Restoration of American Shad to the Susquehanna River

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SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

FEBRUARY 1992

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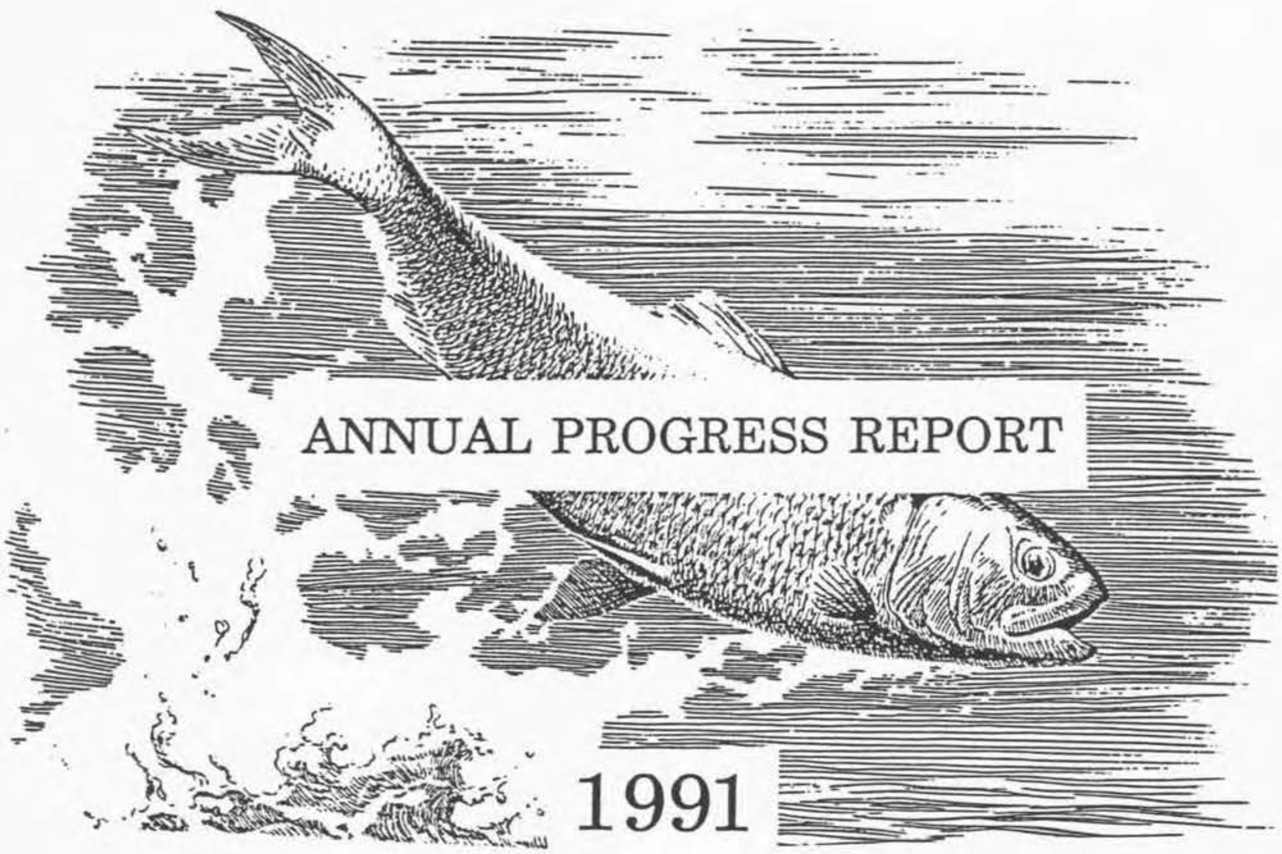

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

MARYLAND DEPARTMENT OF NATURAL RESOURCES
UNITED STATES FISH AND WILDLIFE SERVICE
NEW YORK DIVISION OF FISH AND WILDLIFE
PENNSYLVANIA FISH AND BOAT COMMISSION
PENNSYLVANIA POWER AND LIGHT COMPANY
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SUSQUEHANNA RIVER BASIN COMMISSION
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FEBRUARY 1992

EXECUTIVE SUMMARY

The 1991 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 seventh year of a 10-year program to rebuild stocks based on hatchery releases and natural reproduction of adult shad collected at the Conowingo Dam fish lifts and transferred upstream to spawn. Considerable efforts 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 1991 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 139,862 fish (Petersen Index). This was based on recapture of 192 shad from a tagged population of 942 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay and angling in the Conowingo tailrace. Of the tagged fish which were recaptured, 183 came from the Conowingo lifts. Stock size in 1991 was 11% larger than in 1990 and 17 times greater than that of 1984. The shad population in the Conowingo tailrace was estimated to be 83,990, a 41% increase over 1990.

With completion of the new East fish passage facility at Conowingo Dam, two lifts were operational during the course of the migration season in 1991. Aside from minor interruptions, both facilities operated every day from early April until early June. A total of 1.184 million fish representing 42 taxa and 4 hybrids were handled. The great majority of the catch (92.8%) was comprised of gizzard shad, carp, comely shiner, channel catfish and white perch. Alosa species included 27,227 American shad, 28,765 blueback herring, 2,972 alewives, and 120 hickory shad.

American shad catch in 1991 was 11,263 (70%) more than in 1990 and represented a new record high return to Conowingo. The West lift accounted for 13,330 American shad, 15,616 bluebacks, most alewives and all hickory shad. The new East lift took 13,897 American shad and 13,149 bluebacks. White perch and channel catfish were more plentiful at the West lift whereas common carp were several times more abundant at the East lift. Catch per fishing hour for American shad at both lifts was about 24.5, slightly lower than that recorded at the West lift in 1990.

Most American shad at both lifts (total 18,973) were collected during the 3-week period 28 April to 19 May while river flow declined steadily from about 75,000 cfs to 25,000 cfs. Overall sex ratio of shad in lift collections was 1.5 to 1 favoring males. Males ranged in age from III to VII (80% @ V-VI), and females were IV to VIII (76% @ V-VI). Based on scale analysis of 937 shad, 14.4% (135) were repeat spawners and 20 of these had two spawning checks.

A total of 24,662 American shad was transported to potential upstream spawning areas with less than 3% observed transport mortality. Unusually high water temperature, oxygen supersaturation and problems with the new trailers and tanks led to delayed mortality of several hundred additional fish. Most shad were stocked at the Tri-County Boat Club above York Haven Dam, with smaller numbers being released at the mouth of Swatara Creek. Only 1,160 shad were placed into a net pen at Tri County Marina for delayed release. Spawning was observed in the pen. A total of 4,001 river herring were stocked upstream in the Susquehanna and 703 were placed into three upper Chesapeake Bay tributaries to support restoration efforts by the Maryland DNR.

In an effort to evaluate behavior and movements of adult shad following transport and release, 52 fish were radiotagged in four batches and either stocked directly to the river (30 fish) or held overnight in a net pen (22 fish). Most fish moved downriver upon release and no enhanced upstream movement or schooling behavior was observed in penned shad. Only thirteen tagged fish moved upstream to Dock Street Dam and six reached the Juniata River monitor site within 2-6 days.

Observed shad movements were probably affected by unusually high temperatures and low river flow conditions during May, 1991.

Maryland DNR and University of Maryland researchers continued their stress response study in transported adult shad using serochemical analysis for liver and kidney function and reproductive potential. Blood samples were taken from fish collected by hook and line in the Conowingo tailrace, from both the east and west fish lifts, immediately after hauling to the release site, and following a holding period in a net pen at Middletown. As was the case in 1990, 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 280 adult shad from the Conowingo lift were transported to the RMC Muddy Run laboratory between 23 April and 28 May. These were used in a special study to artificially induce spawning in shad using hormone injections. Multiple injection of luteinizing hormone-releasing hormone ethylamide (LHRH-alpha) was effective in inducing ovulation in shad. Problems were experienced with high temperatures and water supply interruption. With a 1.5 to 3-hour delay interval after initial ovulation, treated females produced an average of 42,000 eggs with 80% viability. A total of 296,400 artificially induced and spawned eggs were sent to the Van Dyke hatchery but only 26,400 hatched (8.9%).

The Pennsylvania Fish and Boat Commission operated the intensive culture facility at Van Dyke and rearing ponds at Thompsontown and Upper Spring Creek. During the period 1 May to 1 June, 29.8 million shad eggs were delivered to Van Dyke from the Delaware River (10.745 M), the Hudson River (17.658 M), the Connecticut River (1.104 M) and the Susquehanna River (296,400). Overall viability of eggs was 60.7% resulting in production of 14.28 million fry.

All fry produced at Van Dyke were distinctively marked with one to five separate 6-hour immersions in 200 ppm tetracycline (TC). About 7.218 million 18-23 day old fry were stocked in the Juniata River at Thompsontown, 4.877 million were stocked in the lower Susquehanna River at Rock Run Landing, MD, and 867,000 were placed in the Lehigh and Schuylkill rivers. The PA Fish and Boat Commission also reared and stocked 54,500 fingerling shad. These were released at Thompsontown between 27 August and 13 September. Maryland DNR produced 111,500 fingerlings which were stocked in the Elk River at 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 1991 included final testing of new bottom screens for Van Dyke jars to improve egg survival and feed trials to determine effectiveness of AP-100 dry diet as a sole source of starter feed. PFBC researchers also completed a special study to evaluate the use of otolith microstructure to distinguish between wild and hatchery-reared shad in the Susquehanna River. Using visual observation of otolith microstructural characteristics, 92% correct classification was achieved for known hatchery and wild fish from four year-classes. Also based on otolith analysis, hatchery shad comprised 73% of the Conowingo trap catch in 1991, an identical figure to that found in 1990.

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 1991, shad were sampled with seines at several sites below York Haven Dam; with a sluice net sampler at York Haven Dam; with lift nets at Holtwood; from cooling water intake strainers and screens at Safe Harbor, Conowingo and Peach Bottom; and by netting and electrofishing in the upper Chesapeake Bay.

Unusually low river flows prevailed throughout the summer and fall of 1991. Though relatively few shad were collected with seines during July through September, most were naturally produced. Outmigration from the river above York Haven occurred during the first 3-weeks in October but was not correlated with a high flow event. Shad were taken in small numbers at Holtwood Dam with a lift net during October through mid-December.

Juvenile shad grew well in the Susquehanna with wild fish showing larger mean sizes than hatchery fish at comparable age. Overall relative abundance of shad appeared lower than in recent years, but this may be an artifact of the low flow situation in the river.

Over 600 shad from collections at York Haven Dam, Columbia, Wrightsville, Safe Harbor, Pequea, Holtwood, Peach Bottom and Conowingo were returned to Benner Spring for tetracycline mark analysis. Otoliths from 133 fish (21.5%) were unmarked and displayed wild microstructure. Rate of recovery of Hudson and Delaware River fish was proportionate to their stocking numbers (87% and 13%, respectively) and relative survival of Hudson fry stocked at Thompsontown during day and night periods was similar. Maryland DNR personnel collected 34 juvenile shad with various gear in the upper Chesapeake Bay during July through October. Of 29 age-0 fish analyzed for tags on otoliths, 69% were double-marked fish stocked at Rock Run Landing and 28% 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. Unlike past year studies, recapture nets were placed in the trash sluiceway and the Unit 1 discharge to determine effectiveness of strobes. Fish gathered at York Haven by late September and 155 strobe tests were run through 27 October. As expected, shad exhibited repeated avoidance response to the strobe lights. An estimated 257,700 shad were pushed through the sluice under test conditions (lights on) compared to 7,400 during controls (lights off). By contrast, only 15,675 shad were estimated to pass through Unit 1 during these tests (6% of sluice passage), and 650 used this route during control episodes. These results demonstrated the effectiveness of underwater strobes to repel shad and concluded the 4-year testing program at York Haven.

In an effort to understand behavior and movements of juvenile shad in the Holtwood forebay, thirty juvenile shad were radiotagged and released under several project operating modes. During generation periods, tagged shad passed through the Holtwood project within 10 minutes to 1.5 hours of release. During non-generation periods, shad were distributed throughout the forebay and showed no areas of concentration. Most of these moved downstream within an hour of start-up. Water temperature appeared to have no affect on shad movements.

American shad egg collection, hatchery culture, research and marking, juvenile recovery and mark analysis, serological stress analysis, artificially induced spawning trials, adult and juvenile shad telemetry were funded from the 1985 settlement agreement with upstream utilities. The strobe light study at York Haven was co-funded by SRAFRC, EPRI and Met Ed. Upstream licensees cooperated with Philadelphia Electric Company in covering most costs associated with collection, sorting and trucking of shad from the two lifts at Conowingo. PECO paid for strainer and screen checks for juvenile shad at Conowingo Dam and Peach Bottom. Maryland DNR funded the adult shad population assessment, juvenile shad 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.

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State College, PA

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JOB I. SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM FISH PASSAGE FACILITIES IN SPRING 1991

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INTRODUCTION

Philadelphia Electric Company (PECO) has operated a fish passage facility (West Lift) at its Conowingo Hydroelectric Station since 1972. It is part of a cooperative private, state, and federal effort to restore American shad to the Susquehanna River. In accordance with the restoration plan, the operational goal has been to monitor fish populations below Conowingo Dam and transport as many migratory fishes (American eel, river herring, American shad, and striped bass) upriver as possible. Funding for the 1991 operation and maintenance of the West Lift was provided by Susquehanna Electric Company, a subsidiary of PECO.

In 1988, PECO negotiated an agreement between state and federal resource agencies and private organizations to enhance its restoration of American shad and other anadromous species to the Susquehanna River. A major element of this agreement was for PECO to construct an east side fish lift at Conowingo Dam. Construction of the East Lift commenced in April 1990 and the lift was operational by spring of 1991. The East Lift was designed according to United States Fish and Wildlife Service (USFWS) guidelines and specifications and resulted from extensive study, design review, hydraulic modeling, and discussion with resource agencies.

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 small (5,000 cfs each) and four large units (10,000 cfs each) is 75,000 cfs.

Objectives of the 1991 operation were to: (1) assess the operation of the newly installed Passage Facility (East Lift) on the east side of the Station, (2) continue restoration efforts by the trap and transfer of prespawned American shad and river herring, (3) monitor species composition and relative abundance of Alosa species, (4) obtain life history information from selected migratory fishes, (5) assist the Maryland Department of Natural Resources (MD DNR) in assessing the American shad population in the upper Chesapeake Bay, and (6) provide American shad for stock assessment and special studies.

1.0 METHODS

Prior to the operation, five surveys were conducted between 18 and 27 March 1991 to detect the arrival of alosids into areas below Conowingo Dam. Surveys were conducted at Shures Landing below Conowingo Dam, the bridge over Deer Creek, along Stafford Road south of Deer Creek, and at Octorara Creek along Route 222.

No river herring were observed during these surveys; water temperature varied from 42.8 to 50.0 F.

Preparations for the operation of the East and West Lifts (Figures 1 and 2) began in early March. Pursuant to the settlement agreement between PECO and the resource agencies, turbine Units 1 and 2 were shutdown when river flows were less than 65,000 cfs. West Lift operation was consistent with the 1991 SRTC Work Plan.

1.1 West Lift

Lift operation commenced on 1 April 1991 and occurred on an alternate half day (0700-1300 hrs) basis through 9 April. The increased collection of American shad on 9 April resulted in daily (0700 to approximately 1900 hrs) operation through 3 June. The Lift was operated on a half day basis from 4 June to the last day of operation (7 June). Work stoppages due to mechanical/electrical failures or maintenance occurred infrequently. Generally, work proceeded around these stoppages to maximize fishing time.

The mechanical aspect of Lift operation in 1991 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, two modifications to normal operation (first implemented in 1985 to maximize collection of American shad (RMC 1986)) were utilized to reduce the large numbers of gizzard shad attracted to the Lift. First, operation

"Fast Fish"[1] (RMC 1986), which reduced the mechanical delays associated with normal operation was employed during periods of heavy fish activity. Second, the weir gate settings were adjusted and operation in the "Fast Fish" mode was continued until the accumulated fish were reduced. Normal Lift operation was resumed after the majority of fish activity was eliminated.

Attraction velocity and flow at the Lift were similar to those maintained since 1982 (RMC 1983). Hydraulic conditions were maintained in the area of the Lift between the crowder and weir gate entrances similar to that reported in RMC (1983). Modifications to weir gates and house service unit settings were made during periods of heavy fish concentration and were similar to those reported in 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 7 June, respectively. Generally, Units 5 and 6 were used to meet minimum flow releases during April and May. Unit 5 was used to release the minimum flow in June. The minimum release from Units 5 and 6 was based on 1982 results and experience, which showed passage effectiveness increased when competition between the attraction flow and the discharge flow was reduced.

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

1.2 East Lift

Initial start-up began on 1 April, however, a mechanical problem with the crowder prohibited continuous sampling until 8 April. Lift operation resumed on 8 April and continued daily (approximately 0700 to 1900 hrs) thereafter until 7 June. Since the East Lift was in its first year of operation some mechanical and electrical problems were encountered and dealt with so that uninterrupted trap/transport operations could continue with maximal fishing time.

The operational guidelines for lift operation were based on the hydraulic model developed by Stone & Webster Engineering Corporation and on comments and operational criteria set by the USFWS. The operational matrix charts developed by Stone & Webster for lift operations utilized the relationship between Conowingo Pond elevation, tailrace elevation, and attraction flow. During start-up testing these charts were revised to reflect actual operating conditions. Water intrusion from operating Units 10 and 11 masked the attraction flow at upstream weir gate A. New matrix charts were developed based on pond and tailrace elevation and turbine unit operation, which listed the various gate settings for lift operation. These settings were changed throughout the day to correspond to changes in hydraulic conditions.

Water velocities at the entrances and within the crowder channel were established to maximize the American shad catch. USFWS guidelines recommended water velocities of 0.5 to 1.0 fps in the crowder channel and 3.0 to 8.0 fps at the entrance. Actual water velocities utilized to maximize the American shad catch ranged from 0.5 to 1.5 fps in the crowder channel, 1.0 to 2.0 fps near the upstream/downstream gate, and 4.0 to 6.0 fps at any entrance. Lifts were conducted at least hourly throughout the day. When large numbers of fish accumulated in the crowder area, operation "Fast Fish" was employed, which was similar to that described in Section 1.1, excepting design differences between the East and West Lifts.

The trough, which allows fish passage directly into Conowingo Pond, was operated on 12 April and 24 May. Prior to conducting any lifts, adjustments were made to the hopper floor plate, trough entrance, and lift operation. Fish were lifted into the trough and counted as they passed the counting window. At the end of operation, the trough was drained slowly to enable personnel to enter and remove any trash or remaining fish.

1.3 Disposition Of Catch

Fishes were processed as reported previously (RMC 1983). Fishes were either counted or estimated (when large numbers were present) at each lift and released back to the tailrace. Length, weight, sex, and scale samples were taken from blueback herring, hickory shad, and alewife. The scientific and common names of fishes collected in 1991 (Table 1) followed Robins et al. (1980). American shad life history information (i.e. length, weight, sex, spawning condition, scales and/or otoliths) was taken from shad that were sacrificed, released back to the tailrace, or that died in handling and transport. Per the 1991 SRTC Work Plan, every 100th shad collected per each lift was sacrificed so otoliths could be removed and utilized in a stock identification study by the Pennsylvania Fish And Boat Commission (PFBC). 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 were similar to those used by MD DNR, and were validated previously.

1.4 Holding and Transport of Shad and River Herring (West Lift)

The primary objective of the project was to trap and transport American shad upstream of the uppermost hydroelectric project (York Haven) on the Susquehanna River. Generally, transport occurred whenever 100 or more green or gravid shad were collected in a day, or at the supervisor's discretion if fewer shad were collected. As feasible, up to 5,000 river herring were scheduled for transport to Upper Chesapeake Bay tributaries to assist MD DNR with restoration activities. Any additional river herring were transported upriver. American shad and river herring were released at the Tri-County Boat Club Marina (Tri-County) located on the east shore of the Susquehanna River above York Haven Dam.

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

1.5 Holding and Transport of Shad and River Herring (East Lift)

The transport system utilized at the East Lift initially required several steps to safely transfer shad across the catwalk. Due to limited space, four trailer units, each equipped with a 750 gal tank, water pump, and oxygen system were designed specifically for the East Lift. The trailer units were used as holding facilities at the Lift due to limited space.

Shad were loaded directly into a trailer unit. When a sufficient number of shad were collected to facilitate a transport event, the trailer unit was moved from the sorting area via a tow motor and hooked to a hy-rail truck designed to tow the trailer unit across the catwalk. When the truck reached the west side of the Station the hy-rail equipment was disengaged, and the truck towed the trailer unit to a staging area where the unit was hooked to a flatbed truck. The transit time for this operation required a minimum of 45 minutes.

Continuous modifications of the new trailer units occurred throughout the season to improve shad transport survival. To reduce vibration, rubber couplers were installed to the pipes leading from the water pump into the transport tank and the water pump was remounted on rubber bushings. To reduce observed abrasions and scale loss on shad, the tank door was modified to fit flush against the inner wall of the tank, and the pipes leading into the tank were cut flush to the inner wall. Needle valves, regulators, and hose connections were added or upgraded to better control the flow of oxygen into the transport tank.

A checklist was prepared for the trailer units and utilized to insure safety and increase transport efficiency. Basically, all nuts and bolts including lug nuts on the wheels were tightened, regulators and valves were checked for proper oxygen exchange, and piping was checked for cracks and leaks.

2.0 RESULTS

2.1 Relative Abundance (West Lift)

The relative abundance of fishes has fluctuated since 1972 at the West Lift (Table 2). 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.

A total of 533,054 fish of 42 taxa and 3 hybrids was caught in 63 days of operation in 1991 (Table 3). Predominant species in order of numerical abundance were gizzard shad, comely shiner, blueback herring, white perch, American shad, and channel catfish. Alosids (blueback herring, alewife, hickory shad, and American shad) comprised 5.9% of the total catch. The catch of gizzard shad was less than half of that observed in 1990, and the lowest recorded since 1980 (Table 2). Gizzard shad dominated the catch daily from 1 April through 7 June and comprised over 81% of the total catch. The daily catch of fish ranged from 141 on 5 April to 50,405 on 14 April.

2.1.1 Relative Abundance (East Lift)

In 60 days of operation at the East Lift, 650,945 fish of 37 taxa and 4 hybrids were caught (Table 4). Predominant species in order of numerical abundance were gizzard shad, common carp, American shad, blueback herring, and comely shiner. Alosids (blueback herring, alewife, and American shad) comprised 4.2% of the total catch. No hickory shad were captured at the East Lift. Gizzard shad dominated the catch daily from 9 April to 11 May and from 13 May to 29 May and comprised 88.4% of the total catch. Common carp were abundant in the daily catch from 17 May to 3 June and were a major nuisance during lift operations. The daily catch of fish ranged from 12 on 8 April to 58,184 on 16 April.

2.2 American Shad Catch (West Lift)

The catch of American shad (13,330) at the West Lift was the second highest recorded (Table 2). Some 10,183 shad were transported. There were 525 shad released back to the tailrace. The remainder consisted of MD DNR recaptures, handling and holding mortalities, and those sacrificed.

A total of 76 shad died during daily operation of the Lift. Mortalities resulted from mechanical operation of the Lift, handling, and holding procedures. This level of mortality is consistent with that observed in past years.

American shad were first taken on 9 April (Table 3 and Figure 3). Most shad (7,426) were collected from 4 through 19 May (Table 3) and when both weir gates were open (Table 5).

As in the past, the catch per effort (CPE) of American shad varied by station generation, weekend or week day, and time of day (Table 6). The CPE was 35.7 and 20.1 on weekends and weekdays, respectively. Generally, catches were greatest between 1100 and 1900 hrs with the highest catches occurring from 1500 to 1900 hrs.

The CPE in April was similar for periods of two unit and higher generation (Table 7). The May CPE during periods of two unit generation was 59.1% higher than during periods of higher generation. Overall CPE, regardless of generation status, was nearly twice as high in May than it was in April, representative of the peak of the shad run during the month of May. June CPE is presented in Table 7, but is not discussed because of the small sample size.

The highest daily American shad catch (1,000) occurred on 19 May (Table 3), and combined with the 891 taken on 18 May represented 14.2% of the 1991 total.

American shad were collected at water temperatures of 51.8 to 84.2 F and at natural river flows of 9,100 to 104,000 cfs

(Table 3 and Figure 3). Nearly 90% of the catch occurred when river flows were less than 50,000 cfs.

Over 66% of the shad were collected at water temperatures <65 F (Table 8). Water temperatures during the period of peak shad abundance (29 April to 19 May) ranged from 57.9 to 71.8 F (Table 3). Water temperatures from 20 May to 1 June, a period of decreased river flow and decreased shad catch, ranged from 71.6 to 81.5 F.

2.2.1 American Shad Catch (East Lift)

During its first year of operation, 13,897 American shad were captured at the East Lift (Table 4); over 70% were transported. A total of 1,162 shad was released back to the tailrace. The remainder consisted of MD DNR recaptures, handling and holding mortalities, and those sacrificed.

A total of 17 shad died during daily operation of the East Lift. Mortalities resulted from mechanical operation of the lift, handling, or holding procedures.

American shad were first captured on 8 April, the first day of operation (Table 4). From 8 to 27 April, a total of 2,648 shad was collected. Most shad (10,213) were collected from 28 April to 18 May. For the period 19 May to 7 June (final day of lift operation), 1,036 American shad were collected.

During the season, a total of 8,783 American shad was collected when only the downstream weir gate was open and Units 10 and 11 were operating (Table 9).

During East Lift operations, modified weir gate openings and operation "Fast Fish" were utilized at various times to decrease the catch of gizzard shad and common carp and increase the American shad catch. From 18 May to 3 June, common carp were extremely plentiful near the East Lift, making it difficult to exclude them from the catch and efficiently collect American shad.

The catch per effort (CPE) of American shad at the East Lift varied by station generation, weekend or week day, and time of day (Table 10). The overall CPE was slightly lower on weekdays (23.5) than on weekends (27.9). Generally, during both periods catches were greatest between 1100 and 1900 hrs with the highest catches occurring from 1500 to 1900 hrs.

The CPE in April during periods of increased generation (three or more units) was 8.4 times greater than during two unit generation (Table 11). A similar situation existed in May, but the difference was only 1.9 times. The overall CPE in May, regardless of generation status, was 1.6 times greater than in April. The CPE for June is presented in Table 11 but is not discussed because of the small sample size.

The highest daily American shad catch (1,088) occurred on 2 May (Table 4), and combined with the 833 taken on 10 May represented nearly 14% of the 1991 total.

American shad were collected at water temperatures of 53.3 to 83.3 F and at natural river flows of 9,100 to 104,000 cfs (Table 4 and Figure 4).

Over 66% of the shad were collected at water temperatures ≤65 F (Table 8). Water temperatures during the period of peak shad abundance at the East Lift (28 April to 18 May) ranged from 55.4 to 72.5 F (Table 4). Water temperatures from 19 May to 7 June, a period of decreasing river flow and shad catch, generally increased and ranged from 71.6 to 83.3 F.

2.3 Sex Ratios (East and West Lifts)

Visual macroscopic inspection of American shad was made to determine daily and seasonal sex ratios at each lift. Differences in sex ratios between the lifts were inconsequential and were pooled for discussion. Generally, when the daily catch exceeded 100 shad, a minimum subsample of 100 fish per lift was examined; when the daily catch was less than 100 shad all were examined. In 1991, 5,030 shad were examined at the West Lift and 4,294 at the East Lift. The daily sex ratios are provided in Table 12. The combined male/female ratio observed in 1991 was 1.5:1. Males comprised 68.4% of the total catch in April and 54.9% in May and June.

2.4 Age Composition (East and West Lifts)

Scale samples from more than 900 American shad were collected in 1991 (Table 13). Scale samples were obtained from shad sacrificed for otolith and DNA analyses, and from transport and handling mortalities.

Over 97% of the scale samples collected in 1991 were aged. Males were III to VII years old while females were IV to VIII years old (Table 13). Most males (80.0%) and females (76.3%)

were V and VI years old. Sixty-four of 435 (14.7%) males were single repeat spawners; nine were double repeat spawners. Fifty-one of 502 (10.2%) females were single repeat spawners; 11 were double repeat spawners. The overall repeat spawners were 14.4%.

2.5 Tag-Recapture (East and West Lifts)

Including multiple recaptures, RMC recovered 274 MD DNR tagged American shad in 1991; 121 at the East Lift and 153 at the West Lift (Table 14). The MD DNR tagged 1,037 shad; 641 from pound nets in the upper Chesapeake Bay and 396 by hook and line in the Conowingo tailrace. Of the 184 first time MD DNR recaptures 117 were tagged in the tailrace and 67 in the upper Bay. The 67 tagged in the upper Bay averaged 23.0 days free before capture while those tagged and recaptured in the tailrace averaged 10.4 days free.

2.6 Other Alosids (East and West Lifts)

The combined catch of river herring (blueback herring and alewife) from both lifts was 31,737. Although the combined 1991 catch of river herring was higher than the catch in recent years at the West Lift, it remained below historic levels (Table 2).

A combined total of 28,765 blueback herring was collected (Tables 3 and 4). Blueback herring typically arrive later than alewife and were first collected on 26 April at the West Lift. Nearly 60% of the catch occurred on 12 May, and they were common from 26 April to 27 May at water temperatures ranging from 51.8 to 77.0 F.

A combined total of 2,972 alewife was collected, with the first taken on 3 April at the West Lift (Tables 3 and 4). More than 89% of the alewife were captured at the West Lift. Nearly 78% of the catch occurred between 25 April and 7 May at water temperatures ranging from 51.8 to 63.9 F.

The hickory shad catch (120) continued to be low although the 1991 catch represents the highest total since 1974 (Table 2). The first hickory shad was taken on 11 April at the West Lift (Table 3); all 120 were captured at the West Lift. Nearly 81% of the total catch was collected from 13 to 24 April at water temperatures ranging from 53.3 to 59.0 F.

2.7 Transport of American Shad and Herring

2.7.1 West Lift

Pre-spawned American shad were transported from 10 April through 31 May. Over 76% of the American shad catch was transported to upstream spawning areas with an overall observed stocking survival of 98.9% (Table 15). Some 7,460 American shad were stocked directly to the Susquehanna River at Tri-County, and 2,339 were stocked at the PFBC access at Swatara Creek. Additionally, 11 went to the USFWS laboratory at Wellsboro, 280 shad were transported to the RMC Muddy Run Ecological Laboratory at Drumore, Pennsylvania for artificial spawning studies, and 104 went to the PFBC Muddy Creek Access, Delta, Pennsylvania.

Transportation of shad occurred on 38 days and was ccomplished in 63 trips (Table 15). The number of trips per day anged from one to four; load size varied from 16 to 280 shad per trip. Trip survival ranged from 87.3 to 100%. Shad were transported at water temperatures of 53.3 to 80.6 F.

The holding facilities were utilized to maximize transport operations and release larger schools of fish. Some 258 shad were held over in 1991. A total of 34 shad died in the holding tanks.

2.7.2 East Lift

Prespawned American shad were transported from the East Lift from 10 April through 27 May. Some 9,738 American shad were transported to upstream spawning areas with an overall observed stocking survival of 96.6% (Table 16). Some 8,247 American shad were stocked directly to the Susquehanna River at Tri-County, 1,270 stocked at Swatara Creek when high river flow or heavy recreational usage prevented access to Tri-County, and 221 shad were stocked in Conowingo Pond at Glen Cove Marina, Darlington, Maryland.

Transportation of shad occurred on 30 days and was accomplished in 53 trips (Table 16). The number of trips per day ranged from one to four; load size varied from 75 to 244 individuals per trip. Trip survival ranged from 76.9 to 100%. Shad were transported at water temperatures of 53.6 to 73.4 F.

Holding facilities were not utilized at the East Lift due to limited space. American shad were either transported to the West Lift for holding or combined with shad captured at the West Lift and transported to upstream release sites.

2.7.3 Combined Transport

Shad captured at both lifts were combined and placed into single transport unit when shad numbers were not sufficient to facilitate a separate transport. Some 3,861 American shad were transported upstream from combined transports (Table 17). Combined transports occurred on 21 days and were accomplished i 25 trips. From these combined transports, 3,502 shad were released at Tri-County, 241 at the Swatara Creek access, and 118 shad were released into Conowingo Pond at the PFBC Muddy Creek Access. Load size varied from 37 to 276 individuals and the trip survival ranged from 77.5 to 100%.

2.7.4 Combined River Herring Transport

During 1991, a total of 4,001 river herring (12.6% of total catch) was transported to upstream release sites in the Susquehanna River (Table 18). The transports included 1,396 alewife and 2,605 blueback herring. Herring were transported between 10 April and 20 May with 100% survival.

A total of 703 blueback herring was transported to three Chesapeake Bay tributaries by the MD DNR (Table 19). The overall stocking survival was 99.0%. The Patapsco River, Big Elk Creek, and Winters Run received stockings that totaled 447, 169, and 87 blueback herring, respectively. Transport was accomplished in ne trips. Load size varied from 17 to 281 fish, and survival ranged from 97.5 to 100%.

2.8 Net Pen

An experimental instream net pen was deployed at the Tri-County Boat Club Marina in 1991. Materials and methods utilized during the net pen study were the same as those described in Job 1A of the 1990 Annual Progress Report.

Due to high river flows in April, the net pen was not installed until mid-May. Ten transport/stocking events occurred between 15 and 29 May (Table 20). A total of 1,160 pre-spawned American shad was transported; loads transported ranged from 56 to 144 fish. Transport survival by trip ranged from 61.7 to 100%; total transport survival was 90.6%. The delayed mortality ranged from 1.6 to 69.0%; overall delayed mortality was 21.2% which included the 69% mortality observed on 27 May. This high mortality appeared related to: high water temperature at time of stocking (82.4 F), large amounts of debris found in and around the net pen, and very shallow water depth in the pen (ave. depth 23.7 in). Low water levels inside the net pen were documented from 24 through 28 May.

Dissolved oxygen values ranged from 5.8 to 10 ppm over the course of the penning program and averaged 8.0 ppm. Water temperatures ranged from 65.3 to 83.3 F and averaged 74.5 F.

2.9 Delayed Transport Mortality

In 1991 some problems were encountered with the trailer units used to haul American shad from the East Lift to upstream locations. In the course of addressing these problems dead shad were observed at the release sites, particularly Tri-County.

A program was instituted on 10 May to monitor and collect any dead shad at least three times weekly. This program began in mid-May and continued through 1 June 1991. Two biologists searched the shoreline above and below the marina for evidence of dead or dying fish. Although these efforts resulted in the recovery of several hundred dead shad this represented <5% of the total shad transported.

Several steps were taken to address the unexpected number of delayed mortalities. A study performed by Dr. Eric May during East Lift transport operations indicated that some shad mortality was associated with oxygen supersaturation (personal communication). Modifications to the trailer units were made in an effort to improve transport survival through the elimination of supersaturation problems, obstructions, and excessive vibration (see Section 1.5). An assessment of these modifications was not completed as higher water temperatures and a decline in the spawning run eliminated additional transports. Because of the changes that were implemented high transport mortality is not expected in 1992.

2.10 Trough Operation

Operation of the trough at the East Lift occurred on 12 April and 24 May. On 12 April, two loads of fish were released into the trough. The velocity in the flume was 1.1 ft/sec. A technician positioned at the viewing window recorded the species and number of fish as they passed. A total of 600 gizzard shad was observed.

Two hours after releasing the second load of fish, the trough was drained. A total of 12 gizzard shad and one shorthead redhorse was removed.

On 24 May, the trough was operated for nine hours and 11 loads of fish were released. A total of 2,909 fish, mostly gizzard shad (2,153), common carp (475), and quillback (107), was observed (Table 21). Thirteen American shad were also observed to exit the trough.

The trough was drained at 1915 hrs, approximately 1,000 fish (mostly common carp) remained in the flume. About 95% of the remaining fish were located downstream of the counting window.

Since fish remained in the trough, it was refilled and the butterfly valve opened slightly to provide a flow. All gates in the counting area were opened. Subsequent draining of the trough the next morning showed all but 20 common carp and 15 American shad had exited the flume into Conowingo Pond during the night. The 35 remaining fish were bucketed out and released to the tailrace.

3.0 DISCUSSION

The run of American shad is primarily dictated by natural river flow and water temperature. The catch at the Fish Lifts was primarily dictated by variations in station discharge (peak load vs. reduced generation), natural river flow, and water temperature.

A combination of several factors contributed to the large overall catch of 27,227 shad. The primary reasons were an eased shad population, modification of station operation ts 1 and 2 off when river flows were less than 65,000 cfs), the operation of two lifts.

The combined American shad CPE in 1991 (24.6 fish/hr) was .ghtly lower than the record observed in 1990 (27.5). However, nce numerous factors affect the catch of shad these data denote ly general trends.

A comparison of the total catch, species composition, and PE between the East and West Fish Lift facilities revealed .ittle difference (Tables 3 and 4). Gizzard shad was the most abundant species comprising over 81% of the total catch at each lift. Other species accounting for >1.0% of the combined catch were common carp, comely shiner, blueback herring, American shad, and white perch. The CPE of these species revealed that the blueback herring, comely shiner, and white perch were more abundant at the West Lift. Although the overall CPE differences were small, some species were much more common at a particular lift. For example, gizzard shad and common carp were more abundant at the East Lift; channel catfish and white perch were common at the West Lift.

The operation of the Conowingo Hydroelectric Station influenced the catch of some species, most notably American shad at a particular Lift. The catch of American shad at the West Lift was influenced by the generation status of Units 1 and 2. Over 91% of the American shad collected at the West Lift occurred when Units 1 and 2 were shutdown (Table 22). The gizzard shad catch was generally higher at the East Lift, except during periods when Units 1 and 2 were in operation. The catch of American shad at the East Lift was affected by the operation of Units 10 and 11. Unlike the West Lift, the catch of American shad increased when Units 10 and 11 were in operation. Nearly 70% of the American shad collected at the East Lift occurred during the operation of Units 10 and 11.

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Table 1. List of scientific and common names of fishes collected at the Conowingo Dam Fish Lifts, 1972 through 1991.

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 mykiss	Rainbow trout
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
S. fontinalis x S. namaycush	Splake
Family - Osmeridae	Smelts
Osmerus mordax	Rainbow smelt
Family - Esocidae	Pikes
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Esox niger	Chain pickerel
E. masquinongy x E. lucius	Tiger muskie
Family - Cyprinidae	Carps and Minnows
Carassius auratus	Goldfish
Cyprinius carpio	Common carp
Nocomis micropogon	River chub
Notemigonus crysoleucas	Golden shiner

Table 1. Continued.

Scientific Name	Common Name
Notropis amoenus	Comely shiner
Notropis hudsonius	Spottail shiner
Notropis procne	Swallowtail shiner
Notropis rubellus	Rosyface shiner
Notropis spilopterus	Spotfin shiner
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	Bullhead catfishes
Ictalurus catus	White catfish
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Noturus insignus	Margined madtom
Noturus gyrinus	Tadpole madtom
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. Continued.

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

TABLE 2

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM WEST FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1991.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
NO. DAYS	54	62	58	55	63	61	35	29	30	37
NO. OF LIFTS	817	1,527	819	514	684	707	358	301	403	490
OPERATING 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
NO. OF TAXA	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	275736	1156662
ATLANTIC MENHADEN	-	-	112	-	506	1596	-	-	16	42
TROUTS	1	-	-	-	-	-	-	-	-	2
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
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-	-	-
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	-	-	-	-	-	-	-	-	-	-
GOLDFISH	-	27	1	9	4	1	-	-	-	1
COMMON CARP	4370	16362	34383	15114	6755	16256	11842	14946	8879	18313
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	761	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 (NOTROPIS SPP)	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	6533
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

TABLE 2 CONTINUED.

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
NO. DAYS	44	29	34	55	59	60	63	51	64	63
NO. OF LIFTS	725	648	519	1,118	831	1,414	1,339	1,117	1,363	1,257
OPERATING TIME(HR)	502	299	251	542	546	639	637	539	664	681
FISHING TIME(HR)	336	224	192	421	449	532	513	457	571	547
NO. OF TAXA	46	40	35	41	43	46	49	45	43	45
AMERICAN EEL	3961	1080	155	550	364	1662	103	157	224	213
BLUEBACK HERRING	25249	517	311	6763	6327	5861	14570	3598	9658	15616
HICKORY SHAD	15	5	6	9	45	35	64	28	77	120
ALEWIFE	3433	50	26	379	2822	357	674	1902	425	2649
AMERICAN SHAD	2039	413	167	1546	5195	7667	5146	8218	15719	13330
GIZZARD SHAD	1226374	950252	912666	2182888	1714441	2488618	1402565	926213	1084073	433108
ATLANTIC MENHADEN	-	1	-	1	-	-	-	-	-	-
TROUTS	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	20	2	5	70	9	14	10	4	14	13
BROWN TROUT	219	225	141	175	65	83	85	110	63	82
BROOK TROUT	5	2	-	1	-	-	1	1	-	7
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	1	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	1	1	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	1	-	6
NORTHERN PIKE	5	1	-	-	2	-	-	-	-	5
MUSKELLUNGE	4	-	-	15	-	-	1	-	2	2
REDFIN PICKEREL	-	-	-	-	-	1	-	-	-	-
GOLDFISH	-	-	-	-	-	-	1	1	-	-
COMMON CARP	15362	16273	8012	6729	2930	4607	8535	875	2761	8257
RIVER CHUB	-	-	-	-	-	-	-	-	-	-
GOLDEN SHINER	92	216	8	292	23	40	28	5	2	7
COMELY SHINER	14214	3176	871	5141	582	21199	11734	35239	5798	18356
SPOTTAIL SHINER	315	2132	-	3525	6247	155	55	282	112	635
SWALLOWTAIL SHINER	-	-	-	-	1	-	-	-	-	-
ROSYFACE SHINER	8	-	-	-	-	-	-	-	-	-
SPOTFIN SHINER	622	501	-	2695	695	796	65	5381	135	2508
BLUNTNOSE MINNOW	-	-	-	-	-	-	65	-	-	-
BLACKNOSE DACE	2	-	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	1	-	-	-
SHINERS (NOTROPIS SPP)	7	-	-	-	-	-	-	-	-	-
QUILLBACK	1617	4679	1942	957	2327	1881	1578	170	1270	2990
WHITE SUCKER	582	412	109	776	853	263	540	410	161	113
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	2871
WHITE CATFISH	565	224	77	1094	284	917	3849	1740	560	1284
YELLOW BULLHEAD	61	10	7	21	35	41	80	445	32	25
BROWN BULLHEAD	338	179	69	461	134	163	345	402	108	260

TABLE 2 CONTINUED.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
NO. DAYS	54	62	58	55	63	61	35	29	30	37
NO. OF LIFTS	817	1,527	819	514	684	707	358	301	403	490
OPERATING 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
NO OF TAXA	40	43	42	41	38	40	44	37	42	48
CHANNEL CATFISH	61042	55084	75663	74042	41508	90442	48575	38251	38929	55528
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	-
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
SUNFISHES (LEPOMIS SPP)	-	-	-	-	-	-	-	-	-	-
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
TESSELLATED DARTER	-	1	4	1	-	-	1	-	-	2
BANDED DARTER	-	-	-	-	-	-	1	-	-	-
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
ATLANTIC NEEDLEFISH	1	-	-	1	-	-	-	-	-	2
SEA LAMPREY	-	2	-	2	29	11	1	3	1	55
LAKE HERRING	-	1	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	-	-	-	-	-	270	273	2674	39
TIGER MUSKIE	-	-	-	-	-	-	13	132	34	53
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-	-	-
TOTAL	241419	1300345	1617888	917043	1175616	1169161	276045	197769	372379	1353308

TABLE 2 CONTINUED.

YEAR	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
NO. DAYS	44	29	34	55	59	60	63	51	64	63
NO. OF LIFTS	725	648	519	1,118	831	1,414	1,339	1,117	1,363	1,257
OPERATING TIME(HR)	502	299	251	542	546	639	637	539	664	681
FISHING TIME(HR)	336	224	192	421	449	532	513	457	571	547
NO. OF TAXA	46	40	35	41	43	46	49	45	43	45
CHANNEL CATFISH	40941	12559	20479	15200	18898	11699	36212	21692	8689	10252
MARGINED MADTOM	7	-	-	-	3	-	1	-	-	-
TADPOLE MADTOM	1	-	-	-	-	-	-	1	-	1
MUMMICHOG	1	-	-	-	-	-	-	-	-	-
WHITE PERCH	53527	23151	6402	68344	56977	29995	90651	15713	24581	14996
STRIPED BASS	60	23	181	213	194	1337	874	357	1068	1682
ROCK BASS	138	269	158	122	200	231	110	352	39	53
REDBREAST SUNFISH	1335	401	465	3366	1433	1471	730	443	187	281
GREEN SUNFISH	91	16	7	133	15	64	19	33	17	22
PUMPKINSEED	848	228	104	1013	402	490	135	115	46	48
BLUEGILL	1184	587	284	6048	1654	2436	1107	1561	446	486
SUNFISHES (LEPOMIS SPP)	-	-	-	-	-	-	-	-	2	-
SMALLMOUTH BASS	1095	1003	608	1081	666	536	548	491	424	704
LARGEMOUTH BASS	20	17	8	67	75	69	117	164	48	176
WHITE CRAPPIE	303	450	59	345	199	272	125	230	33	106
BLACK CRAPPIE	39	46	6	45	51	19	42	45	22	22
TESSELLATED DARTER	-	-	-	1	-	1	1	-	-	6
BANDED DARTER	-	-	-	-	-	1	-	-	2	10
YELLOW PERCH	724	387	487	2145	2267	632	815	310	124	502
LOGPERCH	-	-	-	1	1	1	2	-	2	1
SHIELD DARTER	-	-	-	-	-	-	-	-	-	-
WALLEYE	504	663	236	609	380	267	311	319	460	411
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	2	-	5	-
SEA LAMPREY	56	10	4	164	26	21	59	94	38	34
LAKE HERRING	-	1	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	2	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	1	-	-
STRIPED BASS X WHITE BASS	160	355	282	1377	1713	5895	6203	5243	1172	797
TIGER MUSKIE	56	16	10	73	35	30	20	33	10	5
BROOK TROUT X LAKE TROUT	-	-	2	-	2	5	-	1	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	10	19	1	3	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-	-	2
TOTAL	1403175	1028090	957821	2317797	1830641	2593445	1592965	1035121	1162841	533054

TABLE 3

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM WEST LIFT, 1 APRIL THROUGH 7 JUNE 1991.

DATE	01 APRIL	03 APRIL	05 APRIL	07 APRIL	09 APRIL	10 APRIL	11 APRIL	12 APRIL
LOCATION	641	641	641	641	641	641	641	641
NO. OF LIFTS	6	9	9	11	16	18	15	14
FIRST LIFT	953	657	640	602	600	617	601	600
LAST LIFT	1230	1300	1300	1200	1745	1800	1750	1742
OPERATING TIME (HR)	2.62	6.05	6.33	5.97	11.75	11.72	11.82	11.70
FISHING TIME (HR)	4.95	5.08	5.48	4.83	9.58	9.35	11.88	9.73
AVE RIVER FLOW (CFS)	59400	44700	42800	40500	35200	32200	33200	33700
AVE WATER TEMP (F)	50.0	49.3	50.4	50.9	55.4	57.5	56.9	58.1
AMERICAN EEL	1	2	1	-	-	1	7	12
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	-	-	-	4	1
ALEWIFE	-	1	-	-	15	361	22	6
AMERICAN SHAD	-	-	-	-	99	71	52	176
GIZZARD SHAD	7826	1325	107	5865	4273	4204	4183	7905
RAINBOW TROUT	-	-	-	-	1	-	-	1
BROWN TROUT	-	-	1	2	2	-	-	1
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	1	-	-	1	-	-	-
COMMON CARP	-	2	2	-	-	1	-	1
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	120	-	60	425	256	278	-
SPOTTAIL SHINER	-	60	-	4	58	74	62	24
SPOTFIN SHINER	-	20	-	-	-	-	-	-
QUILLBACK	-	-	2	3	-	-	-	-
WHITE SUCKER	1	-	-	1	6	63	2	1
SHORTHEAD REDHORSE	-	-	-	2	19	31	5	20
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	1	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	161	25	9	44	266	219	110	111
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	-	-	-	-	-	-	-	10
STRIPED BASS	-	-	-	-	3	-	-	1
ROCK BASS	1	-	-	-	2	2	-	1
REDBREAST SUNFISH	-	-	-	-	2	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	1	1	-
BLUEGILL	-	2	-	2	2	5	35	26
SMALLMOUTH BASS	-	-	1	6	13	7	20	6
LARGEMOUTH BASS	-	-	1	3	11	6	1	2
WHITE CRAPPIE	-	-	-	-	-	1	-	-
BLACK CRAPPIE	-	-	-	-	-	1	-	-
TESSELLATED DARTER	-	-	1	1	1	-	2	-
BANDED DARTER	-	-	-	-	-	4	1	-
YELLOW PERCH	3	21	13	30	38	36	18	18
LOGPERCH	-	-	1	-	-	-	-	-
WALLEYE	-	-	-	-	1	7	10	4
SEA LAMPREY	1	-	-	1	1	-	1	-
STRIPED BASS X WHITE BASS	1	1	2	23	29	6	1	5
TIGER MUSKIE	-	1	-	1	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
TOTAL	7995	1581	141	6048	5268	5357	4816	8332

TABLE 3 CONTINUED.

DATE	13 APRIL	14 APRIL	15 APRIL	16 APRIL	17 APRIL	18 APRIL	19 APRIL	20 APRIL
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	21	23	20	24	9	20	22	20
FIRST LIFT	603	601	601	600	1340	600	601	602
LAST LIFT	1800	1746	1747	1740	1748	1750	1753	1730
OPERATING TIME (HR)	11.95	11.75	11.77	11.67	4.13	11.83	11.87	11.47
FISHING TIME (HR)	8.90	9.42	12.30	10.17	3.58	9.38	10.32	8.82
AVE RIVER FLOW (CFS)	36400	39900	36400	35300	36000	37200	40300	38200
AVE WATER TEMP (F)	57.6	53.3	59.0	53.8	57.2	56.7	55.4	55.6
AMERICAN EEL	-	3	-	3	1	1	3	1
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	13	23	4	1	4	-	-	-
ALEWIFE	-	7	1	9	8	4	2	6
AMERICAN SHAD	200	235	96	212	72	171	268	396
GIZZARD SHAD	12663	49930	3025	13475	750	6010	3442	6545
RAINBOW TROUT	-	1	-	1	-	-	-	-
BROWN TROUT	1	2	3	1	-	2	-	2
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
NORTHERN PIKE	-	-	-	5	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	-	3	1	4	1	2	1	-
GOLDEN SHINER	-	-	1	-	-	-	-	-
COMELY SHINER	-	-	-	2	-	-	-	-
SPOTTAIL SHINER	1	34	8	29	12	27	8	6
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	-	-	-	-
WHITE SUCKER	2	3	2	3	1	-	-	-
SHORTHEAD REDHORSE	8	6	5	4	1	17	18	42
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	2	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	15	38	36	3	2	151	3	44
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	1	3	9	8	2	2	20	8
STRIPED BASS	-	1	-	-	-	2	2	-
ROCK BASS	3	3	-	1	-	1	-	1
REDBREAST SUNFISH	-	1	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	1	-	-	-	1	-
BLUEGILL	7	6	6	4	17	3	1	2
SMALLMOUTH BASS	18	33	4	12	2	7	7	10
LARGEMOUTH BASS	4	5	1	7	-	-	1	1
WHITE CRAPPIE	1	3	-	-	1	1	2	-
BLACK CRAPPIE	-	2	-	-	3	1	1	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	1	-	1	-	-	-	-	-
YELLOW PERCH	40	15	15	6	11	7	4	6
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	8	8	4	1	3	2	2	8
SEA LAMPREY	1	1	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	6	39	11	4	5	22	67	22
TIGER MUSKIE	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
TOTAL	12995	50405	3234	13795	896	6433	3853	7100

TABLE 3 CONTINUED.

DATE	21 APRIL	22 APRIL	23 APRIL	24 APRIL	25 APRIL	26 APRIL	27 APRIL	28 APRIL
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	25	20	25	22	25	24	30	28
FIRST LIFT	601	600	602	600	607	605	601	600
LAST LIFT	1753	1751	1754	1755	1756	1608	1759	1748
OPERATING TIME (HR)	11.87	11.85	11.87	11.92	11.82	10.05	11.97	11.80
FISHING TIME (HR)	10.05	7.77	10.98	9.65	8.73	6.18	9.73	8.87
AVE RIVER FLOW (CFS)	38400	38300	51500	86100	104000	101500	92500	78800
AVE WATER TEMP (F)	55.7	55.4	55.0	54.0	53.4	51.8	53.1	57.2
AMERICAN EEL	2	-	4	2	-	1	-	1
BLUEBACK HERRING	-	-	-	-	-	52	160	449
HICKORY SHAD	40	5	3	4	-	2	-	2
ALEWIFE	7	6	1	60	101	87	146	309
AMERICAN SHAD	242	175	179	246	37	17	34	99
GIZZARD SHAD	14750	8325	8430	10105	16971	22300	33605	12905
RAINBOW TROUT	1	-	-	-	-	1	-	-
BROWN TROUT	2	1	1	4	4	2	1	3
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	1	-	2	3	4	17	18	68
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	1	-	1	-	-	-	-	-
SPOTTAIL SHINER	-	-	5	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	-	-	-	1
WHITE SUCKER	-	-	3	-	-	-	-	1
SHORTHEAD REDHORSE	146	71	31	36	35	83	227	340
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	1	-	-	-	-	-	-	-
CHANNEL CATFISH	53	3	13	5	3	3	20	82
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	42	59	37	3	28	21	36	391
STRIPED BASS	2	3	8	10	4	9	11	78
ROCK BASS	-	-	1	-	-	-	-	2
REDBREAST SUNFISH	1	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	2	3	5	-	-	-	-	1
SMALLMOUTH BASS	20	6	6	19	8	8	23	13
LARGEMOUTH BASS	7	1	3	-	1	-	1	2
WHITE CRAPPIE	2	2	-	-	-	-	3	-
BLACK CRAPPIE	2	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	1	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	5	3	1	2	-	2	2	10
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	10	6	2	5	6	3	3	4
SEA LAMPREY	3	1	1	-	1	-	7	2
STRIPED BASS X WHITE BASS	52	25	7	58	32	33	37	34
TIGER MUSKIE	1	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
TOTAL	15395	8695	8744	10562	17236	22641	34334	14797

TABLE 3 CONTINUED.

