	100.0	15.8	14.4	60.8
			116	EXP. NET PEN	0	100.0	14.2	9.0	64.4
01 MAY	1018	-	233	TRI-CO MARINA	4	98.3	16.4	15.2	58.6
			280	TRI-CO MARINA	7	97.5	13.4	13.2	61.2
			207	TRI-CO MARINA	2	99.0	17.6	16.6	64.0
			274	TRI-CO MARINA	8	97.1	12.0	12.9	59.9
02 MAY	750	66.2	149	EXP. NET PEN	10	93.3	10.8	15.0	60.8
			212	TRI-CO MARINA	4	98.1	12.9	15.8	63.5
			165	TRI-CO MARINA	13	92.1	13.6	12.4	62.6
			207	TRI-CO MARINA	5	97.6	-	-	60.8
03 MAY	357	67.1	164	EXP. NET PEN	15	90.9	13.2	15.2	59.0
			180	TRI-CO MARINA	1	99.4	11.5	8.4	59.4
04 MAY	89	66.9	85	EXP. NET PEN	2	97.6	13.8	12.4	58.6
05 MAY	396	-	175	EXP. NET PEN	5	97.1	15.7	10.0	55.0
			210	TRI-CO MARINA	0	100.0	12.8	14.2	54.5
06 MAY	979	65.8	175	TRI-CO MARINA	0	100.0	14.9	9.0	55.4
			190	TRI-CO MARINA	0	100.0	12.6	12.0	58.1
			253	TRI-CO MARINA	1	99.6	9.3	17.0	57.2
			282	TRI-CO MARINA	0	100.0	14.2	14.6	55.4
07 MAY	498	63.9	11	WELLSBORO	-	-	-	-	-
			152	EXP. NET PEN	3	98.0	9.8	12.0	55.0
			250	TRI-CO MARINA	1	99.6	11.2	11.5	59.5
08 MAY	192	64.4	198	TRI-CO MARINA	0	100.0	-	-	59.0
			120	EXP. NET PEN	0	100.0	-	-	62.6
09 MAY	109	62.1	104	EXP. NET PEN	0	100.0	12.2	13.2	66.2

TABLE 1.9

Summary of transportation of American Shad from Conowingo Dam Fish Lift, 02 April TO 23 June, 1990 (continued).

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
10 MAY	59	64.4	59	TRI-CO MARINA	0	100.0	17.7	13.6	61.7
11 MAY	210	63.9	206	TRI-CO MARINA	0	100.0	11.2	12.2	57.2
13 MAY	5	62.6	125	TRI-CO MARINA	0	100.0	13.8	12.0	54.0
16 MAY	78	61.2	31	MUDDY RUN LAB	0	100.0	12.2	11.8	61.7
17 MAY	618	63.0	267	TRI-CO MARINA	0	100.0	12.6	12.2	62.6
			279	TRI-CO MARINA	0	100.0	10.4	13.8	61.7
			20	MUDDY RUN LAB	0	100.0	17.6	14.0	32.0
18 MAY	180	63.2	189	TRI-CO MARINA	1	99.5	11.0	9.5	59.5
19 MAY	222	59.6	10	MUDDY RUN LAB	0	100.0	7.6	11.8	32.0
			203	TRI-CO MARINA	0	100.0	7.6	11.8	60.8
21 MAY	23	62.1	25	MUDDY RUN LAB	0	100.0	20.0	19.0	60.6
22 MAY	98	62.6	165	TRI-CO MARINA	0	100.0	12.4	11.6	59.0
23 MAY	105	61.3	96	TRI-CO MARINA	0	100.0	16.0	11.2	59.0
25 MAY	339	-	237	TRI-CO MARINA	1	99.6	17.4	12.8	63.5
			216	TRI-CO MARINA	1	99.5	10.8	15.7	63.0
26 MAY	77	62.6	113	TRI-CO MARINA	0	100.0	17.0	12.4	60.8
28 MAY	302	62.9	272	TRI-CO MARINA	0	100.0	12.5	12.4	62.6
29 MAY	293	62.1	35	MUDDY RUN LAB	1	97.1	11.8	12.0	32.0
			189	TRI-CO MARINA	0	100.0	12.8	17.4	55.4
30 MAY	178	63.2	57	TRI-CO MARINA	1	98.2	10.4	9.4	60.8
			235	TRI-CO MARINA	0	100.0	19.6	10.0	59.0
31 MAY	346	64.8	10	MUDDY RUN LAB	0	100.0	17.0	16.2	64.4
			268	TRI-CO MARINA	2	99.3	13.2	13.3	60.8
01 JUN	80	62.8	140	TRI-CO MARINA	0	100.0	14.8	13.6	62.6
04 JUN	272	67.1	40	MUDDY RUN LAB	0	100.0	11.4	11.6	67.1
			207	TRI-CO MARINA	0	100.0	13.6	14.0	64.4
05 JUN	143	68.8	43	EXP. NET PEN	0	100.0	12.0	14.6	66.2
06 JUN	796	68.9	234	TRI-CO MARINA	0	100.0	13.1	11.3	64.4
			203	TRI-CO MARINA	3	98.5	13.2	13.4	63.3
			100	EXP. NET PEN	0	100.0	20.0	12.0	67.1
			269	TRI-CO MARINA	5	98.1	10.4	10.2	67.3
07 JUN	279	-	146	EXP. NET PEN	4	97.3	10.4	13.8	69.1
			208	TRI-CO MARINA	0	100.0	11.6	15.0	69.4
08 JUN	178	70.0	138	EXP. NET PEN	1	99.3	14.6	12.4	69.4
09 JUN	155	72.0	162	TRI-CO MARINA	0	100.0	10.6	10.8	67.1
11 JUN	75	72.3	25	MUDDY RUN LAB	0	100.0	13.8	9.8	71.6
			118	EXP. NET PEN	0	100.0	12.2	11.2	67.1
12 JUN	97	71.6	108	EXP. NET PEN	0	100.0	11.2	11.6	68.0
13 JUN	167	73.6	114	EXP. NET PEN	2	98.2	12.4	9.5	67.1
14 JUN	47	71.1	105	EXP. NET PEN	3	97.1	10.8	10.2	71.6
17 JUN	59	70.3	99	TRI-CO MARINA	0	100.0	11.2	11.0	75.2
19 JUN	72	72.5	85	TRI-CO MARINA	0	100.0	15.2	14.0	74.8
23 JUN	5	77.9	44	TRI-CO MARINA	0	100.0	20.0	8.6	75.6
SEASON TOTALS			15282		283	98.1			

TABLE 1.10

Daily sex ratio of American shad at the Conowingo Dam Fish Lift for 1990.

DATE	DAILY CATCH	NO. SEXED	NO. OF MALES	NO. OF FEMALES	RATIO (M/F)
02 APR	0	0			
04 APR	0	0			
06 APR	0	0			
08 APR	0	0			
10 APR	0	0			
12 APR	0	0			
14 APR	1	1	1		1:0
16 APR	0	0			
18 APR	0	0			
20 APR	45	45	41	4	10.3:1
21 APR	28	28	27	1	27.0:1
22 APR	0	0			
24 APR	289	105	90	15	6.0:1
25 APR	436	108	90	18	5.0:1
26 APR	1517	92	89	3	29.7:1
27 APR	1283	64	50	14	3.6:1
28 APR	932	107	88	19	4.6:1
29 APR	561	132	89	43	2.1:1
30 APR	240	110	83	27	3.1:1
01 MAY	1018	112	91	21	4.3:1
02 MAY	750	111	78	33	2.4:1
03 MAY	357	102	68	34	2.0:1
04 MAY	89	85	67	18	3.7:1
05 MAY	396	93	69	24	2.9:1
06 MAY	979	120	90	30	3.0:1
07 MAY	498	113	71	42	1.7:1
08 MAY	192	112	80	32	2.5:1
09 MAY	109	96	81	15	5.4:1
10 MAY	59	59	50	9	5.6:1
11 MAY	210	104	76	28	2.7:1
12 MAY	129	101	87	14	6.2:1
13 MAY	5	5	4	1	4.0:1
14 MAY	14	14	12	2	6.0:1
15 MAY	33	33	26	7	3.7:1
16 MAY	78	77	58	19	3.1:1
17 MAY	618	142	99	43	2.3:1
18 MAY	180	115	88	27	3.3:1
19 MAY	222	109	90	19	4.7:1
20 MAY	16	16	13	3	4.3:1
21 MAY	23	23	9	14	0.6:1
22 MAY	98	98	66	32	2.1:1
23 MAY	105	90	62	28	2.2:1
24 MAY	152	106	74	32	2.3:1
25 MAY	339	110	74	36	2.1:1
26 MAY	77	77	59	18	3.3:1
27 MAY	50	50	37	13	2.8:1

TABLE 1.10

Continued.

DATE	DAILY CATCH	NO. SEXED	NO. OF MALES	NO. OF FEMALES	RATIO (M/F)
28 MAY	302	187	122	65	1.9:1
29 MAY	293	102	69	33	2.1:1
30 MAY	178	117	79	38	2.1:1
31 MAY	346	105	66	39	1.7:1
01 JUN	80	80	55	25	2.2:1
02 JUN	19	19	10	9	1.1:1
04 JUN	272	271	203	68	3.0:1
05 JUN	143	101	62	39	1.6:1
06 JUN	796	122	74	48	1.5:1
07 JUN	279	99	53	46	1.2:1
08 JUN	178	120	65	55	1.2:1
09 JUN	155	101	54	47	1.1:1
10 JUN	147	92	43	49	0.9:1
11 JUN	75	75	33	42	0.8:1
12 JUN	97	95	48	47	1.0:1
13 JUN	167	110	42	68	0.6:1
14 JUN	47	47	28	19	1.5:1
15 JUN	17	16	3	13	0.2:1
16 JUN	26	26	12	14	0.9:1
17 JUN	59	59	19	40	0.5:1
18 JUN	21	21	5	16	0.3:1
19 JUN	72	71	9	62	0.1:1
20 JUN	14	14	3	11	0.3:1
21 JUN	24	24	15	9	1.7:1
22 JUN	24	24	16	8	2.0:1
23 JUN	5	5	4	1	4.0:1
TOTALS	15964	5168	3519	1649	3.2:1

TABLE 1.11

Age and spawning history of American shad collected at the Conowingo Dam Fish Lift in 1990; by sex, with mean, minimum and maximum fork length (mm).

Sex	Age	N	Spawning History			Fork Lengths		
				Repeats				
			Virgins	Once	Twice	mean	min	max
MALE	III	7	7			318	275	347
	IV	78	77	1		376	310	453
	V	147	132	14	1	412	340	503
	VI	62	56	3	3	447	354	504
	VII	4	3	1		487	443	517
Subtotal		298	275	19	4	409	275	517
FEMALE	III	3	3			391	360	422
	IV	25	25			412	363	480
	V	164	156	8		445	371	533
	VI	163	149	10	4	481	412	570
	VII	34	30	3	1	530	473	566
	VIII	1	1			499	499	499
Subtotal		390	364	21	5	465	360	570
Total		688	639	40	9	441	275	570

TABLE 1.12

Daily catch of American shad at the Conowingo Dam Fish Lift when Maryland DNR tagged shad were recaptured at the Lift in 1990.

Date	Daily Catch	No. of MD DNR Recaptures
27 Apr	1283	3*
28 Apr	932	1
29 Apr	561	1
5 May	396	3
6 May	979	4
7 May	498	1
9 May	109	2
11 May	210	1
16 May	78	1
17 May	618	2
18 May	180	2
19 May	222	3
24 May	152	1
25 May	339	2
28 May	302	3
29 May	293	2
30 May	178	2
31 May	346	3
4 Jun	272	1
5 Jun	143	3
6 Jun	796	3
7 Jun	279	4**
8 Jun	178	2
9 Jun	155	2
10 Jun	147	5
12 Jun	97	3
13 Jun	167	2**
16 Jun	26	3
17 Jun	59	1
19 Jun	72	1
20 Jun	14	1
22 Jun	24	1
23 Jun	5	1
Totals	10,110	70

* Includes shad tagged in 1989
** Includes a multiple recapture

TABLE 1.13

Summary of river herrings transportation from Conowingo Dam Fish Lift, 24 April to 25 May 1990.

Date	Release Location	No. Transported	Observed Mortality	Percent Survival
Big Elk Creek				
7 May	Fairhaven	300*	1	99.6
Little Patuxent River				
18 May	Brock Bridge Road	196*	0	100
Patapsco River				
15 May	Ellicot City	94*	0	100
Susquehanna River				
24 Apr	Tri-County Marina	7**	0	100
10 May	Tri-County Marina	566**	0	100
13 May	Tri-County Marina	182**	0	100
17 May	Tri-County Marina	178**	0	100
22 May	Tri-County Marina	98**	0	100
25 May	Tri-County Marina	3**	0	100
Tuckahoe Creek				
9 May	Mason Branch	1068	68	93.6
Winter's Run				
5 May	Abingdon	1000	1	99.9
5 May	Abingdon	1500	5	99.6
5 May	Abingdon	1250	6	99.5

* Transported in loads with river herring captured elsewhere in Maryland.

** Mixed loads of river herring and American shad.

TABLE 1.14

Summary of American Shad catch by constant generation levels
(varying generation during a lift grouped separately)
1 April to 18 June, 1985 through 1990. Cleanout lifts excluded. (continued).

TOTAL DISCHARGE (X 1000 CFS)	UNIT 1	UNIT 2	1988 NO. LIFTS	1988 TIME (MINS.)	1988 TOTAL SHAD	1988 SHAD/HR	1989 NO. LIFTS	1989 TIME (MINS.)	1989 TOTAL SHAD	1989 SHAD/HR	1990 NO. LIFTS	1990 TIME (MINS.)	1990 TOTAL SHAD	1990 SHAD/HR
LE 5	OFF	OFF	257	5984	2250	22.6	33	566	1050	111.3	9	215	46	12.8
LE 5	OFF	ON	16	317	4	0.8	-	-	-	-	-	-	-	-
LE 5	ON	OFF	-	-	-	-	-	-	-	-	-	-	-	-
* TOTAL LE 5			273	6301	2254	21.5	33	566	1050	111.3	9	215	46	12.8
10-65	CHG	CHG	1	27	0	0.0	-	-	-	-	-	-	-	-
10-65	OFF	OFF	250	6045	1189	11.8	819	20959	5309	15.2	782	21825	11563	31.8
10-65	OFF	ON	48	1130	245	13.0	3	96	78	48.8	-	-	-	-
10-65	ON	OFF	3	49	0	0.0	-	-	-	-	1	10	0	0.0
10-65	ON	ON	168	4185	239	3.4	-	-	-	-	-	-	-	-
*TOTAL 10-65			470	11436	1673	8.8	822	21055	5387	15.4	783	21835	11563	31.8
VARYING	CHG	CHG	46	1067	100	5.6	2	10	0	0.0	1	20	2	6.0
VARYING	CHG	OFF	2	60	0	0.0	3	96	0	0.0	1	30	0	0.0
VARYING	CHG	ON	16	432	18	2.5	-	-	-	-	4	75	12	9.6
VARYING	OFF	CHG	10	269	16	3.6	9	319	183	34.4	1	20	15	45.0
VARYING	OFF	OFF	98	2547	638	15.0	150	4205	1466	20.9	103	3078	1826	35.6
VARYING	OFF	ON	5	158	13	4.9	2	90	36	24.0	-	-	-	-
VARYING	ON	CHG	-	-	-	-	-	-	-	-	1	11	0	0.0
VARYING	ON	OFF	1	8	0	0.0	-	-	-	-	1	15	0	0.0
VARYING	ON	ON	31	807	43	3.2	-	-	-	-	5	72	41	34.2
* TOTAL VARYING			209	5348	828	9.3	166	4720	1685	21.4	117	3321	1896	34.3
+ 65	OFF	OFF	-	-	-	-	-	-	-	-	-	-	-	-
+ 65	OFF	ON	-	-	-	-	43	1328	149	6.7	12	185	33	10.7
+ 65	ON	OFF	-	-	-	-	-	-	-	-	29	1297	1	0.0
+ 65	ON	ON	350	8313	401	2.9	44	1123	9	0.5	386	8594	2192	15.3
* TOTAL + 65			350	8313	401	2.9	87	2451	158	3.9	427	10076	2226	13.3
TOTAL			1302	31398	5156	9.9	1108	28792	8280	17.3	1336	35447	15731	26.6

TABLE 1.14

Summary of American Shad catch by constant generation levels
(varying generation during a lift grouped separately)
1 April to 18 June, 1985 through 1990. Cleanout lifts excluded.

TOTAL DISCHARGE (X 1000 CFS)	UNIT 1	UNIT 2	1985 NO. LIFTS	1985 TIME (MINS.)	1985 TOTAL SHAD	1985 SHAD/HR	1986 NO. LIFTS	1986 TIME (MINS.)	1986 TOTAL SHAD	1986 SHAD/HR	1987 NO. LIFTS	1987 TIME (MINS.)	1987 TOTAL SHAD	1987 SHAD/HR
LE 5	OFF	OFF	229	4768	689	8.7	107	4394	3056	41.7	246	4842	2428	30.1
LE 5	OFF	ON	-	-	-	-	-	-	-	-	-	-	-	-
LE 5	ON	OFF	-	-	-	-	-	-	-	-	2	28	0	0.0
*TOTAL LE 5			229	4768	689	8.7	107	4394	3056	41.7	248	4870	2428	29.9
10-65	CHG	CHG	-	-	-	-	-	-	-	-	-	-	-	-
10-65	OFF	OFF	474	11857	494	2.5	320	9883	1212	7.4	452	11443	3727	19.5
10-65	OFF	ON	5	151	3	1.2	36	1328	35	1.6	9	201	8	2.4
10-65	ON	OFF	55	1059	1	0.1	-	-	-	-	-	-	-	-
10-65	ON	ON	26	67	1	0.9	24	730	23	1.9	44	636	23	2.2
*TOTAL 10-65			560	13134	499	2.3	380	11941	1270	6.4	505	12280	3758	18.4
VARYING	CHG	CHG	3	47	0	0.0	21	857	44	3.1	32	801	50	3.7
VARYING	CHG	OFF	4	85	0	0.0	1	30	3	6.0	5	112	3	1.6
VARYING	CHG	ON	-	-	-	-	1	30	23	46.0	4	105	8	4.6
VARYING	OFF	CHG	6	180	6	2.0	16	513	11	1.3	7	211	10	2.8
VARYING	OFF	OFF	184	5050	341	4.1	132	4866	651	8.0	171	4932	920	11.2
VARYING	OFF	ON	3	90	0	0.0	8	470	13	1.7	1	30	2	4.0
VARYING	ON	CHG	1	25	0	0.0	-	-	-	-	-	-	-	-
VARYING	ON	OFF	12	293	1	0.2	-	-	-	-	-	-	-	-
VARYING	ON	ON	3	34	1	1.8	6	424	2	0.3	8	189	17	5.4
*TOTAL VARYING			216	5804	349	3.6	185	7190	747	6.2	228	6380	1010	9.5
+ 65	OFF	OFF	1	25	1	2.4	-	-	-	-	-	-	-	-
+ 65	OFF	ON	12	330	1	0.2	46	1412	51	2.2	21	607	58	5.7
+ 65	ON	OFF	29	770	0	0.0	7	175	0	0.0	29	629	73	7.0
+ 65	ON	ON	26	677	1	0.1	56	2073	16	0.5	323	7170	332	2.8
*TOTAL + 65			68	1802	3	0.1	109	3660	67	1.1	373	8406	463	3.3
TOTAL			1073	25508	1540	3.6	781	27185	5140	11.3	1354	31936	7659	14.4

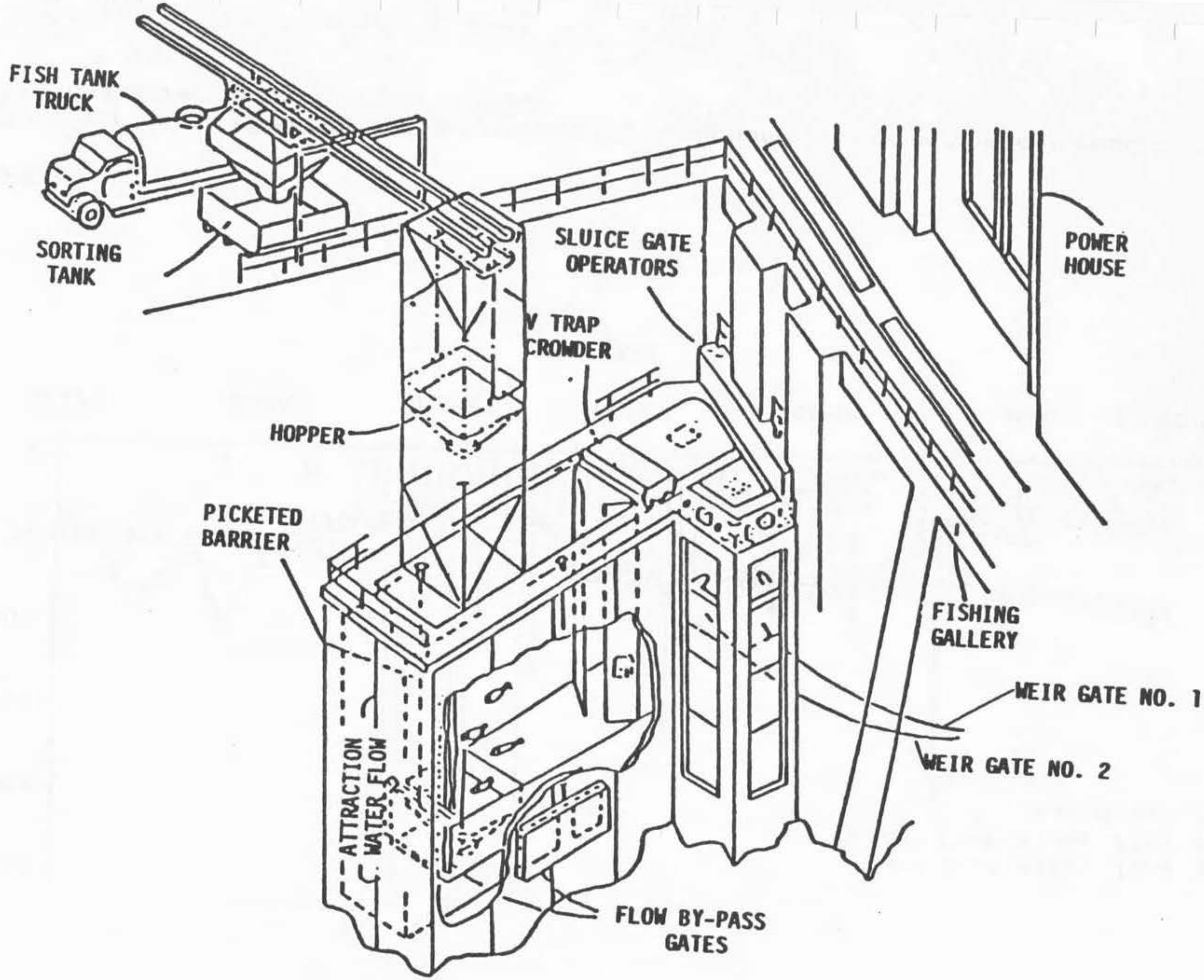

FIGURE 1.1

Schematic drawing of Conowingo Dam Fish Collection Facility, Anonymous (1972).

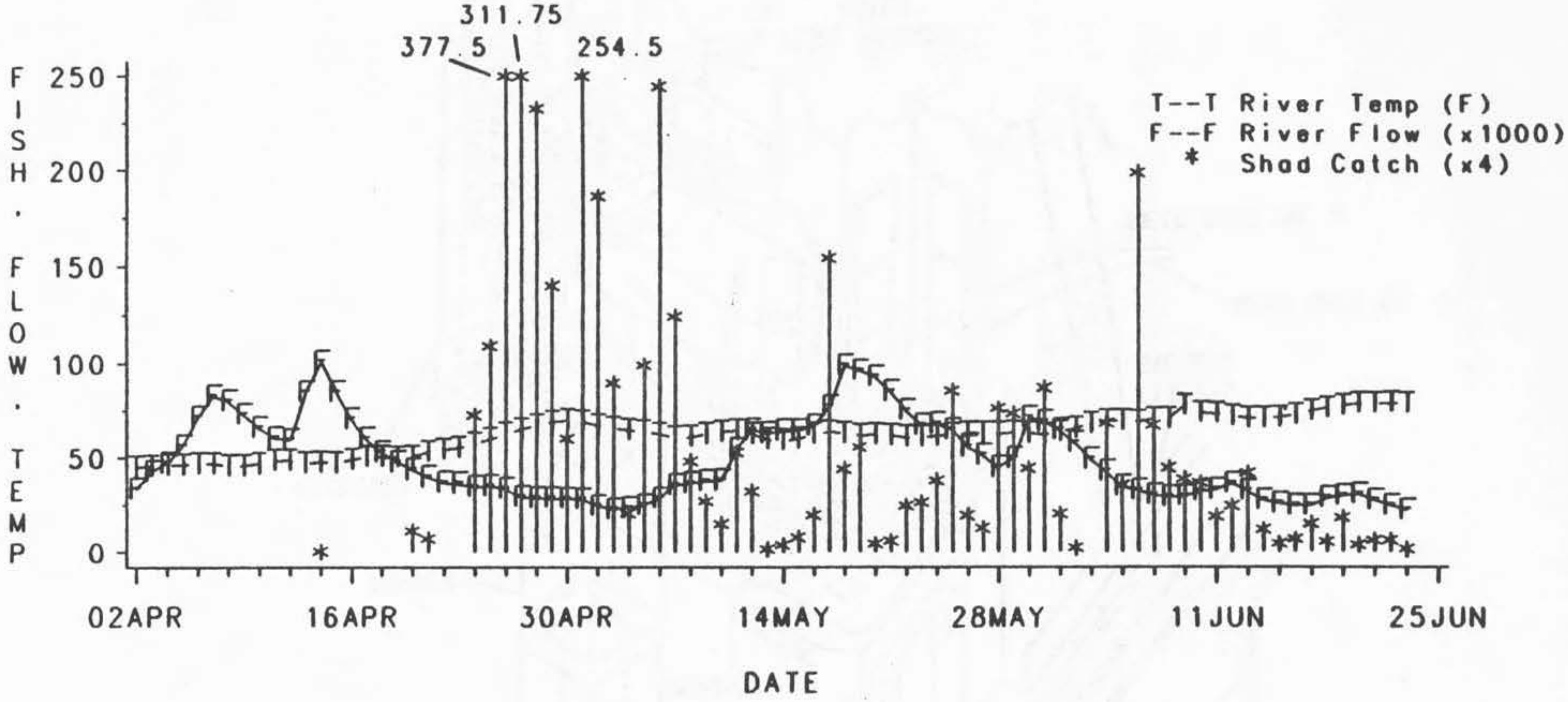

FIGURE 1.2

A plot of river flow (x 1000 cfs) and temperature (F) in relation to the daily American shad catch (x 4) at the Conowingo Dam Fish Lift in 1990.

JOB 1A. SUMMARY OF OPERATION OF THE INSTREAM NET PEN AT TRI-COUNTY MARINA

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I. INTRODUCTION

An experimental instream net pen (pen) was deployed at the Tri-County Boat Club Marina (marina) in 1990. The pen was stocked with pre-spawned American shad trapped and transported from the Conowingo Dam Fish Passage Facility. Initially, the pen was stocked every other day. Later, based on experience and logistics the pen was stocked daily. The purpose for penning shad was multi-faceted and included: (1) reduce stress induced by trap and transport, (2) enhance schooling behavior, and (3) assess mortality associated with the trap and transport program.

II. MATERIALS AND METHODS

The pen was deployed at the marina which is located on the east shore of the Susquehanna River between Swatara Creek and Three Mile Island (Figure 1). The pen was suspended from three booms attached to floating docks provided and installed by the Pennsylvania Fish Commission (Figure 2). The docks were attached to the marina's concrete bulkhead by means of a hinge-type arrangement that allowed the entire system to adjust to fluctuating river flows. Three winches were used to raise and lower the pen to assist in the release of shad, removal of mortalities, and pen maintenance.

The pen was constructed of 4" PVC pipe, and measured 8.5 ft x 18 ft x 4.5 ft. The frame was composed of two halves which were joined by threaded plumbing unions which allowed the pen to be easily transported. The upstream end consisted of a sliding door that allowed for easy release of shad. Black rigid nylon netting (3/4 in mesh) was hung on the outside of the frame with cable ties.

Initially, the pen was stocked every other day until it was established that the shad exhibited schooling behavior overnight and the pen could be reset quickly to allow daily stocking. Normally, shad were quick released directly from the transport truck into the pen. Dead fish removed after shad were stocked into the pen were considered transport mortalities.

At first, a two-man crew was used to release the shad and clean the pen prior to further stocking. To release the shad the dock was lifted, and the fish were allowed to leave on their own volition. If some shad showed a reluctance to leave the pen, the two downstream winches were used to raise that end of the pen. This concentrated the remaining shad at the open (upstream) end of the pen. Normally, this was all that was required for any remaining shad to exit the pen. After all shad had left, the pen was raised, and any mortalities and trash that had accumulated in the pen was removed. Mortalities found in the pen after the shad had been released were classified as delayed mortalities.

Water temperature (C), and dissolved oxygen (ppm) was measured with a YSI Model 57 Dissolved Oxygen Meter inside the pen just prior to fish release. In addition, velocity (ft/sec) measurements were taken with a Marsh McBirney Model 201 current meter when it was available.

III. RESULTS

Prior to construction and deployment the carrying capacity of the pen was unknown. It was anticipated that up to 300 shad could have been stocked into the pen. This assumed that each shad would have a minimum of 3 cubic ft of space available in the pen. However, dock configuration reduced the size of the pen from that originally anticipated. In addition, after deployment it was discovered that the pen rested on the bottom next to the bulkhead further reducing the carrying capacity of the pen. As a result, as river flows increased and/or decreased available carrying capcity in the pen changed. In response to this the number of shad stocked was reduced and varied according to river flow.

High spring river flows prevented deployment of the Pennsylvania Fish Commission docks and pen until the end of

April. Thus, the pen was stocked for the first time on 30 April. Increased river flows(>40,000 cfs) prevented the pen from being stocked from 11 to 17 May (Figure 3). Anticipated river flows in excess of 90,000 cfs resulted in removal of the pen on 18 May. The pen was reinstalled on 4 June and removed for the season on 16 June.

Sixteen transport/stocking events occurred between 30 April and 15 June (Table 1). A total of 1,937 pre-spawned American shad was stocked; loads transported ranged from 43 to 175 fish per trip. Transport mortality by trip ranged from 0 to 9.1%; total transport mortality was 2.8% (54 shad).

Some 1,883 shad were stocked alive in the pen; loads stocked ranged from 42 to 170 fish per event (Table 1). The delayed mortality by event ranged from 0 to 44.1%; overall delayed mortality was 7% (132 shad) including the high mortality due to a flash flood event. Over 56% (75 shad) of the delayed mortality was observed on 6 May. This mortality appeared to be a direct result of poor conditions in the pen that resulted from a flash flood in Swatara Creek. Over half of the pen was full of trash (sticks, leaves, and maple seeds). All mortalities were severely descaled. In addition, the 95 shad that were still alive at time of release from this event were in extremely poor condition. Most were partially descaled and hemorrhaged around the head.

Dissolved oxygen values ranged from 8.4 to 10.4 ppm over the course of the penning program and averaged 9.2 ppm. Water temperatures ranged from 13 to 22° C and averaged 17.5° C. Water velocity (when available) ranged from 0.4 to 1.5 ft/sec and averaged 0.6 ft/sec.

IV. DISCUSSION

Visual observations by personnel that tended and were responsible for release of shad from the pen reported that shad schooled in the pen. Once the door was opened, most shad reportedly exited the pen in various sized schools in a relatively short period of time. However, some shad showed a reluctance at times to cross under the upstream dock and exit the pen. Normally, raising the downstream end of the pen was required to encourage remaining shad to move out.

Visual observations prior to and at release indicated that shad appeared to display normal behavior. However, visual observations can not be used to quantify whether or not stress associated with trap and transport was reduced. Preliminary results of a study conducted by the University of Maryland indicated that holding shad in the pen overnight reduced stress induced by handling and transport (Dr. Eric May, personal communication).

The transport and release of shad to the pen enabled retrieval of all transport and delayed mortalities. In contrast, recovery and enumeration of mortalities of shad transported and released to the river was limited to retrieval of shad found in the truck and on the ramp after each load was released. Fifty-three mortalities (2.7% of 1,937 shad transported from Conowingo Dam) were recovered from the pen. Some 230 mortalities (1.7% of the 13,138 shad transported) were recovered following release of shad to the river. Although the possibility exists that not all transport mortalities of shad stocked to the river are recovered since transport mortality was similar at both locations it appears that the method used to recover and enumerate mortality following release of shad to the river is reflective of transport mortality of shad released to the river.

Some 57 delayed mortalities (3.4% of the 1,656 stocked alive in the pen; data from 6 May excluded) were observed following release of shad from the pen. Since many factors could influence delayed mortality in the pen, it is unknown whether delayed mortality of shad transported and released to the river occurs at a similar rate. However, results indicate that some delayed mortality of shad transported and released to the river may occur. The overall mortality (short-term and delayed) appears to be low. Applying the mortalities observed in the pen to the total number of shad transported from Conowingo Dam it was estiamted that 5.5% (724) of the 13,206 shad transported may have suffered mortality in the river in 1990.

V. RECOMMENDATIONS

(1) If shad are penned in 1991, the existing pen can be utilized. Extend the docks further out into the river (2 or 3 ft). This would allow the pen to be fully deployed and possibly enable similar size loads of shad released to the river to be stocked. If the above modification is made a chute would be required to release shad into the pen. The chute should be collapsable allowing it to be removed from the site by the transport crew to minimize interference with daily activity at the marina.

(2) If possible, reduce the width of the upstream section of dock since some shad showed a reluctance at times to cross under it and exit the pen.

(3) Simultaneously release groups of radio tagged shad from the pen and transport truck. A study of this nature could be used to determine if penning shad is warranted in the future.

Table 1. Summary of Stocking and Holding Events at the Experimental Instream Net Pen at the Tri-County Boat Club Marina, Spring 1990.

STOCK DATE	RELEASE DATE	NUMBER TRANS.	NUMBER STOCKED	NUMBER RELEASED	TRANSPORT MORTALITY	DELAYED MORTALITY	NUMBER HRS. HELD	D.O.	TEMP	VELOCITY
4/30/90	5/1/90	116	108	105	8	3	20:30	10.4	16.20	-
5/2/90	5/3/90	149	139	137	10	2	22:45	9.9	16.00	-
5/3/90	5/4/90	164	149	147	15	2	20:58	9.1	14.80	-
5/4/90	5/5/90	85	83	82	2	1	15:00	8.8	14.00	-
5/5/90	5/6/90	175	170	95	5	75 *	16:05	8.8	13.00	-
5/7/90	5/8/90	152	149	138	3	11	17:10	9.2	15.00	-
5/8/90	5/9/90	120	120	119	0	1	12:45	8.4	17.50	1.5
5/9/90	5/10/90	104	104	102	0	2	13:35	8.6	17.50	0.5
6/5/90	6/6/90	43	42	42	1	0	20:20	9.2	19.50	-
6/6/90	6/7/90	100	100	95	0	5	15:15	9.2	19.50	-
6/7/90	6/8/90	146	142	140	4	2	21:30	9.1	20.00	0.4
6/8/90	6/9/90	138	137	121	1	16	15:00	9.1	19.50	0.6
6/11/90	6/12/90	118	118	115	0	3	17:35	9.2	18.00	0.5
6/12/90	6/13/90	108	108	104	0	4	18:20	9.7	19.00	0.7
6/13/90	6/14/90	114	112	109	2	3	18:35	9.2	19.50	0.4
6/14/90	6/15/90	105	102	100	3	2	18:25	9.2	22.00	0.5
TOTALS		1937	1883	1751	54	132				

* Mortalities a result of flash flood in Swatara Creek.

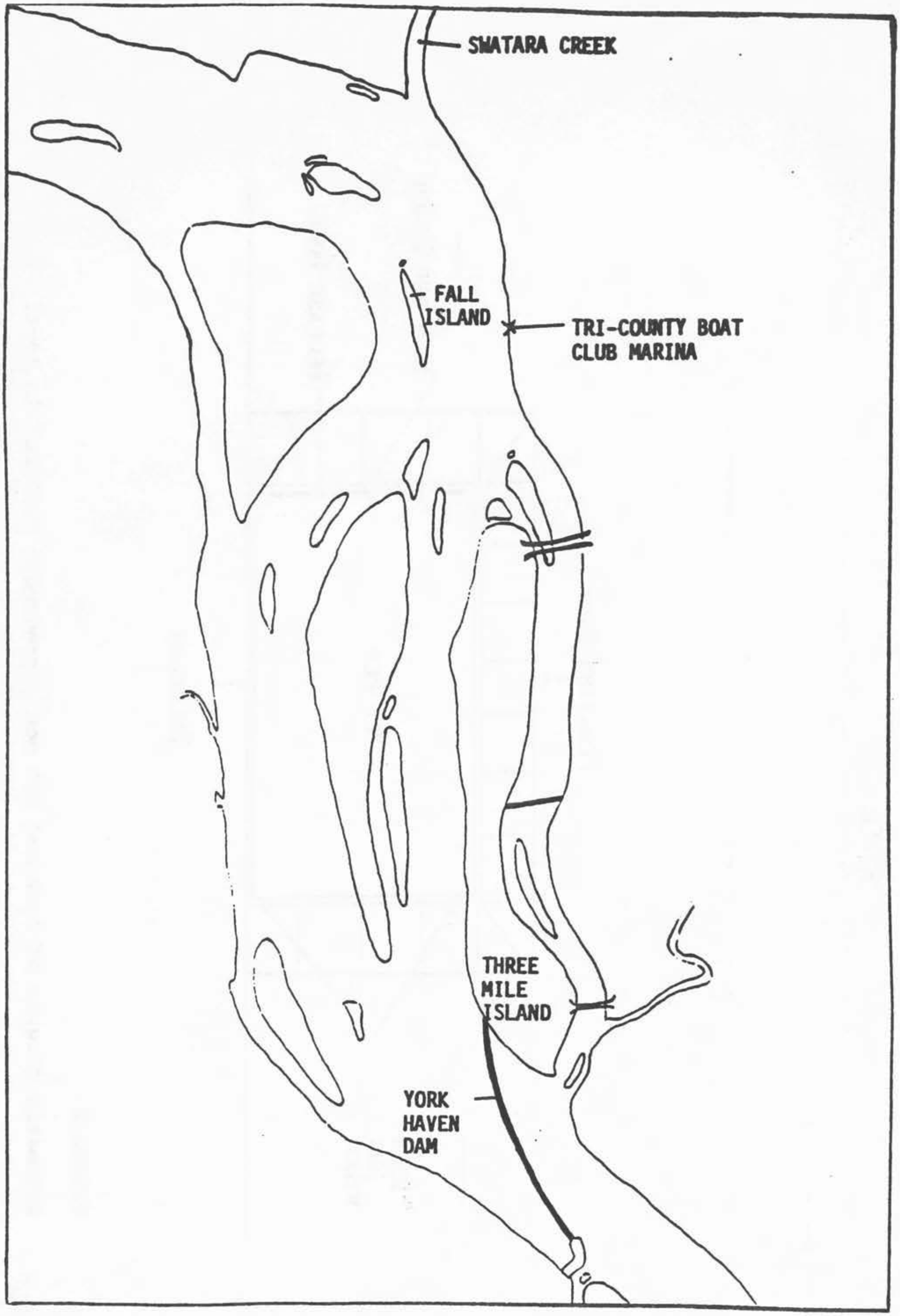


FIGURE 1

Location of Tri-County Boat Club Marina.

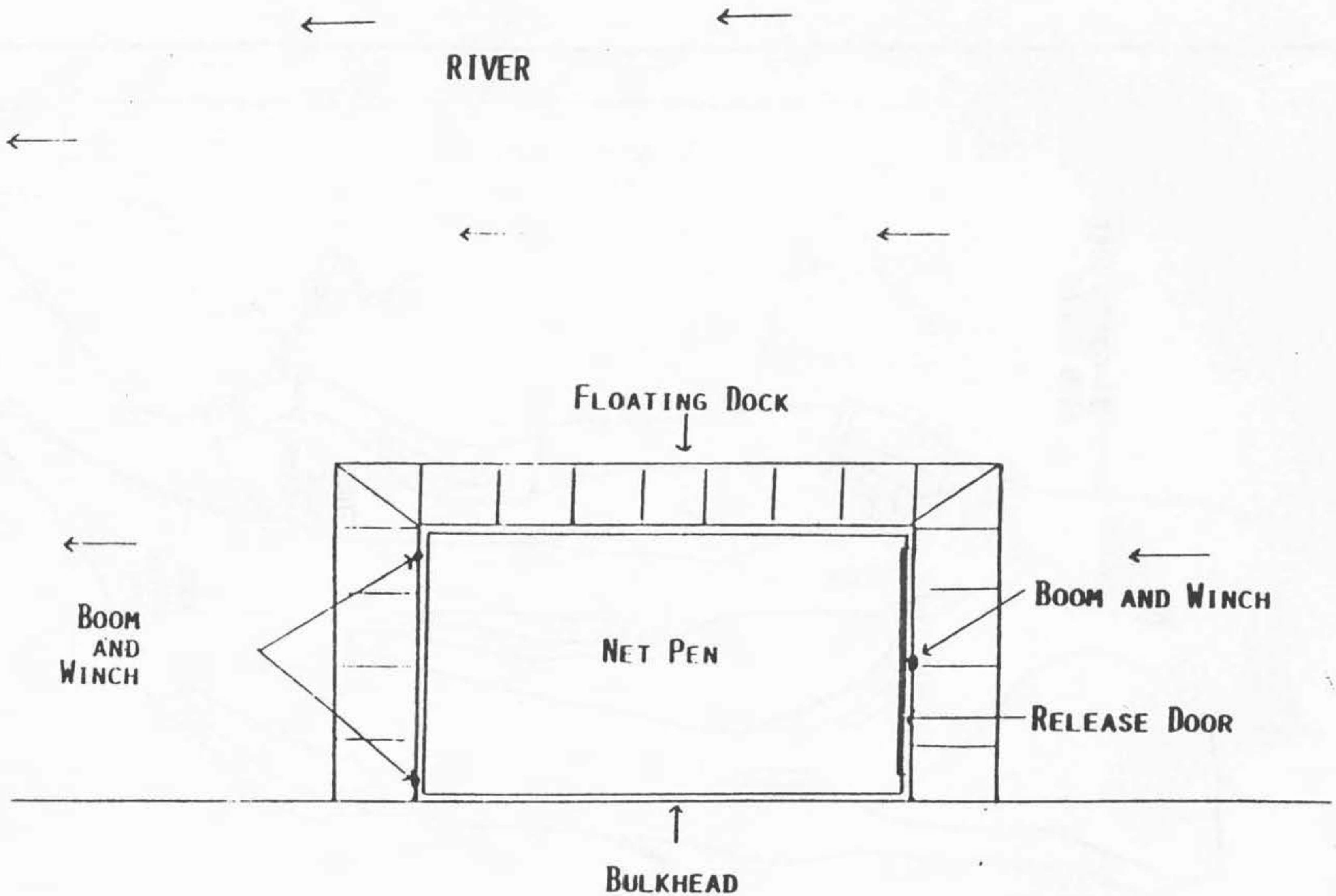
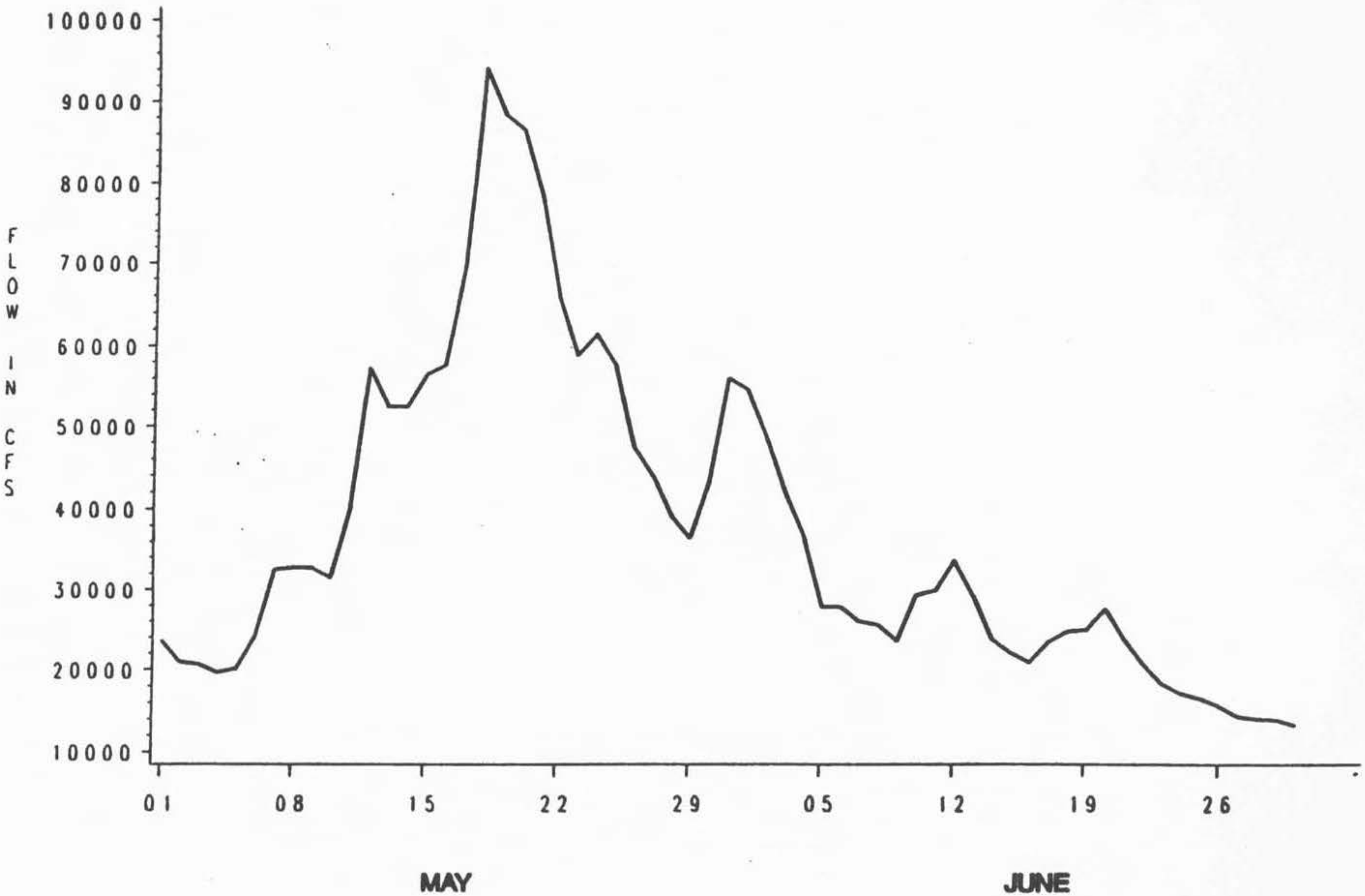


FIGURE 2

Schematic diagram of dock and net pen arrangement utilized in 1990.