DATE	29 APRIL	30 APRIL	02 MAY	03 MAY	04 MAY	05 MAY	06 MAY	07 MAY
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	25	19	23	17	27	24	20	24
FIRST LIFT	608	600	610	610	601	601	600	600
LAST LIFT	1734	1746	1751	1750	1800	1800	1754	1800
OPERATING TIME (HR)	11.43	11.77	11.68	11.67	11.98	11.98	11.90	12.00
FISHING TIME (HR)	8.78	8.78	10.92	9.40	10.00	10.38	8.55	10.18
AVE RIVER FLOW (CFS)	63000	58000	45600	42400	43200	38300	39200	40400
AVE WATER TEMP (F)	58.9	57.9	59.9	60.1	61.7	62.1	62.1	61.7
AMERICAN EEL	-	7	2	1	2	2	16	5
BLUEBACK HERRING	42	68	65	-	6	1497	697	829
HICKORY SHAD	1	1	1	1	-	-	-	-
ALEWIFE	224	89	31	80	54	638	161	212
AMERICAN SHAD	380	404	272	55	527	625	483	594
GIZZARD SHAD	19165	4530	8640	719	10605	8190	3415	11560
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	5	1	9	3	1	3	2	1
BROOK TROUT	-	-	-	-	1	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	40	1	3	2	1	700	-	11
GOLDEN SHINER	-	-	-	-	-	-	-	1
COMELY SHINER	-	7	1	-	31	2351	-	20
SPOTTAIL SHINER	-	-	20	-	-	43	-	-
SPOTFIN SHINER	-	-	-	5	-	-	-	-
QUILLBACK	6	1	1	-	-	4	-	-
WHITE SUCKER	1	1	-	2	-	2	-	-
SHORTHEAD REDHORSE	598	179	139	33	54	85	37	57
WHITE CATFISH	-	1	4	-	-	1	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	2	1
BROWN BULLHEAD	-	-	2	2	1	1	-	8
CHANNEL CATFISH	507	334	40	67	12	8	14	6
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	383	314	169	421	487	2265	915	1158
STRIPED BASS	39	13	12	9	9	39	11	33
ROCK BASS	2	2	2	1	2	2	1	7
REDBREAST SUNFISH	-	1	3	3	1	1	4	11
GREEN SUNFISH	-	1	1	2	-	-	-	2
PUMPKINSEED	1	2	7	4	1	1	4	4
BLUEGILL	2	4	14	12	22	26	9	12
SMALLMOUTH BASS	29	22	76	23	27	70	8	16
LARGEMOUTH BASS	-	4	11	2	4	27	1	5
WHITE CRAPPIE	8	3	9	2	3	17	1	1
BLACK CRAPPIE	1	3	3	1	-	-	2	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	1	-	-	-	-	-
YELLOW PERCH	26	2	18	3	8	27	10	17
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	7	8	4	7	8	18	9	16
SEA LAMPREY	1	-	-	-	2	1	1	-
STRIPED BASS X WHITE BASS	32	4	12	3	16	11	5	13
TIGER MUSKIE	-	-	-	-	-	-	-	1
SUNFISH HYBRIDS	-	-	1	-	-	-	-	-
TOTAL	21500	6007	9573	1463	11885	16655	5808	14601

TABLE 3 CONTINUED.

DATE	08 MAY	09 MAY	10 MAY	11 MAY	12 MAY	13 MAY	14 MAY	15 MAY
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	19	18	20	26	30	19	18	23
FIRST LIFT	603	631	600	601	601	759	604	601
LAST LIFT	1755	1756	1721	1744	1751	1758	1755	1800
OPERATING TIME (HR)	11.87	11.42	11.35	11.72	11.83	9.98	11.85	11.98
FISHING TIME (HR)	9.13	7.18	6.75	7.87	10.15	4.60	8.78	10.55
AVE RIVER FLOW (CFS)	41700	42300	43200	39500	38700	31600	31300	30900
AVE WATER TEMP (F)	62.6	62.6	63.5	64.4	65.3	66.2	66.2	65.9
AMERICAN EEL	1	7	4	4	4	3	5	3
BLUEBACK HERRING	393	645	186	2473	7306	137	316	29
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	1
AMERICAN SHAD	529	409	315	324	415	335	253	160
GIZZARD SHAD	6970	8120	5550	10245	5245	10660	8615	4100
RAINBOW TROUT	-	-	-	-	2	-	-	-
BROWN TROUT	2	-	2	2	-	1	-	6
BROOK TROUT	-	-	-	-	-	-	2	-
CHAIN PICKEREL	-	-	1	-	1	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	2	8	5	3	-	554	29	58
GOLDEN SHINER	2	-	-	2	-	-	1	-
COMELY SHINER	-	92	10	345	510	147	-	982
SPOTTAIL SHINER	-	-	5	-	-	-	100	47
SPOTFIN SHINER	-	-	-	-	45	-	15	34
QUILLBACK	-	5	-	1	2	37	21	18
WHITE SUCKER	-	1	5	1	-	-	-	3
SHORTHEAD REDHORSE	48	51	51	19	61	51	87	51
WHITE CATFISH	-	1	2	19	11	15	3	9
YELLOW BULLHEAD	-	1	1	-	1	1	-	-
BROWN BULLHEAD	1	5	30	21	2	1	8	8
CHANNEL CATFISH	28	34	3	22	20	51	107	22
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	1865	1975	940	725	695	745	360	358
STRIPED BASS	24	8	22	10	9	13	7	14
ROCK BASS	1	3	2	4	-	-	1	-
REDBREAST SUNFISH	3	3	7	4	1	4	2	6
GREEN SUNFISH	-	1	2	1	-	-	-	-
PUMPKINSEED	3	2	3	-	-	1	1	1
BLUEGILL	20	21	21	21	6	24	16	18
SMALLMOUTH BASS	26	9	5	7	6	14	11	24
LARGEMOUTH BASS	6	1	-	6	7	3	6	8
WHITE CRAPPIE	8	5	1	10	2	2	6	-
BLACK CRAPPIE	-	-	-	1	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	21	11	6	6	5	3	6	5
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	12	16	8	8	4	20	8	3
SEA LAMPREY	3	2	-	-	1	-	-	1
STRIPED BASS X WHITE BASS	9	15	4	12	3	8	12	17
TIGER MUSKIE	-	-	1	-	-	-	-	-
SUNFISH HYBRIDS	-	1	-	-	-	-	-	-
TOTAL	9977	11452	7192	14296	14364	12830	9998	5986

TABLE 3 CONTINUED.

DATE	16 MAY	17 MAY	18 MAY	19 MAY	20 MAY	21 MAY	22 MAY	23 MAY
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	24	22	27	21	22	19	23	23
FIRST LIFT	601	602	603	600	600	600	600	600
LAST LIFT	1740	1753	1746	1752	1800	1800	1800	1801
OPERATING TIME (HR)	11.65	11.85	11.72	11.87	12.00	12.00	12.00	12.02
FISHING TIME (HR)	9.98	9.25	6.00	6.12	8.18	9.28	8.57	11.27
AVE RIVER FLOW (CFS)	29400	29100	25200	23900	21300	19100	20300	18700
AVE WATER TEMP (F)	69.3	69.9	71.8	71.6	72.7	71.6	73.4	72.9
AMERICAN EEL	2	5	4	1	3	4	-	2
BLUEBACK HERRING	63	55	51	17	16	47	6	2
HICKORY SHAD	-	-	-	-	-	-	-	9
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	419	147	891	1000	40	218	266	207
GIZZARD SHAD	6799	4150	8106	3680	3918	3112	2720	2811
RAINBOW TROUT	1	-	-	3	-	-	-	-
BROWN TROUT	1	3	1	-	1	-	-	1
BROOK TROUT	-	-	-	2	-	2	-	-
CHAIN PICKEREL	1	-	1	-	1	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	240	239	44	955	155	58	107	267
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	582	1600	2275	1653	680	123	65	60
SPOTTAIL SHINER	7	-	-	-	-	-	-	-
SPOTFIN SHINER	163	10	-	170	250	7	-	35
QUILLBACK	47	65	57	723	2	14	109	351
WHITE SUCKER	-	-	-	1	-	-	2	1
SHORTHEAD REDHORSE	65	39	10	1	3	2	2	-
WHITE CATFISH	1	-	10	-	101	10	31	44
YELLOW BULLHEAD	3	3	-	-	-	1	-	1
BROWN BULLHEAD	1	7	-	3	11	6	16	5
CHANNEL CATFISH	24	64	130	6	120	170	79	170
TADPOLE MADTOM	-	-	-	-	-	-	-	1
WHITE PERCH	108	118	122	31	25	67	12	8
STRIPED BASS	16	21	14	30	54	36	50	58
ROCK BASS	-	-	2	-	1	1	1	-
REDBREAST SUNFISH	3	7	13	8	16	13	6	5
GREEN SUNFISH	-	-	-	2	-	-	1	1
PUMPKINSEED	1	-	-	2	1	1	-	-
BLUEGILL	12	3	28	10	10	5	5	7
SMALLMOUTH BASS	13	12	13	4	7	8	2	5
LARGEMOUTH BASS	7	-	2	-	1	2	5	2
WHITE CRAPPIE	-	1	4	1	1	-	-	1
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	1
YELLOW PERCH	1	-	1	4	-	1	-	2
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	8	11	4	1	1	8	6	19
SEA LAMPREY	-	-	-	-	-	1	-	-
STRIPED BASS X WHITE BASS	20	11	7	8	6	8	3	1
TIGER MUSKIE	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
TOTAL	8608	6571	11790	8316	5424	3925	3494	4077

TABLE 3 CONTINUED.

DATE	24 MAY	25 MAY	26 MAY	27 MAY	28 MAY	29 MAY	30 MAY	31 MAY
LOCATION	641	641	641	641	641	641	641	641
NO OF LIFTS	20	22	21	21	20	22	21	22
FIRST LIFT	601	609	601	601	600	600	604	601
LAST LIFT	1755	1745	1745	1750	1755	1759	1750	1748
OPERATING TIME (HR)	11.90	11.60	11.73	11.82	11.92	11.98	11.77	11.78
FISHING TIME (HR)	10.03	10.12	10.03	10.05	10.68	10.62	10.47	10.42
AVE RIVER FLOW (CFS)	18400	17500	17600	17100	13400	14400	13500	13600
AVE WATER TEMP (F)	71.7	75.8	73.4	75.7	77.7	78.3	79.7	80.6
AMERICAN EEL	4	4	2	4	6	3	6	8
BLUEBACK HERRING	8	-	-	1	-	-	-	-
HICKORY SHAD	-	-	-	-	-	1	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	208	94	159	90	87	138	91	61
GIZZARD SHAD	2934	875	941	1180	661	423	405	454
RAINBOW TROUT	-	1	-	-	-	-	-	-
BROWN TROUT	1	-	-	1	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	1	-	-	-	-	-	-
NORTHERN PIKE	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	1323	70	552	1037	69	114	166	552
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	106	265	525	40	662	436	980	360
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	15	25	220	20	420	156	95	335
QUILLBACK	215	92	373	146	100	232	38	206
WHITE SUCKER	1	-	1	-	-	-	-	1
SHORTHEAD REDHORSE	1	-	-	-	-	-	-	-
WHITE CATFISH	57	10	83	44	103	324	64	46
YELLOW BULLHEAD	1	1	5	-	-	-	-	-
BROWN BULLHEAD	9	9	29	5	12	20	9	7
CHANNEL CATFISH	269	177	460	354	940	956	441	687
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	9	4	3	12	3	3	-	1
STRIPED BASS	38	38	41	35	70	72	111	73
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	6	3	9	3	38	20	31	17
GREEN SUNFISH	-	1	-	-	1	-	1	1
PUMPKINSEED	-	1	-	-	-	1	-	-
BLUEGILL	2	4	4	4	7	-	2	1
SMALLMOUTH BASS	3	-	1	1	2	-	4	1
LARGEMOUTH BASS	-	3	1	-	-	-	-	1
WHITE CRAPPIE	1	2	-	1	-	-	-	-
BLACK CRAPPIE	-	-	-	1	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	1	-	-	-	-	-	-	-
YELLOW PERCH	-	-	2	-	4	-	1	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	12	18	10	10	9	10	11	2
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	3	1	2	-	3	10	2	1
TIGER MUSKIE	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
TOTAL	5227	1699	3423	2989	3197	2919	2458	2815

TABLE 3 CONTINUED.

DATE	01 JUNE	02 JUNE	03 JUNE	04 JUNE	05 JUNE	06 JUNE	07 JUNE	TOTALS
LOCATION	641	641	641	641	641	641	641	
NO OF LIFTS	21	10	20	12	13	13	10	1257
FIRST LIFT	604	601	600	600	601	601	600	
LAST LIFT	1749	1200	1730	1300	1305	1300	1300	
OPERATING TIME (HR)	11.75	5.98	11.50	7.00	7.07	6.98	7.00	680.85
FISHING TIME (HR)	10.23	5.42	8.82	5.42	6.37	6.22	5.23	546.51
AVE RIVER FLOW (CFS)	13400	13600	11600	11700	9100	9200	10500	
AVE WATER TEMP (F)	81.5	82.1	84.2	83.3	83.3	80.6	80.1	
AMERICAN EEL	7	1	10	4	11	4	6	213
BLUEBACK HERRING	-	-	-	-	-	-	-	15,616
HICKORY SHAD	-	-	-	-	-	-	-	120
ALEWIFE	-	-	-	-	-	-	-	2,649
AMERICAN SHAD	13	7	4	11	5	7	10	13,330
GIZZARD SHAD	323	247	1934	826	591	376	394	433,108
RAINBOW TROUT	-	-	-	-	-	-	-	13
BROWN TROUT	-	-	-	-	-	-	-	82
BROOK TROUT	-	-	-	-	-	-	-	7
CHAIN PICKEREL	-	-	-	-	-	-	-	6
NORTHERN PIKE	-	-	-	-	-	-	-	5
MUSKELLUNGE	-	-	-	-	-	-	-	2
COMMON CARP	534	20	170	19	8	7	3	8,257
GOLDEN SHINER	-	-	-	-	-	-	-	7
COMELY SHINER	152	85	785	390	265	473	155	18,356
SPOTTAIL SHINER	-	-	-	-	-	-	1	635
SPOTFIN SHINER	45	70	60	70	75	105	43	2,508
QUILLBACK	52	1	46	1	4	12	2	2,990
WHITE SUCKER	-	-	-	-	-	1	-	113
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	2,871
WHITE CATFISH	1	39	67	111	27	44	1	1,284
YELLOW BULLHEAD	-	-	-	-	-	-	-	25
BROWN BULLHEAD	-	2	-	15	1	1	1	260
CHANNEL CATFISH	213	353	638	571	433	282	21	10,252
TADPOLE MADTOM	-	-	-	-	-	-	-	1
WHITE PERCH	2	2	11	-	-	-	-	14,996
STRIPED BASS	87	210	122	35	27	10	28	1,682
ROCK BASS	-	-	-	-	-	-	-	53
REDBREAST SUNFISH	9	2	4	1	9	-	-	281
GREEN SUNFISH	4	-	-	-	-	-	-	22
PUMPKINSEED	-	-	-	1	1	-	-	48
BLUEGILL	3	1	1	-	-	-	-	486
SMALLMOUTH BASS	1	2	1	2	-	-	-	704
LARGEMOUTH BASS	-	-	-	-	1	1	1	176
WHITE CRAPPIE	-	-	-	-	-	-	-	106
BLACK CRAPPIE	-	-	-	-	-	-	-	22
TESSELLATED DARTER	-	-	-	-	-	-	-	6
BANDED DARTER	-	-	-	-	-	-	-	10
YELLOW PERCH	1	3	-	-	2	-	-	502
LOGPERCH	-	-	-	-	-	-	-	1
WALLEYE	3	-	6	3	-	4	2	411
SEA LAMPREY	-	-	-	-	-	-	-	34
STRIPED BASS X WHITE BASS	1	1	7	1	2	1	-	797
TIGER MUSKIE	-	-	-	-	-	-	-	5
SUNFISH HYBRIDS	-	-	-	-	-	-	-	2
TOTAL	1451	1046	3866	2061	1462	1328	668	533,054

TABLE 4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM EAST LIFT 8 APRIL THROUGH 7 JUNE 1991.

DATE	08 APRIL	09 APRIL	10 APRIL	11 APRIL	12 APRIL	13 APRIL	14 APRIL	15 APRIL
LOCATION	636	636	636	636	636	636	636	636
NO. OF LIFTS	1	17	14	24	17	23	30	32
FIRST LIFT	1530	722	650	623	622	628	619	611
LAST LIFT	1530	1800	1708	1800	1733	1738	1749	1800
OPERATING TIME (HR)	24.00	10.63	10.30	11.62	11.18	11.17	11.50	11.82
FISHING TIME (HR)	3.50	10.00	7.62	9.70	5.28	7.92	10.43	9.57
AVE RIVER FLOW (CFS)	36000	35200	32200	33200	33700	36400	39900	36400
AVE WATER TEMP (F)	55.4	55.4	55.4	57.8	59.9	60.5	59.0	56.8
AMERICAN EEL	-	-	-	-	-	-	1	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
ALEWIFE	-	-	1	1	-	-	2	-
AMERICAN SHAD	12	260	224	78	180	350	247	18
GIZZARD SHAD	-	4005	4389	12482	12441	11495	25219	26485
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	-	-	-	1	-	-	-	3
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	1	-	-	-
COMMON CARP	-	-	-	1	-	-	9	-
COMELY SHINER	-	-	-	-	-	5	-	-
SPOTTAIL SHINER	-	-	-	-	2	6	4	2
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	-	1	3	1	1	9	4	-
WHITE SUCKER	-	13	3	13	3	4	-	2
SHORTHEAD REDHORSE	-	3	6	6	4	11	-	2
BROWN BULLHEAD	-	-	-	-	-	-	1	-
CHANNEL CATFISH	-	-	-	-	-	1	-	-
WHITE PERCH	-	-	-	-	-	-	1	-
STRIPED BASS	-	-	1	-	-	-	-	-
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	1	-	1	-	1	-	-
BLUEGILL	-	-	-	-	-	3	-	1
SMALLMOUTH BASS	-	19	9	10	4	15	17	3
LARGEMOUTH BASS	-	-	-	2	-	1	1	-
WHITE CRAPPIE	-	1	-	-	-	-	1	-
BLACK CRAPPIE	-	-	-	-	-	2	-	-
TESSELLATED DARTER	-	-	-	2	2	-	-	-
BANDED DARTER	-	-	-	-	1	-	2	1
YELLOW PERCH	-	-	-	-	-	1	4	-
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	-	178	-	1	2	6	3	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	1	-	1
STRIPED BASS X WHITE BASS	-	28	9	4	7	97	95	7
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
TOTAL	12	4509	4645	12604	12648	12008	25611	26525

TABLE 4 CONTINUED.

DATE	16 APRIL	17 APRIL	18 APRIL	19 APRIL	20 APRIL	21 APRIL	22 APRIL	24 APRIL
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	46	28	23	16	17	14	15	10
FIRST LIFT	600	615	608	830	628	711	607	707
LAST LIFT	1745	1725	1740	1723	1750	1756	1745	1741
OPERATING TIME (HR)	11.75	11.17	11.53	8.88	11.37	10.75	11.63	10.57
FISHING TIME (HR)	12.32	6.93	11.37	7.18	7.37	10.00	9.87	9.45
AVE RIVER FLOW (CFS)	35300	36000	37200	40300	38200	38400	38300	86100
AVE WATER TEMP (F)	56.8	55.4	56.0	55.4	55.4	55.8	55.0	53.6
AMERICAN EEL	-	-	-	-	1	1	1	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
ALEWIFE	1	-	-	-	5	4	-	-
AMERICAN SHAD	3	203	86	163	598	118	22	77
GIZZARD SHAD	58133	14140	7784	14958	4975	11200	7161	1615
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	-	1	1	-	-	-	-	1
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	1	-	-	-	-	-	-	-
COMMON CARP	-	-	-	-	-	-	1	-
COMELY SHINER	-	-	-	-	2	-	-	-
SPOTTAIL SHINER	1	1	-	2	-	-	1	-
SPOTFIN SHINER	1	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	-	3	-	-	-	2	-	-
WHITE SUCKER	2	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	2	1	3	-	-	5	25
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	1	-	-	-	-	-	4	1
WHITE PERCH	-	-	-	-	-	4	15	-
STRIPED BASS	-	-	-	-	-	1	1	2
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	1	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	19	10	14	4	11	3	6	5
LARGEMOUTH BASS	-	1	-	-	-	1	-	-
WHITE CRAPPIE	-	-	1	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	1	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	1	-	-	-	1	-	-
YELLOW PERCH	-	-	1	-	1	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	-	1	-	-	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	1	-	2	-	1	1	1
STRIPED BASS X WHITE BASS	21	7	25	2	4	19	25	90
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
TOTAL	58184	14371	7913	15135	5597	11356	7244	1817

TABLE 4 CONTINUED.

DATE	25 APRIL	26 APRIL	27 APRIL	28 APRIL	29 APRIL	30 APRIL	01 MAY	02 MAY
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	12	14	18	29	18	25	21	19
FIRST LIFT	616	613	601	602	606	727	615	607
LAST LIFT	1748	1720	1750	1748	1242	1458	1345	1647
OPERATING TIME (HR)	11.53	11.12	11.82	11.77	6.60	7.52	7.50	10.67
FISHING TIME (HR)	10.95	10.32	10.92	11.45	5.87	7.15	7.05	10.15
AVE RIVER FLOW (CFS)	104000	101500	92500	78800	63000	58000	48200	45600
AVE WATER TEMP (F)	53.3	53.6	54.4	55.4	57.0	57.2	59.0	60.6
AMERICAN EEL	-	1	1	2	-	1	-	4
BLUEBACK HERRING	-	-	2	1	-	-	-	-
ALEWIFE	-	11	8	3	-	-	-	2
AMERICAN SHAD	1	5	3	324	405	613	248	1088
GIZZARD SHAD	2716	3088	12845	14730	14605	11511	19957	19152
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	-	1	1	-	-	4	-	3
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	1	-	-	-
COMMON CARP	2	1	-	2	-	-	1	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	2
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	-	1	2	46	66	11	86	5
WHITE SUCKER	-	3	-	-	1	-	1	-
SHORTHEAD REDHORSE	10	26	26	64	87	9	16	6
BROWN BULLHEAD	-	-	-	-	-	-	-	1
CHANNEL CATFISH	11	3	2	2	1	-	-	-
WHITE PERCH	1	-	-	-	-	6	2	35
STRIPED BASS	-	1	1	1	2	2	-	1
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	1	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	2	-	1	-	-	3
SMALLMOUTH BASS	1	3	4	33	28	37	33	39
LARGEMOUTH BASS	-	-	-	1	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	1	-	-	-	-	-	-	-
BANDED DARTER	-	1	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	-	-	10
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	-	-	3	4	9	3	2	3
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	1	-	2	-	2	-	-
STRIPED BASS X WHITE BASS	74	6	32	32	20	3	1	2
TIGER MUSKIE	-	-	-	-	-	-	1	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
TOTAL	2817	3152	12932	15248	15226	12202	20349	20356

TABLE 4 CONTINUED.

DATE	03 MAY	04 MAY	05 MAY	06 MAY	07 MAY	08 MAY	09 MAY	10 MAY
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	21	17	16	18	23	28	20	26
FIRST LIFT	745	626	615	618	602	606	609	605
LAST LIFT	1737	1730	1501	1616	1730	1755	1538	1655
OPERATING TIME (HR)	9.87	11.07	8.77	9.97	11.47	11.82	9.48	10.83
FISHING TIME (HR)	9.18	10.30	8.13	9.07	8.57	10.08	9.70	9.93
AVE RIVER FLOW (CFS)	42400	43200	38300	39200	40400	41700	42300	43200
AVE WATER TEMP (F)	60.8	60.8	61.7	62.6	63.9	63.5	63.9	65.8
AMERICAN EEL	-	2	-	-	1	2	-	3
BLUEBACK HERRING	-	2	772	34	1	34	384	22
ALEWIFE	3	-	155	-	-	2	103	1
AMERICAN SHAD	471	393	718	696	248	427	608	833
GIZZARD SHAD	7312	13700	3553	7374	16353	15028	5847	19995
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	4	2	4	2	1	-	-	1
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	-	-	2	29	5	8	-	4
COMELY SHINER	1	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	10	2	29	121	24	4	3	7
WHITE SUCKER	-	-	1	-	-	1	-	-
SHORTHEAD REDHORSE	15	5	-	36	16	6	2	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	-	-	1	1	2	6	4	2
WHITE PERCH	47	152	260	105	285	442	154	80
STRIPED BASS	4	2	-	5	5	7	-	-
ROCK BASS	-	1	-	-	-	-	1	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	1
BLUEGILL	2	2	4	-	-	-	6	9
SMALLMOUTH BASS	34	20	51	42	20	23	23	20
LARGEMOUTH BASS	-	-	2	-	-	1	-	-
WHITE CRAPPIE	-	-	-	-	-	-	1	2
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	5	2	1	-	1	1	4
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	1	8	3	9	4	12	7	5
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	1	-	-	-	-	-
STRIPED BASS X WHITE BASS	4	5	36	47	16	11	7	8
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
TOTAL	7909	14301	5594	8502	16981	16015	7151	20997

TABLE 4 CONTINUED.

DATE	11 MAY	12 MAY	13 MAY	14 MAY	15 MAY	16 MAY	17 MAY	18 MAY
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	29	21	22	23	29	26	20	25
FIRST LIFT	615	607	617	648	600	601	607	611
LAST LIFT	1734	1717	1749	1758	1741	1752	1543	1751
OPERATING TIME (HR)	11.32	11.17	11.53	11.17	11.68	11.85	9.60	11.67
FISHING TIME (HR)	11.23	10.37	10.68	9.93	10.22	10.53	8.18	10.42
AVE RIVER FLOW (CFS)	39500	38700	31600	31300	30900	29400	29100	25200
AVE WATER TEMP (F)	64.4	65.3	66.2	66.2	69.3	68.9	71.9	72.5
AMERICAN EEL	-	-	1	4	2	4	4	1
BLUEBACK HERRING	153	9836	422	482	334	274	71	101
ALEWIFE	16	-	-	-	5	-	-	-
AMERICAN SHAD	300	776	425	269	344	265	433	329
GIZZARD SHAD	19428	7036	14290	9861	16892	10156	8676	13720
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	1	-	-	2	1	5	-	1
BROOK TROUT	-	1	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	10	5	49	37	52	149	476	2229
COMELY SHINER	-	-	-	-	521	-	2	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	1	-	-	-
QUILLBACK	55	20	199	71	48	75	376	269
WHITE SUCKER	-	-	-	-	-	1	1	-
SHORTHEAD REDHORSE	21	1	5	1	-	1	2	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	1	1	12	3	8	17	25	7
WHITE PERCH	553	121	36	170	13	-	28	45
STRIPED BASS	-	2	-	-	1	-	1	11
ROCK BASS	1	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	3	1	-	3	-	3	11
GREEN SUNFISH	-	-	-	-	-	-	1	-
PUMPKINSEED	-	-	-	2	-	-	-	-
BLUEGILL	3	5	-	6	5	1	2	17
SMALLMOUTH BASS	19	4	14	8	11	1	9	8
LARGEMOUTH BASS	1	1	-	1	1	1	-	-
WHITE CRAPPIE	-	1	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	5	-	-	-
BANDED DARTER	-	-	-	-	-	1	-	-
YELLOW PERCH	3	-	-	-	1	1	2	-
SHIELD DARTER	-	-	-	-	-	-	-	1
WALLEYE	8	1	-	2	-	1	1	3
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	-	-	-	1	1	-
STRIPED BASS X WHITE BASS	4	5	8	11	2	3	5	3
TIGER MUSKIE	1	-	-	-	1	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	1	-	-
TOTAL	20579	17819	15462	10931	18251	10958	10119	16756

TABLE 4 CONTINUED.

DATE	19 MAY	20 MAY	21 MAY	22 MAY	23 MAY	24 MAY	25 MAY	26 MAY
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	27	25	22	21	21	12	13	17
FIRST LIFT	634	617	605	612	605	557	618	603
LAST LIFT	1730	1751	1800	1714	1750	1615	1745	1735
OPERATING TIME (HR)	10.93	11.57	11.92	11.03	11.75	10.30	11.45	11.53
FISHING TIME (HR)	9.48	10.88	11.27	10.73	10.80	8.53	11.23	11.22
AVE RIVER FLOW (CFS)	23900	21300	19100	20300	18700	18400	17500	17600
AVE WATER TEMP (F)	71.6	73.1	71.6	72.5	73.4	-	-	76.5
AMERICAN EEL	4	10	4	3	15	-	1	4
BLUEBACK HERRING	116	31	35	8	5	1	11	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	124	103	175	66	257	28	43	11
GIZZARD SHAD	7386	9157	7850	12110	6031	2153	2030	5624
RAINBOW TROUT	1	-	-	-	-	-	1	-
BROWN TROUT	1	2	-	1	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
MINNOWS	-	-	-	-	-	100	-	-
COMMON CARP	2688	100	154	677	669	475	1310	3136
COMELY SHINER	-	135	5	425	4630	-	385	70
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	3	-	-	1425	-	150	30
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	183	7	162	410	142	107	-	298
WHITE SUCKER	1	1	-	-	-	-	-	-
SHORTHEAD REDHORSE	1	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	1
CHANNEL CATFISH	2	9	4	2	2	6	1	-
WHITE PERCH	14	18	11	4	5	-	3	-
STRIPED BASS	2	1	4	17	13	-	7	12
ROCK BASS	-	-	-	-	-	29	-	-
REDBREAST SUNFISH	8	5	7	14	5	-	4	4
GREEN SUNFISH	-	2	-	-	-	8	-	-
PUMPKINSEED	-	5	-	1	-	-	1	1
BLUEGILL	8	16	2	7	9	1	3	4
SMALLMOUTH BASS	6	2	2	11	7	3	1	-
LARGEMOUTH BASS	-	-	1	-	-	3	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	3	-	-	3	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	6	4	3	1	2	-	4	3
ATLANTIC NEEDLEFISH	-	-	-	-	1	1	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	1	3	2	7	4	4	1	1
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
HYBRIDS	-	-	-	-	-	5	-	-
TOTAL	10552	9617	8421	13764	13225	2924	3956	9199

TABLE 4 CONTINUED.

DATE	27 MAY	28 MAY	29 MAY	30 MAY	31 MAY	01 JUNE	02 JUNE	03 JUNE
LOCATION	636	636	636	636	636	636	636	636
NO OF LIFTS	22	14	20	16	12	18	12	16
FIRST LIFT	600	557	602	602	600	605	600	601
LAST LIFT	1740	1745	1745	1800	1746	1723	1200	1730
OPERATING TIME (HR)	11.67	11.80	11.72	11.97	11.77	11.30	6.00	11.48
FISHING TIME (HR)	11.42	11.22	11.45	10.80	11.22	10.42	5.42	10.63
AVE RIVER FLOW (CFS)	17100	13400	14400	13500	13600	13400	13600	11600
AVE WATER TEMP (F)	77.0	77.0	80.6	81.2	80.6	82.3	82.3	82.1
AMERICAN EEL	3	3	5	1	1	1	1	1
BLUEBACK HERRING	17	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	137	2	16	5	2	11	16	6
GIZZARD SHAD	3790	3515	3547	1805	1014	1683	355	1441
RAINBOW TROUT	1	-	-	-	-	-	-	-
BROWN TROUT	-	-	-	-	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	616	1061	1457	2107	48	1572	3706	947
COMELY SHINER	171	165	1330	850	665	875	75	290
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	215	5	-	116	210	-	100
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
QUILLBACK	-	11	33	145	27	79	23	37
WHITE SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	1	-	2	-	15	6	-	8
WHITE PERCH	-	-	-	-	-	-	-	-
STRIPED BASS	8	11	18	69	40	32	49	78
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	2	4	3	6	8	7	-	1
GREEN SUNFISH	-	-	2	-	-	1	1	-
PUMPKINSEED	-	-	-	1	-	-	-	-
BLUEGILL	2	2	-	5	3	2	1	2
SMALLMOUTH BASS	-	-	1	-	-	1	1	-
LARGEMOUTH BASS	-	-	-	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
BANDED DARTER	-	-	-	-	1	-	-	-
YELLOW PERCH	-	-	1	-	-	-	-	-
SHIELD DARTER	-	-	-	-	1	-	-	-
WALLEYE	1	-	-	1	-	1	1	2
ATLANTIC NEEDLEFISH	-	-	-	-	1	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	2	2	2	5	-	-	-	2
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
TOTAL	4751	4991	6422	5000	1942	4481	4229	2915

TABLE 4 CONTINUED.

DATE	04 JUNE	05 JUNE	06 JUNE	07 JUNE	TOTALS
LOCATION	636	636	636	636	
NO OF LIFTS	8	8	9	8	1168
FIRST LIFT	600	601	603	557	
LAST LIFT	1300	1300	1300	1253	
OPERATING TIME (HR)	7.00	6.98	6.95	6.93	647.72
FISHING TIME (HR)	6.60	6.58	6.55	6.58	561.92
AVE RIVER FLOW (CFS)	11700	9100	9200	10500	
AVE WATER TEMP (F)	82.4	83.3	80.1	79.7	
AMERICAN EEL	2	5	2	-	103
BLUEBACK HERRING	-	-	-	-	13,149
ALEWIFE	-	-	-	-	323
AMERICAN SHAD	3	7	21	3	13,897
GIZZARD SHAD	85	707	610	305	575,505
RAINBOW TROUT	-	-	-	-	7
BROWN TROUT	-	-	-	-	44
BROOK TROUT	-	-	-	-	1
MUSKELLUNGE	-	-	-	-	3
MINNOWS	-	-	-	-	100
COMMON CARP	3	31	3	1	23,833
COMELY SHINER	28	890	2	325	11,847
SPOTTAIL SHINER	-	-	-	-	21
SPOTFIN SHINER	20	300	17	55	2,647
BLUNTNOSE MINNOW	-	-	-	-	1
QUILLBACK	-	-	2	-	3,220
WHITE SUCKER	-	-	-	-	51
SHORTHEAD REDHORSE	-	-	-	-	424
BROWN BULLHEAD	-	-	-	-	3
CHANNEL CATFISH	1	131	12	3	321
WHITE PERCH	-	-	-	-	2,610
STRIPED BASS	76	22	20	22	581
ROCK BASS	-	-	-	-	3
REDBREAST SUNFISH	4	-	-	3	115
GREEN SUNFISH	-	1	1	-	10
PUMPKINSEED	-	-	-	-	16
BLUEGILL	-	5	2	1	149
SMALLMOUTH BASS	2	-	-	-	671
LARGEMOUTH BASS	-	1	-	-	17
WHITE CRAPPIE	-	-	-	-	7
BLACK CRAPPIE	-	-	-	-	3
TESSELLATED DARTER	-	-	-	-	10
BANDED DARTER	-	-	-	-	9
YELLOW PERCH	-	-	-	-	45
SHIELD DARTER	-	-	-	-	2
WALLEYE	8	16	2	-	335
ATLANTIC NEEDLEFISH	-	-	-	-	2
SEA LAMPREY	-	-	-	-	19
STRIPED BASS X WHITE BASS	2	-	-	8	827
TIGER MUSKIE	-	-	-	-	3
BROOK TROUT X LAKE TROUT	-	-	-	-	1
HYBRIDS	-	-	-	-	5
TOTAL	234	2116	694	726	650,945

TABLE 5

Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam West Fish Lift, 1991.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
APR 01	# Shad			-	0
	Hrs Fishing	0.0	0.0	4.9	4.9
	Catch/Hr Fishing	-	-	-	0.00
APR 03	# Shad			-	0
	Hrs Fishing	0.0	0.0	5.1	5.1
	Catch/Hr Fishing	-	-	-	0.00
APR 05	# Shad			-	0
	Hrs Fishing	0.0	0.0	5.5	5.5
	Catch/Hr Fishing	-	-	-	0.00
APR 07	# Shad		-	-	0
	Hrs Fishing	0.0	0.4	4.4	4.8
	Catch/Hr Fishing	-	-	-	0.00
APR 09	# Shad			99	99
	Hrs Fishing	0.0	0.0	9.6	9.6
	Catch/Hr Fishing	-	-	10.31	10.31
APR 10	# Shad			71	71
	Hrs Fishing	0.0	0.0	9.3	9.3
	Catch/Hr Fishing	-	-	7.63	7.63
APR 11	# Shad			52	52
	Hrs Fishing	0.0	0.0	11.9	11.9
	Catch/Hr Fishing	-	-	4.37	4.37
APR 12	# Shad			176	176
	Hrs Fishing	0.0	0.0	9.7	9.7
	Catch/Hr Fishing	-	-	18.14	18.14
APR 13	# Shad			198	198*
	Hrs Fishing	0.0	0.0	8.9	8.9
	Catch/Hr Fishing	-	-	22.25	22.25
APR 14	# Shad		3	232	235
	Hrs Fishing	0.0	1.3	8.1	9.4
	Catch/Hr Fishing	-	2.31	28.64	25.00
APR 15	# Shad			96	96
	Hrs Fishing	0.0	0.0	12.3	12.3
	Catch/Hr Fishing	-	-	7.80	7.80

TABLE 5 Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
APR 16	# Shad	70		142	212
	Hrs Fishing	1.5	0.0	8.7	10.2
	Catch/Hr Fishing	46.67	-	16.32	20.78
APR 17	# Shad			72	72
	Hrs Fishing	0.0	0.0	3.6	3.6
	Catch/Hr Fishing	-	-	20.00	20.00
APR 18	# Shad			171	171
	Hrs Fishing	0.0	0.0	9.4	9.4
	Catch/Hr Fishing	-	-	18.19	18.19
APR 19	# Shad			267	267*
	Hrs Fishing	0.0	0.0	10.3	10.3
	Catch/Hr Fishing	-	-	25.92	25.92
APR 20	# Shad			395	395*
	Hrs Fishing	0.0	0.0	8.8	8.8
	Catch/Hr Fishing	-	-	44.89	44.89
APR 21	# Shad			239	239*
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	23.90	23.90
APR 22	# Shad			174	174*
	Hrs Fishing	0.0	0.0	7.8	7.8
	Catch/Hr Fishing	-	-	22.31	22.31
APR 23	# Shad			179	179
	Hrs Fishing	0.0	0.0	11.0	11.0
	Catch/Hr Fishing	-	-	16.27	16.27
APR 24	# Shad			242	242*
	Hrs Fishing	0.0	0.0	9.6	9.6
	Catch/Hr Fishing	-	-	25.21	25.21
APR 25	# Shad			37	37
	Hrs Fishing	0.0	0.0	8.7	8.7
	Catch/Hr Fishing	-	-	4.25	4.25
APR 26	# Shad			16	16*
	Hrs Fishing	0.0	0.0	6.2	6.2
	Catch/Hr Fishing	-	-	2.58	2.58

TABLE 5 Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
APR 27	# Shad			34	34
	Hrs Fishing	0.0	0.0	9.7	9.7
	Catch/Hr Fishing	-	-	3.51	3.51
APR 28	# Shad			99	99
	Hrs Fishing	0.0	0.0	8.9	8.9
	Catch/Hr Fishing	-	-	11.12	11.12
APR 29	# Shad			380	380
	Hrs Fishing	0.0	0.0	8.8	8.8
	Catch/Hr Fishing	-	-	43.18	43.18
APR 30	# Shad			403	403*
	Hrs Fishing	0.0	0.0	8.8	8.8
	Catch/Hr Fishing	-	-	45.80	45.80
MAY 02	# Shad			271	271*
	Hrs Fishing	0.0	0.0	10.9	10.9
	Catch/Hr Fishing	-	-	24.86	24.86
MAY 03	# Shad			49	49*
	Hrs Fishing	0.0	0.0	9.4	9.4
	Catch/Hr Fishing	-	-	5.21	5.21
MAY 04	# Shad			526	526*
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	52.60	52.60
MAY 05	# Shad			625	625
	Hrs Fishing	0.0	0.0	10.4	10.4
	Catch/Hr Fishing	-	-	60.10	60.10
MAY 06	# Shad			479	479*
	Hrs Fishing	0.0	0.0	8.5	8.5
	Catch/Hr Fishing	-	-	56.35	56.35
MAY 07	# Shad			590	590*
	Hrs Fishing	0.0	0.0	10.2	10.2
	Catch/Hr Fishing	-	-	57.84	57.84
MAY 08	# Shad			528	528*
	Hrs Fishing	0.0	0.0	9.1	9.1
	Catch/Hr Fishing	-	-	58.02	58.02

TABLE 5 Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
MAY 09	# Shad			408	408*
	Hrs Fishing	0.0	0.0	7.2	7.2
	Catch/Hr Fishing	-	-	56.67	56.67
MAY 10	# Shad			315	315
	Hrs Fishing	0.0	0.0	6.8	6.8
	Catch/Hr Fishing	-	-	46.32	46.32
MAY 11	# Shad			324	324
	Hrs Fishing	0.0	0.0	7.9	7.9
	Catch/Hr Fishing	-	-	41.01	41.01
MAY 12	# Shad			412	412*
	Hrs Fishing	0.0	0.0	10.1	10.1
	Catch/Hr Fishing	-	-	40.79	40.79
MAY 13	# Shad			335	335
	Hrs Fishing	0.0	0.0	4.6	4.6
	Catch/Hr Fishing	-	-	72.83	72.83
MAY 14	# Shad			253	253
	Hrs Fishing	0.0	0.0	8.8	8.8
	Catch/Hr Fishing	-	-	28.75	28.75
MAY 15	# Shad			160	160
	Hrs Fishing	0.0	0.0	10.5	10.5
	Catch/Hr Fishing	-	-	15.24	15.24
MAY 16	# Shad			418	418*
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	41.80	41.80
MAY 17	# Shad	23		123	146*
	Hrs Fishing	2.3	0.0	7.0	9.3
	Catch/Hr Fishing	10.00	-	17.57	15.70
MAY 18	# Shad			891	891
	Hrs Fishing	0.0	0.0	6.0	6.0
	Catch/Hr Fishing	-	-	148.50	148.50
MAY 19	# Shad			997	997*
	Hrs Fishing	0.0	0.0	6.1	6.1
	Catch/Hr Fishing	-	-	163.44	163.44

TABLE 5 Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
MAY 20	# Shad		18	22	40
	Hrs Fishing	0.0	1.6	6.5	8.2
	Catch/Hr Fishing	-	11.25	3.38	4.88
MAY 21	# Shad			218	218
	Hrs Fishing	0.0	0.0	9.3	9.3
	Catch/Hr Fishing	-	-	23.44	23.44
MAY 22	# Shad			265	265*
	Hrs Fishing	0.0	0.0	8.6	8.6
	Catch/Hr Fishing	-	-	30.81	30.81
MAY 23	# Shad			207	207
	Hrs Fishing	0.0	0.0	11.3	11.3
	Catch/Hr Fishing	-	-	18.32	18.32
MAY 24	# Shad			208	208
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	20.80	20.80
MAY 25	# Shad		7	86	93*
	Hrs Fishing	0.0	2.3	7.8	10.1
	Catch/Hr Fishing	-	3.04	11.03	9.21
MAY 26	# Shad			159	159
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	15.90	15.90
MAY 27	# Shad			90	90
	Hrs Fishing	0.0	0.0	10.0	10.0
	Catch/Hr Fishing	-	-	9.00	9.00
MAY 28	# Shad			87	87
	Hrs Fishing	0.0	0.0	10.7	10.7
	Catch/Hr Fishing	-	-	8.13	8.13
MAY 29	# Shad			138	138
	Hrs Fishing	0.0	0.0	10.6	10.6
	Catch/Hr Fishing	-	-	13.02	13.02
MAY 30	# Shad			91	91
	Hrs Fishing	0.0	0.0	10.5	10.5
	Catch/Hr Fishing	-	-	8.67	8.67

TABLE 5 Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
MAY 31	# Shad			61	61
	Hrs Fishing	0.0	0.0	10.4	10.4
	Catch/Hr Fishing	-	-	5.87	5.87
JUN 01	# Shad			13	13
	Hrs Fishing	0.0	0.0	10.2	10.2
	Catch/Hr Fishing	-	-	1.27	1.27
JUN 02	# Shad			7	7
	Hrs Fishing	0.0	0.0	5.4	5.4
	Catch/Hr Fishing	-	-	1.30	1.30
JUN 03	# Shad			4	4
	Hrs Fishing	0.0	0.0	8.8	8.8
	Catch/Hr Fishing	-	-	0.45	0.45
JUN 04	# Shad			11	11
	Hrs Fishing	0.0	0.0	5.4	5.4
	Catch/Hr Fishing	-	-	2.04	2.04
JUN 05	# Shad			5	5
	Hrs Fishing	0.0	0.0	6.4	6.4
	Catch/Hr Fishing	-	-	0.78	0.78
JUN 06	# Shad			7	7
	Hrs Fishing	0.0	0.0	6.2	6.2
	Catch/Hr Fishing	-	-	1.13	1.13
JUN 07	# Shad			10	10
	Hrs Fishing	0.0	0.0	5.2	5.2
	Catch/Hr Fishing	-	-	1.92	1.92
TOTAL	# Shad	93	28	13,167	13,288*
	Hrs Fishing	3.8	5.6	536.8	546.3
	Catch/Hr Fishing	24.47	5.00	24.53	24.32

* Excludes American shad taken in clean out lifts.

TABLE 6

Comparison of catch per effort (hr) of American shad on weekdays vs. weekend days by generation (cfs) at the Conowingo Dam West Fish Lift, 1 April - 7 June 1991.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CFS CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	0500-0900	8.6	2.8	23.1	0.0	43.2	9.9	14.0
	0901-1100	25.4	0.6	39.1	0.0	57.9	12.9	18.8
	1101-1500	15.7	0.5	11.0	1.2	5.2	23.3	19.4
	1501-1900	18.3	-	15.9	9.3	20.9	35.2	28.5
MEAN WEEKDAYS		17.0	1.9	24.6	2.5	19.6	21.9	20.1
WEEKEND	0500-0900	17.7	2.2	68.1	8.3	13.2	3.4	30.4
	0901-1100	30.3	1.0	93.2	28.8	3.2	10.6	35.0
	1101-1500	45.0	0.8	50.8	18.9	13.4	37.8	33.8
	1501-1900	33.3	0.7	151.3	14.7	15.6	48.9	44.3
MEAN WEEKEND		32.8	1.3	80.7	17.5	14.0	31.4	35.7
TOTAL		20.4	1.6	44.2	11.3	17.3	23.7	24.3

TABLE 7

Comparison of the American shad catch and catch per effort at three generating conditions at the Conowingo Dam West Fish Lift by month (1 April through 7 June) 1991.

Generation Status	No. Shad Caught	Total Hours Fished	No. of Lifts	Shad Catch per Hour
April				
Two small units	93	6	17	16.27
Higher generation	3768	218	483	17.32
Total for April	3861	224	500	17.29
May				
Two small units	3818	82	201	46.16
Higher generation	5594	193	457	29.01
Total for May	9412	275	658	34.16
June				
One small unit	51	32	64	1.58
Higher generation	6	15	35	0.39
Total for June	57	47	99	1.19
Grand total	13330	546	1257	24.39

TABLE 8

Catch of American shad in the Conowingo Fish Lifts (East and West) by water temperatures, 1 April through 7 June 1991.

Water Temp. (F)	Hours Fishing	CATCH		
		Number	Catch/ Effort	Percent
< 65	612.23	18014	29.42	66.2
> 65	487.68	9185	18.83	33.8
TOTAL	1,099.92	27199	24.73	100.0

TABLE 9

Total catch and catch per hour of American shad by date and weir gate setting at Conwingo Dam East Fish Lift, 1991.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
APR 08	# Shad					12		12
	Hrs Fishing	0.0	0.0	0.0	0.0	3.5	0.0	3.5
	Catch/Hr Fishing	-	-	-	-	3.43	-	3.43
APR 09	# Shad		6			75	179	260
	Hrs Fishing	0.0	0.8	0.0	0.0	1.4	7.3	9.5
	Catch/Hr Fishing	-	7.50	-	-	53.57	24.52	27.37
APR 10	# Shad					26	198	224
	Hrs Fishing	0.0	0.0	0.0	0.0	0.5	7.1	7.6
	Catch/Hr Fishing	-	-	-	-	52.00	27.89	29.47
APR 11	# Shad					2	76	78
	Hrs Fishing	0.0	0.0	0.0	0.0	1.3	8.4	9.7
	Catch/Hr Fishing	-	-	-	-	1.54	9.05	8.04
APR 12	# Shad					67	113	180
	Hrs Fishing	0.0	0.0	0.0	0.0	1.6	3.6	5.3
	Catch/Hr Fishing	-	-	-	-	41.88	31.39	33.96
APR 13	# Shad		2			26	322	350
	Hrs Fishing	0.0	0.4	0.0	0.0	0.3	7.1	7.9
	Catch/Hr Fishing	-	5.00	-	-	86.67	45.35	44.30
APR 14	# Shad					163	84	247
	Hrs Fishing	0.0	0.0	0.0	0.0	1.6	8.8	10.4
	Catch/Hr Fishing	-	-	-	-	101.88	9.55	23.75
APR 15	# Shad					2	16	18
	Hrs Fishing	0.0	0.0	0.0	0.0	0.9	8.6	9.6
	Catch/Hr Fishing	-	-	-	-	2.22	1.86	1.88
APR 16	# Shad		-			-	3	3
	Hrs Fishing	0.0	1.1	0.0	0.0	0.9	10.4	12.3
	Catch/Hr Fishing	-	-	-	-	-	0.29	0.24
APR 17	# Shad					43	160	203
	Hrs Fishing	0.0	0.0	0.0	0.0	0.8	6.1	6.9
	Catch/Hr Fishing	-	-	-	-	53.75	26.23	29.42
APR 18	# Shad					12	74	86
	Hrs Fishing	0.0	0.0	0.0	0.0	1.0	10.3	11.4
	Catch/Hr Fishing	-	-	-	-	12.00	7.18	7.54

TABLE 9 Continued.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
APR 19	# Shad						163	163
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	7.2	7.2
	Catch/Hr Fishing	-	-	-	-	-	22.64	22.64
APR 20	# Shad					172	426	598
	Hrs Fishing	0.0	0.0	0.0	0.0	1.0	6.4	7.4
	Catch/Hr Fishing	-	-	-	-	172.00	66.56	80.81
APR 21	# Shad					44	74	118
	Hrs Fishing	0.0	0.0	0.0	0.0	3.4	6.6	10.0
	Catch/Hr Fishing	-	-	-	-	12.94	11.21	11.80
APR 22	# Shad					5	17	22
	Hrs Fishing	0.0	0.0	0.0	0.0	4.0	5.8	9.9
	Catch/Hr Fishing	-	-	-	-	1.25	2.93	2.22
APR 24	# Shad			77		-		77
	Hrs Fishing	0.0	0.0	7.4	0.0	2.0	0.0	9.4
	Catch/Hr Fishing	-	-	10.41	-	-	-	8.19
APR 25	# Shad					-	1	1
	Hrs Fishing	0.0	0.0	0.0	0.0	10.0	1.0	10.9
	Catch/Hr Fishing	-	-	-	-	-	1.00	0.09
APR 26	# Shad					1	4	5
	Hrs Fishing	0.0	0.0	0.0	0.0	3.8	6.6	10.3
	Catch/Hr Fishing	-	-	-	-	0.26	0.61	0.49
APR 27	# Shad					-	3	3
	Hrs Fishing	0.0	0.0	0.0	0.0	0.6	10.3	10.9
	Catch/Hr Fishing	-	-	-	-	-	0.29	0.28
APR 28	# Shad					3	321	324
	Hrs Fishing	0.0	0.0	0.0	0.0	0.5	10.9	11.4
	Catch/Hr Fishing	-	-	-	-	6.00	29.45	28.42
APR 29	# Shad						396	396*
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	5.9	5.9
	Catch/Hr Fishing	-	-	-	-	-	67.12	67.12
APR 30	# Shad						557	557*
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	7.1	7.1
	Catch/Hr Fishing	-	-	-	-	-	78.45	78.45

TABLE 9 Continued.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
MAY 01	# Shad					44	204	248
	Hrs Fishing	0.0	0.0	0.0	0.0	0.6	6.4	7.0
	Catch/Hr Fishing	-	-	-	-	73.33	31.88	35.43
MAY 02	# Shad					153	935	1,088
	Hrs Fishing	0.0	0.0	0.0	0.0	3.1	7.1	10.1
	Catch/Hr Fishing	-	-	-	-	49.35	131.69	107.72
MAY 03	# Shad					96	375	471
	Hrs Fishing	0.0	0.0	0.0	0.0	4.3	4.8	9.2
	Catch/Hr Fishing	-	-	-	-	22.33	78.13	51.20
MAY 04	# Shad	1				19	373	393
	Hrs Fishing	1.5	0.0	0.0	0.0	3.5	5.3	10.3
	Catch/Hr Fishing	0.67	-	-	-	5.43	70.38	38.16
MAY 05	# Shad	653				65		718
	Hrs Fishing	6.7	0.0	0.0	0.0	1.4	0.0	8.1
	Catch/Hr Fishing	97.46	-	-	-	46.43	-	88.64
MAY 06	# Shad				655	3		658*
	Hrs Fishing	0.0	0.0	0.0	8.1	1.0	0.0	9.1
	Catch/Hr Fishing	-	-	-	80.86	3.00	-	72.31
MAY 07	# Shad				179	57		236*
	Hrs Fishing	0.0	0.0	0.0	8.2	0.3	0.0	8.6
	Catch/Hr Fishing	-	-	-	21.83	190.00	-	27.44
MAY 08	# Shad				427			427
	Hrs Fishing	0.0	0.0	0.0	10.1	0.0	0.0	10.1
	Catch/Hr Fishing	-	-	-	42.28	-	-	42.28
MAY 09	# Shad	135			2	47	424	608
	Hrs Fishing	2.8	0.0	0.0	0.5	1.4	5.0	9.7
	Catch/Hr Fishing	48.21	-	-	4.00	33.57	84.80	62.68
MAY 10	# Shad						755	755*
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	9.9	9.9
	Catch/Hr Fishing	-	-	-	-	-	76.26	76.26
MAY 11	# Shad					23	277	300
	Hrs Fishing	0.0	0.0	0.0	0.0	1.3	9.9	11.2
	Catch/Hr Fishing	-	-	-	-	17.69	27.98	26.79

TABLE 9 Continued.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
MAY 12	# Shad	158				67	551	776
	Hrs Fishing	3.4	0.0	0.0	0.0	3.4	3.5	10.4
	Catch/Hr Fishing	46.47	-	-	-	19.71	157.43	74.62
MAY 13	# Shad					25	399	424*
	Hrs Fishing	0.0	0.0	0.0	0.0	0.8	9.8	10.7
	Catch/Hr Fishing	-	-	-	-	31.25	40.71	39.63
MAY 14	# Shad					35	234	269
	Hrs Fishing	0.0	0.0	0.0	0.0	1.8	8.1	9.9
	Catch/Hr Fishing	-	-	-	-	19.44	28.89	27.17
MAY 15	# Shad	30				-	314	344
	Hrs Fishing	2.6	0.0	0.0	0.0	0.3	7.3	10.2
	Catch/Hr Fishing	11.54	-	-	-	-	43.01	33.73
MAY 16	# Shad	31				17	217	265
	Hrs Fishing	2.8	0.0	0.0	0.0	0.9	6.8	10.5
	Catch/Hr Fishing	11.07	-	-	-	18.89	31.91	25.24
MAY 17	# Shad	34				32	367	433
	Hrs Fishing	2.9	0.0	0.0	0.0	1.3	4.0	8.2
	Catch/Hr Fishing	11.72	-	-	-	24.62	91.75	52.80
MAY 18	# Shad	313				16		329
	Hrs Fishing	6.0	0.0	0.0	0.0	4.4	0.0	10.4
	Catch/Hr Fishing	52.17	-	-	-	3.64	-	31.63
MAY 19	# Shad	123				1		124
	Hrs Fishing	9.1	0.0	0.0	0.0	0.4	0.0	9.5
	Catch/Hr Fishing	13.52	-	-	-	2.50	-	13.05
MAY 20	# Shad	88				12	3	103
	Hrs Fishing	4.1	0.0	0.0	0.0	2.4	4.4	10.9
	Catch/Hr Fishing	21.46	-	-	-	5.00	0.68	9.45
MAY 21	# Shad	103				9	63	175
	Hrs Fishing	3.0	0.0	0.0	0.0	1.7	6.6	11.3
	Catch/Hr Fishing	34.33	-	-	-	5.29	9.55	15.49
MAY 22	# Shad	42				11	12	65*
	Hrs Fishing	3.5	0.0	0.0	0.0	2.6	4.6	10.7
	Catch/Hr Fishing	12.00	-	-	-	4.23	2.61	6.07

TABLE 9 Continued.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
MAY 23	# Shad	148				19	90	257
	Hrs Fishing	6.5	0.0	0.0	0.0	2.3	2.1	10.8
	Catch/Hr Fishing	22.77	-	-	-	8.26	42.86	23.80
MAY 25	# Shad	29	-			14		43
	Hrs Fishing	3.3	2.3	0.0	0.0	5.6	0.0	11.2
	Catch/Hr Fishing	8.79	-	-	-	2.50	-	3.84
MAY 26	# Shad	9				2		11
	Hrs Fishing	7.8	0.0	0.0	0.0	3.4	0.0	11.2
	Catch/Hr Fishing	1.15	-	-	-	0.59	-	0.98
MAY 27	# Shad	137						137
	Hrs Fishing	11.4	0.0	0.0	0.0	0.0	0.0	11.4
	Catch/Hr Fishing	12.02	-	-	-	-	-	12.02
MAY 28	# Shad	1				-	1	2
	Hrs Fishing	4.2	0.0	0.0	0.0	3.6	3.4	11.2
	Catch/Hr Fishing	0.24	-	-	-	-	0.29	0.18
MAY 29	# Shad	15				-	1	16
	Hrs Fishing	7.2	0.0	0.0	0.0	2.0	2.3	11.4
	Catch/Hr Fishing	2.08	-	-	-	-	0.43	1.40
MAY 30	# Shad	2		3		-		5
	Hrs Fishing	4.6	0.0	4.2	0.0	2.0	0.0	10.8
	Catch/Hr Fishing	0.43	-	0.71	-	-	-	0.46
MAY 31	# Shad	2				-		2
	Hrs Fishing	6.0	0.0	0.0	0.0	5.2	0.0	11.2
	Catch/Hr Fishing	0.33	-	-	-	-	-	0.18
JUN 01	# Shad	11						11
	Hrs Fishing	10.4	0.0	0.0	0.0	0.0	0.0	10.4
	Catch/Hr Fishing	1.06	-	-	-	-	-	1.06
JUN 02	# Shad	16						16
	Hrs Fishing	5.4	0.0	0.0	0.0	0.0	0.0	5.4
	Catch/Hr Fishing	2.96	-	-	-	-	-	2.96
JUN 03	# Shad	5				-	1	6
	Hrs Fishing	6.4	0.0	0.0	0.0	2.0	2.2	10.6
	Catch/Hr Fishing	0.78	-	-	-	-	0.45	0.57

TABLE 9 Continued.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	B & DOWN Weir Gates Open	B ONLY Weir Gates Open	CHANGING Weir Gates Open	DOWN ONLY Weir Gates Open	TOTAL Weir Gates Open
JUN 04	# Shad	3				-	-	3
	Hrs Fishing	3.8	0.0	0.0	0.0	2.0	0.8	6.6
	Catch/Hr Fishing	0.79	-	-	-	-	-	0.45
JUN 05	# Shad	3				4	-	7
	Hrs Fishing	4.0	0.0	0.0	0.0	1.8	0.8	6.6
	Catch/Hr Fishing	0.75	-	-	-	2.22	-	1.06
JUN 06	# Shad	12				9		21
	Hrs Fishing	4.8	0.0	0.0	0.0	1.8	0.0	6.5
	Catch/Hr Fishing	2.50	-	-	-	5.00	-	3.23
JUN 07	# Shad	3				-		3
	Hrs Fishing	4.5	0.0	0.0	0.0	2.1	0.0	6.6
	Catch/Hr Fishing	0.67	-	-	-	-	-	0.45
TOTAL	# Shad	2,107	8	80	1,263	1,433	8,783	13,674*
	Hrs Fishing	138.7	4.6	11.6	26.9	109.8	260.6	552.4
	Catch/Hr Fishing	15.19	1.74	6.90	46.95	13.05	33.70	24.75

* Excludes American shad taken in clean out lifts.

TABLE 10

Comparison of catch per effort (hr) of American shad on weekdays vs. weekend days by generation (cfs) at the Conowingo Dam East Fish Lift, 1 April - 7 June 1991.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CFS CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	0500-0900	13.6	1.4	15.6	2.0	12.9	35.6	21.4
	0901-1100	12.4	1.8	4.7	0.0	43.5	23.1	17.1
	1101-1500	8.0	1.5	1.4	2.0	7.4	30.8	21.5
	1501-1900	23.9	-	14.0	12.5	9.4	44.0	32.9
MEAN WEEKDAYS		14.1	1.5	11.2	3.7	12.9	33.4	23.5
WEEKEND	0500-0900	23.9	2.4	37.2	7.0	5.2	6.1	19.3
	0901-1100	2.0	1.6	16.6	24.6	-	16.9	14.1
	1101-1500	48.6	1.9	21.9	23.1	33.4	41.8	34.6
	1501-1900	14.7	0.0	49.3	2.4	8.3	65.2	35.4
MEAN WEEKEND		32.7	1.7	31.1	11.2	12.6	38.4	27.9
TOTAL		17.9	1.6	19.1	7.9	12.8	34.5	24.7

TABLE 11

Comparison of the American shad catch and catch per effort at three generating conditions at the Conowingo Dam East Fish Lift by month, 1 April through 7 June 1991.

Generation Status	No. Shad Caught *	Total Hours Fished	No. of Lifts	Shad Catch per Hour
April				
Two small units	8	3	11	2.46
Higher generation	3982	192	432	20.75
Total for April	3990	195	443	20.45
May				
Two small units	1754	89	173	19.67
Higher generation	8058	216	461	37.26
Total for May	9812	305	634	32.12
June				
One small unit	53	33	51	1.62
Higher generation	14	20	28	0.70
Total for June	67	53	79	1.27
Grand total	13869	553	1156	25.06

* Excludes American shad taken during trough operation on 24 May.

Table 12. Daily sex ratio of American shad at the Conowingo Dam Fish Lifts for 1991.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
9 Apr	359	202	129	73	1.8:1
10 Apr	295	179	109	70	1.6:1
11 Apr	130	130	88	42	2.1:1
12 Apr*	356	205	148	57	2.6:1
13 Apr	550	210	145	65	2.2:1
14 Apr	482	158	96	62	1.5:1
15 Apr	114	113	80	33	2.4:1
16 Apr	215	89	71	18	3.9:1
17 Apr	275	194	142	52	2.7:1
18 Apr	257	158	107	51	2.1:1
19 Apr	431	200	146	54	2.7:1
20 Apr	994	213	142	71	2.0:1
12 Apr	360	199	144	55	2.6:1
22 Apr	197	127	74	53	1.4:1
23 Apr	179	155	113	42	2.7:1
24 Apr	323	173	124	49	2.5:1
25 Apr	38	38	27	11	2.5:1
26 Apr	22	22	17	5	3.4:1
27 Apr	37	37	27	10	2.7:1
28 Apr	423	225	157	68	2.3:1
29 Apr	785	209	132	77	1.7:1
30 Apr	1017	208	123	85	1.4:1
1 May*	248	100	54	46	1.2:1
2 May	1360	220	124	96	1.3:1
3 May	526	166	96	70	1.4:1
4 May	920	230	144	86	1.7:1
5 May	1343	201	107	94	1.1:1
6 May	1179	217	143	74	1.9:1

Table 12. Continued.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
7 May	841	222	163	59	2.8:1
8 May	956	215	132	83	1.6:1
9 May	1017	233	134	99	1.4:1
10 May	1148	223	127	96	1.3:1
11 May	624	221	138	83	1.7:1
12 May	1191	223	110	113	1.0:1
13 May	760	250	150	100	1.5:1
14 May	522	218	107	111	1.0:1
15 May	504	206	103	103	1.0:1
16 May	684	219	117	102	1.1:1
17 May	580	247	132	115	1.1:1
18 May	1220	217	132	85	1.6:1
19 May	1124	238	104	134	0.8:1
20 May	143	143	69	74	0.9:1
21 May	393	215	127	88	1.4:1
22 May	332	170	95	75	1.3:1
23 May	464	244	115	129	0.9:1
24 May*	208	119	64	55	1.2:1
25 May	137	126	65	61	1.1:1
26 May	170	113	54	59	0.9:1
27 May	227	189	95	94	1.0:1
28 May	89	89	35	54	0.6:1
29 May	154	116	48	68	0.7:1
30 May	96	96	59	37	1.6:1
31 May	63	63	29	34	0.9:1
1 Jun	24	24	7	17	0.4:1
2 Jun	23	23	11	12	0.9:1
3 Jun	10	10	3	7	0.4:1

Table 12. Continued.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
4 Jun	14	14	7	7	1.0:1
5 Jun	12	12	3	9	0.3:1
6 Jun	28	28	13	15	0.9:1
7 Jun	13	13	5	8	0.6:1
TOTALS	27,186	9,317	5,562	3,755	1.5:1

* East Lift trough operated on 12 April and 24 May. West Lift did not operate on 1 May.

TABLE 13

Age and spawning history of American shad collected at the Conowingo Dam Lifts in 1991, by sex, with mean, minimum and maximum fork length (mm).

Sex	Age	N	Spawning History			Fork Lengths		
			Virgins	Repeats Once	Repeats Twice	mean	min	max
MALE	III	4	4			307	295	327
	IV	63	58	5		363	296	446
	V	202	168	34		393	330	510
	VI	146	120	21	5	427	341	503
	VII	20	12	4	4	457	410	527
Total for Males		435	362	64	9	402	295	527
FEMALE	IV	11	11			413	384	498
	V	150	131	19		431	335	492
	VI	233	213	16	4	462	390	558
	VII	98	80	13	5	492	422	561
	VIII	10	5	3	2	532	499	548
Total for Females		502	440	51	11	459	335	561
Grand Total		937	802	115	20	433	295	561

Table 14. Daily capture of tagged Maryland DNR American shad at the Conowingo Dam Fish Lifts, 1991.

Date	Daily Catch		No. of MD DNR Recaptures	
	East	West	East	West
12 Apr	180	176	1	0
13 Apr	350	200	2	1
14 Apr	247	235	1	0
17 Apr	203	72	0	1
20 Apr	598	396	0	2
21 Apr	118	242	1	2
23 Apr	0	179	0	1
24 Apr	77	246	1	0
25 Apr	1	37	0	1
28 Apr	324	99	1	1
29 Apr	405	385	2	3
30 Apr	613	404	3	2
1 May	248	0	1	0
2 May	1088	272	4	1
3 May	471	55	0	1
4 May	393	527	3	3
5 May	718	625	6	4
6 May	696	483	5	3
7 May	248	594	1	4
8 May	427	529	3	5
9 May	608	409	7	6
10 May	833	315	7	5
11 May	300	324	4	4
12 May	776	415	10	10
13 May	425	335	7	2
14 May	269	253	4	8
15 May	344	160	9	4
16 May	265	419	4	4

Table 14. Continued.

Date	Daily Catch		No. of MD DNR Recaptures	
	East	West	East	West
17 May	433	147	7	4
18 May	329	891	4	7
19 May	124	1000	4	25
20 May	103	40	2	4
21 May	175	218	3	1
22 May	66	266	3	5
23 May	257	207	8	5
24 May	28	208	0	4
25 May	43	94	0	4
26 May	11	159	0	3
27 May	137	90	2	3
28 May	2	87	0	4
29 May	16	138	0	2
30 May	5	91	1	0
31 May	2	61	0	3
4 Jun	3	11	0	1
TOTALS	12,959	12,094	121	153

TABLE 15

Summary of transports of American Shad from Conowingo Dam West Fish Lift, 1 April through 7 June 1991.

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 APR	71	57.5	84	TRI-CO MARINA	0	100.0	12.2	17.0	61.7
12 APR	176	58.1	175	TRI-CO MARINA	8	95.4	17.4	14.2	57.2
13 APR	200	57.6	186	TRI-CO MARINA	3	98.4	14.0	11.2	53.6
14 APR	235	53.3	204	TRI-CO MARINA	26	87.3	13.6	15.1	50.4
18 APR	171	56.7	217	TRI-CO MARINA	0	100.0	17.2	13.2	57.2
19 APR	268	55.4	262	TRI-CO MARINA	0	100.0	11.0	15.6	55.4
20 APR	396	55.6	254	TRI-CO MARINA	2	99.2	13.6	12.2	52.7
21 APR	242	55.7	236	TRI-CO MARINA	0	100.0	14.4	14.6	50.5
23 APR	179	55.0	35	MUDDY RUN LAB	0	100.0	-	-	-
			137	SWATARA CR.	0	100.0	14.8	14.4	52.3
24 APR	246	54.0	20	MUDDY RUN LAB	0	100.0	14.0	12.4	-
			222	SWATARA CR.	1	99.5	15.6	15.0	53.6
28 APR	99	57.2	96	SWATARA CR.	0	100.0	18.5	15.2	65.5
29 APR	380	58.9	267	SWATARA CR.	0	100.0	13.8	17.4	62.2
			230	SWATARA CR.	0	100.0	18.2	10.8	59.0
30 APR	404	57.9	220	SWATARA CR.	3	98.6	17.0	15.2	61.7
			135	SWATARA CR.	0	100.0	20.0	11.4	59.0
01 MAY	-	-	42	MUDDY RUN LAB	0	100.0	12.0	12.6	56.8
02 MAY	272	59.9	211	TRI-CO MARINA	7	96.7	17.0	13.2	62.6
04 MAY	527	61.7	280	TRI-CO MARINA	1	99.6	12.4	16.0	63.5
			234	TRI-CO MARINA	7	97.0	14.0	14.0	63.5
05 MAY	625	62.1	208	TRI-CO MARINA	1	99.5	17.6	12.2	63.5
			229	TRI-CO MARINA	5	97.8	18.6	16.8	63.5
			178	TRI-CO MARINA	0	100.0	15.8	11.8	63.5
06 MAY	483	62.1	264	TRI-CO MARINA	0	100.0	16.0	15.6	62.6
			210	TRI-CO MARINA	0	100.0	12.6	15.8	62.6
07 MAY	594	61.7	186	TRI-CO MARINA	0	100.0	17.4	11.2	59.9
			190	TRI-CO MARINA	0	100.0	19.8	18.0	61.7
08 MAY	529	62.6	240	TRI-CO MARINA	0	100.0	14.2	14.6	61.7
			41	MUDDY RUN LAB	1	97.6	-	-	68.9
			235	TRI-CO MARINA	0	100.0	10.2	13.6	61.7
09 MAY	409	62.6	252	TRI-CO MARINA	0	100.0	10.2	14.0	59.9
			143	TRI-CO MARINA	0	100.0	18.0	13.0	59.9
10 MAY	315	63.5	213	TRI-CO MARINA	0	100.0	12.0	14.2	63.5
11 MAY	324	64.4	238	TRI-CO MARINA	8	96.6	15.6	9.0	66.2
			-	GLEN COVE	-	-	20.0	20.0	65.3
12 MAY	415	65.3	173	TRI-CO MARINA	6	96.5	16.4	11.4	67.1
			104	MUDDY CREEK	0	100.0	9.4	13.6	68.9
			121	TRI-CO MARINA	0	100.0	16.8	12.0	68.0
13 MAY	335	66.2	219	TRI-CO MARINA	1	99.5	12.0	12.6	70.3
14 MAY	253	66.2	55	MUDDY RUN LAB	2	96.4	11.6	12.0	-
15 MAY	160	65.9	108	TRI-CO MARINA	0	100.0	14.5	13.6	74.3
			94	TRI-CO MARINA	0	100.0	-	-	75.0
16 MAY	419	69.3	175	TRI-CO MARINA	0	100.0	14.4	10.2	74.3

TABLE 15 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
16 MAY	419	69.3	133	TRI-CO MARINA	0	100.0	13.4	13.0	75.2
			96	TRI-CO MARINA	0	100.0	20.0	11.0	69.8
18 MAY	891	71.8	232	SWATARA CR.	0	100.0	11.0	11.0	71.8
			181	SWATARA CR.	1	99.4	10.8	11.6	71.6
			191	SWATARA CR.	0	100.0	9.2	12.8	73.4
			197	SWATARA CR.	0	100.0	11.0	10.5	72.5
19 MAY	1000	71.6	193	TRI-CO MARINA	0	100.0	12.6	13.8	70.7
			231	SWATARA CR.	14	93.9	9.8	10.0	70.7
			251	TRI-CO MARINA	5	98.0	16.6	8.4	70.7
			190	TRI-CO MARINA	6	96.8	11.4	11.0	72.5
22 MAY	266	73.4	16	MUDDY RUN LAB	0	100.0	15.0	11.8	71.6
			150	TRI-CO MARINA	0	100.0	8.0	10.6	73.4
			113	TRI-CO MARINA	1	99.1	8.0	10.2	71.6
23 MAY	207	72.9	138	TRI-CO MARINA	7	94.9	10.8	12.8	77.0
25 MAY	94	75.8	38	MUDDY RUN LAB	0	100.0	19.4	10.6	-
28 MAY	87	77.7	70	TRI-CO MARINA	0	100.0	7.8	8.5	80.6
29 MAY	138	78.3	33	MUDDY RUN LAB	1	97.0	13.0	8.0	-
30 MAY	91	79.7	76	TRI-CO MARINA	0	100.0	11.8	9.3	78.8
31 MAY	61	80.6	31	TRI-CO MARINA	0	100.0	13.4	10.0	80.6
SEASON TOTALS			10183		117	98.9			

TABLE 16

Summary of transports of American Shad from Conowingo Dam East Fish Lift, 1 April through 7 June 1991.

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 APR	224	55.4	221	GLEN COVE	4	98.2	18.6	20.0	59.9
12 APR	180	59.9	175	TRI-CO MARINA	5	97.1	19.0	16.6	57.2
13 APR	350	60.5	176	TRI-CO MARINA	6	96.6	10.8	15.8	51.8
17 APR	203	55.4	201	TRI-CO MARINA	10	95.0	6.0	10.8	57.2
19 APR	163	55.4	161	TRI-CO MARINA	0	100.0	20.0	17.8	55.4
20 APR	598	55.4	170	TRI-CO MARINA	2	98.8	12.0	14.0	53.6
			175	TRI-CO MARINA	0	100.0	20.0	18.0	53.6
			219	TRI-CO MARINA	4	98.2	20.0	16.2	53.6
21 APR	118	55.8	115	TRI-CO MARINA	0	100.0	20.0	14.8	50.0
24 APR	77	53.6	75	SWATARA CR.	1	98.7	9.6	11.2	55.2
28 APR	324	55.4	194	SWATARA CR.	2	99.0	16.0	16.2	-
29 APR	405	57.0	190	SWATARA CR.	0	100.0	13.8	14.0	61.7
			209	SWATARA CR.	17	91.9	17.4	14.6	60.8
30 APR	613	57.2	199	SWATARA CR.	46	76.9	15.2	12.2	61.7
			195	SWATARA CR.	0	100.0	13.8	14.5	61.2
			208	SWATARA CR.	0	100.0	13.7	18.2	61.7
01 MAY	248	59.0	230	TRI-CO MARINA	7	97.0	17.8	16.2	62.6
02 MAY	1088	60.6	225	TRI-CO MARINA	4	98.2	19.0	15.0	59.9
			225	TRI-CO MARINA	1	99.6	11.6	16.0	63.5
			212	TRI-CO MARINA	2	99.1	20.0	14.2	61.2
			215	TRI-CO MARINA	1	99.5	20.0	13.0	62.6
03 MAY	471	60.8	201	TRI-CO MARINA	16	92.0	10.5	17.6	63.5
			177	TRI-CO MARINA	0	100.0	16.0	13.6	64.4
04 MAY	393	60.8	225	TRI-CO MARINA	4	98.2	15.4	19.4	63.5
			157	TRI-CO MARINA	0	100.0	17.2	14.4	63.5
05 MAY	718	61.7	244	TRI-CO MARINA	10	95.9	11.4	13.2	61.7
			238	TRI-CO MARINA	13	94.5	12.4	14.4	64.0
			210	TRI-CO MARINA	1	99.5	19.0	14.6	63.5
06 MAY	696	62.6	226	TRI-CO MARINA	15	93.4	10.4	13.8	62.6
			221	TRI-CO MARINA	0	100.0	13.6	18.2	62.6
			229	TRI-CO MARINA	4	98.3	11.0	12.4	62.6
07 MAY	248	63.9	189	TRI-CO MARINA	0	100.0	9.2	11.6	61.7
08 MAY	427	63.5	205	TRI-CO MARINA	27	86.8	13.4	12.8	62.6
			215	TRI-CO MARINA	3	98.6	17.4	12.4	61.7
09 MAY	608	63.9	118	TRI-CO MARINA	2	98.3	13.8	15.0	59.9
			222	TRI-CO MARINA	0	100.0	10.2	12.2	59.0
			209	TRI-CO MARINA	0	100.0	13.2	13.6	59.9
10 MAY	833	65.8	171	TRI-CO MARINA	0	100.0	15.8	12.6	60.8
			181	TRI-CO MARINA	0	100.0	16.2	14.0	62.6
			159	TRI-CO MARINA	0	100.0	15.8	12.0	64.4
			178	TRI-CO MARINA	1	99.4	10.4	14.0	62.6
11 MAY	300	64.4	160	TRI-CO MARINA	1	99.4	10.2	12.2	64.4
12 MAY	776	65.3	156	TRI-CO MARINA	2	98.7	9.8	15.6	68.0
			175	TRI-CO MARINA	10	94.3	10.8	12.0	69.8

TABLE 16 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
12 MAY	776	65.3	175	TRI-CO MARINA	37	78.9	14.6	13.8	68.0
			175	TRI-CO MARINA	29	83.4	17.6	13.8	68.0
13 MAY	425	66.2	176	TRI-CO MARINA	5	97.2	20.0	13.0	71.6
14 MAY	269	66.2	120	TRI-CO MARINA	2	98.3	18.8	13.8	73.4
			142	TRI-CO MARINA	0	100.0	12.6	10.4	72.0
15 MAY	344	69.3	145	TRI-CO MARINA	1	99.3	13.0	14.2	75.2
16 MAY	265	68.9	112	TRI-CO MARINA	23	79.5	20.0	14.4	75.2
21 MAY	175	71.6	113	TRI-CO MARINA	7	93.8	19.6	11.8	68.9
23 MAY	257	73.4	124	TRI-CO MARINA	10	91.9	13.0	12.0	75.2
SEASON TOTALS			9738		335	96.6			

TABLE 17

Summary of combined transports of American Shad from both Conowingo Dam Fish Lifts, 1 April through 7 June 1991.

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
09 APR	359	55.4	276	TRI-CO MARINA	29	89.5	8.9	15.0	64.4
11 APR	130	57.2	128	TRI-CO MARINA	1	99.2	18.1	11.0	59.0
13 APR	550	58.6	177	TRI-CO MARINA	36	79.7	13.0	13.4	51.8
15 APR	114	57.5	133	TRI-CO MARINA	0	100.0	15.2	15.4	48.6
16 APR	215	55.3	210	TRI-CO MARINA	7	96.7	11.4	10.0	54.3
18 APR	257	56.4	106	TRI-CO MARINA	2	98.1	13.4	12.0	57.2
20 APR	994	55.5	154	TRI-CO MARINA	0	100.0	19.4	14.4	52.7
22 APR	197	55.2	193	TRI-CO MARINA	0	100.0	17.2	17.6	48.2
26 APR	22	52.4	59	TRI-CO MARINA	0	100.0	10.2	8.0	56.3
27 APR	37	54.3	37	SWATARA CR.	1	97.3	11.6	11.8	64.4
02 MAY	1360	60.0	152	TRI-CO MARINA	0	100.0	20.0	20.0	62.6
03 MAY	526	60.6	143	TRI-CO MARINA	0	100.0	13.6	13.6	62.6
07 MAY	842	62.8	262	TRI-CO MARINA	0	100.0	10.2	12.8	59.0
10 MAY	1148	65.0	190	TRI-CO MARINA	1	99.5	12.8	16.8	64.4
11 MAY	624	64.4	206	TRI-CO MARINA	12	94.2	12.6	13.8	65.3
13 MAY	760	66.2	171	TRI-CO MARINA	0	100.0	11.8	14.8	69.8
			159	TRI-CO MARINA	4	97.5	7.6	14.6	69.8
17 MAY	580	71.2	145	TRI-CO MARINA	8	94.5	16.4	12.2	73.4
			118	MUDDY CREEK	0	100.0	13.5	13.8	75.2
			169	TRI-CO MARINA	38	77.5	16.0	14.2	75.2
			142	TRI-CO MARINA	16	88.7	12.4	14.0	73.4
18 MAY	1220	72.5	204	SWATARA CR.	14	93.1	18.2	10.4	73.4
19 MAY	1124	71.6	133	TRI-CO MARINA	0	100.0	9.2	13.2	72.5
23 MAY	464	73.2	113	TRI-CO MARINA	3	97.3	11.0	10.2	73.4
29 MAY	154	79.5	81	TRI-CO MARINA	0	100.0	7.8	8.4	78.6
SEASON TOTALS			3861		172	95.5			

117
335
624
-2579
1955

Table 18. Summary of river herring transported from the Conowingo Dam Fish Lifts to upstream release sites on the Susquehanna River, 1991.

Species	Release Site	No. Transported	Percent Survival
Alewife	Tri-County Marina	733	99.9
Alewife	Swatara Creek	662	100
Alewife	Glen Cove Marina	1	100
Blueback herring	Tri-County Marina	519	100
Blueback herring	Swatara Creek	950	100
Blueback herring	Muddy Crk Access	700	100
Blueback herring	Glen Cove Marina	429	100
Blueback herring	Tri-County Experimental Net Pen	7	100
Total		4,001	100

Table 19. Summary of blueback herring transported from the Conowingo Dam West Fish Lift to three Chesapeake Bay tributaries by the Maryland DNR, 1991.

Date	Release Location	No. Transported	Observed Mortality	Percent Survival
Big Elk Creek				
10 May	Fairhaven	45	0	100
15 May	Fairhaven	17	0	100
16 May	Fairhaven	18	0	100
17 May	Fairhaven	27	0	100
18 May	Fairhaven	23	0	100
21 May	Fairhaven	39	1	97.5
Patapsco River				
8 May	Daniels	166	0	100
14 May	Ellicott City	281	6	97.9
Winter's Run				
13 May	Abingdon	87	0	100
Total		703	7	99.0

Table 20. Summary of stocking and holding events at the experimental instream net pen at the Tri-County Boat Club Marina, spring 1991.

Stock Date	No. Transported	No. Released	Transport Mortality	Delayed Mortality	Hours Held	DO	Water Temp(F) at Stocking Site
14 May	129	122	5	2	19	8.8	73.8
18 May	130	45	27	58	11	7.4	72.5
20 May	144	128	0	16	11	7.2	68.0
21 May	144	110	19	15	19	9.7	70.7
22 May	56	48	0	8	12	7.2	71.6
24 May	136	104	9	23	16	6.2	77.4
25 May	126	104	5	17	9	6.0	77.0
26 May	132	100	3	29	10	6.9	78.8
27 May	94	18	36	40	16	6.5	82.4
28 May	69	49	5	15	42	7.2	83.3
Total	1,160	828	109	223			

Table 21. Fish observed swimming past the counting window at the Conowingo Dam East Fish Lift during trough operation on 24 May 1991.

Species	No. Observed	Percent
Gizzard shad	2,153	74.0
Carp	475	16.3
Quillback	107	3.7
Minnows	100	3.4
Striped bass	29	1.0
American shad	13	0.4
Striped bass hybrids	9	0.3
Redbreast sunfish	8	0.2
Channel catfish	6	0.2
Bluegill	3	0.1
Smallmouth bass	3	0.1
Pumpkinseed	1	+
Blueback herring	1	+
Atlantic needlefish	1	+

+ Less than 0.05%.

TABLE 22

Summary of American Shad catch by constant generation levels (varying generation during a lift was grouped seperately) at the Conowingo Dam East vs. West Fish Lift, 1 April through 7 June 1991. Cleanout lifts were excluded.

TOTAL DISCHARGE (X 1000 CFS)	UNIT closest to the lift	UNIT 2nd closest to the lift	EAST FISH LIFT NO. LIFTS	EAST FISH LIFT TIME (MINS)	EAST FISH LIFT TOTAL SHAD	EAST FISH LIFT SHAD/HR	WEST FISH LIFT NO. LIFTS	WEST FISH LIFT TIME (MINS)	WEST FISH LIFT TOTAL SHAD	WEST FISH LIFT SHAD/HR
< 5	OFF	OFF	51	1966	53	1.6	64	1936	51	1.6
*TOTAL < 5			51	1966	53	1.6	64	1936	51	1.6
10-65	CHG	CHG	-	-	-	-	1	45	2	2.7
10-65	OFF	OFF	272	8527	2343	16.5	821	22931	10832	28.3
10-65	OFF	ON	18	539	86	9.6	-	-	-	-
10-65	ON	OFF	37	1113	588	31.7	-	-	-	-
10-65	ON	ON	486	12292	8017	39.1	12	419	48	6.9
*TOTAL 10-65			813	22471	11034	29.5	834	23395	10882	27.9
VARYING	CHG	CHG	38	1423	318	13.4	9	230	160	41.7
VARYING	CHG	OFF	5	245	154	37.7	-	-	-	-
VARYING	CHG	ON	6	151	65	25.8	-	-	-	-
VARYING	OFF	CHG	2	36	1	1.7	-	-	-	-
VARYING	OFF	OFF	28	1372	205	9.0	128	3816	1258	19.8
VARYING	OFF	ON	2	95	0	0.0	-	-	-	-
VARYING	ON	CHG	14	386	219	34.0	-	-	-	-
VARYING	ON	OFF	4	150	66	26.4	-	-	-	-
VARYING	ON	ON	29	1409	555	23.6	14	292	54	11.1
*TOTAL VARYING			128	5267	1583	18.0	151	4338	1472	20.4
> 65	ON	ON	105	3245	951	17.6	145	2950	883	18.0
*TOTAL > 65			105	3245	951	17.6	145	2950	883	18.0
TOTAL			1097	32949	13621	24.8	1194	32619	13288	24.4

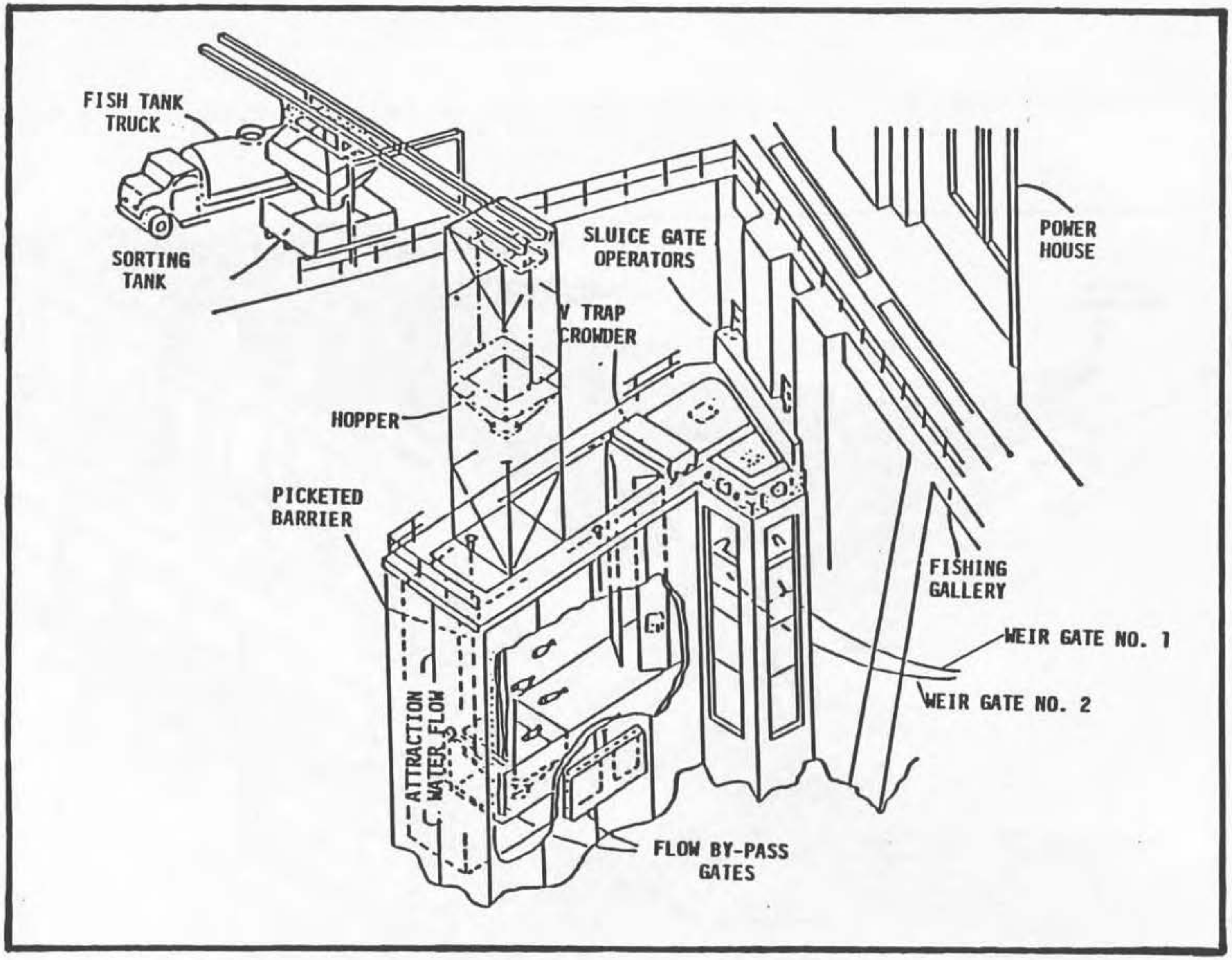


Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

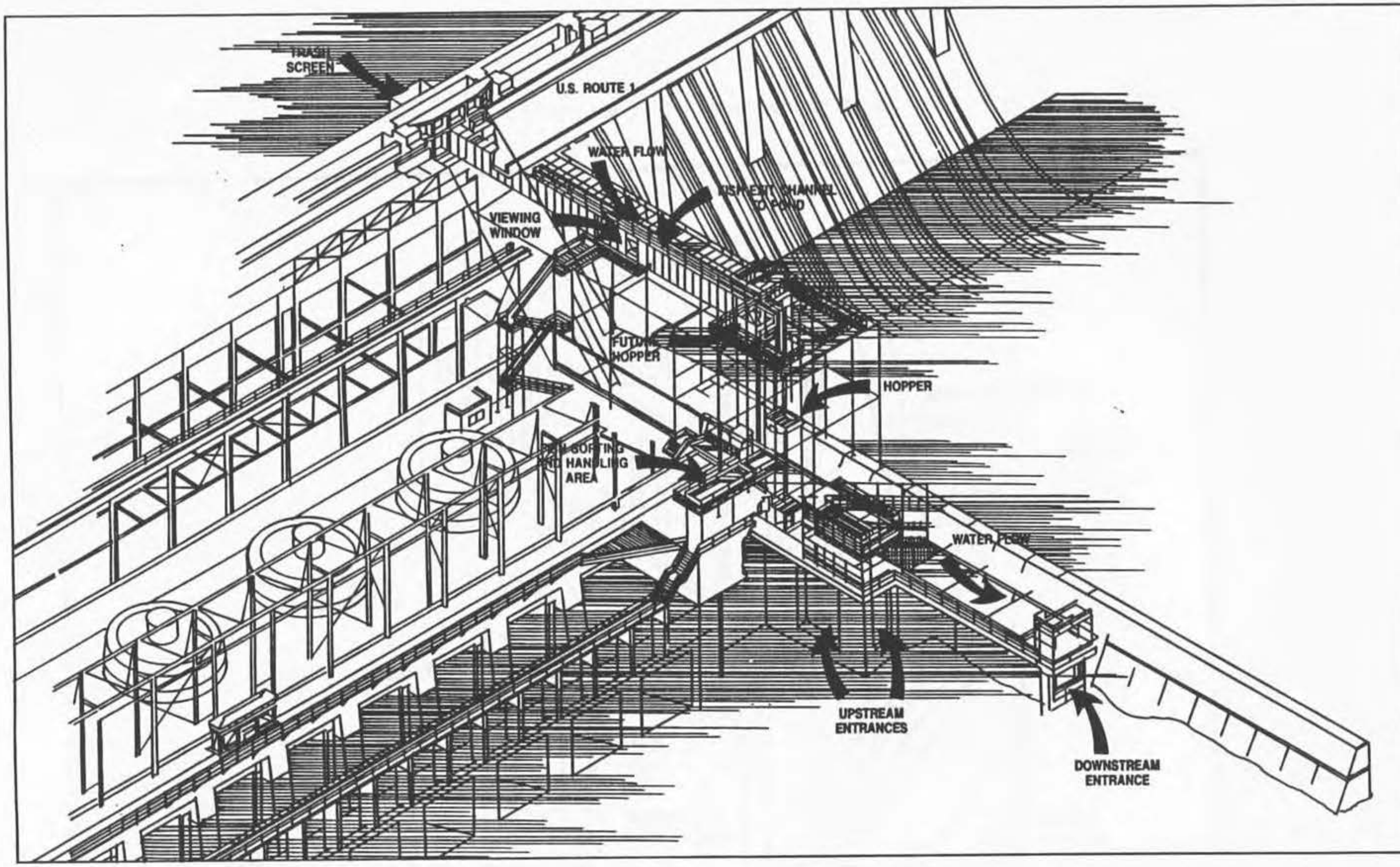


Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

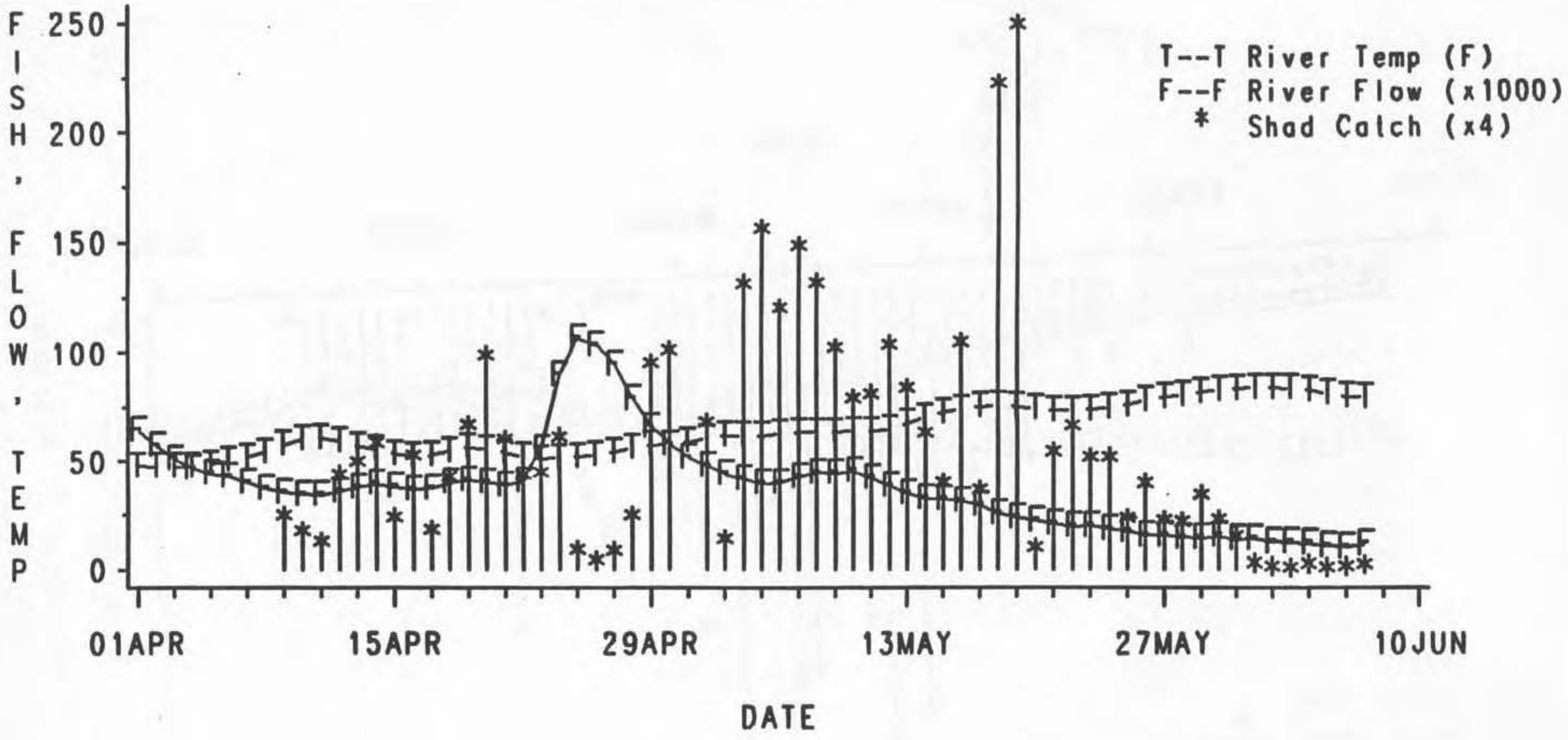
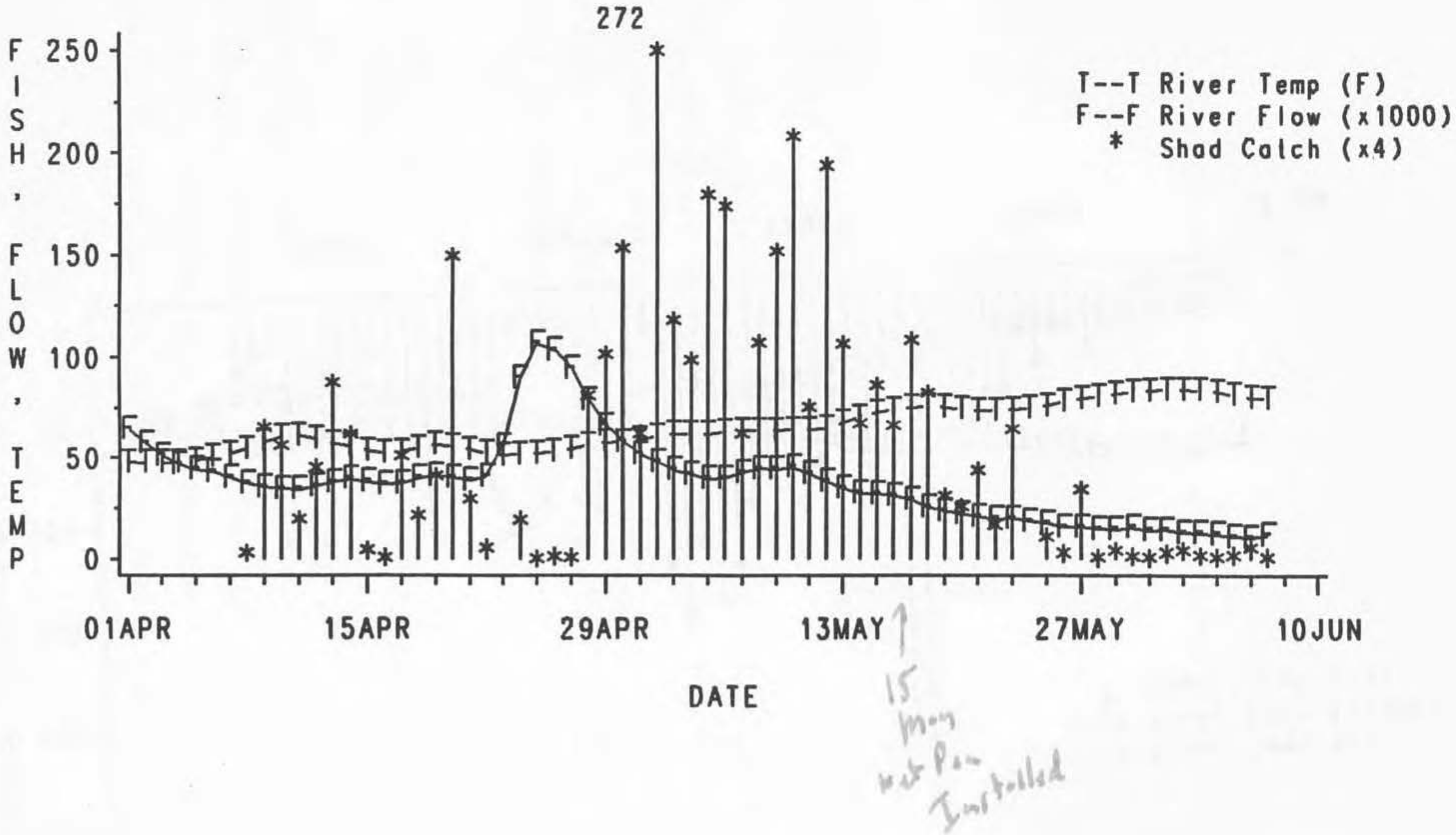


FIGURE 3

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch (x 4) at the Conowingo Dam West Lift in 1991.



I-84

FIGURE 4

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch (x 4) at the Conowingo Dam East Lift in 1991.

JOB II.

AMERICAN SHAD EGG COLLECTION PROGRAM

THE WYATT GROUP, Inc.

Lancaster, Pennsylvania

INTRODUCTION

The shad restoration program is an on-going effort. This report is a synopsis of egg collection efforts in the spring of 1991. The SRAFRC goal for 1991 was to obtain a minimum of 30 million shad eggs over a three month period (April-June). In the last 18 years (1973-1990) slightly over 600 million eggs have been collected for the program (Table 1).

FIELD COLLECTION PROCEDURES

The shad egg collection schedule is based on past experience, communications with commercial fisherman, advice of resource agency biologists and water temperature. Collection activities begin when water temperature is 55-58 °F. The 1991 schedule of collection activities is shown in Table 2. Collection is terminated on a river when either (1) the production goal for that river is reached or (2) when it is obvious that sufficient quantities of eggs (usually less than five liters) do not justify shipment to the Van Dyke Hatchery.

Egg Collection

Every attempt is made to obtain eggs and sperm from shad as soon after capture as possible. Ability to do so varies according to the method of capture, especially the size of the fishing vessel used and whether or not shad are caught by, contractors (The Wyatt Group or Ecology III) or commercial fishermen.

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

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

Egg Fertilization

The process of egg fertilization is essentially that described by Kilcer (1973). Ideally, eggs from four to six spawning females are squeezed into a dry collecting pan and fertilized with sperm from up to six live males. Eggs and sperm from fewer fish are often fertilized, rather than defer the effort to obtain a specific number of fish. After dry mixing eggs and sperm for about one minute, a small amount of water is then added to the mixing pan to activate sperm and eggs to ensure fertilization. The fertilized eggs are then allowed to settle for two to four minutes, after which the water is decanted and clean water added to the mixing pan.

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

Once the eggs are hardened (about 1 hour), the water is decanted through the mouth of a filtering cloth (approximately 2.0 millimeter aperture) held over the rim of the egg container and five liters each of eggs and clean river water are placed in double plastic bags. The primary plastic bag is squeezed shut by hand and pure oxygen injected into the bag. Each bag is then secured with a rubber O-ring. The bags are placed in styrofoam containers which has a cardboard box outer liner. Each box is labeled to show river name, date, number of eggs, and water temperature. The fertilized eggs are then ready for shipment.

Egg Viability

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

Disposal of Shad

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

Transportation of Eggs to Hatchery

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

FACTORS WHICH AFFECT EGG COLLECTION PROGRAM

Weather Conditions

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

Water Temperature

Water temperature is an important factor in stimulating the spawning of shad, and thus the availability of mature eggs. Although differences occur between rivers, ripe shad are not collected until water temperature is consistently above 58 °F. Spawning is concluded by the time water temperature reaches about 68 °F. Monitoring water temperature on rivers where eggs are to be collected is very important in determining the appropriate time to begin collecting efforts. The initial availability of eggs (spawning) can vary one to two weeks annually due to water temperature. Under unusually warm spring conditions, as occurred in the Hudson in 1990 and the Connecticut in 1991, water temperature can increase quickly. For example,on May 28, 1991, water temperature at Turners Fall, (in the vicinity of the spawning area) was equal to that recorded in the same location three weeks later in the spring of 1990.

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

Tidal Conditions

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

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

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

LOCATION OF EGG COLLECTION EFFORT

Through the years since 1971, the rivers chosen each year for sampling have changed in an attempt to gradually improve the program. 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) was eliminated from the 1990 program, and presumably all future years, due to poor fry survival (as indicated by otolith analysis) and the potential presence of viral hemorrhagic septicemia (VHS). The James River was eliminated in 1990 due to lack of egg production in the previous two years and the Pamunkey River program was scaled down to a two week sampling effort. The Savannah River was added to the 1990 program in an effort to collect up to 5 million eggs in April, but only few eggs with low viability were collected. In 1991, the Pamunkey and the Savannah rivers were eliminated with the desire to add the Chowan River (North Carolina/Virginia) and the Connecticut River (Massachusetts). Experimental efforts in South Carolina on the Santee River system continued.

Santee River (South Carolina)

Biologists from the Marine Resources Division (MRD) of the South Carolina Wildlife and Marine Resources Department (SCWMRD) surveyed selected areas of the Santee River to determine the potential for making collections of spawning American shad. This survey was conducted between 16 April and 1 May 1991. In addition to determining the feasibility and logistic requirements of future egg collections, shad ovaries and scales were also collected for mtDNA stock identification.

Several areas were investigated to determine their potential for providing adequate numbers of spawning shad. Initial efforts focused on the re-diversion canal at St. Stephan, South Carolina. The re-diversion canal and St. Stephan powerhouse were constructed by the Corps of Engineers to direct most of the flow coming from Lake Marion into the Santee River, rather than the Cooper River. The re-diversion project was constructed to alleviate silting problems in the Charleston harbor shipping channels. The St. Stephan dam was constructed to generate hydro-electric power and includes a fish lift to allow passage of anadromous species, primarily American shad and blueback herring, into the Santee-Cooper Lakes and their headwater sources, the Wateree and Congaree rivers. The original structure impounding the Santee River is Wilson Dam approximately 30 river miles above the confluence of the re-diversion canal with the Santee. Wilson Dam has no generating turbines and is primarily a spillway producing high flows in the river below the dam only during heavy rainfall periods. Biologists with the Game and Freshwater Fish Division (SCWMRD) believe that the majority of American shad are attracted to the re-diversion canal because of its greater flow during normal flow conditions. Only during flood conditions when substantial releases are made at the Wilson Dam do large quantities of anadromous species proceed upriver to the base of Wilson Dam.