FIGURE 3.
River flows at Harrisburg for the months of May and June, 1990 (Harrisburg Forecast Center).



JOB II

AMERICAN SHAD EGG COLLECTION PROGRAM

THE WYATT GROUP

Environmental Service Division

Lancaster, PA

INTRODUCTION

In 1970, an agreement was signed between various utilities (Philadelphia Electric Power Company, Susquehanna Electric Company, Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, Metropolitan Edison Company, the States (Maryland, Pennsylvania and New York), and the U.S. Department of Interior for the implementation of a program for restoration of the American shad to the Susquehanna River. Part of the agreement called for a program to annually obtain 50 million or more artificially fertilized American shad eggs for transplantation to areas above existing dams on the Susquehanna River. The objective is to artificially develop a population of American shad which, as adults, will return to the River with the urge to migrate upriver above Conowingo and the other hydroelectric dams.

The shad egg collection program began in the spring of 1971 and has continued annually to date. From 1971 through 1974 all shad eggs were transplanted to the Susquehanna River and released at various sites. Beginning in 1975 a few eggs were delivered to a hatchery for experimental culture and by 1978 virtually all eggs were delivered to hatcheries for culture and rearing.

The following is a report of the 1990 results. It includes the result of efforts to meet the SRAFRC production goals and a description of the conditions encountered on the various rivers that effect the efficiency and quality of the egg collection program.

HATCHERY PROGRAM

Since the direct release of shad eggs to the Susquehanna River and tributaries did not appear to create a substantial population of juvenile shad, probably due to high rates of early natural mortality, culture at hatcheries was considered in 1974 as a potential means to improve success of the egg transplant program. The purpose was to: (1) attempt to increase the number of out-migrating shad through intensive rearing on the assumption that one juvenile shad is equivalent to a great number of shad eggs in terms of probability of survival to adult, (2) establish whether or not intensive rearing operations were possible and feasible, and if so, to demonstrate such, (3) demonstrate the use of the Susquehanna River Basin by out-migrating juvenile shad and (4) conduct experiments concerning the culturing, handling, and transporting of shad.

Shad had not been raised in hatcheries for more than 25 years; it remained to be determined if it was feasible to use this method. At the recommendation of the Evaluation Sub-Committee Susquehanna Shad Advisory Committee, shad eggs (954,600) were delivered to Harrison Lake National Fish Hatchery, Charles City, Virginia in 1975 for experimental pond culture. Eggs (520,000) also were transferred to Harrison Lake in 1976.

It was demonstrated at Harrison Lake that shad eggs could be hatched and young cultured in ponds. On the basis of this work, the Van Dyke Research Station for Anadromous Fishes was constructed in 1976 at Thompsontown, Pennsylvania. It is staffed by the Pennsylvania Fish Commission (PFC). The site was selected because it was desirable to culture shad at a location on the Susquehanna River drainage above the hydroelectric dams. By this means shad would be raised in water of a quality to which these shad would home as adults.

OBJECTIVE OF PROGRAM

The SRAFRC goal for 1990 was to obtain a minimum of 30 million shad eggs over a three month period (April-June) to support the shad hatchery cultural program (Job III). Over the last 16 years (from 1973 to 1989) nearly 500 million eggs were collected for the program (Table 1). A record 52.5 million eggs (5,535.7 liters) was sent to the Van Dyke Hatchery in 40 shipments in 1986. In 1989, a record 20.7 million shad fry was stocked in the Susquehanna River from 42.7 million eggs delivered to the hatchery. More than half of these eggs were collected from the Columbia River.

In 1990, eggs were to be collected from four rivers; Pamunkey (Virginia), Delaware (New Jersey-Pennsylvania), Hudson (New York) and the Savannah (South Carolina-Georgia). The Columbia River, (Oregon-Washington), from which more than 200 million eggs were collected in the last nine years, was eliminated from the 1990 program due to poor fry survival, as indicated by otolith analysis, and the potential presence of viral hemorrhagic septicemia (VHS). The James River was also eliminated due to lack of egg production in the past few years. The Pamunkey River program was scaled down to a two week sampling effort in order to reduce cost and maximize collection potential. The Savannah River was added to the 1990 program in an effort to collect up to 5 million eggs in April.

METHODS

Locations

Savannah River

The fishing site was near Millet, SC (about 30-35 miles downriver from Augusta, SC and 75 miles upriver from the mouth at Savannah, GA). The area selected is dam-controlled by the Clarke Hill Dam approximately 70 miles upstream. Collections took place near Steel Creek Landing at river mile 145.

Pamunkey River

On the Pamunkey River gill-netting was conducted at Thompson's Landing, New Kent, (New Kent County) located about 4-6 miles upriver from Lestor Manor.

Delaware River

The egg collection program is conducted at Smithfield Beach, about eight miles upstream from East Stroudsburg, PA.

Hudson River

There are two main collection areas on the Hudson River. For the haul seine, netting is done near Hudson, NY (River Mile 115). For the gill-netting, the main sampling is at Cheviot, NY (River Mile 107). Some gill-netting is done as far upstream as Hudson.

Collection Schedule

The shad egg collection schedule is based on experience gained over a 13 year period. Initiation of collection activities on any river is determined through communications with commercial fisherman and/or participation in fishing activities which document that spawning shad are available in sufficient numbers. Collection activities begin when water temperature is 55-58 °F. For 1990 the schedule of collection activities is shown in Table 2. Collection is terminated on a river when the production goal for that river is reached or when it is obvious that ripe shad can no longer be taken.

Egg Collection

Handling shad after capture

Every attempt is made to obtain eggs and sperm from shad soon after they are taken from nets. Conditions for doing so vary somewhat from river to river. On the Savannah, Pamunkey and Delaware rivers, gill-netted shad are brought to the shoreline. The ripe shad are then processed by biologists. If there are no ripe males, a smaller meshed gill-net is set to specifically catch them and they are immediately brought to the shoreline.

On the Hudson River, the haul seine is pulled to the shoreline, and the catch is retained in the bag of the net. Ripe males and females are sorted from the catch and placed into separate tubs. Biologists immediately process the shad in a boat tied along the side of the seine. Live male shad are placed in a tank with cold water to keep them alive, thereby ensuring active sperm for fertilization. For shad captured by gill-net the processing is done in the boat. Live males are taken from the net and placed in a tub of water in the boat. Ripe females are generally spawned immediately after they are taken from the net.

Artificial fertilization

Eggs are artificially fertilized using essentially the same method established by Kilcer (1973). A brief description of the procedure follows: Eggs are stripped from four to six spawning females into a dry collecting pan and fertilized with sperm from up to six live males. After dry mixing eggs and sperm for about one minute, a small amount of water is then added to the mixing pan to activate sperm and the gametes to ensure fertilization. The eggs are then allowed to set for 2 to 4 minutes. After the eggs settle, the water is drained and clean water added to the mixing pan. The eggs are rinsed to remove dead sperm, unfertilized and broken eggs, and debris. This rinsing process continues until all eggs are clean, which takes four or more rinses. Eggs are then poured into large plastic buckets filled with clean river water and allowed to soak for a minimum of one hour to become hardened. During this period, water is periodically decanted and clean water added.

Once the eggs are hardened (about 1 hour), the water is drained and five liters each of eggs and clean water are placed in double plastic bags. Pure oxygen is injected into the bag containing eggs and then each bag is secured with a rubber O-ring. The bags are shipped in cardboard boxes with styrofoam container inserts. Each box is labeled to show river name, date, number of liters of eggs, and water temperature.

Egg Viability

Each year, improvements are made in quality control to enhance egg viability and thereby production. Techniques employed in the field have a substantial impact on egg viability. These techniques have evolved through the mutual interests and concerns of the field biologists and hatchery staff to determine the factors which increase egg viability. Only very ripe females are used for obtaining eggs and eggs are not "forced" during stripping. To optimize conditions for fertilization, blood (which contains lactic acid) is quickly removed after eggs are stripped and sperm is obtained only from live males. Eggs are rinsed repeatedly after fertilization. Clean, fertilized eggs are placed in clear river water for hardening. In the packaging process, eggs are handled carefully to prevent breakage.

Disposal of Shad

Although efforts are made to return shad used for artificial fertilization back to the river, most die soon after eggs are extracted. Shad gill-netted from the Pamunkey and Savannah Rivers are sold at local markets by commercial fisherman.

Shad gill-netted from the Delaware River are disposed of in several ways. By terms of contract, Ecology III is responsible for removing dead shad from the landing site. Shad can not be returned to the river or sold for profit. Most of the dead shad are disposed of in two approved 10 by 10-foot hand dug pits located about 100 yards west of the PFC Area Number 5 office. Garbage cans of lime are staged near the pits and dead shad are covered with lime. In 1990, some of the Delaware River shad were used as raptor food in an osprey research program while others were donated for use at the Delaware River Shad Festival at Easton, PA.

On the Hudson River, all live shad (and other fish) are released back to the river as soon as possible. Dead shad are gutted and released into the river channel where they sink to the bottom.

Transportation of Eggs to Hatchery

Shad eggs from the Pamunkey, Delaware, and Hudson rivers are packaged and shipped nightly by automobile to the Van Dyke Hatchery. This method of delivery has been followed since 1983 with good results. From the Savannah River, shad eggs are held overnight and shipped the next morning by air freight from Charleston, SC to Baltimore, MD. The eggs are then delivered to the hatchery by automobile.

Personnel at the various rivers arrange transportation and the project manager notifies the hatchery nightly as to the number of liters shipped and the ETA of the shipment. The average delivery time from Delaware and Pamunkey-Hudson rivers is approximately 3 and 6 hours, respectively. The flight time from Charleston, SC to Baltimore, MD is 2.5 hours and the driving time to the hatchery is 2 hours.

FACTORS WHICH AFFECT EGG COLLECTION PROGRAM

Weather Conditions

Weather conditions can have a significant impact on the egg collection program. High winds and rain storms create river conditions unsuitable for netting. Extensive rain can increase river flow to a point that water temperature decreases result in short term periods when ripe shad cannot be netted. This is either because ripe shad do not move onto the spawning ground when water temperature is not appropriate or because shad tend to move downstream and away from the spawning ground. In the case of the Hudson River, flood waters impact tidal conditions (see below), an important factor in collecting ripe shad.

Water Temperature

Water temperature is an important factor in obtaining ripe shad. Although differences occur between rivers, ripe shad are not collected until water temperature is consistently above 58 °F. Spawning is concluded by the time water temperature reaches about 66 °F. Monitoring water temperature on rivers where egg collection takes place is important in determining the appropriate time to begin collection. Starting time for egg collection can vary one to two weeks annually because of this. Under unusually warm spring conditions, as in 1990, water temperature can increase quickly.

Water temperature fluctuations during the spawning season have an impact on egg collection success. With increased river flow and cool air temperature, water temperature can decrease as much as 10 °F in a few days, or 5 °F in a matter of 24 hours. When water temperature decreases to less than 55 °F, spawning ceases and ripe shad cannot be netted consistently until water temperature increases to 58 °F or higher.

Tidal Conditions

On some rivers, such as the Columbia and the Delaware, netting is conducted in nontidal areas. Thus, a sampling program can be established which is relatively easy to repeat. Known spawning grounds can be netted and ripe shad collected using standard methods year after year. The Hudson River, however, can only be netted effectively when the tidal conditions permit.

The tidal cycle includes an ebb (descending) and flood (ascending) tide. Every 4-6 hours the tide changes direction. For a short period of time when the tide changes there is relatively slow movement of water, referred to as the slack. The slack is either during high or low tide at the time when the river changes direction. There are basically two high and two low tides per 24-hours. In each 24-hour cycle the high or low slack tide is approximately 1 hour later in the day. Understanding the tidal system and the factors that influence the tidal cycle (river flow, weather, lunar cycle, etc.) is important to success on the Hudson River. For example, the effects of several days of abnormally high or low barometric pressure, several days of continual north or south winds, or a period of heavy rain can alter the timing and strength (current) of the tide. These natural events can change the times shown in tidal charts by up to 90 minutes.

The specific spawning requirements of shad, such as time of day and location, must be coordinated with tidal factors in order to be successful at netting ripe shad. Netting can be conducted only when tidal conditions permit sampling at dusk or later and at a location near shore. The appropriate use of gill nets and the haul seine must include the tidal conditions (see below).

DESCRIPTION OF OPERATIONS

Savannah River

The South Carolina Wildlife and Marine Resource Division (SCWMRD) was contracted by SRAFRC to conduct the sampling program utilizing a commercial fisherman to catch shad using drift and anchored gill nets. The Wyatt Group provided technical support by demonstrating the artificial fertilization methods. Field gear, including shipping boxes, bags, and an egg incubation tank were provided by The Wyatt Group.

Because the netting site was at a remote location, eggs could not be brought to an airport in sufficient time to ship them on the same night that they were collected. Therefore, arrangements were made to drive the eggs to Charleston, SC where they were held overnight in an egg incubator constructed by the PFC. They were air freighted in the morning to Baltimore, MD.

The Savannah River in the collection area is subject to rapid fluctuations in level and flow rate due to discharges from upstream hydroelectric plants. Water temperatures are generally cooler than if the River were free flowing. The general pattern of water fluctuation during the collection period was falling water levels on the weekend and a gradual to rapid rise beginning on Tuesday or Wednesday.

The first night of netting on the Savannah River was on 16 April. The operation terminated on 8 May.

Pamunkey River

Egg collection efforts on the Pamunkey River commenced on 11 April when water temperature was 56 °F. Operations ceased on 25 April when ripe shad were no longer being caught.

Wyatt Group biologists worked with up to four commercial fishermen. Gill-nets, up to 300 feet in length with 4.5-6.00 inch stretched mesh, were set and drifted over a two mile stretch of river to catch ripe shad. Netting operations were conducted throughout the day beginning at 7 AM and concluding at about 9 PM, six days a week.

Delaware River

SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative (New Jersey), to collect some 10 million shad eggs from the Delaware River. Biologists from the PFC and Ecology III, Inc.(Berwick PA) conducted the collection program. Netting was conducted on nine days from 29 April to 9 May. Fishing was not conducted on 4 and 5 May. Shad were captured with 200 x 6-foot, anchored, gill nets, with sections of 4.75-6.00 inch mesh, set parallel to the current. Up to 10 net sets were made in an evening. Nets were set between dusk and midnight.

An attempt was made to collect shad by electrofishing for 3 hours on 6 May. The electrofisher consisted of a 4-KW generator and a variable voltage pulsator mounted on a 20-foot flat bottom boat. Direct pulse current was used. This method did not prove effective as an alternative to gill-nets.

Hudson River

Egg collection efforts on the Hudson River began in 1988. By 1989 it was demonstrated that ripe shad could be captured effectively by gill-net and haul seine. This led to an expanded effort in 1990. The Hudson River egg collection program began on 3 May and continued until 11 June, a period of 40 days. A total of 25 days were spent netting for ripe shad. This included 16 days of gill-netting and nine days of haul seining.

METHODS OF CAPTURE ON HUDSON RIVER

Gill-netting

Successful use of gill-nets depended on locating the shad spawning grounds. Although the Hudson River has one of the largest populations of shad on the East Coast, commercial fishermen do not consistently capture ripe shad in large numbers. Commercial fishermen typically drift gill-nets up and down the main river channel (an area not suitable for spawning), and net mostly prespawned shad. The fishermen do not net near dusk or into the night, the period in which spawning takes place.

Therefore, Wyatt Group biologists undertook the task to conduct gill-net operations, as well the processing of eggs. As a result of several years experience, field personnel had located spawning areas and were equipped to gill-net at the most desirable time of day.

Because of the relatively large size of shad spawning areas on the Hudson River, many feet of gill-net must be set in order to capture sufficient numbers of shad to reach the egg production goal. In 1990, two monofilament gill-nets (900 x 8-foot with 6 inch stretch mesh and 1000 x 6-foot with 5.5 inch stretch mesh) were set on a daily basis beginning at about 6 PM, tide permitting. Nets were anchored perpendicular to the shoreline at slack tide or during a slow moving flood tide. Water depth ranged from 4-6 feet.

Gill-nets were anchored in areas known to be spawning grounds based on previous experience (1988 and 1989). The main areas included: (1) Cheviot, (2) on the east shore off the mouth of Roeliff Jansen Kill and (3) on the west shore off Rodgers Island north of the Rip Van Winkle Bridge. An area south of Rodgers Island on the west shore was occasionally sampled. Ripe shad were taken at all locations.

The most effective time to catch ripe shad by gill-net is at a time when the tide is flooding. Gill-netting is most successful under the following conditions:

1) in areas adjacent to the main channel where large numbers of shad spawn.
2) between 7 and 11 PM.
3) in an area where 1,000 feet of gill-net can be anchored along tidal flats perpendicular to the shoreline or channel; up to 2,000 feet of gill-net must be set to catch sufficient numbers of ripe shad.
5) the netting site should have a minimum water depth of four

feet during flood tide.

6) gill-netting can be conducted for 5 or 6 consecutive days every other week when the flood tide occurs near dusk.

Haul Seine

Shad have been captured by haul seine on the Hudson River since 1984. Although thousands of shad were captured between 1984 and 1987 for the SRAFRC adult transfer program, ripe female shad were uncommon in the catch. In 1989, ripe females were taken when haul seining was moved to shallower water along shore and sampling was done at dusk.

A 500 by 12-foot haul seine with 2-inch stretched mesh was used to collect shad. Netting was done along the west shore of Rodgers Island, immediately north of the Rip Van Winkle Bridge. Seine operations were conducted on an ebb tide, between late afternoon and dusk at a time when the tidal conditions provided a landing site where the catch could be effectively beached. Haul seining is most effective under the following conditions:

1) several hours after the tide has been ebbing in areas where the shoreline is exposed on an ebb tide.
2) from 7 to 10 PM, the optimal time to collect ripe female shad; ripe male shad seem to be present at any time of day.
4) with sufficient labor since the operation can only be carried

out with a minimum crew of 6 to 8 people, excluding boat operators.

5) haul seining can be conducted on 5 or 6 consecutive days every other week when the ebb tide occurs in the late afternoon.

MITOCHONDRIAL DNA STUDIES

Egg collection contractors were required to collect ovarian tissue and scale samples from 50 female shad from each river to be used for mtDNA analysis by the Chesapeake Biological Laboratory, Shady Side, MD (under contract to the Maryland Department of Natural Resources). The objective is to document the DNA characteristics of the Delaware, Pamunkey, Savannah and Hudson River strains of the American shad. A subsample of five pairs of otoliths were collected by shipping 10 shad heads from each river to the PFC for research. Samples were shipped in sealed containers for next day service via Federal Express.

RESULTS

Savannah River

One shipment of 3 liters was made on 2 May. It contained 123,000 eggs (Table 3). This was the result of collections on 30 April and 1 May. Few spawning shad (39) were collected in the nine days in which fishing operations were conducted.

Pamunkey River

Collection efforts resulted in only one shipment of eggs on 16 April(Table 4). Water temperatures ranged from 56 to 65 °F (Table 3). Egg collection efforts were halted on 25 April when commercial fishermen no longer caught shad. A total of 477,700 eggs was collected.

Delaware River

Pennsylvania Fish Commission biologists and Ecology III biologists conducted shad egg collection efforts on the Delaware River beginning three weeks earlier than in 1989. Approximately 12.9 million eggs (Table 5) were shipped to the Van Dyke Hatchery on 10 dates. The consistency of the results was excellent; more than one million eggs were shipped on 8 of 10 collection days. Ripe shad were caught at water temperatures which ranged from 57 °F to 64 °F (mean = 61 °F).

Hudson River

A total of 14,531,200 eggs was obtained on the Hudson River (Table 6). This included 10,557,700 from shad captured by gill-net and 3,973,500 from shad captured by haul seine. For gill-netting, egg shipments were made on 13 of 16 days. On 11 of the 13 days at least 500,000 eggs were shipped. Ripe shad were captured at water temperatures of 55-67 °F (mean = 58 °F). For the nine days of haul seining, shipments were made on 6 days. Ripe shad were taken at temperatures of 58-65 °F (mean = 60 °F).

The chronological sequence of utilization of the haul seine and gill-net was as follows: Collection on the Hudson River began on 3 May with haul seine operations on the west shore of Rodgers Island, the same site where ripe female shad were captured in 1989. Water temperature was 59 °F. No eggs were obtained on the first day of seine effort, most likely because the tidal conditions were not appropriate. Low slack tide on 3 May was at 6:51 PM, a time too early in the evening to collect ripe female shad. Gill- netting was conducted on 4 May to determine if ripe shad could be collected. Some ripe shad were netted but not enough eggs (5 liters) were obtained to justify a shipment.

Haul seining continued on 5 May and was repeated for the next four days. A total of 179.7 liters of eggs were collected in this period with a maximum of 62.8 liters on 7 May. Eggs were not collected in the next three days because rain and poor tidal conditions prevented netting.

On 13 May, the field crew initiated gill-netting at Cheviot. Gill-netting continued for the next five days (through 17 May) and a total of 95 liters of eggs were collected. On 18 and 19 May tidal conditions were unsuitable for either gill-netting or haul seining. Over the next four days (20-23 May) gill-netting and seining efforts were alternated. In this period 48.2 liters were collected by gill-net and no eggs were collected with the seine. Gill-netting continued from 28 May through 11 June with a total of 171.3 liters of eggs being collected. Seining was conducted for the last time on 5 June but only 6 liters of eggs were collected.

All Rivers Combined

The total number of eggs collected in 1990 was 28,280,000. The Savannah River and Pamunkey River made virtually no contribution to the program. The production goal was exceeded on the Delaware River and more eggs were obtained from the Hudson River than in 1989. Results on the Hudson River show that a goal of 20 million eggs for this river is realistic. Perhaps the most significant aspect of the 1990 results was the demonstration that reliance on the Columbia River is not necessary.

COMMENTS ON SAVANNAH RIVER EFFORTS

The following are comments offered by the South Carolina Wildlife and Marine Resources Division (SCWMRD) in reference to their efforts on the Savannah River:

The lack of success in obtaining significant quantities of eggs was disappointing. Spawning in southern rivers may be more protracted and less concentrated in time and area than in northern rivers. Water temperatures in South Carolina rivers in 1990 warmed early in the season and shad apparently ascended the rivers as soon as they arrived in the estuaries. When water temperatures stay low early in the season, shad concentrate in the estuaries and river mouths prior to moving upstream to spawn. Rising water temperatures trigger upstream movement and subsequent peaks in commercial catches in the upriver areas. Commercial fishermen on the Savannah and other South Carolina Rivers reported that there were no pronounced peaks in the 1990 shad run, with shad catch being distributed uniformly throughout the season. This may explain the inability to catch sufficient quantities of running ripe fish during a period when spawning activity should have been at a peak.

The rapidly fluctuating water levels (and possibly the cooler water temperatures) in the collection area were also problematic. Catch rates of fish (ripe and unripe) consistently declined as the river level rose during the mid-week period. River level dropped over the weekend, started rising slowly on Monday or Tuesday and peaked Wednesday or Thursday. If future collecting were to be anticipated on the Savannah River, the activity should be structured to permit weekend collections.

In the course of work on the Savannah River, an exploratory trip was made to the Pinopolis Dam on the Cooper River on 23 April. Flow from the dam was insufficient to concentrate shad along the wing walls where they would be available for capture.

In the interest of future considerations, another exploratory trip was made to the re-diversion canal on the Santee River at St. Stephens, South Carolina. Biologists from the SCWMRD used their electro-shocking boat to determine if any shad were available in the vicinity of the St. Stephens Dam. Only two male shad were observed;, however the biologists reported that there had been large concentrations of American shad in this area one to two weeks previously. This area may be promising for future egg collection efforts. There is a striped bass hatchery at the site and some of their hatching jars could be made available for holding shad eggs prior to shipment. The support facilities at the St Stephens hatchery are far preferable to the conditions on the Savannah River. The major factor that must be determined for success in this area is whether spawning shad are available for collection.

Personnel at the Dennis Wildlife Center (SCWMRD) have agreed to make their facilities at the striped bass hatchery on the re-diversion canal available if future South Carolina collections of shad eggs are contemplated. Considerable numbers of American shad traverse this area as evidenced by the large number pased through the St. Stephens fish lift into Lake Marion. There is, however, the question of the stage of maturation of these shad. A cooperative effort between the Freshwater and Marine Division's of the SCWMRD would be the best approach to determining the potential for successful future egg collections here.

CONNECTICUT RIVER EGG COLLECTION FEASIBILITY STUDY

Background

With the termination of the Columbia River as a source of shad eggs, the egg collection program is somewhat vulnerable to annual variations in production from two rivers, the Delaware and Hudson. The production from the Delaware River is limited to 10 million eggs through agreement between resource agencies. The Hudson River appears to be a source which can replace the Columbia but there is not enough experience to determine this. Therefore, one goal in 1990 was to examine the Connecticut River as a possible contingency source for eggs. Some 5 million eggs were obtained from this river in 1974.

From 18-22 June 1990, The Wyatt Group investigated the logistics and field conditions which would permit egg collection on the Connecticut River. The purpose of this study was to determine if it was feasible to net shad in known spawning areas, in the event that the egg collection programs on the Delaware and Hudson rivers did not meet the SRAFRC production goal.

Sources of Information

Information was gathered through contacts with federal and state resource agency personnel, commercial fishermen, and a boat survey of the Connecticut River between Enfield, CT north to the Cabot Station Laboratory at Turners Falls, MA. Information on spawning areas, boat launches, permits etc. was obtained from personnel at the Richard Cronin Salmon Station (USF&WS), Sunderland MA, Cabot Station Laboratory (USF&WS), Turners Fall, MA., Massachusetts Cooperative Fisheries Research Unit, University of Massachusetts, Amherst, MA, the Massachusetts Fish & Wildlife Division, Belchertown, MA, and the Connecticut Department of Environmental Protection, Anadromous Fish Division, Waterford, CT.

Sampling Below Holyoke Dam

On the evening of 21 June, arrangements were made to meet Mr. Sam Chapman (Aquaculture Specialist from the Darling Marine Laboratory, Walpole Maine) at a Marina in West Springfield MA. Mr. Chapman was authorized, by permit from the Massachusetts Division of Fisheries and Wildlife, to gill-net shad for the purpose of collecting eggs for his aquaculture studies being conducted in Maine. Information on this gill net effort would be helpful in the research of shad spawning areas. However, only one male shad was collected in the three hours of gill-netting. Two 150 x 6-foot gill-nets, with 4 1/2 to 5 1/2- inch stretch mesh were set between 7:30 and 10:00 PM along the east shore approximately one mile below the Holyoke Dam.

Location of Spawning Areas

Shad spawning areas in the Connecticut River are best characterized by examination of three regions: (1) The Holyoke Pool, (that area north of the Holyoke Dam), (2) south of the Holyoke Dam to Hartford, CT, and (3) south of Hartford, CT.

Holyoke Pool

Information on shad spawning areas in the Holyoke Pool was obtained from a 1972 M.S. thesis entitled "Spawning sites and behavior of American Shad, Alosa sapidissima, in the Connecticut River between Holyoke and Turners Falls, MA" by James B. Layzer, University of Massachusetts at Amherst. With information in this document as a guide, Wyatt Group biologists conducted a boat survey in the Holyoke Pool. Through this survey it was determined that the best area to net in the Holyoke Pool is from the 4th Island, (RM 117) at East Greenfield, MA north to Rawson Island (RM 119.8). The river current makes it feasible to gill net upstream of the Cabot Station power plant tailrace. Currents downstream from the tailrace are much stronger and would make gill-netting more difficult. Shad eggs have been collected from this area as late as 15 July (1972).

Holyoke, MA to Hartford, CT

Another spawning area lies between Holyoke, MA and Hartford, CT. Shad eggs have been collected in the Holyoke-Chicopee-West Springfield, MA area by state (MA and CT) resource agencies. Spawning also occurs near Enfield, CT, and south to Thomsonville, CT (the Bissel Bridge, Route 291).

South of Hartford, CT

Historically, shad eggs have been collected by the efforts of commercial fishermen gill-netting in the Rocky Hill, CT area.

Access to Connecticut River

Netting shad on the Connecticut River is restricted to certain areas because of the limited boat launch access. Only by use of acceptable boat launches can spawning grounds be reached in a reasonable time to allow for capture of shad and the collection and processing of eggs.

Holyoke Pool

The northern most boat launch within the Holyoke Pool is at

Sunderland, MA (RM 109.3) on the east shore at the Route 116 bridge. This access area does permit launching. It is reached by an unpaved road; only 4-6 vehicles with trailers can park at this access. The distance by river from this site to the power plant at Turners Fall, a known spawning area, is about 10 miles.

Jones Ferry, South Holyoke, MA

This is a private launch on the west side of the Connecticut River in South Holyoke. Formerly known as Crowley's Marina, it is at River Mile 80.5, about 4-5 miles south of Holyoke.

Chicopee, MA

A public launch exists immediately north of the confluence of the Connecticut and Chicopee rivers on the east shore of the Connecticut River, about 5.1 miles south of the Holyoke Dam (RM 79.6).

Thompsonville, CT

A boat launch is located on the west shore near Riverside Park (RM 70.4).

Bissel Bridge, Thompsonville, CT

Located at Exit 35 off Route 91, Rt 291 in Connecticut (RM 54.2).

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Kilcer, T.F. 1973. Report on the 1973 American shad egg transplant program in the Susquehanna River. Ichth. Assoc., Inc., Drumore, PA. Shad Egg Report No. 3 for Susquehanna River Shad Advisory Committee: 26p.

Table 1. Total number (millions) of American shad eggs collected from the Pamunkey, James, Delaware, Hudson, Columbia and Savannah rivers, 1973 - 1990.

YEAR	PAMUNKEY	JAMES	DELAWARE	COLUMBIA	HUDSON	SAVANNAH	TOTAL
1973	8.45	-	-	-	-	-	8.45
1974	9.75	19.20	-	8.18	-	-	37.13
1975	1.88	7.15	-	18.42	-	-	27.45
1976	-	-	4.10	54.80	-	-	58.90
1977	4.40	3.42	-	8.90	-	-	16.72
1978	6.90	10.11	-	-	-	-	17.01
1979	3.17	4.99	-	-	-	-	8.16
1980	6.73	6.83	-	-	-	-	13.56
1981	4.58	1.26	-	5.78	-	-	11.62
1982	2.03	1.25	-	22.57	-	-	25.85
1983	5.49	5.91	2.40	19.51	1.17	-	34.48
1984	9.83	0.74	2.64	27.88	-	-	41.09
1985	5.28	2.05	6.16	12.06	-	-	25.55
1986	5.62	1.07	5.86	39.97	-	-	52.52
1987	4.35	0.11	5.01	23.53	-	-	33.00
1988	1.92	0.05	2.91	26.92	0.00	-	31.80
1989	1.91	0.53	5.96	23.11	11.18	-	42.69
1990	0.48	-	13.15	-	14.53	0.12	28.28
TOTAL	82.77	64.67	48.19	291.63	26.88	0.12	514.26

TABLE 2. Sampling period for East Coast Rivers for collection of American shad eggs, 1990.

RIVER	DATES	TOTAL DAYS
Pamunkey	11 April - 25 April	15
Savannah	16 April - 8 May	22
Delaware	29 April - 9 May	11
Hudson	3 May - 11 June	40

TABLE 3. Collection data for American shad eggs taken on the Savannah River, South Carolina, 1990.

Date	Water Temp. (°F)	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number
May 2*	68	3	123,000	5
TOTAL		3	123,000	1

* Shipping date; collected on 30 April and 1 May.

TABLE 4. Collection data for American shad eggs taken on the Pamunkey River, Virginia, 1990.

Date	Water Temp. (°F)	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number
April 16	62	14.5	477,700	1
TOTAL	Avg=62	14.5	477,700	1

TABLE 5. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1990.

Date	Water Temp. (°F)	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number
April 29	64	36.6	1,258,500	2
30	62	23.8	775,600	3
May 1	62	32.3	1,323,900	4
2	62	70.9	2,790,900	6
3	63	67.5	2,256,600	7
6	57	6.3	185,900	9
7	59	34.8	1,027,100	11
8	59	44.6	1,533,600	13
9	62	57.4	1,994,800	15
TOTAL	Avg=61	374.2	13,146,900	9

TABLE 6. Collection data for American shad eggs taken on the Hudson River, New York, 1990.

Date	Water Temp. (°F)	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Gear
May 5	58	9.3	242,100	8	Seine
6	59	35.6	915,800	10	Seine
7	58	62.8	1,615,500	12	Seine
8	59	36.0	1,038,900	14	Seine
9	59	36.0	992,800	16	Gill
13	55	13.0	371,000	17	Gill
15	57	29.9	912,500	18	Gill
16	57	31.5	1,026,600	19	Gill
17	56	20.6	601,200	20	Gill
21	52	41.7	1,136,800	21	Gill
23	51	6.5	187,600	22	Gill
28	55	48.9	1,508,900	25	Gill
30	59	18.0	537,200	26	Gill
31	61	56.4	1,818,200	27	Gill
June 1	63	38.0	1,172,500	30	Gill
4	65	4.3	129,800	31	Gill
5	65	6.0	161,200	32	Seine
7	67	5.7	162,600	33	Gill
TOTAL	Avg=59	500.2	14,531,200	18	
	Gill-net =	350.5	10,557,700	13	
	Seine =	149.7	3,973,500	5	

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1990

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Pennsylvania Fish Commission

Benner Spring Fish Research Station

State College, PA

INTRODUCTION

The Pennsylvania Fish Commission has operated the Van Dyke Research Station for Anadromous fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River system. The objectives of the Van Dyke Station are to research culture techniques for American shad and to rear juveniles, both fry and fingerlings, for release into the Juniata and Susquehanna Rivers. The program goal is 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 1990 included the stocking of 10-15 million 18-day-old shad fry, and 50-100 thousand fingerlings. All hatchery-reared American shad fry were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in 1990 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Research was scaled back in 1990 to facilitate a smooth transition to electronic data processing. Research included testing of a third new bottom screen for Van Dyke jars and a preliminary test of feeding shad fry on AP-100 only. In addition, all hatchery fry releases were coordinated with the USFWS National Fishery Research and Development Lab (NFRDL) to facilitate their study of predation on newly stocked fry.

EGG SHIPMENTS

As a result of the discontinuation of Columbia River egg shipments, only 29 million eggs (897 L) were received in 34 shipments in 1990 (Table 1), representing the second lowest total since 1983 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 56.7% compared to 40.9%, 40.7%, 47.9%, 38.7%, and 60.1% in 1985 through 1989, respectively. One shipment of eggs was received from the Savannah River but included no viable eggs. One shipment of eggs was received from the Pamunkey River (478 thousand eggs) with a viability of 45.7%. Nine shipments of eggs were received from the Delaware River (13.1 million eggs) with a viability of 51.9%. The Hudson River produced 18 shipments (14.5 million eggs) with a viability of 62.9%. Eggs from the Susquehanna River were received for the first time in 1990. Pre-spawn adult American shad were collected at the Conowingo Dam fish trap, injected with hormones to induce maturation, and spawned artificially. Five shipments of eggs were received (327 thousand eggs), two of which contained viable eggs. Overall viability for Susquehanna River eggs was 9.4%.

SURVIVAL

Survival of all fry was 80.6% compared to 72.8%, 76.2%, 75.6%, 70.1%, 89.8%, and 88.4% in 1984 through 1989, respectively. Survival of fry from hatch and overall survival from fertilization are plotted in Figure 1. For the third consecutive year we had no major mortality episodes due to human error.

FRY PRODUCTION

Survival, production and stocking of American shad fry are presented in Tables 2, 3, and 4. Total fry production was 13.1 million compared to 13.5 million, 7.9 million, 16.6 million, 11.1 million, 11.1 million and 22.7 million in 1984 through 1989, respectively. Of the total fry production, 5.7 million were released in the Juniata River and 3.9 million in the Susquehanna River below Conowingo Dam. Approximately 1 million fry were stocked into ponds for fingerling production at various sites including three new ponds in Elkton, MD and one new pond in Havre de Grace, MD (Table 4).

VAN DYKE JAR TESTING

Testing of our home-made Van Dyke jars was initiated in 1987. Egg viability has been consistently higher in Van Dyke jars than in May-Sloan jars (Hendricks et al., 1988; 1989; 1990). In addition, conversion of 1/2 of our egg battery to accommodate these jars has increased the capacity of our egg battery from 250 L of eggs to 450 L of eggs.

Standard bottom screens for the Van Dyke jars are constructed of aluminum window screen. The window screen puts very little back-pressure on the upwelling flow through the jar and because the diameter of the jar is large (33 cm), "dead spots" can occur (Hendricks et al., 1990). These "dead spots" collect egg shells after hatch, smothering any remaining unhatched eggs and promoting fungal growth. Delaying transfer of the jar from the egg battery to the rearing tank has largely eliminated this problem by promoting hatching within a short period of time immediately after the jar is moved. Most fry now hatch within 20 minutes of the transfer of the jar to the tank. In some cases, however, hatching is still delayed and "dead spots" can occur. Dead spots can also occur when air bubbles enter the jar with the influent water and collect under the bottom screen. This occurs with all types of bottom screens. In our continuing attempts to eliminate these problems we tested yet another bottom screen.

New bottom screens were constructed from 2 inch thick open-cell foam. The foam was cut on a band saw to a diameter slightly larger than the jar diameter. A plastic retaining ring approximately 2 mm thick was glued in the jar to prevent water pressure from lifting the foam bottom. An air bubble escape tube was incorporated into the bottom screen to prevent air bubbles from accumulating under the screen. The air bubble escape tube was constructed by gluing a washer to the end of a piece of 1/4" PVC pipe. Using a cork borer a small hole was cut in the center of the foam screen and the tube inserted (washer down) in the foam prior to installing the foam in the jar. The purpose of the washer was to prevent the tube from pulling up through the foam.

Survival of eggs incubated in Van Dyke jars with foam bottom screens was compared to survival in jars with window screen bottom screens. Two replicates were conducted using equal numbers of eggs from the same egg shipment (Figure 2, Table 5). Survival of eggs incubated with the foam bottom screens was slightly lower than that exhibited by the window screen bottom screens for both replicates. In addition, after the initial burst of hatching activity, jars with the foam bottom screens appeared to have more unhatched eggs remaining in the jar. This may be due to decreased flows through the jar associated with the density of the foam. Increasing flows through the foam screen by opening the influent valves was only minimally effective and care had to be taken to avoid dislodging the foam with excessive pressure.

On the positive side, the foam bottom screens were extremely effective in producing uniform flow over the entire surface area of the foam. The air bubble escape tubes also performed well. Air bubbles which had collected under the foam were easily removed by slightly lifting and wiggling the tube. The foam bottom screens were more easily constructed than the traditional window screens, were easy to clean and install, and could be used in jars without a false bottom, eliminating a labor-intensive step in Van Dyke jar construction. In addition, our notes indicate that jar 225 (Table 5, window screen) had dead fry present in the jar after hatching while jar 215 (foam) did not. These dead "fry" probably represent fully developed eggs which died prior to hatch as a result of smothering and fungus associated with "dead spots" (Hendricks et al., 1989).

Enumeration of these dead "fry" has always been problematic. Standard procedure has been to use fry mortality methods (volumetric subsamples) since traditional von Bayer egg enumeration methods are not applicable. The use of these fry mortality methods probably results in under-estimation of dead eggs which are also present with the dead "fry." The dead fry estimation procedure for jar 225 resulted in an estimate of 37,000 fry (Table 5, day IX), or only 8.5% of the initial density in the jar. Since this is probably an under-estimate, the true survival in jar 225 may have been very close to that observed for the foam bottom screen (Table 5, replicate 2, jar 215). In any case, this "dead fry" problem, while not a serious problem in replicate 2, has resulted in significant mortality in the past and was the underlying cause for the search for a better bottom screen.

In summary, use of foam bottom screens was found to have both advantages and disadvantages. Additional testing will be conducted in 1991.

FEED RESEARCH

Use of the dry diet AP-100 (Zeigler Brothers) as a supplement to brine shrimp was tested in 1984 (Wiggins et al., 1985) and has been standard procedure since 1985. Culture and feeding of brine shrimp is very labor intensive and therefore costly when compared to feeding dry diet. We estimate that it takes approximately four times as long to feed brine shrimp as it does to feed dry diet. Substantial savings could be realized by feeding dry diet alone, without brine shrimp.

We conducted a preliminary test on a low density (112,500) tank to evaluate survival of fry fed on AP-100 only. Survival of fry in the test tank (D42, Shipment 33) was compared to other tanks from the same egg source (Hudson River) but from different shipments (Figure 3). Included for comparison were all tanks from shipments received in the latter part of the Hudson River egg take (after May 28), which exhibited similar egg viability (60% or more). These shipments included shipment 25 (Tanks A32, A42, B12, B22), shipment 26 (Tanks B32, B42) and shipment 32 (Tank D32).

Eighteen-day survival (Figure 3) for the test tank was lower than survival in five of the comparable tanks and higher than the other two. Based on Figure 3, however, survival was largely determined prior to day 4 when feeding was initiated. After day 4, survival in the test tank was comparable to that in the other tanks. This experiment had no true controls and was not replicated. In addition, no growth data was collected. Further testing will be conducted in 1991.

FINGERLING PRODUCTION

An estimated 20,000 fingerlings were released from the Canal Pond at Thompsontown on August 23, 1990. As in 1989, slow drawdown minimized problems with algae and drawdown was timed so that the critical crowding period occurred after dark when the fish have ceased schooling and are more calm.

In the past, Canal Pond fingerlings were crowded into the kettle and then quick-released to Delaware Creek via an 8 inch by 12 inch quick-release gate built into a set of pond boards. The quick-release gate was installed in the last set of keyways approximately 5 inches from the back of the kettle and directly in front of a 24 inch diameter pipe leading to Delaware Creek.

The design of this apparatus resulted in extremely turbulent flows exiting the quick-release gate. Turbulent, swirling water currents were set-up in the 5 inch space between the last set of boards and the back of the kettle. In addition, abrasion of the fish on the 24 inch concrete pipe must have contributed to mortality.

Recoveries of marked fish over the last several years have failed to demonstrate consistent survival of fingerlings from the Canal Pond (Table 6). For example, Canal Pond fingerlings received unique marks in 1988 and 1989. Release of these fish occurred early enough (9/1/88 and 9/21/89) to expect recovery at downstream collecting sites. Respective recovery rates for hatchery fry for 1988 and 1989 were 0.000043 and 0.000018 fry recovered for each fry stocked (Table 6). Based on these recovery rates, if we assume that survival of Canal Pond fingerlings was equivalent to that of 18-20 day-old fry we would have expected to recover 1.29 Canal Pond fingerlings in 1988 and 0.36 in 1989.

In fact, no Canal Pond fingerlings were recovered for either year despite the fact that we would expect survival of fingerlings to be much higher than survival of 18-20 day-old fry.

In 1987, an estimated 60,000 Canal Pond fingerlings were released on August 23 (Table 6). They were marked with the same mark as 309 fingerlings from the Van Dyke rearing pond and 21,150 fingerlings from two Benner Spring Ponds (Hendricks et al., 1988). Twenty-seven of these fish were recovered between October 4 and October 25 at York Haven and Safe Harbor Dams (Young, 1988). Since the Benner Spring fish were released at Thompsontown on October 8 and 16, it is likely that most of the 27 marked fingerlings recovered were from the Canal Pond or the Van Dyke rearing pond. If all 27 marked fingerlings were from the Canal Pond and our estimate of 60,000 Canal Pond fish released was accurate, relative survival of Canal Pond fingerlings was 5.6 (27/4.8) times that of fry stocked at 18-20 days of age.

In an attempt to improve survival of fingerlings released from the Canal Pond we eliminated the quick-release mechanism and released the fish through a 4 inch smooth-bore plastic hose. The hose was connected to a bulkhead union installed on the bottom board in the rear keyway of the kettle. The hose was long enough to reach directly to a deep pool in Delaware Creek. A 6 inch pond board was used to block the entrance to the hose until the fish were ready to be released. The use of the hose appeared to work well, eliminating the turbulence behind the quick-release board and minimizing abrasion of the fish along the walls of the concrete pipe. The majority of the fish observed in Delaware Creek were similar in appearance to previous years i.e. most were alive but exhibited signs of stress and some de-scaling. Plans for 1991 include installation of the 4 inch hose much earlier in the drawdown to allow the fish to exit the pond before they are crowded.

The three Upper Spring Creek ponds were stocked with approximately 117,000 fry each on May 30, 1990. Attempts to harvest the ponds during early October were hampered by heavy rains which caused influent water to be extremely turbid. Two of the ponds were harvested during the last week of October; approximately 8,000 fingerlings were harvested from Pond #1 and 20,000 from Pond #2. An estimated 10,000 fingerlings were lost in Pond #1 the night before harvest when the main intake blocked with leaves at a time when the fish were concentrated in the catch basin. Pond #3 was harvested in early November and produced an estimated 42,000 fingerlings. Overall, the Upper Spring Creek ponds yielded an estimated 81,500 fingerlings (23% survival), 70,000 of which were released into the Juniata River at Thompsontown. Approximately 11,500 fingerlings were lost during harvest. The fish averaged 89 mm in length and 5.8g in weight (n = 25). As in 1989, harvesting techniques worked extremely well.

One problem, encountered with all three ponds, was an excessive amount of silt build-up in the pipes which provide water to the catch basin. Extremely muddy water persisted for more than an hour in each of the ponds. Approximately 1,500 fish were lost in one of these episodes during harvest of Pond #3. This problem did not occur in 1989 and it is felt that complete flushing of the entire piping system in early spring will prevent reoccurence of silt build up. Although filamentous algae was again plentiful in 1990, the first appearance of muskgrass (or stonewort) caused a minor problem in two of the ponds by creating an uneven bottom, trapping several hundred fish during final drawdown. A couple of Aquazine treatments during mid-summer should eliminate this problem. No problems with loading, transport or stocking were encountered this year.

Tetracycline Marking

All American shad fry and fingerlings stocked in the Susquehanna River Basin received marks produced by immersion in or feeding of tetracycline (Table 7). Immersion marks were administered to all fry by bath treatments at 200 ppm tetracycline for 6 hours duration. Fry stocked below Conowingo Dam received a double mark at 5 and 9 days of age. Fry stocked in the Juniata

River were uniquely marked, according to egg source river, to determine relative survival of fry from the various egg sources. Fry originating from Hudson River eggs received a triple mark on days 5, 9 and 13. Delaware River fry received a triple mark on days 3, 13 and 17. Virginia River fry received a quadruple mark on days 5, 9, 13 and 17. Susquehanna River source fry were marked on days 5 and 19, stocked into Benner Spring Raceway F1, and then marked again by feeding feed laced with tetracycline at a rate of 40g TC per pound of food. Fry destined for fingerling production at Maryland DNR ponds in Havre de Grace (1 pond) and Elkton (3 ponds) were also given immersion marks on days 5 and 19 and then marked again with TC laced feed. Fry destined for fingerling production in the Canal and Upper Spring Creek Ponds were given the appropriate immersion mark (based on egg source) and then marked again with TC laced feed. Prior to marking, fingerlings were starved for a period of 2 days and then fed tetracycline laced feed for 3 days. Multiple feed tags were administered at least 7 days apart.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways or ponds and examining otolith samples collected during harvest. Retention of immersion marks was 100% for all specimens examined (Table 8). Mark retention for the double immersion mark (days 5, 9) administered to fry released below Conowingo Dam was scheduled to be verified by analysis of specimens grown-out at the rearing pond at Van Dyke. Unfortunately, the fish in the pond suffered complete mortality approximately 2 to 3 weeks after they were stocked in the pond. As a result, the immersion mark administered on days 5 and 9 was not verified. Based on 100% mark retention for all other immersion marks in 1990 and previous years experience, we assume that mark retention for this group was 100% as well.

Feed mark retention varied from group to group (Table 8). Fingerlings from the Canal Pond and Upper Spring Creek Pond 3 exhibited 100% feed mark retention, as did the single fish from the pond at Havre de Grace. Upper Spring Creek Ponds 1 and 2 and Benner Spring Raceway F1 exhibited 96% feed mark retention. Elkton Ponds 1, 2 and 3 exhibited 36%, 95% and 90% feed mark retention respectively. All pond fingerlings analyzed exhibited at least one feed mark and thus were distinguishable from fish released as fry.

SUMMARY

A total of 34 shipments (29 million eggs) was received at Van Dyke in 1990. Total egg viability was 56.7% and survival to stocking was 80.6%, resulting in production of 13.1 million fry. The majority of the fry were stocked in the Juniata River (5.7 million), with lesser numbers stocked in the Susquehanna River below Conowingo Dam (3.9 million), the Lehigh River (2.1 million), and the Schuylkill River (285 thousand). A total of 90,000 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River. One thousand fingerlings from the Susquehanna River egg source were produced at Benner Spring Raceway F1 and released below Conowingo Dam. An additional 162,000 fingerlings were produced in Maryland DNR ponds at Havre de Grace and Elkton, and released directly into receiving waters at those sites.

All American shad fry were tagged by immersion in 200 ppm tetracycline for 6 hours. Fry released in the Susquehanna River below Conowingo Dam received a double tag on days 5 and 9. Fry released in the Juniata River received unique tags based on egg source river. Delaware River fry received a triple tag on days 3, 13 and 17; Hudson River fry received a triple tag on days 5, 9 and 13, and Virginia River fry received a quadruple tag on days 5, 19 13 and 17.

All American shad fingerlings received tags administered by feeding tetracycline laced feed at a rate of 40g tetracycline per pound of food. Tagging was accomplished by feeding the tetracycline laced food for a period of 3 days, preceded by 2 days of starvation. Fingerlings received unique tag combinations in order to distinguish fingerling rearing site. Single, double, and triple feed tags were produced, in addition to the double, triple, and quadruple immersion tags.

Retention of tetracycline marks was 100% for immersion marks, and ranged from 36 to 100% for feed marks. All fingerlings analyzed exhibited at least one feed mark.

RECOMMENDATIONS FOR 1991

1. Continue to disinfect all egg shipments at 80 ppm free iodine.
2. Continue to stock one-half of production fry below Conowingo Dam (up to 5 million fry).
3. Continue to feed all ponded fingerlings by hand in addition to automatic feeder to ensure complete TC mark retention.
4. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
5. Continue testing an alternate bottom screen for the Van Dyke jars.
6. Attempt mark-recapture population estimates for pond fingerlings prior to harvest.

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Figure 1. Survival of American shad fry reared at Van Dyke, 1990.

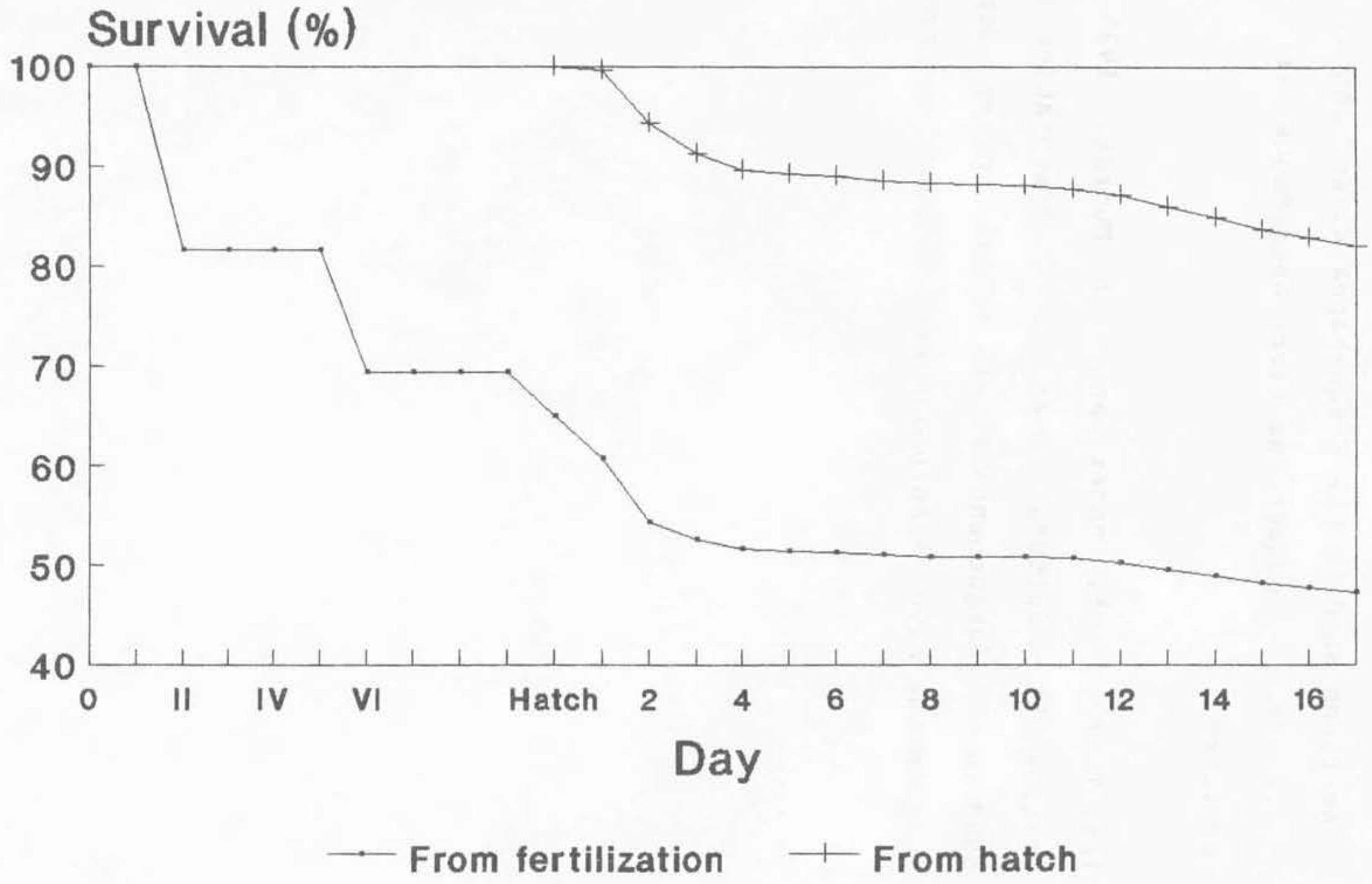
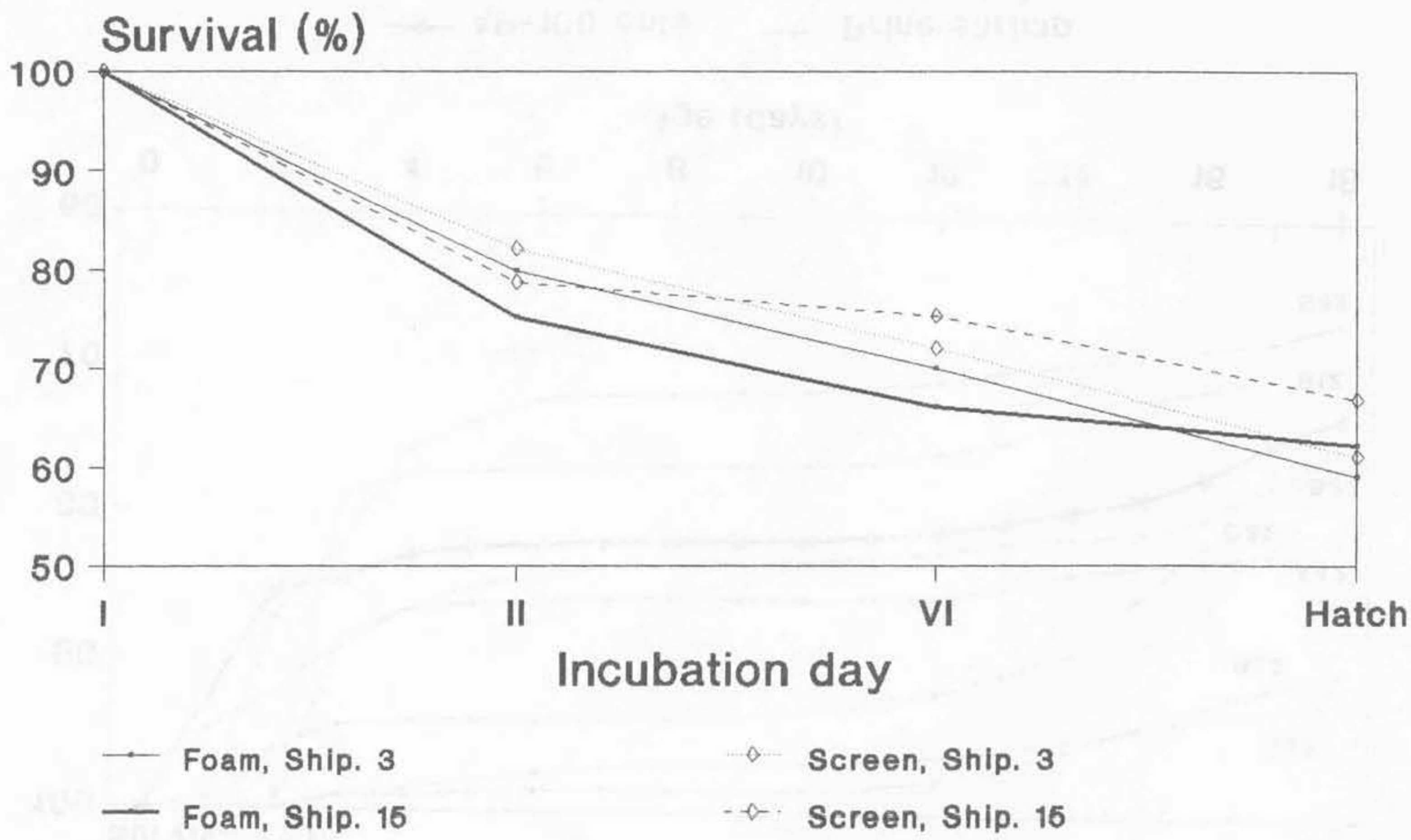


Figure 2. Survival of American shad eggs incubated with 2 types of bottom screens



Van Dyke, 1990

Figure 3. Survival of American shad fry fed AP-100 only vs. AP-100 and brine shrimp, Van Dyke, 1990.

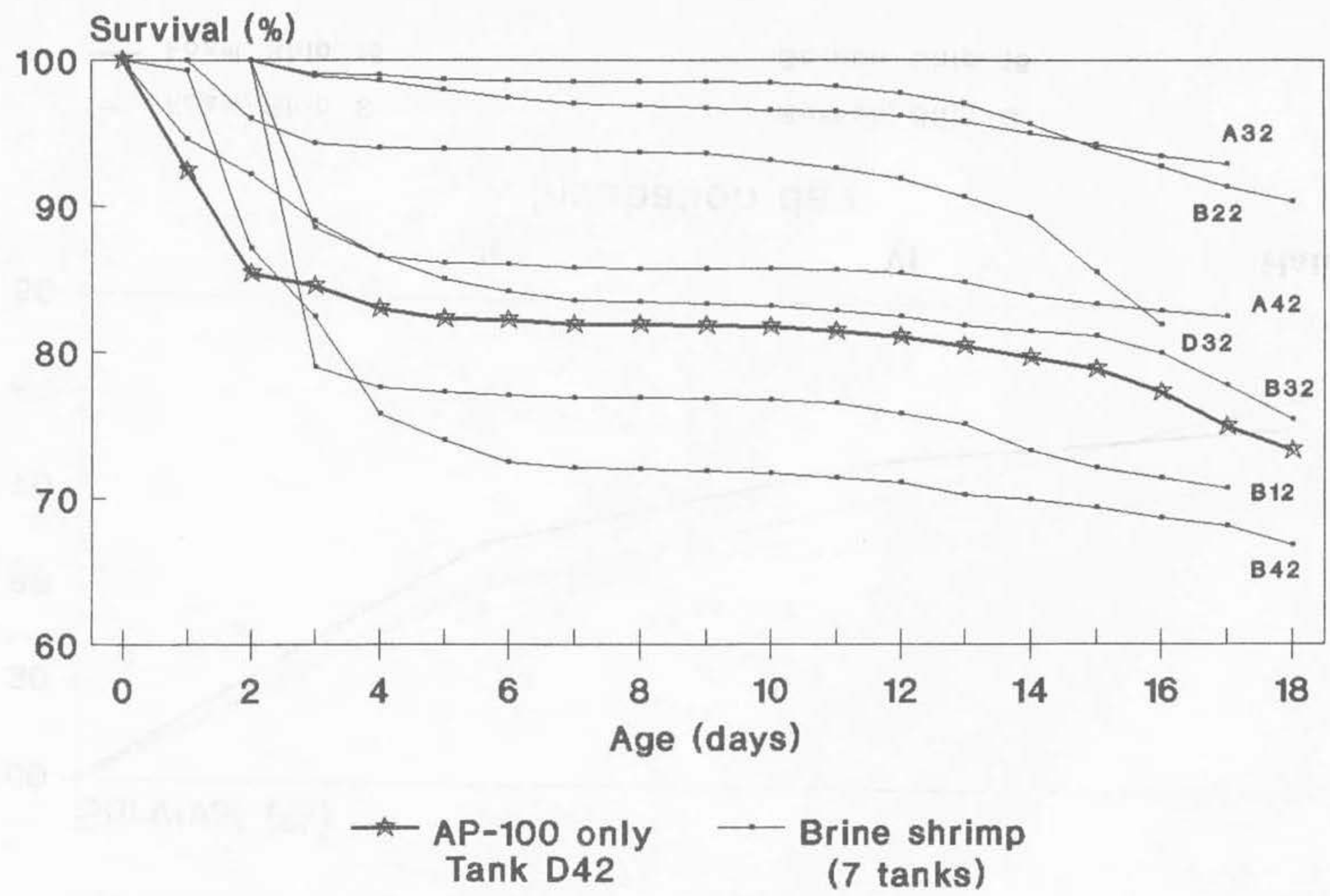


Table 1. American shad egg shipments received at Van Dyke, 1990.

Shipment No.	River	Date Shipped	Date Received	Vol. Received (L)	Eggs	Percent Viable	Viable Eggs
1	Pamunkey	4/16/90	4/17/90	14.5	477,700	45.7%	218,400
2	Delaware	4/29/90	4/30/90	36.6	1,258,500	49.0%	616,200
3	Delaware	4/30/90	5/1/90	23.8	775,600	60.0%	465,500
4	Delaware	5/1/90	5/2/90	32.3	1,323,900	57.7%	764,100
5	Savannah	5/1/90	5/2/90	3.0	123,000	0.0%	0
6	Delaware	5/2/90	5/3/90	70.9	2,790,900	45.3%	1,263,100
7	Delaware	5/3/90	5/4/90	67.5	2,256,600	56.1%	1,265,600
8	Hudson	5/5/90	5/6/90	9.3	242,100	40.0%	96,900
9	Delaware	5/6/90	5/7/90	6.3	185,900	0.0%	0
10	Hudson	5/6/90	5/7/90	35.6	915,800	70.7%	647,200
11	Delaware	5/7/90	5/8/90	34.8	1,027,100	31.0%	318,600
12	Hudson	5/7/90	5/8/90	62.8	1,615,500	67.6%	1,091,600
13	Delaware	5/8/90	5/9/90	44.6	1,533,600	55.9%	857,500
14	Hudson	5/8/90	5/9/90	36.0	1,038,900	66.2%	687,400
15	Delaware	5/9/90	5/10/90	57.4	1,994,800	63.7%	1,271,500
16	Hudson	5/9/90	5/10/90	36.0	992,800	78.0%	774,100
17	Hudson	5/13/90	5/14/90	13.0	371,000	73.8%	273,900
18	Hudson	5/15/90	5/16/90	29.9	912,500	77.8%	709,900
19	Hudson	5/16/90	5/17/90	31.5	1,026,600	64.8%	665,200
20	Hudson	5/17/90	5/18/90	20.6	601,200	68.7%	413,000
21	Hudson	5/21/90	5/22/90	41.7	1,136,800	66.4%	755,100
22	Hudson	5/23/90	5/24/90	6.5	187,600	52.8%	99,100
23	Susquehanna	5/23/90	5/24/90	0.5	28,300	0.0%	0
24	Susquehanna	5/25/90	5/25/90	1.2	80,900	0.0%	0
25	Hudson	5/28/90	5/29/90	48.9	1,508,900	74.7%	1,127,200
26	Hudson	5/30/90	5/31/90	18.0	537,200	64.7%	347,300
27	Hudson	5/31/90	6/1/90	56.4	1,818,200	55.6%	1,010,800
28	Susquehanna	5/31/90	6/1/90	1.1	48,800	7.0%	3,400
29	Susquehanna	6/1/90	6/1/90	0.8	59,200	0.0%	0
30	Hudson	6/1/90	6/2/90	38.0	1,172,500	18.4%	215,200
31	Hudson	6/4/90	6/6/90	4.3	129,800	0.0%	0
32	Hudson	6/5/90	6/6/90	6.0	161,200	73.3%	118,200
33	Hudson	6/7/90	6/8/90	5.7	162,600	69.2%	112,500
34	Susquehanna	6/13/90	6/13/90	1.2	110,000	25.0%	27,500
Totals		No. of shipments					
	Savannah	1		3.0	123,000	0.0%	0
	Pamunkey	1		14.5	477,700	45.7%	218,400
	Delaware	9		374.2	13,146,900	51.9%	6,822,100
	Hudson	18		500.2	14,531,200	62.9%	9,144,600
	Susquehanna	5		4.8	327,200	9.4%	30,900
	Grand Total	34		896.7	28,606,000	56.7%	16,216,000

Table 2. Annual summary of Van Dyke production, 1976-1990.

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)	Finger-ling (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

Table 3. American shad stocking and fish transfer activities, 1990. All tetracycline tags administered by 6 hour immersion in 200ppm tetracycline except feed tags administered by feeding 40g tetracycline per pound of food.

Date	Tank	Number	Tag (days)	Location	Origen	AGE	SIZE
5/14/90	E12	5,000	N/A	NFRDL	Delaware	0	Fry
5/22/90	A11	7,900	5,9,13,17	Thompsontown	Pamunkey	29	Fry
5/22/90	A21	6,400	5,9,13,17	Thompsontown	Pamunkey	29	Fry
5/22/90	A31	164,000	5,9,13,17	Thompsontown	Pamunkey	29	Fry
5/24/90	A41	255,100	5,9	Lapidum	Delaware	18	Fry
5/24/90	B11	289,900	5,9	Lapidum	Delaware	18	Fry
5/24/90	B21	209,300	5,9	Lapidum	Delaware	17	Fry
5/24/90	B31	214,900	5,9	Lapidum	Delaware	17	Fry
5/26/90	B41	291,300	3,13,17	Thompsontown	Delaware	18	Fry
5/26/90	B41	100,000	3,13,17	Canal Pond	Delaware	18	Fry
5/26/90	C11	326,400	3,13,17	Thompsontown	Delaware	18	Fry
5/29/90	C21	650,000	3,13,17	Lehigh River	Delaware	19	Fry
5/29/90	C31	564,100	3,13,17	Lehigh River	Delaware	19	Fry
5/29/90	C41	420,500	3,13,17	Lehigh River	Delaware	18	Fry
5/29/90	D11	453,100	3,13,17	Lehigh River	Delaware	18	Fry
5/30/90	D41	349,900	5,9,13	Upper Spr. Cr. Ponds	Hudson	16	Fry
6/1/90	E22	235,100	5,9	Lapidum	Hudson	17	Fry
6/1/90	E32	296,400	5,9	Lapidum	Hudson	17	Fry
6/1/90	E42	213,700	5,9	Lapidum	Hudson	17	Fry
6/4/90	E12	285,100	3,13,17	Schuylkill River	Delaware	20	Fry
6/5/90	G11	523,100	5,9	Lapidum	Delaware	19	Fry
6/5/90	G21	450,900	5,9	Lapidum	Delaware	19	Fry
6/5/90	G31	284,700	5,9	Lapidum	Hudson	19	Fry
6/5/90	G41	300,300	5,9	Lapidum	Hudson	19	Fry
6/6/90	H11	199,500	5,9,13	Thompsontown	Hudson	17	Fry
6/7/90	D21	335,100	3,13,17	Thompsontown	Delaware	27	Fry
6/7/90	D31	254,500	5,9,13	Thompsontown	Hudson	24	Fry
6/7/90	F31	147,900	5,9,13	Thompsontown	Hudson	23	Fry
6/7/90	F42	168,600	5,9,13	Thompsontown	Hudson	23	Fry
6/8/90	F11	373,600	3,13,17	Thompsontown	Delaware	24	Fry
6/8/90	F21	296,400	3,13,17	Thompsontown	Delaware	24	Fry
6/12/90	D22	4,000	5,9,13	NFRDL	Hudson	3	Fry
6/14/90	H21	289,500	5,9,13	Thompsontown	Hudson	21	Fry
6/14/90	H31	283,200	5,9,13	Thompsontown	Hudson	21	Fry
6/14/90	H41	175,600	5,9,13	Thompsontown	Hudson	21	Fry
6/14/90	I11	224,500	5,9,13	Thompsontown	Hudson	21	Fry
6/15/90	I21	318,500	5,9,13	Thompsontown	Hudson	21	Fry
6/18/90	A12	3,000	5.9	VD Rearing Pond	Hudson	19	Fry
6/19/90	I31	197,000	5,9	Lapidum	Hudson	20	Fry
6/19/90	I31	4,000	5,9	NFRDL	Hudson	20	Fry
6/19/90	I41	155,200	5,9	Lapidum	Hudson	20	Fry
6/19/90	A12	239,800	5,9	Lapidum	Hudson	20	Fry
6/19/90	A22	77,800	5,9	Lapidum	Hudson	18	Fry

Table 3. (continued)

Date	Tank	Number	Tag (days)	Location	Origen	AGE	SIZE
6/22/90	A32	250,600	5,9,13	Thompsontown	Hudson	17	Fry
6/22/90	A42	261,900	5,9,13	Thompsontown	Hudson	17	Fry
6/22/90	B12	204,900	5,9,13	Thompsontown	Hudson	17	Fry
6/23/90	B22	225,800	5,9,13	Thompsontown	Hudson	18	Fry
6/25/90	B32	149,500	5,9,13	Thompsontown	Hudson	18	Fry
6/25/90	B42	99,000	5,9,13	Thompsontown	Hudson	18	Fry
6/25/90	C42	231,100	5,9,13	Thompsontown	Hudson	17	Fry
6/28/90	D22	154,000	5,9,13	Thompsontown	Hudson	19	Fry
6/29/90	D32	96,800	5,9,13	Thompsontown	Hudson	16	Fry
7/2/90	D42	82,500	5,9,13	Thompsontown	Hudson	18	Fry
7/2/90	D42	6,000	5,9,13	NFRDL	Hudson	18	Fry
7/5/90	D12	2,300	5,19	Havre de Grace Pond	Susquehanna	27	Fry
7/5/90	C22	208,000	5,19	Havre de Grace Pond	Hudson	27	Fry
7/5/90	C32	74,000	5,19	Havre de Grace Pond	Hudson	27	Fry
7/5/90	C32	100,000	5,19	MDNR Pond, Elkton	Hudson	27	Fry
7/11/90	C12	135,300	5,19	2 MDNR Ponds, Elkton	Hudson	27	Fry
7/11/90	C12	10,000	5,19	DEL Pond, Elkton	Hudson	27	Fry
7/11/90	F12	26,300	5,19	BS Raceway F1	Susquehanna	20	Fry
8/23/90	Canal Pond	20,000	3,13,17+ Single Feed	Thompsontown	Delaware	107	Fing.
10/1/90	Elkton Pond 3	70,000	5,19+ Double Feed	Elkton	Hudson	123	Fing.
10/3/90	Elkton Pond 2	45,000	5,19+ Double Feed	Elkton	Hudson	111	Fing.
10/4/90	Havre de Grace Pond	2,000	5,19+ Single Feed	Havre de Grace	Hudson/ Susquehanna	126	Fing.
10/5/90	Elkton Pond 1	45,000	5,19+ Double Feed	Elkton	Hudson	112	Fing.
10/24/90	Benner Spring Raceway F1	1,000	5,19+ Triple Feed	Rock Run Landing	Susquehanna	125	Fing.
10/29/90	Upper Spring Creek Pond 1	8,000	5,9,13+ Single Feed	Thompsontown	Hudson	168	Fing.
10/31/90	Upper Spring Creek Pond 2	20,000	5,9,13+ Double Feed	Thompsontown	Hudson	170	Fing.
11/2/90	Upper Spring Creek Pond 3	30,000	5,9,13+ Triple Feed	Thompsontown	Hudson	172	Fing.
11/5/90	Upper Spring Creek Pond 3	12,000	5,9,13+ Triple Feed	Thompsontown	Hudson	175	Fing.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1990.

	Site	Fry	Fingerling
Releases	Juniata River	5,619,000	90,000
	Susquehanna R. (below Conowingo Dam)	3,943,200	163,000*
	Lehigh River	2,087,800	
	Schuylkill River	285,100	
	Sub-Total	11,935,100	253,000
Transfers	Canal Pond	100,000	
	Van Dyke Pond	3,000	
	Benner Spring Raceways	26,300	
	Upper Spring Creek Ponds	349,900	
	NFRDL (Wellsboro)	19,000	
	Maryland DNR		
	Havre de Grace Pond	284,300	
	Elkton Ponds	235,300	
	D.E.L. (Elkton Pond)	10,000	
	Sub-Total	1,027,800	
	Total Production	13,062,700	
	Viable eggs	16,216,000	
	Survival of fry (%)	80.6%	

*Includes fingerlings from MDNR ponds.

Table 5. Survival(%) of American shad eggs incubated in Van Dyke jars with standard (window screen) bottom screens vs. eggs incubated in jars with bottom screens constructed of 2 inch open-cell foam, Van Dyke, 1990.

	Replicate:	1	1	2	2
	Shipment:	3	3	15	15
	Jar:	206	215	225	215
	No. of eggs:	387,800	387,800	434,400	434,400
	Bottom:	Window screen	Foam	Window screen	Foam
Incubation	0	100.0%	100.0%	100.0%	100.0%
Day	I				
	II	82.1%	79.8%	78.6%	75.1%
	III				
	IV				
	V				
	VI	72.0%	70.0%	75.2%	66.1%
	VII				
	VIII				
	IX	61.0%	59.1%	66.8%	62.2%

Table 6. Recovery of hatchery fry and uniquely marked Canal Pond fingerlings, 1987-1990.

	FRY (stocked above Conowingo)			CANAL POND				
Year	# Stocked	# hatchery fry Recovered*	Recovery Rate	Date Stocked	# Stocked	# Recovered	Recovery Rate	# CP Fing. recoveries expected if survival of fry & CP Fing. were equal
1987	5,179,790	414	0.000080	8/23	60,000	27**	0.000450	4.80
1988	6,450,685	280	0.000043	9/1	30,000	0	-	1.29
1989	9,556,590	177	0.000018	9/21	20,000	0	-	0.36
1990	5,619,000			8/23	20,000			

* includes all hatchery fry recovered during juvenile assessment at least 7 days after date of Canal Pond stocking

** some may have been from other ponds

Table 7. Tetracycline marking regime for American shad stocked in the Susquehanna River basin, 1990.

Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Tag (days)	Feed tag	No. Stocked
Fry	-	Thompsontown	Savannah	-	-	-
Fry	-	Thompsontown	Pamunkey	Quadruple (5,9,13,17)	-	178,300
Fry	-	Thompsontown	Delaware	Triple (3,13,17)	-	1,622,800
Fry	-	Thompsontown	Hudson	Triple (5,9,13)	-	3,817,900
Fry	-	Thompsontown	Susquehanna	-	-	-
Fry	-	Lapidum (Below Conowingo)	All Sources	Double (5,9)	-	3,943,200
Fingerling	Canal Pond	Thompsontown	Delaware	Triple (3,13,17)	Single	20,000
Fingerling	Upper Spring Creek Pond 1	Thompsontown	Hudson	Triple (5,9,13)	Single	8,000
Fingerling	Upper Spring Creek Pond 2	Thompsontown	Hudson	Triple (5,9,13)	Double	20,000
Fingerling	Upper Spring Creek Pond 3	Thompsontown	Hudson	Triple (5,9,13)	Triple	42,000
Fingerling	Havre de Grace Ponds	Below Conowingo	Hudson/ Susquehanna	Double (5,19)	Double	2,000
Fingerling	Elkton Ponds	Below Conowingo	Hudson	Double (5,19)	Triple	160,000
Fingerling	Benner Spring Raceway F1	Lapidum (Below Conowingo)	Susquehanna	Double (5,19)	Triple	1,000

Table 8. Tetracycline mark retention for American shad reared in 1990.

Pond/ Raceway	Attempted Mark Immersion/Feed	Observed Mark Immersion/Feed	Number Exhibiting Mark	Projected Number Stocked	Disposition
Canal Pond	Triple/single (3,13,17)	Triple/single	29/29(100%)	20,000	Stocked Thompsontown
Upper Spring Creek Pond 1	Triple/single (5,9,13)	Triple/single Triple/ -	28/29(97%) 1/29(3%)	7,700 300	Stocked Thompsontown
Upper Spring Creek Pond 2	Triple/Double (5,9,13)	Triple/Double Triple/ -	24/26(92%) 2/26(8%)	18,500 1,500	Stocked Thompsontown
Upper Spring Creek Pond 3	Triple/Triple (5,9,13)	Triple/Triple	28/28(100%)	42,000	Stocked Thompsontown
Havre de Grace Pond	Double/Double (5,19)	Double/Double*	1/1(100%)	2,000	Direct Release
Benner Spring Raceway F1	Double/Triple (5,19)	Double/Triple Double/Double	24/25(96%) 1/25(4%)	960 40	Stocked Rock Run Landing
Elkton Pond 1	Double/Triple (5,19)	Double/Triple Double/Double Double/Single	8/22(36%) 11/22(50%) 3/22(14%)	16,400 22,500 6,100	Direct Release
Elkton Pond 2	Double/Triple (5,19)	Double/Triple Double/Double	20/21(95%) 1/21(5%)	42,900 2,100	Direct Release
Elkton Pond 3	Double/Triple (5,19)	Double/Triple Double/Double Double/Single	30/33(91%) 1/33(3%) 2/33(6%)	63,600 2,100 4,300	Direct Release
Elkton Subtotal	Double/Triple (5,19)	Double/Triple Double/Double Double/Single		122,900 26,700 10,400	

*Immersion mark on days 5,9- fish released at Lapidum and entered pond prior to boarding pond or via pumps.

JOB IV.

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

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INTRODUCTION

Juvenile American shad were collected at numerous locations in the lower Susquehanna River in 1990 in an effort to document timing of the migration, growth rates and abundance. Analysis of tetracycline marks on otoliths of subsampled shad was used to indicate what proportion of the collection was of hatchery origin. Also, because the various shad egg sources and pond culture sites were distinctively marked, the relative contribution of each stocked strain and culture situation to the outmigrant population could be differentiated.

Many individuals were involved in collection and analysis of juvenile shad in 1990. For their contributions to this report, appreciation is extended to Barbara Lathrop and Tim Robbins (Wyatt Group), Chris Frese (RMC), Ted Rineer (SHWPC), Dale Weinrich (DNR), and Mike Hendricks (PFC). Don Torsello (PFC) processed most of the shad otoliths.

HATCHERY AND ADULT SHAD STOCKING SUMMARY

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

A total of 15,075 adult American shad were hauled from the Conowingo fish lift during mid-April through mid-June and stocked above York Haven Dam (see Jobs I and IA). Overall sex ratio in these transfers was 3.2 : 1.0 favoring males and there were 283 observed mortalities associated with transporting fish. This stocking level compares with 6,355 live shad above Safe Harbor in 1989 and 4,645 in 1988.

During the 1990 shad production season, PA Fish Commission biologists reared and released 9.562 million shad fry and 90,000 fingerlings in the Susquehanna watershed. Fry were stocked between 22 May and 2 July in the Juniata River at Thompsontown (5.619 million), and between 24 May and 19 June at Lapidum, MD (3.943 million). All except 1,000 fingerlings reared in Pennsylvania ponds were stocked at Thompsontown between 23 August and 5 November. Maryland DNR released 162,000 fingerling shad from ponds at Havre de Grace and Elkton, MD on October 1-5.

The 5.62 million shad fry stocked above dams in the Susquehanna in 1990 compares to 13.46 M, 6.45 M, and 5.18 M in 1989, 1988, and 1987, respectively. Shad fry stocking below Conowingo Dam in 1990 was approximately one-half of that stocked in 1989 and similar to the average of 4.41 million during 1986-1988. With the addition of new production ponds in Maryland, fingerling shad stocking greatly exceeded past year efforts (61,000-81,000 in 1986-1989).

JUVENILE SHAD COLLECTIONS

Juvenile American shad occurrence and outmigration in the river above Conowingo Dam was assessed during August - October with haul seines above and below York Haven Dam; at the York Haven headrace with cast net in September and October; at the Holtwood inner forebay with lift net during September - November; from cooling water strainers at Safe Harbor Dam (mid-September through November) and Conowingo Dam (late October - November); and from intake screens at the Peach Bottom Atomic Power Station (mid-October - late November).

Late summer to early autumn collections of young shad were made at numerous sites between Columbia-Wrightsville and New Cumberland using a 400-ft. x 6 ft. haul seine with 1/4" mesh. A 20-ft. diameter cast net (3/8" mesh) was used to sample shad at York Haven Dam and an 8-ft. square lift net with 1/2" mesh liner was used at Holtwood's inner forebay. Shad were taken in the lower Susquehanna River and Flats during July-October by Maryland DNR in their annual juvenile finfish recruitment survey, yellow perch project, and shad outmigration assessment (see Job VI). Gear used here included 100-ft. and 200-ft. seines, otter trawl and electrofishing. Samples of shad from most collections were returned to PFC's Benner Spring Research Station for tetracycline mark analysis. Most collecting sites used in 1990 are shown in Figure 1 and Figures 6-2 and 6-3.

<u>Columbia to New Cumberland, Pennsylvania</u>

With a record 15,075 potential spawning shad placed in the river above York Haven Dam in 1990, SRAFRC sought to document occurrence of naturally produced juvenile shad during the mid-summer nursery period and the stock composition of autumn outmigrants in the river reach from Columbia to Harrisburg, PA. Under contract to Texas Eastern Gas Pipeline Company in 1989, The Wyatt Group demonstrated considerable success in collecting juvenile shad with large haul seines (Robbins and Lathrop, 1990). During 1990, sampling with this gear began on 1 August and continued weekly at select sites until 2 November.

Sixteen to 22 hauls were made each week at up to seven sites above and below York Haven Dam during August and September. Since the purpose for this work was to document occurrence and to provide fish for otolith analysis, no effort was made to standardize collecting effort. A total of 986 shad were collected between 1 August and 24 September in 156 hauls from all sites. Shad were netted during each of the first 9 weeks of sampling at Columbia and Wrightsville (rm 42). A total of 343 shad were caught (range

1-93 fish per week) and 212 were frozen and delivered to Benner Spring. A site at Marietta (rm 47) was seined on 5 occasions and produced 8 shad. Highspire (rm 65) and New Cumberland (rm 67) sites produced a total of 359 shad during 8 sample weeks (range 8-98 fish/week) with 230 returned for otolith analysis.

Backwater areas in the York Haven pool near Three Mile Island (rm 58) were sampled on three occasions and produced 276 shad including a single haul of 230 fish on 19 September. Fifty shad from these collections were also provided to the PFC. Weekly seine sampling continued at Columbia and Wrightsville through 2 November but no additional shad were collected. Catch and effort for all shad seine collections are shown in Table 1.

York Haven Dam

Wyatt Group biologists also sampled for juvenile shad in the York Haven headrace on six occasions between 11 September and 26 October. Though this effort was redundant considering success with haul seines above and below this point, SRAFRC sought to document first occurrence and relative abundance of shad at York Haven to assist Stone & Webster in timing the placement of floating docks and hydroacoustic equipment needed for the strobe light study at this site (Job V, Task 2).

A total of 133 juvenile shad were collected with cast nets at York Haven in six trips. The first shad was taken on 11 September in 25 casts. Abundance peaked by 20 September with 75 fish in 10 casts, and catch per effort progressively declined in subsequent collections. No shad were taken in 10 casts on 26 October and this effort was terminated. Seventy-nine shad were frozen and delivered to Benner Spring for otolith analysis.

Safe Harbor Dam

Cooling water strainers in the turbine intakes at Safe Harbor Dam were inspected for juvenile American shad each day from 10 September through 30 November. A total of 218 shad were collected during this period. From 10 September through 13 October, 45 shad were removed from strainers for an average catch per day (cpd) of 1.26 fish. Downstream migration at this site apparently peaked during the period 14-28 October with 153 shad taken (average cpd = 10.2 fish). From 29 October to 14 November, an additional 20 shad were removed from strainers (cpd 1.17), and none were found in remaining daily clean-outs through 30 November (Table 2).

Holtwood Dam

RMC Environmental Services was contracted in 1990 to collect juvenile American shad at the Holtwood inner forebay with a lift net during late August through November. Sampling consisted of 10 lifts per day and was conducted at dusk. Netting occurred once per week during 23 August through 19 September and the first 8 shad were collected on 6 September.

Following collection of 64 fish on 26 September, sampling frequency increased to three times per week (Monday-Wednesday-Friday) through 26 November. On the eight sample dates from 26 September through 12 October 326 shad were taken (cpd 40.75). As was the case at Safe Harbor, migration past Holtwood apparently peaked during the next 3 weeks with 3,594 shad taken on eight dates from 15 October through 2 November (range 113 to 893 shad/date; cpd = 449.25). Sampling was not conducted on 26 October due to extremely high flows which submerged the collection platform in the inner forebay. Collections continued from 5-26 November with 60 additional shad taken on four of eight sample dates (cpd = 15.0). Again, sampling was not attempted on 12 and 14 November due to high forebay elevation. Up to 25 fish per date (total 389) were frozen and delivered to Benner Spring for otolith analysis.

In addition to American shad, 6 juvenile blueback herring and 2 alewives were collected at Holtwood. Other fish in samples included 23,505 gizzard shad of which 22,449 were taken concomitant with peak collections of American shad (15 October - 2 November), and 50 other fishes representing 10 species. All Holtwood collection data is provided in Table 3.

<u>Peach Bottom Atomic Power Station</u>

With the cooperation of Philadelphia Electric Company, RMC biologists also examined intake water travelling screen washes for impinged American shad at Units 2 and 3 of the Peach Bottom Atomic

Power Station (PBAPS) in lower Conowingo Pond. Screen sampling usually occurred three times per week (M-W-F) during 17 October through 21 November. A total of 20 shad were taken from the outer screens at Unit 2 during 16 clean-outs. Sixteen of these fish occurred on October 17 and 19. Unit 3 screens produced 10 shad during eleven sample dates. Only 5 shad were taken from both Units after a peak flow event on 26 October. PBAPS shad collections are summarized in Table 4.

A total of 815 juvenile blueback herring was collected from PBAPS intake screens. Of these, 88% (720) were taken on 26 October when river flow peaked at 209,300 cfs. As was the case at Holtwood, the dominant fish in collections here was the gizzard shad. This species accounted for over 75% of all samples and 25,393 of the total 34,009 gizzard shad were taken on 9 and 10 November. Unidentified sunfishes comprised 19% of total collections (8,570 fish), and 21 other species (1,576 fish) were also represented.

<u>Conowingo Dam</u>

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged American shad once per week from 21 October through 25 November. Only 3 shad were collected on six sample dates (2 on 21 October and 1 on 28 October). Other fishes in Conowingo collections included 3 blueback herring (28 October), 6,738 gizzard shad, and 19 others representing 7 species.