In the river below the confluence of the re-diversion canal, flood conditions are the rule during the shad run because of spring rains and the power-generation flows from the St. Stephan dam. Gill net fishing in this area is difficult due to the high flow rates.

Chowan River (North Carolina-Virginia)

The Chowan River, extending approximately fifty-five miles north from the western section of Albermarle Sound, was a new area of exploration in the spring of 1991. Efforts were concentrated in the general vicinity of the mouth of the Chowan River and extended to Edenton Bay to the east. In addition, a survey was conducted along the entire river to Cortland, VA. to seek information with respect to the historical and current characteristics of the American shad fishery and to identify spawning locations. North Carolina State Division of Marine Fisheries personnel and commercial fishermen were very helpful in this effort.

Delaware River (Pennsylvania-New Jersey)

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

Hudson River (New York)

The Hudson is a relatively large estuarine system which is simple in configuration but very complex in physical and chemical characteristics. For these reasons, egg collections efforts during 1989 were spread over an extensive reach of the estuary from Kingston (River Mile 92 to Hudson (River Mile 117). Egg collection efforts fell into two categories: collections by anchor gill-nets and an 800-foot haul seine. Gill-netting was conducted at various locations whereas the haul seine was used only off the northwest shore of Rogers Island (River Mile 114).

The 1990 efforts were concentrated in two primary areas, Rogers Island for haul seining and off Cheviot,NY (River Mile 106) for gill-netting. These two techniques were alternated in accordance with the changing tidal conditions; the haul seine was used during periods of low water and gill-nets were used at all other times.

In 1991, gill-net and haul seine efforts were repeated in the same primary areas, Cheviot and Rogers Island, (respectively) used in 1990. In addition, the approach for 1991 incorporated greater flexibility to use the services of commercial fisherman, as needed.

Connecticut River (Massachusetts)

The Connecticut River was fished in the vicinity of the Holyoke Dam on an experimental basis in the spring of 1990 but with no success in acquiring running-ripe American shad. Because of potential, an effort on the Connecticut was continued during the spring of 1991. This was after extensive communications with U.S. Fish and Wildlife Service personnel and staff of the University of Massachusetts Cooperative Fish and Wildlife Unit.

Prior to the shad spawning season for the spring of 1991, Mr. Richard St. Pierre made arrangements for The Wyatt Group personnel to communicate with Mr. Ted F. Meyers, Executive Assistant for the Connecticut River Atlantic Salmon Commission (CRASC), to obtain suggestions as to possible American shad spawning areas in the Connecticut River. In turn, Mr. Meyers arranged for Mr. John O'Leary, Anadromous Fish Coordinator for Massachusetts Division of Fish and Wildlife (and a member of the CRASC Technical Committee) to meet with a representative of The Wyatt Group. On May 23, Mr. William Dovel, The Wyatt Group, met with Mr. Meyers and Mr. O'Leary at Turners Falls, MA. Following that meeting Mr. O'Leary provided maps of known shad spawning areas on the Connecticut River and led a site visit to the three most promising spawning locations. These were:

1) River Miles 190 to 191, between the railroad bridge and the island at River Mile 191.
2) River Miles 187 to 189, between the Dick Moody farm and the island at River Mile 187.
3) From the Route 116 bridge at Sunderland, MA. south to River Mile 169 where the Connecticut River makes a sharp bend to the west.

The fishing effort was conducted between Turners Fall and Sunderland, MA. It evolved from anchor gill-netting to drift netting at two locations (between Miles 185 and 192) reported as the sites where most spawning activity for the American shad has been observed in the past. In addition, a third location (south of the Route 116 Sundersland Bridge, Miles 178 to 168) was examined as a possible spawning site.

RESULTS OF 1991 FIELD COLLECTION EFFORTS

This section provides the results of the efforts in the spring of 1991. In addition, discussion is presented when explanation is useful in describing events or in consideration of making plans for the future.

Santee River (South Carolina)

Freshwater biologists at the St. Stephan hatchery observed numerous shad at the base of the dam and other areas of the re-division canal while conducting electro-fishing to collect striped bass brood stock. These biologists provided the use of their electro-fishing boats to determine the presence of shad in these areas. Extensive shocking near the dam and in the canal failed to produce any shad. Only one male shad was observed during the shocking operations. The shad observed earlier in the season (approximately 2 weeks before) had apparently been passed into the lake by the fish lift or had moved downstream.

The fish lift at St. Stephan dam passes large quantities of shad into Lake Marion. The original plan was to trap fish moved into the lift after dark and examine them for spawning condition. This was not accomplished because the lift was not operational during this survey.

Drift and set gill nets were the most effective means of determining the presence and spawning condition of American shad. The gill nets used were constructed of 5.5 inch stretched monofilament and were 250 feet long and about 14 feet deep. These nets were effective for roe shad but smaller mesh nets (4.5-5 inch) would have to be fished to consistently obtain male fish during actual egg collection operations. Drift nets worked effectively in the re-diversion canal which is uniformly, deep and free of obstructions. The drift nets were used during daylights hours to determine the abundance and spawning condition (virgin, partially spawned or spent) of shad in the survey area. Drift nets were not used at night because observations of the biologists and information obtained from local commercial fisherman indicated that shad were spawning near the shoreline and in eddies in the river; areas impossible to fish with drift nets. Catch per effort was as good in the re-diversion canal, and as late as the last week in April over 50% of the fish showed no signs of previous spawning. Ovary and scale samples from fish obtained in this sampling were sent to for mtDNA analysis.

Set gill nets were effectively used in the river near the confluence of the canal. Information obtained from local commercial fisherman indicated that this area was good spawning habitat based on their capture of running ripe fish and the frequency that they could hear the shad "washing" in this area. "Washing" refers to the splashing sound made as the shad spawn.

Observations of a commercial fisherman's catch on 30 April showed the presence of running ripe fish in a set near the canal mouth. Two 250-foot set nets were fished on 1 May in the same area which produced 26 American shad females, 9 of which were running ripe. About half of the running ripe fish showed evidence of prior spawning, but all produced good flows of eggs.

Commercial fisherman that were interviewed said that the amount of spawning activity during biologists observations and collections was less than they had observed earlier in the season. They reported observing running ripe shad as early as the second week in April. The abundance of gar and gizzard shad in the study was a problem requiring frequent checking on nets to remove these fish. Gar caused substantial damage to nets, particularly when they become badly tangled in the mesh. Substantial quantities of drifting aquatic weeds also fouled the nets and required frequent net cleaning.

Chowan River (North Carolina/Virginia)

Although appreciable effort was expended in an effort to obtain fertilized shad eggs from the Chowan River, no eggs were collected. The inability to obtain eggs can be attributed to several factors, none of which could be controlled by the biologists. Factors include: (1) the spawning run for American shad starts well before the Van Dyke Hatchery is ready to accept eggs, perhaps as early as February; (2) the spawning run for shad in southern tributaries seems to be protracted, probably a direct result of the water temperature profile, thus eliminating concentration of fish to provide eggs and sperm; (3) commercial fishermen who can provide a source of spawning shad are far more concerned with catching herring and herring roe and treat all other species, including the American shad, as incidental; and (4) North Carolina State Fisheries personnel stated that offshore intercept fisheries have appreciably reduced the stock of adult American shad which could return to the Chowan to spawn.

The concentration of gill-nets, among numerous pound nets, just south of the Route 17 bridge, was certainly adequate to capture adult shad if present. According to fishermen the Chowan bridge structure serves as a temporary deterrent and concentration area for fish, which will momentarily continue their upstream migration to spawning areas.

Delaware River (Pennsylvania-New Jersey)

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 (Berwick PA) conducted the collection program. Shad were captured with 200 x 6-foot, anchored, gill-nets, with sections 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.

Approximately 10.74 million eggs (Table 3) were shipped to the Van Dyke Hatchery on 10 dates. The consistency of the results was excellent; more than a million eggs were shipped on 7 of 10 collection days. Ripe shad were caught at water temperatures which ranged from 61 to 72 °F (mean = 66.9 °F).

Hudson River (New York)

A total of 17.66 million eggs were obtained on the Hudson River (Table 4). This included 14.60 million eggs from shad captured by gill-net and 3.06 million eggs from shad captured by haul seine. The Hudson River egg collection program began on 2 May and continued until 23 May, a period of 21 days. This included 17 days of gill-netting and three days of haul seining. Based on experience on the Hudson in 1990 The Wyatt Group field crew initiated field sampling by gill-net off Cheviot, NY on May 2, when the water temperature was 56 °F. Fishing effort was maintained at that location until May 11 at which time, and for the next three days (May 11, 12 & 13), The Wyatt Group field crew assisted Mr. Everett Nack in capturing shad by haul seine off the northwest corner of Rogers Island. On May 14 The Wyatt Group crew returned to gill-net off Cheviot, NY, where they remained until termination of the effort on the Hudson (May 22). In retrospect, the production of eggs through gill-net and haul seine methods was generally comparable (Table 4). However, the cost of the two methods was substantially different; the haul seine operation was much more expensive.

In 1991, 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 nightly basis beginning just before dark, 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.

A 500-foot x 12-foot haul seine with 2-inch stretch mesh was also 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.

With the exception of one night, the weather during the shad spawning on the Hudson was excellent. The first substantial collection of shad eggs from the Hudson in the spring of 1991 was made about one week earlier than the first substantial collection made in the spring of 1990. In retrospect, it would appear that water temperatures in the Hudson increased faster than usual in the spring of 1991.

The Wyatt Group approached the egg collection program in the spring of 1991 with a desire to incorporate greater flexibility in using the expertise of commercial fishermen. Accordingly, necessary arrangements were made and a number of fishermen agreed to cooperate with the program. However, in-house production in obtaining eggs by The Wyatt Group field crew precluded the need to employ additional assistance in collecting eggs.

Connecticut River (Massachusetts)

With the termination of the Columbia River as a source of shad eggs, the egg collection program is somewhat vulnerable to annual variations in productions 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 estuary will produce substantial numbers of shad eggs but may not produce the numbers collected from the Columbia River. Therefore, one goal in 1991 was to examine the Connecticut River as a possible contingency source for eggs. Prior to the arrival of The Wyatt Group field crew on the Connecticut River, it was the consensus of knowledgeable people interviewed that the first two weeks of June should be an ideal period in which to obtain shad eggs. All past evidence indicated this to be the case. However, upon arriving on the Connecticut on May 28 the water temperature was 71 °F, well above the 58 °F when spawning usually commences.

On the night of the 28 May a 500-foot gill-net was set at River Mile 191 in an area reputed to be a spawning area. Much shad activity was heard and observed; numerous shad were observed moving around the research boat. It was noted that these fish appeared smaller than the Hudson River shad and that most exhibited signs of hemorrhaging on their sides, where, on examination scales were found to be missing. These shad did not appear to be in good shape.

The anchor net set on the evening of May 28 collected appreciable trash but no shad. Therefore, on May 29 the nets were converted to drift nets. A third alternative fishing technique to anchoring or drifting individual nets, that of anchoring several nets parallel with the flow of the river, and one used successfully on the Delaware River, would probably work in the Connecticut. However, multiple nets were not available for use. This approach will be considered in future effort on the Connecticut River.

Between May 29 and June 4 the activity of shad on the spawning ground diminished precipitously. During this period approximately 1.81 million eggs were obtained (Table 5); 1.11 million were transported to the Van Dyke Hatchery, 0.52 million were given to the University of Maine and 0.1 million were returned to the river.

In retrospect, the attempt to collect shad eggs from the Connecticut River, on the heels of efforts on the Hudson, and as early as the effort could be reasonably transferred from the Hudson to the Connecticut, were too late for environmental conditions existing in the spring of 1991. A record of water temperature at the Cabot Fish Ladder at Turners Falls for the spring of 1990 indicated that all American shad had passed the falls in the spring of 1990 by the time the water temperature rose to 72 °F, the temperature recorded on May 28, 1991 but not until June 17 of 1990. The eight to ten degree temperature range(58 to 66/68 °F) universally conducive to the spawning of American shad complicates efforts to collect shad eggs from the Connecticut and Hudson if pronounced early increases in water temperature cause the shad in both river systems to spawn in the same time period. However, the overall experience of attempting to collect American shad eggs from the Connecticut River in the spring of 1991 was positive. Given an opportunity to fish at the appropriate time it is reasonable to believe that appreciable numbers of eggs can be obtained.

All Rivers Combined

The total number of eggs collected in the spring of 1991 was 29.8 million eggs. The production goal was exceeded on the Delaware River and more eggs were obtained from the Hudson River than in 1990. Results on the Hudson River show that a goal of 20 million eggs for this river is realistic. However, the future development of egg collection goals for several tributaries located in different latitudes and for tributaries of vastly different characteristics should address the potential modifications of fishing techniques throughout the entire geographical range from which eggs will be sought.

The Santee River has potential for egg collections in April with little impact on local stocks. However, these collections would require substantial expense and effort. The advantage of obtaining eggs earlier in the season for a longer hatchery production season would have to be weighed against the costs of these collections relative to collections in the Delaware and Hudson rivers where substantially larger quantities of eggs can be produced in a shorter time period.

REFERENCES

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 for the Susquehanna restoration program, 1973-1991.

YEAR	Pamunkey	James	Columbia	Delaware	Hudson	Other*	Totals
1973	8.45	-	-	-	-	50.16	58.61
1974	9.75	19.20	8.18	-	-	12.89	50.02
1975	1.88	7.15	18.42	-	-	5.70	33.15
1976	-	-	54.80	4.10	-	-	58.90
1977	4.40	3.42	8.90	-	-	0.92	17.64
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	19.51	2.40	1.17	-	34.48
1984	9.83	0.74	27.88	2.64	-	-	41.09
1985	5.28	2.05	12.06	6.16	-	-	25.55
1986	5.62	1.07	39.97	5.86	-	-	52.52
1987	4.35	0.11	23.53	5.01	-	-	33.00
1988	1.92	0.05	26.92	2.91	-	-	31.80
1989	1.91	0.53	23.11	5.96	11.18	-	42.69
1990	0.48	-	-	13.15	14.53	0.46	28.61
1991	-	-	-	10.74	17.66	1.41	29.81
TOTALS	**82.77**	**64.67**	**291.63**	**58.93**	**44.54**	**71.54***	**614.07**

* Includes Potomac (45.9 M), Susquehanna (5.4 M), Mattaponi (13.9 M), Connecticut (6.3 M), and Savannah (0.1 M).

TABLE 2. Sampling schedule for collecting the eggs of American shad during the spring of 1991.

RIVER	DATES	TOTAL
Santee	16 April - 1 May	-
Chowan	29 March - 16 April	-
Delaware	29 April - 9 May	10
Hudson	2 May - 22 May	16
Connecticut	28 May - 4 June	3

TABLE 3. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1991.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number
May	05	61.6	1,677,002	5
	08	18.8	500,634	9
	09	35.0	976,274	10
	12	36.4	1,375,362	13
	13	31.0	1,135,470	15
	14	16.0	610,809	17
	15	23.0	1,081,428	19
	16	30.0	1,465,331	21
	19	19.0	717,909	24
	20	32.2	1,004,570	26
TOTAL		303.0	10,544,789	10

TABLE 4. Collection data for American shad eggs taken on the Hudson River, New York, 1991.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Gear
May 2	50.5	1,659,931	2	Gill
4	97.0	2,960,167	4	Gill
5	83.0	2,532,927	6	Gill
6	58.1	1,567,240	7	Gill
7	32.2	939,780	8	Gill
9	40.0	1,180,595	11	Gill
11	36.4	1,098,574	12	Seine
12	38.0	1,159,653	14	Seine
13	26.4	804,654	15	Seine
14	32.0	1,088,590	18	Gill
15	14.1	464,595	20	Gill
16	17.0	584,565	22	Gill
18	7.3	306,252	23	Gill
19	8.0	255,108	25	Gill
20	25.4	892,124	27	Gill
21	4.7	163,340	28	Gill
TOTAL	568.1	17,658,095	16	

Gill-net = 469.3	14,595,214	13
Seine = 100.8	3,062,881	3

TABLE 5. Collection data for American shad eggs taken on the Connecticut River, Massachusetts, 1991.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number
May 29	10.7	421,198	31
30	8.7	488,169	32
31	3.8	194,531	33
TOTAL	23.2	1,103,898	3

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1991

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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 1991 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 distinquish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in 1991 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Research conducted in 1991 involved continued testing of new bottom screens for Van Dyke jars, feeding of American shad fry on dry diet (AP-100) only and comparison of relative survival of American shad fry released at night vs controls released during daylight.

EGG SHIPMENTS

A total of 29.8 million eggs (903 L) were received in 33 shipments in 1991 (Table 1), representing the third lowest total since 1983 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 60.7%, the second highest since the program began. Ten shipments of eggs were received from the Delaware River (10.7 million eggs) with a viability of 59.3%. The Hudson River produced 16 shipments (17.7 million eggs) with a viability of 65.7%. Eggs from the Susquehanna River were received for the second time. Pre-spawn adult American shad were collected at the Conowingo Dam fish trap, injected with hormones to induce maturation, and spawned artificially. Four shipments of eggs were received (290 thousand eggs), three of which contained viable eggs. Overall viability for Susquehanna River eggs was 8.9%. Three shipments of eggs were received from the Connecticut River (1.1 million eggs). Viability for Connecticut River eggs was 7.2% presumably due to uncharacteristically high water temperatures (71-72^{0}F).

SURVIVAL

Survival of all fry was 79.0% as compared to a range of 70.1% to 89.8% from 1984 through 1990. Survival of fry from hatch and overall survival from fertilization are plotted in Figure 1. For the fourth 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 14.3 million. Of the total fry production, 7.2 million were released in the Juniata River and 4.9 million in the Susquehanna River below Conowingo Dam. Other sites stocked included the Lehigh River (793 thousand fry) and the Schuylkill River (75,000 fry).

VAN DYKE JAR TESTING

Testing of our home-made Van Dyke jars was initiated in 1987. Except for 1990, egg viability has been consistently higher in Van Dyke jars than in May-Sloan jars (Hendricks et al., 1988; 1989; 1990; 1991). 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 larger (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 helps eliminate 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 are collected under the bottom screen. This occurs with all types of bottom screens.

In 1990 we began testing of new bottom screens 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.

In 1990, survival of eggs incubated in the foam bottom screens was slightly lower than that exhibited by the window screen bottom screens for two replicates. The foam bottom screens, however, were extremely effective in producing uniform flow over the entire surface area of the foam and were more easily constructed than the traditional window screens. They 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. The experiences with foam bottom screens were limited in 1990, but the new screens appeared to eliminate the problem of "dead fry" in the jar after hatch. 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."

In 1991 we compared survival of eggs incubated in foam bottom jars to controls with screen bottoms for four replicates (Table 5). Survival for eggs incubated in jars with foam bottom screens was higher than controls in two of the four replicates (1, 4) and lower in the other two (2, 3). Both replicates which exhibited lower survival for the foam bottom screens were Delaware River egg source and neither exhibited good egg layering, particularly in the screen bottom jars. This resulted in low numbers of dead eggs taken off (and high apparent survival) on days II and VII (Table 5). This inefficient layering ultimately results in large numbers of dead eggs present after hatch, making precise enumeration difficult (Hendricks, et al. 1991). In addition, jar 206 (shipment 17, window screen) contained large numbers of dead fry after hatch. As a result, the last egg mortality estimate was done using the dead fry method, making under-estimation of dead eggs more likely. Because of the enumeration problems, strict reliance on survival data would be unwise. Foam bottom screens were also evaluated based on the presence of "dead fry" in the jar after hatch. Since these "dead fry" represent fully developed eggs which died after hatching they are indications of problems with egg incubation. Van Dyke jars with screen bottoms were utilized a total of 36 times in 1991. In 30 of these, "dead fry" were present and the final dead egg count was done using "dead fry" methods. By contrast, foam bottom egg jars were used 25 times in 1991, yet none exhibited dead fry after hatch. As a result, we have converted all our Van Dyke jars to foam bottom screens. We have also converted 3/4 of the egg battery to accommodate Van Dyke jars, increasing incubation capacity to 550 L of eggs.

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.

In 1990, we conducted a preliminary test on a low density (223,500) tank to evaluate survival of fry fed on AP-100 only

(Hendricks, et al., 1991). AP-100 was fed at three times the normal ration to make up for the loss of the brine shrimp. Survival of fry in the test tank was compared to other tanks from the same egg source (Hudson River) but from different shipments.

Eighteen-day survival for the test tank was lower than survival in five of the comparable tanks and higher than the other two. 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.

In 1991 we replicated the experiment twice using one test and one control tank in each replicate. Within each replicate, test and control tanks were from the same egg shipment. Initial number of fry in each test tank was similar to the corresponding control (Tank I21, test, 311,747; Tank I11 control, 316,243; Tank A12, test, 376,494; Tank A22, control, 359,221).

The results of the test are depicted in Figures 2 and 3. American shad fed dry diet only experienced lower 20 day survival and mean total length. Mean total lengths at 20 days of age were subjected to ANOVA (Ott, 1979). At 20 days of age the fish fed dry diet only exhibited significantly smaller mean total lengths (a = .01) than did controls. There were no significant differences between shipments and no significant interaction.

Feeding of dry diet only also created problems with buildup of unused feed which resulted in turbid water and growth of "gray beard". Based on these results further testing is not warranted.

FINGERLING PRODUCTION

American shad fingerlings were produced in the Canal Pond (Thompsontown) and Upper-Spring Creek Ponds. An attempt was made to conduct a mark-recapture population estimate prior to the release of fingerlings from the Canal Pond. During marking, a block net was set across the mid-point of the pond to prevent marked specimens from being recaptured and marked a second time. Specimens were collected for marking using a conical lift net similar to the one described by Backman and Ross (1990). The lift net was 6 feet (1.9 m) in length and measured 60 inches (1.5 m) in diameter at the top. It was tapered to 29 inches (.7 m) in diameter 4 feet (1.2m) from the top. The bottom 24 inches (.6 m) was cylindrical. Juvenile American shad were attracted above the net by feeding and, using a tripod and boom, the net was lifted to entrain the fish. The bottom of the net was left open, resting in the pond bottom to prevent escape. A circular fiberglass tub was submerged under the lift net, and the net was then lifted out of the water, leaving the fish in the tub. At no time were the fish netted or removed from the water. Bismark Brown Y was then added to the tub to produce a solution of 10-15 g/50 gal. of water. Pure oxygen was bubbled into the tub and after a 20 minute immersion the fingerlings were water-brailed from the tub and hand counted as they were returned to the pond. A sample of specimens from each marking run was retained in a tank to assess handling and marking mortality and mark retention.

Results of the marking runs are presented in Table 6. Specimens from the first marking run were marked at 15 g Bismark Brown Y per 50 gallons of water. This concentration appeared to be excessive and resulted in widespread narcosis. Most of the fish returned to the pond appeared to recover, however, two of the six fish released in the control tank were dead 15 minutes after marking. Addition of the Bismark Brown Y caused a decrease in pH from 7.6 to 6.9. As a result, further trials were conducted with 10 g Bismark Brown Y to 50 gallons of water and sodium bicarbonate was added as a buffer (Table 6).

Five more lift net hauls were made, resulting in the marking of a total of 1,091 fish. Some 112 of those were released in the control tank. All control fish were swimming normally with the exception of the two dead from the first marking. These could be clearly observed, dead on the bottom of the tank. After the first six lift net hauls the fish would no longer school above the net and additional marking collections had to be made with a 20 foot seine. Despite our best efforts, we were not able to water brail the shad out of the seine without injury to the fish. As a result, an additional 19 fish were found dead in the control tank 24 hours after marking. These mortalities were presumed to be due to rough handling in the seine rather than exposure to dye. Overall, a total of 1,435 marked fingerlings were released into the pond (Table 6). Additional feeding revealed that marked fish could be clearly distinguished from unmarked fish at a distance of 15 feet.

Approximately 24 hours after marking, nine marked fry and 11 unmarked fry were sacrificed and a blind trial conducted to determine mark retention. Each of two researchers independently examined individual specimens, classifying them as marked or unmarked. Each researcher classified all 20 specimens correctly, however, the intensity of the dye would not have permitted classification without first sacrificing the fish. After 48 hours the dyed specimens were not distinguishable from undyed controls. Due to logistics, recapture sampling was scheduled during harvest, approximately 48 hours after marking. As a result, no marked specimens were recaptured and a population estimate was not possible.

The Canal pond was harvested differently than in previous years. All pond boards were removed except a single set in the front of the catch basin. The catch basin was then cleared of ashes and debris. Boards were reinstalled in the rear of the catch basin with a quick release board on the bottom. The quick release board consisted of a 10 inch board fitted with a bulkhead union in the center. On the upstream (pond) side of the union a flapper valve was installed. On the down stream (effluent) side a four inch smooth bore hose was installed to provide passage for the shad from the pond to a pool in Delaware Creek. Leakage through the front set of boards (caused by removal of the ashes) filled the catch basin to the level of the pond relieving pressure on the front boards and allowing their removal. The pond was then drained by opening the flapper valve. No attempt was made to crowd the fish in the pond prior to release. Fish were allowed to exit the pond at any time during drawdown.

Since initial drawdown was proceeding slowly, boards were removed to drain the pool down from the top in addition to the bottom. Effluent from both top and bottom was sampled periodically to determine if fish were exiting the pond and to assess their condition. No fish exited the pond until it was more than halfway drained. Fish exited the pond over the boards before they exited through the effluent hose. Effluent over the boards hit the back wall of the catch basin and cascaded down as much as five feet to the floor of the catch basin before exiting through a 24 inch diameter pipe. Fish which used this exit route were collected by bucket as they dropped into Delaware Creek. Surprisingly no descalation or mortality was observed in these fish or in fish exiting the pond via the 4 inch hose.

Mortality problems did occur later, during the last few minutes of pond release. The canal pond influent was fitted with a small mesh sock to prevent introduction of predators and competitors. A small hole in the sock was observed during June which apparently enabled introduction of young-of-the-year carp into the pond. At the time of harvest these carp were approximately 10 inches in length and numbered an estimated 300 - 500. The majority of the shad and carp remained in the pond until they were forced to leave by the receding waters. The combined biomass of struggling shad and carp in the pond caused severe turbidity and resulted in mortality to an estimated 1,000 shad which were later recovered from Delaware Creek.

Based on these observations we are considering options for pond drawdown in 1992.

Upper Spring Creek

The three Upper Spring Creek ponds were stocked with approximately 100,000 fry each on May 31, 1991. About mid-June, when supplemental feeding was initiated, it was obvious that ponds 1 and 2 contained few fish compared to pond 3. The fry were all from the same lot and were all stocked at the same time in the same manner. All three ponds were half filled and fertilized about three days before the stocking took place, as had been done in previous years. It is not known why so few fish survived in Upper Spring Creek Ponds 1 and 2; no predator fish were found during harvest.

On August 15th, ponds 1 and 2 were drained and approximately 100 fish (about half of the fish in pond 1) were crowded, netted, placed into buckets and put into a pickup tank. The fish were then transferred to Benner Spring and quick-released in a raceway. The fish were approximately 5 inches in length, and suffered no mortality in the raceway. Surviving fish in pond 2, approximately 600, were moved to pond 1. These fish were eventually moved to a raceway at Benner Spring and along with those moved to Benner Spring in August, were used in a dummy radio tagging test done in late October in cooperation with RMC.

On September 12 and 13, surviving fish in pond 3 were harvested and transported to Thompsontown, where they were released into the Juniata River. Mean length was 86 mm (3.3 inches). Harvesting techniques again worked well and only about 100 fish were lost during harvest and loading operations. No problems were encountered during transport and stocking.

A mark recapture population estimate was conducted on the fingerlings in Upper Spring Creek Pond 3. After the pond was drained and the catch basin cleaned, a group of fish was crowded at one end of the catch basin and bucketed into a tub. Water was added to the 50 gallon mark. Ten grams of Bismark Brown Y was dissolved in a small amount of water and added to the tub. Pure oxygen was bubbled into the tub and after a 20 minute immersion, the dyed fish were hand counted back into the catch basin using 5 gallon buckets. A representative sample of 317 fish was released into a control tank to determine marking and handling mortality. A total of 1,775 fingerlings were marked and released into the catch basin.

Approximately 30 minutes after release of the marked fish a group of fish was crowded for recapture. Twenty samples were collected by bucket and hand counted back into the main population. Marks were easily detected without handling the fish. These samples included 79 marked fish and 1,001 unmarked fish. The population estimate was then calculated using N = MC/R where N is the population estimate, M is the number of fish marked (1,765), C is the recapture sample size (1,140) and R is the number of recaptures (79). Note that 10 of the 1,775 fingerlings marked were omitted from the analysis since they were found dead or dying on the effluent screen prior to the recapture run. Using this formula the population estimate was 25,470 fish. All 317 of the fish in the control tank were alive and swimming normally. The return of these to the catch basin brought the total to 25,787. The 95% confidence interval for the estimate was 20,491-31,003 (Everhart, Eipper and Youngs; 1975).

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 six hours duration. Fry stocked below Conowingo Dam received a double mark at five and nine days of age except for fry from the Susquehanna River egg source which received a double mark at five and 19 days of age. Fry stocked in the Juniata River were uniquely marked, according to egg source river and time of day stocked. Fry originating from Delaware River eggs received a triple mark on days 3, 13, and 17. Connecticut River fry received a quintriple mark on days 5, 9, 13, 17 and 21. Hudson River Fry were given one of three unique marks. Fry used in a day/night stocking study were given a single mark on day 5 or day 18 depending on time of day stocked (Table 7). Hudson River fry not used in the day/night study were given a triple mark on days 5, 7 and 13.

Fry destined for fingerling production at Maryland DNR ponds in Hǎvre de Grace (1 pond) and Elkton (3 ponds) were given immersion marks on days 5 and 9 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 two days and then fed tetracycline laced feed for three days. Multiple feed tags were administered at least seven 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 American shad specimens examined (Table 8). Specimens collected from the Maryland DNR pond in Havre de Grace were identified as Hickory Shad, Alosa mediocris. These exhibited no immersion marks and had otolith microstructure typical of wild fish. We, therefore, speculate that they were introduced into the pond via the river pump or were present in the pond when it was boarded up.

Retention of feed marks ranged from 45% to 100%. The lowest feed mark retention was observed in Elkton Pond 3 (Table 8). This is not surprising since only 4,000 fingerlings were present in the pond. At low fish densities it is possible for the fish to find ample natural food. Consequently, they consume little or no TC treated food and do not exhibit a mark. Feed mark retention was 90% or higher in all other ponds.

DAY/NIGHT STOCKING

Improvement of culture methods to maximize hatchery production has been the focus of much of the research conducted at Van Dyke to date. Survival of fry from hatch to stocking at 20 days of age has ranged from 70 to 90% for the last seven years. Little improvement can be gained by directing more research effort here. Egg viability for the same period has ranged from 38% to 60% and appears to be affected by many factors out of our control. Egg takers are striving to maintain and improve fertilization rates and egg viability.

Enhancement of survival of fry after stocking has great potential for increasing the overall population of hatchery outmigrants but has received little attention to date. In 1989, the USFWS, National Research and Development Lab located at Wellsboro began a three year investigation of predation upon newly stocked hatchery fry. For the last three years, hatchery releases have been coordinated with the USFWS to facilitate the study. The major goal of the study is to estimate how many shad are consumed by predators at the stocking site and in immediate downstream areas by determining the number of shad present in predators stomachs, estimating predator populations and determining gastric evacuation rates.

While the study is still ongoing, preliminary results indicate that predation has the potential to be a significant factor in survival of newly stocked hatchery fry (Johnson and Dropkin, in press). In one post-stocking sample some fifteen species of predators were identified. Juvenile smallmouth bass had consumed a meañ 345 shad larvae. The last year of the study (1991) involved a cooperative effort to compare the success of stocking American shad fry during day time vs. night time hours. Selected shipments of Hudson River eggs were used for the study. Our goal was to divide each egg shipment to produce two or four tanks of approximately equal numbers of fry which could then be marked uniquely and released at the appropriate time.

Upon receipt at Van Dyke, four bags of eggs (approximately 5 L each) were placed in an egg net and disinfected in 80 ppm free iodine. After rinsing, the eggs were scooped into 2.5 L, screen bottom, graduated pitchers, four at a time. Eggs were then poured into May-Sloan or Van Dyke incubation jars (Table 9). Each May-Sloan jar received 2.5 L of eggs from a single graduated pitcher. Van Dyke jars were filled in groups of two, alternating between two to eliminate variability in egg handling. The process was repeated until all eggs had been disinfected and placed in incubation jars. Egg incubation jars from each shipment were assigned to two or four rearing tanks to provide pairs of tanks with approximately equal numbers of fry in each tank. Van Dyke jars were assigned to tanks to ensure that simultaneously filled jars were assigned to adjacent tanks (Table 9). When eggs were incubated in an odd number of May-Sloan jars, their tank assignments were made to distribute eggs as equally as possible between two tanks. One of each pair of tanks was randomly chosen for release during daylight hours while the other tank was released during night time hours. Night releases were scheduled for evening hours (approximately 10:00 P.M.). Day time releases were alternated between afternoon releases (5:30 P.M.) and morning releases (10:30 A.M.). This eliminated potential bias caused by attraction of predators into the area by the first release. No other releases were scheduled on days when study releases occurred. Tanks chosen for day time release were marked by 6 hour immersion in 200 ppm tetracycline on day 5 while those chosen for night time release were marked on day 18.

A total of six shipments of eggs (12 tanks of fry) were used in the study encompassing only four day/night releases (Table 9). Additional releases would have been desirable but could not be accomplished due to other commitments for fry (pond culture, release below Conowingo Dam). A total of 4.2 million fry were involved in the study with surprisingly equal numbers assigned to the two groups (Table 9). This total represents 69% of the 6.1 million Hudson River fry cultured at Van Dyke in 1991 (Table 7).

A total of 647 juvenile American shad otoliths were examined for tetracycline marks (see Job IV for details). Some 157 of those (24%) exhibited a day 5 mark (day stocking) while 179 (28%) exhibited a day 18 mark (night stocking). Recovery rates were 7.54 x 10^{-5} for day stocked fish and 8.50 x 10^{-5} for night stocked fish. Since night stocking requires more man power, creates logistic problems and results in lower recovery rates, we recommend discontinuing night stocking.

SUMMARY

A total of 33 shipments (30 million eggs) was received at Van Dyke in 1991. Total egg viability was 60.7% and survival to stocking was 79.0%, resulting in production of 14.3 million fry. The majority of the fry were stocked in the Juniata River (7.2 million), with lesser numbers stocked in the Susquehanna River below Conowingo Dam (4.9 million), the Lehigh River (793 thousand), and the Schuylkill River (75 thousand). A total of 54,400 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River. An additional 111,500 fingerlings were produced in Maryland DNR ponds at Elkton, and released directly into receiving waters. Some 67,500 fingerlings, produced in the Maryland DNR pond in Havre de Grace were identified as Hickory shad, <u>Alosa mediocris</u> based on 39 specimens frozen for mark retention analysis.

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 or 5 and 19. Fry released in the Juniata River received unique tags based on egg source river and time of day stocked. Delaware River fry received a triple tag on days 3, 13, 17; Connecticut River fry received a quintriple tag on days 5, 19, 13, 17, and 21, and Hudson River fry received a single tag on day 5 or 18 depending upon time of day stocked or a triple tag on days 5, 9 and 13.

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 distinquish fingerling rearing site. Single and double feed tags were produced, in addition to the single, double, triple and quintriple immersion tags.

Retention of tetracycline marks was 100% for immersion marks, and ranged from 45 to 100% for feed marks.

Further testing of foam bottoms in Van Dyke egg incubation jars was completed and found to alleviate problems of "dead fry" in the jar after hatching.

Mark-recapture population estimates were attempted for fingerling shad reared in the Canal Pond and Upper Spring Creek Pond 3. Fingerlings in the Canal Pond did not retain the dye for the 48 hours between marking and recapture. The mark-recapture estimate was successful in Upper Spring Creek Pond 3 and resulted in an estimate of 25,787 fingerling shad (95% conf. int. 20,491-31,003).

Survival of uniquely marked American shad fry stocked at night (recovery rate 8.50×10^{-5}) was found to be similar to that of fry stocked during daylight (recovery rate 7.54×10^{-5}).

RECOMMENDATIONS FOR 1992

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. Utilize foam bottom screens in Van Dyke jars to promote egg survival and increase egg battery capacity.
6. Conduct mark-recapture population estimates for pond fingerlings prior to harvest.
7. Discontinue night stocking.

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Figure 1. Survival of American Shad Fry
Van Dyke, 1991

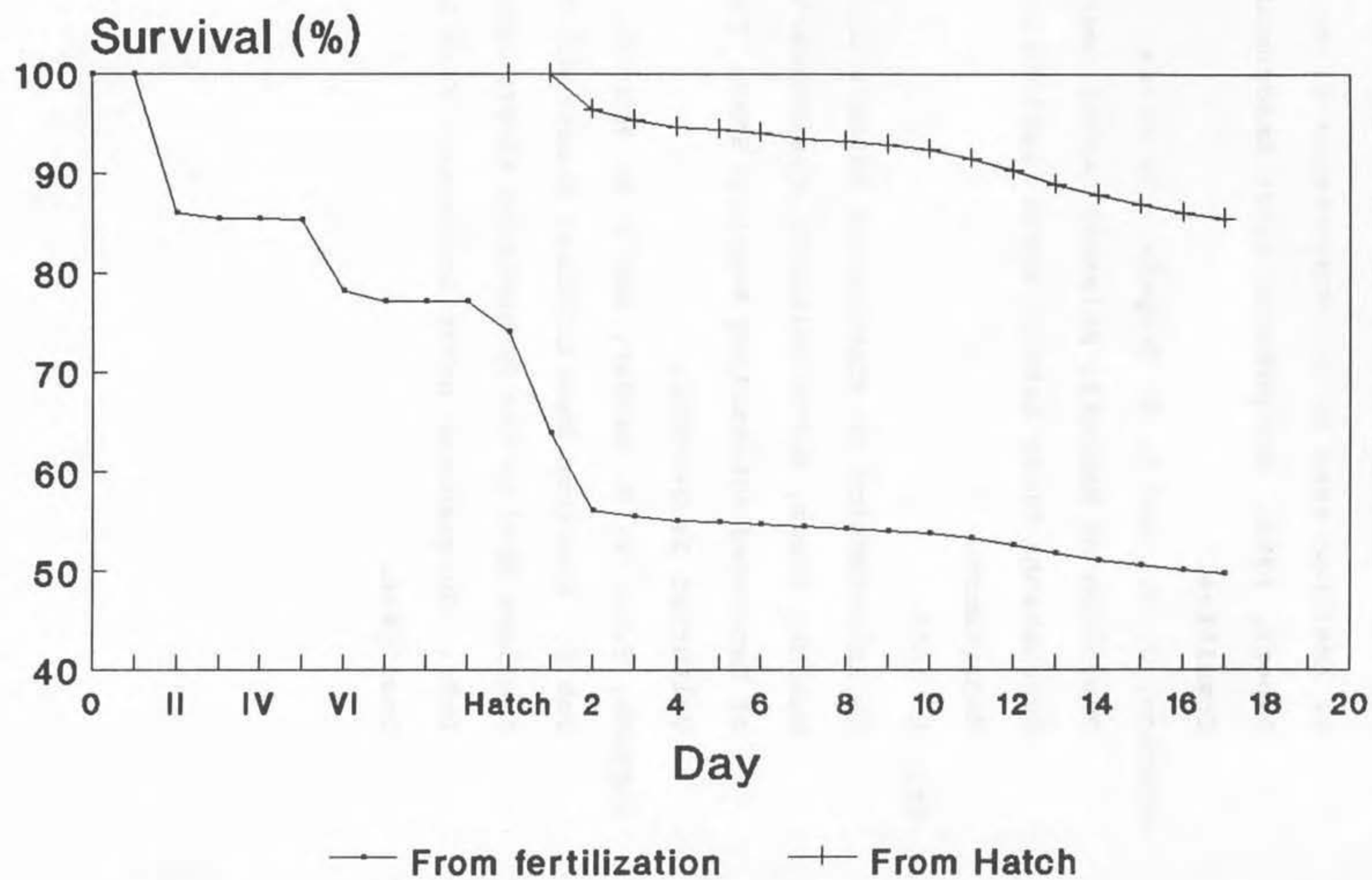
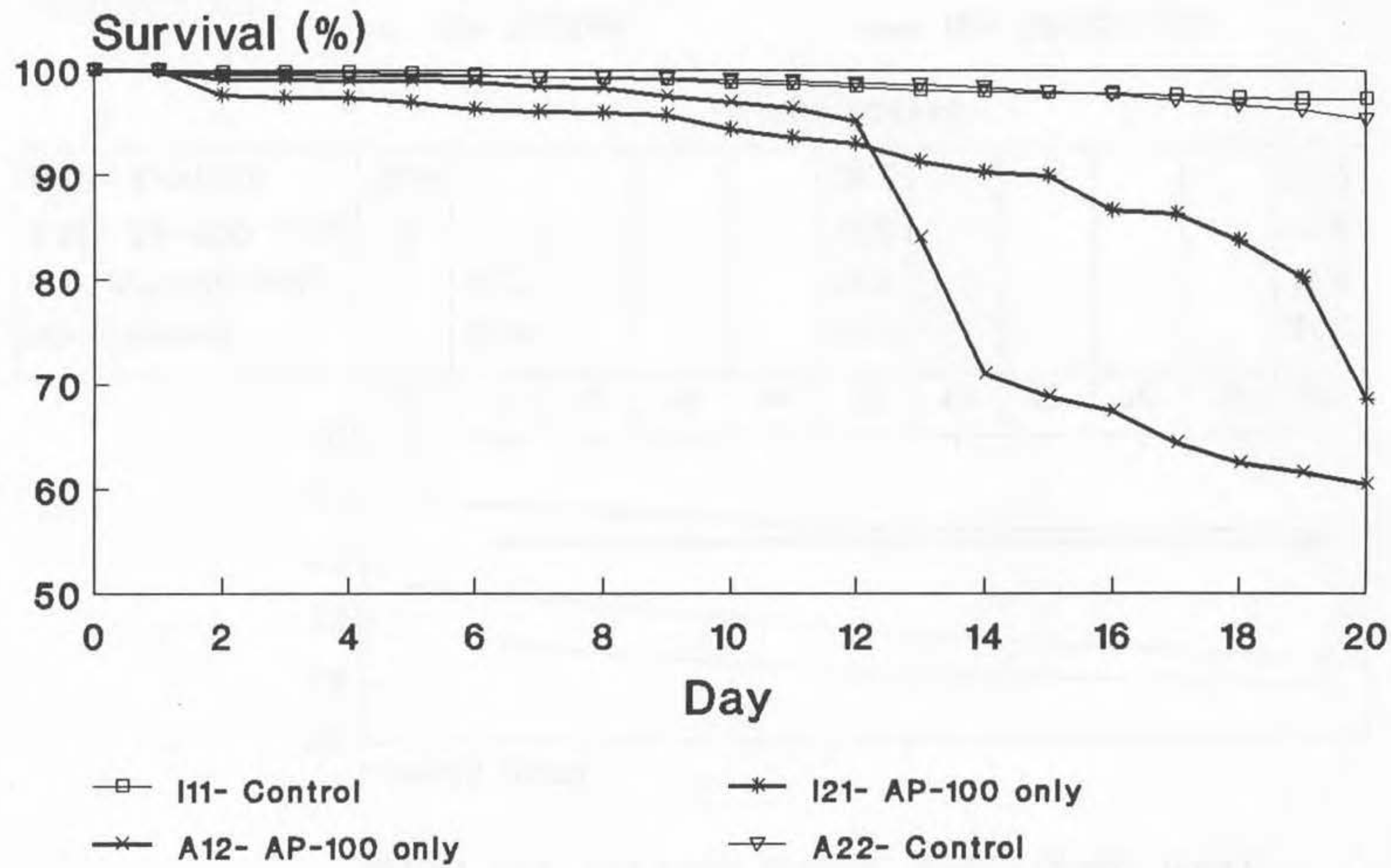
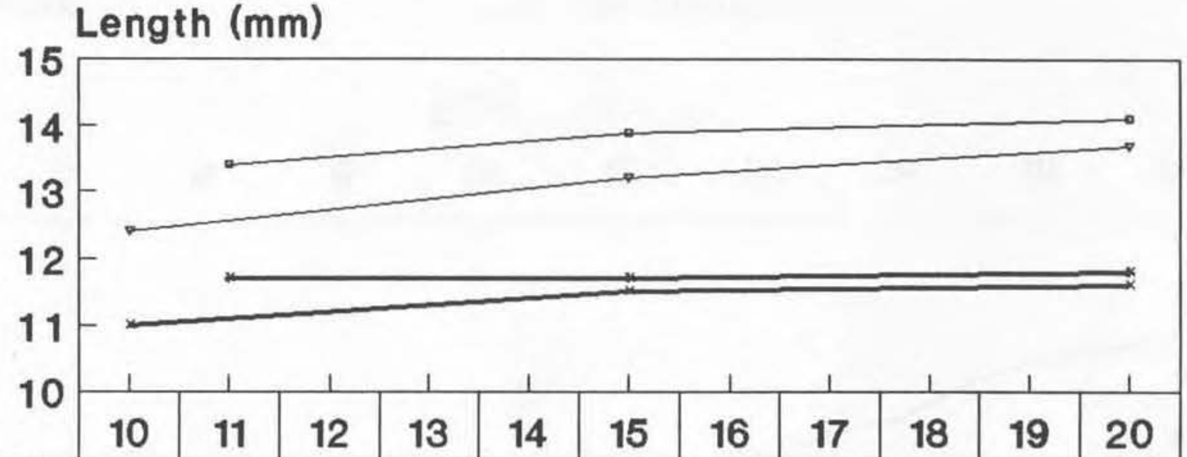


Figure 2. Survival of American shad fed two diets, Van Dyke, 1991.



Survival computed from hatch.

Figure 3. Mean total length of American shad fed on two diets, Van Dyke, 1991.



	10	11	12	13	14	15	16	17	18	19	20
I11- Control		13.4				13.9					14.1
I21- AP-100 only		11.7				11.7					11.8
A12- AP-100 only	11					11.5					11.6
A22- Control	12.4					13.2					13.7

Age (days)

I11- Control
I21- AP-100 only
A12- AP-100 only
A22- Control

Table 1. American shad egg shipments recieved at Van Dyke, 1991.

Shipment No.	River	Date Shipped	Date Recieved	Vol. Received (L)	Eggs	Viable Eggs	Percent Viable
1	Susquehanna	5/1/91	5/1/91	1.1	33,000	2,200	6.7%
2	Hudson	5/2/91	5/3/91	53.5	1,659,900	840,100	50.6%
3	Susquehanna	5/3/91	5/3/91	4.3	174,500	17,300	9.9%
4	Hudson	5/4/91	5/5/91	97.0	2,960,200	1,766,300	59.7%
5	Delaware	5/5/91	5/6/91	61.6	1,877,000	1,040,400	55.4%
6	Hudson	5/5/91	5/6/91	83.0	2,532,900	1,503,300	59.4%
7	Hudson	5/6/91	5/7/91	53.1	1,567,200	1,167,400	74.5%
8	Hudson	5/7/91	5/8/91	32.2	939,800	616,300	65.6%
9	Delaware	5/8/91	5/9/91	18.8	500,800	339,000	67.7%
10	Delaware	5/9/91	5/10/91	35.0	976,300	564,400	57.8%
11	Hudson	5/9/91	5/10/91	40.0	1,180,600	706,200	59.8%
12	Hudson	5/11/91	5/12/91	36.4	1,098,600	700,700	63.8%
13	Delaware	5/12/91	5/13/91	36.4	1,375,400	828,100	60.2%
14	Hudson	5/12/91	5/13/91	38.0	1,159,700	764,800	65.9%
15	Delaware	5/13/91	5/14/91	31.0	1,135,500	277,200	24.4%
16	Hudson	5/13/91	5/14/91	26.4	805,700	626,700	77.8%
17	Delaware	5/14/91	5/15/91	16.0	610,800	442,600	72.5%
18	Hudson	5/14/91	5/15/91	32.0	1,088,700	808,600	74.3%
19	Delaware	5/15/91	5/16/91	23.0	1,081,400	628,000	58.1%
20	Hudson	5/15/91	5/16/91	14.1	464,500	376,800	81.1%
21	Delaware	5/16/91	5/17/91	30.0	1,465,300	1,037,800	70.8%
22	Hudson	5/16/91	5/17/91	17.0	584,600	433,000	74.1%
23	Hudson	5/18/91	5/19/91	7.3	305,300	235,000	77.0%
24	Delaware	5/19/91	5/20/91	19.0	717,900	482,400	67.2%
25	Hudson	5/19/91	5/20/91	8.0	255,100	175,700	68.9%
26	Delaware	5/20/91	5/21/91	32.2	1,004,600	735,700	73.2%
27	Hudson	5/20/91	5/21/91	25.4	892,100	761,000	85.3%
28	Hudson	5/21/91	5/22/91	4.7	163,300	113,600	69.5%
29	Susquehanna	5/27/91	5/27/91	1.9	43,400	6,900	16.0%
30	Susquehanna	5/27/91	5/27/91	1.1	45,500	0	0.0%
31	Connecticut	5/29/91	5/30/91	10.7	421,200	8,200	2.0%
32	Connecticut	5/30/91	5/31/91	8.7	488,200	48,700	10.0%
33	Connecticut	5/31/91	6/1/91	3.8	194,500	22,700	11.7%
Totals		No. of shipments					
	Susquehanna	4		8.4	296,400	26,500	8.9%
	Hudson	16		568.1	17,658,100	11,595,500	65.7%
	Delaware	10		303.0	10,745,000	6,375,600	59.3%
	Connecticut	3		23.2	1,103,900	79,600	7.2%
	Grand Total	33		902.7	29,803,300	18,077,200	60.7%

Table 2. Annual summary of Van Dyke production, 1976–1991.

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
1991	903	29.8	60.7	18.1	12,963	233	13,196	0.443	0.729

Table 3. American shad stocking and fish transfer activities, 1991. 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
5/29/91	A22	5,000	5,9	NFRDL	Delaware	1	Fry
5/29/91	A42	5,000	5	NFRDL	Hudson	1	Fry
5/29/91	B41	6,000	5,9,13	NFRDL	Hudson	17	Fry
5/29/91	D21	5,000	5	NFRDL	Hudson	16	Fry
5/29/91	C11	383,000	5,9	Rock Run Landing	Hudson	17	Fry
5/29/91	C21	400,000	5,9	Rock Run Landing	Hudson	17	Fry
5/29/91	C31	423,000	5,9	Rock Run Landing	Hudson	17	Fry
5/30/91	B31	363,000	5	Thompsontown-day	Hudson	20	Fry
5/30/91	B31	5,000	5	BS Raceway F1	Hudson	20	Fry
5/30/91	B21	439,000	18	Thompsontown-night	Hudson	20	Fry
5/30/91	B21	5,000	18	BS Raceway F2	Hudson	20	Fry
5/31/91	C41	300,000	3,13,17	Upper Spr. Cr. Ponds	Delaware	18	Fry
5/31/91	C41	143,000	3,13,17	Thompsontown	Delaware	18	Fry
5/31/91	D11	516,000	3,13,17	Thompsontown	Delaware	18	Fry
6/1/91	B41	298,000	5,9,13	Thompsontown	Hudson	20	Fry
6/1/91	B41	100,000	5,9,13	Canal Pond	Hudson	20	Fry
6/3/91	D31	382,000	18	Thompsontown-night	Hudson	21	Fry
6/3/91	D41	260,000	18,19	Thompsontown-night	Hudson	21	Fry
6/3/91	F21	3,000	3,13,17	NFRDL	Delaware	18	Fry
6/3/91	F41	1,000	5,9	NFRDL	Hudson	17	Fry
6/3/91	A32	1,000	18	NFRDL	Hudson	6	Fry
6/4/91	D21	410,000	5	Thompsontown-day	Hudson	22	Fry
6/4/91	E11	245,000	5	Thompsontown-day	Hudson	22	Fry
6/5/91	F21	315,000	3,13,17	Lehigh River	Delaware	20	Fry
6/5/91	F31	478,000	3,13,17	Lehigh River	Delaware	19	Fry
6/6/91	E31	464,000	5	Thompsontown-day	Hudson	23	Fry
6/6/91	E41	218,000	5	Thompsontown-day	Hudson	22	Fry
6/6/91	E21	359,000	18	Thompsontown-night	Hudson	23	Fry
6/6/91	F11	273,000	18	Thompsontown-night	Hudson	22	Fry
6/7/91	B11	16,000	5,19	Rock Run Landing	Susquehanna	27	Fry
6/7/91	F41	225,000	5,9	Rock Run Landing	Hudson	21	Fry
6/7/91	G11	249,000	5,9	Rock Run Landing	Hudson	21	Fry
6/7/91	G21	503,000	5,9	Rock Run Landing	Hudson	19	Fry
6/8/91	H21	551,000	5,9,13	Thompsontown	Hudson	18	Fry
6/9/91	H31	426,000	3,13,17	Thompsontown	Delaware	18	Fry
6/10/91	G31	708,000	5,9	Maryland Ponds	Delaware	21	Fry
6/10/91	G41	448,000	5,9	Rock Run Landing	Hudson	21	Fry
6/10/91	H11	300,000	5,9	Rock Run Landing	Delaware	20	Fry
6/11/91	I31	3,000	5,9	NFRDL	Hudson	19	Fry
6/11/91	H41	581,000	5,9,13	Thompsontown	Hudson	20	Fry
6/12/91	J11	264,000	5,9,13	Thompsontown	Hudson	19	Fry
6/12/91	J11	100,000	5,9,13	Canal Pond	Hudson	19	Fry

Table 3. (continued)

Date	Tank	Number	Tag (days)	Location	Origen	Age	Size
6/13/91	I11	200,000	5,9	Rock Run Landing	Delaware	21	Fry
6/13/91	I21	50,000	5,9	Rock Run Landing	Delaware	21	Fry
6/13/91	I31	259,000	5,9	Rock Run Landing	Hudson	21	Fry
6/13/91	I41	500,000	5,9	Rock Run Landing	Delaware	20	Fry
6/14/91	J21	217,000	5,9,13	Thompsontown	Hudson	19	Fry
6/17/91	A32	393,000	18	Thompsontown-night	Hudson	20	Fry
6/18/91	A42	381,000	5	Thompsontown-day	Hudson	21	Fry
6/18/91	J31	1,000	5,9	VD Rearing Pond	Delaware	21	Fry
6/20/91	J31	444,000	5,9	Rock Run Landing	Delaware	24	Fry
6/20/91	J41	142,000	5,9	Rock Run Landing	Hudson	25	Fry
6/20/91	A22	333,000	5,9	Rock Run Landing	Delaware	23	Fry
6/20/91	B22	2,000	2,16	Rock Run Landing	Susquehanna	17	Fry
6/20/91	J31	50,000	5,9	Pot. Elec. Co.	Delaware	24	Fry
6/20/91	A22	10,000	5,9	NFRDL	Delaware	23	Fry
6/20/91	B32	7,000	5,9,13,17,21	NFRDL	Connecticut	14	Fry
6/21/91	A12	75,000	3,13,17	Schuylkill River	Delaware	24	Fry
6/28/91	B32	35,000	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
6/28/91	B32	3,000	5,9,13,17,21	BS Raceway E1	Connecticut	22	Fry
8/27/91	Canal Pond	30,000	5,9,13 + Single Feed	Thompsontown	Hudson	107	Fing.
9/12/91	Upper Spring Creek Pond 3	15,000	3,13,17 + Single Feed	Thompsontown	Delaware	122	Fing.
9/13/91	Upper Spring Creek Pond 3	9,400	3,13,17 + Single Feed	Thompsontown	Delaware	123	Fing.
10/3/91	Havre de Grace Pond	67,500	5,9 + Single Feed	Havre de Grace	Delaware	136	Fing.*
10/8/91	Elkton Pond 3	4,000	5,9 + Double Feed	Elk River	Delaware	141	Fing.
10/9/91	Elkton Pond 2	72,500	5,9 + Double Feed	Elk River	Delaware	142	Fing.
10/11/91	Elkton Pond 1	35,000	5,9 + Double Feed	Elk River	Delaware	144	Fing.