Susquehanna River Mouth and Flats

Maryland DNR collected 32 juvenile American shad with 100-ft. and 200-ft. haul seines; 6 with otter trawl; and 23 with electrofishing gear in the lower Susquehanna and Northeast rivers and the upper Chesapeake Bay during July through October. Collections were made at numerous sites (see Figures 6-1 and 6-2) in conjunction with Maryland DNR's annual juvenile finfish recruitment survey, yellow perch project and shad outmigration assessment. Collection results by gear, location and date are provided in Job VI. Otoliths from 60 juvenile shad taken in these collections were provided to the Pennsylvania Fish Commission and analysis of these fish is included in this report.

OTOLITH MARK ANALYSIS

Hundreds of American shad taken in collections by The Wyatt Group, RMC, and Maryland DNR were frozen and returned to Benner Spring for hatchery mark assessment on otoliths. Fish were subsampled from these collections to provide a representation of the entire collecting season at select sites. Otoliths were surgically removed from the fish, cleaned and mounted on slides with Permount, ground and polished to the focus on the sagittal plane on both sides, and viewed under ultraviolet light to detect the presence of fluorescent rings indicative of tetracycline immersion and laced-feed treatments. Techniques are explained in further detail by Lorson and Mudrak (1987). The marking regime employed by the Pennsylvania Fish Commission in 1990 is described in Job III (see Table 7 on page 3-30).

Susquehanna River Above York Haven Dam

A total of 280 shad were provided from haul seine collections at New Cumberland, Highspire, Three Mile Island and York Haven Pond during 2 August to 20 September. PFC researchers analyzed 273 otoliths from these collections and found 265 (97%) to be of Hudson River origin; 4 (1.5%) were Delaware River fish; 1 Pamunkey River; and, 3 were classified as wild (i.e. no tetracycline marks). One of the two unmarked fish taken on 9 August displayed hatchery microstructure.

York Haven Forebay

Seventy-four of the 79 shad submitted by Wyatt Group from York Haven cast net collections were analyzed. Of these, 67 (91%) were Hudson River origin; 6 (8%) were Delaware River; and 1 fish (19 October) was a fingerling released from Thompsontown canal pond.

Marietta, Columbia, and Wrightsville

All but 6 of the 220 shad provided from seine collections at Columbia, Wrightsville and Marietta were successfully processed for otolith marks. Hudson River origin fry releases again dominated collections with 193 fish (90%). Twelve shad (6%) had no TC mark but 3 of these showed hatchery microstructure; 8 (4%) were Delaware River origin; and one fish was Pamunkey River source.

Holtwood Inner Forebay

A total of 204 shad from lift net collections at Holtwood between 26 September and 16 November were analyzed for hatchery marks. Consistent with upstream results, Hudson fish comprised 93% (189 fish). One fish was Delaware River origin, 2 (1%) were Pamunkey River, and 3 (1.5%) were unmarked. In the final two weekly collections, 9 of 43 shad examined originated as fingerling releases from Pennsylvania ponds.

Lower Susquehanna River and Upper Chesapeake Bay

Fifty-nine of the 60 shad otoliths provided from Maryland DNR collections were analyzed. Weekly sample size ranged from 1 to 17 fish with representatives from most weeks between early July and mid-October. Two yearlings from mid-May pound net collections were included. From these samples, 31 shad (53%) carried the double immersion tag indicating that they were stocked as fry at Lapidum and 28 fish (47%) including the two yearlings were wild.

Otolith Summary

The 765 shad analyzed from collections above Conowingo Dam included samples for every week between 1 August to 16 November. Weekly sample size ranged from 8 to 109 fish (all sites combined) and averaged 48. Regardless of collection location, results were very consistent. Hudson River fry (triple tag on days 5, 9, and 13) comprised 93.3% (range 90.2% to 97.1%) or 714 of 765 fish. Only four fish were from Virginia source fry (quadruple tag) and made up 0.5% of collections (range 0 to 1%). Delaware shad (triple tag on days 3, 13, and 17) were also poorly represented in collections above Holtwood (18 of 561 fish, 3.2%). At Holtwood, only one Delaware fish was detected from 204 samples.

Wild (unmarked) shad made up 5.6% of the Columbia/Wrightsville collection (12 of 214), less than 2% from upriver seine sites and Holtwood, and none were taken at York Haven. A total of 10 fingerling released shad were recaptured including 9 from Holtwood collections in early November.

Age 0 shad from collections made below Conowingo Dam were comprised of 54% fry releases at Lapidum and 46% wild fish. Unlike last year, no fish from upstream stockings were taken here. Fingerlings cultured in Maryland's ponds were not released until early October and recovery opportunity was limited to only 3 electrofishing runs in mid-October. All tag analysis data by site and collecting week are displayed in Table 5.

DISCUSSION

Run Timing and In-Stream Movements

Mid-summer seining for juvenile shad was initiated in the 25-mile reach from Columbia to New Cumberland to assess occurrence and abundance of juvenile shad during the nursery period. This effort was scheduled to continue at select sites until outmigration past Columbia was completed. Lift net sampling at Holtwood and strainer and screen checks at Safe Harbor, Peach Bottom and Conowingo were principally aimed at documenting autumn outmigration. Analysis of shad otoliths from net collections was used to determine stock composition relative to hatchery fry and fingerling releases in the Juniata River and natural production from transplanted adults.

As pointed out earlier, juvenile shad were abundant in weekly seine collections above and below York Haven Dam from 1 August through 24 September. No shad were taken with this gear during October and early November. Small numbers of shad (1-7 per day) appeared in strainers at Safe Harbor between 18 September and 13 October and relatively modest collections of shad were made with lift nets at Holtwood prior to 15 October. Peach Bottom and Conowingo were not sampled until mid-October.

River conditions during the summer and early fall of 1990 were relatively stable with average daily flow exceeding 40,000 cfs, as measured at Safe Harbor, on only 5 dates between 5 June and 13 October. Unlike 1989 when juvenile shad were displaced downstream early in the season by high river flows in June and July (St. Pierre, 1990), the 1990 collecting season was more predictable and consistent with other average flow years.

The Juniata River was not sampled and little can be said about residency time for stocked fry or natural production in this tributary. Most shad recovered in juvenile collections above Conowingo Dam were cultured Hudson River fish released at Thompsontown as 16-24 day old fry in 10 stockings from 6 June through 2 July. These fish occurred in abundance in seine collections at Columbia and Wrightsville every week in August and September. Based on dates of stocking and recovery it appears that juvenile shad moved at least 68 miles downstream from the stocking site within 30-56 days. Since river flows were modest and water temperatures consistent at about 24-27°C throughout most of the period, this movement is considered to be pre-migratory. Hatchery released juvenile shad apparently show little fidelity to the Juniata River and use much of the Susquehanna River above Safe Harbor as a summer nursery.

Shad collecting effort at Safe Harbor and Holtwood was consistent from mid-September through November and results demonstrated clearly when outmigration from the river occurred in 1990. Few shad were taken at these sites prior to 14 October. Over the next 19 days, 74% of all shad taken at Safe Harbor and 90% of those at Holtwood appeared in collections. This peak in shad abundance coincided with a high flow event and rapidly declining water temperature (Figures 2 and 3), conditions typical of autumn outmigration. Flow at Safe Harbor averaged less than 20,000 cfs from late July through 12 October. During the next 3 weeks, river discharge never fell below 45,000 cfs and peaks of 158,000 and 209,000 cfs were recorded on 14 and 26 October, respectively (Figure 4). As expected, water temperature declined quickly during this period from 21 to 9°C.

Though numbers of American shad collected from screens and strainers at Peach Bottom and Conowingo were meager, 30 of 33 fish were also taken during the high flow episode. Migratory urge is best demonstrated by rapid movements of pond-reared juvenile shad released at Thompsontown on 2-5 November and recaptured 85 miles downstream at Holtwood Dam on 7 November (Table 6).

In 1989, marked shad released as fry at Thompsontown appeared in Maryland DNR collections in the Upper Bay between 23 July and 1 October. These fish were apparently pushed out of the river with unusually high summer flows (St. Pierre, 1990). With relatively stable summer/fall flow conditions in 1990, DNR collections produced no shad of known upstream origin. This collecting effort terminated by the end of October prior to peak outmigration from the river.

Abundance

Comparison of relative abundance of juvenile shad in the Susquehanna River from year to year is difficult due to lack of consistent collecting effort, the opportunistic nature of net sampling, and potentially wide variation in river conditions which may influence success. The most consistent and least biased sampling activity employed in the SRAFRC program for this type analysis involves removing fish from cooling water strainers at Safe Harbor Dam. Impinged fish are collected from strainers for all operational units on a daily basis during autumn months. Peach Bottom (travelling screens) and Conowingo Dam (strainers) offer similar opportunity - but too few shad have been taken at these sites in recent years to allow meaningful comparison.

Table 7 shows numbers of American shad taken from Safe Harbor strainers during peak autumn collecting periods in 1987 through 1990. Collections ranged from a low of 10 fish in 1988 in 18 days to this year's 161 fish in 20 days, a 13-fold improvement in relative abundance expressed as catch per day (cpd). Collections made in 1987 and 1989 showed cpd values of 1/2 to 1/4 that recorded in 1990.

Shad collections with the fixed-dimension lift net employed at Holtwood's inner forebay show a similar apparent increase in abundance (Table 7). During peak collecting dates in 1990, numbers of shad per lift averaged 45 fish. This compares with an average of 3 to 10 fish/lift in 1987-1989. Rigorous conclusions on relative abundance should not be drawn from this data however. Collections at Holtwood in 1989 were atypical since it appeared that many shad moved past the project prior to the netting season with high summer flows. Though timing of peak abundance at Holtwood was similar in 1990, 1988 and 1987, this year's effort was conducted at dusk, rather than during midday hours as in earlier years.

Cast net data from York Haven and seine collections at Columbia and Wrightsville are not useful for assessment of relative abundance from year to year due to vagaries of the gear, collection timing and variability in river and weather conditions. Net collections in the Upper Chesapeake Bay suffer similar difficulties and the DNR electrofishing sampling design was altered from prior years to make comparison impossible.

If shad collections at Safe Harbor (and perhaps Holtwood) are representative of relative abundance during autumn outmigration in recent years, 1990 results would indicate either substantially improved reproductive success from transplanted adults and/or enhanced survival of hatchery released fry. Even though a record number of potential spawning adults were released above dams in 1990, analysis of otoliths from 765 juvenile shad taken from New Cumberland to Holtwood over a 16-week period revealed only 18 unmarked fish, a ratio almost identical to that of 1989.

The number of shad fry stocked from Van Dyke in 1990 was similar to that for 1988 and 1987 and less than one-half the number released in 1989. Shad abundance appeared greater in 1990 than in prior years based on improved catch per unit of effort in select collections. This improvement is probably not related to numbers of adult shad stocked (i.e. natural reproduction), and we can only speculate which factors may have influenced enhanced survival of hatchery release shad.

Growth

In 1989, juvenile shad collected with seines in the vicinity of the Texas Eastern pipeline crossing at Marietta averaged about 35 mm total length (TL) in early August and 57 mm in late August. Fish ranged in size from about 25 to 95 mm. Shad were considerably larger in 1990, showing mean total lengths of 72 mm in collections from Columbia and Wrightsville during 1-8 August and 104 mm by the end of the month. Fish ranged in size from about 40 mm to 120 mm. By the end of September, fish from all seine sites averaged over 120 mm and ranged as large as 140 mm (Tables 8 and 9). Of almost 500 juvenile shad from August-September seine collections which were examined for tetracycline marks on otoliths, only 12 were unmarked. Eight of these were definitely wild fish and four showed hatchery microstructure. Naturally produced juvenile shad in collections were of similar size to hatchery fish.

Twenty-five fish samples from several cast net collections at York Haven forebay were measured and found to average 10-20 mm larger than seine caught fish above and below that site and in lift net samples from Holtwood for comparable dates (Table 10). This size range is similar to that measured 4-8 weeks later at York Haven during 1988 collections. Hudson River shad fry were stocked at Thompsontown over a 4-week period (6 June to 2 July). Since most fish collected at seine sites and at York Haven were Hudson origin, the size disparity noted in these collections may relate to age of fish (i.e. date of release), or more likely, a gear bias whereby larger shad avoided seines and lift nets or small shad were not adequately sampled with the cast net.

Subsamples of up to 26 fish each were measured from lift net collections at Holtwood during 28 September through 16 November (389 total). As in past years at most collecting sites, fork length was measured. Young (1987) provided a conversion formula to total length [TL=1.16(FL)-2.68; r=0.9985] to allow comparison of all data in consistent terms. Fish in Holtwood collections averaged 114 mm to 128 mm TL prior to the high flow episode which apparently triggered outmigration (28 September - 12 October). During the next 3 weeks when fish were most abundant, average size in net collections rose to 140 mm (range 120-165 mm). As the run tapered off at Holtwood average size of shad in samples decreased. Holtwood cast net samples taken during peak migration in 1989 and 1988 averaged 139 mm and 128 mm (TL), respectively. Figure 5 shows shad growth trend from all collections during August to November.

The PA Fish Commission released 70,000 pond-reared fingerling shad (168-175 days old) at Thompsontown between 29 October and 5 November. Based on otolith analysis, 9 of 43 fish examined from Holtwood collections during 5-16 November were fingerling recaptures. These shad were consistently the smallest fish measured, ranging in size from about 70 to 105 mm TL (Table 11). Four of the five shad taken from Peach Bottom screens after November 2 ranged in size from 71-92 mm compared to 119-166 mm TL prior to the high flow event. It is likely that these fish were also stocked fingerlings.

Stock Composition and Mark Analysis

Of the 5,619,000 shad fry stocked at Thompsontown in 1990, 3,817,900 (68%) were Hudson River origin released on 10 dates between 6 June through 2 July. Net collections from New Cumberland to Holtwood during August through mid-November, produced a disproportionate 97% (714 of 737) Hudson fish based on mark analysis. The recovery rate for these fish was 0.000187 (about 1 in 5,300), the highest such value recorded since 1988 when this type analysis began.

The 178,300 Pamunkey River fry were stocked on 22 May. They comprised 3% of all fry released and, with only 4 recoveries, 1% of recaptures. Virginia fish demonstrated much better survival in 1989 and 1988, when they represented 4% and 11% of fish stocked and 26% and 40% of recoveries. Delaware River shad fry made up

1,622,800 (29%) of the total Juniata River stocking in 1990, with four releases between 26 May and 8 June. Otolith analysis showed that this source was poorly represented in juvenile collections, making up only 3% (19 of 737 fish) and producing a recovery rate of 0.000012. In terms of relative survival from stocking to recovery, Hudson River fish outperformed those from the Pamunkey by a factor of 8.3 and the Delaware by 16.7. Table 12 displays release and recovery numbers and rates and relative survival for all egg source fry stockings in 1988 through 1990.

As noted above, Virginia source fry produced highest relative survival in 1988 and 1989. St. Pierre (1990, 1989) observed that shad survival is likely related to river conditions at time of stocking (temperature, flows, water clarity), abundance of food, and amount of competition and predation. In prior years, earliest stocked fish (Virginia/Delaware in 1988 and VA/Hudson in 1989) demonstrated a survival advantage over later (Columbia River) releases. In 1990, however, Hudson River fish were the latest releases and produced highest recovery rates. Mike Hendricks (PFC) examined daily river flow and temperature records for the Juniata River at Newport (USGS gauge) during stocking periods in 1988 through 1990 and found no trend in river conditions which could explain differences observed in relative survival.

A total of 3,943,200 shad fry were distinctively marked (double tag) and stocked below Conowingo Dam at Lapidum, MD on four dates between 24 May and 19 June. The stockings were equally split between Delaware and Hudson source fish. Maryland DNR personnel collected 31 double-marked shad during early July to mid-October, a recovery rate considerably smaller than that noted in upstream collections - but consistent with 1989 results (77 of 7.65M). Wild fish (no hatchery marks or microstructure on otoliths) comprised 46% (26 of 56) of DNR collections in 1990, a 10-fold improvement over 1989.

The 90,000 fingerling shad produced in Pennsylvania ponds were released at Thompsontown between 23 August and 5 November. Ten of these fish were recovered, one at York Haven 2 months after stocking from the canal pond, and 9 at Holtwood within 5-16 days of release (Table 13). In 1989, none of the 64,000 fingerlings stocked were recovered in late season collections downstream.

SUMMARY

River conditions during the summer and early fall of 1990 were much more stable and predictable than in 1989. Seine collections above and below York Haven Dam indicated that hatchery released fry grew well and utilized much of the mid-Susquehanna River as nursery in August and September. Shad collections from cooling water strainers at Safe Harbor and with lift nets at Holtwood indicated greater relative abundance than in previous years, and directed outmigration at these sites was well-defined and correlated with a high flow event in late October. Very few naturally produced shad were taken in upstream collections.

Hudson River source juvenile shad survived much better than those from the Pamunkey or Delaware River. Unlike 1989, no hatchery fish of upstream origin were taken below Conowingo Dam, but wild fish were very well represented in these collections. Pond cultured fingerling shad released in Pennsylvania during a high river flow condition moved rapidly downstream and made up a significant portion of net collections at Holtwood during mid-November. These fish were much smaller than similar aged fish released as fry. Fingerlings reared in Maryland ponds were stocked too late for recovery in upper Bay collections.

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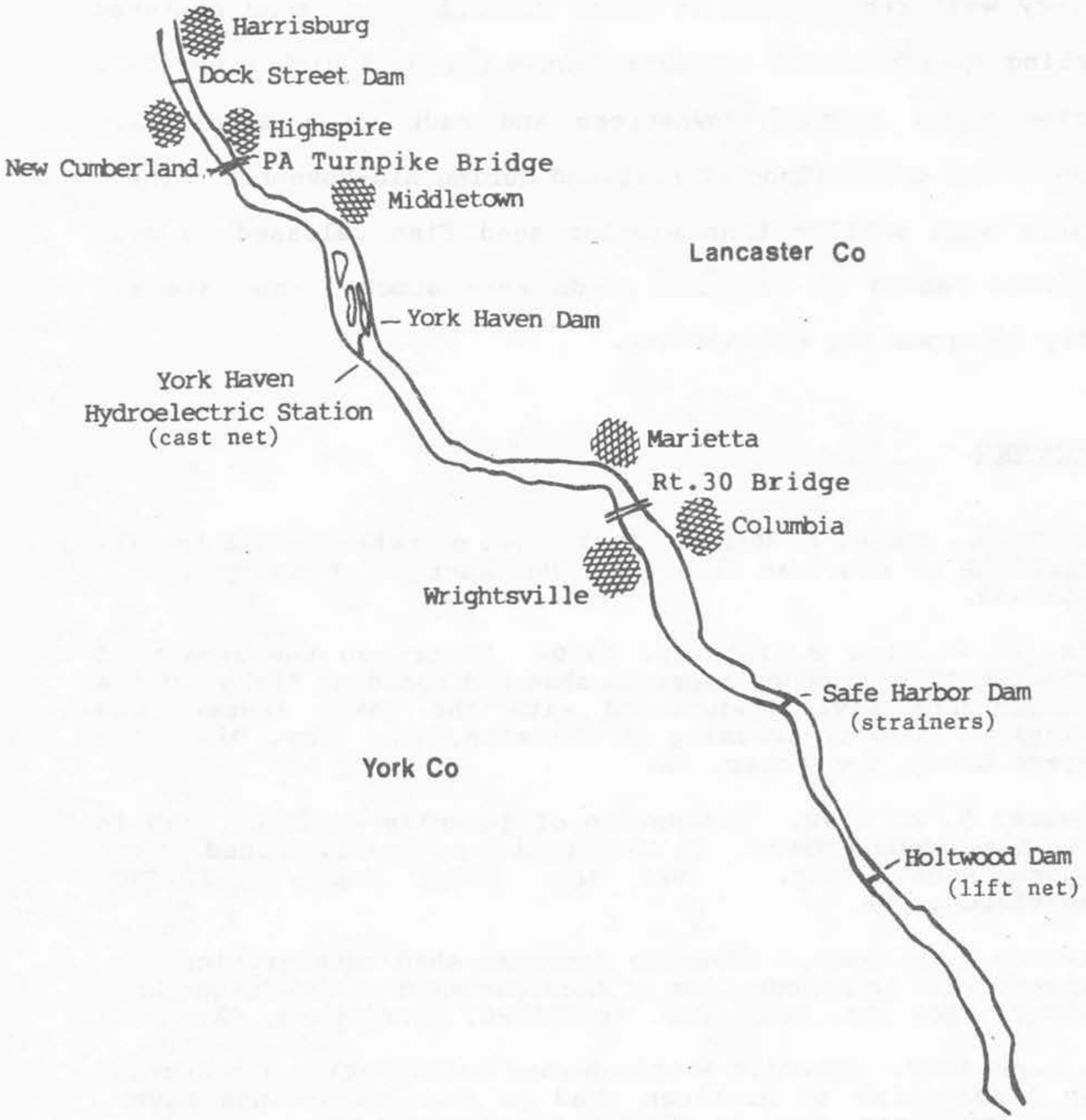


Figure 1. Location of haul seine sampling sites located on the lower Susquehanna River during 1990.

Fig. 2. Juvenile Shad Taken from Safe Harbor Strainers, Sept.-November, 1990.

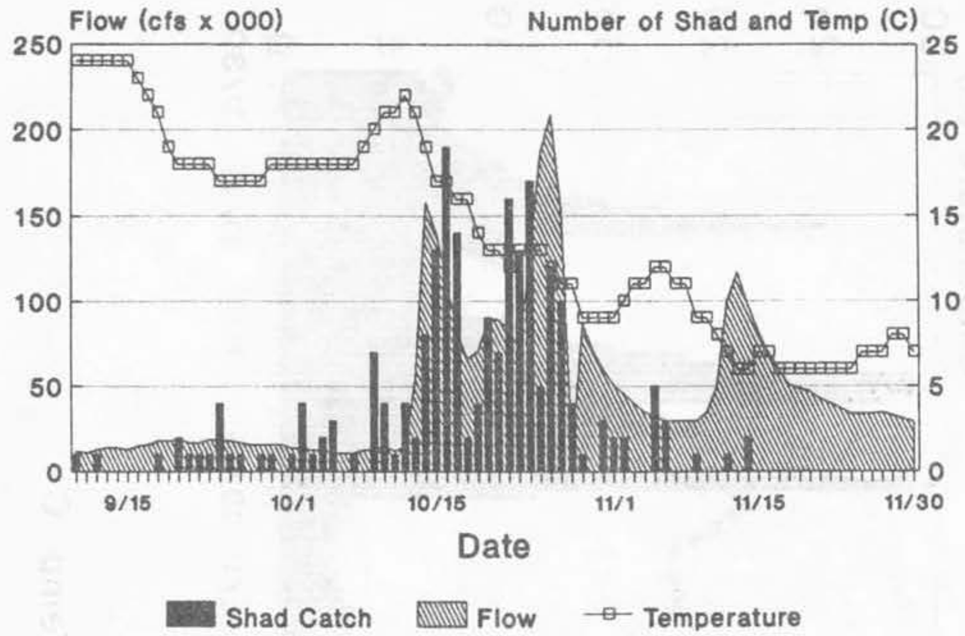


Fig. 3. Juvenile Shad Catch with Lift Net at Holtwood, Sept.-November, 1990.

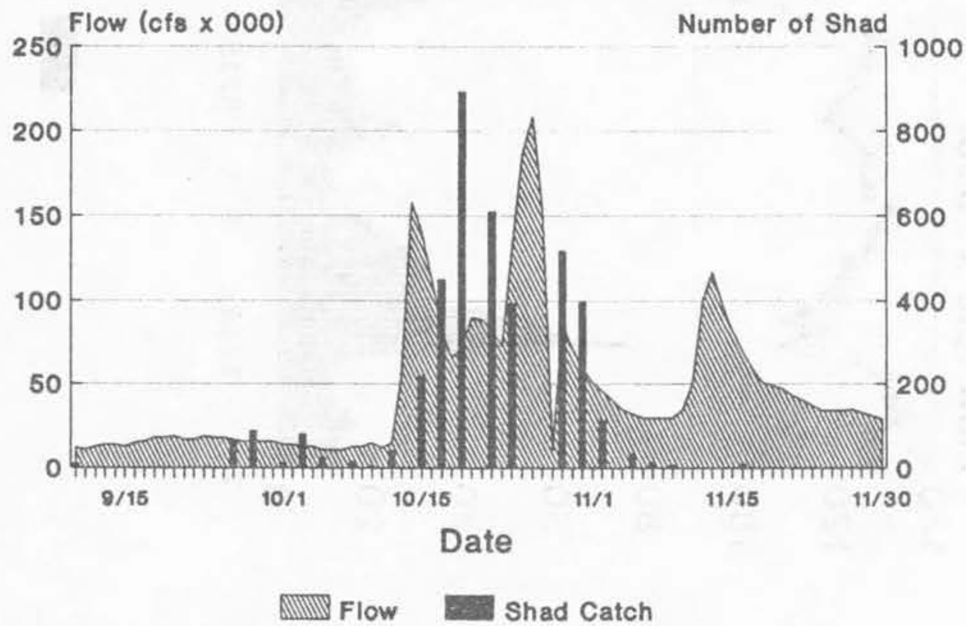
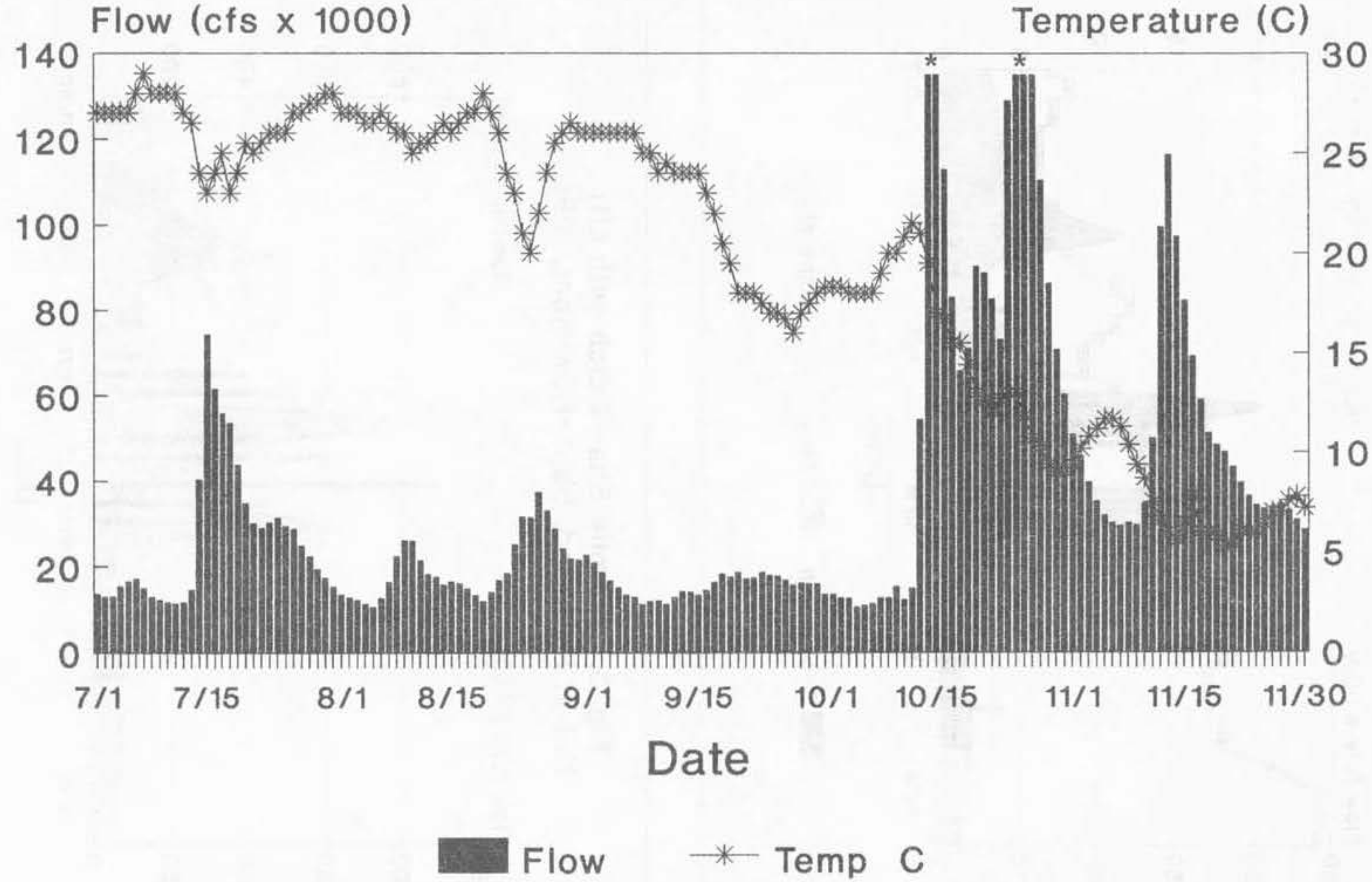


Fig. 4. Temperature and Flow Data at Safe Harbor Dam, July-Nov., 1990



* Flow peaked at 158,000 cfs on 10/14 and 208,700 cfs on 10/26

Fig. 5. Growth of Juvenile Shad Based on Mean Lengths in Daily Net Collections - New Cumberland to Holtwood, 1990.

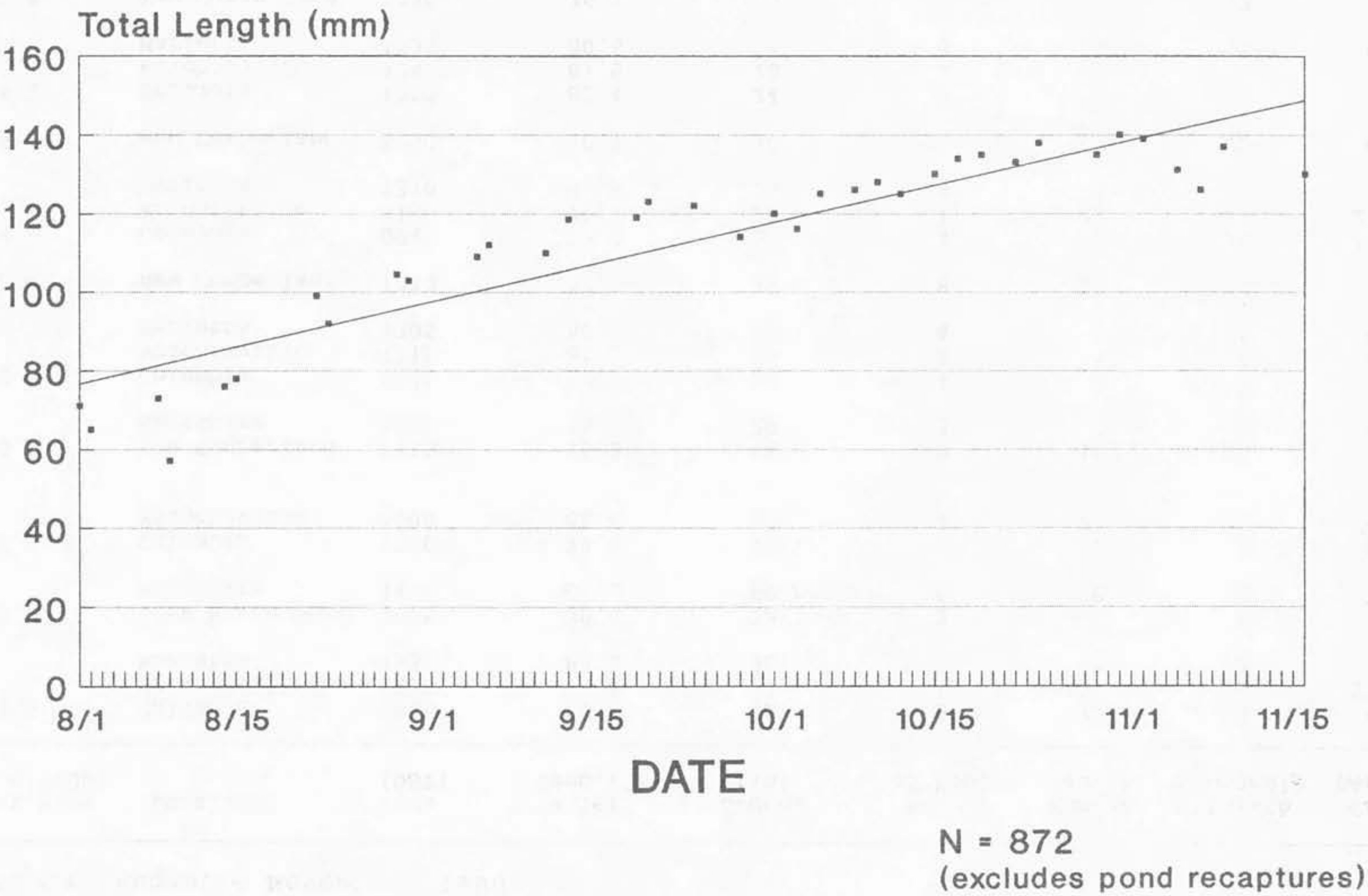


Table 1. Results of haul seine effort to collect young American shad on the lower Susquehanna River, August - November, 1990.

Date	River Flow (cfs x 1000)	Location	Time (DST)	Water Temp.(°F)	Secchi (in)	Number of Hauls	Number Caught	Otolith Subsample	Catch per Haul
1 Aug	13.5	Columbia	1035	80.6	42	5	31	30	6.20
		Wrightsville	1235	80.6	30	1	57	28	57.00
		Marietta	1530	84.2	36	3	4	4	1.33
2 Aug	12.7	York Haven Pond	1125	80.6	28	2	0	0	0.00
		Highspire	1415	80.6	60(bot)	5	8	8	1.60
8 Aug	22.3	Columbia	1030	77.0	42	5	0	0	0.00
		Wrightsville	1200	82.4	25	2	20	20	10.00
9 Aug	26.1	New Cumberland	1115	75.2	48	9	10	10	1.11
		Highspire	1600	75.2	29	3	0	0	0.00
14 Aug	15.8	Columbia	1045	77.9	34	4	0	0	0.00
		Wrightsville	1115	81.5	26	2	1	1	0.50
		Marietta	1305	80.6	27	4	1	1	0.25
15 Aug	16.4	New Cumberland	1010	77.9	37	8	22	22	2.75
22 Aug	18.4	Columbia	0945	70.7	28	4	56	26	14.00
		Wrightsville	1130	70.7	28	1	23	23	23.00
		Marietta	1310	69.8	24	4	1	1	0.25
23 Aug	25.1	New Cumberland	1100	70.7	30	10	68	25	6.80
29 Aug	24.2	Columbia	1000	82.4	24	3	0	0	0.00
		Wrightsville	1245	81.5	28	3	4	4	1.33
		Marietta	1530	80.6	28	3	2	2	0.67
30 Aug	21.8	New Cumberland	1030	76.1	25	9	13	13	1.44
		Highspire	1430	78.8	28	3	55	25	18.33
5 Sep	15.1	Columbia	0930	76.1	30	5	25	25	5.00
		Wrightsville	1115	76.1	36	1	1	1	1.00
		Marietta	1430	78.8	50	4	0	0	0.00

Table 1 (continued). Results of haul seine effort to collect young American shad on the lower Susquehanna River, August - November, 1990.

Date	River Flow (cfs x 1000)	Location	Time (DST)	Water Temp.(°F)	Secchi (in)	Number of Hauls	Number Caught	Otolith Subsample	Catch per Haul
6 Sep	13.5	New Cumberland	1000	76.6	28	9	15	15	1.67
		Highspire	1445	79.7	32	1	34	26	34.00
11 Sep	11.2	Columbia	1000	74.3	30	5	4	4	0.80
		Wrightsville	1115	75.2	28	1	0	0	0.00
		York Haven Pond	1415	84.2	30	2	46	25	23.00
13 Sep	14.3	New Cumberland	1040	75.2	24	7	52	25	7.43
		Highspire	1500	77.9	32	3	46	25	15.33
19 Sep	17.6	Columbia	1015	63.5	26	8	93	25	11.63
		Wrightsville	1155	65.3	24	1	0	0	0.00
		York Haven Pond	1545	63.5	28	1	230	25	230.00
20 Sep	18.5	New Cumberland	1130	64.4	22	5	11	11	2.20
		Highspire	1430	66.2	34	5	25	25	5.00
24 Sep	18.0	Columbia	1040	61.7	22	4	28	25	7.00
		Wrightsville	1215	64.4	50	1	0	0	0.00
3 Oct	12.7	Columbia	1045	62.6	34	3	0	0	0.00
		Wrightsville	1215	65.3	36	1	0	0	0.00
11 Oct	12.4	Columbia	1005	69.8	36	4	0	0	0.00
		Wrightsville	1130	71.6	36	1	0	0	0.00
18 Oct	65.8	Columbia	1130	64.4	4	1	0	0	0.00
2 Nov	45.9	Columbia	1200	53.6	15	2	0	0	0.00
		Wrightsville	1315	55.4	32	1	0	0	0.00
				TOTALS	(thru 9/24)	156	986	500	6.32
					(after 9/24)	13	0	0	0.0

Table 2. Daily Catch of Juvenile American Shad in Cooling Water Strainers at Safe Harbor Dam, September-November, 1990.

DATE	# Shad	DATE	# SHAD
9/10	1	10/21	7
9/11	0	10/22	16
9/12	1	10/23	13
9/13	0	10/24	17
9/14	0	10/25	5
9/15	0	10/26	12
9/16	0	10/27	10
9/17	0	10/28	4
9/18	1	10/29	1
9/19	0	10/30	0
9/20	2	10/31	3
9/21	1	11/1	2
9/22	1	11/2	2
9/23	1	11/3	0
9/24	4	11/4	0
9/25	1	11/5	5
9/26	1	11/6	3
9/27	0	11/7	0
9/28	1	11/8	0
9/29	1	11/9	1
9/30	0	11/10	0
10/1	1	11/11	0
10/2	4	11/12	1
10/3	1	11/13	0
10/4	2	11/14	2
10/5	3	11/15	0
10/6	0	11/16	0
10/7	1	11/17	0
10/8	0	11/18	0
10/9	7	11/19	0
10/10	4	11/20	0
10/11	1	11/21	0
10/12	4	11/22	0
10/13	2	11/23	0
10/14	8	11/24	0
10/15	13	11/25	0
10/16	19	11/26	0
10/17	14	11/27	0
10/18	2	11/28	0
10/19	4	11/29	0
10/20	9	11/30	0
		TOTAL	218

Table 3. Summary of fishes collected by lift net at Holtwood Forebay, Fall 1990.

DATE	Aug 23	Aug 30	Sep 6	Sep 12	Sep 19	Sep 26	Sep 28	Oct 1	Oct 3	Oct 5	Oct 8	Oct 10	Oct 12	Oct 15	Oct 17	Oct 19	Oct 22	Oct 24
TEMP(C)	28	27.5	26	26	20.5	16.2	17	17	18.2	18	18	19.5		16.5	16.5	14.8	12.2	13
Species																		
American Shad	-	-	8	-	-	64	87	12	80	24	15	4	40	218	450	893	611	394
Blueback Herring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alewife	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Gizzard Shad	96	7	1	7	344	97	37	74	-	6	17	1	1	975	3033	2752	3508	6815
Swallowtail Shiner	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Roseyface Shiner	-	-	-	1	-	-	-	-	-	4	-	-	-	-	-	-	-	-
Spotfin Shiner	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shorthead Redhorse	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Channel Catfish	5	-	-	-	-	1	1	-	-	-	-	1	-	-	2	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	1
Smallmouth Bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Largemouth Bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tiger Muskie	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* High water elevations prevented sampling.
** No fish collected.

Effort was usually 10 lifts per date

Table 3. (continued)

DATE	Oct 26	Oct 29	Oct 31	Nov 2	Nov 5	Nov 7	Nov 9	Nov 12	Nov 14	Nov 16	Nov 19	Nov 21	Nov 23	Nov 26	
TEMP(C)		9.2	9.2	10.2	11.4	11.2	10			6	5.7	5	5.2	7	
Species															Totals
American Shad	*	518	397	113[1]	34	13	5	*	*	8	-	**	-	**	3988
Blueback Herring	-	-	1	-	-	5	-	-	-	-	-	-	-	-	6
Alewife	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2
Gizzard Shad	-	3680	1185	501	46	-	-	-	-	290	30	-	2	-	23505
Swallowtail Shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Roseyface Shiner	-	-	-	-	1	-	-	-	-	1	-	-	-	-	7
Spotfin Shiner	-	-	-	-	-	-	-	-	-	-	1	-	-	-	10
Shorthead Redhorse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Channel Catfish	-	-	-	-	1	-	-	-	-	-	1	-	-	-	12
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Bluegill	-	-	3	2	-	-	-	-	-	-	1	-	-	-	11
Smallmouth Bass	-	-	1	1	-	-	-	-	-	-	-	-	-	-	2
Largemouth Bass	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3
Tiger Muskie	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1

* High water elevations prevented sampling.

** No fish collected.

Table 4. Summary of Juvenile American Shad Collected at Peach Bottom Atomic Power Station, October-November, 1990.

Collection Date	Hours Unit 2	Hours Unit 3	Intake Temp (°C)	No. Shad	Length Range (mm)
10/17	50.5	50.0	-	9	119-163
10/19	70.5	70.5	15.0	11	135-166
10/22	48.0		13.5	0	
10/23		22.2	-	2	148-154
10/24	48.0	48.0	13.8	0	
10/26	73.0	73.0	13.0	3	131-152
10/29	48.0		10.7	0	
10/31	47.7		10.2	0	
11/02	72.3		10.8	2	72-131
11/05	48.1		12.0	1	92
11/07	47.8		12.0	0	
11/09	71.8		11.2	0	
11/12	48.0	48.0	8.5	1	82
11/14	48.3	48.3	7.0	1	84
11/16	72.3	72.3	7.0	0	
11/19	47.5	47.5	6.2	0	
11/21	120.5	120.5	6.0	0	
TOTALS	**961.8**	**600.3**		**30**	**72-166**

Table 5. Egg source river and tetracycline marking of juvenile American shad collected in the Susquehanna River and Flats, 1990.
Wild– No TC tag. Va– Quadruple immersion tag, Juniata River release. De– Triple immersion tag (days 3,13,17), Juniata River release.
Hu– Triple immersion tag (days 5,9,13), Juniata River release. Fing– released as pond-reared fingerlings.
BC– released as fry below Conowingo Dam, any egg source.
* includes one individual with no tag but with hatchery microstructure. **– yearlings.

	New Cumberland/ Highspire/ Three Mile Is./ York Haven Pond (seine)					York Haven Forebay (cast net)					Marietta/ Columbia/ Wrightsville (seine)					Holtwood Forebay (lift net)					Susquehanna Flats/ Chesapeake Bay (various gears)					
Week of:	Wild	Va	De	Hu	Fing	Wild	Va	De	Hu	Fing	Wild	Va	De	Hu	Fing	Wild	Va	De	Hu	Fing	Wild	Va	De	Hu	BC	Fing
5/20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2**	–	–	–	–	–
7/8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	4	–
7/15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11	–	–	–	6	–
7/22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
7/29	–	–	–	8	–	–	–	–	–	–	–	–	2	55	–	–	–	–	–	–	–	–	–	–	2	–
8/6	2*	–	–	7	–	–	–	–	–	–	2	–	–	18	–	–	–	–	–	–	–	–	–	–	–	–
8/13	–	–	1	21	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	1	–	–	–	8	–
8/20	1	–	–	24	–	–	–	–	–	–	3	1	–	46	–	–	–	–	–	–	1	–	–	–	3	–
8/27	–	–	–	37	–	–	–	–	–	–	1*	–	–	5	–	–	–	–	–	–	1	–	–	–	1	–
9/2	–	–	–	36	–	–	–	–	–	–	1*	–	2	22	–	–	–	–	–	–	–	–	–	–	–	–
9/9	–	1	1	73	–	–	–	–	1	–	–	–	–	4	–	–	–	–	–	–	1	–	–	–	1	–
9/16	–	–	2	59	–	–	–	–	23	–	1*	–	2	22	–	–	–	–	–	–	2	–	–	–	4	–
9/23	–	–	–	–	–	–	–	1	23	–	4	–	2	19	–	1	–	–	23	–	2	–	–	–	1	–
9/30	–	–	–	–	–	–	–	3	20	–	–	–	–	–	–	–	–	–	23	–	–	–	–	–	–	–
10/7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15	–	–	–	–	–	1	–
10/14	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	1	–	23	–	2	–	–	–	–	–
10/21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	23	–	–	–	–	–	–	–
10/28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50	–	–	–	–	–	–	–
11/4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	26	8	–	–	–	–	–	–
11/11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	6	1	–	–	–	–	–	–
Unknown																					1	–	–	–	–	
Total	3	1	4	265	0	0	0	6	67	1	12	1	8	193	0	3	2	1	189	9	28	0	0	0	31	0
(percent)	1	0	1	97	0	0	0	8	91	1	6	0	4	90	0	1	1	0	93	4	47	0	0	0	53	0
																			Grand Total		46	4	19	714	31	10
																			(percent)		6	0	2	87	4	1

Table 6. Recovery of pond-reared American shad in the Susquehanna River, 1990.