Note: Rock Run Landing was utilized as a release site below Conowingo Dam due to construction activities at Lapidum access area.

* - Identified as Hickory shad based on 39 specimens frozen for mark retention analysis.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1991.

	Site	Fry	Fingerling
Releases	Juniata River		
	Day/Night study-day	2,081,000	
	Day/Night study-night	2,106,000	
	Other	3,031,000	54,400
	Total	7,218,000	
	Susquehanna R.		
	(below Conowingo Dam)	4,877,000	179,000 *
	Lehigh River	793,000	
	Schuylkill River	75,000	
	Sub-Total	12,963,000	233,400
Transfers	Canal Pond	200,000	
	Van Dyke Pond	1,000	
	Benner Spring Raceways	13,000	
	Upper Spring Creek Ponds	300,000	
	NFRDL (Wellsboro)	46,000	
	Maryland DNR Ponds	708,000	
	Potomac Elec. Co.	50,000	
	Sub-Total	1,318,000	
	Total Production	14,281,000	
	Viable eggs	18,077,200	
	Survival of fry (%)	79.0	

*Includes 67,500 Hickory shad fingerlings from MDNR pond in in Havre de Grace.

Table 5. Survival(%) of American shad eggs incubated in Van Dyke jars with foam bottoms vs. controls with window screen bottoms, Van Dyke, 1991.

	Replicate:	1	1	2	2	3	3	4	4
	Shipment:	16	16	17	17	24	24	27	27
	Egg Source:	Hudson	Hudson	Delaware	Delaware	Delaware	Delaware	Hudson	Hudson
	Jar:	204	307	206	316	217	304	218	317
	No. of eggs:	402,800	402,800	305,400	305,400	359,000	359,000	446,100	446,100
	Bottom:	Window screen	Foam	Window screen	Foam	Window screen	Foam	Window screen	Foam
Incubation Day	0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	I								
	II	89.5%	89.0%	98.0%	85.5%	93.6%	86.3%	90.9%	90.5%
	III								
	IV								
	V								
	VI								
	VII	86.0%	86.0%	91.5%	71.2%	84.5%	68.4%	86.1%	86.4%
	VIII								
	IX	71.7%	83.9%	85.6%	59.4%	72.2%	62.2%	84.2%	86.4%

Table 6. Number of juvenile American shad marked by 20 minute immersion in Bismark Brown Y, Canal Pond, Aug. 26,1991.

Marking Run	Concentration Bismark Brown Y (g/50 gal H2O)	Grams Sodium Bicarbonate buffer added	pH before buffer*	pH after buffer	Capture Gear	No. Released in Pond	No. Released in Control Tank	Total No. Marked
1	15	-	6.9	-	Lift Net	53	6	59
2	10	10	7.1	7.3	Lift Net	106	19	125
3	10	10	7.1	7.3	Lift Net	276	23	299
4	10	10	-	7.5	Lift Net	226	22	248
5	10	10	-	7.6	Lift Net	198	25	223
6	10	10	-	7.6	Lift Net	120	17	137
7	10	10	-	7.5	Seine	215	21	236
8	10	10	-	7.6	Seine	127	11	138
					Subtotal	1321	144	1465
					No. dead in control tank		-21	
					No. sacrificed		-9	
					Total	1321	114	1435

*Pond pH at start- 7.6

Table 7. Tetracycline marking regime for American shad stocked in the Susquehanna River basin, 1991.

Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Mark (days)	Feed mark	No. Stocked
Fry	–	Thompsontown-day*	Hudson	Single (5)	–	2,081,000
Fry	–	Thompsontown-night*	Hudson	Single (18)	–	2,106,000
Fry	–	Thompsontown-other	Hudson	Triple (5,9,13)	–	1,911,000
Fry	–	Thompsontown	Delaware	Triple (3,13,17)	–	1,085,000
Fry	–	Thompsontown	Connecticut	Quintuple (5,9,13,17,21)	–	35,000
Fry	–	Rock Run Landing (Below Conowingo)	Susquehanna	Double (5,19)	–	18,000
Fry	–	Rock Run Landing (Below Conowingo)	Other Sources	Double (5,9)	–	4,859,000
Fingerling	Canal Pond	Thompsontown	Hudson	Hudson (5,9,13)	Single	30,000
Fingerling	Upper Spring Creek Pond 1	Thompsontown	Delaware	Triple (3,13,17)	None	Too few to stock
Fingerling	Upper Spring Creek Pond 2	Thompsontown	Delaware	Triple (3,13,17)	None	Too few to stock
Fingerling	Upper Spring Creek Pond 3	Thompsontown	Delaware	Triple (3,13,17)	Single	24,400
Fingerling	Havre de Grace Pond	Below Conowingo	Delaware	Double (5,9)	Single	67,500 **
Fingerling	Elkton Ponds	Below Conowingo	Delaware	Double (5,9)	Double	111,500

* Day/Night stocking survival study.

** Identified as Hickory shad based on 39 specimens retained for mark retention analysis.

Table 8. Tetracycline mark retention for American shad reared in 1991.

Pond/ Raceway	Attempted Mark Immersion/Feed	Observed Mark Immersion/Feed	Number Exhibiting Mark	Projected Number Stocked	Disposition
Benner Spring Raceway F1	Single (5)	Single	30/30(100%)	2,081,000	Stocked Thompsontown (day)
Benner Spring Raceway F2	Single (18)	Single	27/27(100%)	2,106,000	Stocked Thompsontown (night)
Benner Spring Raceway E1	Quintuple (5,9,13,17,21)	Quintuple	30/30(100%)	35,000	Stocked Thompsontown
Rearing Pond	Double (5,9)	Double	29/29(100%)	4,859,000	Stocked Rock Run Landing
Canal Pond	Triple/single (5,9,13)	Triple/single	30/30(100%)	30,000	Stocked Thompsontown
Upper Spring Creek Pond 3	Triple/Single (3,13,17)	Triple/Single Triple/0	49/50(98%) 1/50(2%) Subtotal	23,912 488 24,400	Stocked Thompsontown
Upper Spring Creek Ponds 1 & 2	Triple (3,13,17)	Triple	Not Analyzed	-	Too few to stock
Havre de Grace Pond	Double/Single (5,9)	Double/Single 0/Single 0/0	0/20(0%) 18/20(90%) 2/20(10%) Subtotal	0 60,750 6,750 67,500	Direct Release
Elkton Pond 1	Double/Double (5,9)	Double/Double	24/24(100%)	35,000	Direct Release
Elkton Pond 2	Double/Double (5,9)	Double/Double	24/24(100%)	72,500	Direct Release
Elkton Pond 3	Double/Double (5,9)	Double/Double Double/Single Double/0	10/22(45%) 3/22(14%) 9/22(41%) Subtotal	1,818 545 1,637 4,000	Direct Release

Table 9. Numbers of uniquely marked American shad fry stocked during daylight or nightime hours, Van Dyke, 1991. All fry were Hudson River egg source, stocked at Thompsontown, Juniata River.

Egg Shipment	Date Shipped	Egg Jar	Egg Jar Type	No. of Eggs	Tank	Egg Viability	Survival (hatch to stocking)	TC Mark (day)	Stocking Date	Stocking Time	Stocking Age (days)	Stocking Number
2	5/2	201	VD	418,900	B21	59%	96%	18	5/30	9:40PM(night)	20	439,000
		204	VD	411,100	B21	52%						
		202	VD	418,900	B31	39%	95%	5	5/30	5:15PM(day)	20	363,000
		203	VD	411,100	B31	53%						
6	5/5	217	VD	387,600	D21	59%	92%	5	6/4	10:50AM(day)	22	410,000
		219	VD	387,600	D21	56%						
		218	VD	387,600	D31	56%	92%	18	6/3	9:50PM(night)	21	382,000
		220	VD	387,600	D31	52%						
		301	VD	381,500	D41	67%	78%	18,19*	6/3	9:50PM(night)	21	260,000
		10	MS	76,300	D41	55%						
		11	MS	67,100	D41	55%						
		302	VD	381,500	E11	68%	79%	5	6/4	10:50AM(day)	22	245,000
		9	MS	76,300	E11	67%						
7	5/6	304	VD	368,900	E21	74%	64%	18	6/6	10:45PM(night)	23	359,000
		305	VD	377,800	E21	77%						
		221	VD	377,800	E31	78%	77%	5	6/6	5:30PM(day)	23	464,000
		303	VD	368,900	E31	71%						
		12	MS	73,800	E31	64%						
8	5/7	14	MS	73,000	E41	47%	81%	5	6/6	5:30PM(day)	22	218,000
		222	VD	370,700	E41	63%						
		13	MS	73,000	F11	63%	78%	18	6/6	10:45PM(night)	22	273,000
		15	MS	52,500	F11	62%						
		223	VD	370,700	F11	73%						
27	5/20	218	VD	446,100	A32	84%	90%	18	6/17	10:30PM(night)	20	393,000
28	5/21	12	MS	86,900	A32	72%						
27	5/20	317	VD	446,100	A42	86%	87%	5	6/18	11:15AM(day)	21	381000
28	5/21	13	MS	76,500	A42	67%						
										Subtotal (day)		2,081,000
										Subtotal (night)		2,106,000
										Total		4,187,000

*Water supply erroniously left on during marking on day 18. Tank marked again on day 19 to ensure marking.

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 1991 in an effort to document timing of the migration, growth rates and abundance. Otoliths of subsampled shad were analyzed for tetracycline marks to indicate what proportion of the collection was of hatchery origin. Also, because various shad egg sources, pond culture sites and day versus night fry stockings were distinctively marked, the relative contribution of each strain, culture situation and stocking strategy to the outmigrant population could be differentiated.

Many individuals were involved in collection and analysis of juvenile shad in 1991. For their contributions to this report, appreciation is extended to Barbara Lathrop (Wyatt Group), Chris Frese (RMC), Ted Rineer (Safe Harbor), Dale Weinrich (Maryland DNR), and Mike Hendricks (PA Fish and Boat Commission). Don Torsello (PFBC) processed most of the otoliths.

HATCHERY AND ADULT SHAD STOCKING SUMMARY

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

A total of 24,662 adult American shad were hauled from the Conowingo fish lifts during mid-April through mid-June. All but 443 fish were stocked above York Haven Dam, and total transport mortalities amounted to 2,579 shad (see Job I). Overall sex ratio in these transfers was 1.64 to 1 favoring males. This stocking level compares with 14,792 live shad above dams in 1990 at a sex ratio of 3.2 to 1.

During the 1991 shad production season, PA Fish and Boat Commission biologists reared and released 12.095 million shad fry and 54,400 fingerlings in the Susquehanna watershed. Fry were stocked between 30 May and 28 June in the Juniata River at Thompsontown (7.218 million), and between 29 May and 20 June at Rock Run Landing, MD (4.877 million). Fingerlings reared in Pennsylvania ponds (122-136 days old) were stocked at Thompsontown between 27 August and 13 September. Maryland DNR released 111,500 fingerling shad from ponds at Elkton, MD on 8-11 October.

The 7.218 million shad fry stocked above dams in the Susquehanna in 1991 compares to 5.62 M, 13.46 M, and 6.45 M in 1990, 1989, and 1988, respectively. Shad fry stocking below Conowingo Dam in 1991 was similar to the average of 5.1 million during 1987-1990. Fingerling shad stocking from Pennsylvania and Maryland ponds was down about 96,000 from last year.

JUVENILE SHAD COLLECTIONS

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

Summer and autumn collections of young shad were made at several sites between Columbia-Wrightsville and Pequea (head of Lake Aldred) using a 400-ft. x 6 ft. haul seine with 1/4" mesh. York Haven collections were made with a fixed sluiceway sampling net with an opening of 1 meter x 4" with 1/4" mesh (see Job V, Task 2). An 8-ft. square lift net with 1/2" mesh liner was used at Holtwood inner forebay. Shad were also taken in the lower Susquehanna River and Flats during July-October by Maryland DNR in their annual juvenile Alosa recruitment survey, striped bass and yellow perch projects (see Job VI). Gear used here included 100-ft. and 200-ft.

seines, otter trawl and electrofisher. Samples of shad from most collections were returned to PFBC's Benner Spring Research Station for tetracycline mark and microstructure analysis of otoliths. Most collecting sites used in 1991 are shown in Figure 1 and Figures 6-2 and 6-3.

Columbia to Pequea, Pennsylvania

With a record 22,083 live shad placed in the river above dams in 1991, and the most favorable adult sex ratio observed to date, SRAFRC sought to document occurrence of naturally produced juvenile shad during the summer nursery period. Initial plans were to sample at Columbia and Wrightsville weekly starting in mid-July and to continue until autumn outmigration was completed. These sites proved very effective in 1990.

During the period 12-31 July, 35 seine hauls were made on five dates at Wrightsville and Columbia. Most of this effort was conducted after dark, and although only 10 shad were collected, all were determined to be naturally produced. With unusually low river flows and the lack of hatchery fish in early collections, sampling strategy was adjusted to seek out wild fish in lower river areas not previously sampled. Throughout August, the Wyatt Group seine crew made 70 hauls on nine dates at Peach Bottom, Holtwood, Pequea and Long Level. A total of 14 shad were collected, all from the Pequea site on five dates - and all of these proved to be wild.

During early September through late October, seine sampling resumed weekly at Columbia and Wrightsville to document timing of outmigration of hatchery and wild fish from upstream waters. A total of 91 seine hauls were made on ten dates and produced 167 shad. Peak collections occurred during 24 September through 9 October when catch per effort averaged 4.7 fish/haul. Shad catch by date and location for all seine collections is shown in Table 1.

York Haven Dam

Wyatt Group biologists collected a few juvenile shad with cast net in the York Haven headrace on three occasions during late September and early October. SRAFRC sought to document first occurrence and relative abundance of shad at York Haven to assist Stone & Webster in timing the start of their strobe light study at this site. That study commenced on 29 September and continued daily through late October (see Job V, Task 2). Thousands of juvenile shad were collected in the trash sluice sampling net, and Stone & Webster personnel provided four weekly samples totalling 135 fish (range 25-52) for otolith analysis.

Safe Harbor Dam

Cooling water strainers in the turbine intakes at Safe Harbor Dam were inspected for juvenile American shad every other day from 10 September through 4 October, and daily thereafter through 30 November. A total of 122 shad was collected during the 6-week period 4 October through 19 November (Table 2). Almost 84% of shad taken at Safe Harbor (102 fish) came from new Units 8-12. All fish were provided to the PA Fish and Boat Commission for otolith analysis.

Holtwood Dam

RMC Environmental Services was initially contracted in 1991 to collect juvenile American shad at the Holtwood inner forebay with a lift net during September through November. The sampling plan called for 10 lifts per day twice weekly to be conducted at dusk. With the occurrence of wild juveniles in seine collections during July and early August, RMC initiated sampling at Holtwood in mid-August. Continued presence of shad in collections delayed termination of this effort until 19 December.

No juvenile shad were collected at Holtwood on 15 sample dates from 15 August through 3 October. Thereafter, small numbers of shad (range 1-48) were taken on 19 of 22 dates. A total of 208 shad was collected at Holtwood and all were sent to the Benner Spring Research Station for otolith analysis. In addition to American shad, 19 juvenile alewives were collected at Holtwood on three sample dates between 29 November and 9 December. Other fish in samples included 22,104 gizzard shad, 860 shiners and minnows (4 species), and 99 other fishes representing 11 species. All Holtwood collection data is provided in Table 3. Daily catch of shad at Safe Harbor and Holtwood as related to water temperature is shown in Figure 2.

Peach Bottom Atomic Power Station

With the cooperation of Philadelphia Electric Company, RMC biologists examined intake water travelling screen washes for impinged American shad at Unit 2 of the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pond. Screen sampling occurred twice per week (Tuesday and Friday) during 1 October through

17 December. The first shad appeared at Peach Bottom on 4 October and 7 of the 15 total fish taken in this effort were recovered in the last three samples in mid-December. Other fish in Peach Bottom collections included 17 alewives, 1 blueback herring, 116,601 gizzard shad and 3,027 others representing 21 species (Table 4). Though American shad abundance in 1991 was similar to that in 1990, over three times as many gizzard shad were collected this year.

Conowingo Dam

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged American shad once per week from 2 October through 6 December and three times each week during 9-20 December. A total of 9 shad were collected on four sample dates between 6-18 December. Other fishes in Conowingo collections included 3 alewives (11 December), 46,460 gizzard shad, and 25 others representing 6 species. Over 99% of the gizzard shad collected here in 1991 appeared in the last eight sample dates as water temperature dropped below 10°C.

Susquehanna River Mouth and Flats

Maryland DNR collected 15 juvenile American shad with haul seines; 2 with otter trawl; and 17 with electrofishing gear in 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 striped bass, yellow perch and anadromous alosid juvenile recruitment survey. Collection results by gear, location and date are provided in Job VI. Otoliths from these 34 juvenile shad as well as 14 yearlings taken in pound nets during spring tagging were provided to the Pennsylvania Fish and Boat Commission for analysis.

OTOLITH MARK ANALYSIS

Otoliths from 643 juvenile American shad taken in summer/autumn collections by The Wyatt Group, Stone & Webster, Safe Harbor Dam personnel, RMC Environmental Services, and Maryland DNR were successfully prepared for hatchery mark assessment. Four additional juveniles were taken from the Juniata River in mid-October, and 14 spring yearlings were examined.

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 used by the Pennsylvania Fish and Boat Commission in 1991 is described in Job III (see Table 7 on page 3-34).

York Haven Forebay

Otolith analysis was completed on 135 shad provided by Stone & Webster from the York Haven sluice net collections and 17 fish taken by Wyatt Group with cast nets at that site. All but 4 of these 152 fish taken in late September and October carried hatchery marks. Of these, 135 (91%) were Hudson River origin and 13 (9%) were Delaware River fish.

As noted in Job III, three distinct tag combinations were placed on Hudson River fish in 1991. These included a single day 5 mark for 2.081 million fry stocked during daylight hours; a day 18 tag for 2.106 million fry stocked at night as part of a survival comparison test; and the standard triple mark on days 5, 9, and 13 for the remaining 3.031 million Hudson fish which were not part of the stocking study. Otolith analysis showed that these three stocked elements were represented at York Haven as follows: day stocked - 54 fish (40%); night stocked - 60 fish (44%); and, other Hudson - 21 fish (16%).

Columbia, Wrightsville and Pequea

Seine collections made during mid-July through late October provided 135 shad for otolith mark analysis. All 14 fish taken at Pequea (August) and all 21 fish from Columbia and Wrightsville collected through 9 September were wild. Thirty-six of the 40 shad taken at Columbia on 17 and 24 September were also wild (90%), but hatchery fish dominated collections thereafter (50 of 60 or 83% hatchery for four weekly collections in October). Four seine caught shad showed hatchery micro-structure but no marks. Of the 50 hatchery marked fish in these seine collections, 94% were Hudson River origin [23 fish (49%) day stocked; 15 fish (32%) night stocked; 9 fish (19%) other]. Three fish (6% of total) were Delaware source.

Safe Harbor Strainers

Otoliths from 115 shad taken at Safe Harbor Dam were analyzed. Wild fish comprised 25-50% of collections on 11 of 25 sample dates between 18 October and 14 November. Overall, hatchery fish constituted about 77% of Safe Harbor collections (88 of 115). Eighty marked shad (92%) were Hudson origin (27% day-stocked; 54% night-stocked; 19% other) and 7 fish (8%) were Delaware.

Holtwood Inner Forebay

Of the 197 shad otoliths processed from Holtwood collections, 178 (90%) were hatchery origin. The 19 wild fish occurred in low abundance (1-3 fish) on 10 different collecting dates between 17 October and 16 December. Hudson River fish comprised 78% of marked juveniles (38% day-stocked; 40% night-stocked; 22% other). Thirty-six Delaware source fish made up 20% of the collection and there were three feed-marked fingerlings (two canal pond and one Upper Spring Creek Pond #3).

Peach Bottom and Conowingo

Of the 15 shad otoliths analyzed from Peach Bottom (13) and Conowingo (2) collections, 13 (87%) were hatchery fish. The two wild fish came from Peach Bottom on 1 November and 10 December. Twelve of the marked shad were Hudson origin, about equally split between day-stocked, night-stocked and other. Only one fish (8%) was Delaware.

Lower Susquehanna River and Upper Chesapeake Bay

Twenty-nine of the 34 age-0 shad provided from Maryland DNR summer-fall collections in the estuary were analyzed for hatchery marks. Two-thirds of these (20 fish) had the double immersion mark (days 5 and 9) indicating that they were stocked as fry at Rock Run Landing. Eight of the remaining 9 juveniles were wild and one otolith showed hatchery microstructure but no marks. Otoliths from 2 of the 14 yearling shad examined from springtime pound net collections had hatchery marks (one double mark on days 5 and 9; one triple mark on days 5, 9, and 13).

Another otolith displayed hatchery microstructure but no mark and the remaining 11 fish were wild.

<u>Otolith Summary</u>

The 618 shad analyzed from collections above Conowingo Dam included samples from every week except one between 12 July and 16 December. Monthly sample sizes ranged from 10 fish in July to 289 in October for all sites combined. A total of 479 fish (77.5%) were marked, 6 (1%) had hatchery microstructure but no marks, and 133 (21.5%) were wild.

Hudson River fry comprised 91-94% of all marked fish in collections from York Haven, Columbia, Safe Harbor, and Peach Bottom/Conowingo. Delaware fry made up the remaining 6-9% of these collections. Ratio of Hudson to Delaware fish differed from this pattern only at Holtwood where 78% were Hudson, 20% Delaware and 2% fingerlings stocked from ponds. The sources of marked fish in all collections combined was 86.6% Hudson, 12.7% Delaware and 0.6% pond-reared fingerlings.

Of the 415 shad determined to be of Hudson River fry origin, 157 (37.8%) were day-stocked, 179 (43.1%) night-stocked, and (19%) other. Ratio of day- to night-stocked Hudson fry was similar at all collecting sites except Safe Harbor where night-stocked fish were twice as prevalent. There were no Connecticut River shad in 1991 collections.

Age 0 shad from collections made below Conowingo Dam were comprised of (double-marked fry released at Rock Run Landing, 3% with hatchery microstruct but no mark, and 27% wild fish. As was the case last year, no fish from kno upstream stockings were taken here. Fingerlings cultured in Maryland's ponds Elkton were released late in the season and recovery opportunity was limite Otolith analysis for all collecting dates and sites is presented in Table 5.

DISCUSSION

Run Timing and In-Stream Movements

All efforts to collect juvenile shad in 1991 were affected by unusually low river conditions. A serious drought prevailed in the basin from June through November. Rainfall deficiencies of up to 14" were recorded with the Juniata sub-basin being hardest hit. During this period, river stage at Harrisburg rarely reached 4-ft. and discharge measured at Safe Harbor generally ranged from 3,000 to 7,000 cfs, exceeding 10,000 cfs on only a few days. Water temperature exceeded 25°C from mid-June through mid-September, followed by a steady decline to about 6°C over the next 2 months. Figure 3 compares the 1991 flow situation during June through December with the long-term monthly averages.

Haul seining was adversely affected by the drought. Because of unusual water clarity and the probability of net avoidance, most seining was conducted at dusk and night. Also, many seine sites which proved effective for juvenile shad collection in previous years were too shallow for the gear. This situation was further compounded by a scheduled draw-down of Lake Clarke from 23 September until 2 October which rendered the seine most ineffective at Columbia and Wrightsville at he period of peak movement past the York Haven project.

Small numbers of juvenile shad were taken in most weekly seine collections from 12 July through 30 October. A total of 232 seine hauls were made on 25 dates (4 to 14 hauls per date) and 191 shad were collected. Of this number, 143 fish (75%) were taken in four consecutive weekly samples from 17 September to 9 October.

Shad first appeared in abundance at York Haven Dam on 29 September. From that date through 19 October, an estimated 278,500 shad were passed through the sluice gate and Unit 1 at York Haven as part of the strobe light study (Job V, Task 2). Peak passage days were 16-18 October (71,000 fish), and greater than 10,000 shad were passed on 13 of 21 dates. Fewer than 3,000 shad were passed in five additional testing days in late October and the study was terminated.

Of the 122 shad collected from cooling water strainers at Safe Harbor in 1991, 17 were taken during 4-17 October, 75 during 18-30 October, and 30 during 1-19 November. Peak abundance occurred when water temperature dropped below 15°C.

Little can be said about run timing for juvenile shad at Holtwood. No shad were collected here until early October, and thereafter small numbers of shad were taken on 19 of 22 dates. Catch was about equally split for the periods mid-October to mid-November and late November to mid-December. In 1990, juvenile gizzard shad demonstrated a directed downstream migration past Holtwood coincident with that of American shad. That year, 96% of the 23,500 gizzard shad and 91% of the 4,000 American shad were collected on nine dates between 15 October and 5 November.

In 1991, total collection of gizzard shad was similar at 22,104, but relatively small numbers were taken on all 37 collecting dates and no peak in abundance was noted.

As pointed out earlier, Peach Bottom screens and Conowingo strainers produced only 24 juvenile shad in 1991. Most of these (75%) appeared in six late season collections between 29 November and 18 December. Juvenile shad left the river too late in 1991 to be caught in Maryland DNR recovery efforts which terminated in late October.

In past years, outmigration typically corresponded with an autumn flow event (St. Pierre, 1991). Since no such event occurred in 1991, juvenile shad lingered throughout the nursery areas, particularly in Lake Aldred, much later than has been observed. With water temperature dropping to 1°C by 19 December, it is possible that late outmigrants would experience winterkill unless they found refuge in thermal discharge areas.

Virtually all shad collected by seine at Columbia and Pequea through 9 October were naturally produced. Since all adults were stocked above York Haven, it appears that many of these fish dropped below that dam and spawned successfully. Natural production above York Haven appeared relatively weak, as represented by fewer than 3% of the shad analyzed from York Haven sluice net collections.

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. This problem can best be shown by comparing collection results for 1990 and 1991, two very different flow years.

Seining effort in 1991 included 232 hauls at numerous locations on 25 dates between 12 July and 30 October. A total of only 191 shad was collected including 10 at Wrightsville, 14 at Pequea and 167 at Columbia. Other sites examined included Conowingo Pond, Peach Bottom, Holtwood, Long Level and Three Mile Island. Overall catch per unit effort (CPUE) amounted to 0.82 shad per haul. In 1990, shad stocking included 1.6 million fewer hatchery fry and almost 10,000 fewer adults. Yet seine collections produced 986 shad in only 156 hauls between Columbia and New Cumberland for a CPUE of 6.32.

Strainers at Safe Harbor passively sample the outmigrant shad population and may provide useful information on relative abundance from year to year. No spilling occurred at Safe Harbor and all fish were exposed to turbine entrainment. In 1991, catch per day of juvenile shad averaged 1.3 fish during 4-17 October; increased to 5.8 for late October; and dropped to 1.0 during November. In 1990, early and late portions of the run were similar at 1.3 and 1.2 fish per sample day, but the peak of migration (14-28 October) produced an average catch of 10.2 fish per day. It should be noted that efficiency of capture may relate to frequency of generator operation - and 1991 was a near-record low energy production year.

Even though wild shad were recorded below Safe Harbor Dam throughout August (Pequea collections), fish did not appear in the Holtwood lift net until 7 October. This is another indication of a late outmigration. From early October through 18 November, 116 shad were taken in 130 lifts (CPUE = 0.89). From 21 November through 19 December, water temperature fell from 10°C to less than 5°C and an additional 92 shad were taken in 90 lifts (CPUE = 1.02). Under more "normal" flow conditions in 1990, the lift net at Holtwood collected 3,988 shad during 6 September through 16 November. About 90% of those fish (CPUE = 45) occurred in a 19-day period in late October.

Peach Bottom and Conowingo produced a total of 24 shad in 1991, mostly in December. In 1990, 23 shad were collected at these passive sampling sites with peak abundance during mid-October. Seine, trawl and electrofishing in the lower river and Susquehanna Flats produced 34 shad in 1991 compared to 61 in 1990.

Because of the unusually low flow regime in the Susquehanna River during the summer and fall of 1991, few conclusions should be drawn regarding relative abundance of juvenile shad. Wild fish were much more prevalent than in any prior year, comprising 95% of all fish analyzed from seine collections during July through September. Hatchery fish dominated collections at all power projects during October through November.

Based on overall catch per unit effort for seine, lift net and strainer collections the 1991 outmigrant shad population appeared to be considerably smaller than in 1990. The only observed directed migration in 1991 occurred at York Haven during the 3-week period 29 September through 19 October. Even with adverse netting conditions already noted, seine collections at Columbia during 24 September through 9 October produced 127 fish in 27 hauls, a CPUE of 4.7. This compares with 1990 collections at Columbia and Wrightsville during September, 1990 of 151 shad in 25 hauls (CPUE = 6.0).

Peak collection of shad at Safe Harbor occurred during a 2-week period in late October in both 1991 and 1990. Catch per effort for this period was 40% less in 1991, but some of this difference may be related to reduced plant operations. During 16-30 October, 1991, the station shut down altogether on 3 days (no shad) and maintained some generation at all units on eight dates while taking one-half of all fish collected for the season (62 shad; cpd = 7.75).

Peach Bottom and Conowingo collections were almost identical for the two years, but timing of peak shad catch was almost 2-months later this year. Holtwood lift net collections in 1991 were obviously reduced from past years. Low river flows, reduced operation of the facility, and replacement of the shallow trash boom at the head of the enclosed forebay with a deeper skirt may have influenced this collection.

Growth

Wild juvenile shad collected with seines at Wrightsville in July averaged 71 mm total length (TL) and at Pequea in August they averaged 116 mm. Most shad collected in 1990 below York Haven Dam were hatchery origin and were smaller, showing mean total lengths of 72 mm in early August and 104 mm by the end of the month. Mean length of wild shad in September collections at Columbia this year was 137 mm compared to 120 mm for hatchery fish by the end of September, 1990.

During the period 30 September through 22 October, total lengths were measured from 269 shad from seven collections at York Haven and Columbia. Almost 94% of these were hatchery origin and mean total length was 129 mm (range 100-150 mm). This is almost identical to the mean length of about 130 mm measured for shad at Holtwood during October, 1990. Seventeen wild fish taken in late October, 1991 collections continued to show growth advantage over hatchery fish with a mean length of 145 mm.

Shad in Holtwood collections this year, produced a smaller average size from that measured at York Haven. During October and November, 137 fish from this site averaged only 120 mm TL. As expected however, twelve wild fish collected at Safe Harbor and Holtwood in November showed a larger average size of 159 mm. By December, mean length of hatchery shad in Holtwood collections increased to 135 mm TL, again similar to late season lengths in 1990. Wild fish from Holtwood and Peach Bottom averaged 173 mm and six young-of-year wild shad from late season collections exceeded 190 mm TL. Figure 4 displays wild and hatchery growth curves for most collections.

All 7.2 million hatchery reared shad fry from Hudson and Delaware River egg sources were stocked at Thompsontown between 30 May and 18 June at 18-23 days of age. Shad appeared in substantial abundance in the Juniata River below Thompsontown throughout summer months. Since no hatchery fish were taken in net collections prior to 17 September, it appears that the cultured component of the stock remained largely segregated from wild fish during the nursery period. Size disparity between these two groups may relate to differences in age, food availability or levels of feeding competition.

About 75% of all adult shad stocked from Conowingo in 1991 occurred over a 21-day period, 29 April through 19 May. Water temperature exceeded 15 °C throughout this period and major spawning might have been expected within a few days of release. All Hudson and Delaware River shad eggs provided to Van Dyke this year were taken during 2-21 May. Thus, most naturally produced and cultured shad were approximately the same age. Both sources of juvenile shad were exposed to unusually low river flows and elevated temperatures throughout the summer. Differences noted in average size of wild and hatchery fish from collections in October through December probably relate to reduced feeding competition and/or increased food availability in lower river impoundments as compared to the Juniata River.

Hudson and Delaware River shad eggs were collected over the same time period, cultured under identical conditions, and stocked simultaneously at Thompsontown. If growth of shad is related to environmental conditions, food availability and competition, then these sources should have shown near identical growth rates. Length frequency analysis by strain was examined for three collections in which Delaware River fish were well represented.

In the York Haven collection from 22 October, eight Delaware fish averaged 131 mm TL and twenty Hudson fish averaged 121 mm. Size disparity was greater in the 11 November collection at Holtwood, with Delaware fish showing a mean TL of 129 mm (n = 10) and Hudson 113 mm (n = 35). Again, in the pooled Holtwood sample from 2-5 December, Delaware shad lengths exceeded that of Hudson fish, 144 mm (n = 9) to 122 mm (n = 24). According to state biologists in New York and New Jersey, size of shad in natural outmigration collections from the Hudson and Delaware rivers are similar. We have no explanation for the size difference noted in the Susquehanna.

Stock Composition and Mark Analysis

Of the 7,218,000 shad fry stocked at Thompsontown in 1991, 6,098,000 (84.5%) were Hudson River origin released on 11 dates between 30 May through 18 June. Delaware River shad fry made up 1,085,000 (15%) of the total Juniata River stocking in 1991, with two releases on 31 May and 9 June. The remaining 35,000 fry (0.5%) were Connecticut River origin stocked at Thompsontown on 28 June.

All collections with tetracycline marked shad were dominated by Hudson source fish as expected. Overall, Hudson fish represented 87% (415 of 476 fish) and Delaware comprised the remaining 13% (61 fish) as shown below.

	Hudson		Delaware	
Site	No.	%	No.	%
Newport	3	75	1	25
York Haven	135	91	13	9
Columbia	47	94	3	6
Safe Harbor	80	92	7	8
Holtwood	138	78	36	20
PB/Cono.	12	92	1	8
TOTALS	415	87	61	13

Recovery rates for these two sources were similar at 0.000068 for Hudson and 0.000056 for Delaware. No Connecticut juveniles were collected. Numbers of shad released and recovered and relative survival from various egg sources stocked in the Susquehanna River during 1988 through 1991 are shown in Table 6.

As pointed out earlier, comparable numbers of specially marked Hudson River shad fry were stocked at Thompsontown on select dates during daytime (2.081 million) and night hours (2.106 million). The purpose for this work was to compare relative survival from the two stocking strategies. In 1989 and 1990, U. S. Fish and Wildlife Service ecologists from the fishery research lab at Wellsboro, PA determined that heavy predation occurred immediately following each daytime stocking.

In 1991, Service researchers sampled for larval shad and predators at and below the release site for each paired stocking. Overall abundance of predators and rate of predation was much less this year, though predation rates were generally higher for daytime stocking (Jim Johnson, pers. comm.). Due to low flows in the Juniata River this year, fry were stocked further from shore near the mouth of Delaware Creek.

A total of 336 juvenile shad from day/night stockings were recovered in downstream collections during late September through mid-December. Of these, 157 (46.7%) were day-stocked (catch rate 0.00075) and 179 (53.3%) were night stocked (catch rate 0.00085). Only Safe Harbor strainer collections showed disproportionate abundance with night-stocked fish being twice as prevalent.

More wild juvenile shad were collected above Conowingo in 1991 than in all previous years combined. A total of 133 shad (21.5%) of 618 fish analyzed for hatchery marks and microstructure were naturally produced. During the prior four years, a total of only 50 of 1,831 juveniles (2.7%) were wild (range 1.4% to 4.0%). Improved reproduction observed in 1991 may relate to favorable environmental conditions and increased numbers of potential spawning fish. Based on 22,000 adult shad stocked from Conowingo with a 1.65 : 1.0 sex ratio, an estimated 8,300 females were placed into spawning waters in 1991. This compares to only 1,200-3,600 potential female spawners stocked during 1987-1990.

A total of 4,877,000 shad fry were distinctively marked (double tag) and stocked below Conowingo Dam at Rock Run Landing on five dates between 29 May and 20 June. Stockings included 3.032 million Hudson fish (62%), 1.827 million Delaware (37.5%) and 18,000 Susquehanna fish (0.4%). Of the 29 shad otoliths analyzed from Maryland DNR collections below Conowingo, 20 were double-marked on days 5 and 9, the combination used for Hudson and Delaware source fry. One fish showed hatchery microstructure but no mark and the remaining 8 fish (27.6%) were wild.

The proportion of hatchery fish in DNR collections was higher than in 1990 (72% versus 54%). Recovery rate for shad stocked below Conowingo however, was considerably lower than was shown in 1989 and 1990, and was less than 10% of that recorded in upstream collections.

A total of 54,400 fingerling shad were stocked from Pennsylvania ponds into the Juniata River including 30,000 Hudson fish from the Thompsontown canal pond on 27 August and 24,400 Delaware fish from Upper Spring Creek pond #3 on 12-13 September. Two canal pond fingerlings were collected at Holtwood (one each on 14 November and 2 December) and one fish from Pond #3 was taken there on 11 November. This compares with a recovery of 10 fish from 90,000 fingerlings released from ponds in 1990.

The 111,500 fingerling shad produced in ponds at Elkton, MD were released into the Elk River on 8-11 October. None were collected in late season seine or electrofishing collections in the upper Bay. PA Fish and Boat Commission personnel examined 39 fish from the fingerling production pond at Havre de Grace. None of these carried hatchery marks and all were identified as hickory shad. American shad fry placed in this pond on 10 June may have been lost to predation. We cannot readily explain the appearance of hickory shad juveniles.

SUMMARY

River conditions during the summer and fall of 1991 were unusual because of a prolonged drought in the basin. Although the haul seine took small numbers of juvenile shad at numerous sites during July through October, catch efficiency was undoubtedly reduced due to low water and increased clarity. The seine did successfully document occurrence of naturally produced shad in the river reach from Columbia to Pequea.

Although there was no autumn high flow event, large numbers of hatchery stocked shad passed York Haven during the first 3-weeks in October. A corresponding peak in abundance was noted from Safe Harbor strainer collections in late October, but this directed outmigration was not observed at Holtwood. Most shad in collections at Peach Bottom and Conowingo occurred in December as water temperatures approached the reported lethal level for the species.

Overall abundance of juvenile shad in 1991 was lower than that reported in recent years, but for the first time, wild fish were well represented in the catch. Hatchery released fry grew well, reaching an average size of about 125 mm within 4-months. Delaware River source shad were larger than their Hudson counterparts by 8-18%.

Wild fish, presumed to be about the same age as hatchery shad, consistently showed substantially larger average sizes in mixed collections.

Hudson and Delaware River source juvenile shad were captured in relative proportion to their abundance at stocking. Specially marked Hudson fry released during day and night stocking episodes showed similar survival rates based on juvenile recaptures in the autumn. Pond reared fingerlings were poorly represented in downstream recovery efforts.

Fewer juvenile shad were taken in Maryland DNR net and electrofishing collections in the upper Bay in 1991 than in 1990. This was somewhat unexpected since the adult population in the upper Bay and lower river continued to increase and 25% more hatchery fry were released below Conowingo this year. The wild component of DNR's collection also decreased substantially from 1990.

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St. Pierre, R. A. 1990. Evaluation of juvenile American shad in the Susquehanna River. In Restoration of American shad to the Susquehanna River. 1989 Ann. Prog. Rep. to SRAFRC, Harrisburg, PA.

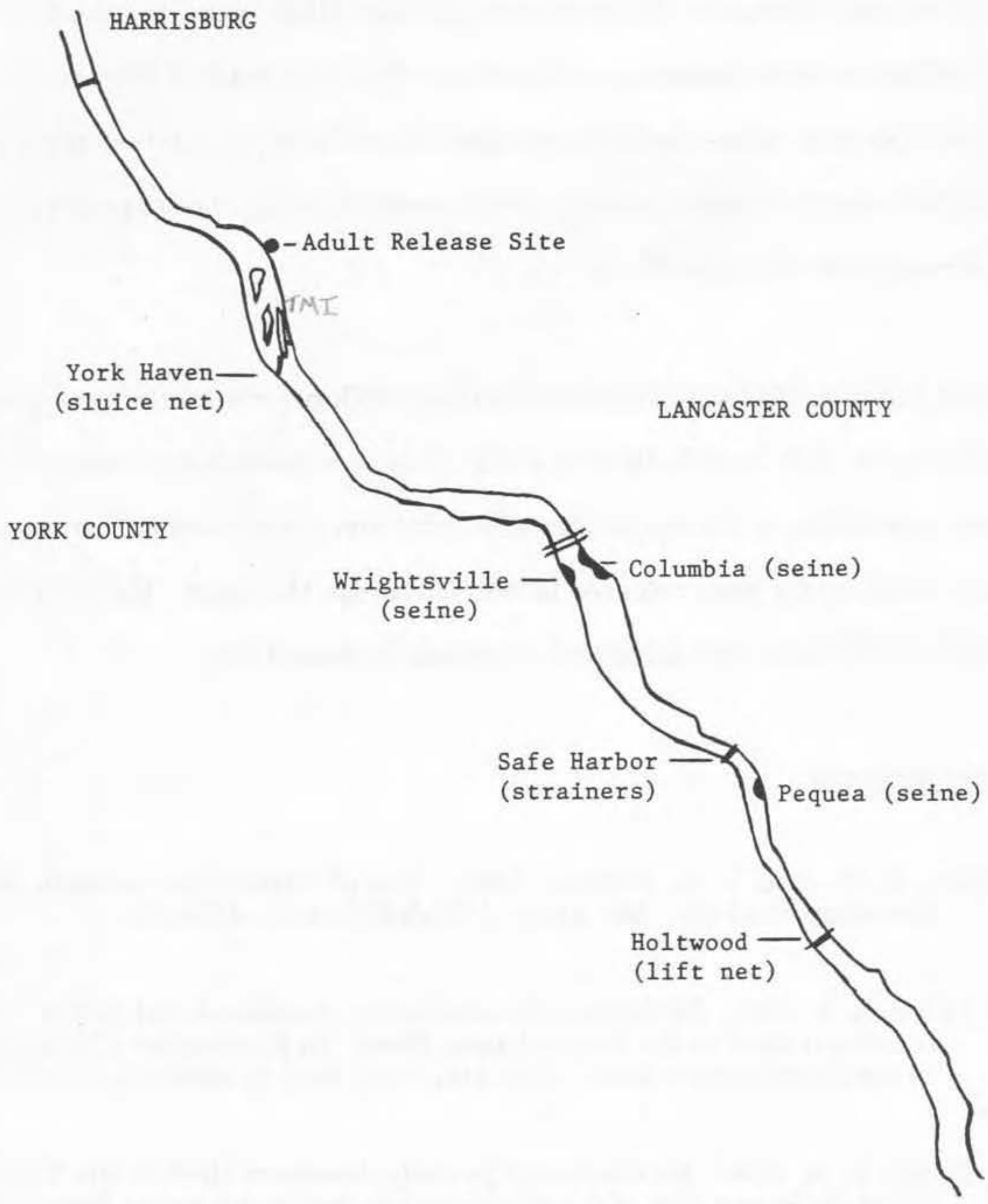
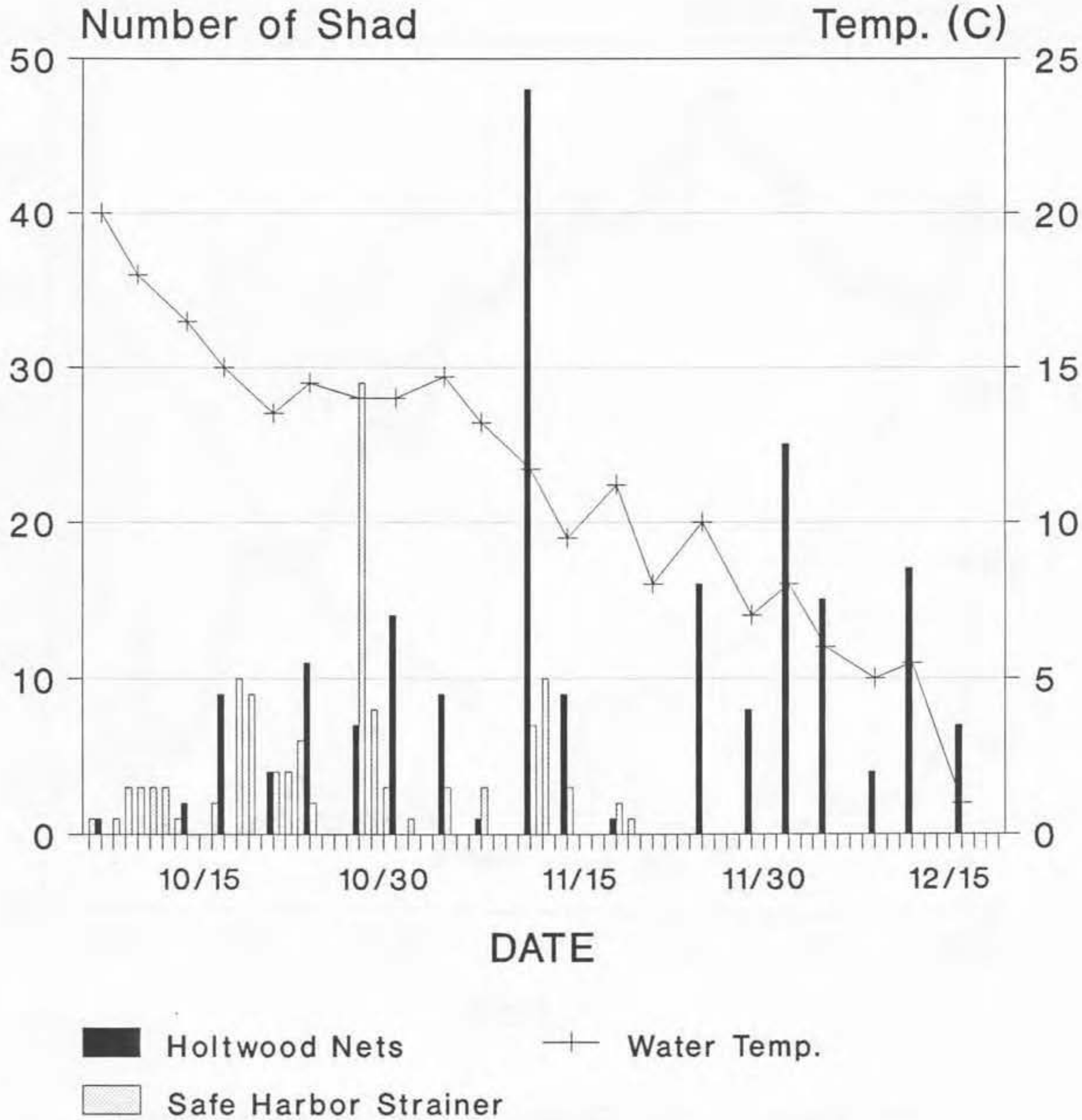


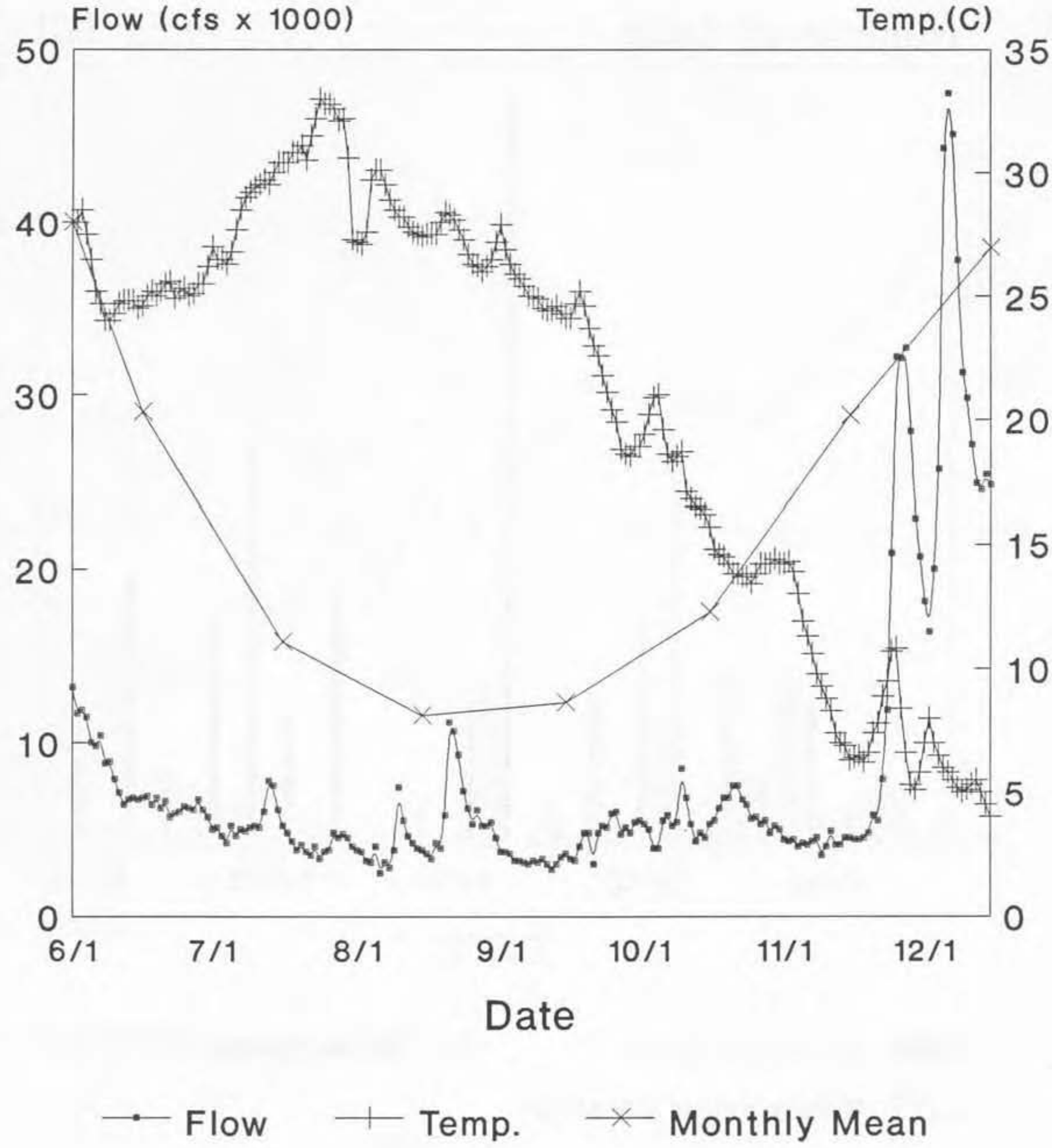
FIG. 1. Locations for Juvenile Shad Sampling During July through December, 1991.

Fig. 2. Catch of Juvenile American Shad at Safe Harbor and Holtwood Dam, October - December, 1991



(Holtwood n=208; Safe Harbor n=122)

Fig. 3. Comparison of River Flow and Temperature in June-December, 1991 with Long-term Mean Monthly Flow*.



*Data for 1932-1991 at Marietta (USGS)

Fig. 4. Growth of Juvenile Shad Based on Mean Length Frequencies at Three Collection Sites, July-December, 1991.