Pond	Pond Release Date	Collection Date	Number Collected	Collection Site
Canal Pond	8/23	10/19	1	York Haven Forebay
Upper Spring Creek Pond 1	10/29	11/5	3	Holtwood Forebay
		11/7	2	Holtwood Forebay
Upper Spring Creek Pond 2	10/31	11/7	1	Holtwood Forebay
		11/16	1	Holtwood Forebay
Upper Spring Creek Pond 3	11/2,11/5	11/7	2	Holtwood Forebay

Table 7. Relative Abundance of Juvenile American Shad at Safe Harbor Dam (strainers) and Holtwood Inner Forebay (lift net), 1987-1990.

	1990	1989	1988	1987
Fry Stocked Above Dams	5.62M	13.47M	6.45M	5.18M
Safe Harbor				
Peak Dates	10/14-11/2	10/2-25	11/7-24	10/8-11/2
Shad Catch	161	30	10	94
Catch/Day	8.05	1.25	0.6	3.6
Holtwood				
Peak Dates	10/5-11/2	10/20-26	10/26-11/10	10/5-11/6
Shad Catch	3,594	470	905	785
Catch/Lift	44.9	5.5	9.7	3.1

Table 8. Length frequency data (5 mm groups) for juvenile American shad taken by haul seine at New Cumberland and Highspire in August and September 1990.

	2-Aug	9-Aug	15-Aug	23-Aug	30-Aug	6-Sep	13-Sep	20-Sep	Total
Length (mm)									
36 - 40	-	1	-	-	-	-	-	-	1
41 - 45	-	-	-	-	-	-	-	-	-
46 - 50	-	2	-	-	-	-	-	-	2
51 - 55	2	1	-	-	-	-	-	-	3
56 - 60	1	2	-	-	-	-	-	-	3
61 - 65	1	2	2	-	-	-	-	-	5
66 - 70	1	2	2	-	-	-	-	-	5
71 - 75	2	-	2	-	-	-	-	-	4
76 - 80	1	-	9	-	1	-	-	-	11
81 - 85	-	-	4	7	-	-	-	-	11
86 - 90	-	-	1	7	2	-	-	-	10
91 - 95	-	-	1	5	3	-	-	-	9
96 - 100	-	-	1	3	13	4	-	-	21
101 - 105	-	-	-	-	4	4	1	1	10
106 - 110	-	-	-	-	6	6	5	1	18
111 - 115	-	-	-	1	6	14	14	2	37
116 - 120	-	-	-	2	3	10	13	10	38
121 - 125	-	-	-	-	-	1	8	9	18
126 - 130	-	-	-	-	-	2	4	5	11
131 - 135	-	-	-	-	-	-	3	7	10
136 - 140	-	-	-	-	-	-	1	1	2
141 - 145	-	-	-	-	-	-	1	-	1
Total	8	10	22	25	38	41	50	36	230
Mean Length	64.8	56.6	78.2	92.3	103.0	111.8	118.5	123.1	

Table 9. Length frequency data (5 mm groups) for juvenile American shad taken by haul seine at Columbia and Wrightsville in August and September 1990.

	1-Aug	8-Aug	14-Aug	22-Aug	29-Aug	5-Sep	11-Sep	19-Sep	24-Sep	Total
Length (mm)										
36 - 40	-	1	-	-	-	-	-	-	-	1
41 - 45	-	-	-	-	-	-	-	-	-	-
46 - 50	4	-	-	-	-	-	-	-	-	4
51 - 55	2	-	-	-	-	-	-	-	-	2
56 - 60	6	-	-	-	-	-	-	-	-	6
61 - 65	4	2	-	-	-	-	-	-	-	6
66 - 70	7	5	-	-	-	-	-	-	-	12
71 - 75	13	5	-	-	-	-	-	-	-	18
76 - 80	11	3	1	-	-	1	-	-	-	16
81 - 85	7	3	-	1	-	-	-	-	-	11
86 - 90	2	-	-	4	-	-	-	1	-	7
91 - 95	1	1	-	8	-	-	-	-	-	10
96 - 100	1	-	-	21	1	1	-	-	-	24
101 - 105	-	-	-	5	2	5	2	1	-	15
106 - 110	-	-	-	5	1	9	1	4	1	21
111 - 115	-	-	-	4	-	5	1	4	2	16
116 - 120	-	-	-	1	-	4	-	9	7	21
121 - 125	-	-	-	-	-	1	-	2	10	13
126 - 130	-	-	-	-	-	-	-	3	2	5
131 - 135	-	-	-	-	-	-	-	1	2	3
136 - 140	-	-	-	-	-	-	-	-	1	1
Total Wild	58	20	1	49	4	26	4	25	25	212
Mean Length	71.4	73.2	76.0	99.5	104.5	109.2	106.8	116.0	121.7	

Table 10. Mean length and Duncan's New Multiple Range Test groupings for groups of Hudson River source American shad collected in the Susquehanna River, 1990.

Collection Date	Collection site	Gear	N	Mean length (mm)	Duncan Grouping
9/19	Columbia	seine	22	112.9	A
9/28	Holtwood forebay	lift net	23	116.2	A B
9/19,9/20	Highspire, N. Cumberland, Three Mile I.	seine	59	118.0	B
9/24	Columbia	seine	19	118.1	B
10/1	Holtwood forebay	lift net	23	119.9	B
9/24	York Haven forebay	cast net	23	127.5	C
9/20	York Haven forebay	cast net	23	130.5	C D
10/3	York Haven forebay	cast net	20	132.9	D

Table 11. Length-frequency of hatchery-reared American shad collected in the Susquehanna River after release as fry vs. release as fingerlings, 1990.

Length Interval (mm)	Nov. 4 Fry Release	Nov. 4 Fingerling Release	Nov. 11 Fry Release	Nov. 11 Fingerling Release
71-75				1
76-80				
81-85		4		
86-90		1		
91-95				
96-100		2		
101-105	1	1		
106-110				
111-115			1	
116-120	2		1	
121-125	7		3	
126-130	6		1	
131-135	4			
136-140	3			

Table 12. Relative survival of American shad fry from various egg source rivers, stocked in the Susquehanna River, 1988-1990.

Year	Egg Source	Release Dates	Fry Released Number	%	Juveniles Recovered Number	%	Recovery Rate	Relative Survival
1988	Va.	5/13-5/31	682,685	11	111	40	0.000163	1.00
	Del.	6/1-6/10	495,670	8	69	25	0.000139	0.85
	Col.	7/5-7/25	5,272,330	82	99	36	0.000019	0.12
1989	Va.	5/30-6/1	477,320	4	67	26	0.000140	1.00
	Hud.	6/5-6/28	2,864,720	21	94	37	0.000033	0.23
	Del.	6/16-7/7	1,644,630	12	11	4	0.000007	0.05
	Col.	6/30-7/11	8,477,980	63	80	32	0.000009	0.07
1990	Va.	5/22	178,300	3	4	1	0.000022	0.12
	Del.	5/26-6/8	1,622,800	29	19	3	0.000012	0.06
	Hud.	6/6-7/2	3,817,900	68	714	97	0.000187	1.00

Table 13. Recovery of pond-reared American shad in the Susquehanna River, 1990.

Pond	Pond Release Date	Collection Date	Number Collected	Collection Site
Canal Pond	8/23	10/19	1	York Haven Forebay
Upper Spring Creek Pond 1	10/29	11/5	3	Holtwood Forebay
		11/7	2	Holtwood Forebay
Upper Spring Creek Pond 2	10/31	11/7	1	Holtwood Forebay
		11/16	1	Holtwood Forebay
Upper Spring Creek Pond 3	11/2,11/5	11/7	2	Holtwood Forebay

Job V, Task 1

INDUCED SPAWNING OF AMERICAN SHAD

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Introduction

A reliable method to induce spawning in adult American shad (Alosa sapidissima) would provide the Pennsylvania Fish Commission's Van Dyke hatchery (Thompsontown, PA) with fertilized eggs for culture and stocking. Preliminary studies indicated that human chorionic gonadotropin (HCG) induces maturation of gonads (higher gonadosomatic index, GSI) but not ovulation (Backman and Liu 1990). A similar phenomenon has been reported in other fishes (Lasker 1974; Stacey and Pandey 1975).

In addition to HCG, other hormones such as salmon pituitary extract, luteinizing hormone-releasing hormone (LHRH), luteinizing hormone-releasing hormone ethylamide (LHRHa), and prostaglandin (PGF_{2a}) were also tested in this study. LHRH has been widely used in fish culture (Hirose and Ishida 1974; Lam et al. 1976; Chan 1977; Harvey and Hoar 1979; Crim and Evans 1980; Crim et al. 1981) and has been shown not only to induce spawning in many fishes (Lee et al. 1986, Hirose and Arai 1988) but also to increase survival rates after spawning (Harvey and Hoar 1979). PGF_{2a} is considered a local hormone that accelerates ovulation and causes follicular rupture and oviduct contraction (Laycock and Wise 1983). Although PGF_{2a} induces ovulation in many fishes, it has not been widely used in fish culture (Peter and Billard 1976; Stacey and Pandey 1975; Stacey et al. 1979). Our primary objective was to determine if ovulation can be induced by hormone treatment, particularly, with HCG and LHRHa.

Method

Experimental Facilities

The experiments were conducted at the Muddy Run Station (RMC) in Drumore, PA, from May 15 to June 20, 1990. Test fish were obtained as spring-run adults from the Conowingo Dam fish lift and transported to RMC the same day. During the experiments, females were kept in four fiberglass 8-foot circular tanks, males in a metal 8-foot circular tank. Water supply was directly pumped from the nearby Muddy Run Reservoir to each tank with an average flow of 3 gpm. No additional devices were used for reducing suspended solids or controlling water temperature. Water temperature ranged from 15°C in May to 26°C at the end of the experiment. The pH remained almost a constant 6.8. Dissolved oxygen concentrations fluctuated daily from 7.4 to 8.6 ppm.

Experimental Protocol

During the study period, about 20 female and 5 male fish were transported from Conowingo Dam to the experimental station weekly. Most appeared healthy upon arriving at the station, and mortality was reduced to two or fewer fish per shipment. The shad were allowed to acclimate in tanks for one day before treatment. Fish received HCG or PGF_{2a} by intraperitoneal and LHRH, LHRHa, or salmon pituitary extracts by intramuscular injection. Five replicates for each treatment were established. Before treatment some eggs were sampled by cannulation and checked for development. Eggs were classified by three developmental categories: (1) early vitellogenesis with small yellow eggs, (2) late vitellogenesis with large yellow eggs, and (3) pre-ovulatory stage with large transparent eggs. Fish containing ovulated eggs at the beginning of the experiment were discarded. When ovulation was observed, eggs were stripped from the female, fertilized in dry condition, and allowed to water harden. Fertilized and water-hardened eggs were then transported to the Van Dyke hatchery within 12 h. Some eggs were incubated at Muddy Run in liter hatching jars.

Result

Treatment with Human Chorionic Gonadotropin

Initial tests in water temperatures of 15 - 19°C effected ovulation in only two of 25 HCG-treated females (Table 1). A third injection of PGF_{2a} did not induce ovulation of previously HCG-treated individuals. Fish responded better to 500 IU/lb of HCG treatment when the injection interval was shortened from 24 to 12 h and the temperature ranged from 17 to 21°C (Table 2). All treated fish, but none of the control fish, ovulated in temperatures of 19 - 26°C (Table 3). When water temperatures reached 22 - 26°C, 75% of the low dosage HCG-treated groups ovulated (Table 4).

Treatment with LHRHa

LHRHa induced ovulation in American shad at all temperature ranges with injection intervals of either 12 or 24 h (Tables 5 - 8). First injection dosage was effective as low as 2 μg/lb of fish weight. The second injection, however, was held constant at 10 μg/lb of fish weight.

Other Treatments

Combination treatment with HCG and salmon pituitary extract induced ovulation in two of four fish (Table 9). The combination treatment with HCG and LHRHa also induced ovulation in two of four fish (Table 10). Two injections of salmon pituitary were about as effective as the combination groups (Table 11). Finally, LHRH induced ovulation in three of five fish (Table 12).

Fertilization of the Eggs

Five shipments of fertilized eggs were made to the Van Dyke hatchery as a result of induced spawning (Table 13). Two of five shipments produced eggs that hatched, and survival to day 20 in the last shipment was 96% of those eggs that hatched.

Discussion

All hormone injections resulted in egg development to ovulation. Initial treatments were effective either in the morning or at night. HCG induced ovulation effectively in American shad when water temperature was high (19 - 26°C). Low effectiveness of HCG at low temperatures (15 - 19°C) may have been due to a temperature effect that precluded HCG from stimulating ovarian release. Alternatively, the interval (24 h) between injections may not have been appropriate. Theoretically, the first HCG injection should have stimulated the ovaries to respond to luteinizing hormone. Correctly timed, a second injection should have supplied enough HCG to complete the maturation and ovulation processes. Therefore, lapsed time between injections of HCG may affect the success of ovulation. We do not have sufficient data to demonstrate that short injection intervals are more effective for inducing ovulation at low temperatures. The ovulation process is considered to be independent of pituitary control (Harvey and Hoar 1979) and has been proposed to be mediated by both prostaglandins and catecholamines (Jalabert 1976). However, oocyte maturation and follicular development must have been completed prior to ovulation and required not only LH but also other hormones. The steroid 17α-hydroxy-20β-dihydroprogesterone (17α-20β-Pg), produced by the follicular envelope, is responsive to pituitary gonadotropin and has been proposed as the most probable mediator of oocyte maturation in many fish (Jalabert 1976). Corticosteroid may also play an indirect role in oocyte maturation (Sundararaj and Vasal 1976). Therefore, either decreased potency of HCG due to low temperature or the timing of HCG treatments may be cause for incomplete maturation.

HCG alone failed to induce ovulation in shad. Some fish from other experimental groups treated with the combination of HCG (first injection) and LHRHa (second injection) or HCG and salmon pituitary extracts ovulated. Thus a second injection of either salmon pituitary extracts or LHRHa appears to be important for inducing maturation and ovulation at low temperatures.

PGF_{2a} did not induce ovulation in American shad, perhaps also because of inappropriate timing of injection. If treatment was given before eggs were mature, follicles failed to respond to the treatment.

Unlike HCG, LHRHa induced ovulation in American shad at all temperature ranges. In our study, most shad ovulated after two injections of LHRHa; these shad contained stage-1 or stage-2 eggs before they were treated. Some shad, containing stage-3 eggs in their ovaries before treatment, ovulated after a single injection of LHRHa. The lowest dosage of LHRHa for first injection was 2 μg/lb, which effected ovulation in two fish (Table 7). In China, ovulation in the bighead carp (Aristichthys nobilis) was induced from two dosages of LHRHa as low as 0.22 to 0.45 μg/lb and 1.00 to 2.00 μg/lb (C. Liu, personal observation). Further studies to determine the effective minimum dosage of LHRHa for inducing ovulation in shad are needed.

Production of viable fertilized eggs ranged from 0 - 25% per shipment (Table 13). Though egg development was not adequately monitored in all experimental fish, many shad contained overripe eggs when the last examination was made. Most shad injected with LHRHa ovulated within 24 to 48 h. Oocyte development should be tracked more precisely through ovulation in future studies. The percentage of viable eggs should improve as we determine with greater precision the sequence of events and their causes leading to ovulation after hormone treatment.

Recommendations

The development of techniques to induce spawning in spring-run American shad should continue and include: (1) further improvement in the use of LHRHa to minimize the expense for mass production, (2) tests of the effectiveness of HCG by reducing the injection interval under low-temperature conditions, (3) documentation of ovulation time relating to oocyte development before treatment, and (4) more careful measurement of fertilization rates, hatch rates, and larval survival after treatment.

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Table 1. Effectiveness of human chorionic gonadotropin (HCG, IU/lb of fish weight) and prostaglandin F_{2a} (PGF_{2a}, µg/lb of fish weight) for ovulation induction in American shad at low temperatures (15 - 19°C).

Date	No. of fish	Injection (IU/lb) 1st HCG	2nd HCG	3rd PGF_{2a}	No. of ovulated fish
05-16-90 to 05-19-90	5	100	500	---	0
	5	100	500	100	1
	5	500	500	---	1[1]
	5	500	500	100	0
05-22-90 to 05-26-90	5	500	500	---	0

[1] Ovulation occurred at about 24 h after first treatment.

Table 2. Post-treatment ovulation times for American shad injected with HCG (500 IU/lb) twice within 12 h. Three of five fish were given a third injection (LHRHa, 10 μg/lb).

	Injection time			Time from 1st
	1st	2nd	3rd	injection to
Fish ID	May 29	May 30	May 31	ovulation (h)
1	18:00	09:00	---	38
2	18:05	09:07	---	38
3	18:11	09:11	08:30	--
4	18:15	09:16	08:40	53
5	18:17	09:22	08:48	--

Table 3. Time from treatment to ovulation in American shad injected with HCG and kept at 19 - 26°C.

Fish ID	Injection time 1st June 5	Injection time 2nd June 6	Time from 1st injection to ovulation (h)	Percent of ovulation
HCG-treatment group				
HCG-151	19:00	08:00	36	
HCG-152	19:05	08:07	36	
HCG-153	19:10	08:12	36	100
HCG-154	19:15	08:15	36	
HCG-155	18:17	09:25	36	
Control group				
NO-001	---	---	--	
NO-002	---	---	--	
NO-003	---	---	--	0
NO-004	---	---	--	
NO-005	---	---	--	

Table 4. Post-treatment ovulation times for American shad injected with low-dosage HCG (100 IU/lb) followed by moderate dosage (200 IU/lb) at high temperatures (19 - 26°C).

	Injection time			
	1st	2nd	Time from 1st injection to	Percent
Fish ID	June 12	June 12	ovulation (h)	ovulation
HCG-121	08:00	20:00	26	
HCG-122	08:05	20:07	--	75
HCG-123	08:10	20:12	38	
HCG-124	08:15	20:15	40	

Table 5. Post-treatment ovulation times for American shad twice injected with LHRHa at 15 - 19°C.

	Injection time		Dosage (μg/lb)			
	1st	2nd	1st	2nd	Time from 1st injection to	Percent
Fish ID	May 22	May 23			ovulation (h)	ovulation
a1001	18:00	---	10	--	27	
a1002	18:05	19:55	10	10	46	
a1003	18:10	19:59	10	10	46	100
a1004	18:15	20:02	10	10	62	
a1005	18:22	20:07	10	10	62	

Table 6. Post-treatment ovulation times for American shad twice injected with LHRHa at 17 - 21°C.

	Injection time		Dosage (μg/lb)		Time from 1st	
	1st	2nd	1st	2nd	injection to	Percent
Fish ID	May 29	May 30			ovulation (h)	ovulation
a1006	18:30	19:00	10	10	--	
a1007	18:33	19:04	10	10	38	
a1008	18:37	19:08	10	10	--	60
a1009	18:43	20:17	10	10	38	
a1010	18:51	20:22	10	10	37	

Table 7. Post-treatment ovulation times for American shad twice injected with LHRHa at 19 - 26°C.

	Injection time		Dosage (μg/lb)			
	1st	2nd	1st	2nd	Time from 1st injection to	Percent
Fish ID	June 5	June 6			ovulation (h)	ovulation
al011	18:00	18:00	10	20	37	
al012	18:10	---	10	--	24	
al013	18:15	18:10	10	20	28	100
al014	18:20	---	10	--	31	
al015	18:24	18:22	10	20	63	
al016	18:00	19:10	2	10	36	
al017	18:05	---	2	--	25	
al018	18:08	---	2	--	26	100
al019	18:12	19:15	2	10	26	
al020	18:15	19:15	2	10	30	

Table 8. Post-treatment ovulation times for American shad twice injected with LHRHa at 22 - 26°C.

Fish ID	Injection time 1st June 12	Injection time 2nd June 15	Dosage (µg/lb) 1st	Dosage (µg/lb) 2nd	Time from 1st injection to ovulation (h)	Percent ovulation
a1021	08:00	20:00	5	10	24	
a1022	08:05	20:10	5	10	--	
a1023	08:13	20:15	5	10	--	50
a1024	08:20	20:20	5	10	26	
a1025	08:30	20:35	10	10	25	
a1026	08:35	20:40	10	10	24	
a1027	08:38	20:45	10	10	25	100
a1028	08:42	20:50	10	10	25	

Table 9. Post-treatment ovulation times for American shad injected with HCG (500 IU/lb) followed by salmon pituitary extract (1.5 mg/lb) at 15 - 19°C.

Fish ID	Injection time 1st May 22	Injection time 2nd May 23	Time from 1st injection to ovulation (h)	Percent ovulation
HCGSP1	17:00	(died at 17:10, May 22)		
HCGSP2	17:07	19:00	--	
HCGSP3	17:11	19:05	61	50
HCGSP4	17:15	19:10	54	
HCGSP5	17:20	19:14	--	

Table 10. Post-treatment ovulation times for American shad injected with HCG (500 IU/lb) followed by LHRHa (10 $\mu g/lb$) at 15 - 19°C.

Fish ID	Injection time 1st May 22	Injection time 2nd May 23	Time from 1st injection to ovulation (h)	Percent ovulation
HCGLRHa1	17:42	18:35	--	
HCGLRHa2	17:45	18:39	66	
HCGLRHa3	17:49	18:42	66	50
HCGLRHa4	17:58	18:45	--	
HCGLRHa5[1]	17:20	---	--	

[1] Fish died immediately after 1st injection.

Table 11. Post-treatment ovulation times for American shad twice injected with salmon pituitary extract (2 mg/lb) at 17 - 21°C.

Fish ID	Injection time 1st May 29	Injection time 2nd May 30	Time from 1st injection to ovulation (h)	Percent ovulation
SP1	19:30	20:00	51	
SP2	19:33	20:04	--	
SP3	19:37	20:09	--	40
SP4	19:43	20:15	50	
SP5	19:46	20:19	--	

Table 12. Post-treatment ovulation times for American shad twice injected with LHRH (0.5 mg/lb) at 17 - 21°C.

	Injection time			
	1st	2nd	Time from 1st injection to	Percent
Fish ID	May 29	May 30	ovulation (h)	ovulation
SP1	19:00	19:30	--	
SP2	19:04	19:34	31	
SP3	19:10	19:40	31	60
SP4	19:14	19:45	--	
SP5	19:20	19:49	48	

Table 13. Size of shipment, hatch rate, and larval survival of fertilized eggs shipped to VanDyke Hatchery as a result of induced spawning of American shad.

Shipment no.	Date	No. eggs	Hatch rate (%)	Survival of hatch to day 20 (%)
1	24 May 90	28,300	0	
2	25 May 90	80,900	0	
3	01 June 90	48,800	7	unknown
4	01 June 90	59,200	0	
5	13 June 90	110,000	25	96

JOB V, TASK 2

EVALUATION OF STROBE LIGHTS FOR FISH DIVERSION AT YORK HAVEN HYDROELECTRIC PLANT - 1990

Stone & Webster Environmental Services
Boston, Massachusetts

INTRODUCTION

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

On the basis of the excellent results obtained with strobe lights, a large-scale study was planned for 1989 in which strobe lights would be placed in front of Units 1 through 6. These are the units which are most likely to be operated during the fall shad outmigration period. The intent of this study was to determine whether a complete strobe light system could effectively eliminate turbine passage at the York Haven site. A strobe system was installed in the fall and was fully operational when the shad began to arrive in early October. Unfortunately, heavy rains and unit outages early in the testing caused the fish to pass over the dam, thereby severely limiting the ability to evaluate the strobe system. During the first few days of testing, sufficient shad were in the study area to determine that the strobe lights did, in fact, repel the fish. However, the number of fish available for evaluation declined quickly over several days and it was not possible to complete testing.

In order to complete the study begun in 1989, the strobe light system was reinstalled in 1990. The scope of work for this effort was similar to that in 1989, as described in the following discussion.

PURPOSE

The purpose of the 1990 study program was to provide a full-scale demonstration of the effectiveness of the strobe light system in guiding downstream migrating juvenile American shad past the turbine intakes to a trash sluice bypass at York Haven. To demonstrate the effectiveness of the system, both underwater sonar and net sampling near the trash racks were conducted. The continuously-operating scanning sonar was used to yield the primary data on system effectiveness. Periodic netting was used to determine the passage of fish through the turbine intake relative to the sluice gate.

MATERIALS AND METHODS

Description of Strobe Light System

The strobe light test system is shown on Figure 1. The system consists of six, interconnected floats which are anchored immediately upstream of Units 1 through 6. The floats are constructed of wood and foam ballast. The strobe lights are deployed on metal poles which are suspended from the downstream side of the floats. Each pole supports two lights; the lights are located 3 ft and 9 ft, respectively, below the water surface. The poles are spaced at 12 ft intervals. When deployed, the light flashheads on floats 3 through 6 are pointed in an upstream direction. The spacing was selected based on the beam spread of the lights and is designed to create a continuous "wall" of light across Units 2 through 6.

The floats closest to Unit 1 (floats 1 and 2) are oriented differently, as shown on Figure 1. These floats support strobe lights that are angled to flash toward the sluiceway gate. In addition, a separate, moveable float supporting a single pole with two lights is located between float 1 and the powerhouse cableway.

The strobe light system is configured as two arrays: the lights on floats 3 through 6 are operated together and are sequenced by one controller; the lights on floats 1 and 2 and the moveable float operate together on a different controller. The design concept allows the strobes in front of Units 2 through 6 to operate continuously such that shad are repelled from this area and move downstream to the area in front of Unit 1 near the sluiceway gate. This area is kept dark most of the time to allow fish to accumulate. On a periodic basis (interval to be determined based on early test results), the sluiceway gate can be opened and the strobes on floats 1 and 2 and the moveable float are activated to repel fish through the sluiceway.

A problem which has been encountered in past studies with the EG&G strobe lights is water leakage into the underwater light housings via the power cable connectors. This problem was largely rectified in 1989 by installing new, heavy duty cable entry seals. However, some lights still experienced leakage. Therefore, a different light manufacturer (Flash Technology, Inc.) was contracted for the 1990 studies to supply an improved light design that was used on an experimental basis. The experimental unit consisted of a four-light array operated by a separate controller. This unit was deployed from one of the upstream floats and evaluated for its technical performance. While a separate unit, the lights were sequenced to flash at the same time as the existing lights.

As in the past, scanning sonar units were used to monitor fish reaction to the strobe light system. In 1990, a net was also used to collect fish that might pass through the trash racks of Unit 1 when the strobe lights in the area were periodically activated. Visual observations of fish response to the lights in 1988 indicated that they form a tight school and pass quickly through the sluiceway gate when the lights are turned on. It is possible that some fish, particularly those that are deeper in the water column and cannot be seen, are frightened through the trash racks. Past attempts have not been made to quantify the degree to which turbine passage might occur. Therefore, in 1990, a moveable trammel net was fabricated and placed at different locations in front of the trash racks to collect fish. The scanning sonar and net systems are described individually below.

Scanning Sonar

As in the 1989 study, two WESMAR Model SS390 scanning sonar systems were used to monitor fish behavior and response to the strobe lights. Each system included a sonar control console, a soundome and preamplifier with connecting cables, a time lapse video recorder, a color video monitor and a power supply. One unit was deployed from float 1 (range set at 50 ft) to monitor fish in the area of Unit 1 and the sluiceway, particularly at the times when the gate was opened and the strobe lights were activated. The second unit was deployed in front of Unit 4 (set at a range of 150 ft) to monitor fish as they entered the forebay area and approached the strobe light system. The ranges, gains and transducer angles on the units was set to achieve optimal detection and coverage of the fish. The systems were calibrated using fixed targets with known backscattering characteristics.

The sonar units were set up to sector-scan in order to optimize the rate at which data was obtained. The two units combined provided complete coverage of the test area. Data was recorded by the time lapse VCRs in VHS format. The VCRs provided date and time information on-screen which was also recorded. This approach permitted paired tapes (ie., one tape from each unit) to be reviewed simultaneously at a later date.

Netting

In order to better quantify the possible passage of fish through the trash racks and turbines at York Haven, a netting program was implemented in 1990. The net frame was constructed of aluminum and measured 6 ft deep and 10 ft wide. The net was securely fastened within the frame. The net was supported by adjustable bouys that were set to allow the net to fish at surface, mid-depth and bottom locations. The net was manually placed into the water for each test and was positioned via a series of lines and snatch blocks. This arrangement also permitted the net to be positioned directly in front of the sluice gate.

The net was used primarily to collect fish that might have been repelled toward the trash racks when the strobe lights near Unit 1 were activated. Since response to the strobes is nearly instantaneous, the net was partially retrieved shortly after the downstream strobes were activated. This procedure minimized the potential loss of fish and prevented excessive wear on the net in the relatively high velocity zone near the racks.

The net collection process was repeated numerous times at different times of day and at different depths such that all depths were sampled repeatedly.

SAMPLING DESIGN

A simple cross-over design blocked within each 24 hour sampling period (testing day) was used to evaluate the effectiveness of the the strobe array. Past studies have shown that, except during the peak outmigration period, daily passage rates can be highly variable. Therefore, blocking by date helps to control for this effect.
Testing within each sample day consisted of running sequential control and test conditions from around dusk to as late as 3 AM, depending on fish availability. The order of testing varied from night to night but included the following conditions:

o CONTROL: all lights OFF; sluice gate closed

o UPSTREAM LIGHTS ON: strobe lights on floats 3 through 6 activated; downstream lights OFF; sluice gate closed

o UPSTREAM AND DOWNSTREAM LIGHTS ON: net in fishing position and sluice gate open.

The sequence of strobe light testing consisted of operating the separate upstream lights (floats 3-6) for approximately 25 minutes. Most tests were conducted at a flash rate of 300 flashes per minute.

For each test, the downstream sonar unit was set at one of several transducer angles. All shad collected in the trammel net were counted and returned to the river below the dam.

SUPPLEMENTAL SAMPLING

In order to document the lighting and hydraulic conditions to which fish are exposed, two supplemental sampling efforts were undertaken. First, a complete mapping of the light field upstream of the float system and in the sluiceway gate area was recorded periodically using a Li-Cor photometer. The frequency of sampling was based on changing turbidity conditions. Turbidity was monitored qualitatively on a daily basis using a Secchi disc and photometric measurements.

Velocity measurements were recorded on a periodic basis using a Swoffer propellor meter. Measurements were taken along the front of the float assembly, at several transects upstream, and in the area of the sluiceway gate. Measurements were repeated periodically to collect a complete data set at all plant operating conditions that occurred over the duration of the study period.

RESULTS

The biological field evaluation began September 25 and continued until October 21. One scanning sonar unit was deployed in mid-September to monitor the forebay area for fish occurrence. Hydroacoustic data was recorded by the time lapse recorder. In 1988 and 1989, the fish arrived during the first week in October. In 1990, the fish arrived nearly two weeks earlier, and the field sampling crew was sent to the site to begin sampling the afternoon of September 26. At this time, the water temperature was 17 °C and the shad did not appear to be actively migrating. Temperatures throughout most of the study remained above 16 °C (Figure 2). Unlike the previous years, fish were observed in the forebay during the day as well as at night and were deeper in the water column (greater than 6 feet). The scanning sonar observations showed that shad were "milling" in the forebay in a wide area upstream of the bar racks. In previous years, the sonar showed the shad in tight, active schools immediately in front of the trash racks. It is surmised from the observed behavior that the shad were using the forebay as a residence area prior to beginning their downstream migration.

Over the 26 day sampling period, 117 tests were run (Table 1). The trammel net was used in 66 of these tests at surface, mid-depth and bottom locations immediateley upstream of Unit 1. The response of the fish to the strobe lights in 1990 was the same as that observed in 1988. However, while total avoidance of the strobes was observed in all tests, the fish were not observed passing out through the sluiceway gate in very large numbers as they did in 1988. This lack of downstream movement is probably attributable to the fact that the shad were not actively migrating and avoided the accelerating flow field in the area of the gate.

In almost all tests, groups of fish from about 5 individuals to over many hundred were observed to pass through the gate. However, these fish were oriented upstream and appeared to be swimming at burst speed in an attempt to move upstream. This behavior is very different from that observed in 1988 when masses of fish moved head first downstream through the gate when the downstream strobe lights were activated. Nonetheless, the strobe lights were highly effective in moving fish out of the lighted area. Further, trammel net data and scanning sonar observations indicated that the predominant movement of shad was upstream. The number of fish collected in the net ranged from zero to 58; most of the samples had no fish or a few fish. A total of 306 fish were collected in 66 samples. By comparison, hundreds of fish were observed passing through the sluice gate in many of the tests.

A final review and analysis of the data has not been completed. However, the review to date indicates that the strobe lights continue to create a strong avoidance response in juvenile shad whether or not they are in a migratory mode. It had been hoped that testing would continue long enough into the fall migration period to verify 1988 results and demonstrate that most fish do not pass through the trash racks when the lights are activated. Unfortunately, several unseasonably severe floods occurred over a short period of time before the active outmigration had begun. Prior to the flooding water turbidity was low and the range of the strobe light effect was at a maximum (Figure 3). However, during and immediately following the flooding, turbidity was high and the effectiveness of the strobes was greatly reduced. After the flood flows subsided, few fish were remaining and the study was ended after several additional nights of monitoring for fish with the scanning sonar units.

The results obtained are very encouraging. It is anticipated that additional testing in the future will demonstrate more completely that the strobe lights do not repel fish through the racks. With this final question answered, strobe lights should become an acceptable and cost-effective means of preventing turbine passage at York Haven and other sites.

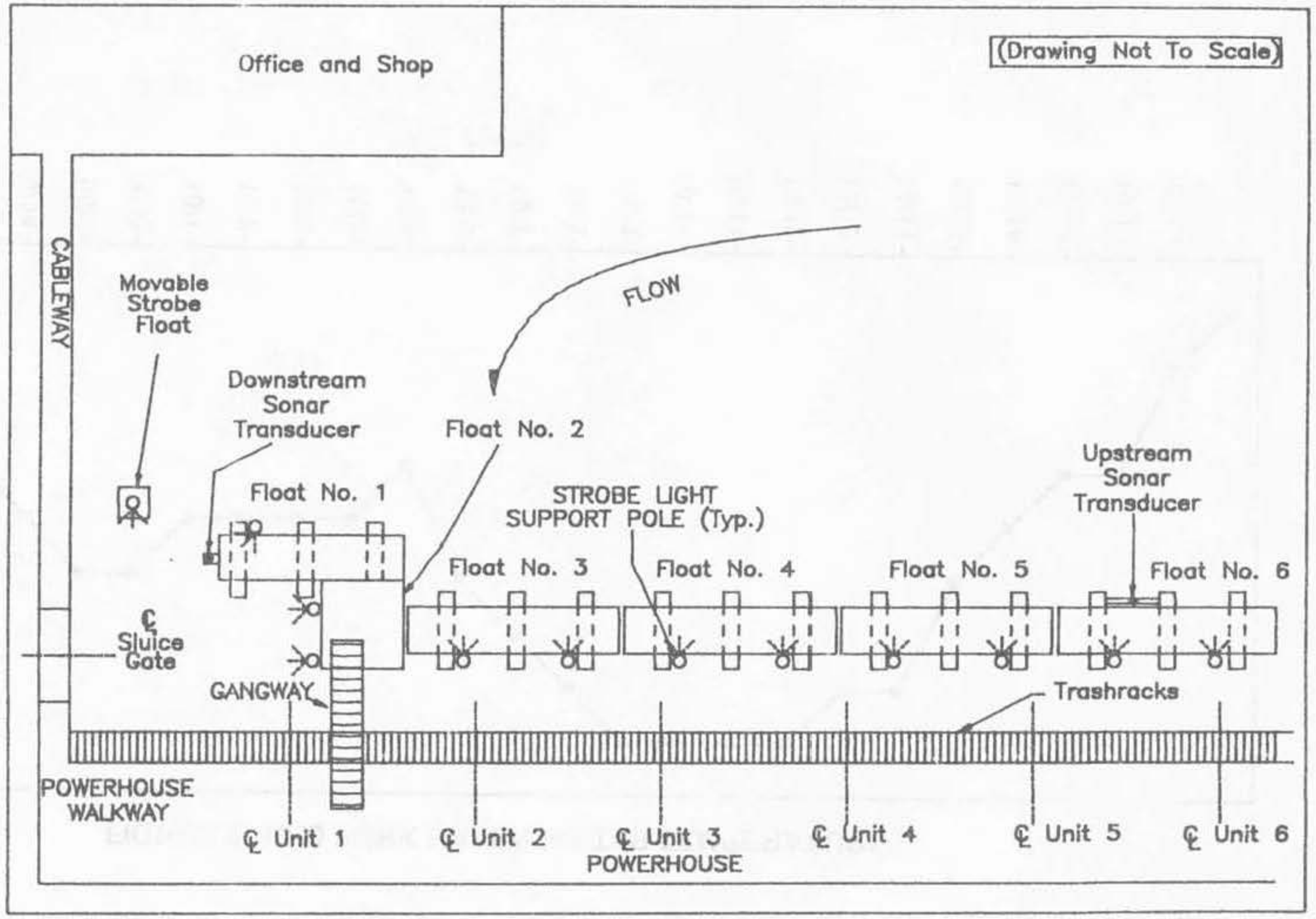

FIGURE 1
York Haven
Forebay and Float Positions

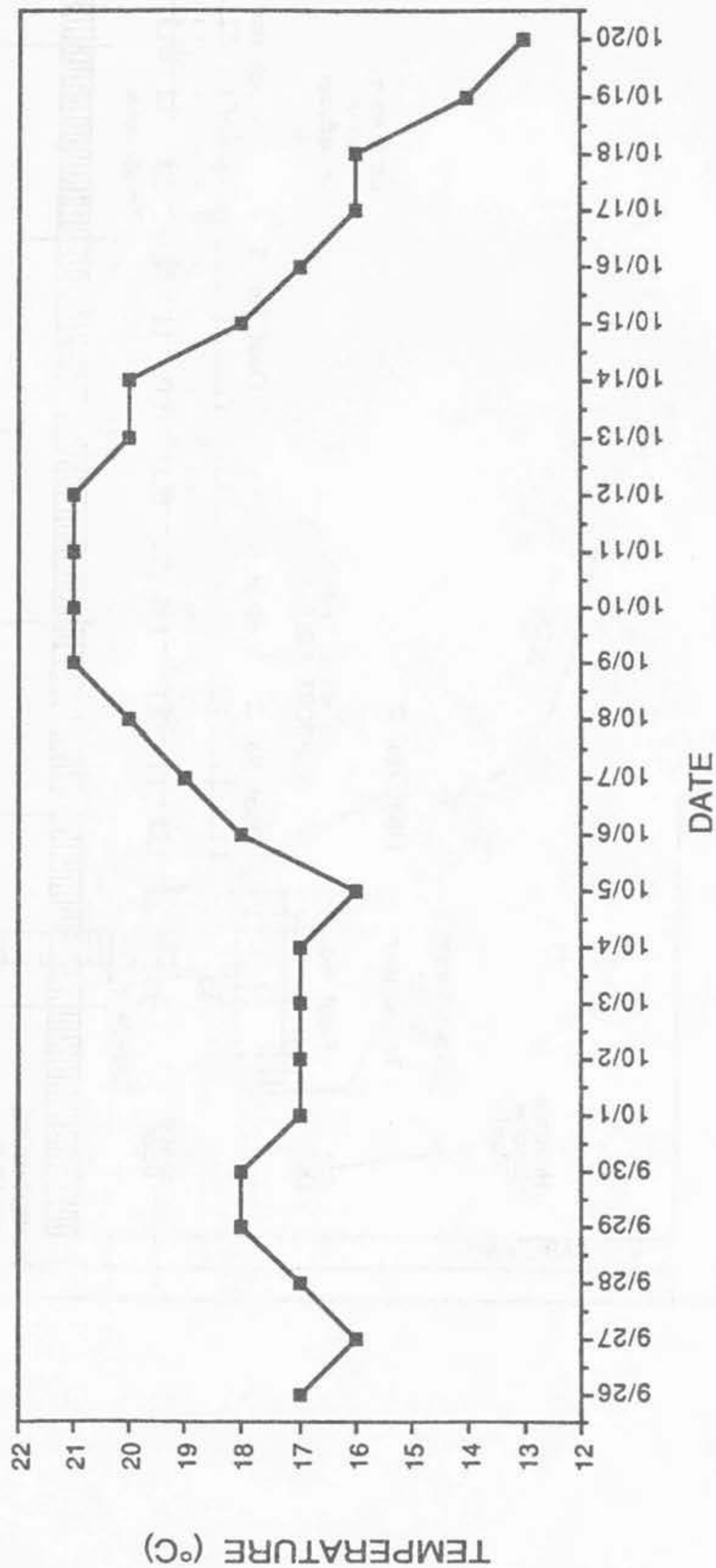

FIGURE 2: 1990 YORK HAVEN WATER TEMPERATURE

FIGURE 3: LIGHT INTENSITIES UNDER LOW AND HIGH WATER CONDITIONS AT THE SLUICEGATE

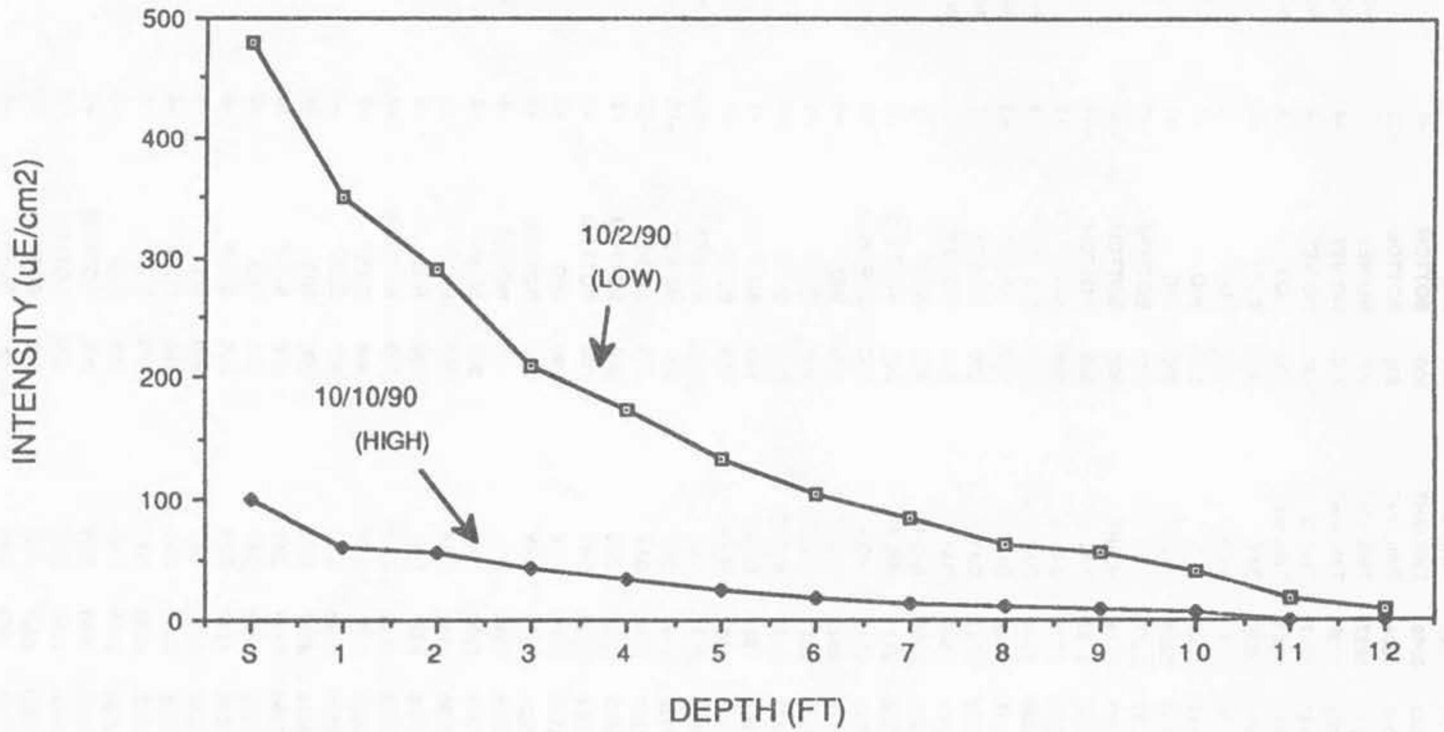

TABLE 1 1990 TEST RESULTS

DATE	TEST #	TIME START	TIME STOP	STROBE INTENSITY	FLASH RATE	LOCATION OF NET	SONAR ANGLE	NO. OF FISH NETTED	NO. OF FISH OBSERVED
9/26/90	1	1932	2042	DAY	300	NO NET	*	NO NET	*
	2	2140	2248	DAY	300	SURF	-2 TO -20	26	0
	3	2350	0104	DAY	300	SURF	*	17	0
9/27/90	4	1905	2045	TWILIGHT	300	NO NET	-10	NO NET	100
	5	*	2111	TWILIGHT	300	SURF	-8	2	30
	6	2119	2230	TWILIGHT	300	MID	-6	6	*
	7	2235	2345	TWILIGHT	300	MID	-4	17	50
	8	2343	0059	TWILIGHT	300	BOTTOM	-2	4	75
	9	0059	0209	TWILIGHT	300	BOTTOM	-12	4	75
9/28/90	10	1915	2027	TWILIGHT	200	NO NET	-4	NO NET	30
	11	2027	2137	TWILIGHT	200	NO NET	-4	NO NET	*
	12	2137	2247	TWILIGHT	150	NO NET	-4	NO NET	10
	13	2247	2357	TWILIGHT	100	NO NET	-4	NO NET	*
9/29/90	14	1930	2035	DAY	300	SURF	-2	4	30
	15	2035	2141	NIGHT	300	SURF	-2	NO NET	30
	16	2141	2249	DAY	300	MID	-4	NO NET	30
	17	2250	2355	NIGHT	300	MID	-4	NO NET	50
9/30/90	18	1937	2037	DAY	300	BOTTOM	-8	6	20
	19	2037	2145	NIGHT	300	BOTTOM	-8	2	20
	20	2146	2257	DAY	300	BOTTOM	-12	6	75
	21	2300	0005	DAY	300	SURF	-12	0	50
10/1/90	22	1930	2036	DAY	100	NO NET	-3	NO NET	0
	23	2037	2136	DAY	150	NO NET	-3	NO NET	0
	24	2136	2241	DAY	200	NO NET	-3	NO NET	20
	25	2241	2346	DAY	300	NO NET	-3	NO NET	50
10/02/90	26	1900	2006	NIGHT	300	SURF	-8	9	100
	27	2006	2111	NIGHT	200	SURFACE	-8	4	100
	28	2111	2216	NIGHT	150	SURFACE	-8	1	100
	29	2216	2321	NIGHT	100	MID	-8	2	50
	30	2321	0027	NIGHT	300	SURF	-1	4	*
	31	0027	0132	NIGHT	200	SURF	-1	4	*
10/3/90	32	1900	1921	NIGHT	150	SURF	-1	3	5
	33	1921	2027	NIGHT	100	SURF	-1	4	10
	34	2026	2031	DAY	300	NO NET	-10	NO NET	10
	35	2032	2237	DAY	200	NO NET	-10	NO NET	50
	36	2237	2342	DAY	150	NO NET	-10	NO NET	25
10/04/90	37	1915	2024	DAY	300	BOTTOM	-8	58	100
	38	2024	2105	DAY	300	BOTTOM	+2	30	200
	39	2110	2146	DAY	200	MID	+2	9	0
	40	2221	2315	DAY	300	BOTTOM	+2	9	200
10/05/90	41	0016	0044	*	*	NO NET	-8	NO NET	75
	42	1915	2050	DAY	300	SURF	-8	28	100
	43	2050	2152	DAY	300	MID	+0	0	200
	44	2152	2321	DAY	300	MID	-4	2	200
	45	2323	0022	DAY	300	BOTTOM	-4	2	200
10/06/90	46	0021	0055	DAY	300	SURF	+0	2	150
	47	1930	2006	DAY	300	SURF	-4	0	100
	48	2010	2047	DAY	300	MID	-8	2	200
	49	2050	2125	DAY	300	SURF	+0	3	50
	50	2130	2205	DAY	300	MID	-4	*	125
	51	2205	2240	DAY	300	SURF	-8	0	100
	52	2245	2320	DAY	300	MID	-8	1	100
	53	2325	0000	DAY	300	SURF	-4	*	70
10/7/90	54	1955	2030	DAY	300	MID	-8	1	75
	55	2035	2110	DAY	300	MID	+0	*	75
	56	2115	2151	DAY	300	BOTTOM	+0	3	100
	57	2156	2230	DAY	300	BOTTOM	-4	3	100
	58	2235	2327	DAY	300	BOTTOM	+0	0	5
	59	2330	0007	DAY	300	SURF	-8	1	75