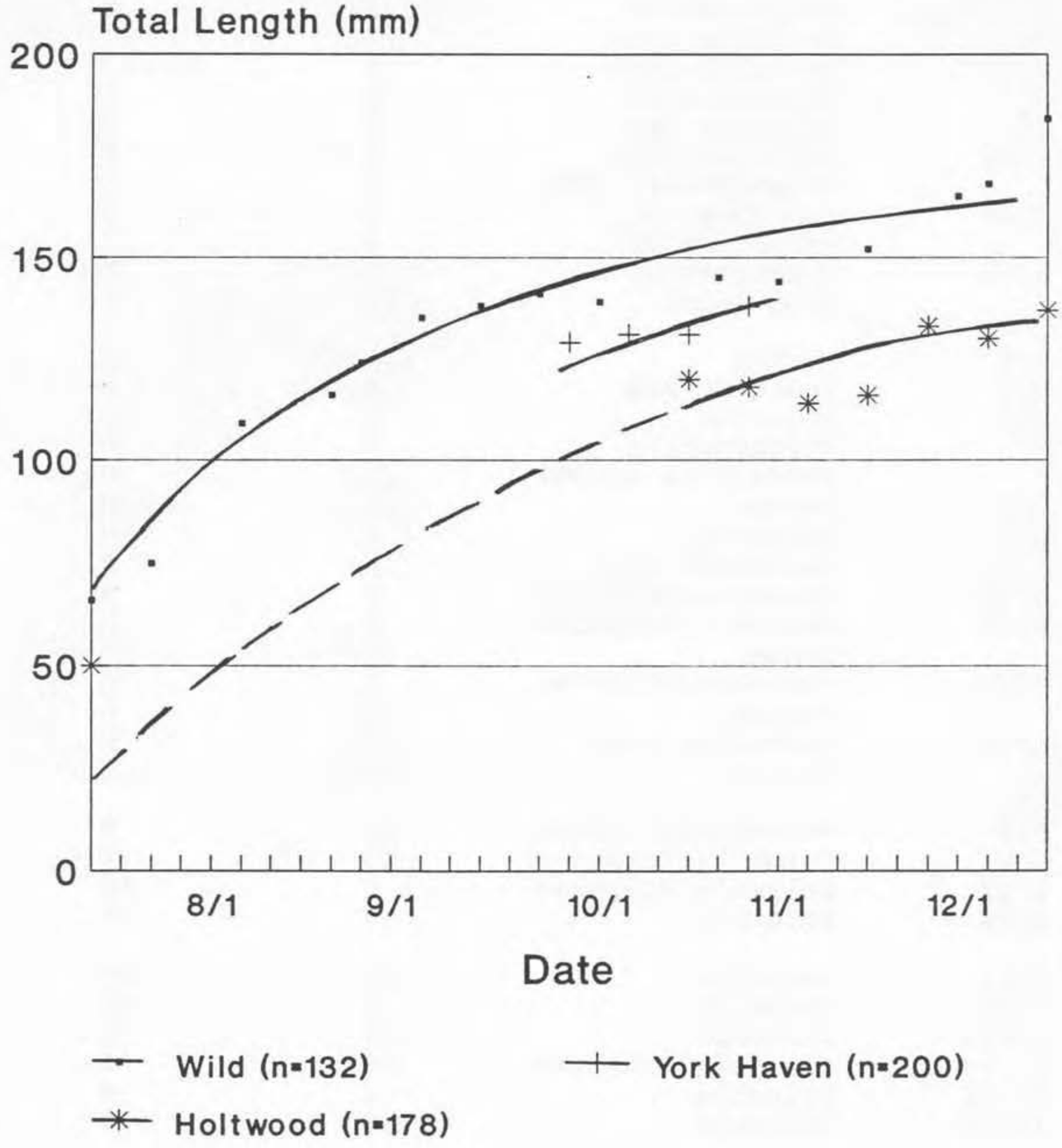


Table 1. Summary of Juvenile American Shad Collected with Haul Seine in the Lower Susquehanna River, July - October, 1991.

Date	Location	No. Hauls	No. Shad
7/12	Columbia (am)	3	0
	Wrightsville	2	3
	Columbia (pm)	2	0
7/16	Columbia (am)	3	0
	Wrightsville	5	2
	Columbia (pm)	3	0
7/19	Holtwood (am)	6	0
	Wrightsville (pm)	3	0
7/23	Columbia	6	0
	Wrightsville	4	5
7/31	Wrightsville	4	0
	Long Level	4	0
8/5	Pequea	10	0
8/6	Peach Bottom	8	0
8/7	Columbia	3	0
	Wrightsville	3	0
	Three Mile Island	3	0
8/8	Pequea	10	5
8/9	Holtwood	7	0
8/12	Conowingo Pond	8	0
8/13	Columbia/Wrightsv.	8	0
8/21	Columbia/Wrightsv.	6	0
	Pequea	6	3
8/27	Columbia/Wrightsv.	7	0
	Pequea	7	1
8/29	Conowingo Pond	3	0
	Pequea	7	5
9/3	Columbia/Wrightsv.	11	3
9/9	Columbia/Wrightsv.	12	9
9/17	Columbia/Wrightsv.	9	16
9/24	Columbia	10	30
10/1	Columbia	10	28
10/9	Columbia	7	69
10/16	Columbia	11	7
10/23	Columbia/Wrightsv.	10	1
10/24	Columbia	4	4
10/30	Columbia	7	0
Totals		**232**	**191**

Table 2. Summary of Juvenile American Shad Collected from Cooling Water Strainers at Safe Harbor Dam, September - November, 1991.

Date	No. Shad	Date	No. Shad
9/10	0	10/28	29
9/13	0	10/29	8
9/16	0	10/30	3
9/18	0	10/31	0
9/20	0	11/1	1
9/23	0	11/2	NR
9/25	0	11/3	NR
9/27	0	11/4	3
9/30	0	11/5	0
10/2	0	11/6	0
10/4	1	11/7	3
10/5	NR	11/8	0
10/6	NR	11/9	0
10/7	0	11/10	0
10/8	1	11/11	7
10/9	3	11/12	10
10/10	3	11/13	0
10/11	3	11/14	3
10/12	3	11/15	0
10/13	1	11/16	NR
10/14	0	11/17	NR
10/15	0	11/18	2
10/16	2	11/19	1
10/17	0	11/20	0
10/18	10	11/21	0
10/19	9	11/22	0
10/20	NR	11/23	NR
10/21	4	11/24	0
10/22	4	11/25	0
10/23	6	11/26	0
10/24	2	11/27	0
10/25	0	11/28	0
10/26	NR	11/29	0
10/27	NR	11/30	0
		Total	**122**

NR = Not Running

Table 3.

Summary of Fishes Collected by Lift Net at Holtwood Forebay, 15 August - 19 December 1991.

Date	Aug 15	Aug 19	Aug 22	Aug 26	Aug 29	Sep 3	Sep 5	Sep 9	Sep 12	Sep 16	Sep 19	Sep 23	Sep 26	Sep 30
Water Temp (C°)	29.5	29.5	29.5	30.0	31.5	29.5	25.2	30.0	28.5	24.0	28.0	27.0	20.5	21.0
Species														
Alewife	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American shad	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gizzard shad	121	145	166	54	130	182	1200	72	950	1042	11	34	1113	1217
Comely Shiner	-	11	4	7	2	8	45	9	35	31	30	64	9	77
Spottail shiner	-	-	-	5	10	1	-	1	-	-	1	3	-	-
Spotfin shiner	7	-	-	-	-	-	-	-	27	-	-	-	-	-
Bluntnose minnow	49	16	2	-	-	-	-	-	-	-	-	-	1	-
Quillback	-	1	1	-	-	-	-	-	1	-	-	-	-	-
Yellow bullhead	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Channel catfish	1	-	2	2	-	4	7	4	-	-	1	-	7	-
Rock bass	-	-	-	-	-	1	1	-	-	-	1	-	-	-
Green sunfish	-	1	-	-	1	1	-	1	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	2	-	1	-	-	-	-	-	-
Bluegill	1	1	3	1	1	3	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White crappies	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Black crappie	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Tiger muskie	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	179	175	178	69	144	202	1253	88	1013	1073	44	101	1133	1299

Table 3 continued

Date	Oct 3	Oct 7	Oct 10	Oct 14	Oct 17	Oct 21	Oct 24	Oct 28	Oct 31
Water Temp(C°)	21.0	20.0	18.0	16.5	15.0	13.5	14.5	14.0	14.0
Species									
Alewife	-	-	-	-	-	-	-	-	-
American shad	-	1	-	2	9	4	11	7	14
Gizzard shad	741	994	109	7	1249	156	109	1157	4
Comely shiner	1	49	148	10	-	3	3	-	-
Spottail shiner	133	3	1	3	-	3	4	-	1
Spotfin shiner	-	-	-	-	-	-	-	-	-
Bluntnose minnow	-	-	-	-	-	-	-	-	-
Quillback	1	-	-	-	-	-	-	-	-
Yellow bullhead	-	-	-	1	1	-	-	-	1
Channel catfish	1	4	7	2	4	-	1	1	-
Rock bass	-	-	-	1	-	-	-	-	-
Green sunfish	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	2	1	1
Largemouth bass	-	-	-	-	-	-	-	-	-
White crappie	-	-	-	1	-	-	-	1	-
Black crappie	-	-	-	-	-	-	-	-	-
Tiger muskie	-	-	1	-	-	-	-	-	-
Totals	877	1051	266	27	1263	166	130	1167	21

Table 3 continued

Date	Nov 4	Nov 7	Nov 11	Nov 14	Nov 18	Nov 21	Nov 25	Nov 29
Water Temp(C°)	14.7	-	11.7	9.5	11.2	8.0	10.0	7.0
Species								
Alewife	-	-	-	-	-	-	-	3*
American shad	9	1	48	9	1	-	16	8
Gizzard shad	434	699	2262	3842	1238	1303	1272	52
Comely shiner	18	-	-	4	4	10	-	-
Spottail shiner	1	-	-	1	2	1	-	-
Spotfin shiner	-	1	-	-	-	1	-	-
Bluntnose minnow	-	-	-	-	-	-	-	-
Quillback	-	1	-	-	-	-	-	-
Yellow bullhead	-	-	-	-	-	-	-	-
Channel catfish	1	-	-	-	2	-	-	-
Rock bass	-	-	-	-	-	-	-	-
Green sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	2	-	-	-
White crappie	-	-	-	-	-	-	-	-
Black crappie	-	-	-	-	2	-	-	-
Tiger muskie	-	-	-	-	-	-	-	-
Totals	463	702	2310	3856	1251	1315	1288	63

* Identity questionable, potential alewife 29 November

Table 3 continued

Date	Dec 2	Dec 5	Dec 9	Dec 12	Dec 16	Dec 19	Totals for 15 August - 19 December
Water Temp(C°)	8.0	6.0	5.0	5.5	5.0	1.0	
Species							
Alewife	-	11*	5	-	-	-	19
American shad	25	15	4	17	7	-	208
Gizzard shad	19	9	6	1	1	3	22104
Comely shiner	-	-	-	-	-	-	582
Spottail shiner	-	-	-	-	-	-	174
Spotfin shiner	-	-	-	-	-	-	36
Bluntnose minnow	-	-	-	-	-	-	68
Quillback	-	-	-	-	-	-	5
Yellow bullhead	-	-	-	-	-	-	4
Channel catfish	-	-	-	-	-	-	51
Rock bass	-	-	-	-	-	-	4
Green sunfish	-	-	-	-	-	-	4
Pumpkinseed	-	-	-	-	-	-	3
Bluegill	-	-	-	-	-	-	14
Largemouth bass	-	-	-	-	-	-	2
White crappie	-	-	-	-	-	-	7
Black crappie	-	-	-	-	-	-	4
Tiger muskie	-	-	-	-	-	-	1
Totals	44	36	15	18	8	3	**23291**

* Identity questionable, potential alewife 5 December

Table 4

Summary of Fishes Collected at Peach Bottom Power Station Unit No. 2, 1 October to 17 December 1991.

Date	Oct 1	Oct 4	Oct 8	Oct 11	Oct 15	Oct 18	Oct 22	Oct 25	Oct 29
Species									
American shad	-	1	-	-	-	-	-	-	1
Alewife	-	-	-	-	-	-	-	-	-
Blueback herring	-	-	-	-	-	-	-	-	-
Gizzard shad	63	1050	166	22	5	38	17	20	165
Common carp	2	-	1	1	-	-	-	-	6
Comely shiner	-	-	1	-	-	-	-	-	-
Spottail shiner	1	-	-	1	-	-	-	-	-
Spotfin shiner	-	-	-	1	-	-	-	-	-
Quillback	4	1	1	-	1	-	-	-	-
White catfish	2	-	-	-	-	-	-	-	-
Channel catfish	3	7	7	7	-	6	2	4	25
Banded killifish	-	-	-	-	-	-	-	-	-
White perch	-	-	-	-	-	-	-	-	-
Striped bass	-	-	-	-	-	-	-	-	-
Rock bass	-	-	-	-	-	-	1	4	-
Redbreast sunfish	-	-	-	-	-	1	-	-	-
Green sunfish	-	-	-	-	1	-	-	8	-
Pumpkinseed	-	-	-	-	-	1	-	-	-
Bluegill	-	6	-	2	-	-	-	8	-
Smallmouth bass	5	-	-	3	-	-	1	-	-
Largemouth bass	-	1	-	-	-	-	-	-	-
White crappie	-	-	-	-	-	1	-	-	-
Sunfishes	-	-	6	-	-	8	-	-	35
Tessellated darter	-	1	-	-	-	-	-	-	5
Yellow perch	-	-	-	1	-	-	-	-	-
Logperch	-	-	-	-	-	-	-	-	-
Totals	80	1067	182	38	7	55	21	44	237

Table 4 continued

Date	Nov 1	Nov 5	Nov 8	Nov 12	Nov 15	Nov 19	Nov 22	Nov 26	Nov 29
Species									
American shad	1	-	-	2	-	1	-	-	2
Alewife	-	-	-	-	-	-	-	-	-
Blueback herring	-	-	-	-	-	-	-	-	-
Gizzard shad	104	53	356	721	903	718	40000	12000	19500
Common carp	-	2	-	-	2	-	16	15	45
Comely shiner	-	-	-	-	-	-	-	-	-
Spottail shiner	-	-	1	-	1	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-
Quillback	-	1	-	-	-	-	-	10	1
White catfish	-	-	-	6	-	-	-	-	-
Channel catfish	8	5	12	-	6	5	8	10	30
Banded killifish	-	-	-	-	-	-	-	-	1
White perch	-	-	-	-	-	-	-	-	-
Striped bass	-	-	-	-	-	-	-	1	-
Rock bass	-	1	-	-	-	-	-	-	-
Redbreast sunfish	-	-	-	-	-	-	-	-	-
Green sunfish	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-
Smallmouth bass	2	-	1	-	-	1	-	6	-
Largemouth bass	1	-	-	-	-	-	-	6	-
White crappie	2	-	-	1	-	1	80	30	45
Sunfishes	7	14	9	7	5	4	96	240	45
Tessellated darter	-	-	-	-	-	-	-	-	-
Yellow perch	1	-	1	-	1	-	-	5	-
Logperch	-	-	-	-	-	-	-	1	-
Totals	126	76	380	737	918	730	40200	12324	19669

Table 4 continued

Date	Dec 3	Dec 6	Dec 10	Dec 13	Dec 17	Totals
Species						
American shad	-	-	3	1	3	15
Alewife	7	3	4	3	-	17
Blueback herring	-	-	1	-	-	1
Gizzard shad	35000	600	950	600	3550	116601
Common carp	30	-	-	-	-	120
Comely shiner	-	-	-	-	-	1
Spottail shiner	-	-	-	-	-	4
Spotfin shiner	10	-	-	-	-	11
Quillback	-	-	-	-	-	19
White catfish	-	-	-	-	-	8
Channel catfish	40	-	-	2	2	189
Banded killifish	-	-	-	-	-	1
White perch	-	-	-	-	1	1
Striped bass	-	-	-	-	-	1
Rock bass	-	-	-	-	-	6
Redbreast sunfish	-	-	-	-	-	1
Green sunfish	-	-	-	-	-	9
Pumpkinseed	-	-	-	-	-	1
Bluegill	-	-	-	6	8	30
Smallmouth bass	10	-	-	-	1	30
Largemouth bass	10	-	-	-	-	18
White crappie	380	20	8	3	25	596
Sunfishes	1460	15	-	-	-	1951
Tessellated darter	-	-	-	-	-	6
Yellow perch	10	-	-	1	2	22
Logperch	-	-	1	-	-	2
Totals	36957	638	967	616	3592	119661

Table 5 . Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1991

Collection Site	Coll. Date	No. of fish with TC mark: Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,13,17	Days 5,9,13+ Single Feed	Days 3,13,17+ Single Feed	Total Marked	Not marked (Microstructure): Hatchery	Wild	Tot.
Newport	10/16/91	2	1			1			4			4
York Haven	9/25/91	2	4						6			6
York Haven	9/30/91	22	16		12	1			51		1	52
York Haven	10/3/91		4		2				6			6
York Haven	10/7/91	10	14		4	1			29			29
York Haven	10/14/91	11	10		1	2			24		1	25
York Haven	10/21/91		3			1			4		1	5
York Haven	10/22/91	9	9		2	8			28		1	29
York Haven	subtotal	54	60	0	21	13	0	0	148	0	4	152
Wrightsville	7/12/91								0		3	3
Wrightsville	7/16/91								0		2	2
Wrightsville	7/23/91								0		5	5
Columbia	9/3/91								0		3	3
Columbia	9/9/91								0		8	8
Columbia	9/17/91	1	1						2	1	12	15
Columbia	9/24/91	1							1		24	25
Columbia	10/1/91	8	5		4	1			18	1	6	25
Columbia	10/9/91	11	4		3	1			19	2	3	24
Columbia	10/16/91	2	3		2				7			7
Columbia	10/24/91		2			1			3		1	4
Wri/Col	subtotal	23	15	0	9	3	0	0	50	4	67	121

Table 5. (continued)

Collection Site	Coll. Date	No. of fish with TC mark: Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,13,17	Days 5,9,13+ Single Feed	Days 3,13,17+ Single Feed	Total Marked	Not marked (Microstructure): Hatchery	Wild	Tot.
Safe Harbor	10/4/91				1				1			1
Safe Harbor	10/8/91		1						1			1
Safe Harbor	10/9/91	3							3			3
Safe Harbor	10/10/91	1	2						3			3
Safe Harbor	10/11/91		1		1	1			3			3
Safe Harbor	10/12/91	1	1		1				3			3
Safe Harbor	10/13/91				1				1			1
Safe Harbor	10/16/91		1			1			2			2
Safe Harbor	10/18/91	2	3		1				6		4	10
Safe Harbor	10/19/91	3	3		1				7		2	9
Safe Harbor	10/21/91	1	1						2		2	4
Safe Harbor	10/22/91		1		2				3		1	4
Safe Harbor	10/23/91		3		1				4		2	6
Safe Harbor	10/24/91	1	1						2			2
Safe Harbor	10/28/91	5	7		2	1			15		5	20
Safe Harbor	10/29/91	2	4		2				8			8
Safe Harbor	10/30/91	1	1						2		1	3
Safe Harbor	11/1/91		1						1			1
Safe Harbor	11/4/91		3						3			3
Safe Harbor	11/7/91		1		1				2		1	3
Safe Harbor	11/11/91	1	2			1			4	1	2	7
Safe Harbor	11/12/91	1	4			2			7		5	12
Safe Harbor	11/14/91				1				1		2	3
Safe Harbor	11/18/91		1			1			2			2
Safe Harbor	11/19/91		1						1			1
Safe Harbor	subtotal	22	43	0	15	7	0	0	87	1	27	115

Table 5 . (continued)

Collection Site	Coll. Date	Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,13,17	Days 5,9,13+ Single Feed	Days 3,13,17+ Single Feed	Total Marked	Not marked Microstructure Hatchery	Wild	Tot.
		No. of fish with TC mark										
Pequea	8/8/91								0		5	5
Pequea	8/21/91								0		3	3
Pequea	8/27/91								0		1	1
Pequea	8/29/91								0		5	5
Pequea	subtotal	0	0	0	0	0	0	0	0	0	14	14
Holtwood	10/7/91				1				1			1
Holtwood	10/14/91	1	1						2			2
Holtwood	10/17/91	3	5						8		1	9
Holtwood	10/21/91	1	3						4			4
Holtwood	10/24/91	6	4						10		1	11
Holtwood	10/28/91	3			2				5		2	7
Holtwood	10/31/91	8	4		1	1			14			14
Holtwood	11/04/91	4	1		3				8			8
Holtwood	11/7/91		1						1			1
Holtwood	11/11/91	10	15		11	9		1	46		1	47
Holtwood	11/14/91	3	2		1	2	1		9			9
Holtwood	11/18/91				1				1			1
Holtwood	11/25/91	3	6			4			13		3	16
Holtwood	11/29/91	2	1			2			5		3	8
Holtwood	12/2/91	5	3		6	5	1		20	1	3	24
Holtwood	12/5/91	2	5		2	4			13		2	15
Holtwood	12/9/91		1			2			3		1	4
Holtwood	12/12/91	1	2		1	6			10			10
Holtwood	12/16/91	1	1		1	1			4		2	6
Holtwood	subtotal	53	55	0	30	36	2	1	177	1	19	197

Table 5 . (continued)

Collection Site	Coll. Date	No. of fish with TC mark: Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,13,17	Days 5,9,13+ Single Feed	Days 3,13,17+ Single Feed	Total Marked	Not marked: Microstructure Hatchery	Wild	Tot.
Peach Bot.	11/1/91								0		1	1
Peach Bot.	11/5/91				1				1			1
Peach Bot.	11/15/91				2				2			2
Peach Bot.	11/22/91					1			1			1
Peach Bot.	12/10/91								0		1	1
Peach Bot.	12/13/91	2	1						3			3
Peach Bot.	12/17/91		1						1			1
Peach Bot.	12/20/91		2		1				3			3
Conowingo	11/7/91		1						1			1
Conowingo	11/12/91	1							1			1
P.B./Con.	subtotal	3	5	0	4	1	0	0	13	0	2	15
Susq. Flats/ Up. Ches.	3/21/91– 5/13/91*			1	1				2	1 **	11	14
Susq. Flats/ Up. Ches.	6/26/91– 10/16/91			20					20	1 **	8	29
Total (yearlings excl.)		157	179	20	79	61	2	1	499	7	141	647
	%	24%	28%	3%	12%	9%	0%	0%	77%	1%	22%	

Key: Day 5–Hudson R. origin, Day stocking
Day 18–Hudson River origin, Night stocking
Days 5,9,13–Hudson River origin, not part of Day/Night study
Days 3,13,17–Delaware River origin
Days 5,9,13 +single feed mark–Canal Pond
Days 3,13,17 +single feed mark–Upper Spring Creek Pond 3

* Yearlings
** TC mark obscured by autofluorescence
Conowingo fish from flume test

Table 6. Relative survival of American shad fry from various egg source rivers, stocked in the Susquehanna River, 1988-1991.

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
1991	Del.	5/31-6/9	1,085,000	15	61	13	0.000056	0.83
	Hud.	5/30-6/18	6,098,000	84	415	87	0.000068	1.00
	Conn.	6/28	35,000	<1	0	0	0.000000	0.00

Introduction

In 1990 we demonstrated that ovulation of captured adult American shad (Alosa sapidissima) can be induced by administration of leutinizing hormone release hormone alpha ($LHRH_a$), human chorionic gonadotropin (HCG), leutinizing hormone release hormone (LHRH), and salmon pituitary gland extract (Backman et al. 1990). In that study, $LHRH_a$ was probably the best hormone for inducing ovulation in American shad at both low (< 20°C) and high (> 20°C) temperatures. While two doses was the usual treatment, some fish ovulated after receiving a single injection of $LHRH_a$. A single injection of $LHRH_a$ would be more convenient and less stressful to the fish.

In our previous studies (Backman et al. 1990), the goal of reliably producing viable fertilized eggs was hindered by a lack of information on the time of ovulation in hormone-treated fish. If the fertilization procedures were performed at an incorrect time in rainbow trout (Oncorhynchus mykiss), then the maximum fertilization rate could not be obtained (Craik and Harvey 1984). Eggs stripped before or after the critical period might not be viable. The period that ovulated eggs can be fertilized varies among species. For example, white sturgeon (Acipenser transmontanus) eggs become overripe within 2 to 3 hours after ovulation (Conte et al. 1988). In striped bass (Morone saxatilis) overripe eggs were detected as early as 1 hour following ovulation. The eggs had a characteristic white spot or cloud and failed to water harden (Bayless 1972). In American shad both underripe and overripe non-viable eggs can be distinguished from viable eggs after water hardness (C.F. Liu, personal observation). Overripe

American shad eggs will not fertilize but may undergo water hardening as in normal, ripe, fertilized eggs. However, the yolk of overripe eggs is whitish in color instead of transparent in healthy eggs. Underripe ovulated eggs will not fully undergo water hardening. Their size remains the same or slightly larger than the size before placement in water, and the color remains transparent. This phenomenon has also been observed by other biologists (M. Hendricks, Pennsylvania Fish Commission, personal communication). Presently, the critical period or window for fertilization in American shad is unknown. To increase hatchery production of viable eggs, it is necessary to know the details of egg development and the ovulation process in hormone-treated fish.

This year's study was conducted with the use of $LHRH_a$ as an ovulation-induction hormone. The objectives of this study were to 1) minimize the dosage of $LHRH_a$ for inducing ovulation and test whether a single injection of $LHRH_a$ can be reliably used to induce ovulation, 2) monitor the characteristics of eggs prior to and during the ovulation period, and 3) determine the critical period for fertilization after ovulation begins.

Materials and Methods

Adult American shad (239 total, 3.5 females/male) were transported by fish tank truck from the Conowingo (Maryland) Fish Lift to the Muddy Run Laboratory at Drumore, Pennsylvania, from April 23 to May 28, 1991. One fourth of the fish died prior to initiation of experiments, which ran from April 23 to May 31. Four 2.44-m-diameter fiberglass tanks (each approximately 1,890 L in volume) were used to hold females. One or two males were introduced into each tank after the females were treated with hormone. A 1.8-m-diameter tank was used to hold the males from which sperm was to be extracted. Tank water temperature increased from 14 °C in early May to 31 °C in late May with an average temperature of 26 °C. During the early experimental period, a water pump (Aquaclear 802, 21-L/min flow rate) was used in each tank to create current and to maintain adequate dissolved oxygen (DO) levels. Because of the shortage of water supply and hot weather throughout the study period, the system could not maintain sufficient DO levels. Dissolved oxygen concentrations dropped sharply from saturation (above 7.8 mg/L) to below 4.0 mg/L within 2 hours after fish were introduced to each tank. Air pumps and water agitators were employed after the middle of May to help maintain DO levels. However, DO levels remained low and fluctuated daily from 4.8 to 7.6 mg/L, depending on water temperature.

The effect of low dosage of $LHRH_a$ was examined in two trials. First, a single injection of $LHRH_a$ at concentrations of 20-25, 2-3, and 0.2-0.3 μg/kg of fish weight was tested with saline water as a control. The treatment was considered effective if ovulation occurred within 48 hours of treatment. In the second trial, two injections of $LHRH_a$ were given. The first injection contained 4-5 μg/kg of $LHRH_a$ and the second (12 hours later) 10, 5, or 2 μg/kg of $LHRH_a$ with a saline-water control. If ovulation occurred within 36 hours of the second injection, the treatment was considered effective. All males received one injection of 4-5 μg/kg $LHRH_a$ when the females received their second injection.

To study egg development and monitor the critical time for stripping eggs, fish were injected twice with 4-5 μg/kg $LHRH_a$ in a 12-hour interval. Prior to each injection, a sample of eggs was taken from each fish by means of oviduct cannulation. Morphological characteristics of the eggs were examined microscopically, and egg size was measured to the nearest mm of diameter. After the second injection, an egg sample was collected periodically (every 1 to 3 hours) from each fish. Eggs were classified to different developmental stages based on size, coloration, opacity, cellular morphology, and shape. When ovulation was observed, eggs were stripped from the fish at times ranging from 0 to 7 hours post-ovulation. The initial ovulation stage was considered to have occurred when a few of the eggs were ovulated (ie. some had ovulated but most had not). Stripped eggs were fertilized immediately. Following hardening in water, unfertilized eggs were removed and counted to estimate percent fertilization. A regression analysis was performed on the post-injection ovulation times as a function of mean ambient water temperatures.

Results and Discussion

A single injection of $LHRH_a$ did not effectively induce ovulation (Table 1). Regardless of the amount of $LHRH_a$ used, ovulation could only be induced in those fish that contained large clear eggs prior to the treatment. However, all fish receiving two injections of $LHRH_a$ ovulated (Table 2). Ovulation was triggered with two injections of $LHRH_a$ at concentrations as low as 4-5 μg/kg for each injection. These dosages were much lower than those previously used (Backman et al. 1990). $LHRH_a$ not only induced ovulation but also induced vitellogenesis in American shad. $LHRH_a$ serves as secondary stimulating mechanism signalling the pituitary gland to release the hormones that are necessary for egg development, and only a small amount of $LHRH_a$ is enough to stimulate the pituitary to release hormones (Harvey and Hoar 1979).

Ten different developmental stages of eggs were observed (Table 3). During the development process the color of eggs changed from yellow-brown to transparent, but prior to ovulation eggs in those stages were always opaque and spherical in shape. Approximately 1 to 3 hours before ovulation, the germinal vesicle started migrating to the periphery of the animal pole (peripheral germinal vesicle or PGV). Ovulation then occurred within a short period of time after the PGV stage. After ovulation eggs became soft and irregular in shape. A space between the yolk and chorion was observed. In early stages of ovulated eggs, the yolk membrane has a short single cleavage, but more cleavages are formed subsequently.

It was difficult to know the precise time of ovulation in an individual American shad, since ovarian development varied among the treated fish. The period between injection and ovulation was negatively correlated with ambient water temperature ($P < 0.0001$, $R^2 = 0.6337$, Figure 1). Most females had spawned at least once before delivery to the experiment station because of unusually high water temperatures during the 1991 spawning season. Eggs in the majority of the females were medium sized (stage 2). Females that had not spawned prior to the experiment usually had large eggs ranging from stage 3 to 7. Few females contained eggs that were earlier than stage 2. After treatment, those fish containing eggs in developmental stage 5 or later ovulated within a short period of time, and some ovulated before they received the second treatment. Females containing medium eggs (stage 2) ovulated at similar time to that of females containing large brown eggs (stage 2 or 3).

Initial ovulation was observed in only seven females (Table 4). Eggs were stripped from these females at different times after the initial ovulation occurred. During the initial ovulation stages, only a few ovulated eggs can be stripped from the fish, as most eggs in the ovaries have not yet ovulated. The completion of the ovulation process requires some period of time. Bayless (1972) assumed that one-half hour was needed for ovulation in striped bass to assure completion of the process after initial ovulation. In American shad eggs, a small and shallow cleavage can be seen at the yolk membrane immediately after ovulation. These eggs usually could not be fertilized and would not fully undergo water hardening; however, their color remained transparent for several hours. A small number of these eggs can be found among those stripped from each fish. These eggs were among the last eggs to be stripped from the fish. To avoid contamination of the most viable eggs by these underripe eggs, stripping was done in a very gentle manner to increase the likelihood that ripe eggs were exuded. A high percentage of viable eggs were obtained by stripping between 1.5 to 3.0 hours after initial ovulation. Approximately 38,000-50,000 eggs were produced from each treated fish with 80% viability. Five hours after initial ovulation, females released (or spawned) eggs in the tank, but no equivalent male behavior was observed. The eggs collected from the bottom of the tank were not fertilized.

Recommendations

Among hormones tested during 3 years of study, $LHRH_a$ is recommended because of its demonstrated effectiveness in spawning induction and subsequent egg viability. Fish should be treated twice about 12 hours apart at 4-5 μg/kg of fish weight. Because American shad are sensitive to stress by handling, high mortality is expected during the process of treatment. Research on reducing mortality during treatment should be included in any future study. A large number of mature female fish are required for mass production of viable eggs because treated females only produce an average of 42,000 eggs with 80% viability.

Acknowledgments

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Table 1. Induced ovulation by one $LHRH_a$ treatment.

Dosage (µg/kg)	No. of injected fish	No. of fish surviving	No. of fish ovulating	% of fish ovulating
20.0-25.0	7	5	2	40
2.0-3.0	7	2	1	50
0.2-0.3	7	6	1	16
Saline water	5	3	1	33

Table 2. Induced ovulation by two injections of $LHRH_a$.

Dosage (μg/kg) 1st	Dosage (μg/kg) 2nd	No. of injected fish	No. of fish surviving	No. of fish ovulating	% of fish ovulating
4-5	20-25	5	3	3	100
4-5	10-12	5	3	3	100
4-5	4-5	5	4	4	100
Saline water		5	4	1	25

Table 3. The development of eggs based on size, color, and other characteristics (PGV = peripheral germinal vesicle).

Stage	Diameter (mm)	Color	Other characteristics
1	≤ 1.2	yellow-brown	opaque, spherical
2	1.3-1.5	yellow-brown	opaque, spherical
3	1.5-1.7	yellow-brown	opaque, spherical
4	1.5-1.7	semi-transparent	spherical
5	≥ 1.7	transparent	spherical
6	≥ 1.7	transparent	PGV apparent
7	1.7-2.1	transparent	follicular breakdown
8	2.1-2.3	transparent	ovulated eggs, soft, single fold
9	2.1-2.3	transparent	soft, multiple folds
10	2.2-3.1	transparent-white	degenerated

Table 4. Percent viable eggs stripped from fish at different delay times after initial ovulation.

Date of test	Delay time (hours)	No. of eggs stripped	No. of viable eggs	% viable eggs
05-10	0	0	0	0
05-26	1.5	37,600	26,200	70
05-26	2.0	49,600	39,700	80
05-26	2.1	34,000	27,000	79
05-22	3.0	48,000	37,900	79
05-10	5.0	0	0	0
05-10	7.0	0	0	0

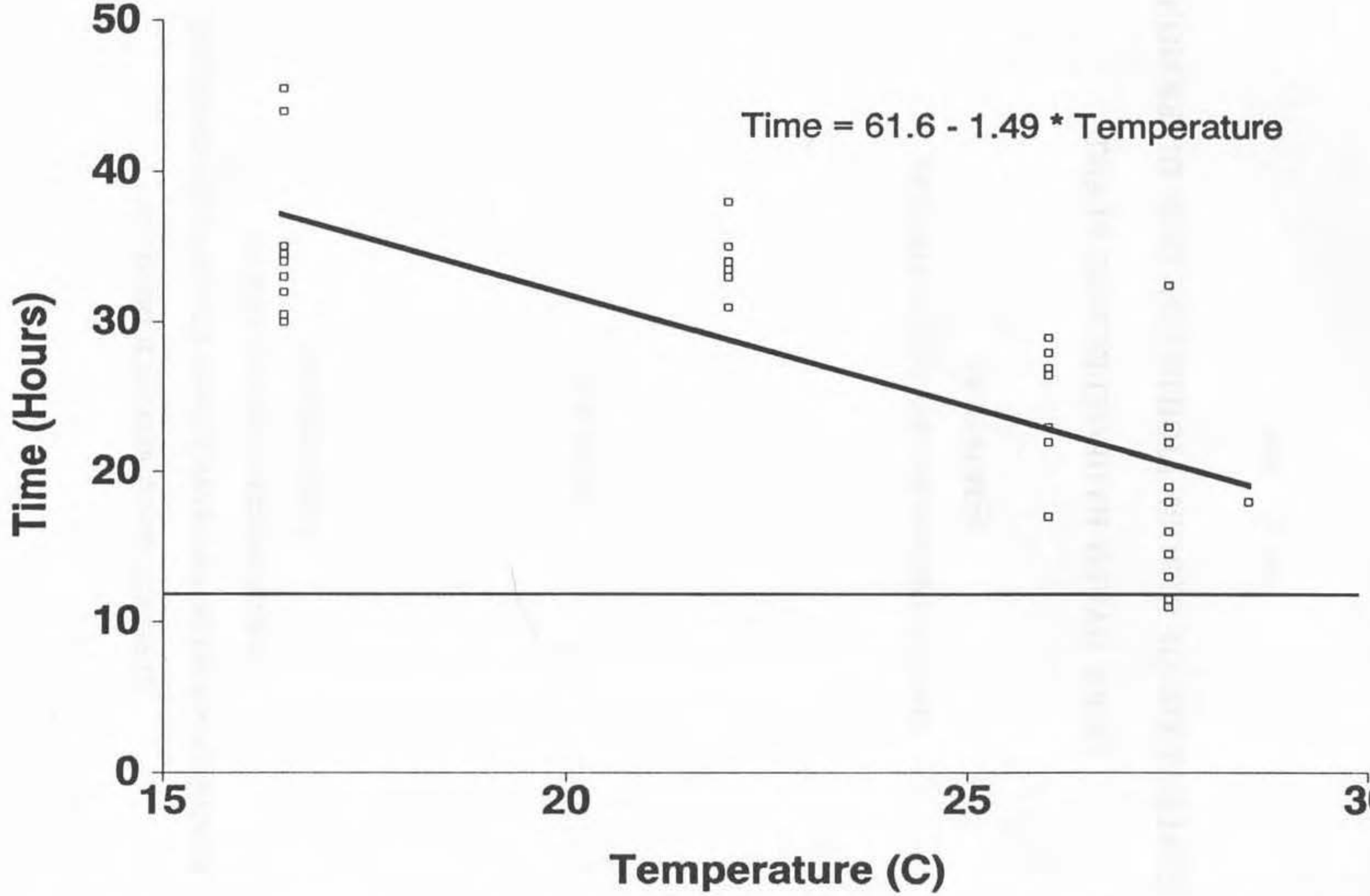


Figure 1. Relationship of the estimated time from first injection to initial ovulation as a function of mean water temperature (°C). (Horizontal line at 12 hours indicates time of second injection.)

JOB V. TASK 2

EVALUATION OF STROBE LIGHTS FOR FISH DIVERSION

YORK HAVEN HYDROELECTRIC PLANT

PREPARED BY

STONE & WEBSTER ENVIRONMENTAL SERVICES

January 1992

PREPARED FOR

METROPOLITAN EDISON COMPANY

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

ELECTRIC POWER RESEARCH INSTITUTE

SUMMARY OF STUDY RESULTS
EVALUATION OF STROBE LIGHTS FOR FISH DIVERSION
YORK HAVEN HYDROELECTRIC PLANT

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 and 1990 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 of each year and was fully operational when the shad began to arrive in early October. Unfortunately, heavy rains in both years caused the fish to pass over the dam early in the study, thereby severely limiting the ability to evaluate the strobe system. However, optimal conditions for testing occurred in 1991 and the full study program was successfully completed, as described below.

PURPOSE

The purpose of the 1991 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. Visual and sonar observations of fish response to the lights in 1988 and 1989 indicated that they formed a tight school and passed quickly through the sluiceway when the lights were turned on. However, it was not possible to determine whether some of the fish were being frightened through the trash racks when the strobes were activated. In order to evaluate passage through the trash racks, a trammel net was fished at several depths and locations in front of the trash racks at Unit 1 during the 1990 tests. Although only small numbers of fish were caught in the trammel net in 1990, there was some concern that this may have been at least partially due to net avoidance. In 1991, in order to provide a more definitive estimate of trashrack and turbine passage, a net was deployed at the tailrace of Unit 1. A similar net was also deployed in the sluiceway to quantify sluice passage rates.

MATERIALS AND METHODS

Description of Strobe Light System

The strobe light test system is shown on Figure 1. The system consisted of five, interconnected floats which were anchored immediately upstream of Units 1 through 5. A separate float supporting four strobe lights was positioned upstream of Unit 1 and was capable of being moved to different locations. All of the floats were constructed of wood and foam ballast. The strobe lights were deployed on metal poles which were suspended from the downstream side of the floats. Each pole supported two lights; the lights were located 3 ft and 9 ft, respectively, below the water surface. The poles were spaced at 12 ft intervals. When deployed, the light flashheads on floats 3 through 5 were pointed in an upstream direction. The spacing was selected based on the beam spread of the lights and was designed to create a continuous "wall" of light across Units 2 through 5.

The floats closest to Unit 1 (floats 1 and 2) were oriented differently. These floats supported strobe lights that were angled to flash toward the sluiceway gate. In addition, a separate, moveable float supporting a single pole with two lights was located between float 1 and the powerhouse cableway. An additional float (float 6) was located upstream of Unit 1, as shown in Figure 1. This float contained four strobe lights on two poles that were configured as described above for the upstream lights. The purpose of this float was to determine whether upstream movement of shad upon strobe activation witnessed in previous years could be prevented by placing lights in the path of upstream movement.

The strobe light system was configured as two arrays: the lights on floats 3 through 5 were operated together and were sequenced by one controller; the lights on floats 1 and 2 and the moveable floats operated together on a different controller. The design concept allowed the strobes in front of Units 2 through 5 to operate continuously such that shad were repelled from this area and moved downstream to the area in front of Unit 1 near the sluiceway gate. This area was kept dark most of the time to allow fish to accumulate. On a periodic basis, the sluiceway gate was opened and the strobes on floats 1 and 2 and the moveable floats were activated to repel fish through the sluiceway.

A problem which had been encountered in past studies with the EG&G strobe lights was 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 float and evaluated for its reliability. All of the other floats were equipped with the light units used in previous years. While the four-light unit was separate from the other lights, the strobes were synchronized to flash at the same time as the existing lights.

In addition to the strobe light system, limited tests were conducted to obtain a preliminary indication of whether an underwater mercury light might act to attract fish to the sluicegate. A single, 250-watt Remote Ocean Systems Omni-250 mercury light was evaluated.

Scanning Sonar

As in the 1989 and 1990 studies, 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 were 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.

During a portion of the 1991 study, one of the sonar units was deployed on a small float and moved around the forebay area to view the behavior of fish of fish from different aspects. In addition, an American Pioneer Dualscan I Sonar System was used on a trial basis for two nights to determine its capabilities for tracking fish location and movement.

<u>Netting</u>

In 1991, nets were used to collect fish that passed through the trash racks and turbine 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. Attempts were not made in 1988 and 1989 to quantify the degree to which turbine passage was occurring. In 1990, a moveable trammel net was fabricated and placed at different locations in front of the trash racks to collect fish. Results indicated that fish were not passing through the trash racks. However, since the fish were not in an active migration mode during the limited test period, the results were not conclusive.

In 1991, it was decided that the most effective method for quantifying turbine and sluiceway passage of fish was to utilize sampling nets at each location. As shown on Figure 2, the sluiceway net was installed immediately downstream of the sluiceway gate discharge. As shown on Figure 3, the tailrace net and support frame were supported from parallel steel cables anchored to the powerhouse wall and the bottom of the Unit 1 discharge. Both sample nets had a one meter square opening, measured 4 meters long and were fabricated with 1/4-inch mesh.

The sluiceway net was initially positioned such that it sampled the full depth of the water column passing through the sluiceway. With the one meter wide net, approximately 30 percent of the flow passed through the net. In the first few tests, thousands of fish were collected. In order to reduce the number of fish injured or killed in subsequent tests, the width of the mouth of the net was reduced to 4 inches. With this aperture, the net sampled approximately 2.7 percent of the sluiceway flow. With the much smaller numbers of fish collected with the new net configuration, injury was reduced such that nearly all of the fish that were collected could be released alive.

The tailrace net was positioned near the centerline of the Unit 1 draft tube exit with the top of the frame just below the water surface. The tailrace net was fished with the full square meter opening. Assuming a uniform flow distribution, approximately five percent of the Unit 1 discharge passed through the net.

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 propeller 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.

SAMPLING DESIGN

Following an initial shakedown period of several days, testing within each sample day consisted of running sequential control and test conditions (each for a one hour period) from approximately dusk to dawn throughout most of the outmigration period. The test sequence was comprised of a control test in which the sluice gate was open without use of strobes, a strobe test in which the sluice gate was opened and the strobes were activated, and a tailrace netting period used to assess ambient levels of turbine passage at Unit 1. Control tests were performed prior to the strobe tests so that each could be performed with a large number of fish in the vicinity of the sluiceway (it often took some time for fish to move back into the test area after a strobe test was performed). The upstream strobe lights (floats 3-5) were operated continuously over the entire testing period each night to reduce turbine passage at these units and enhance aggregation of fish in the area of the sluice.

The following sequence of tests was repeated from six to eight times on most nights:

- CONTROL: Sluice gate open for two minutes (downstream strobes off); sluice and tailrace nets retrieved at end of test.

- STROBE: Sluice gate open for one minute before strobes are turned on; strobe lights then illuminated for one minute; strobes off and sluice gate closed; this timing resulted in the sluice gate being opened for a total of two minutes; sluice and tailrace nets retrieved at end of test.

- LONG-TERM TAILRACE NETTING: Sluice gate left closed and downstream strobes (floats 1, 2 and 6) left off; tailrace net fished for one hour before retrieval.

Tests were conducted at a strobe flash rate of 300 flashes per minute. For each test, the downstream sonar unit was set to scan a 50 foot radius (acoustic axis offset angle set between 0 and +2°) which included the test area near the sluice gate, the trashracks, and the area in front of the upstream strobe light support floats (up to Unit 5). Shad collected in the nets were counted and returned to the river below the dam. Some specimens were retained and transferred to the Pennsylvania Fish Commission for otolith analysis.

1991 RESULTS

The scanning sonar units were deployed in early September to monitor the forebay area for fish occurrence. Hydroacoustic data was recorded by the time lapse recorders. The data obtained was reviewed daily to determine whether sufficient numbers of shad had arrived at the site to begin strobe light testing. Based on these data, it was decided that the biological field evaluation would begin the night of September 29.

Over the 29 day sampling period, which ended on October 27, 155 strobe light tests were conducted. Results for American shad are presented in Table 1. During the first two nights of testing, the meter net in the sluiceway was sampled in a fully opened position. This arrangement resulted in the capture of thousands of fish, many of which were injured or killed. To minimize the number of fish injured, the net opening was reduced to a width of 4 inches in all subsequent tests. This reduced the number of fish sampled by approximately 90% and resulted in fewer injuries to the fish that were collected. The tailrace and sluice gate nets were used in most tests.

As observed in 1988, large masses of fish moved downstream through the gate when the downstream strobe lights were activated. The strobe lights were highly effective in moving fish out of the lighted area. Scanning sonar observations indicated that the predominant movement of shad was downstream. The average adjusted numbers of American shad passing through the sluice gate and the Unit 1 tailrace under strobe light test and control conditions (based on the numbers presented in Table 1) are summarized below:

	Control	Strobe
Sluicegate Net	49.05	1684.3
Tailrace Net	4.54	107.4

Thus, the strobe lights effectively moved nearly all of the shad through the sluicegate, assuming no fish passed through upstream Units 2 through 5 which were equipped with strobe lights. This assumption appears valid since the upstream strobe lights were operating at all times and shad were not observed on the sonar passing through these upstream units. The data further demonstrate that, not only are the strobe lights effective in pulsing fish through the sluicegate, but that few fish would have passed through the gate over the same period of time without the lights.

Figure 4 shows the cumulative number of fish that passed through the sluiceway and the Unit 1 tailrace over the 27 days of testing. Periods of no fish passage appear as horizontal sections of the figure while periods of abundant fish passage appear as steeply sloped sections of the figure. The figure clearly indicates the overwhelming number of shad that passed out the sluiceway as opposed to through Unit 1 (note y-axis scales). Furthermore, comparison of the control to the strobe tests for the sluice reveals the necessity for strobes lights (as opposed to just opening the gate) in order to bypass the shad. Figure 5 shows the average number of fish that passed out the sluiceway and tailrace during different times of the night. Revealed in the figure is a trend of little fish passage prior to sunset, maximum fish passage during early night and a gradual tapering off toward morning. Peak shad passage occurred at 20:00 hours (8 pm). Figure 6 shows the ambient or inter-test periods of tailrace netting when only the upstream strobe lights were turned on. During these periods, it is evident that passage through Unit 1 is minimal (average of about 2 shad per hour unadjusted for the entire flow volume, or 50 per/hour adjusted). Comparison of the graphs at the bottom of the page on Figures 4 and 6 reveals a similar trend over time for tailrace netted shad between strobe tests and ambient netting. Perhaps the increase in tailrace netted fish during strobe tests is an artifact of the naturally increasing numbers of shad passing downstream during the outmigration.

A final review and analysis of the data has not been completed. However, the review to date demonstrates that the strobe lights create a strong and repeatable avoidance response in juvenile shad and that, under the conditions existing at York Haven, they effectively repel fish through the sluiceway with only a small proportion of the fish passing through the turbine. Further, the avoidance response to the strobe lights lasts as long as the lights are activated; there is no evidence of acclimation to the light even after many hours of operation.

Since water leakage problems were resolved via the use of heavy-duty seals in 1990, the strobe light system has functioned in a very reliable manner with only minor equipment malfunction.

The brief series of tests conducted with the mercury light indicated that American shad were not strongly attracted to this light source. These results are consistent with those obtained in 1988 with a 1000-watt mercury light. On the other hand, gizzard shad which occured at the site in large numbers for about one week of the study period were very strongly attracted to the mercury light. This species could actually be led to the bypass by slowly moving the light from an upstream location toward the sluicegate. Further, when the sluicegate was opened, the gizzard shad passed rapidly through the opening without the strobe lights activated. Also, the gizzard shad did not appear to be as strongly repelled by the strobe lights as the American shad. Therefore, these two morphometrically similar species appear to respond very differently to the same types of light stimuli. This observation could be significant relative to the potential effect of lights on other similar species at other sites.

Holtwood implications

TABLE 1

DATE	TIME	TEST NO.	SLUICEGATE NET				TAILRACE NET			
			CONTROL		STROBE		CONTROL		STROBE	
			ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED
9/29	2000	1	*	*	800	2667	*	*	*	*
	2200	2	*	*	2700	9000	*	*	*	*
9/30	2000	3	3	10	3300	11000	0	0	11	275
	2200	4	59	196	2100	7000	1	25	4	100
10/1	2000	5	2	72	290	10440	0	0	12	300
slu. shut	2100	6	*	*	*	*	*	*	11	275
	2200	7	0	0	162	5832	0	0	9	225
10/2	0000	8	1	36	174	6264	0	0	2	50
	0200	9	1	36	117	4212	0	0	1	25
	0400	10	0	0	2	72	0	0	0	0
	0500	11	1	36	0	0	0	0	0	0
	2000	12	0	0	21	756	0	0	20	500
	2100	13	0	0	49	1764	0	0	0	0
	2300	14	1	36	72	2592	0	0	0	0
10/3	0100	15	0	0	15	540	0	0	2	50
	0200	16	1	36	1	36	0	0	0	0
	0400	17	0	0	4	144	0	0	0	0
net open	0600	18	*	*	*	*	*	*	*	*
	2000	19	0	0	4	144	0	0	2	50
	2200	20	0	0	41	1476	0	0	0	0
10/4	0000	21	0	0	1	36	0	0	0	0
	0100	22	0	0	0	0	0	0	0	0
	0300	23	0	0	0	0	0	0	0	0
	0500	24	0	0	0	0	0	0	0	0
	2000	25	0	0	4	144	0	0	0	0
	2100	26	0	0	16	576	0	0	2	50
	2300	27	0	0	4	144	0	0	2	50
10/5	0100	28	0	0	0	0	0	0	0	0
	0200	29	0	0	0	0	0	0	0	0
	0500	30	0	0	0	0	0	0	0	0
	1900	31	0	0	0	0	0	0	0	0
	2100	32	0	0	0	0	0	0	1	25
	2200	33	0	0	0	0	0	0	2	50
10/6notrn	0000	34	0	0	6	216	*	*	*	*
no trn	0100	35	0	0	28	936	*	*	*	*
no trn	0200	36	0	0	0	0	*	*	*	*
no trn	0300	37	0	0	0	0	*	*	*	*
no trn	0400	38	0	0	0	0	*	*	*	*
no trn	0500	39	0	0	0	0	*	*	*	*
no trn	0600	40	0	0	2	72	*	*	*	*
	1900	41	0	0	15	540	0	0	7	175
	2100	42	0	0	3	108	0	0	1	25
	2300	43	0	0	34	1224	0	0	3	75
10/7	0000	44	0	0	40	1440	1	25	5	125
*1	0100	45	0	0	19	684	0	0	2	50
	0300	46	0	0	18	648	0	0	1	25
	0400	47	0	0	8	288	0	0	2	50
	0600	48	0	0	0	0	0	0	0	0
	1900	49	0	0	128	4608	0	0	1	25
	2100	50	7	252	97	3492	0	0	0	0
	2200	51	0	0	148	5328	0	0	1	25
10/8	0000	52	0	0	65	2340	0	0	9	225
	0100	53	0	0	43	1548	0	0	3	75
	0300	54	0	0	39	1404	0	0	2	50
	0400	55	0	0	15	540	0	0	1	25
	0500	56	0	0	1	36	0	0	0	0
	1900	57	1	36	158	5688	0	0	12	300
	2100	58	0	0	65	2340	0	0	3	75
	2200	59	0	0	105	3780	1	25	3	75
10/9	0000	60	1	36	145	5220	0	0	4	100

TABLE 1 (cont.)