* INFORMATION NOT RECORDED

TABLE 1 CONTINUED

DATE	TEST #	TIME START	TIME STOP	STROBE INTENSITY	FLASH RATE	LOCATION OF NET	SONAR ANGLE	NO. OF FISH NETTED	NO. OF FISH OBSERVED
10/8/90	60	2145	2220	DAY	300	NO NET	+0	NO NET	150
	61	2245	2320	DAY	300	SURF	−8	1	150
	62	2325	0001	DAY	300	SURF	−4	1	150
10/9/90	63	1905	1940	DAY	300	NO NET	−4	NO NET	0
	64	1940	2015	DAY	300	NO NET	−8	NO NET	0
	65	2025	2100	DAY	300	NO NET	+0	NO NET	125
	66	2100	2135	DAY	300	NO NET	−4	NO NET	150
	67	2140	2316	DAY	300	NO NET	−4	NO NET	125
	68	2220	2316	DAY	300	NO NET	−8	NO NET	230
	69	2320	2356	DAY	300	NO NET	+0	NO NET	100
	70	2356	0031	DAY	300	NO NET	+0	NO NET	2
10/10/90	71	1900	1940	DAY	200	NO NET	+0	NO NET	0
	72	1945	2021	DAY	200	NO NET	−8	NO NET	25
	73	2025	2101	DAY	200	NO NET	−4	NO NET	50
	74	2105	2141	DAY	200	NO NET	−8	NO NET	30
	75	2145	2221	DAY	200	NO NET	+0	NO NET	40
	76	2225	2315	DAY	200	NO NET	−4	NO NET	70
	77	2320	2324	DAY	200	NO NET	−8	NO NET	40
10/11/90	78	0000	0037	DAY	300	NO NET	0	NO NET	150
	79	1955	2030	DAY	300	SURF	+0	9	*
	80	2040	2118	DAY	300	NO NET	−4	NO NET	150
	81	2120	2156	DAY	300	SURF	−8	14	0
	82	2200	2236	DAY	300	NO NET	+0	NO NET	75
	83	2240	2319	DAY	300	SURF	−4	1	1
	84	2325	0000	DAY	300	NO NET	−8	NO NET	20
10/12/90	85	0005	0042	DAY	300	SURF	+0	0	0
	86	1850	1926	DAY	300	NO NET	−8	NO NET	0
	87	1940	2016	DAY	300	NO NET	−4	NO NET	5
	88	2020	2055	DAY	300	NO NET	+0	NO NET	60
	89	2100	2135	DAY	300	SURF	−8	0	0
	90	2145	2220	DAY	300	SURF	−4	0	0
	91	2225	2306	DAY	300	SURF	+0	0	0
	92	2320	2355	DAY	300	NO NET	−8	NO NET	200
	93	0000	0035	DAY	300	NO NET	−4	NO NET	5
	94	0040	0115	DAY	300	NO NET	+0	NO NET	100
10/13/90	95	1845	1927	DAY	300	NO NET	−2	NO NET	*
	96	1930	2011	DAY	300	NO NET	−4	NO NET	*
	97	2015	2050	DAY	300	NO NET	−8	NO NET	*
	98	2050	2130	DAY	300	NO NET	−4	NO NET	*
	99	2130	2206	DAY	300	NO NET	−2	NO NET	*
	100	2210	2245	DAY	300	NO NET	−8	NO NET	*
	101	2246	2320	DAY	300	NO NET	−4	NO NET	*
	102	2320	2357	DAY	300	NO NET	−2	NO NET	*
10/14/90	NO FISHING DUE TO HIGH WATER CONDITIONS								
10/15/90	103	2015	2050	DAY	300	NO NET	+0	NO NET	0
	104	2055	2139	DAY	300	SURF	−4	0	0
	105	2140	2211	DAY	300	NO NET	−8	NO NET	0
	106	2215	2250	DAY	300	SURF	+0	0	0
	107	2025	2103	DAY	300	SURF	+0	0	0
10/16/90	NO FISHING DUE TO DEBRIS.								
10/17/90	108	2110	2220	DAY	300	SURF	−4	*	*
10/18/90	NO FISHING DUE TO MALFUNCTIONING LIGHTS, DEBRIS, HEAVY WINDS								
10/19/90	NO FISHING DUE TO LACK OF FISH								
10/20/90	109	1935	2023	DAY	300	NO NET	+0	NO NET	0
	110	2025	2100	DAY	300	SURF	−4	0	0
	111	2105	2140	DAY	300	MID	−8	0	0
	112	2145	2220	DAY	300	BOTTOM	−2	0	0
	113	2225	2303	DAY	300	SURF	−2	0	0
10/21/90	114	1845	1920	DAY	300	SURF	−2	1	0
	115	1925	2000	DAY	300	SURF	+0	0	0
	116	2005	2040	DAY	300	SURF	−4	0	0
	117	2045	2120	DAY	300	SURF	−4	0	0

* INFORMATION NOT RECORDED

JOB V, TASK 3. PRELIMINARY EVALUATION OF THE LOG CHUTE AT HOLTWOOD HYDROELECTRIC STATION AS A DOWNSTREAM PASSAGE ROUTE AND EFFECTS OF THE STEAM STATION THERMAL DISCHARGE ON EMIGRATING JUVENILE AMERICAN SHAD

By

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INTRODUCTION

Efficient passage of emigrating juvenile American shad past hydroelectric plants is a precursor to the successful re-establishment of a self-sustaining population in the Susquehanna River. Preliminary studies were conducted for the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) at Holtwood Hydroelectric Station to evaluate the potential of the log chute at the eastern most portion of the dam as a fish passage route. Utilization of the chute by radio tagged juvenile shad was investigated during three station operating scenarios. In addition, a preliminary investigation on effects of passage through the chute on juvenile shad was conducted.

Also, a thermal profile investigation was conducted in the forebay of Holtwood Dam to evaluate the effects of the steam station discharge on juvenile shad emigration. Water temperatures were monitored extensively in the inner forebay in conjunction with routine lift net sampling to correlate shad catches with water temperature.

MATERIALS AND METHODS

Log Chute Evaluation

Juvenile American shad captured by lift net in Holtwood's inner forebay were externally radio tagged and released at the floating boat dock (Figure 1) just upstream of the forebay proper under three station operating conditions: log chute open for 12 hr with no generation, log chute open for 72 hr with normal generation and log chute open with normal generation and spill. Specimens were released between 1700 and 1800 hr.

Each specimen was externally tagged with a specially prepared miniature radio transmitter. Transmitters, supplied by Lotek Engineering, Inc., were encapsulated in 000 gelatin capsules, then immersed in liquid foam. After hardening (24 hr) foam was shaved off until the transmitter package was semi-buoyant. Prepared transmitters averaged 30 mm in length and 12 mm in diameter. Each tag incorporated a 40 mm length of 10-lb test monofilament tied to a #6 fish hook. Specimens were tagged without anesthesia by inserting the fish hook through the musculature just posterior to the dorsal fin. Prior to tagging test fish, three shad were tagged as controls and observed for 4-24 hr.

Transmitters propagated signals between 150.315 and 151.994 MHz through 280 mm thin wire whip antennas. Tags of the same or near same frequency were pulsed at different rates to ensure identification of each individual. Expected life of transmitters was 5 days.

Remote monitoring stations were deployed at the log chute and on the retaining wall near Piney Island (Figure 1). One Lotek SRX_400 receiver data logger was installed and calibrated at each station. The log chute was monitored with a 12 gauge stranded single lead wire antenna suspended above water level the entire length of the chute. The receiver was configured to scan at a high rate (1 frequency every 0.8 sec) to ensure detection of tagged shad which entered and passed down the chute. The downstream monitor station near Piney Island utilized two 4-element YAGI antennas connected serially to receive signals of tagged shad in the tailrace and spill areas. This receiver scanned at a rate of 1 frequency every 3 seconds. Since the primary objective of the study was to identify the proportion of tagged shad which utilized the log chute for downstream passage, interpretation of data follows the rationale that tagged specimens recorded on the log chute and downstream monitors passed by the chute. Individuals recorded on the downstream monitor only, passed by other routes.

Manual tracking was conducted periodically in addition to remote continuous monitoring. After tagged specimens were released, their movements were monitored for a minimum of 2 hr. The forebay, tailrace, spill and release site areas were monitored daily to keep track of specimens which had not passed the station and to supplement continuous monitoring data.

Injury and mortality to shad which passed down the log chute was investigated with the HI-Z Turb'N Tag and recovery technique (RMC 1990). Specimens were tagged with a Turb'N Tag and miniature radio transmitter, observed for a few minutes then lowered by bucket to an area just upstream of the open chute. Shad were released into the flow and after passage, the chute was closed. An inflatable raft was used within the spill area to recover fish. After specimen recovery, tags were removed, condition of fish was assessed and shad were transported to a holding facility. Mortality was enumerated after 4 and 24 hr of passage.

Controls were tagged and handled in the same manner as test fish.

Thermal Monitoring

A temperature monitoring station was installed on the floating trash boom at the inner forebay. Two Micro Temp thermographs were deployed approximately midway along the boom by suspending one near the surface and one at a 10 ft depth. They were attached to a weighted 3/16" plastic coated stainless steel cable suspended from the boom. Temperature was logged every 15 minutes from 1 October to 30 November.

A temperature profile of the entire forebay was conducted during a period of hydrostation shutdown and steam station operation. Transects were established by measuring and marking 75 ft intervals along the headworks of the hydro station (Figure 2). A boat crew in the forebay then moved perpendicularly away from the marked intervals and measured temperatures every 75 ft. A calibrated Ranging Opti Meter 620 range finder was used to determine perpendicular distances from the station headworks. Temperatures were measured at each transect station at the surface, 5 ft, 10 ft, and in 10 ft intervals thereafter to the bottom. Only surface temperature was measured at shoreline stations. Ambient river temperatures were measured approximately 30 ft upstream of the log chute at the same depth intervals as in the forebay. All temperatures were measured with a Yellow Springs Instrument Model 57 Dissolved Oxygen meter calibrated with a NIST traceable thermometer.

RESULTS AND DISCUSSION

Log Chute Evaluation

A total of 10 juvenile American shad was radio tagged and released during each of three test conditions. Specimens were approximately 110 to 125 mm fork length.

Initial movement of shad released during the first test condition (log chute open-no generation) was primarily across the river (Table 1). There was no appreciable current at the release site. Two each moved downstream and upstream upon release. Signals were lost on two initially; they must have rapidly moved deep in the water column. Eventually, three shad were logged on the log chute monitor; two became stationary at the bottom of the chute. The third was logged on the downstream monitor indicating that it had moved or been swept downstream. Two shad, which initially moved across the river were never located again after release. They may have moved upstream or deep in the water column. Manual surveillance identified two stationary signals, one in the middle of the forebay and one near the log boom inside the forebay. Two signals were also detected in the tailrace near the discharge draft tubes. The fate of individuals associated with these stationary signals is unknown. Transmitters may have detached during passage or specimens may have died.

The second lot of 10 shad was tagged and released during a period of log chute open for 72 hr and normal hydrostation operation. Most specimens initially moved downstream after release (Table 1). Ambient current at the release site appeared to be 0.5 fps. The known direction of three shad was across river. The signals of three others could not be detected shortly after release. Of these, one apparently moved deep into the forebay and passed through turbines quickly. It was logged on the downstream monitor

13 min after release. One signal was located at the bottom of the log chute approximately 40 min from release. The log chute monitor indicated it had passed through the chute 29 min after release. Three individuals were last located in the inner forebay, the forebay proper and far upstream of the dam.

During the release of the final lot of 10 shad, ambient current at the release site was substantially greater than that for the second lot. River flow was 113,100 cfs with 91,700 cfs of spill. Consequently, only five signals could be detected shortly after release and all had moved downstream. No tagged shad utilized the log chute for passage. Four shad passed through turbines, three over the spillway and three specimens were unaccounted for.

Overall, 13.3% of the shad released, utilized the log chute for passage (Table 2). During the period when it was the only available route, three shad passed it in a mean time of 8 hr 40 min from release. In contrast, the one shad which passed by this route when the station was generating, did so in 29 min.

Shad which passed through turbines (30.0%) did so in a mean time of 38 hr 6 min from release. This value is inflated since all but four elapsed times were estimates and reflected the times the individuals were located manually. These manually located shad were in the tailrace near the draft discharge tubes and were not logged on the downstream monitor (which monitored the area approximately 150 ft downstream of the station).

The spillway passed 30% of the individuals offered three passage routes. Passage times ranged from 17 min to 36 hr. During this test condition, 40% utilized turbines for passage.

In total, 10 tagged juvenile shad (33.3%) were unaccounted for. Although the ultimate fate of these shad is unknown, they did not pass via the log chute during the study period. Barring transmitter failure, it was virtually impossible for a tagged shad to pass this route undetected. Therefore, these shad most likely used another passage route.

A total of 10 juvenile shad was passed down the log chute in 2 lots of 5 each to evaluate passage mortality. Specimens ranged from 110 to 120 mm FL (Table 3). After passage, all but one was recovered; only the Turb'N Tag and transmitter were recovered. Overall immediate mortality numbered one, but all specimens exhibited substantial descaling. During recovery of the second lot of fish passed, one from the first lot jumped out of the holding cooler and was lost. Of the remaining eight specimens, all but one was dead after 4 hr from passage. The following day, it was dead. Approximate descaling of test specimens ranged from 40 to 75%.

Five controls were tagged using the same procedure as test specimens. After 24 hr, all were alive and active. Eleven non-tagged controls (handled and transported with test and tagged controls) were also healthy after 24 hr.

Temperature Monitoring

Mean daily temperatures are presented in Tables 4 and 5. Overall, surface temperatures ranged from 26.8 C (12 Oct) to 5.3 C (21 Nov). Temperatures at a 10 ft depth varied from 25.2 C (11 Oct) to 5.2 C (21 Nov). The daily ranges in temperature were pronounced during periods of hydrostation shutdown and generally exceeded 6 C for the surface and 4 C for the 10 ft depth. The minimum temperature values on Tables 4 and 5 are considered river ambient; differences in temperatures logged on the Brown recorder at Holtwood Station varied, at most, by only 0.2 C.

The steam station effluent increased the ambient temperature by up to 6.7 C near the surface and 5.4 C at a depth of 10 ft. However, the ΔT values (difference between ambient and affected location) were variable and related to hydrostation generation. At periods of no generation, ΔT was generally 6 C. Once turbines began operating, temperatures reached ambient levels within 15 min. Conversely, after turbines were shutdown, ambient temperatures rose to maximum ΔT values in one to two hours.

The steam station discharge appears to affect the entire forebay area during hydro turbine shutdowns. The thermal profile of the forebay proper taken on 6 October indicated that the entire forebay was influenced and temperatures were greater than ambient river temperatures (Table 6). The hydrostation had been shutdown 11 hr prior to the survey; only exciter units were operating at an intake rate of 4 cfs. Stratification was generally uniform throughout the forebay. Surface temperatures were an average 5.3 C higher than ambient; average temperature at a 5 ft depth was 5.5 C greater than ambient (Table 7). Temperatures generally approached ambient at depths greater than 10 ft.

The source of heated water was the steam station discharge. Temperatures in the discharge canal exceeded 30 C (Table 7). The effluent entered the powerhouse at a rate of approximately 98 cfs[1] (Debbie Runkle personal communication) and water not utilized for the exciters diffused through the intake arches of the headworks into the forebay. Diffusion into the forebay was relatively uniform across the headworks except at Station 6 (Figure 2) where the greatest change in temperature ($\Delta T = 7$ C) was observed at the surface (Table 6).

Recirculation of forebay water was evident. Temperatures measured at Stations 1 through 4 indicated less

[1] Based on a discharge rate of 63.5 mgd for 6 October 1990.

stratification (more mixing) suggesting more current in these areas. Temperatures measured in the inner forebay and at the steam station intake (Figure 1) were similar to temperatures at Stations 1, 2 and 3a (Tables 6 and 7).

CONCLUSIONS

The log chute evaluation study was designed to provide a preliminary indication of the feasibility of this route for juvenile shad passage. Based on results, the log chute is not a viable passage route; utilization was limited, even when it was the only available route for passage. In addition, the probability of mortality to those fish which did utilize it is high.

Maximum ΔT was observed in the Holtwood Hydrostation forebay during hydrostation shutdown. Correlation of increased forebay temperatures to abundance of juvenile shad could not be observed since peak abundance occurred during times of increased river flow, and accordingly, hydro generation.

LITERATURE CITED

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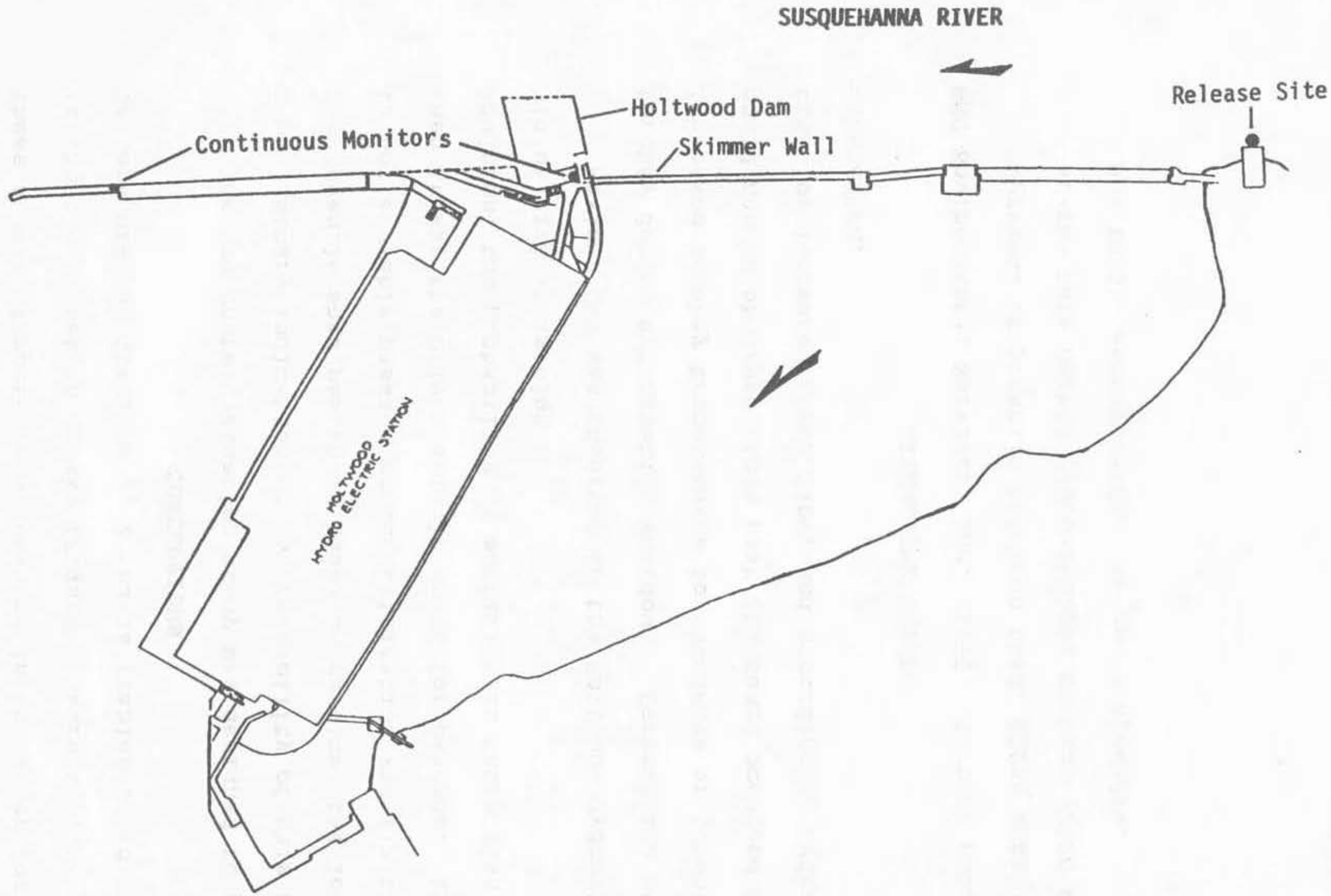

Figure 1

Locations of continuous radiotelemetry monitors and release site, Holtwood Hydroelectric Station, September and October 1990.

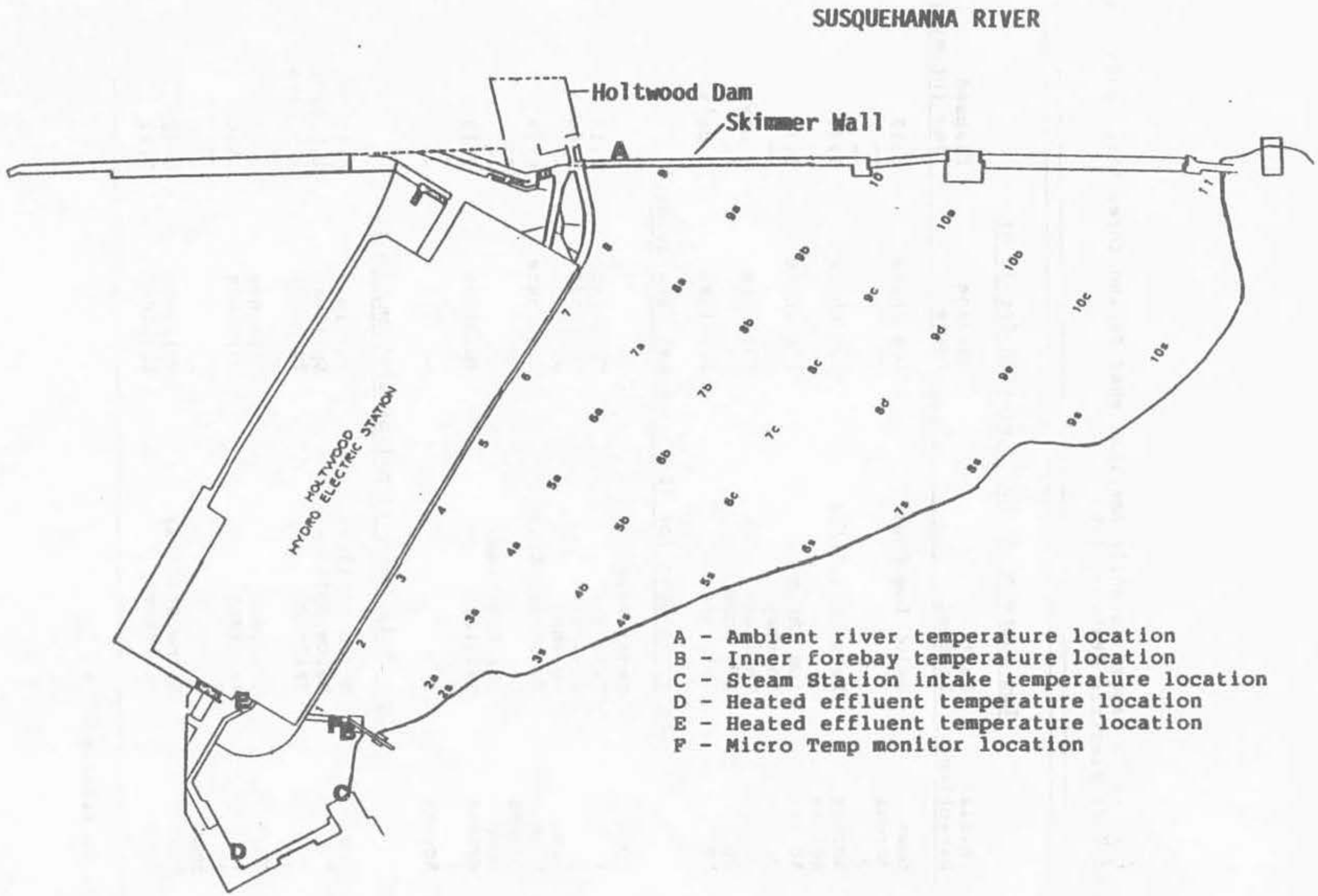

Figure 2

Water temperature profile stations in Holtwood Hydroelectric Station forebay, 6 October 1990.

TABLE 1

Movement of 30 radio tagged juvenile American shad during three test conditions at Holtwood Hydroelectric Station, 1990.

Fish Number	Initial Direction*	Last Located	Passage Route	Elapsed Time (hr:min)
		Log chute open, no generation for 12 hr		
315	Down	Below Log Chute	Log Chute	8:19
353	Across	?	--	--
393	?	?	--	--
411	Across	Below Log Chute	Log Chute	9:42
443	Across	?	--	--
464	Across	Log Chute	Log Chute	8:12
511	Down	Forebay	--	--
844	?	Tailrace	Turbines	7 days
944	Up	Log Boom	--	--
984	Up	Tailrace	Turbines	3 days
		Log chute open for 72 hr, normal generation		
564	Down	Inner Forebay	--	--
352	?	Tailrace	Turbines	0:13
384	?	Tailrace	Turbines	4 days
434	Down	Forebay	--	--
557	Down	Below Log Chute	Log Chute	0:29
924	Across	?	--	--
956	Down	Far Upstream	--	--
974	Across	Tailrace	Turbines	2:12
984	?	?	--	--
994	Across	?	--	--
		Log chute open, normal generation, spill		
317	Down	Below Spillway	Spillway	0:17
563	?	Below Spillway	Spillway	1.5 days
374	?	Tailrace	Turbines	1.5 days
405	?	?	--	--
509	Down	Tailrace	Turbines	1:13
554	?	Tailrace	Turbines	15:00
555	?	?	--	--
954	Down	?	--	--
973	Down	Below Spillway	Spillway	0:55
977	Down	Tailrace	Turbines	0:21

* Relative to release site

TABLE 2

Summary of passage routes utilized by radio tagged juvenile American shad during three test conditions at Holtwood Hydroelectric Station, 1990.

Passage Route	N	Elapsed Time (hr:min)	Mean Time (hr:min)
		Log chute open, no generation for 12 hr	
Log Chute	3	8:19, 9:42, 8:12	8:40
Turbines	2	3 days, 7 days	5 days
None-Stationary *	2	--	--
Unknown	3	--	--
		Log chute open for 72 hr, normal generation	
Log Chute	1	0:29	0:29
Turbines	3	0:13, 2:12, 4 days	1.4 days
None-Stationary *	2	--	--
Unknown	4	--	--
		Log chute open, normal generation, spill	
Log Chute	0	--	--
Turbines	4	1:13, 0:21, 15:00, 36:00	13:09
Spillway	3	0:17, 0:55, 36:00	12:24
Unknown	3	--	--
		Combined	
Log Chute	4	0:29, 8:12, 8:19, 9:42	6:40
Turbines	9	0:13, 0:21, 1:13, 2:12, 15:00, 36:00, 3, 4, 7 days	38:06
Spillway	3	0:17, 0:55, 36:00	12:24
None	4	--	--
Unknown	10	--	--

* Specimens' transmitter signals were stationary above the dam

TABLE 3

Summary of injury and mortality of juvenile American shad passed down the log chute at Holtwood Hydroelectric Station, 12 October 1990.

Fork Length (mm)	Test Fish Immediate	Test Fish 4 hr	Test Fish 24 hr	Approximate Descaling (%)
117	Alive	Dead	--	75
110	Alive	Dead	--	50
120	Alive	Dead	--	60
115	Alive	Dead	--	50
118	Alive	Dead	--	50
115	Dead	--	--	40
113	Alive	Dead	--	50
115	Alive	Alive	Dead	75
*	Alive	--	--	--
**	--	--	--	--
Total Mortality	1	6	1	
	Control Fish			
Tagged	0	0	0	
Non-Tagged	0	0	0	

* Escaped during recovery of second lot of fish

** Only tags were recovered

TABLE 4

Daily mean, range and standard deviations of water temperature readings from the Microtemp monitor at Holtwood Hydroelectric Station forebay, October 1990.

	SURFACE						10 FT DEPTH					
DATE	MEAN	SD	MIN TEMP	MAX TEMP	RANGE		MEAN	SD	MIN TEMP	MAX TEMP	RANGE	
01OCT90	19.9	2.61653	17.9	24.3	6.4	*	18.0	0.23758	17.9	20.2	2.3	*
02OCT90	19.9	2.24493	18.1	24.0	5.9	*	18.3	0.19554	18.1	19.0	0.9	
03OCT90	20.4	2.36977	18.4	24.1	5.7	*	18.6	0.47917	18.4	23.1	4.7	*
04OCT90	20.2	2.42906	18.3	24.5	6.2	*	18.4	0.18257	18.3	19.3	1.0	
05OCT90	20.2	2.36327	18.2	23.7	5.5	*	18.3	0.12354	18.1	18.8	0.7	
06OCT90	21.5	2.61085	18.3	24.5	6.2	*	18.5	0.56020	18.2	23.6	5.4	*
07OCT90	21.9	2.75245	18.5	25.2	6.7	*	18.6	0.48373	18.4	22.9	4.5	*
08OCT90	20.4	2.39065	18.6	25.0	6.4	*	18.8	0.46854	18.5	23.1	4.6	*
09OCT90	20.5	2.33804	18.7	25.2	6.5	*	19.0	0.19371	18.7	20.0	1.3	
10OCT90	22.4	2.73293	19.5	26.1	6.6	*	19.6	0.39247	19.2	22.3	3.1	*
11OCT90	21.8	2.48047	20.0	26.6	6.6	*	20.1	0.53940	19.9	25.2	5.3	*
12OCT90	22.1	2.28012	20.4	26.8	6.4	*	20.5	0.25243	20.3	21.1	0.8	
13OCT90	21.6	0.16527	21.2	21.9	0.7		21.6	0.16583	21.2	21.9	0.7	
14OCT90	20.6	0.96063	18.9	21.8	2.9	*	20.5	0.96197	18.9	21.8	2.9	*
15OCT90	18.0	0.33269	17.7	18.9	1.2		18.0	0.33558	17.6	18.8	1.2	
16OCT90	17.2	0.28069	16.8	17.7	0.9		17.2	0.27395	16.7	17.7	1.0	
17OCT90	16.5	0.19624	16.2	16.8	0.6		16.5	0.17917	16.1	16.7	0.6	
18OCT90	16.3	0.15381	16.1	16.5	0.4		16.3	0.13527	16.1	16.4	0.3	
19OCT90	15.5	0.50959	14.5	16.1	1.6		15.5	0.49974	14.4	16.0	1.6	
20OCT90	13.9	0.31135	13.3	14.5	1.2		13.9	0.30890	13.3	14.4	1.1	
21OCT90	13.3	0.15492	12.9	13.4	0.5		13.2	0.15180	12.8	13.3	0.5	
22OCT90	13.0	0.09583	12.8	13.1	0.3		12.9	0.08450	12.8	13.0	0.2	
23OCT90	13.0	0.09889	12.8	13.1	0.3		13.0	0.10728	12.8	13.1	0.3	
24OCT90	13.2	0.19682	12.9	13.4	0.5		13.1	0.19761	12.8	13.4	0.6	
25OCT90	13.3	0.08205	13.1	13.4	0.3		13.3	0.09578	13.1	13.4	0.3	
26OCT90	12.6	0.35674	11.9	13.3	1.4		12.6	0.35786	11.8	13.3	1.5	
27OCT90	11.2	0.21685	11.0	11.8	0.8		11.2	0.22270	11.0	11.8	0.8	
28OCT90	10.9	0.12642	10.7	11.1	0.4		10.8	0.13508	10.7	11.1	0.4	
29OCT90	10.2	0.34109	9.7	10.7	1.0		10.2	0.35288	9.6	10.7	1.1	
30OCT90	9.7	0.07913	9.5	9.8	0.3		9.6	0.06854	9.4	9.7	0.3	
31OCT90	9.7	0.18439	9.5	10.0	0.5		9.7	0.16510	9.5	9.9	0.4	

* - Data were flagged when the range or temperatures exceeded 2 C for a given day.

TABLE 5

Daily mean, range and standard deviations of water temperature readings from the Microtemp monitor at Holtwood Hydroelectric Station forebay, November 1990.

	SURFACE						10 FT DEPTH					
DATE	MEAN	SD	MIN TEMP	MAX TEMP	RANGE		MEAN	SD	MIN TEMP	MAX TEMP	RANGE	
01NOV90	9.8	0.23025	9.6	10.2	0.6		9.8	0.22416	9.6	10.2	0.6	
02NOV90	10.4	0.29046	10.1	10.8	0.7		10.3	0.29415	10.0	10.8	0.8	
03NOV90	10.9	0.31534	10.6	11.5	0.9		10.9	0.31688	10.6	11.5	0.9	
04NOV90	11.5	0.13610	11.4	11.9	0.5		11.5	0.12977	11.4	11.9	0.5	
05NOV90	12.1	0.11208	11.9	12.4	0.5		12.0	0.10654	11.9	12.4	0.5	
06NOV90	12.4	0.09482	12.2	12.5	0.3		12.3	0.09262	12.2	12.5	0.3	
07NOV90	12.0	0.10117	11.9	12.2	0.3		11.9	0.11144	11.8	12.2	0.4	
08NOV90	11.6	0.35509	10.8	12.0	1.2		11.5	0.34917	10.8	12.0	1.2	
09NOV90	10.6	0.12680	10.3	10.8	0.5		10.6	0.12835	10.3	10.8	0.5	
10NOV90	10.6	1.71484	9.4	15.8	6.4	*	10.0	0.47520	9.4	13.3	3.9	*
11NOV90	8.9	0.24017	8.3	9.4	1.1		8.9	0.23625	8.3	9.3	1.0	
12NOV90	7.6	0.35195	7.1	8.3	1.2		7.6	0.35123	7.0	8.2	1.2	
13NOV90	6.6	0.28465	6.2	7.1	0.9		6.6	0.28175	6.2	7.0	0.8	
14NOV90	6.1	0.13803	5.9	6.3	0.4		6.0	0.13983	5.8	6.2	0.4	
15NOV90	6.0	0.04892	5.9	6.0	0.1		5.9	0.07255	5.8	6.0	0.2	
16NOV90	6.2	0.19654	5.9	6.5	0.6		6.2	0.20583	5.8	6.5	0.7	
17NOV90	6.6	0.26606	6.3	7.1	0.8		6.6	0.27477	6.2	7.0	0.8	
18NOV90	6.7	0.08578	6.4	6.8	0.4		6.6	0.08885	6.4	6.8	0.4	
19NOV90	6.4	0.99017	6.0	12.6	6.6	*	6.2	0.23522	5.9	7.6	1.7	
20NOV90	5.7	0.17040	5.4	6.0	0.6		5.6	0.17509	5.3	6.0	0.7	
21NOV90	5.5	0.19664	5.3	5.9	0.6		5.5	0.19547	5.2	5.8	0.6	
22NOV90	5.9	0.14350	5.7	6.2	0.5		5.9	0.16080	5.7	6.2	0.5	
23NOV90	6.2	0.05789	6.1	6.4	0.3		6.2	0.07380	6.1	6.3	0.2	
24NOV90	6.5	0.08543	6.4	6.7	0.3		6.4	0.09090	6.3	6.6	0.3	
25NOV90	6.7	0.11270	6.6	7.0	0.4		6.7	0.12297	6.5	6.9	0.4	
26NOV90	7.0	0.11343	6.9	7.3	0.4		7.0	0.12019	6.8	7.3	0.5	
27NOV90	7.3	0.10662	7.2	7.6	0.4		7.2	0.12395	7.1	7.6	0.5	
28NOV90	7.7	0.21980	7.5	8.3	0.8		7.6	0.20246	7.5	8.2	0.7	
29NOV90	8.2	0.17785	7.9	8.4	0.5		8.2	0.16918	7.9	8.3	0.4	
30NOV90	7.8	0.10821	7.6	7.9	0.3		7.7	0.09505	7.6	7.9	0.3	

* - Data were flagged when the range or temperatures exceeded 2 C for a given day.

TABLE 6

Depth (ft) and water temperature (C) profiles of Holtwood Hydroelectric Station forebay, 6 October 1990.

Depth In Feet	Ambient Temp.	Sta 1	Sta 2	Sta 2a	Sta 2s	Sta 3	Sta 3a	Sta 3s	Sta 4	Sta 4a	Sta 4b	Sta 4s	Sta 5	Sta 5a	Sta 5b	Sta 5s
1	18.8	23.5	23.0	24.0	24.1	24.0	23.0	23.8	24.0	23.8	24.0	24.0	24.5	24.0	24.2	24.2
5	18.2	22.0	23.0	23.5		23.9	23.0		23.9	23.7	23.9		24.2	23.6	24.0	
10	18.1	19.0	21.0	23.0		22.5	21.2		21.1	21.5	20.1		22.5	20.8	19.8	
20	18.0	18.5	19.0	(8 ft)		19.5	19.0		19.2	19.0	19.1		18.9	19.0	19.0	
30	18.0	18.5	18.5			19.0	(13 ft)		19.0		(17 ft)		18.7	18.8		
40	18.0	(25 ft)	18.5			19.0			19.0				18.6	(23 ft)		
50			18.5			18.7			(41 ft)				18.6			
60						(42 ft)							(41 ft)			

Depth In Feet	Sta 6	Sta 6a	Sta 6b	Sta 6c	Sta 6s	Sta 7	Sta 7a	Sta 7b	Sta 7c	Sta 7s	Sta 8	Sta 8a	Sta 8b	Sta 8c	Sta 8d	Sta 8s
1	25.8	24.5	24.3	24.3	24.2	24.0	24.0	24.2	24.2	24.0	24.0	24.0	24.2	24.1	24.0	24.1
5	24.2	23.9	24.0	24.0		23.3	23.6	23.5	23.8		23.8	23.6	23.7	23.7	23.8	
10	19.2	19.2	19.8	20.0		19.1	19.0	19.0	19.0		19.8	19.2	19.0	19.0	19.0	
20	19.0	18.8	18.9	19.0		18.8	18.8	18.8	18.8		19.0	18.8	18.9	18.7	18.8	
30	18.5	18.8	18.8	18.[illegible]		18.8	18.7	18.7	18.8		19.0	18.7	18.8	18.6	18.8	
40	19.0	18.7		(28 ft)		18.7	18.6	18.7	18.7		18.7	18.6	18.7	18.5	(25 ft)	
50	18.7	18.5				18.7	18.5	(37 ft)	(38 ft)		18.7	18.5	18.7	(32 ft)		
60	18.5	(46 ft)				18.5	(47 ft)				18.7	18.5	18.6			
	(52 ft)					(56 ft)					(52 ft)	(55 ft)	(52 ft)			

Depth In Feet	Sta 9	Sta 9a	Sta 9b	Sta 9c	Sta 9d	Sta 9e	Sta 9s	Sta 10	Sta 10a	Sta 10b	Sta 10c	Sta 10s	Sta 11
1	24.1	24.0	23.9	24.0	23.9	24.0	24.0	24.2	24.1	24.0	24.0	24.1	24.3
5	23.9	23.8	23.8	23.8	23.4	23.8		24.1	23.9	23.8	23.9		
10	21.8	21.0	19.5	19.4	18.9	19.0		20.1	20.1	19.2	19.4		
20	19.0	19.2	18.9	18.8	18.7	18.9		19.1	19.1	18.8	18.9		
30	19.0	19.0	18.7	18.7	18.7	18.7		18.9	18.9	18.7	18.7		
40	18.7	18.8	18.7	18.6	18.6	18.6		19.0	18.7	18.7	(28 ft)		
50	18.7	18.7	18.5	18.5	18.5	(35 ft)		(38 ft)	18.7	18.5			
60	18.6	18.7	18.5	(48 ft)	18.5				18.7	(48 ft)			
	(53 ft)	(53 ft)	(55 ft)		(55 ft)				(55 ft)				

Note-Bottom depths in parentheses

TABLE 7

Comparison of water temperatures (C) measured in specific areas* during Holtwood Hydroelectric Station shutdown and Steam Station operation, 6 October 1990.

Depth (ft)	Ambient River	Forebay Mean	Forebay SD	Steam Station Discharge Immediate	Steam Station Discharge Entering Station	Steam Station Intake	Inner Forebay
1	18.8	24.1	0.3902	30.9	30.9	23.0	23.0
5	18.2	23.7	0.4090	30.9	30.5	--	22.8
10	18.1	20.0	1.1799	30.9	--	--	22.5
20	18.0	18.9	0.1811	--	--	--	--
30	18.0	18.8	0.1375	--	--	--	--
40	18.0	18.7	0.1461	--	--	--	--

* Specific areas are identified on Figure 1.

JOB V, TASK 4

<u>AMERICAN SHAD STUDY</u>: Evaluation of Serochemical Markers to Demonstrate Response to Transport

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INTRODUCTION:

Basis of Study - The proposal submitted to SRAFRC indicated that a relationship may exist between, factors which induce a stress response in fish and serochemical changes which could suggest how such effects are manifested. Manifestations should appear as disease (non-infectious) and/or loss of reproductive activity. It is known that fish respond to adverse external conditions via the general adaption syndrome (GAS), and when this syndrome is active it can result in changes in energy budgets, mobilization of macronutrients, direct damage to critical organs, and behavior. Since the American shad is placed under the most adverse conditions possible i.e., captured by a trap, held in tanks, transported by truck, and released it was felt that some effect was to be expected. However, it was not known what effect is being produced by this method of handling.