			SLUICEGATE NET				TAILRACE NET			
			CONTROL		STROBE		CONTROL		STROBE	
DATE	TIME	TEST NO.	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED
	0100	61	0	0	52	1872	0	0	1	25
	0300	62	0	0	5	180	0	0	1	25
	0400	63	0	0	0	0	0	0	0	0
	0500	64	0	0	0	0	0	0	0	0
*2	2000	65	0	0	89	3204	1	25	26	650
merc lite	2200	66	0	0	10	360	0	0	24	600
merc lite	2300	67	54	1944	104	3744	4	100	18	450
10/10	0100	68	57	2052	46	1656	no ctrl net	*	13	325
merc lite	0300	69	7	252	21	756	1	25	15	375
	0400	70	2	72	18	648	0	0	7	175
merc lite	0600	71	0	0	41	1476	0	0	2	50
*3	2000	72	3	108	26	936	4	100	44	1100
merc lite	2100	73	15	540	67	2412	2	50	13	325
	2300	74	6	216	19	684	0	0	11	275
10/11mlte	0100	75	12	432	68	2448	1	25	2	50
	0200	76	0	0	52	1872	0	0	2	50
merc lite	0400	77	0	0	8	288	0	0	3	75
merc lite	0500	78	0	0	4	144	0	0	2	50
10/12 *4	2000	79	5	180	174	6264	0	0	10	250
	2100	80	0	0	50	1800	0	0	2	50
	2200	81	0	0	40	1440	0	0	0	0
10/13	0000	82	0	0	15	540	0	0	0	0
	0200	83	1	36	0	0	0	0	0	0
	0300	84	0	0	0	0	0	0	0	0
	2000	85	0	0	171	6156	0	0	18	450
	2100	86	1	36	72	2592	0	0	4	100
*5	2200	87	0	0	128	4608	0	0	11	275
10/14	0000	88	0	0	155	5580	0	0	4	100
	0100	89	0	0	125	4500	0	0	8	200
	0200	90	0	0	0	0	0	0	0	0
	0400	91	0	0	17	612	1	25	0	0
	2000	93	0	0	146	5256	0	0	17	425
	2100	94	0	0	104	3744	0	0	8	200
	2200	95	0	0	40	1440	0	0	4	100
10/15	0100	97	0	0	5	180	0	0	0	0
	0200	98	0	0	1	36	0	0	1	25
	0300	99	0	0	1	36	0	0	0	0
	0400	100	0	0	2	72	0	0	3	75
	1900	103	0	0	37	1332	0	0	10	250
merc lite	2100	104	0	0	91	3276	0	0	1	25
10/16	0000	105	0	0	131	4716	0	0	10	250
merc lite	0200	106	0	0	47	1692	1	25	5	125
	0300	107	0	0	13	468	0	0	19	475
	2000	108	1	36	67	2412	1	25	20	500
	2100	109	0	0	90	3240	0	0	13	325
	2200	110	0	0	251	9036	0	0	12	300
10/17	0000	111	0	0	28	1008	0	0	3	75
	0100	112	0	0	0	0	0	0	3	75
	0300	113	0	0	1	36	0	0	0	0
	0400	114	0	0	1	36	0	0	0	0
	2000	115	7	252	139	5004	1	25	18	450
	2100	116	0	0	340	12240	1	25	11	275
	2300	117	1	36	201	7236	0	0	11	275
10/18	0100	118	0	0	96	3456	0	0	2	50
	0200	119	2	72	90	3240	0	0	10	250
	0400	120	0	0	49	1764	1	25	4	100
	2000	121	0	0	118	4248	0	0	26	650
	2200	122	0	0	95	3420	1	25	13	325
	2300	123	0	0	79	2844	0	0	5	125
10/19	0100	124	0	0	149	5364	0	0	3	75

TABLE 1 (cont.)

			SLUICEGATE NET				TAILRACE NET			
			CONTROL		STROBE		CONTROL		STROBE	
DATE	TIME	TEST NO.	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED	ACTUAL	ADJUSTED
	0200	125	5	180	53	1908	0	0	5	125
	0400	126	0	0	sluicenet open		0	0	1	25
	0600	127	0	0	63	2268	0	0	1	25
	0700	128	0	0	1	36	0	0	1	25
10/23	2000	179	0	0	54	1944	0	0	3	75
	2100	180	1	36	6	216	3	75	0	0
	2200	181	1	36	3	108	0	0	0	0
10/24	2330	182	0	0	0	0	0	0	1	25
	0000	183	2	72	0	0	0	0	0	0
	0200	184	0	0	0	0	0	0	0	0
	0330	185	0	0	0	0	0	0	0	0
	0500	186	0	0	1	36	0	0	0	0
	0600	187	0	0	0	0	0	0	0	0
	1900	188	1	36	2	72	0	0	1	25
	2100	189	0	0	0	0	0	0	0	0
	2200	190	0	0	1	36	0	0	0	0
	2300	191	0	0	0	0	0	0	0	0
10/25	0100	192	0	0	0	0	0	0	0	0
	0200	193	0	0	0	0	0	0	0	0
	0300	194	0	0	0	0	0	0	0	0
	0500	195	0	0	0	0	0	0	0	0
no cntrl	0600	196	*	*	0	0	*	*	0	0
	1900	197	0	0	0	0	0	0	0	0
merc lite	2000	198	0	0	4	144	0	0	0	0
merc lite	2100	199	0	0	0	0	0	0	0	0
10/26mlte	0000	200	0	0	0	0	0	0	0	0
merc lite	0030	201	0	0	0	0	0	0	0	0
merc lite	1900	202	0	0	0	0	0	0	0	0
merc lite	2100	203	0	0	0	0	0	0	0	0
	2200	204	0	0	0	0	0	0	0	0
	2300	205	0	0	0	0	0	0	0	0
10/27	1800	206	0	0	0	0	0	0	0	0
	1900	207	0	0	0	0	0	0	0	0
merc lite	2000	208	0	0	0	0	0	0	0	0
merc lite	2100	209	0	0	0	0	0	0	0	0
merc lite	2300	210	0	0	0	0	0	0	0	0
			262	7406	15236	257691	26	650	627	15675

notes:
*1 float #6 moved 6 ft closer to sluicegate
*2 mini strobe float moved between transducer and trashracks
*3 float #6 moved another 6 ft closer to sluicegate, mini strobe float strung between float #1 and #6
*4 mini strobe float moved to trash rack, strobe inoperative
*5 float #6 moved 10 ft off cableway wall and 5 ft closer to sluicegate

note: ambient tailrace netting tests not included in this table

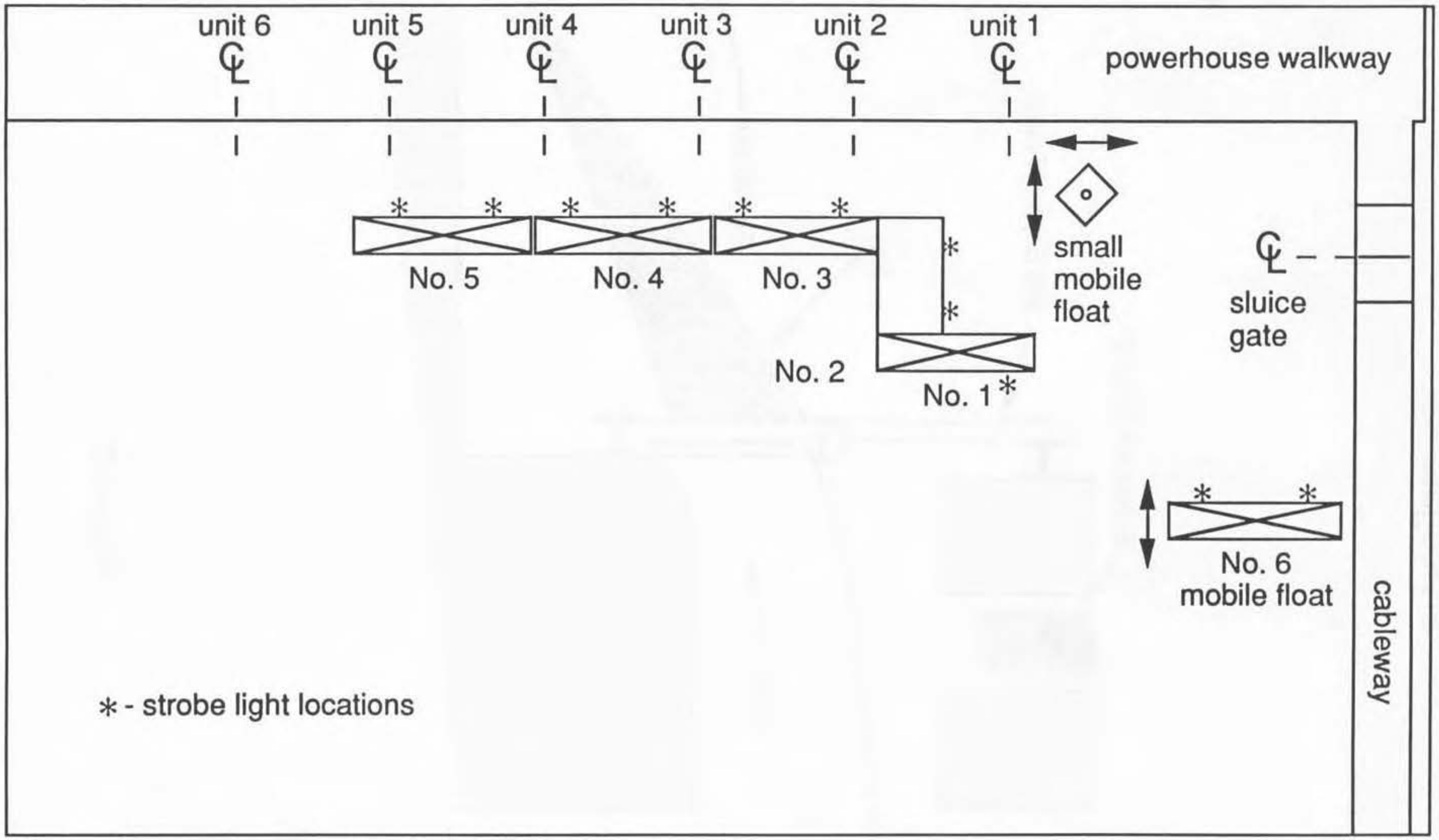


FIGURE 1
Strobe Light Float System
General Location Plan

Sluicegate Net

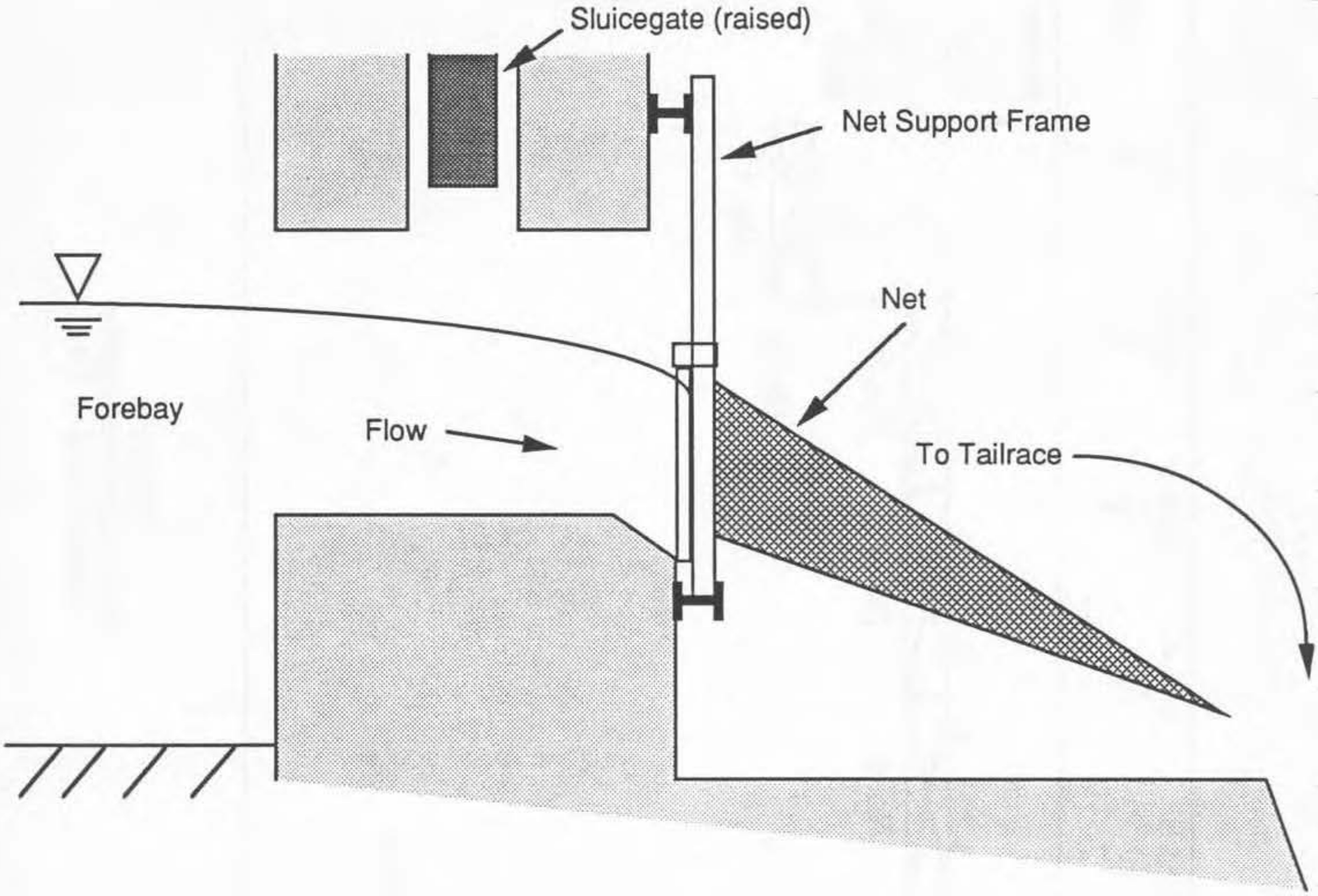


Figure 2

Tailrace Sampling Net 1991 York Haven Strobe Light Study

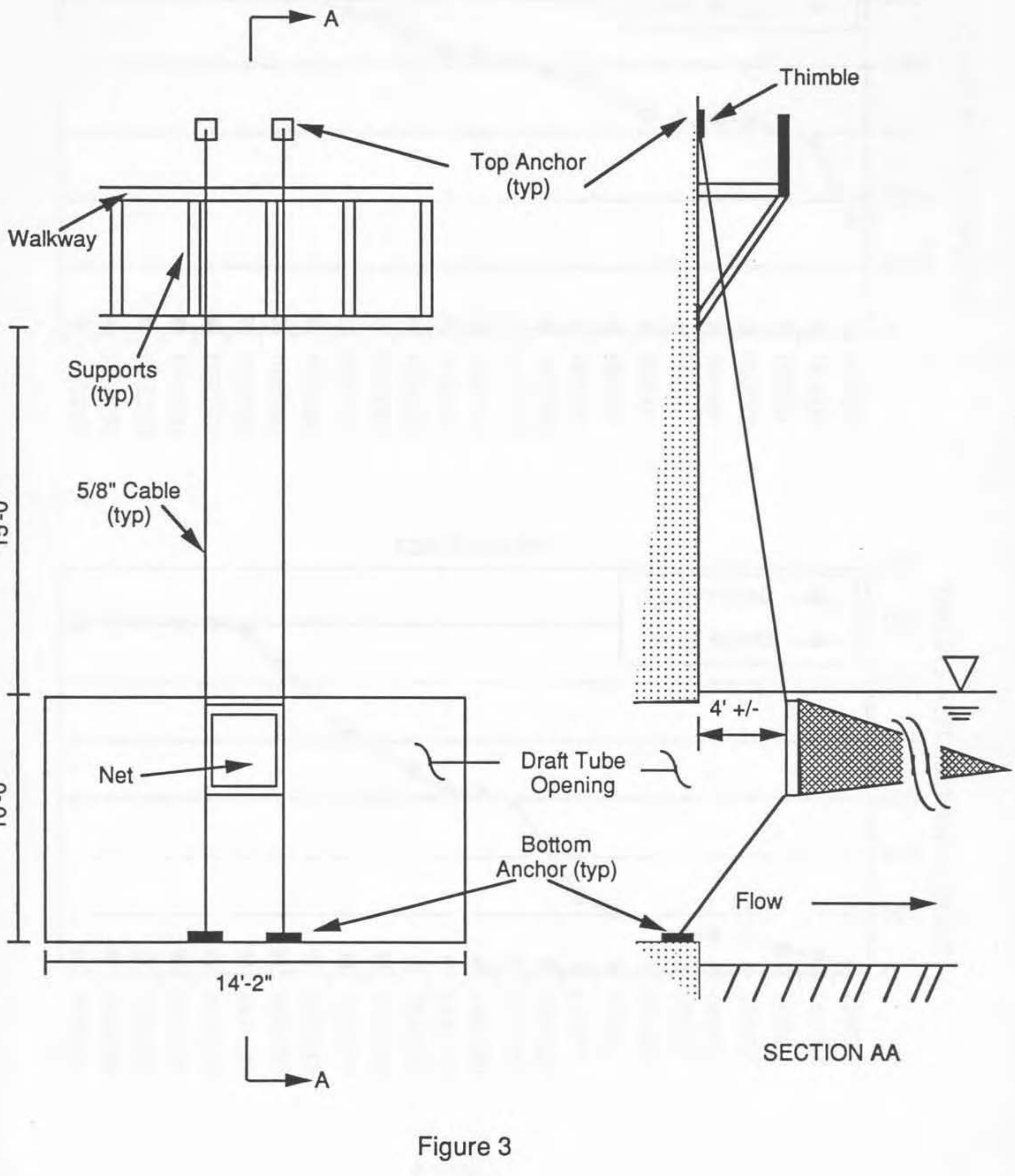
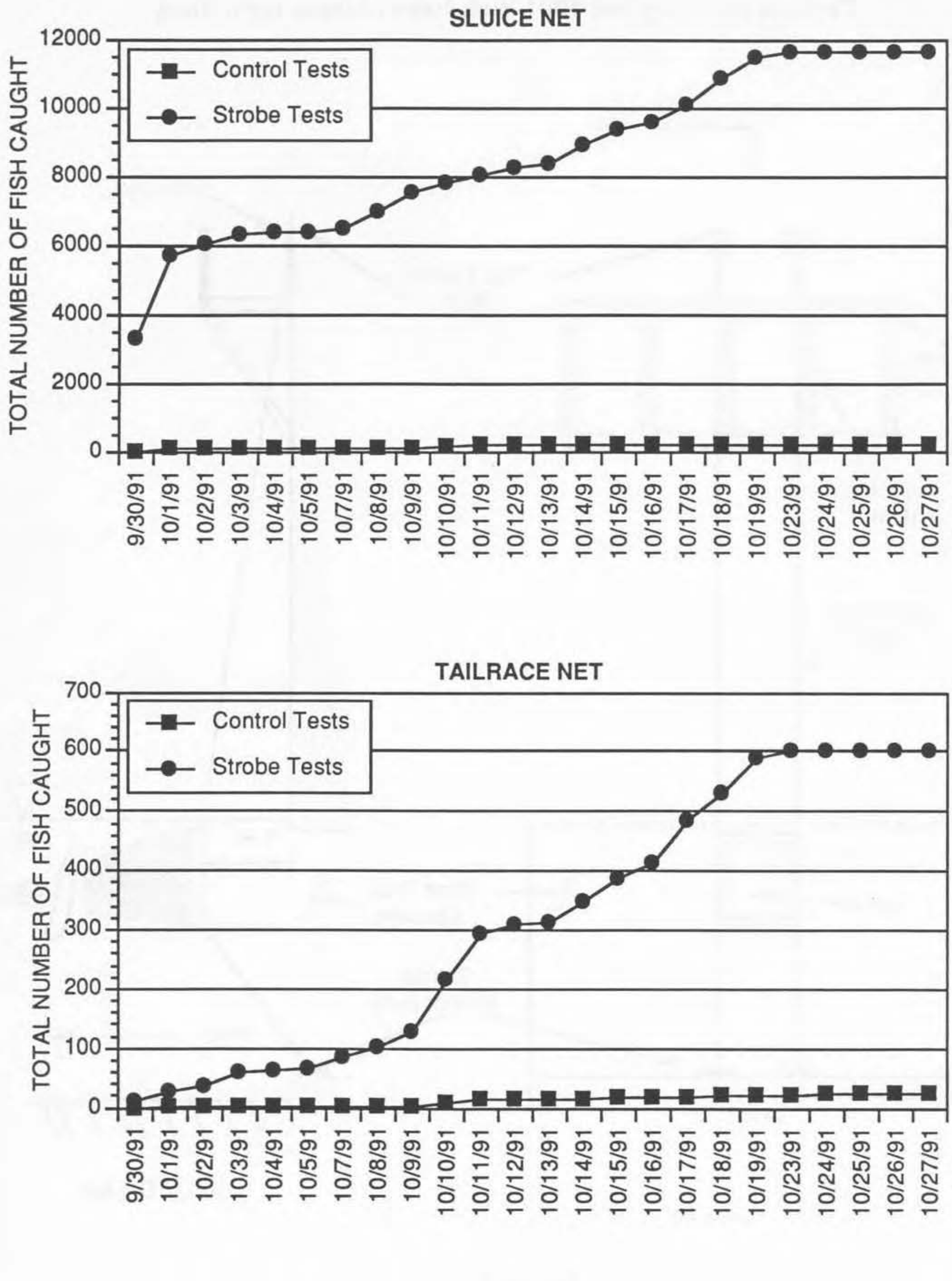


Figure 3


SLUICE NET
TOTAL NUMBER OF FISH CAUGHT
12000
10000
8000
6000
4000
2000
0
Control Tests
Strobe Tests
9/30/91
10/1/91
10/2/91
10/3/91
10/4/91
10/5/91
10/7/91
10/8/91
10/9/91
10/10/91
10/11/91
10/12/91
10/13/91
10/14/91
10/15/91
10/16/91
10/17/91
10/18/91
10/19/91
10/23/91
10/24/91
10/25/91
10/26/91
10/27/91
TAILRACE NET
TOTAL NUMBER OF FISH CAUGHT
700
600
500
400
300
200
100
0
Control Tests
Strobe Tests
9/30/91
10/1/91
10/2/91
10/3/91
10/4/91
10/5/91
10/7/91
10/8/91
10/9/91
10/10/91
10/11/91
10/12/91
10/13/91
10/14/91
10/15/91
10/16/91
10/17/91
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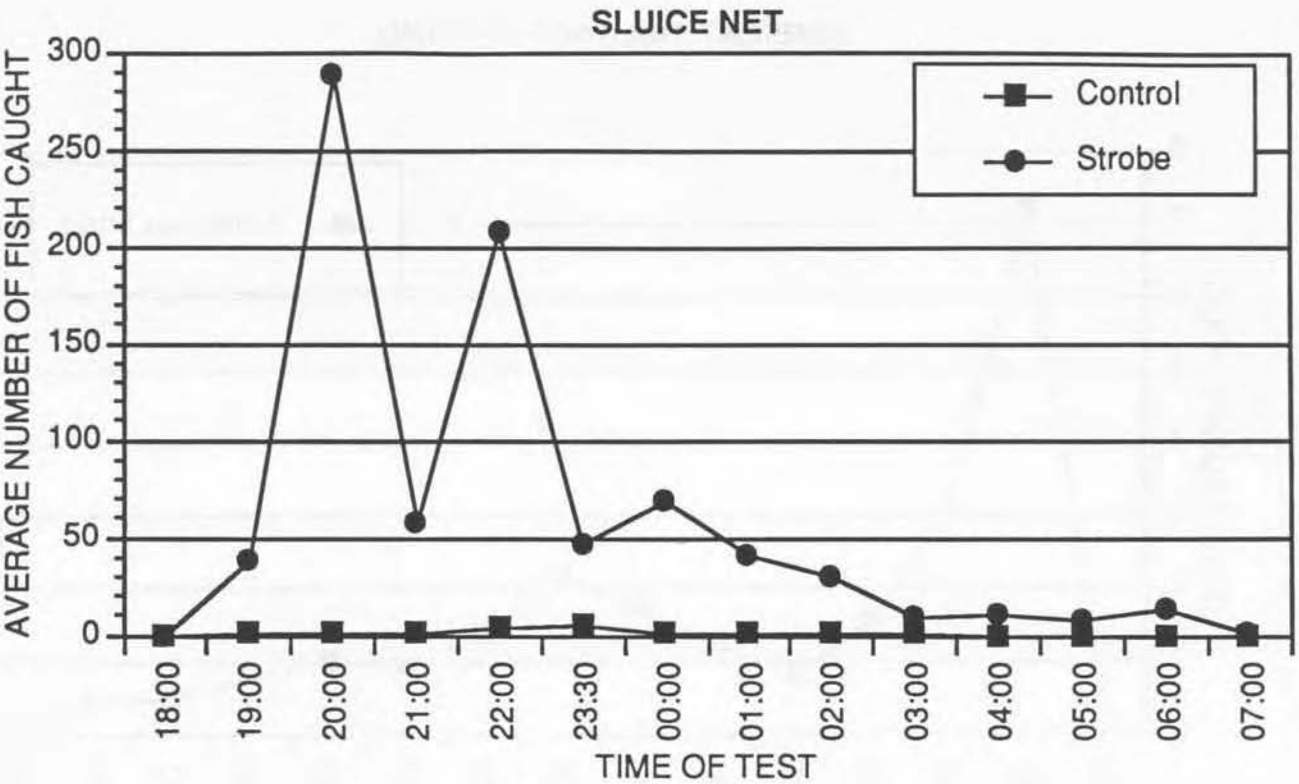
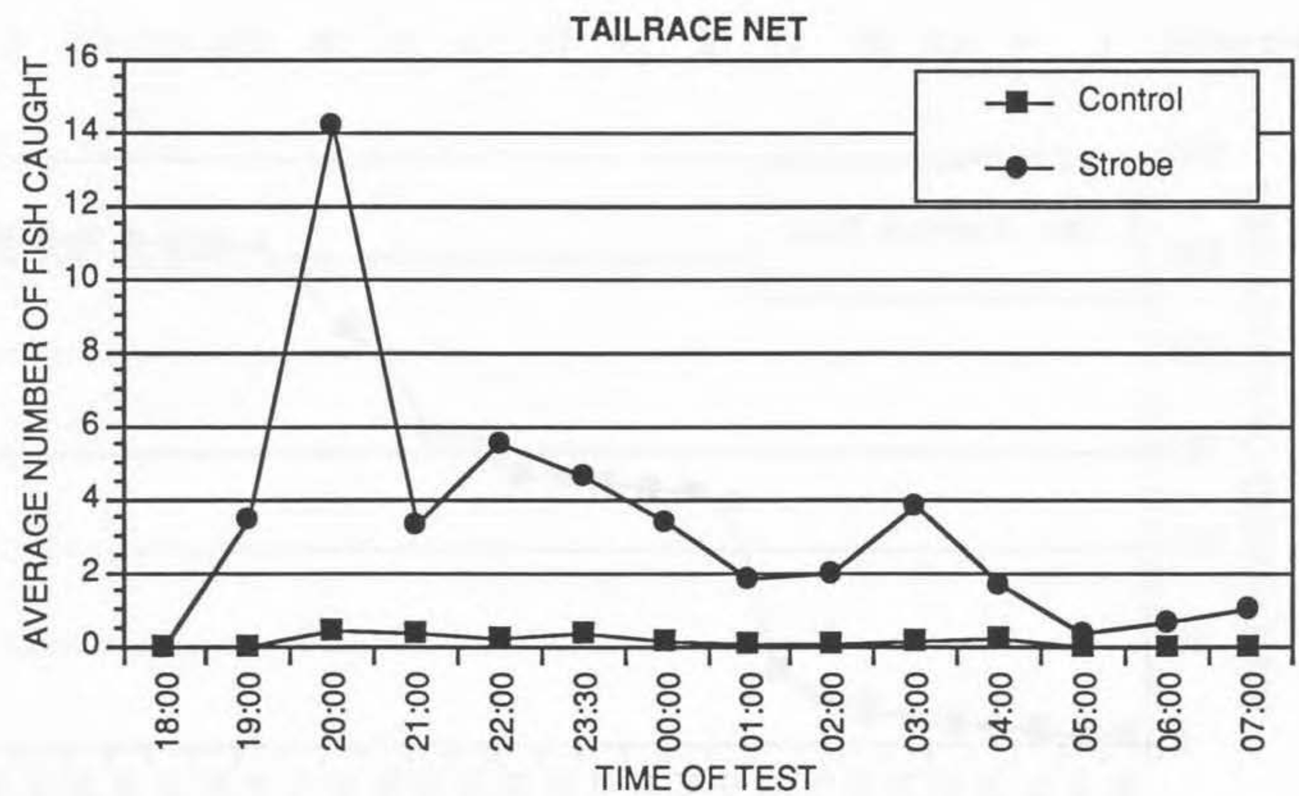
10/23/91
10/24/91
10/25/91
10/26/91
10/27/91

Figure 4



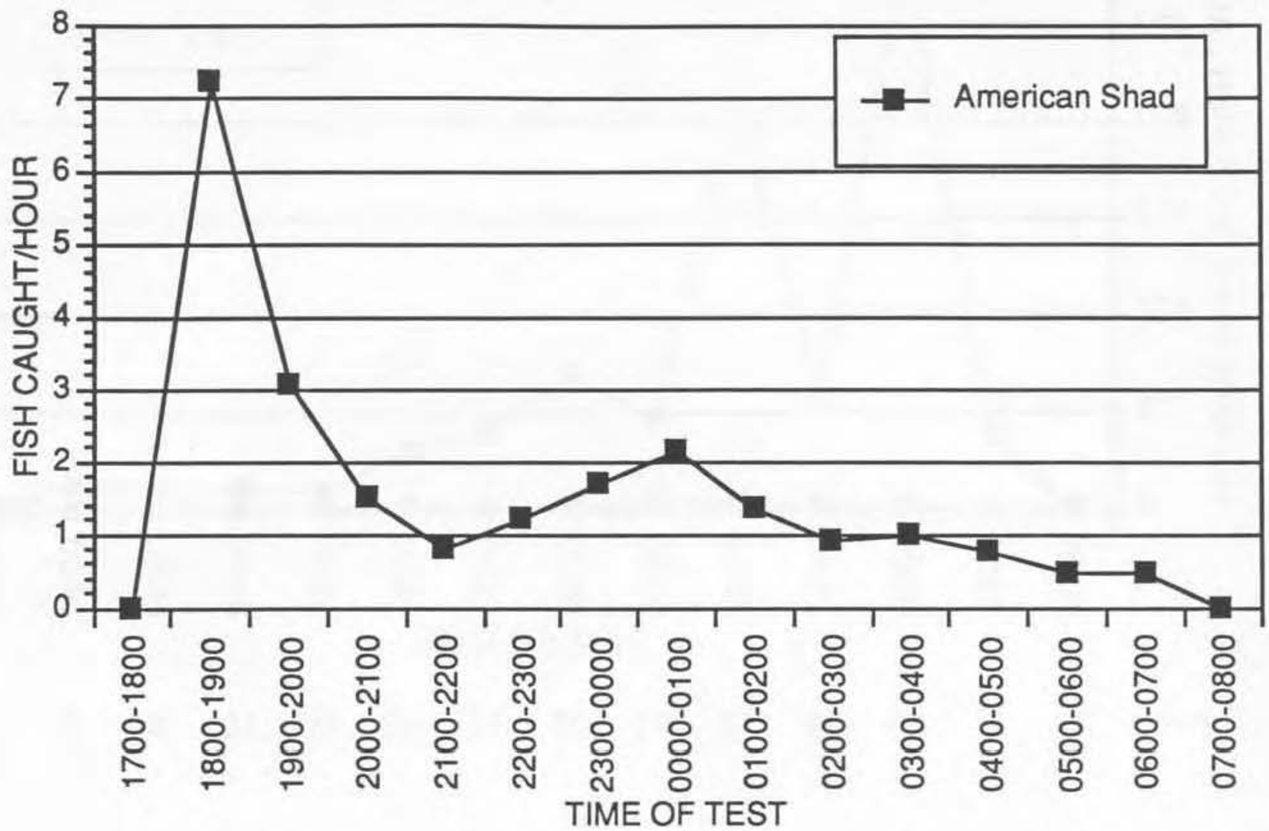
n = 1 9 16 18 15 11 11 14 12 10 12 9 3 1



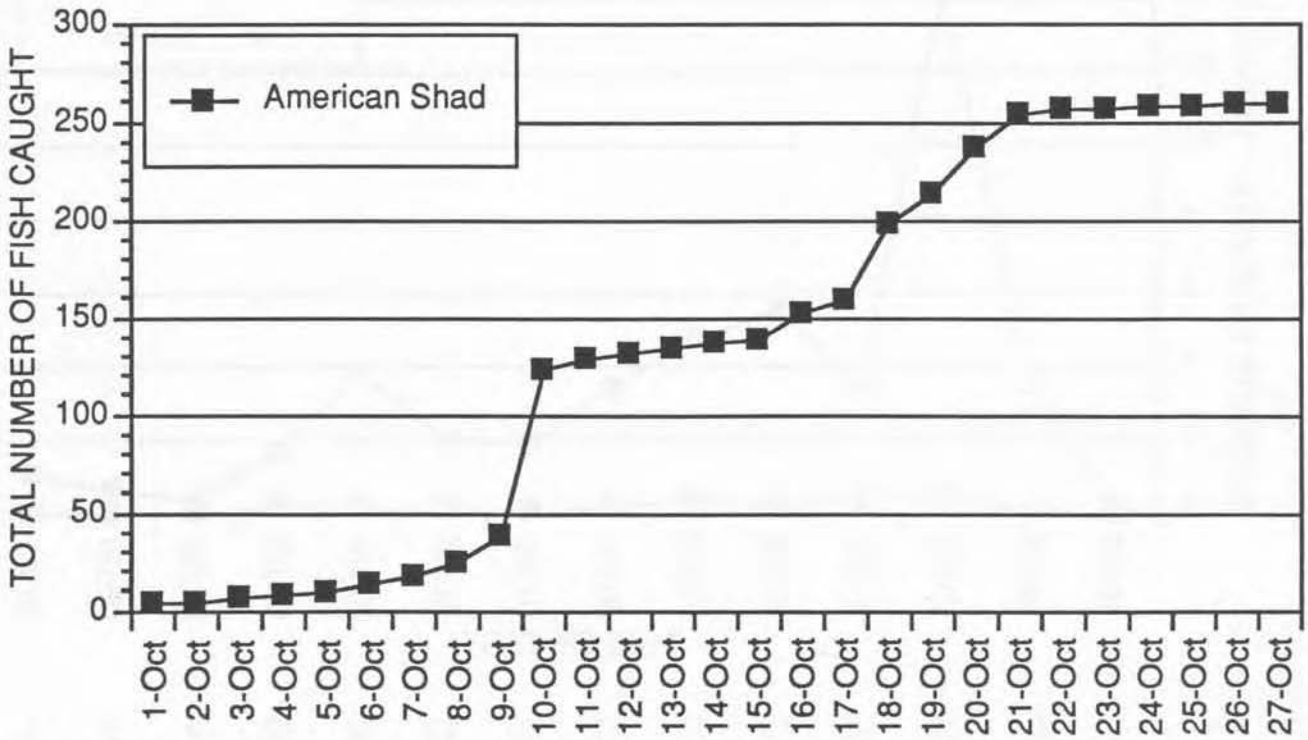
n = 1 9 16 18 15 11 11 14 12 10 12 9 3 1

Figure 5

AMBIENT TAILRACE NETTING



hours netted - 1 5 9.5 21 19 19 13 16 14 12 16 15.5 6.5 6.5 1



hours netted - 1 6 6 7 7 3 8 7 6 9 9 6 6 9 8 8 9 12 9 7 10 7 4 4 8 4 4

Figure 6

JOB V, Task 3: EFFECTS OF THREE GENERATION CONDITIONS ON JUVENILE SHAD MOVEMENT IN THE HOLTWOOD HYDROELECTRIC STATION FOREBAY, SUSQUEHANNA RIVER, 1991

By

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EXECUTIVE SUMMARY

Thirty externally radio tagged juvenile American shad were tracked in the Holtwood Hydroelectric Station forebay to determine their movement and distribution with respect to three generation conditions and water temperature. Nine of 10 shad exited the forebay via turbines within 10 min to 1.5 h after release with six units operating. During hydrostation shutdown tagged shad did not concentrate in any specific area and fish were distributed throughout the forebay more evenly at night than during the day. Six of 20 shad released during hydrostation shutdowns left the forebay via the turbines within an hour of generation startup. One of those was recovered at Peach Bottom Atomic Power Station 29 hours after it passed Holtwood. Water temperatures varying from 12.2 to 20.0° C (average change = 2.4° C from ambient) had little effect on tagged shad movement. Little delay occurred in passage of young shad at the Holtwood Station.

If there weren't numbers of untagged fish in Holtwood Forebay at time of release this study is not representative of what schools of shad would do at Hltwd

INTRODUCTION

In years of low river flow when little spillage occurs at Holtwood Hydroelectric Station, large numbers of emigrating juvenile American shad (Alosa sapidissima) congregate in the forebay. An earlier study (RMC 1990) explored the relative merits of downstream passage via the log chute and turbines at Holtwood Hydroelectric Station. Also, the thermal plume created in the forebay was profiled in 1990, however, its effects on shad movement remained unknown. Little was known about how various operational modes of the power station affected juvenile shad behavior.

Knowledge of the behavior of downstream migrant juvenile shad in the Holtwood forebay is important relative to station operation to enhance shad passage and in designing bypass or diversion routes should they be necessary.

The purpose of this radio telemetry investigation was to examine the movement and distribution of juvenile shad in the Holtwood forebay with respect to operational status of the hydrostation and steam station during shutdown.

METHODS AND MATERIALS

Prior to testing at Holtwood, six juvenile shad were tagged and released into a raceway at Benner Spring Fish Research Station to assess the effects of tagging on their behavior when schooling with untagged fish. Results of this study showed that effects of radio tagging on juvenile shad were negligible (Ross and Bennett 1991, Appendix A). Thus, radio telemetry was considered a viable technique to study juvenile shad behavior in the Holtwood forebay.

Juvenile shad for the present study were lift netted (8x8 ft, 1/2 mesh) in the Holtwood or Safe Harbor forebays and transported to the stoplog gallery at Holtwood where they were placed in a 2500 L circular holding pool continuously supplied with river water and held for at least 24 hours for acclimation. On test days, equal numbers of test and control fish were tagged. Test fish were fitted with miniature radio transmitters supplied by Advanced Telemetry Systems Inc. while controls were tagged with dummy transmitters of equal dimensions and buoyancy. Each transmitter was encapsulated to provide a slight positive buoyancy and was externally attached to the fish's musculature just posterior to the dorsal fin. Each tag was attached with a modified ear piercing gun and 10 mm stainless steel pin. Each tag propagated a unique 148 Mhz frequency via a 280 mm coated wire antenna.

Test fish and untagged shad (0-13) were placed in 5 ppt salt solution in circular 80 liter tanks for transport to the forebay release site while control specimens were returned to another 2500 L circular pool for assessment of the delayed effects of tagging. Because of scarcity of shad, tagged fish could not always be released with 10 untagged fish as specified in the study plan.

A total of 30 shad was tagged on 9 separate days (Table 1). Ten shad were released at each of the three generation conditions: day generation, day non-generation and night non-generation. Three or four fish were released each test day. All fish tagged for day generation were released near the northeast corner of the forebay (Figure 1). These fish were tracked from shore with three 4 element Yagi antennas linked to Lotek SRX_400 receivers located around the forebay. Location bearings were obtained simultaneously on the three antennas at 5 to 10 minute intervals. Fish fixes were assigned to the intersection of lines drawn between the intersection of the triangulated bearings and the center of the opposite side of the triangles. If all three lines did not intersect then the fish location was placed at the point where two bearings intersected.

During periods of non-generation, fish were released two meters east of the log boom, 40 m south of the forebay shoreline. Tracking was done by boat. Locations were plotted approximately every 30 min on a forebay map by triangulating on shore points and maximum signal power levels were recorded. Care was taken to minimize the effect of the boat proximity on shad behavior yet maximize fish location accuracy.

To assist in profiling the thermal plume, a Microtemp monitor was installed on the east side of the trash skimmer boom on the inner forebay. The thermistor was situated at a depth of 30 cm.

Automatic inner forebay temperature recording continued every 15 minutes between 24 October and 8 November. Temperature data are summarized in Table 2.

Initially, fish passage through the station was monitored with 2 Lotek SRX_400 receivers, one scanning the area immediately in front of the trash racks inside the hydrostation via two 4 element Yagi antennas while the other was linked to a half wave dipole antenna placed on the east shoreline of the tailrace approximately 75 m upstream of Norman Wood Bridge. On 28 October these receivers were replaced with one SRX_400 receiver installed on the transformer deck overlooking the tailrace which was linked to five 4-element Yagi antennas oriented to cover the entire tailrace area. Data were off loaded as necessary with a Toshiba 1200 HB laptop computer and was stored on a 3.5 in diskette.

Five foot increment temperature profiles were taken with a YSI (Model 57) DO meter on selected fish fixes at least once an hour and signal power levels were recorded (receiver gain of 75) at these locations for later correlation with known depth tags (Table 3) to quantify the actual depth of the tagged shad.

All shad location data were summarized by consolidating all fixes from individual days onto master maps and then plotting all fixes from the three test conditions on individual maps. A comparison of fish locations and signal strength measurements with temperature profile data completed the analyses.

RESULTS

Condition and Behavior of Tagged Shad Upon Release

All tagged shad were in good condition at release. The post release condition of the test fish was deemed good since control survival was 97% at the time tracking was terminated. After 24 h 70% of the control fish were in good condition. Test fish were not measured but were generally larger than control fish which had a mean fork length of 107 mm (N=30). The selection of larger specimens for radio tagging should have increased their survival rate. This is similar to the findings of the preliminary tagging study conducted at Benner Spring Fish Research Station (Ross and Bennett 1991, Exhibit A).

Those shad released with other untagged fish sometimes tightly schooled for a few seconds then separated. At other times no tight schooling was observed and all fish moved in separate directions.

Distribution During Day Non-generation

Ten shad were tracked an average 3.5 h over three separate days. Most meandered in the north end of the forebay especially near the log boom. Five of ten fish released swam > 100 meters from the release site toward the station (Figures 2-4). Three fish moved between 30 and 100 meters from the release site and one was lost after only one fix. The last fish remained within 30 m of the log boom or north end of the forebay. Sixty-seven percent of the total 85 fixes were within 30 meters of the log boom (Figure 5). Most shad movement in the north end of the forebay paralleled the log boom.

Distribution During Night Non-generation

Ten fish were tracked an average 4.9 h over three separate days. Seven of 10 shad moved more than 100 m toward the station; four of these eventually moved back to the vicinity of the log boom at least one time while the other did not (Figures 6-9). The other two meandered extensively in the north end of the forebay, at times > 100 m toward the station. One of the remaining three moved toward the station then was next located a few meters west of the log boom. It did not reenter the forebay during the tracking period. The last two remained in the north end of the forebay, one within 30 m of the log boom. Forty-four percent of the total 106 fixes were within 30 m of the log boom (Figure 10).

Distribution During Generation

Most location fixes were concentrated away from the shorelines towards the middle of the forebay when six or more units were generating (Figures 11-14). Tracking the movements of shad during generation proved to be difficult due to the wide reception angle of the Yagi antennas and variation in tag signal strength caused by the fish's own activity that caused errors in the triangulated bearings. Detailed movements of test fish were not obtainable from the shore based antennas. Unfortunately, station safety regulations prohibited boat tracking in the forebay during times of generation. However, due to rapid exit of shad through the power station it is unlikely that much distributional data could have been collected (see later).

Passage After Day Non-generation

Five of ten fish released during day non-generation periods were logged on the monitors in the tailrace or at Norman Wood Bridge when the station was generating. Four of these fish exited the day of release within an hour after the station started operation. The fifth fish did not pass until the following day about one and a half hours after the station was brought on line. It is unknown if the other five fish exited at the same time.

Passage After Night Non-generation

Three shad released during night non-generation were logged in the tailrace after the station commenced generating. Two fish passed the morning following release within 10 minutes after generation started. The last fish exited while units were being brought on line the day after release. The other seven fish were not recorded by the monitor covering the tailrace. One tag which was recorded in the tailrace at 0500 hours on 31 October was recovered from the strainer bin at Peach

Bottom Atomic Power Station about 1000 h on 1 November. The tag with its stainless steel pin was negatively buoyant so was presumed to have been attached to the shad when entrainment occurred.

Passage During Scheduled Generation

Shad moved out of the forebay and through the units rapidly when released with six units generating. Five of 10 fish released were recorded on downstream monitors. Passage times from release to the signal being logged in the tailrace varied from 10 minutes to 1 hr 24 min and averaged approximately 30 min. The signals on four other fish were suddenly lost near the station between 32 min to 1 hour after release. These fish were not recorded on the tailrace monitor but likely passed through the units based on signal characteristics. The last fish was inactive in the forebay and was later picked up in the tailrace 5 hr 44 min after release.

Temperature Effects on Depth and Distribution

Microtemp data showed that on non-generation test days water temperature rose to near maximum levels at the inner forebay log boom within 1 h 30 m after hydrostation shutdown (approximate change from ambient = 4° C). The slightly higher water temperatures caused by thermal discharge from the steam station during hydrostation shutdown had little noticeable effect on the movements of juvenile shad.

During the day 54% of 24 fixes were within 1.5 m (5 ft) of the surface and the rest were from 1.5 to 7 m (5 to 22 ft) deep. Temperatures at the depth where all these fish locations were observed ranged from 12.2-20° C ($\overline{X}$ = 15.4° C) and the change from ambient water temperature ranged from 0-6° C ($\overline{X}$ = 2.3° C). Ninety percent of 39 locations on which temperature profiles were taken at night were also within 1.5 m (5 ft) of the surface. At night, temperatures at which shad were located ranged from 13 - 17° C ($\overline{X}$ = 15.3° C) and change from ambient ranged from 0-5° C ($\overline{X}$ = 2.5° C).

DIURNAL VARIATIONS

Because of the negatively phototactic nature of shad, only half of the fixes were within 1.5 m of the surface during the day as opposed to 90% at night. Fewer fish (5) moved more than 100 m from the release site during the day than at night (7). A comparison of Figures 5 and 10 show the overall wider distribution of fish throughout the forebay at night as opposed to during the day.

CONCLUSIONS

The study objectives were met; radio telemetry proved viable in obtaining much useful data. During generation periods juvenile shad rapidly exited the forebay. The rapid passage of tagged shad released during generation suggests that Holtwood Station does not delay outmigrating juvenile shad. This is corroborated by some fish released during non-generation periods which rapidly exited the forebay after generation began.

No specific areas of concentration were noticed during either non-generation condition. Tagged shad were more scattered at night in the forebay than in the day. Shorter tracking time and visual orientation of shad during daylight hours probably accounted for the lack of fixes throughout the forebay during day non-generation when compared with night non-generation. The greater number of fixes observed near the log boom may partly be a function of the proximity to the release site.

The movement of tagged shad did not appear to be influenced by the thermal plume of the steam station during shutdown of the hydrostation. The thermal plume does not reach the forebay during generation so would not hinder the passage of shad during hydro operation.

Juvenile shad occupied mostly the top 5 ft of the water column in the forebay. Observations indicated that the shad abundance in the forebay was much less in 1991 than in previous years.

LITERATURE CITED

RMC Environmental Services. 1990. 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. Report prepared for Susquehanna Anadromous Fish Restoration Committee, Harrisburg, PA.

Table 1

Summary of 30 radio tagged shad released in the Holtwood Hydroelectric Station forebay on the Susquehanna River, 1991.

Release Date	Time Released	Number Released	Generation Condition	# Recorded Downstream	Control Condition
24 Oct	1225	3	Day Non	0	Alive
25 Oct	1405	3	Day Gen	1	Alive
28 Oct	1351	3	Day Gen	2	Alive
29 Oct	1315	4	Day Non	2	Alive
30 Oct	1955	3	Nite Non	2	Alive
4 Nov	1634	4	Nite Non	0	*Alive
5 Nov	1348	3	Day Non	2	1 Dead
6 Nov	1633	3	Nite Non	2	Alive
7 Nov	1300	4	Day Gen	3	Alive

* Fish in poor condition, all swimming on their sides.

TABLE 2. Daily mean, range and standard deviations of water temperature readings from the Microtemp monitor at Holtwood Hydroelectric Station forebay, October - November, 1991.

DATE	DAILY MEAN	STD	MIN TEMP	MAX TEMP	RANGE	FLAG
18OCT91	16.1	1.72819	14.6	19.3	4.7	*
19OCT91	17.9	2.41669	14.4	21.1	6.7	*
20OCT91	20.9	0.92872	18.4	21.9	3.6	*
21OCT91	16.8	2.73503	13.9	21.0	7.1	*
22OCT91	16.8	2.23864	13.6	19.9	6.2	*
23OCT91	16.8	2.26573	13.6	20.0	6.4	*
24OCT91	16.4	2.57895	13.7	19.9	6.2	*
25OCT91	16.8	2.08228	13.9	19.9	6.0	*
26OCT91	18.9	2.19006	14.1	21.0	6.9	*
27OCT91	18.7	2.51039	14.0	20.9	6.9	*
28OCT91	16.9	2.48768	14.2	21.0	6.8	*
29OCT91	18.2	2.34412	14.1	21.2	7.1	*
30OCT91	17.5	2.39845	14.1	20.1	6.0	*
31OCT91	17.1	2.43361	13.8	19.6	5.8	*
01NOV91	17.6	1.58089	13.8	20.3	6.4	*
02NOV91	18.5	1.98887	14.0	20.4	6.4	*
03NOV91	18.1	2.39581	13.7	20.5	6.7	*
04NOV91	17.4	1.68964	13.4	19.2	5.8	*
05NOV91	16.5	2.42269	12.4	19.3	6.9	*
06NOV91	16.3	1.96015	12.2	18.1	5.9	*
07NOV91	14.6	2.81708	11.2	18.1	6.9	*
08NOV91	13.7	2.68344	10.6	17.2	6.6	*
09NOV91	16.6	0.26376	16.0	17.3	1.3	
10NOV91	16.7	0.22174	16.1	17.3	1.1	
11NOV91	13.5	3.53123	9.6	17.1	7.5	*

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

Table 3

Depth vs signal power level calibration for single and double battery radio tags.

Depth (ft)	Single Battery Power Level	Double Battery Power Level
1	230	230
5	190-206	210-230
10	144-165	160-180
15	0	60-90
20	0	0

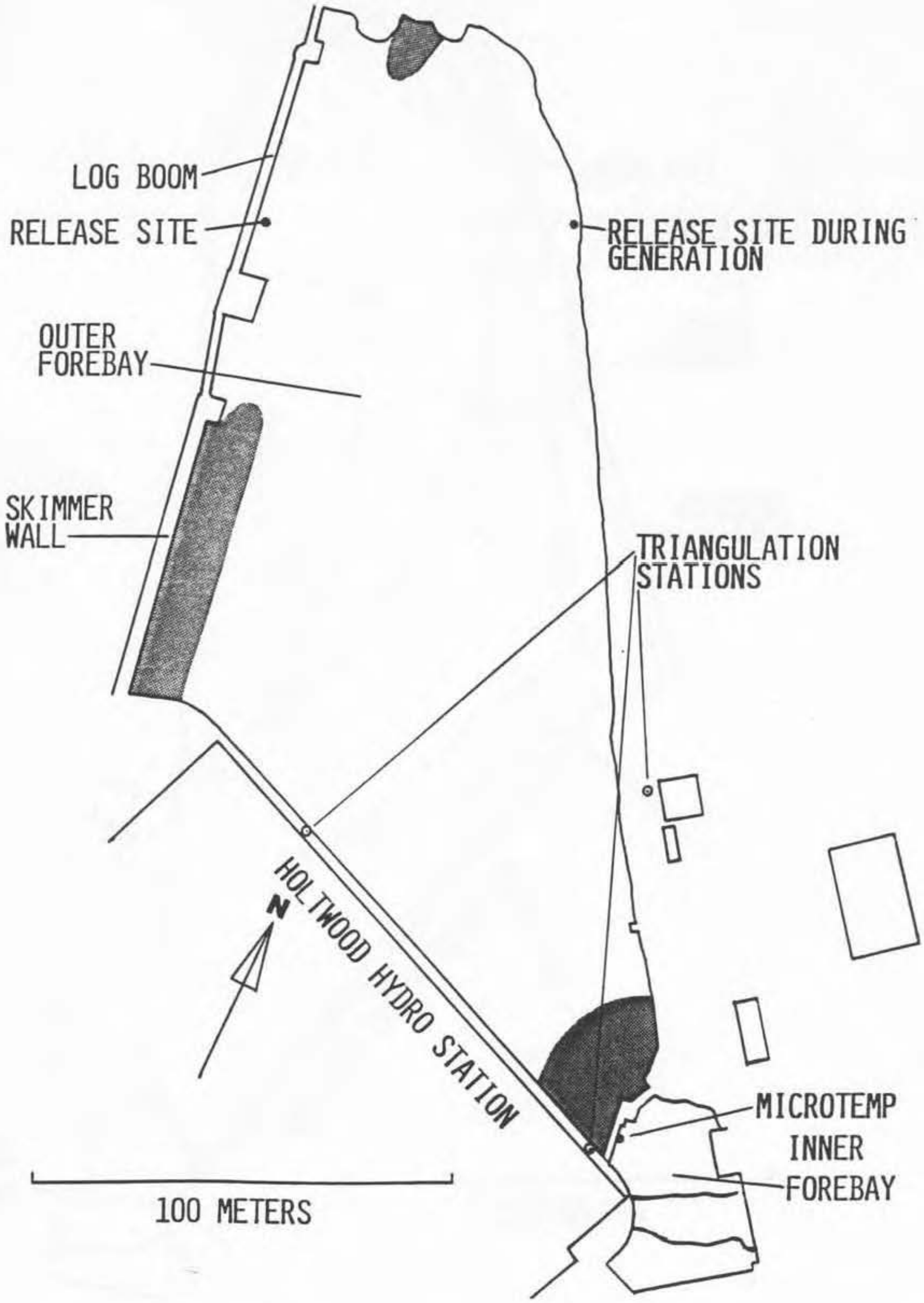


Figure 1

Physical characteristics of Holtwood Hydroelectric Station forebay including areas illuminated at night (shaded) during periods of hydrostation shutdown, Susquehanna River, 1991.