Since construction of a new lift for the Conowango Dam is nearing completion, it becomes critical to know how fish respond to being captured, and whether or not any method should be altered with respect to transport.

OBJECTIVES OF STUDY:

The original proposal had as it's main objective to demonstrate if specific blood enzymes, constituents, and hormones altered as a result of transport of female American shad from the time of capture to release upstream. At that time the author of the proposal did not have access to information regarding specific methodology of transport and specific conditions that would be experienced by investigators collecting blood. Further, considerable delays in implementing the contract resulted in project initiation during the final spawning runs thus limiting our ability to complete the project as originally outlined. Further, since the amount of blood is dependent on size of fish it is not possible to take the original amount of blood as projected i.e., 5 ml but rather this had to be reduced to 2.0 ml of blood maximum. In spite of these obstacles the following objectives were accomplished:

1. initial assessment of 45 individual fish for 17 priority parameters including electrolyte, liver, and renal suites.

2. analysis of same fish, and others for egg maturity based on similar methodology applied to striped bass.

3. The correlation of parameters with specific organ or organotropic damage, and delineation of critical parameters for analysis which would involve the remaining 200 samples collected during the course of the study (1990).

4. Establishment of better protocols of sampling, and better timing of sample collection to fit real world situations.

METHODOLOGY, TECHNICAL ASPECTS:

Transport Scenario: American shad arrive at the Conowango Dam approximately late March and continue to be available until approximately mid to late June. The lift is configured such that water is directed into the lower level of the trap to attract fish. Once the shad and other fish are in the vertical lift they are raised vertically with sufficient water and dumped into a 12' x 6' x 4' (LWD) stainless steel tank for sorting and counting. Fish are identified, sexed, and placed in black 800 to 1000 gallon circular tanks through which water is pumped at rates to insure proper orientation for swimming. The fish are then at varying times loaded into tanks for transport to a location one mile north of York Haven Dam to continue northward migration to spawning reaches. As a part of ongoing research into reducing the stress response due to transport some of the shad were placed in square net pens measuring approximately 18 x 8 1/2 x 4 1/2 (LWD) and held for 24 hours prior to release.

The investigator as a result of this scenario established the following sampling points:

1. At initial capture (immediately following vertical lift and sorting to circular tanks) Designated ASA

2. After 24 hours holding (circular tanks) Designated ASB

3. After 24 hours (holding circular tanks and subsequent transport to release site) Designated ASC

4. After immediate transport (transport without holding) Designated ASC

5. After transport (Either following 24 hour or immediate transport with subsequent 24 hour holding in net pens) Designated ASD

It was not possible to sample prior to entry into the trap nor to sample at spawning grounds.

SPECIFIC METHODOLOGY:

Fish handling: All fish were collected by the fish trap, sorted as male and female, females placed in separate holding tanks, and all males released. Fish were collected with routine or standard dip nets, placed in 1000 gallon tank trucks for transport to the release site. All handling procedures were rapid and did not appear to unduly stress the shad.

Blood Collection: In all cases blood was taken through caudal venipuncture with insertion of a 3.0 ml syringe fitted with a 21 gauge 1 1/2" needle at a position level with the middle of the anal fin with the tip of the needle entering the "caudal sinus". Once blood was observed in the syringe light negative pressure was applied, and a total of 2.0 ml of blood was withdrawn. Fish were restrained by leaving them in the dip net with blood withdrawn between the mesh or at release by wrapping in wet towels to ensure that the fish did not move during venipuncture.

The blood was placed in sterile, clean 3 ml vacutainer tubes. To reduce the risk of hemolysis the needle was removed, and blood slowly injected along lateral walls of the vacutainer tube until the syringe was empty. The blood filled tubes were left at room temperature for two hours to initiate clotting reactions, and placed on ice for transport. At arrival at the laboratory the tubes were centrifuged at 3000 rpm for five minutes, and serum removed using a sterile pasteur pipette. The serum placed in 1.0

ml Ependorf tubes, appropriately labeled, and frozen for transport to the blood chemistry laboratory for analysis.

All sera were analyzed using an automated Kodak Ektachem 7000 Blood Chemistry analyzer. Analysis included: Electrolytes (sodium, potassium, chloride), carbon dioxide (as carbonite), glucose, urea nitrogen, creatinine bile urea-creatinine ratio, calcium, phosphorus, total protein, albumin, globulin, AG (Albumen:Globulin) ratio, bilirubin, uric acid, SGPT (Alanine Amino Transferase), SGOT (Aspartate Amino Transferase), alkaline phosphatase, LDH (Lactate Dehydrogenase), cholesterol, and triglyceride. Results were reported by individual fish, and data stored on floppy for subsequent analysis using dBase III Plus.

<u>Egg Collection, and Analysis</u>: All eggs were removed by using a disposable sterile polypropylene pasteur pipette. The pipette was inserted in the vent (anus), tilted so that the tip was oriented to the left lateral body wall, then stabbed in sharply to break the ovarian sack, and eggs withdrawn (approximately 500 per sample). Eggs were immediately placed in alcohol formalin and acetic acid at a ratio of 7:2:1. Immediately prior to analysis 5% glycerol was added to the solution, and when eggs cleared sufficiently, evaluation of yolk to albumen ratios to determine degree of maturity. Data was correlated against each fish examined.

RESULTS:

These are preliminary results based on 87 American shad. These results must be considered preliminary, as technical and logistical difficulties, may have influenced the results. However, differences were seen which suggest that the techniques employed can detect differences. Final results will be based on 1990 and 1991 values. These results are being included now in preparation for the 1991 study.

The analysis was directed towards alterations in electrolyte balance (sodium, potassium, chloride and carbon dioxide) kidney function (nephrology panel:glucose, BUN, creatinine, sodium, potassium, sodium chloride, carbon dioxide and cholesterol), liver function (liver panel:alkaline phosphatase, LDH, ALT, AST, total bilirubin, albumin:globulin ratio), and reproductive assays (FSH: Follicle Stimulating Hormone, LH: Luteinizing Hormone). The results are shown as tables 1 - 20, and are reported here as ranges and averages. Final statistical analysis will be conducted on these values plus additional those taken in 1991. Other serum samples have been purposely held back for other analyses, specifically: PREG (pregnancy), FSH (Follicle Stimulating Hormone), LH (Luteinizing Hormone), Prolactin, Estrogen, Progesterone as well as Alkaline Phosphate, ALT, AST, LDH, and CPK (Creatinine Phosphokinase). Due to the high cost of these analyses, they will be employed only if a clear indication that they would provide valuable insights is found. The results are as follows:

a. Electrolytes and related ions (Electrolytes: sodium, potassium , chloride/related ions:carbon dioxide, calcium and phosphorus): Tables 1 - 6 provide the levels of sodium, potassium, chloride, carbon dioxide (as carbonate), calcium and phosphorus, respectively. In all cases, with the exception of carbon dioxide, there was significant lowering of blood values for sodium, potassium and chloride based on analysis of both averages and lower ranges. In the case of sodium there was a consistent lowering of the sodium level from approximately 158 mmole per liter to 126 mmole per liter. With respect to potassium there was a lowering following a transient spike from 6.1 to 9.6 mmole per liter to a final level of 5.6 mmole per liter. Chloride levels dropped from 121 to 84 mmole per liter. Of specific interest is carbon dioxide which rose from approximately 11.0 mmole to 22.69 mmole per liter following a high of 26.38 mmole per liter. Calcium levels were unaffected. Phosphorus levels did change, but no pattern was seen that would make sense of the change.

b. Kidney Function (Nephrology panel:glucose, BUN, creatinine, sodium, potassium, chloride, carbon dioxide, cholesterol): With respect to those parameters useful in assessing kidney function, the electrolytes (sodium, potassium and chloride) were shown, as stated previously, to decline (Tables 1, 2 and 3) with respect to each group which sequentially (ASA to ASD) represent a time series. Glucose was found to increase from 75.67 MG/DL to approximately 132 MG/DL. Correspondly, cholesterol was likewise seen to increase from approximately 184 MG/DL to 212 MG/DL. Bile urea nitrogen (Table 9), uric acid (Table 10) and creatinine (Table 11) levels all remained relatively constant. Uric acid (Table 10) and creatinine (Table 11) fell below detectable limits in most cases. As noted previously, and as seen in Table 4, carbon dioxide levels rose and achieved a final level of two times that of fish taken at the trap.

c. <u>Liver function</u> (liver panel:alkaline phosphatase, LDH, ALT, AST, total bilirubin, total protein): Values of those enzymes indicative of liver disfunction are found in tables 12 -16. In all cases (alkaline phosphatase, LDH, ALT, AST) the enzymes rose significantly between treatment groups, first to last. In all cases, with the exception of alkaline phosphatase, the levels were twice those of fish immediately caught at the lift. In particular, LDH (lactic dehydrogenase) rose from an average 19,309 units per liter to a maximum of 41,031 units per liter and approximately nine of the cases the values were beyond ranges of accurate quantification i.e., (greater than 42,000). With regard to those two parameters which reflect liver function bilirubin values rose with second level treatment, and fell to value levels lower than that of the initial treatment group i.e., 3.39 MG/DL to 2.39 MG/DL. Total protein values appear to be unchanged.

d. Nutritional Status (Triglyceride): We use triglyceride values as a rough assessment of nutrient status, as expected values (See Table 18) fell from an average of 202 MG/DL to a final value of 122.46 MG/DL which was expected as the fish were not fed during the course of the study. Note that this does not correspond well to values of glucose (Table 7) which rose.

e. Reproductive assays (FSH, LH): In both sets (Tables 19, 20) values declines, however, at late stages of egg development (i.e., ovulation or release of eggs) these values decline markedly as they are no longer needed. Thus, levels may be reflective only of the later stages of the cycle and not of any real impact of fish handling.

DISCUSSION:

The use of serum chemistries, hematology, serology have been incompletely explored as tools for fishery management. Complete effectiveness of this tool will be possible only after considerable numbers of animals have been sampled. However, it is also possible to obtain information provided that specific treatments (catch, haul, etc...) are instituted and that sampling is prior to and after those treatments. In this way we are able to define the incident and/or condition eliciting a change in serum parameters and define what those changes may signify with regard to survival of the fish and/or completion of it's reproductive cycle. In this particular study sample sizes were limited however treatment of the fish was very clear, and the sizes of fish used were uniform.

With regard to those tests which would indicate a dysfunction of the urinary system (Tables 1, 2, 3, 4, 9, 10, and 11) none of the parameters altered with the exception of sodium, potassium, chloride and carbon dioxide (Tables 1, 2, 3, and 4). Parameters involving sodium, potassium and chloride lowered suggesting a hemodilution which would be expected with anadromous fish going from salt to fresh water environments for spawning. It is interesting that carbon dioxide values (Table 4) rose significantly. They will be discussed separately.

Of interest are changes in "non-exportable" electrolytes, phosphorus and calcium (Tables 5 and 6) which were not altered.

No metabolic system for regulation of these ions exist, loss is precluded by cell barriers, and balances are actively maintained through renal function.

Values for FSH and LH (Tables 19 and 20) when compared against egg maturity do not provide any real information. All eggs were uniform in size between groups, and the degree of yolk formation suggests that maturation is complete. If this is so, the FSH/LH values only suggest a normal drop, and not any handling effect.

The most significant set of changes occurred with those enzymes indicative of altered liver function (i.e., alkaline phosphatase, LDH, ALT, AST). The values doubled between treatment groups, and suggest the strong likelihood of liver damage. The source of damage is very possibly due to hypoxia induced through method of handling. Values of carbon dioxide (Table 4) in blood rose to levels approximately twice that of fish obtained from the trap, and fell only slightly after being held for 24 hours in the net pen. Those parameters, total protein and total bilirubin, did alter during the course of the study, however final values did return to near normal levels or at least levels which would be considered normal.

It is known that in the face of hypoxia carbon dioxide levels will rise, resulting in acid/base shifts within the blood, and have the capacity to induce liver damage both through hypoxic effects and shifts in PH. Since the carbon dioxide levels rose significantly during the course of the study, it is clear that this would be a likely cause of the liver damage. Carbon dioxide will not directly damage the liver cells. It is the lack of oxygen which is reflected by increased carbon dioxide levels that must be considered as problematic.

During holding and transport, even though sufficient levels of oxygen are being supplied, hypoxia is still seen. Physiologically we are dealing with an oxygen demanding system and the levels of oxygen provided are insufficient to ensure against early non-lethal liver damage. It is possible that the fish can not utilize their gills effectively. American shad are fast swimming fish, and this increases water exchange over the gills. Physical restraint (traps, tanks, nets) reduces this water flow thereby reducing oxygen availability. While no evidence of significant liver dysfunction (i.e., bilirubin levels) was found, it is clear that damage due to mild hypoxia occurred as evidenced by the release of liver specific enzymes into the blood. Elevated levels of alkaline phosphatase, LDH, ALT and AST indicate some damage to/or alterations in cell membrane integrity occurred. Studies are now underway to determine how this in fact would impact on reproductive success as the eggs tended to be uniformly mature. Thus we did not have a clear correlation between blood parameters and reproductive success.

Particularly distressful was the degree of hemolysis (red blood cell rupture) that occurred in all groups. The level of hemolysis was ranked at 0 to 4+ (none to high) and any time when the value of hemolysis exceed 3 (i.e., 3+ or greater) samples were discarded. This affected nearly 1/2 of all samples, thus greatly diminishing our sample size. To overcome this, we will be using 19 gauge 1" needles, portable centrifuges, and reduced clotting times (4 hours maximum). An alternative would be to use EDTA or Heparin treated tubes, but these methods are cumbersome in application and thus not suitable for field work.

CONCLUSION:

The following can be drawn from this study:

1. The greatest effect on the fish is seen in the liver as indicated by alteration of LDH, ALT, AST, and alkaline phosphatase levels.

2. The likely cause is hypoxia as liver enzyme levels are affected without significantly affecting liver function.

3. Correlation between reproductive success was not possible due to lateness of study initiation.

4. Method of transport is the likely cause of the liver damage.

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Table 1: Serum Electrolyte Levels (American Shad: <u>Alosa Sapidissima</u>)
Sodium
Expressed As Millimoles Per Liter

	ASA	ASB	ASC	ASD
	1. 157 MMOL/L	1. 139 MMOL/L	1. 139 MMOL/L	1. 119 MMOL/L
	2. 147	1*. -	2. 141	2. 103
	3. 157	2. 150	3. 137	3. 131
	5. 164	3. 148	4. 139	4. 125
	6. 152	4. 129	5. 150	5. 93
	7. 155	5. 139	6. 124	6. 150
	8. 156	6. 115	7. 137	7. -
	9. 167	7. 126	8. 142	8. 125
	11. 164	7*. 134	9. 147	9. 135
	12. 176	8. 134	10. 140	10. -
	13. 162	10. 160	11. 147	11. 145
	14. 169	11. 127	12. -	12. 127
	15. -	12. 149	13. 150	13. 132
	21. 149	13. 140	14. 145	14. 138
	24. 138	14. 130	15. 135	15. 116
RANGE High	176	160	150	93
RANGE Low	138	115	124	145
AVERAGE	158.07	127.21	140.93	126.08
Na++	Initial	24h holding	~~[illegible]~~ transport	[illegible]

Table 2: Serum Electrolyte Levels (American Shad:<u>Alosa Sapidissima</u>)
Potassium
Expressed as Millimoles Per Liter

	ASA		ASB		ASC		ASD
1.	5.0 MMOL/L	1.	8.3 MMOL/L	1.	2.5 MMOL/L	1.	1.5 MMOL/L
2.	2.9	1*.	>14.0	2.	4.8	2.	3.0
3.	8.2	2.	>14.0	3.	5.6	3.	1.2
5.	2.4	3.	>14.0	4.	3.3	4.	<1.0
6.	6.1	4.	>14.0	5.	2.1	5.	3.3
7.	6.6	5.	>14.0	6.	6.9	6.	1.0
8.	11.4	6.	>14.0	7.	8.1	7.	-
9.	13.5	7.	>14.0	8.	8.5	8.	<1.0
11.	3.5	7*.	6.3	9.	1.6	9.	>14.0
12.	4.3	8.	3.7	10.	5.0	10.	3.1
13.	3.7	10.	6.3	11.	2.7	11.	>14.0
14.	2.4	11.	2.3	12.	13.3	12.	9.5
15.	>14.0	12.	3.8	13.	3.2	13.	1.5
21.	5.2	13.	8.3	14.	9.6	14.	>14.0
24.	2.5	14.	7.2	15.	6.2	15.	>14.0
RANGE High	>14.0		>14.0		13.3		>14.0
RANGE Low	2.4		2.3		1.6		1.0
AVERAGE	6.1		9.6		5.56		5.86

Table 3: Serum Electrolyte Levels (American Shad:<u>Alosa Sapidissima</u>)
Chloride
Expressed as Millimoles Per Liter

	ASA		ASB		ASC		ASD
1.	126 MMOL/L	1.	89 MMOL/L	1.	80 MMOL/L	1.	70 MMOL/L
2.	87	1*.	114	2.	85	2.	-
3.	119	2.	139	3.	81	3.	76
5.	122	3.	118	4.	95	4.	64
6.	113	4.	97	5.	99	5.	-
7.	129	5.	124	6.	-	6.	98
8.	125	6.	94	7.	68	7.	-
9.	152	7.	120	8.	107	8.	62
11.	116	7*.	81	9.	109	9.	89
12.	156	8.	63	10.	83	10.	-
13.	116	10.	111	11.	98	11.	111
14.	131	11.	-	12.	97	12.	78
15.	149	12.	110	13.	119	13.	-
21.	114	13.	94	14.	113	14.	107
24.	74	14.	69	15.	90	15.	-
RANGE High	156		139		119		111
RANGE Low	74		63		68		62
AVERAGE	121.93		101.64		94.57		84

Cl^-

Table 4: Serum Electrolyte Level (American Shad: <u>Alosa Sapidissima</u>)
Carbon Dioxide
Expressed as Millimoles Per Liter

	ASA	ASB	ASC	ASD
	1. 10 MMOL/L	1. 13 MMOL/L	1. 27 MMOL/L	1. 28 MMOL/L
	2. 14	1*. 16	2. 29	2. 25
	3. 11	2. 10	3. 26	3. 20
	5. 10	3. 17	4. 30	4. 28
	6. 9	4. 15	5. 30	5. 20
	7. 7	5. 15	6. 30	6. 16
	8. 9	6. 12	7. 25	7. -
	9. 9	7. 15	8. 23	8. 27
	11. 13	7*. 19	9. 24	9. 27
	12. 10	8. 25	10. 24	10. -
	13. 16	10. 10	11. 28	11. 20
	14. 10	11. 21	12. -	12. 17
	15. -	12. 19	13. 22	13. 18
	21. 12	13. 12	14. 25	14. 24
	24. 14	14. 19	15. 26	15. 25
RANGE High	14	25	30	28
RANGE Low	7	10	22	16
AVERAGE	11.00	15.87	26.38	22.69

Table 5: Serum Electrolyte Levels (American Shad: *Alosa Sapidissima*)
Calcium
Expressed as Milligrams Per Liter

	ASA	ASB	ASC	ASD
	1. 13.2 MG/DL	1. 8.4 MG/DL	1. 14.4 MG/DL	1. 11.5 MG/DL
	2. 22.3	1*. 15.6	2. 14.5	2. 15.3
	3. 12.4	2. 12.4	3. 15.2	3. 14.7
	5. 19.2	3. 14.7	4. 23.1	4. 21.6
	6. 15.5	4. 14.1	5. 13.2	5. 18.8
	7. -	5. 12.7	6. 22.7	6. 14.9
	8. 14.3	6. 12.8	7. 22.6	7. -
	9. 12.4	7. 9.7	8. 15.0	8. 18.5
	11. 15.8	7*. 20.5	9. 15.6	9. 13.7
	12. 13.9	8. 19.6	10. 14.4	10. -
	13. 25.2	10. 14.1	11. 13.0	11. 15.1
	14. 18.8	11. 15.0	12. -	12. 12.7
	15. -	12. 14.6	13. 13.3	13. 15.2
	21. 15.8	13. 15.0	14. 15.7	14. 13.1
	24. 20.6	14. 15.6	15. 22.3	15. 19.7
RANGE High	25.2	19.6	23.1	21.6
RANGE Low	12.4	8.4	13.0	11.5
AVERAGE	15.67	14.32	16.79	15.75

Table 6: Serum Electrolyte Levels (American Shad:Alosa Sapidissima)
Phosphorus
Expressed as Milligrams Per Decaliter

ASA		ASB		ASC		ASD	
1.	31.2 MG/DL	1.	45.0 MG/DL	1.	29.7 MG/DL	1.	4.7 MG/DL
2.	38.3	1*.	>13.0	2.	40.5	2.	32.2
3.	27.6	2.	34.4	3.	40.3	3.	5.5
5.	31.6	3.	28.0	4.	44.1	4.	6.1
6.	-	4.	26.3	5.	22.7	5.	28.3
7.	-	5.	35.4	6.	43.0	6.	6.0
8.	36.1	6.	35.1	7.	37.0	7.	-
9.	33.9	7.	4.8	8.	41.7	8.	5.5
11.	37.7	7*.	44.7	9.	22.7	9.	5.2
12.	23.3	8.	38.1	10.	40.2	10.	-
13.	28.2	10.	30.1	11.	33.6	11.	8.7
14.	24.6	11.	35.3	12.	-	12.	12.8
15.	36.9	12.	31.9	13.	28.8	13.	8.0
21.	32.8	13.	54.6	14.	37.3	14.	4.0
24.	21.3	14.	81.9	15.	32.8	15.	8.3
RANGE High	38.3		81.9		43.0		32.2
RANGE Low	21.3		4.8		22.7		4.0
AVERAGE	31.04		37.54		35.31		10.41

Table 7: Serum Glucose Levels (American Shad:Alosa sapidissima)
Glucose
Expressed as Milligrams Per Decaliter

	ASA	ASB	ASC	ASD
	1. 58 MG/DL	1. 96 MG/DL	1. 98 MG/DL	1. 70 MG/DL
	2. 50	1*. 212	2. 61	2. 50
	3. 58	2. 57	3. 79	3. 149
	5. 60	3. 71	4. 189	4. 219
	6. 53	4. 70	5. 76	5. 218
	7. 66	5. 139	6. 40	6. 103
	8. 67	6. 180	7. 73	7. -
	9. 33	7. 65	8. 130	8. 166
	11. 102	7*. 42	9. 108	9. 137
	12. 92	8. 43	10. 64	10. 125
	13. 77	10. 53	11. 112	11. 102
	14. 122	11. 101	12. 98	12. 125
	15. 92	12. 60	13. 92	13. 200
	21. 81	13. 105	14. 116	14. 140
	24. 124	14. 55	15. 128	15. 178
RANGE High	124	212	189	219
RANGE Low	33	42	40	50
AVERAGE	75.67	89.93	97.6	132.1

Glucose

Table 8: Serum Cholestrol Levels (American Shad:Alosa Sapidissima)
Cholesterol
Expressed as Milligrams Per Decaliter

	ASA	ASB	ASC	ASD
	1. 158 MG/DL	1. 149 MG/DL	1. 201 MG/DL	1. 176 MG/DL
	2. 210	1*. 226	2. 184	2. 190
	3. 129	2. 164	3. 197	3. 214
	5. 180	3. 198	4. 310	4. 214
	6. 176	4. 169	5. 189	5. 322
	7. 255	5. 207	6. 181	6. 186
	8. 175	6. 218	7. 185	7. -
	9. 172	7. 263	8. 257	8. 231
	11. 170	7*. 184	9. 245	9. 296
	12. 192	8. 164	10. 174	10. -
	13. 243	10. -	11. 184	11. 185
	14. 157	11. 145	12. 184	12. 181
	15. -	12. 187	13. 189	13. 119
	21. 193	13. 180	14. 237	14. 246
	24. 176	14. 172	15. 193	15. 196
RANGE High	255	263	310	322
RANGE Low	129	145	174	119
AVERAGE	184.7	187.6	207.3	212

Table 9: Serum Bile Urea Nitorgen (BUN) (American Shad:Alosa Sapidissima)
Urea Nitrogen
Expressed as Milligrams Per Decaliter

	ASA	ASB	ASC	ASD
	1. 2 MG/DL	1. 4.0 MG/DL	1. 3.0 MG/DL	1. 2 MG/DL
	2. 2	1*. -	2. 3	2. 3
	3. 2	2. 4	3. 3	3. <2
	5. 4	3. 3	4. 3	4. <2
	6. 3	4. 5	5. 2	5. 3
	7. 3	5. 3	6. 4	6. <2
	8. 3	6. 5	7. 3	7. -
	9. 3	7. 6	8. 3	8. <2
	11. 3	7*. 4	9. <2	9. <2
	12. <2	8. 4	10. 3	10. -
	13. 3	10. 2	11. 3	11. <2
	14. 2	11. 3	12. -	12. 4
	15. -	12. 5	13. 2	13. <2
	21. 3	13. 3	14. 2	14. <2
	24. 2	14. 3	15. 3	15. 2
RANGE High	4	6	4	4
RANGE Low	<2	2	<2	<2
AVERAGE	2.60	3.86	2.78	2.31

Table 10: Serum Uric Acid Levels (American Shad:Alosa Sapidissima)
Uric Acid
Expressed as Milligrams Per Decaliter

	ASA	ASB	ASC	ASD
	1. <.5 MG/DL	1. <.5 MG/DL	1. <.5 MG/DL	1. <.5 MG/DL
	2. <.5	1*. <.5	2. <.5	2. <.5
	3. <.5	2. <.5	3. <.5	3. <.5
	5. <.5	3. <.5	4. <.5	4. <.5
	6. <.5	4. <.5	5. <.5	5. <.5
	7. <.5	5. <.5	6. <.5	6. <.5
	8. <.5	6. <.5	7. <.5	7. -
	9. .7	7. <.5	8. <.5	8. <.5
	11. <.5	7*. <.5	9. <.5	9. <.5
	12. <.5	8. <.5	10. <.5	10. <.5
	13. <.5	10. <.5	11. <.5	11. <.5
	14. <.5	11. <.5	12. .6	12. <.5
	15. <.5	12. <.5	13. <.5	13. <.5
	21. <.5	13. <.5	14. <.5	14. <.5
	24. <.5	14. <.5	15. <.5	15. <.5
RANGE High	.7	<.5	.6	<.5
RANGE Low	<.5	<.5	<.5	<.5
AVERAGE	.513	<.5	<.5	<.5

Table 11: Serum Creatinine Levels (American Shad:<u>*Alosa sapidissima*</u>)
Creatinine
Expressed as Milligrams Per Liter

	ASA	ASB	ASC	ASD
	1. <.1 MG/DL	1. <.1 MG/DL	1. .4 MG/DL	1. <.1 MG/DL
	2. <.1	1*. -	2. <.1	2. <.1
	3. <.1	2. .2	3. <.1	3. <.1
	5. <.1	3. <.1	4. <.1	4. <.1
	6. .2	4. <.1	5. <.1	5. <.1
	7. <.1	5. <.1	6. <.1	6. <.1
	8. <.1	6. <.1	7. <.1	7. -
	9. .2	7. <.1	8. <.1	8. <.1
	11. <.1	7*. <.1	9. <.1	9. <.1
	12. .3	8. <.1	10. <.1	10. -
	13. <.1	10. <.1	11. <.1	11. <.1
	14. <.1	11. <.1	12. -	12. <.1
	15. -	12. <.1	13. <.1	13. <.1
	21. <.1	13. <.1	14. <.1	14. <.1
	24. <.1	14. <.1	15. <.1	15. <.1
RANGE High	.3	.2	.4	<.1
RANGE Low	<.1	<.1	<.1	<.1
AVERAGE	.128	.11	.121	<.1

Table 12: Serum Alkaline Phosphatase Levels (American Shad: Alosa Sapidissima)
Alkaline Phosphatase
Expressed as Active Units Per Liter Serum

	ASA	ASB	ASC	ASD
	1. 80 UNS/L	1. <20 UNS/L	1. 128 UNS/L	1. 130 UNS/L
	2. <20	1*. 26	2. 130	2. 271
	3. 34	2. <20	3. 136	3. 99
	5. 77	3. 129	4. 75	4. 99
	6. 45	4. 37	5. 127	5. 125
	7. 106	5. 49	6. 157	6. 105
	8. 110	6. 37	7. 70	7. -
	9. 160	7. <20	8. 49	8. 88
	11. 55	7*. 29	9. 88	9. 84
	12. 50	8. 58	10. 190	10. -
	13. 100	10. 57	11. 120	11. 81
	14. 66	11. 123	12. -	12. 29
	15. -	12. 60	13. 64	13. 297
	21. 104	13. 149	14. 81	14. 83
	24. 115	14. 89	15. 80	15. 113
RANGE High	160	149	190	291
RANGE Low	<20	<20	49	29
AVERAGE	80.1	60.2	106.8	123.38

Table 13: Serum LDH (Lactate Dehydrogenase) Levels (American Shad:Alosa Sapidissima)
LDH
Expressed as Active Units Per Liter Serum

	ASA		ASB		ASC		ASD
1.	14598 UNS/L	1.	16140 UNS/L	1.	16412 UNS/L	1.	- UNS/L
2.	9781	1*.	-	2.	>43000	2.	>43000
3.	26430	2.	>43000	3.	40810	3.	34810
5.	>43000	3.	24075	4.	38900	4.	>43000
6.	-	4.	43000	5.	43000	5.	>43000
7.	-	5.	43000	6.	28568	6.	-
8.	12479	6.	18673	6.	21500	7.	-
9.	16719	7.	>43000	8.	31223	8.	29540
11.	11914	7*.	>16364	9.	23073	9.	>43000
12.	13248	8.	>43000	10.	25530	10.	-
13.	39030	10.	14602	11.	31962	11.	>43000
14.	15675	11.	>43000	12.	-	12.	>43000
15.	-	12.	36000	13.	>43000	13.	>43000
21.	11509	13.	>43000	14.	38330	14.	>43000
24.	17328	14.	29721	15.	31423	15.	>43000
RANGE High	>43000 = 1		>43000 = 7		>43000 = 3		>43000 =9
RANGE Low	9781		16140		16412		29540
AVERAGE	19309.25		32612.5		32623		41031.81

LDH

Table 14: Serum ALT/SGPT (Alanine Aminotransferase) Levels (American Shad:Alosa Sapidissima)
ALT (SGPT)
Expressed as Active Units Per Liter

	ASA	ASB	ASC	ASD
	1. <3 UNS/L	1. <3 UNS/L	1. <3 UNS/L	1. <3 UNS/L
	2. <3	1*. <3	2. 24	2. 102
	3. <3	2. <3	3. <3	3. <3
	5. <3	3. <3	4. <3	4. <3
	6. -	4. <3	5. <3	5. 3.0
	7. <3	5. <3	6. <3	6. <3
	8. <3	6. -	7. <3	7. -
	9. <3	7. -	8. <3	8. <3
	11. <3	7*. <3	9. <3	9. 4.0
	12. <3	8. 51	10. <3	10. -
	13. <3	10. <3	11. <3	11. <3
	14. <3	11. <3	12. -	12. <3
	15. -	12. <3	13. 39	13. 25
	21. <3	13. 39	14. <3	14. 18
	24. <3	14. <3	15. <3	15. 28
High	<3	51	39	102
RANGE	= 0	= 2	= 2	= 6
Low	<3	<3	<3	<3
AVERAGE	<3	9.46	6.86	18.10

ALT

Table 15: Serum AST/SGOT (Asparate Aminotransferase) Levels (American Shad: <u>Alosa Sapidissima</u>)
AST (SGOT)
Expressed as Active Units Per Liter

	ASA	ASB	ASC	ASD
	1. 170 UNS/L	1. 220 UNS/L	1. 295 UNS/L	1. - UNS/L
	2. 57	1*. -	2. 594	2. 5406
	3. 174	2. 480	3. 382	3. 372
	5. 316	3. 213	4. 477	4. 654
	6. -	4. 308	5. 501	5. 1882
	7. 578	5. 462	6. 348	6. 319
	8. 110	6. 976	7. 254	7. -
	9. 160	7. 647	8. 443	8. 239
	11. 120	7*. 161	9. 522	9. 1706
	12. 69	8. 1397	10. 309	10. -
	13. 375	10. 152	11. 436	11. 523
	14. 194	11. 123	12. -	12. 908
	15. -	12. 240	13. 977	13. 3908
	21. 369	13. 1847	14. 720	14. 1345
	24. 273	14. 457	15. 761	15. 1769
RANGE High	578	1847	977	5406
RANGE Low	57	123	254	239
AVERAGE	228	548.79	501.36	1585.92

Table 16: Serum Total Billirubin Levels (American Shad:*Alosa Sapidissima*)
Total Billirubin
Expressed as Milligrams Per Decaliter

ASA		ASB		ASC		ASD	
1.	.8 MG/DL	1.	12.4 MG/DL	1.	.6 MG/DL	1.	2.7 MG/DL
2.	1.7	1*.	4.6	2.	2.2	2.	4.3
3.	4.3	2.	11.1	3.	1.2	3.	.3
5.	.9	3.	4.9	4.	1.5	4.	.4
6.	9.5	4.	10.9	5.	.7	5.	7.0
7.	7.2	5.	5.4	6.	3.0	6.	.5
8.	6.1	6.	14.7	7.	2.3	7.	-
9.	6.6	7.	17.8	8.	2.7	8.	.2
11.	1.0	7*.	5.5	9.	1.6	9.	.5
12.	1.9	8.	3.8	10.	1.2	10.	-
13.	2.9	10.	3.7	11.	1.1	11.	<.1
14.	.7	11.	1.7	12.	-	12.	14.4
15.	-	12.	3.2	13.	.7	13.	.1
21.	3.6	13.	6.6	14.	1.2	14.	.4
24.	.3	14.	3.4	15.	4.5	15.	.2
RANGE High	9.5		14.7		4.5		14.4
RANGE Low	.3		1.7		.6		<.1
AVERAGE	3.39		7.31		1.75		2.39

Table 17: Total Protein of Serum (American Shad:Alosa Sapidissima)
Total Protein
Expressed as Grams Per Decaliter

	ASA	ASB	ASC	ASD
	1. 4.4 G/DL	1. 10.6 G/DL	1. 4.8 G/DL	1. 5.9 G/DL
	2. 6.4	1*. 7.7	2. 6.0	2. 7.1
	3. 6.0	2. 10.1	3. 5.3	3. 4.8
	5. 5.8	3. 6.8	4. 8.9	4. 6.0
	6. 9.5	4. 10.0	5. 4.8	5. 10.3
	7. 9.0	5. 7.6	6. 5.7	6. 4.6
	8. 7.3	6. 14.0	7. 6.5	7. -
	9. 7.4	7. 14.2	8. 8.5	8. 5.1
	11. 4.3	7*. 8.4	9. 6.6	9. 5.2
	12. 5.4	8. 7.1	10. 4.7	10. 4.8
	13. 7.5	10. 6.5	11. 5.4	11. 4.7
	14. 4.6	11. 5.0	12. 8.8	12. 11.1
	15. 8.5	12. 6.7	13. 5.2	13. 3.0
	21. 6.6	13. 8.5	14. 7.6	14. 4.8
	24. 4.8	14. 7.1	15. 8.7	15. 5.1
RANGE High	9.5	14.2	8.9	11.1
RANGE Low	4.3	5.0	4.7	3.0
AVERAGE	6.5	7.8	6.5	5.89

Table 18: Serum Triglycerides (American Shad:Alosa Sapidissima)
Triglyceride
Expressed as Milligrams Per Decaliter

	ASA	ASB	ASC	ASD
	1. 169 MG/DL	1. 159 MG/DL	1. 145 MG/DL	1. 100 MG/DL
	2. 230	1*. 194	2. 115	2. 140
	3. 186	2. 203	3. 160	3. 100
	5. 201	3. 189	4. 180	4. 154
	6. 248	4. 228	5. 122	5. 218
	7. 182	5. 220	6. 154	6. 107
	8. 223	6. 264	7. 188	7. -
	9. 156	7. 213	8. 199	8. 117
	11. 170	7*. 233	9. 161	9. 96
	12. 210	8. 171	10. 203	10. -
	13. 214	10. 204	11. 135	11. 123
	14. 236	11. 241	12. 205	12. 158
	15. 193	12. 182	13. 183	13. 71
	21. 194	13. 203	14. 178	14. 83
	24. 219	14. 235	15. 203	15. 125
RANGE High	248	246	205	218
RANGE Low	156	159	115	71
AVERAGE	202.00	209.00	168.73	122.46

Table 19: Serum Follicle Stimulating Hormone (FSH) Levels. (American Shad: *Alosa sapidissima*) Expressed as MIUs

	ASA		ASB		ASC
16.	<.3 mciu/ml	19.	1.6 mciu/ml	27.	-
17.	-	23.	<.3	35.	-
18.	<.3	24.	.4	36.	-
19.	2.3	26.	<.3	39.	-
20.	.5	27.	<.3	43.	-
21.	<.3	28.	.8	44.	-
25.	.5	29.	-	45.	-
		30.	<.3	47.	-
		31.	<.3	48.	-
		33.	<.3	49.	-
RANGE High	2.3		1.6		-
RANGE Low	<.3		<.3		-
AVERAGE	0.70		0.46		-

Table 20; Serum Luteinizing Hormone (LH) Levels (American Shad: Alosa sapidissima)
Expressed as MCIUs

	ASA		ASB		ASC
17.	.3 mciu/ml	19.	3.0 mciu/ml	27.	-
18.	<.3	23.	<.3	35.	-
19.	3.0	24.	.6	36.	-
20.	.7	26.	<.3	39.	-
21.	<.03	27.	<.3	43.	-
25.	.5	28.	1.0	44.	-
		29.	-	45.	-
		30.	<.03	47.	-
		31.	<.3	48.	-
		33.	<.03	49.	-
RANGE High	3.0		3.0		-
RANGE Low	<.03		<.03		-
AVERAGE	0.81		0.65		-

JOB V, Task 5. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad in the Susquehanna River.

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Introduction

Tetracycline marking of juvenile American shad was first reported in 1984 (Wiggins et al., 1985) but high mark retention was not achieved until 1986 (Hendricks et al., 1987). Assuming a 7 year life expectancy for some American shad, it is therefore possible that unmarked hatchery shad will be returning to the Conowingo Dam Fish Trap as late as 1992. In order to assess the present contribution of hatchery shad to the population of returning adults, a method was developed to use otolith microstructure to determine origin. Preliminary results of the study were presented by Hendricks, Backman and Torsello (1990). This report summarizes activities which occurred during 1990, including additional analysis of Conowingo Dam Fish Trap catch data from 1989, classification of otoliths extracted from adult shad collected in the trap in 1990, a fourth and final blind classification trial, and additional analysis of otolith increment widths using the Optical Pattern Recognition System (OPRS). Terminology and methods used in this report are identical to those of Hendricks, et al. (1990). A final report on the study should be available for inclusion in the 1991 SRAFRC report.

1989 Trap Catch

In 1989, every 50th shad to enter the trap was sacrificed and the otoliths extracted for microstructure analysis. Otoliths were also extracted from holding and transport mortalities and the data was combined and presented in Hendricks et al. (1990, Table 6). Subsequent to submission of the 1989 report, RMC provided sex and scale aging data for adult shad collected in 1989 (Tables 1 and 2). Holding and transport mortalities included a significantly higher percentage (X^2=33.71, df=1, a=.05) of female shad (48%) when compared to the sacrificed fish (18%, Table 1). In addition, holding or transport mortalities were significantly (X^2=37.15, df=4, a=.05) older (mean age 5.5 years) than sacrificed fish (mean age 4.6 years, Table 2). It is clear that holding and transport mortalities do not represent a random sample of the total population of shad entering the trap and should not be included in microstructural analysis.

Otoliths were classified visually based upon characteristics described in Hendricks, et al. (1990). Visual microstructure classification (Table 3) and tetracycline marking (Table 4) of the two groups were not significantly different. For example, 80% of the sacrificed fish were classified as hatchery, while 86% of the mortalities were classified as hatchery (Table 3). This is not statistically significant (X^2=1.89, df=1, a=.05). Similarly, differences between the two groups in tetracycline marking (Table 4) were not statistically significant (X^2=9.44, df=4, a=.05).

Since the microstructure and marking data presented in Hendricks et al. (1990, Table 6) included the potentially misleading data from holding and transport mortalities, we have re-tabulated the 1989 data by sex (Table 5) and by age (Table 6). Overall, 81% of the adults entering the trap in 1989 exhibited hatchery microstructure and 18% exhibited wild microstructure (Table 5). One (1%) had microstructure upon which the two researchers could not agree. More males exhibited hatchery microstructure(82%) than did females (76%).

Ninety-four (72%) of the fish with hatchery microstructure did not exhibit a tetracycline mark. This is not surprising since production marking was not initiated until 1985. In addition, 3.0 million (48%) of the shad stocked in 1985 were marked at 25 ppm with an estimated mark retention of 5-7% (Hendricks, et al., 1986). The remainder of the shad released in 1985 and all shad released in 1986 were marked at 50 ppm. These marks exhibited retention of 94-100%, but were much more faint and diffuse than the 200 ppm marks produced beginning in 1987. Therefore, we would not expect mark retention to adulthood to approach 100% until year classes prior to 1987 are no longer a component of the fishery.

Age structure of returning adults by sex is presented in Table 7. As expected males returned at an earlier age (mean 4.4 years) than did females (mean 5.6 years).

1990 Trap Catch

In 1990, one of every 100 American shad returning to the Conowingo Dam Fish Trap was sacrificed and classified according to otolith microstructure (Table 8). Thirty-two shad (26%) exhibited wild microstructure, 91 (73%) exhibited hatchery microstructure and on two (2%) the researchers could not agree. Forty-nine (54%) of the shad with hatchery microstructure also exhibited a tetracycline mark. By comparison, in 1989, only 26% of the shad with hatchery microstructure exhibited a mark. As expected, the percentage of marked fish is increasing as the marked year classes become more fully recruited into the trap catch.

Analysis of the 1990 data by sex (Table 8) revealed that 27% of the males and 21% of the female exhibited wild microstructure. Seventy percent of the males and 80% of the females exhibited hatchery microstructure. For shad with hatchery microstructure, 57% of the males exhibited marks, while 50% of the females exhibited marks.

Blind Microstructure Classification Finals

A major portion of the otolith microstructure study involved testing of our ability to classify otoliths based solely upon microstructure laid down within the first thirty days after hatch. Otoliths of known origin (known by the presence or absence of a TC mark) were given a blind number and visually classified by two researchers, according to microstructure alone. Three trials were conducted in 1989 (Hendricks et al., 1990) using wild and hatchery origin otoliths from shad collected in the Susquehanna River from 1986 through 1988. Trial 1 included five of the six groups, while trials 2 and 3 included four of the six groups.

In 1990, a comprehensive fourth trial (Table 9) was conducted using all groups from the Susquehanna River (1986 through 1989) and a group of known wild otoliths from juvenile shad collected in the Delaware River in 1990. The Delaware River shad were collected well upstream from the mouth of the Lehigh River to minimize any possibility of collecting hatchery juveniles released in the Lehigh. In addition, the Delaware River group were examined under UV light prior to the assignment of blind numbers to ensure that no marked (hatchery) shad were present in the group.

The Susquehanna River groups included all wild (unmarked) otoliths from juvenile shad collected in the Susquehanna River during the period 1986 through 1989. A randomly chosen number (120 to 250) of hatchery otoliths from the same years was added to complete the sample. The classifications were done without a priori knowledge of how many total specimens were in the test. In addition, specimens were classified in groups of 10 to 15 otoliths and the researchers did not know how many groups would be classified. During the trial, 6 otoliths (5 wild, 1 hatchery) were eliminated because the grind was so poor or the specimen so badly cracked that the microstructure could not be classified.

A total of 270 specimens were included in the trail (Table 9). Of those, 244 (89%) were classified correctly, 26 (9%) incorrectly and on 5 (2%) the researchers disagreed. Of the individual groups in the trial, the poorest results were obtained with the group of wild fish from the Delaware River. Only 17 (59%) of the 29 otoliths in that group were classified correctly. Eliminating the Delaware River otoliths from the trial, 92% of the otoliths were classified correctly. Further discussion of otoliths from Delaware River juveniles is deferred until later.

A total of 167 hatchery otoliths were included in the trial, with 163 (98%) classified correctly and four (2%) classified incorrectly. A total of 108 wild otoliths were included in the trial, with 81 (75%) classified correctly, 22 (20%) classified incorrectly and on five (5%) we disagreed. Excluding Delaware River otoliths, 67 (81%) of 79 wild otoliths were classified correctly, while 14 (18%) were classified incorrectly and on one

(1%) we disagreed. Thus, accuracy of our classifications for an unknown sample from the Susquehanna River would be expected to vary from 81% for a sample of all wild fish, to 98% for a sample of all hatchery fish.

Optical Pattern Recognition System

A Biosonics Optical Pattern Recognition System (OPRS) was used to measure otolith increment widths for groups of known origin otoliths. Measurements on only two groups of otoliths (hatchery and wild, 1987) were completed in time for the 1989 report (Hendricks et al., 1990). Since that time, five additional groups have been completed (Table 10). Groups completed to date include otoliths from juvenile wild and hatchery shad collected in the Susquehanna River in 1986, 1987, and 1988, and wild adult shad collected in the Delaware River in 1988. Mean otolith increment width ranged from 2.88 microns for the 1987 hatchery group to 5.89 microns for the 1988 wild (Susquehanna group). ANOVA was performed on the data and the differences were found to be statistically significant at a < .0001 (df=6). Duncan's and Scheffe's multiple comparisons were performed and the results are depicted in Table 10. In each case, wild groups were significantly different from hatchery groups. The data is depicted graphically in Figure 1. These results confirm our subjective observations that otolith increments are wider in wild fish than in hatchery fish, one of the major identifying characteristics used in the subjective visual microstructure classifications. Note that mean otolith increment width in adult fish from the Delaware River is not significantly different from the wild 1986 group of Susquehanna River juveniles (Table 10). These groups exhibited increment widths closest to those of the three groups of hatchery fish. This may explain the relatively poor results obtained in blind classification Trial 4 (Table 9, Delaware River) where only 59% of the group was classified correctly. It should be noted that the Delaware River otoliths utilized in Trial 4 were from juvenile fish collected in 1990 while those used in the OPRS work were from adults collected in 1988.

Measurement of increment width will be performed on the three remaining groups: Wild, 1990 Delaware River juveniles, and wild and hatchery, 1989 Susquehanna River juveniles. These data, plus a complete final report, will be submitted for inclusion in the 1991 SRAFRC report.

Summary

Analysis of sex and age data for adult American shad, collected in the Conowingo Dam Fish Trap in 1989, indicated that a sample of shad which suffered mortality during holding or transport included a larger proportion of females and older fish, than did a randomly selected sample of every 50th fish to enter the trap. It follows that holding and transport mortalities do not represent a random sample of adult shad entering the trap and should not be used to determine trap catch composition.

Based on microstructure of otoliths extracted from randomly sampled adult shad collected in the trap, hatchery shad comprised 81% of the trap catch in 1989 and 73% in 1990. Wild shad comprised 18% of the trap catch in 1989 and 26% in 1990.

In a blind study, classifying otoliths based solely upon microstructure, 89% of the known origin otoliths were classified correctly. These results support the validity of using subjective visual classifications to distinguish between hatchery and wild shad from the Susquehanna River. Otolith increment widths from seven groups of known origin shad, were measured using a Biosonics Optical Pattern Recognition system. Mean otolith increment widths (first 15 days after hatch) were found to be significantly larger in groups of known wild shad than in groups of known hatchery shad.

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Figure 1. Mean otolith increment width and 95% confidence intervals for groups of known origin otoliths, 1986-1988. Increments 1 through 15 only.

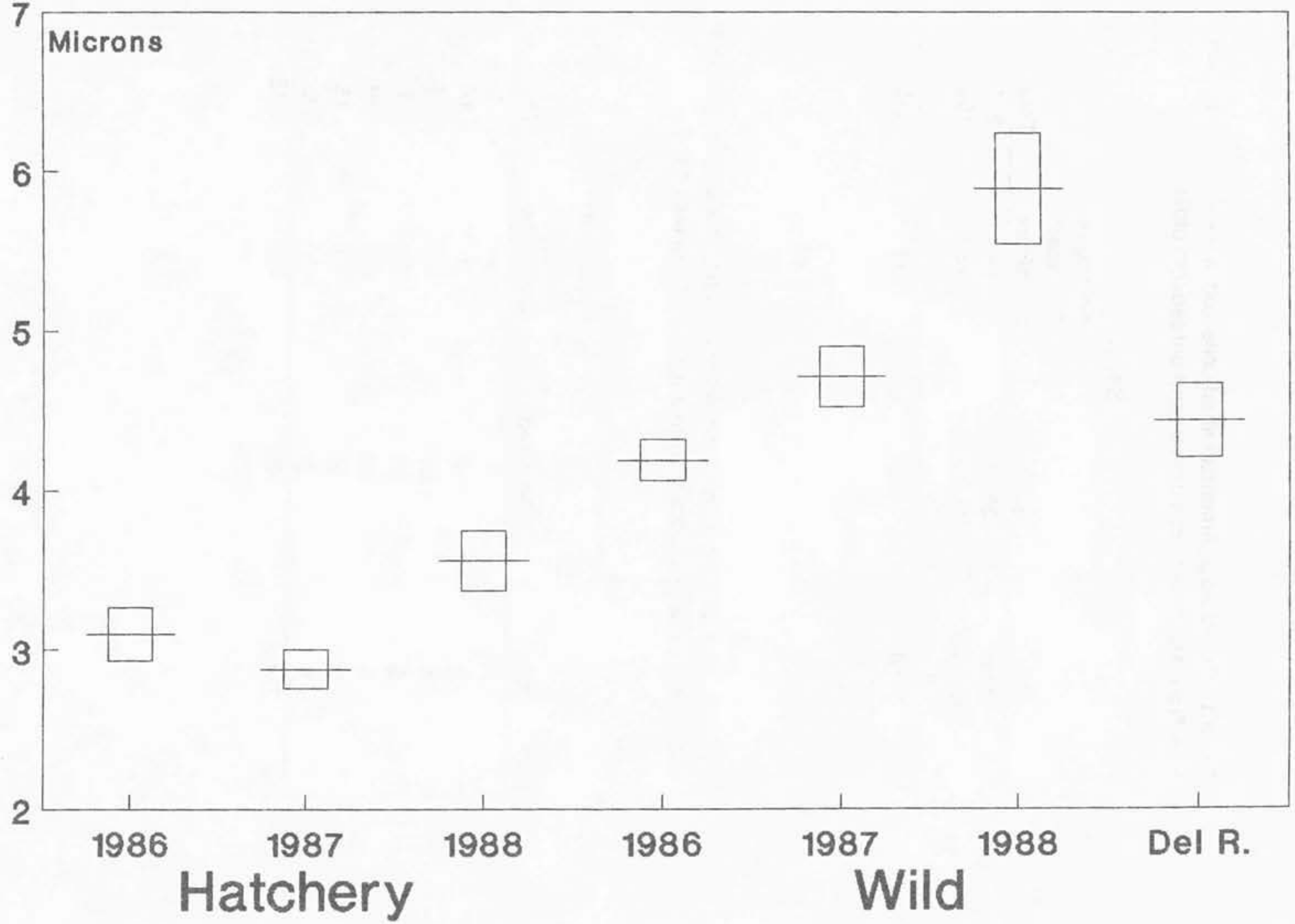

Table 1. Sex of adult American shad collected in the Conowingo Dam Fish Trap, 1989. Includes broken and unreadable otoliths.

Sex	Sample		Total
	Sacrificed	Holding or Transport Mortalities	
Male	133 (82%)	78 (51%)	211
Female	29 (18%)	74 (48%)	103
?	-	1 (1%)	1
Total	162	153	315

Table 2. Age of adult American shad collected in the Conowingo Dam Fish Trap, 1989. Includes broken and unreadable otoliths.

Age	Sample		Total
	Sacrificed	Holding or Transport Mortalities	
2	1	-	1
3	15	3	18
4	61	22	83
5	54	76	130
6	20	39	59
7	6	10	16
?	5	3	8
Total	162	153	315

Table 3. Microstructure of otoliths from adult American shad collected in the Conowingo Dam Fish Trap, 1989. Includes broken and unreadable otoliths.

Microstructure	Sample: Sacrificed	Sample: Holding or Transport Mortalities	Total
Hatchery	130 (80%)	132 (86%)	262
Wild	29 (18%)	19 (12%)	48
?	3 (2%)	2 (1%)	5
Total	162	153	315

Table 4. Tetracycline marking of adult American shad collected in the Conowingo Dam Fish Trap, 1989. Includes broken and unreadable otoliths.

TC Marking	Sample: Sacrificed	Sample: Holding or Transport Mortalities	Total
No mark	124	127	251
Day 5 mark	14	2	16
Day 12 mark	1	1	2
Day 15 mark	19	20	39
Days 5, 15 mark	–	1	1
TC mark ?	4	2	6
Total	162	153	315

Table 5. Sex, microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Fish Trap, 1989. One of every 50 fish to enter the trap was sacrificed. Holding or transport mortalities, and broken or unreadable otoliths were not included in the analysis.

			Hatchery Microstructure						
Sex	Wild Micro-structure	Disagreed on Micro-structure	No TC Mark	TC Mark Day 5	TC Mark Day 12	TC Mark Day 15	TC Mark ?	Total Hatchery	Total
M	22	1	75	14	1	16	2	108	131
F	7	–	19	–	–	3	–	22	29
Tot.	29 (18%)	1	94	14	1	19	2	130 (81%)	160

Table 6. Age, microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Fish Trap, 1989. One of every 50 fish to enter the trap was sacrificed. Holding or transport mortalities, and broken or unreadable otoliths were not included in the analysis.

			Hatchery Microstructure						
Age	Wild Micro-structure	Disagreed on Micro-structure	No TC Mark	TC Mark Day 5	TC Mark Day 12	TC Mark Day 15	TC Mark ?	Total Hatchery	Total
2	1	–	–	–	–	–	–	–	1
3	1	–	10	4	–	–	–	14	15
4	8	–	34	5	–	10	2	51	59
5	7	1	32	5	1	8	–	46	54
6	6	–	14	–	–	–	–	14	20
7	6	–	–	–	–	–	–	–	6
?	–	–	4	–	–	1	–	5	5
Tot.	29	1	94	14	1	19	2	130	160

Table 7. Age distribution by sex of adult American shad collected in the Conowingo Fish Trap, 1989. One of every 50 fish to enter the trap was sacrificed. Holding or transport mortalities, and broken or unreadable otoliths were not included in the analysis.

Age	Male	Female
2	1	–
3	15	–
4	55	4
5	46	8
6	9	11
7	2	4
?	3	2
Tot.	131	29

Table 8. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Fish Trap, 1990. One of every 100 fish to enter the trap was sacrificed. Holding or transport mortalities, and broken or unreadable otoliths were not included in the analysis.

Sex	Wild Microstructure	Disagreed on Microstructure	Hatchery Microstructure: No TC Mark	TC Mark Day 5	TC Mark Day 15	TC Mark Days 5, 12	TC Mark ?	Total Hatchery	Total
M	24	2	25	19	14	1	1	60	86
F	8	–	15	2	13	–	–	30	38
?	–	–	1	–	–	–	–	1	1
Tot.	32 (26%)	2	41	21	27	1	1	91 (73%)	125

Table 9. Classification of juvenile American shad otoliths by two researchers based on microstructure laid down during the first 30 days after hatch, Trial 4, 1990. Samples were assigned blind numbers and included marked (hatchery) and unmarked (wild) fish collected from the Susquehanna River during the period 1986–1989, and unmarked fish collected from the Delaware River in 1989.

Known Origen:		Hatchery (marked)				Wild (unmarked)			
		Sample	Classification			Sample	Classification		
Year	Source	Size	Hatchery	Wild	Disagreed	Size	Hatchery	Wild	Disagreed
1986	Susquehanna	44	41(93%)	3(7%)	-	37	8(22%)	29(78%)	-
1987	Susquehanna	40	39(98%)	1(2%)	-	21	5(24%)	16(76%)	-
1988	Susquehanna	46	46(100%)	-	-	11	1(9%)	9(82%)	1(9%)
1989	Susquehanna	37	37(100%)	-	-	10	-	10(100%)	-
1990	Delaware	_	_	_	_	29	8(28%)	17(59%)	4(14%)
	Total	167	163(98%)	4(2%)	-	108	22(20%)	81(75%)	5(5%)
	Total (Del. excluded)	167	163(98%)	4(2%)	-	79	14(18%)	64(81%)	1(1%)
			Correct	Incorrect	Disagreed				
	Grand Total	275	244(89%)	26(9%)	5(2%)				
	Grand Total (Del. excluded)	246	227(92%)	18(7%)	1(<1%)				

Table 10. Mean otolith increment widths for known origin American shad collected in the Susquehanna and Delaware Rivers, 1986- 1989. Includes the first 15 increments only. Susquehanna River fish were juveniles and Delaware River fish were adults.

Group	River	Mean Otolith Increment Width (microns)	Standard Deviation	N	Multiple Comparisons Duncan's	Multiple Comparisons Scheffe's
Wild 1988	Susquehanna	5.89	2.49	198	A	A
Wild 1987	Susquehanna	4.71	1.72	299	B	B
Wild 1988	Delaware	4.44	1.90	270	BC	BC
Wild 1986	Susquehanna	4.18	1.25	330	C	C
Hatchery 1988	Susquehanna	3.56	1.70	300	D	D
Hatchery 1986	Susquehanna	3.10	1.47	300	E	DE
Hatchery 1987	Susquehanna	2.88	1.10	300	E	E

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

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INTRODUCTION

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

METHODS AND MATERIALS

Collection procedures for adult American shad assessment in 1990 were nearly identical to those in 1989, the only difference being the elimination of the Beaver Dam pound net site in the Susquehanna Flats (Figure I). Hook and line sampling in the Conowingo tailrace continued unchanged from 1989. Tagging procedures and data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Juvenile production was monitored by haul seine as was done from 1980 through 1987 and 1989. Eight seine stations were sampled bi-weekly with a 200' x 10' x 1/4" haul seine from early July through October (Figure II). In addition, electrofishing was conducted weekly from August through October at nine of 18 randomly selected sites (Figure III). Juvenile sampling results from other DNR projects (yellow perch/otter trawl, striped bass/haul seine) were also utilized in analysis of the reproductive success of American shad in the upper Bay during 1990.

RESULTS

Pound net tagging for 1990 began on 14 March and continued until 22 May while hook and line effort started on 30 April and ended 12 June. Of the 708 adult American shad captured, 581 (82%) were tagged and 70 (10%) subsequently recaptured (Table 1). Recapture data for the 1990 season is summarized as follows:

a. 68 fish recaptured by the Conowingo Fish Lift
   (does not include 2 double recaptures)
   5 fish recaptured by pound net
   2 fish recaptured by hook and line from tailrace
   2 fish recaptured outside the system

b. 55 fish recaptured originally caught by hook and line
   20 fish recaptured originally caught by pound net

c. 54 fish recaptured in the same area as initially tagged
   17 fish recaptured upstream of their initial tagging site
   4 fish recaptured downstream of their initial tagging site

d. shortest period at large: 1 day
   longest period at large: 53 days (1990 fish only)
   mean number days at large: 20.2

e. number of 1989 tagged fish recaptured: 2
   number of double recaptures: 2

The population estimate for adult shad in the upper Chesapeake Bay for 1990 using the Petersen Index was 125,574 (Table 2). The Petersen estimate for those fish captured, marked and recaptured only from the Conowingo tailrace (angling and fish trap) was 60,541 (Table 3). The 1990 estimates were the highest recorded to date for both the upper Bay and tailrace and represent a 66% and 35%, respectively, increase over 1989 (Figures IV and V).

Effort, catch, and catch-per-unit-of-effort (CPUE) by gear type for adult American shad in the upper Bay during 1990 and comparison with previous years is presented in Table 4. Catch per angler hour decreased to five fish in 1990 but still represented a 107% increase over 1984. The shad catch per pound net day for both nets combined also decreased slightly in 1990 over the previous year. However, the nearly five fish per pound net day collected at the Rocky Point net was the highest ever recorded at this site.

A total of 688 adult American shad (305 hook and line, 383 pound net) were examined for physical characteristics by DNR biologists in 1990. In addition, information from 688 adult shad was collected from the Conowingo Fish Trap by RMC biologists. Of the 712 males examined, 80% were ages IV and V with age group V predominating (Table 5). As in the previous year, the pound net and fish trap tended to catch greater numbers of older males although the incidence of repeat spawners was nearly identical for pound net and hook and line males (Table 6). Nearly 80% of the 664 female shad examined were comprised of V and VI year old fish (Table 5). As with their male counterparts, the hook and line females tended to be younger (age group IV) than those collected by pound net or fish trap. The incidence of repeat spawning in females, normally lowest in hook and line fish, was higher than that for pound net, but less than for the fish trap (Table 6).

Juvenile alosid sampling in the upper Bay during 1990 produced fewer numbers of young-of-the-year American shad than the previous year. Table 7 presents results from 1990 haul seine and otter trawl sampling arranged by catch, catch by site, and associated CPUE. Comparison of 1990 results with previous years (Table 8) indicates a decline in the juvenile shad catch by otter trawl, but substantial increases in river herring, white perch, and striped bass production over 1989 for both gears. The haul seine catch of shad in 1990 increased by 1 over the previous year.

Supplemental haul seine sampling for the Department's juvenile striped bass survey in 1990 captured 19 young-of-the-year American shad, a decrease of 48 fish in 1989. The 19 fish were collected from Carpenter Point (4) on July 17, Plum Point (7) and Poplar Point (5) on July 18, Elk Neck State Park (1) on August 14, and

Plum Point (2) on September 2.

Numbers of juvenile shad collected by electrofisher also decreased over 1989 from 97 to 23. This 76% decrease, however, may be related to substantial changes in the electrofishing sampling design initiated in 1990. Instead of sampling in areas of known juvenile shad concentrations as was done in 1989, the Susquehanna Flats shoreline area was gridded off into 36 separate cells approximately 2,000 feet long (Figure III). Electrofishing was carried out in two stages: stage 1 involved randomly selecting nine of the first 18 cells for sampling during week one, while stage 2 was conducted the following week on nine randomly chosen sites from cells 19 to 36. Results of this sampling are presented in Table 9.

FIGURE I. GEAR AND LOCATION UTILIZED IN CAPTURING ADULT AMERICAN SHAD FROM THE UPPER CHESAPEAKE BAY IN 1990.

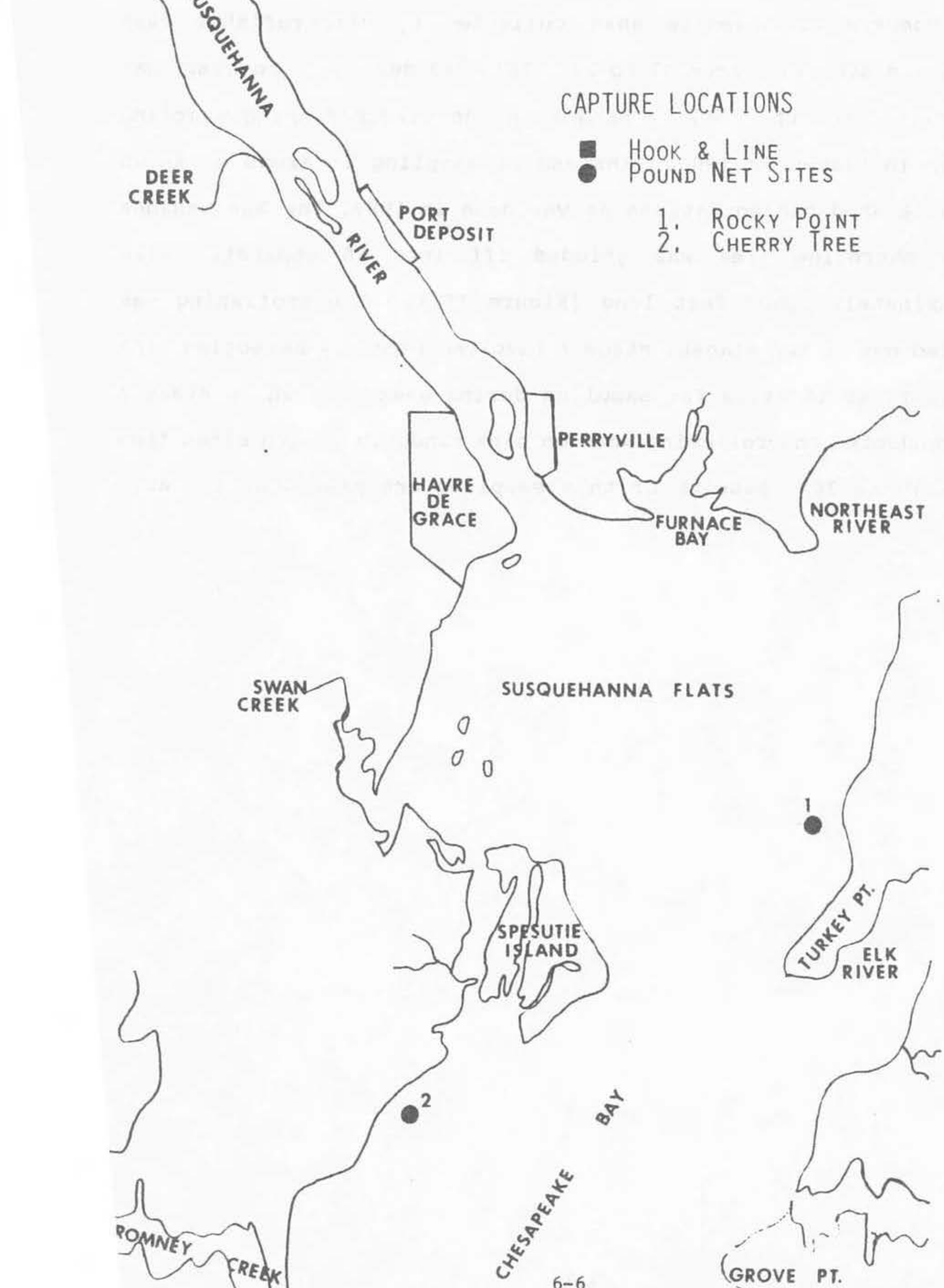
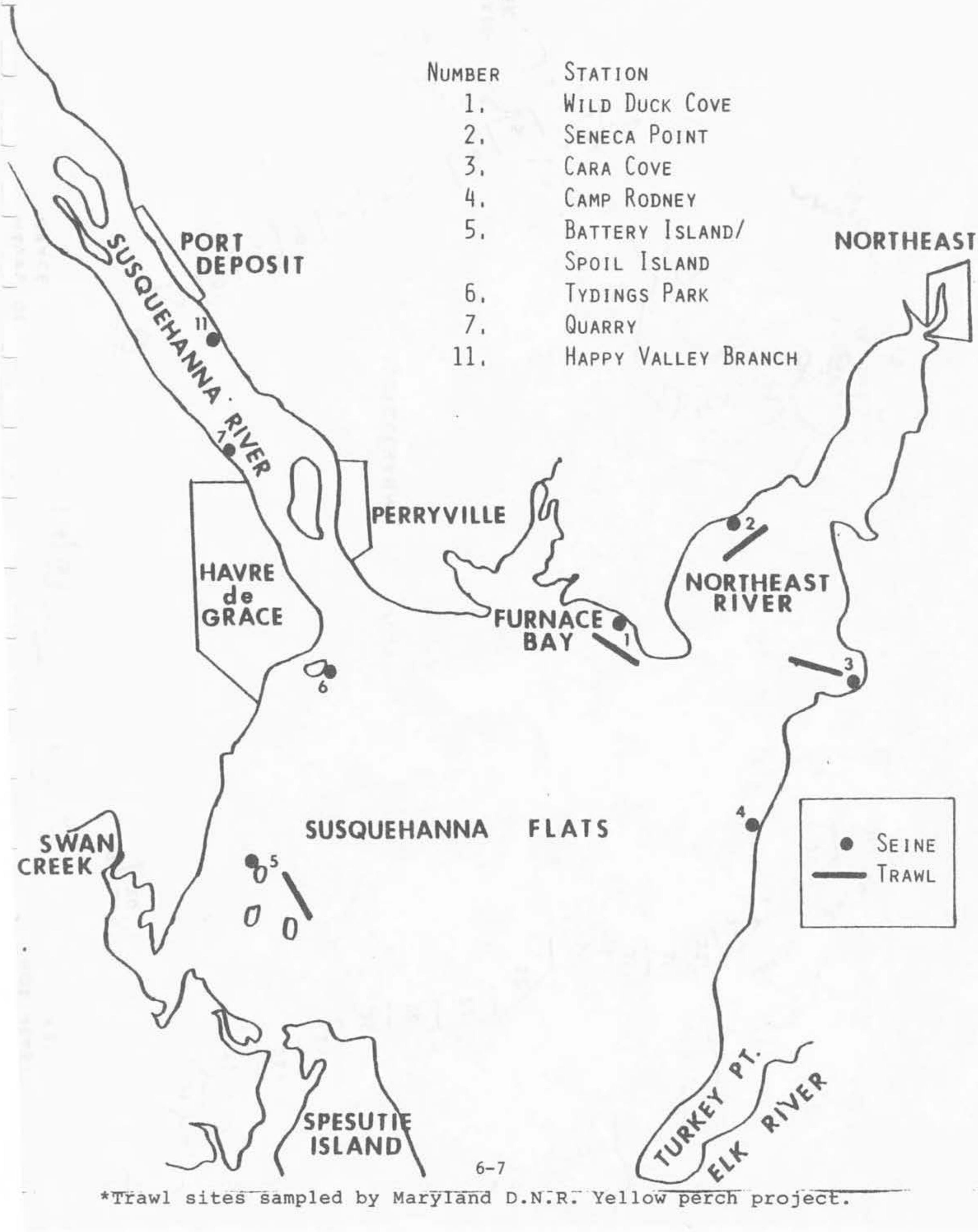


FIGURE II. SEINE AND TRAWL* SITES SAMPLED DURING THE 1990 JUVENILE RECRUITMENT SURVEY.

Number	Station
1.	Wild Duck Cove
2.	Seneca Point
3.	Cara Cove
4.	Camp Rodney
5.	Battery Island/ Spoil Island
6.	Tydings Park
7.	Quarry
11.	Happy Valley Branch



*Trawl sites sampled by Maryland D.N.R. Yellow perch project.

FIGURE III. UPPER CHESAPEAKE BAY ELECTROFISHING SITES SAMPLED DURING THE 1990 JUVENILE RECRUITMENT SURVEY.

FIGURE IV. **YEARLY COMPARISONS OF THE ADULT AMERICAN SHAD POPULATION ESTIMATES IN THE UPPER CHESAPEAKE BAY.**

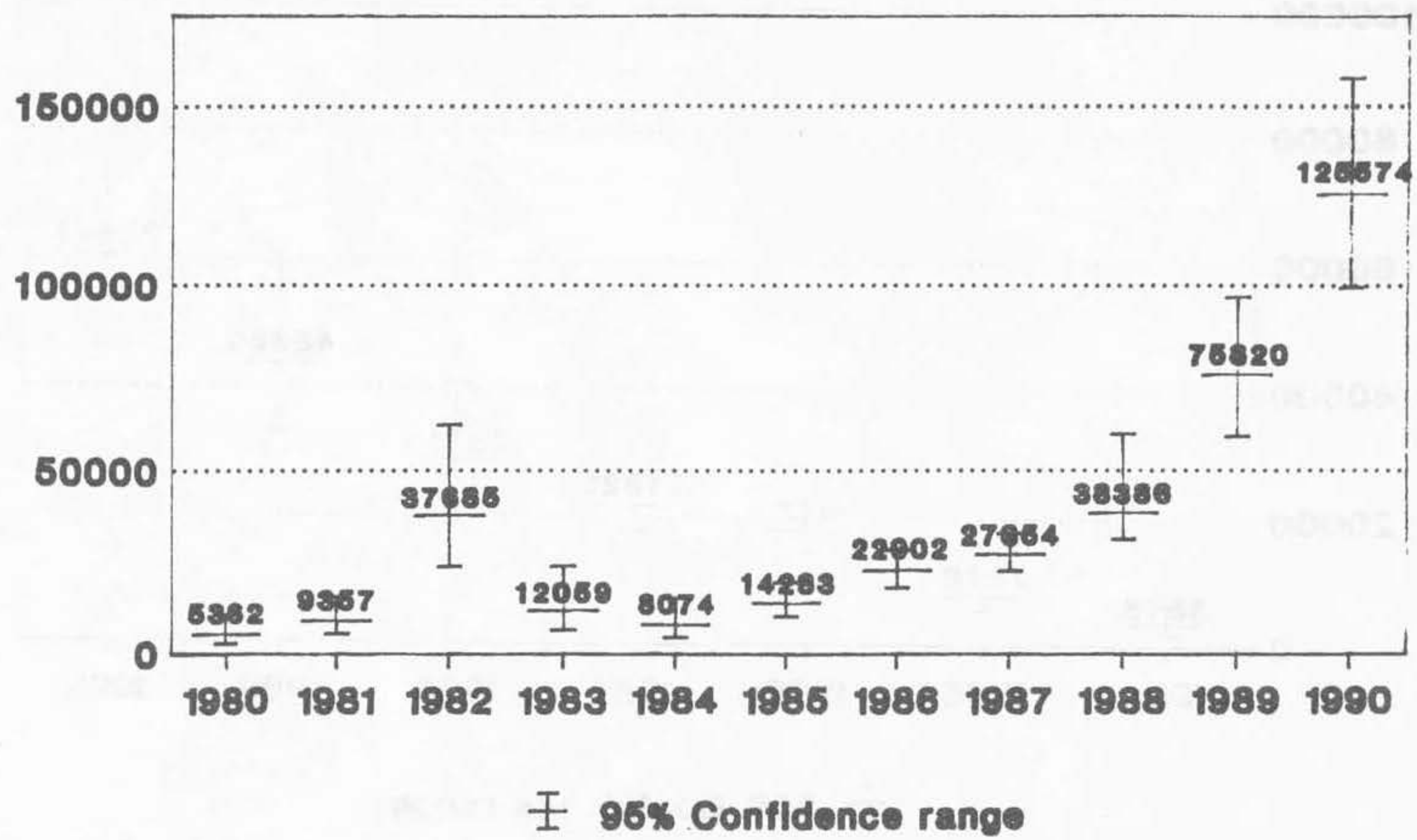


FIGURE V. **YEARLY COMPARISONS OF THE ADULT AMERICAN SHAD POPULATION ESTIMATES IN THE CONOWINGO DAM TAILRACE.**

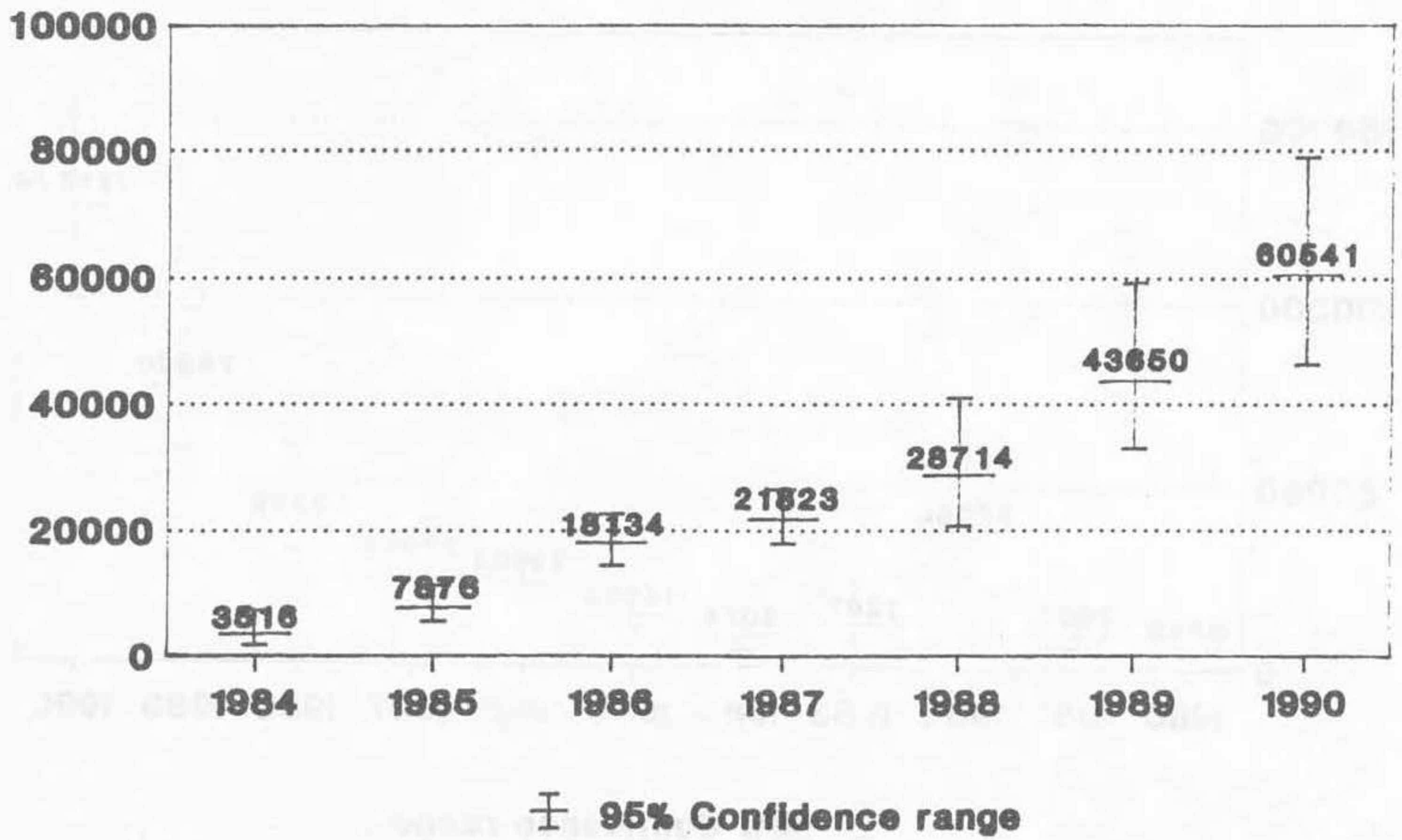


Table 1. **Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1990.**

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	178	135
	Rocky Point	221	151
	Total	399	286
Hook and Line	Conowingo Tailrace Susquehanna River	309	295
Fish Lift	Conowingo Tailrace Susquehanna River	15962*	
	TOTALS	16670	581

* Does not include two DNR double recaptures

Table 2. **Population estimate of adult American shad in the upper Chesapeake Bay during 1990 using the Petersen estimate.**

Chapman's Modification to the Petersen estimate-

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

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

For the 1990 survey-

C = 16664
R = 70
M = 534

Therefore-

$$N = \frac{(534 + 1)\ (16664 + 1)}{(70 + 1)}$$

$$= 125{,}574$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(534 + 1)\ (16664 + 1)}{55.41 + 1} = 158{,}053$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(534 + 1)\ (16664 + 1)}{88.44 + 1} = 99{,}684$$ @ .95 confidence limits

Table 3. Population estimate of adult American shad in the Conowingo tailrace during 1990 using the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1990 survey-

C = 11,179
R = 52
M = 286

Therefore-

$$N = \frac{(286 + 1)\ (11,179 + 1)}{(52 + 1)}$$

$= 60,541$

From Ricker (1975): Calculation of sampling error using the recapture numbers in conjunction with a Poisson distribution approximation and acceptable confidence limits.

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(286 + 1)\ (11,179 + 1)}{39.7 + 1} = 78,837$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(286 + 1)\ (11,179 + 1)}{68.2 + 1} = 46,368$$ @ .95 confidence limits

Table 4. Catch, effort and catch per unit effort (CPUE) for adult American shad by hook and line and pound net during the 1980-1990 tagging program in the upper Chesapeake Bay.

A. Hook & Line

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPAH*	CPUE HTC**	POP. EST.
1982	***	88	-	-	37,685
1983	***	11	-	-	12,059
1984	52.0	126	2.42	0.41	7,957
1985	85.0	182	2.14	0.47	14,283
1986	147.5	437	2.96	0.34	22,840
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	125,574

B. Pound Net

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POP. EST.
1980	Rocky Pt.	26	50	1.92	5,362
1981	Rocky Pt.	38	50	0.86	9,357
1982	Rocky Pt.	27	62	2.29	37,685
1985	Rocky Pt.	10	30	3.00	14,283
1988	Rocky Pt.	33	87	2.64	
	Cherry Tree	41	75	1.83	
	Romney Cr.	41	8	0.20	
	1988 Total	115	170	1.48	38,386
1989	Rocky Pt.	32	91	2.84	
	Cherry Tree	62	295	4.76	
	Beaver Dam	11	14	1.27	
	1989 Total	105	400	3.81	75,820
1990	Rocky Pt.	38	221	5.82	
	Cherry Tree	71	178	2.50	
	1990 Total	109	399	3.66	125,574

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

Table 5. **Catch and age composition by sex and gear type for American shad collected during the 1990 tagging program in the upper Chesapeake Bay.**

Sex Gear	II	III	AGE IV	GROUPS V	VI	VII	VIII
Male							
Hook and Line							
Number caught	-	15	102	59	6	-	-
Percent age comp.	-	8	56	32	4	-	-
Pound net							
Number caught	1	18	74	109	27	4	-
Percent age comp.	<1	8	32	47	12	2	-
Trap							
Number caught	0	7	78	146	62	4	-
Percent age comp.	0	2	27	49	21	1	-
All gears combined							
Number caught	1	40	254	314	95	8	-
Percent age comp.	<1	6	36	44	13	1	-
Female							
Hook and Line							
Number caught	-	1	36	60	22	4	-
Percent age comp.	-	1	29	49	18	3	-
Pound net							
Number caught	-	-	16	73	39	22	-
Percent age comp.	-	-	10	49	26	15	-
Trap							
Number caught	-	3	25	165	163	34	1
Percent age comp.	-	1	6	42	42	9	<1
All gears combined							
Number caught		4	77	298	224	60	1
Percent age comp.		<1	12	45	34	9	<1

Table 6. **Age frequency, number and repeat spawners by gear type and sex for adult American shad collected during the 1990 upper Chesapeake Bay tagging program.**

GEAR TYPE	SEX	SEX RATIO	II	III	AGE GROUPS IV	V	VI	VII	VIII	%REPEAT SPAWNERS	TL
Hook	M			15	102	59	6	0			182
&	Rpts.			0	0	3	2	0		2.7	5
Line		1 : 0.68									
	F			1	36	60	22	4			123
	Rpts.			0	0	1	2	2		4.1	5
Pound	M		1	18	74	109	27	4			233
Net	Rpts.		0	0	0	5	1	0		2.6	6
		1 : 0.64									
	F		-	0	16	73	39	22			150
	Rpts.		-	0	0	1	1	0		1.3	2
Trap	M			7	78	146	62	4			297
	Rpts.			0	1	15	6	1		7.7	23
		1 : 0.42									
	F			3	25	165	163	34	1		391
	Rpts.			0	0	8	14	4	1	6.9	27
Totals	M		1	40	254	314	95	8			712
	Rpts.		0	0	1	23	9	1		4.8	34
		1 : 0.93									
	F		0	4	77	298	224	60	1		664
	Rpts.		0	0	0	10	17	6	1	5.1	34
							TOTALS			4.9	1376
											68

Table 7. Catch and catch-per-unit-effort (CPUE) by gear type (HS = haul seine; OT* = otter trawl) and sampling station for juvenile American shad, blueback herring, alewife herring, striped bass, and white perch during the 1990 upper Chesapeake Bay juvenile recruitment survey.

A. Catch by Gear Type

Species	Gear	Station 1	2	3	4	5	6	7	11	Total
American	HS	7	0	0	0	1	1	4	0	13
shad	OT	2	0	0	NA	4	NA	NA	NA	6
blueback	HS	87	305	0	413	14	105	171	225	1320
herring	OT	93	81	41	NA	65	NA	NA	NA	280
alewife	HS	50	42	160	300	0	0	0	0	552
herring	OT	33	88	122	NA	134	NA	NA	NA	377
striped	HS	13	8	8	7	12	17	4	1	70
bass	OT	4	10	6	NA	69	NA	NA	NA	89
white	HS	457	226	305	427	32	381	1	4	1833
perch	OT	138	373	728	NA	87	NA	NA	NA	1276

B. CPUE by Gear Type

Spp.	Gear	Station 1	2	3	4	5	6	7	11	Tot.
Amer.	HS	.8	0	0	0	.1	0	.7	0	0.2
shad	OT	.4	0	0	NA	.6	NA	NA	NA	0.3
bluebk.	HS	9.7	33.9	0	45.9	1.6	11.7	28.5	25.0	19.1
herring	OT	18.6	16.2	8.2	NA	9.3	NA	NA	NA	12.7
alwife.	HS	5.6	4.7	17.8	33.3	0	0	0	0	8.0
herring	OT	6.6	24.4	24.4	NA	19.1	NA	NA	NA	17.1
striped	HS	1.4	0.9	0.9	0.8	1.3	1.9	0.7	0.1	1.0
bass	OT	.8	2.0	1.2	NA	9.9	NA	NA	NA	4.1
white	HS	50.8	25.1	33.9	47.4	3.6	42.3	0.2	0.4	26.6
perch	OT	27.6	64.6	145.6	NA	12.4	NA	NA	NA	58.0

* Data provided by Maryland estuarine fisheries yellow perch project.

Table 8. Total catch and catch-per-unit-effort for five juvenile species by gear type (HS = haul seine; OT = otter trawl) during the years 1980-1990 in the upper Chesapeake Bay juvenile recruitment survey.

A. TOTAL CATCH

	American Shad		Blueback Herring		Alewife Herring		White Perch		Striped Bass	
YEAR	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**
1980	0	0	108	27	194	38	1315	1453	55	8
1981	0	0	2	0	108	35	174	347	8	0
1982	0	1	130	8	14	19	1631	3973	235	49
1983	0	0	1	2	4	6	208	553	8	2
1984	0	0	40	17	11	49	914	2410	22	10
1985	0	1	96	16	99	171	228	1014	8	1
1986	8	6	3484	1988	175	241	1686	3028	60	37
1987	0	3	40	3	6	13	101	457	6	1
1989	12	16	538	96	35	15	1124	3125	44	18
1990	13	6	1320	280	552	377	1833	1276	70	89

B. CATCH-PER-UNIT-EFFORT

	American Shad		Blueback Herring		Alewife Herring		White Perch		Striped Bass	
YEAR	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**	**HS**	**OT**
1980	0	0	0.6	0.2	1.1	0.4	7.2	14.4	0.3	0.1
1981	0	0	0.02	0	0.8	0.4	1.3	3.8	0.1	0.0
1982	0	0.01	0.8	0.1	0.1	0.2	10.0	37.8	1.4	0.5
1983	0	0	0.01	0.02	0.03	0.1	1.5	5.5	0.1	0.02
1984	0	0	0.3	0.3	0.1	0.7	7.2	35.4	0.2	0.2
1985	0	0.02	0.7	0.2	0.7	1.7	1.6	10.1	0.1	0.01
1986	0.1	0.1	24.2	18.9	1.2	2.3	11.7	28.8	0.4	0.4
1987	0	0.03	0.3	0.03	0.1	0.1	0.8	4.6	0.1	0.01
1989	0.2	0.6	7.8	3.4	0.5	0.5	16.3	111.6	0.6	0.6
1990	0.2	0.3	19.1	12.7	8.0	17.1	26.6	58.0	1.0	4.1

Table 9. Juvenile American shad captured by date and cell and associated catch-per-unit-effort during the 1990 upper Chesapeake Bay electrofishing survey.

CELL NO.	AUGUST			SEPTEMBER				OCTOBER					CATCH	SHOCK TIME (SEC.)	* CPUE
	15	22	30	5	17	20	27	3	10	18	24	30			
1			0						0		0		0	1500	0.0
2			0		1				1		0		2	2000	3.6
3			1				0						1	1000	3.6
4	1				0						0		1	1500	2.4
5											0		0	1500	0.0
6	0		1		1		1		0		0		3	3000	3.6
7					1		0						1	1000	3.6
8	0		0								0		0	1500	0.0
9	3				0				0				3	1500	7.2
10	0				0		0						0	1500	0.0
11			0								0		0	1000	0.0
12			0				2				0		2	1500	4.8
13							0		0				0	1000	0.0
14	1				0		0		0				1	2000	1.8
15	0				0								0	1000	0.0
16	2		0				0		0				2	2000	3.6
17	0		0						0				0	1500	0.0
18					0		0		0		0		0	2000	0.0
19		2											2	500	14.4
20						1		0				0	1	1500	2.4
21		1						0		1			2	1500	4.8
22										0			0	500	0.0
23				0		0							0	1000	0.0
24				0				0				0	0	1500	0.0
25		0				0		0		0			0	2000	0.0
26		0										0	0	1000	0.0
27		0		0		0				1			1	2000	1.8
28		0		0				0				0	0	2000	0.0
29				0		0		0				0	0	2000	0.0
30						0				0		0	0	1500	0.0
31		0		0									0	1000	0.0
32						0				0			0	1000	0.0
33		0		0				0		0			0	2000	0.0
34				0		0				0		0	0	2000	0.0
35		0		0				0		0		0	0	2500	0.0
36						1		0				0	1	1500	2.4
TOTL	7	3	2	0	3	2	3	0	1	2	0	0	23	54000	1.5

* CPUE = number of American shad captured per shock hour
* No sampling at a particular date and cell is represented by a blank space.

LAST

PAGE