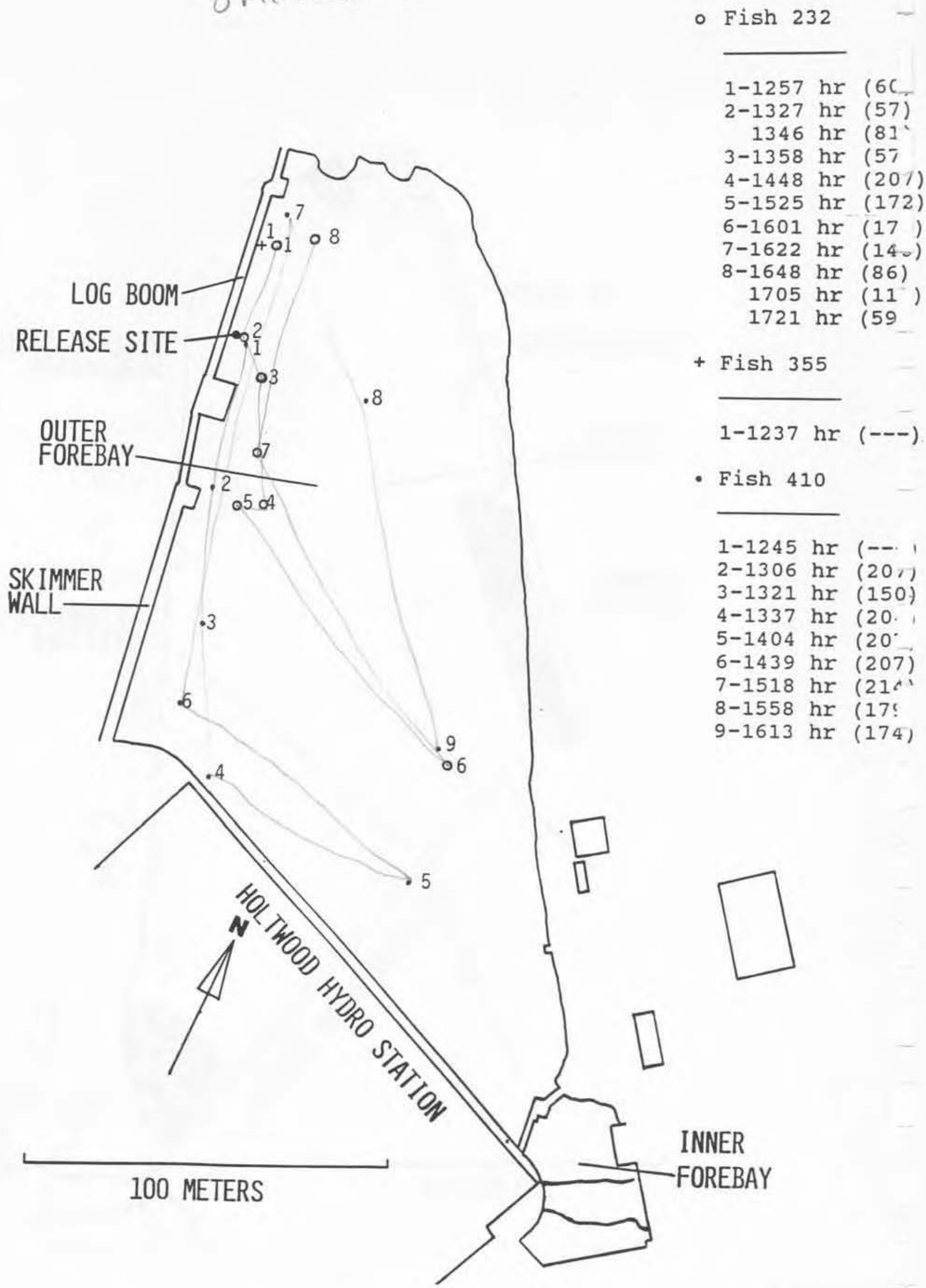


FIGURE 2

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during day non-generation on 24 October 1991.

2 rec downstream

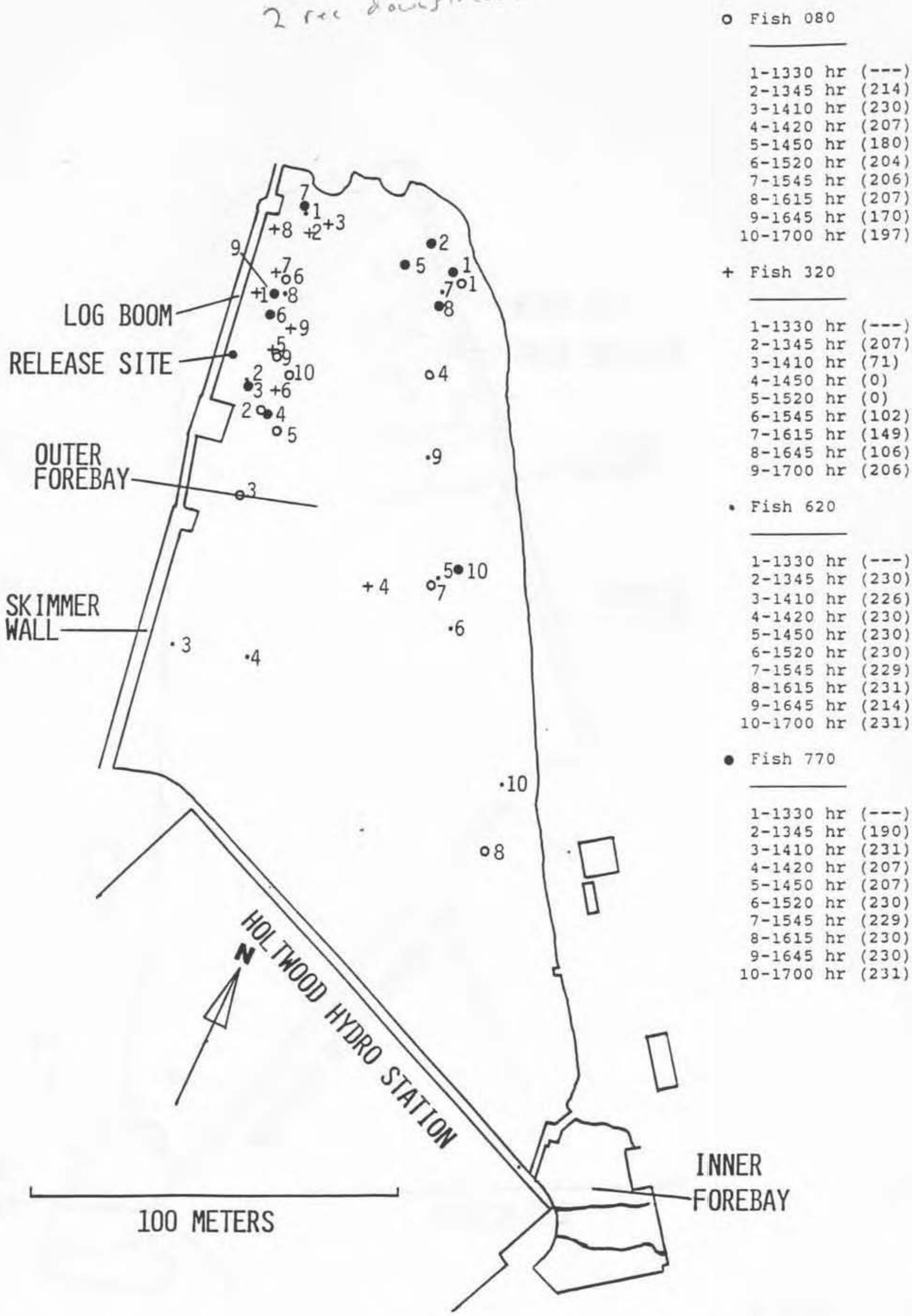


FIGURE 3

Summary of all fixes on four shad released in the Holtwood Hydroelectric Station forebay during day non-generation on 29 October 1991.

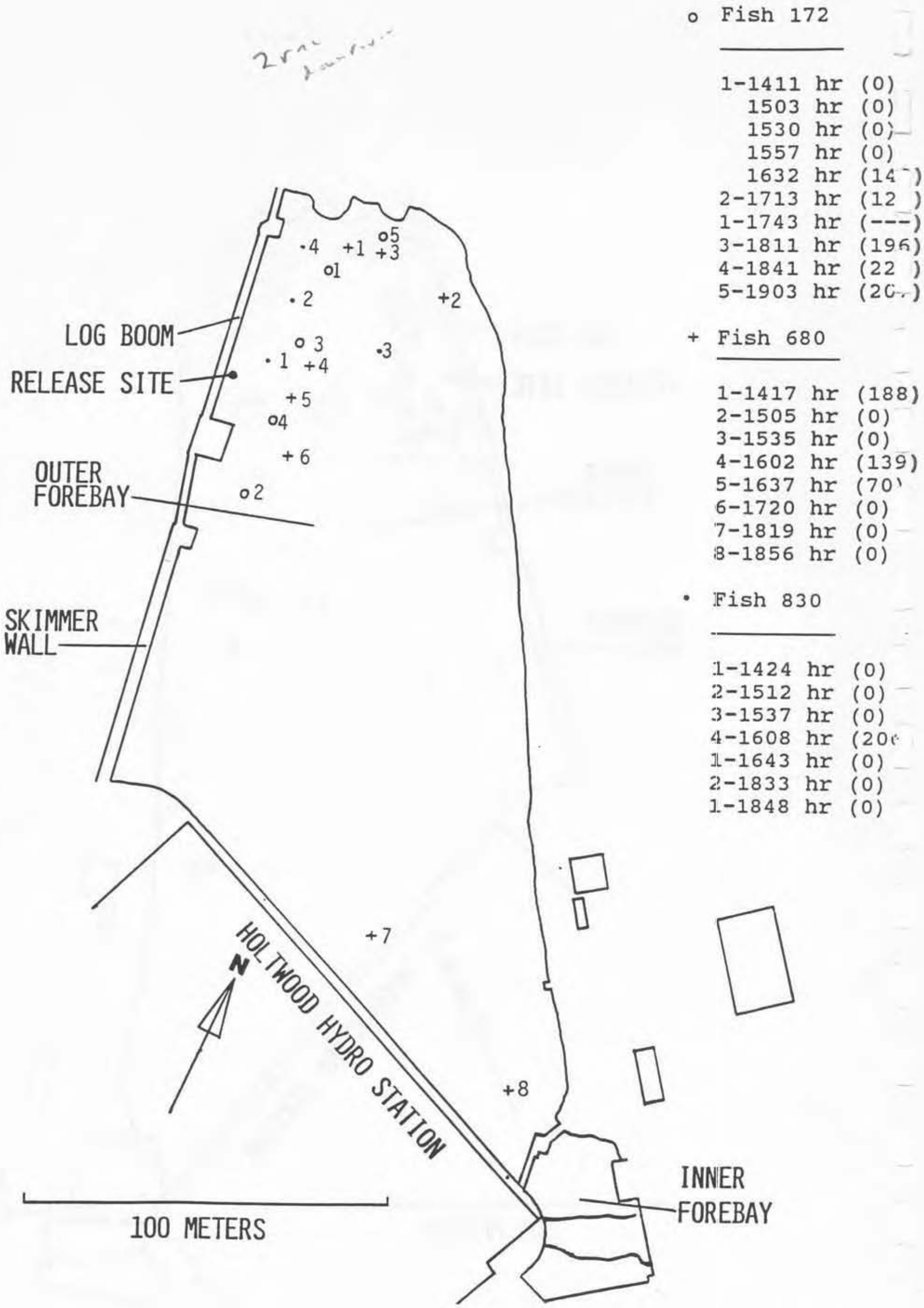


FIGURE 4

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during day non-generation on 5 November 1991.

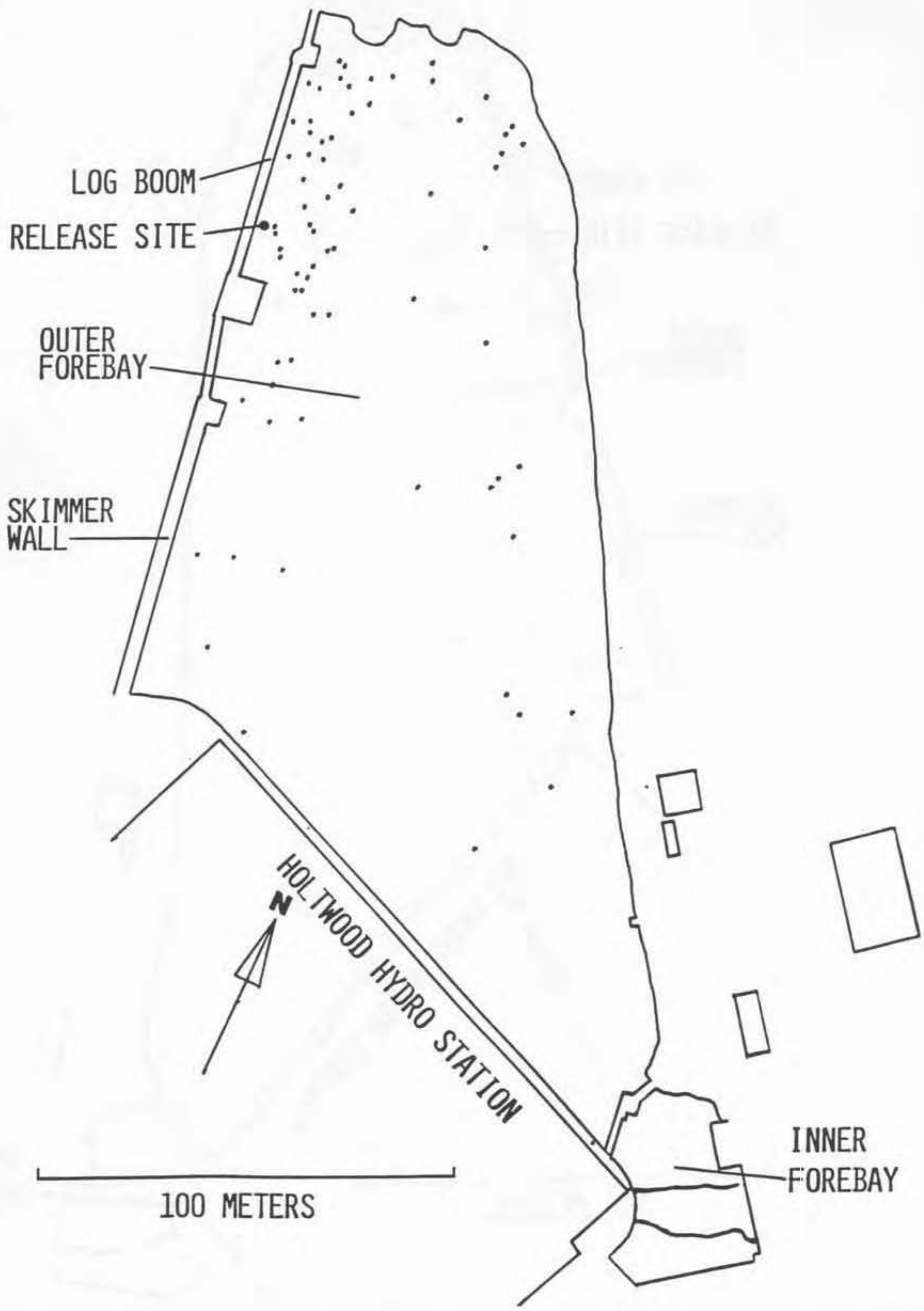


Figure 5

Summary of all fixes on ten shad released in the Holtwood Hydroelectric Station forebay during day non-generation conditions in 1991.

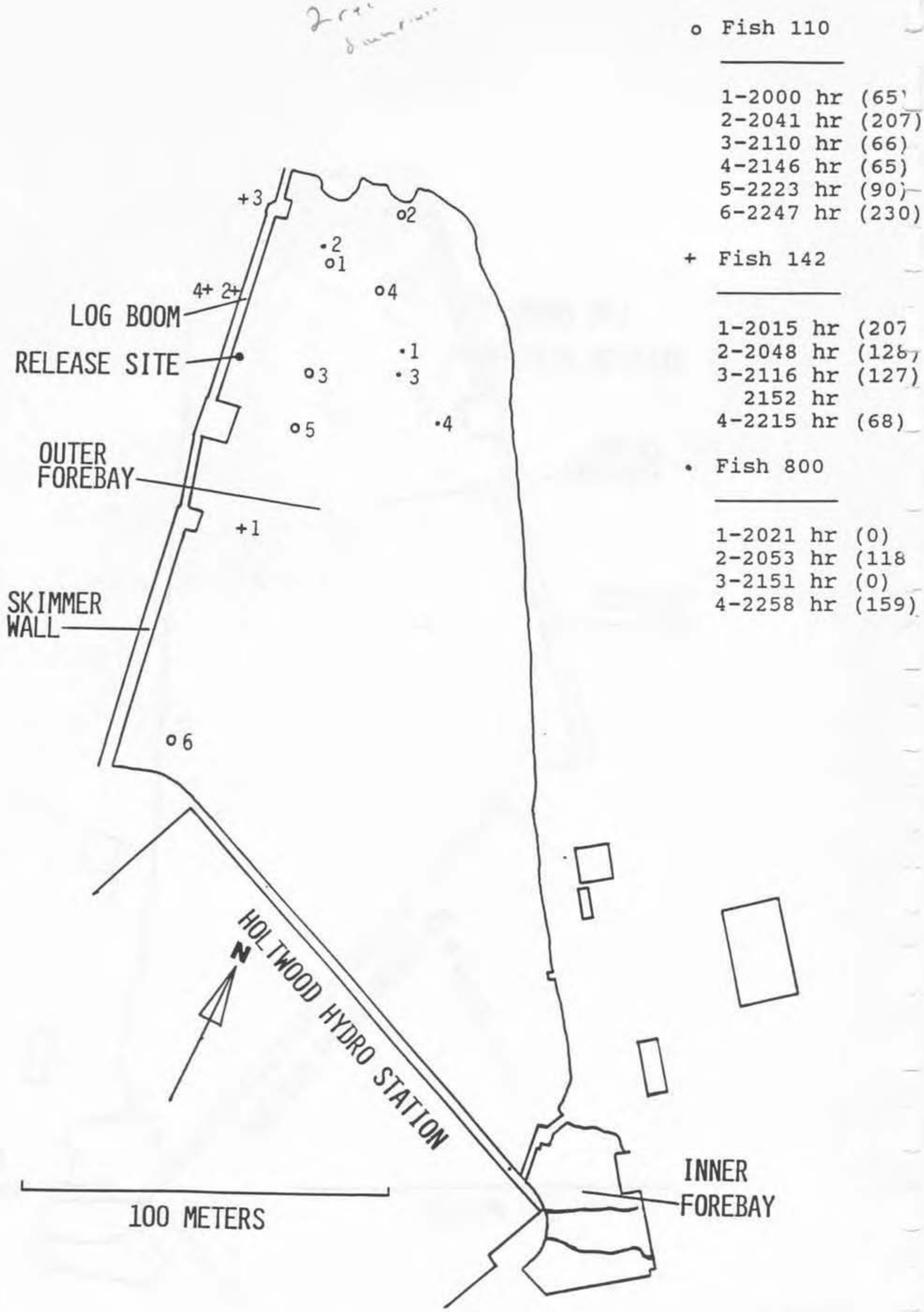


Figure 6

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during night non-generation on 30 October 1991.

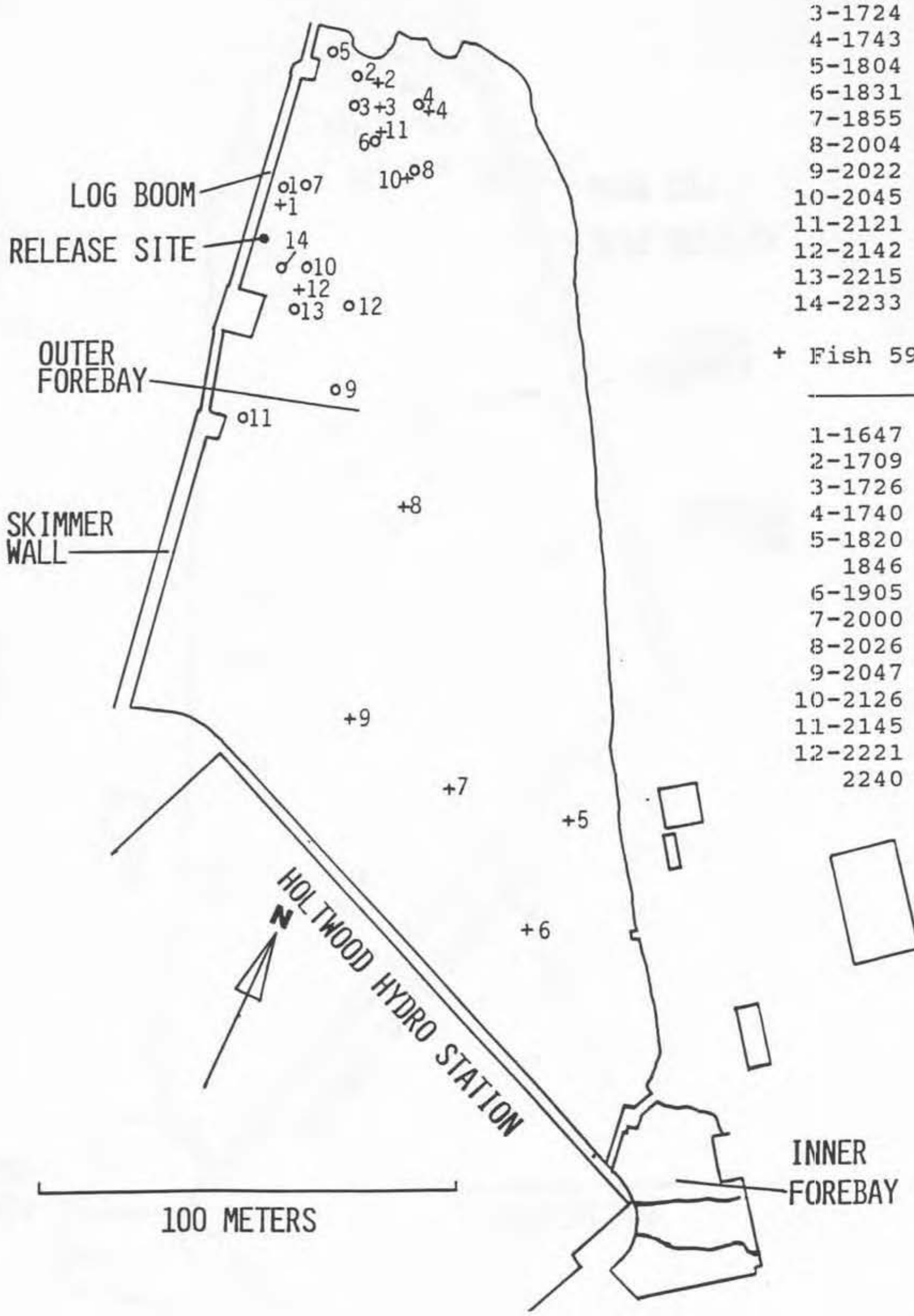


Figure 7

Summary of all fixes on two shad released in the Holtwood Hydroelectric Station forebay during night non-generation on 4 November 1991.

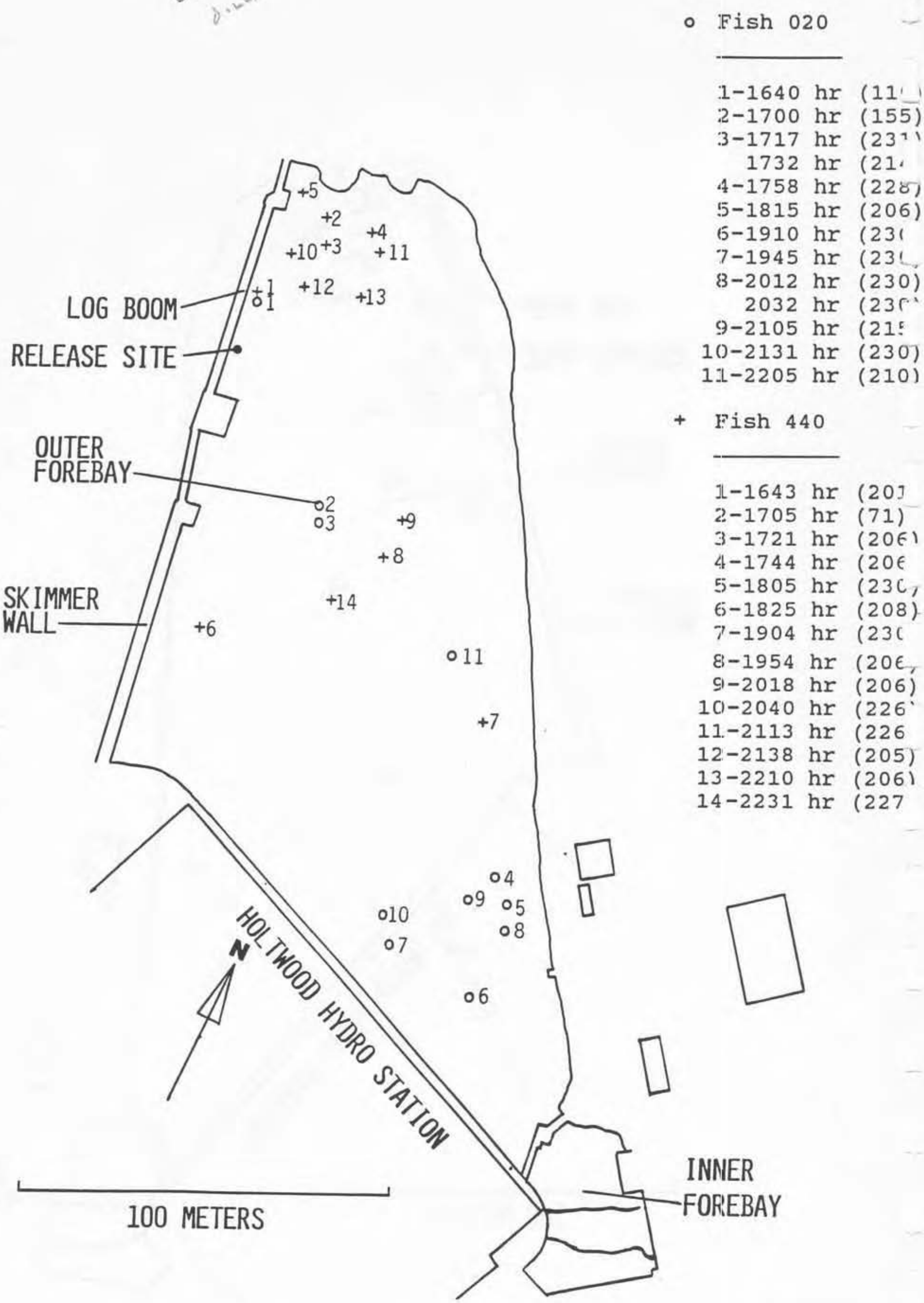
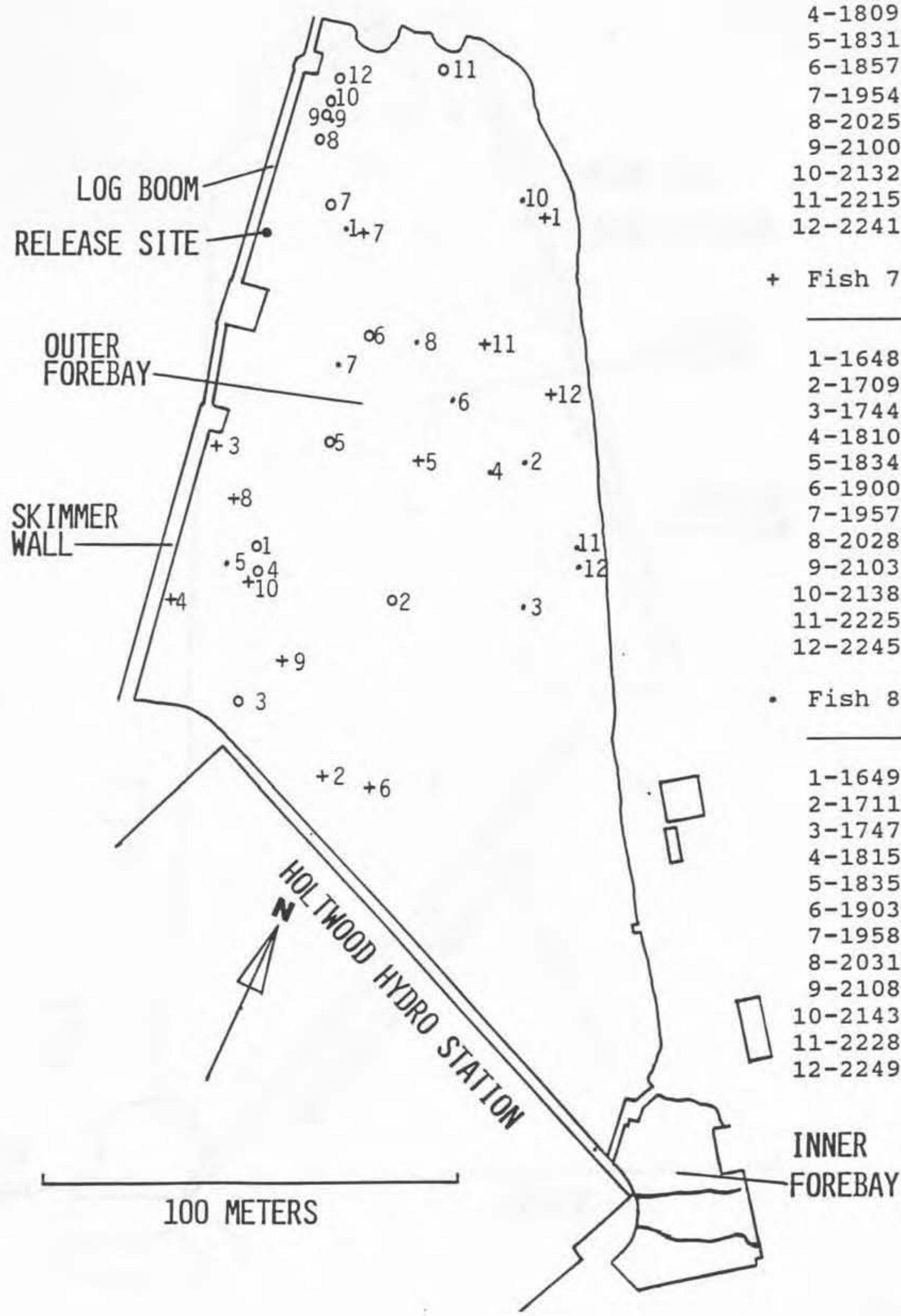


Figure 8

Summary of all fixes on two shad released in the Holtwood Hydroelectric Station forebay during night non-generation on 4 November 1991.



o Fish 382

1-1645 hr (212)
2-1705 hr (207)
3-1740 hr (231)
4-1809 hr (230)
5-1831 hr (231)
6-1857 hr (206)
7-1954 hr (230)
8-2025 hr (206)
9-2100 hr (219)
10-2132 hr (206)
11-2215 hr (206)
12-2241 hr (231)

+ Fish 740

1-1648 hr (206)
2-1709 hr (230)
3-1744 hr (220)
4-1810 hr (230)
5-1834 hr (229)
6-1900 hr (206)
7-1957 hr (231)
8-2028 hr (231)
9-2103 hr (204)
10-2138 hr (231)
11-2225 hr (217)
12-2245 hr (206)

• Fish 860

1-1649 hr (230)
2-1711 hr (230)
3-1747 hr (230)
4-1815 hr (230)
5-1835 hr (229)
6-1903 hr (230)
7-1958 hr (230)
8-2031 hr (231)
9-2108 hr (230)
10-2143 hr (230)
11-2228 hr (230)
12-2249 hr (231)

Figure 9

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during night non-generation on 6 November 1991.

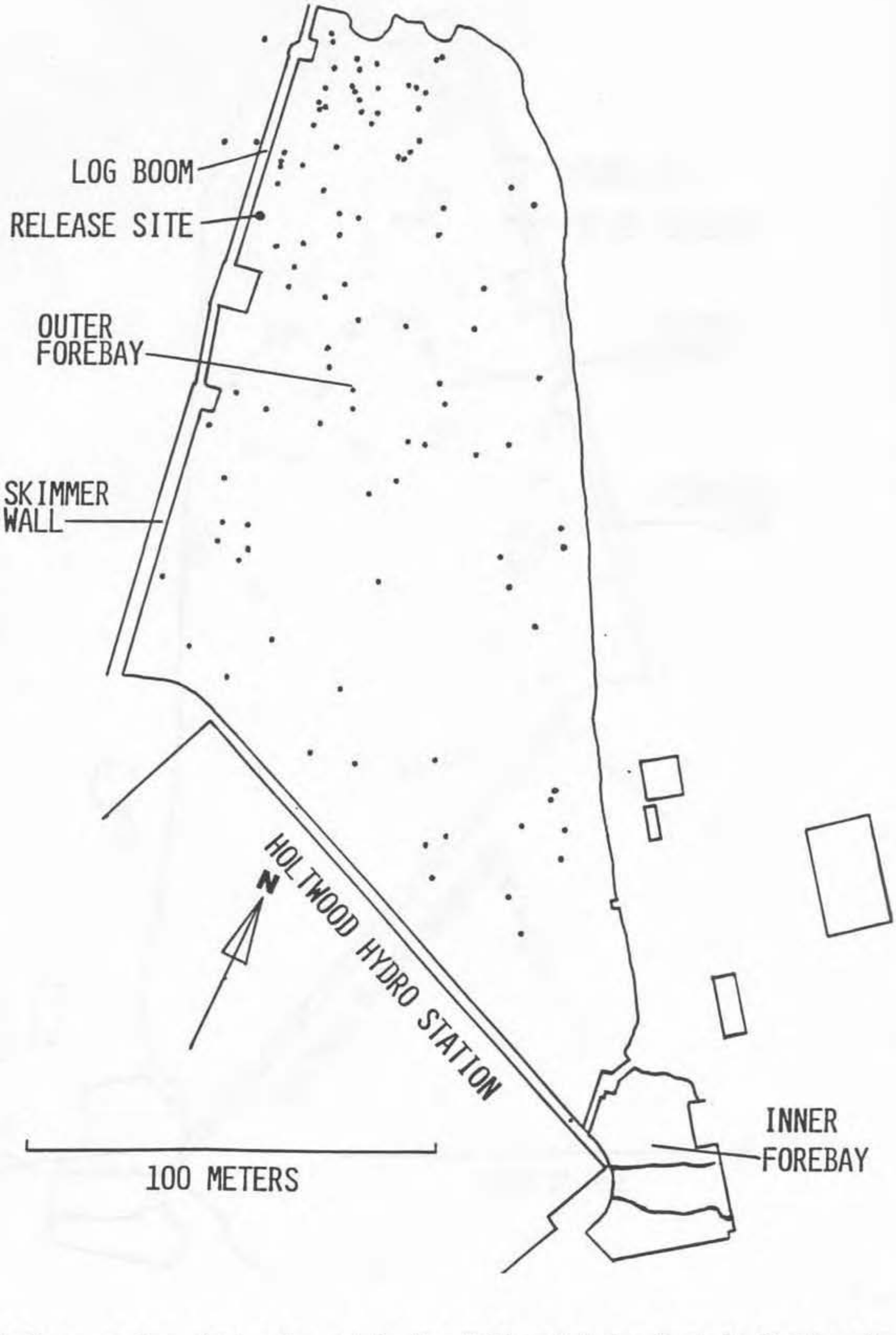


Figure 10

Summary of all fixes on ten shad released in the Holtwood Hydroelectric Station forebay during night non-generation conditions in 1991.

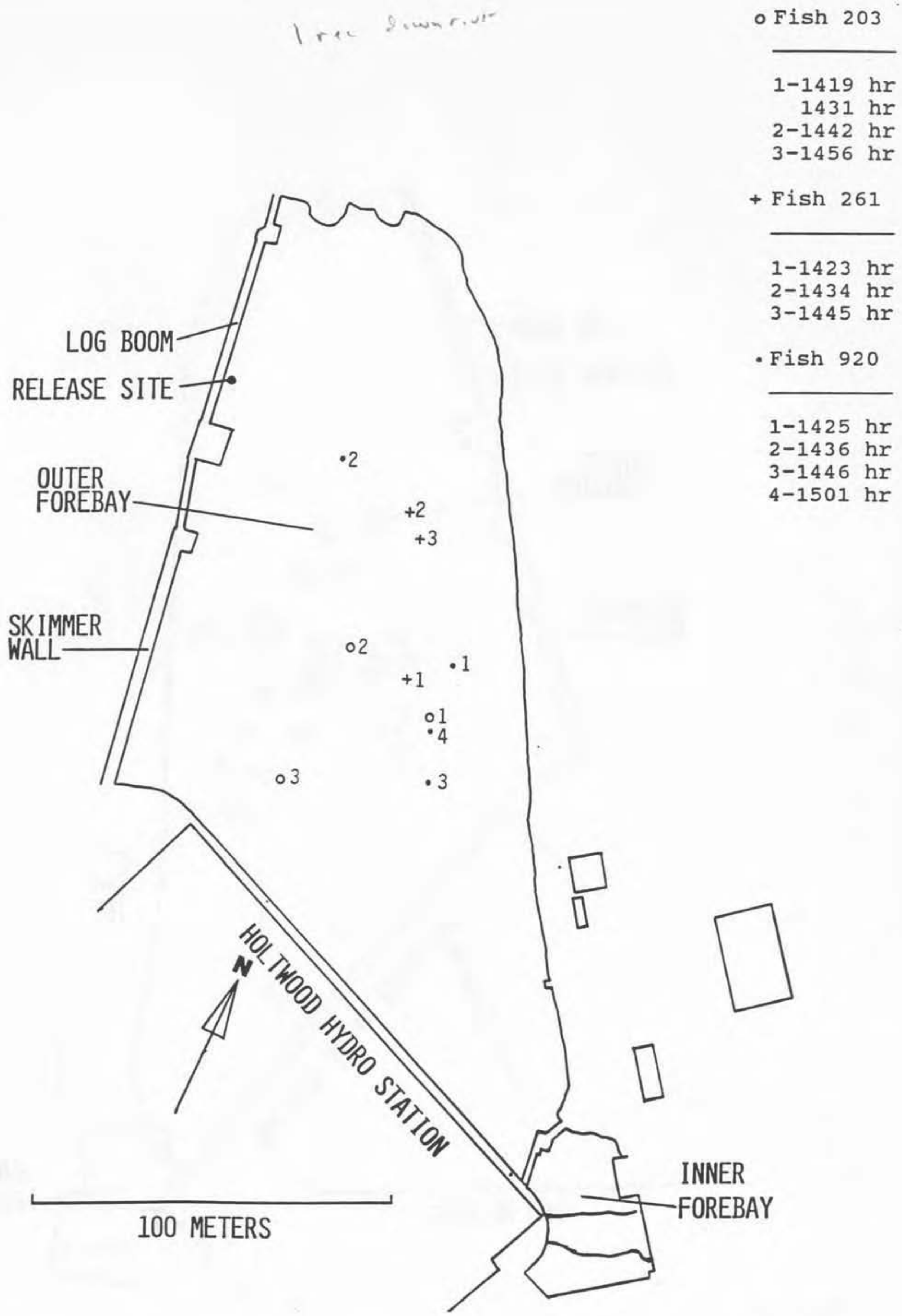
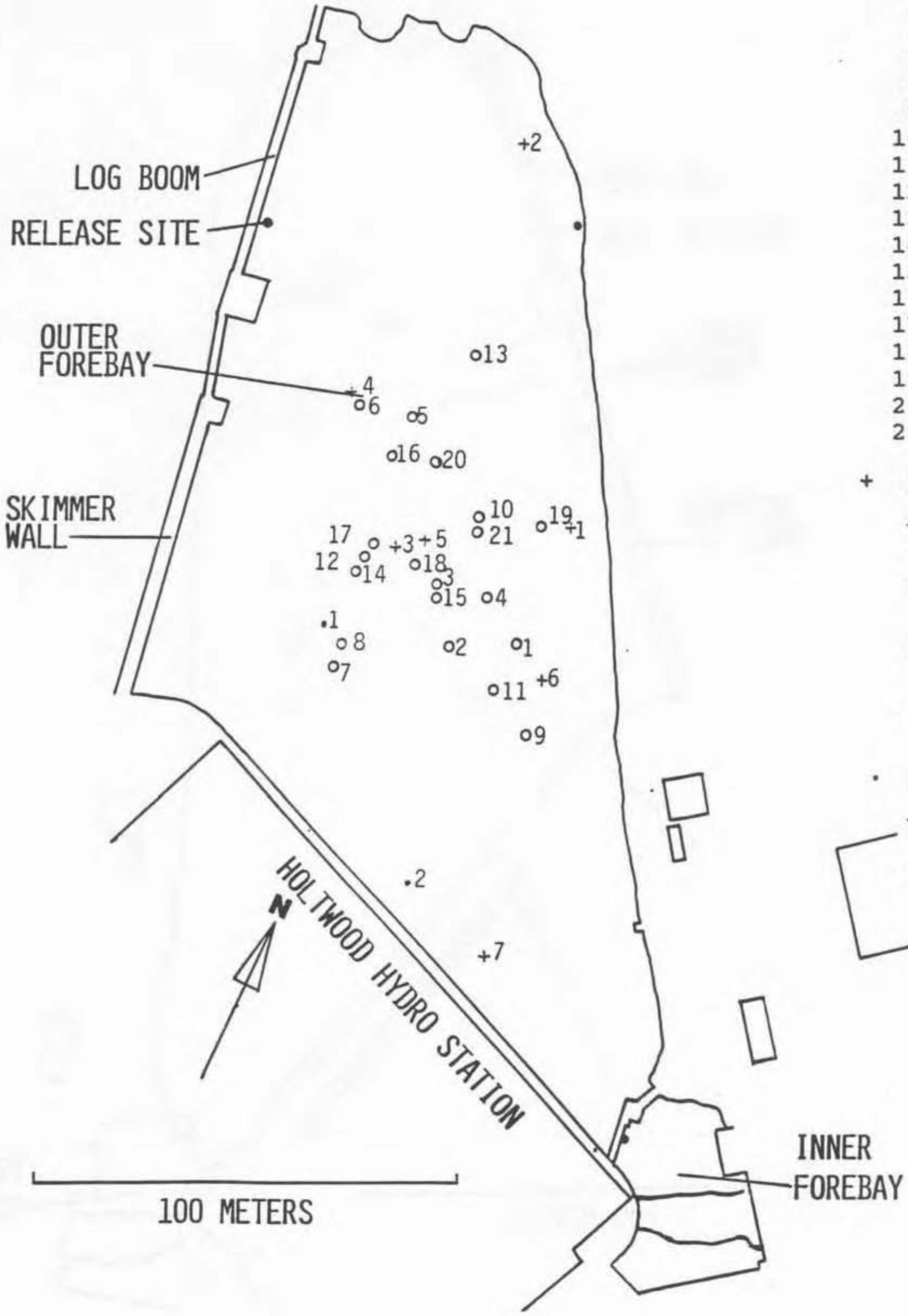


Figure 11

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during six unit generation on 25 October 1991.



o Fish 29

1-1400
2-1410
3-1418 hr
4-1430 hr
5-1436 h
6-1446 hr
7-1456 hr
8-1509 h
9-1516 h
10-1526 hr
11-1550 hr
12-1557 h
13-1607 hr
14-1617 hr
15-1629 h
16-1638 h
17-1647 hr
18-1705 h
19-1717 h
20-1728 hr
21-1735 hr

\+ Fish 950

1-1402 h
2-1411 hr
3-1420 hr
4-1432 h
5-1438 h
6-1448 hr
7-1458 h

· Fish 980

1-1413 h
2-1423 hr

Figure 12

Summary of all fixes on three shad released in the Holtwood Hydroelectric Station forebay during six unit generation on 28 October 1991.

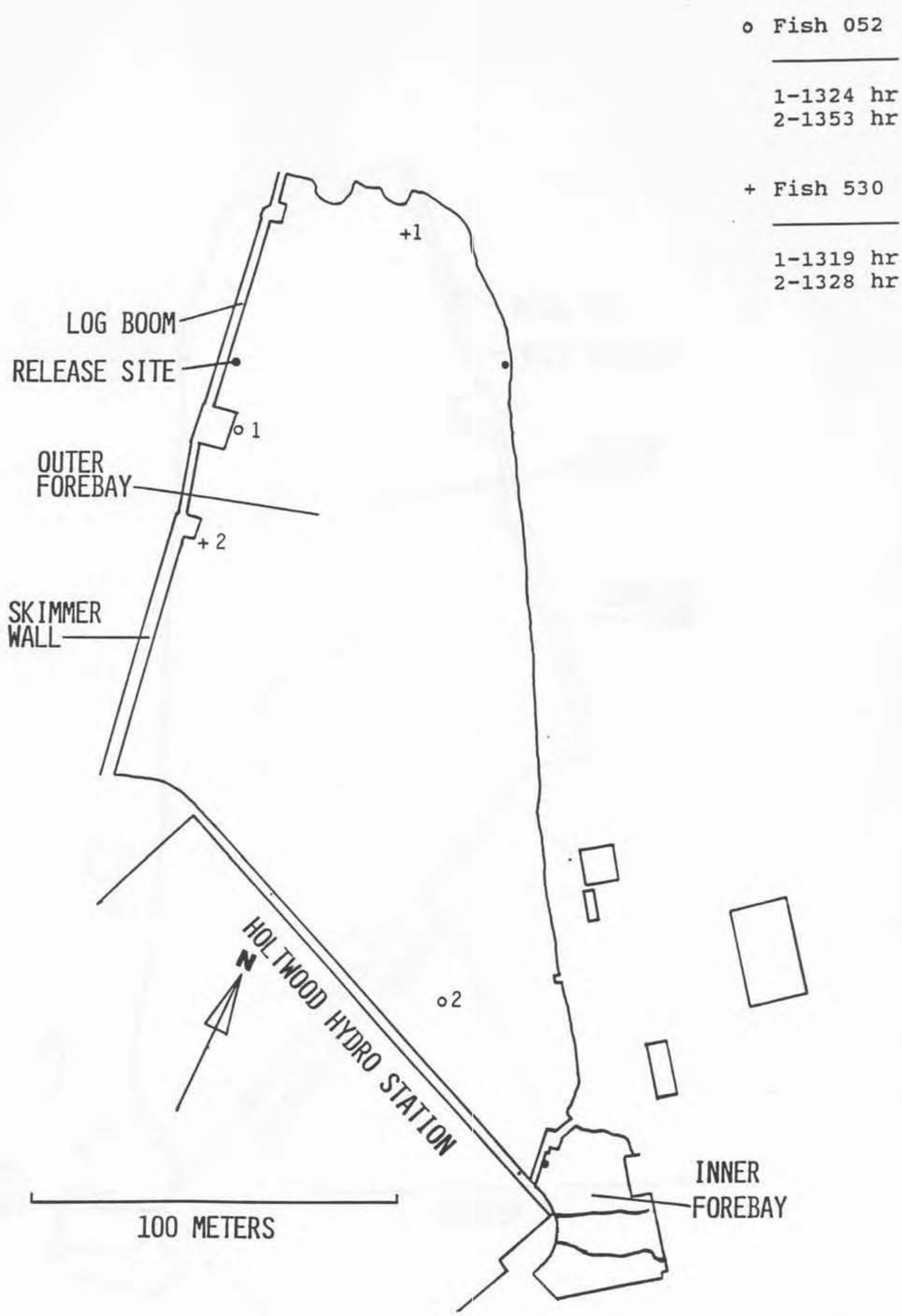


Figure 13

Summary of all fixes on two shad released in the Holtwood Hydroelectric Station forebay during six unit generation on 7 November 1991.

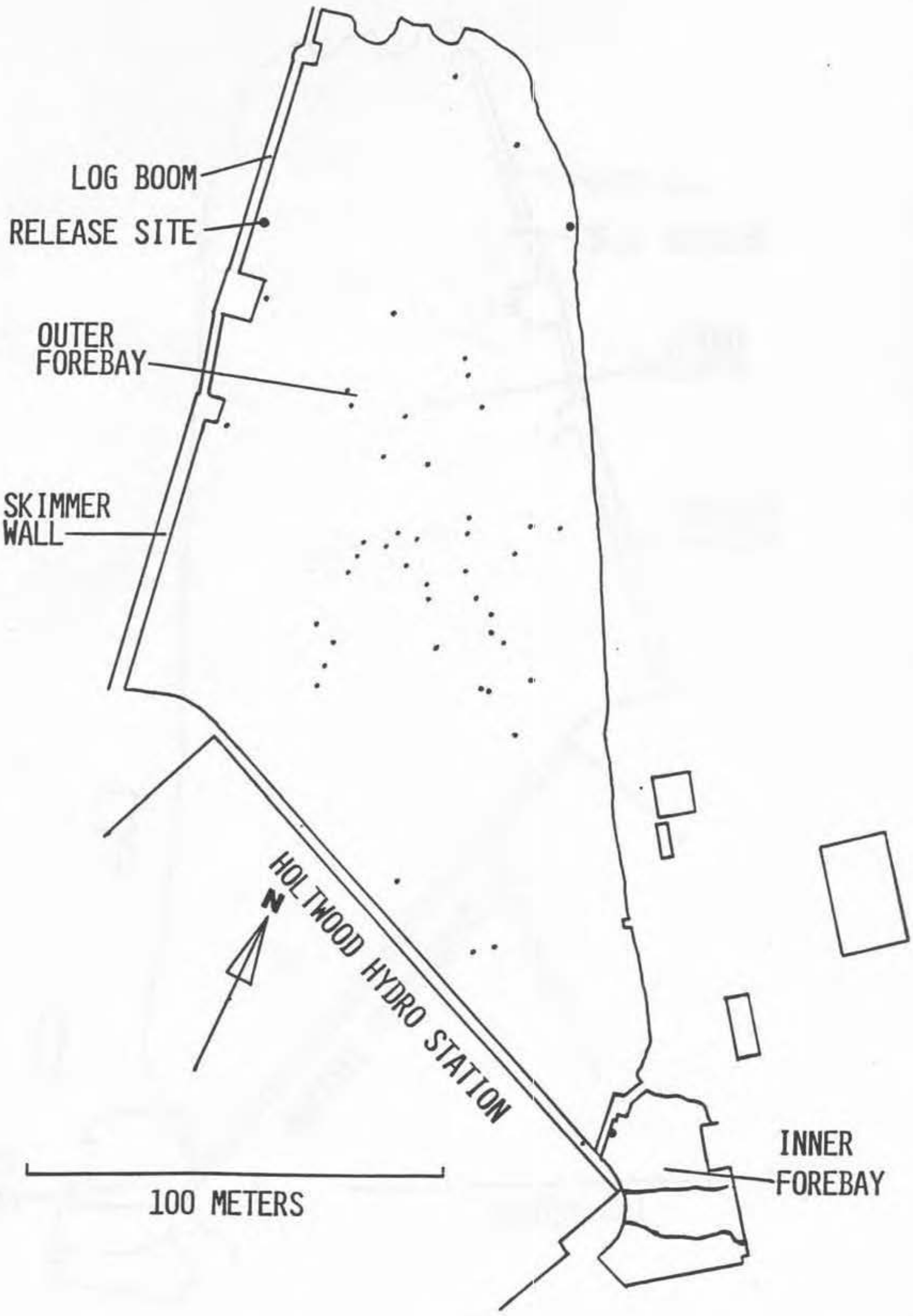


Figure 14

Summary of all fixes on ten shad released in the Holtwood Hydroelectric Station forebay during six unit generation conditions in 1991.

EXHIBIT A

Results of behavioral observations on radio-tagged

versus non-tagged subyearling

American shad (Alosa sapidissima) in a raceway

November 4, 1991

A Technical Report by

Robert M. Ross and Randy M. Bennett

National Fishery Research and Development Laboratory

U.S. Fish and Wildlife Service

Rural Delivery #4, Box 63

Wellsboro, Pennsylvania 16901

for use by

Pennsylvania Fish Commission

Benner Spring Fish Research Station

State College, Pennsylvania

RMC Environmental Services

Muddy Run Ecological Laboratory

Drumore, Pennsylvania

and

Susquehanna River Coordinator

Susquehanna River Basin Commission

Harrisburg, Pennsylvania

This report summarizes results of behavioral observations on tagged and non-tagged juvenile American shad (<u>Alosa</u> <u>sapidissima</u>) in the raceway environment. The purpose of the study was to assess the ability of radio-tagged subyearling shad to maintain "normal" equilibrium and mobility with a relatively large external radio tag attached to the fish through dorsal musculature. Fish tagged in this manner are used in hydropower dam passage studies on the Susquehanna River (see St. Pierre 1991) with the assumption that little if any impairment of normal behavior occurs in test fish.

The study was conducted on 21 October 1991 at the Benner Springs Fish Research Station (Pennsylvania Fish Commission) in central Pennsylvania where both subyearling American shad and sufficiently large study environments (raceways and ponds) were available. Juvenile American shad (≈ 6 from a group of ≈ 100 fish) approximately 100-120 mm total length fish were tagged by hand with dummy radio tags without anesthetics. After a 10-minute acclimation period in the raceway, the behavior of non-tagged fish was first sampled by selecting a representative individual and following it visually as long as possible from a fixed location. All observed behavior was recorded with a lap-top computer/event recorder. When an individual was no longer visible or the school moved too far away, observation continued on a new fish when possible. Thus the behavior of several different fish was sampled during a single observation session. Observation time for behavioral events on control (non-tagged) fish totalled 520 sec. The same protocol was then followed for individual tagged fish, and a total observation time of 594 sec resulted. Analysis then consisted of multiplying all control fish data (number of bouts of specific behavior types and total time spent performing other behavior types) by the ratio of 594/520 to correct for slightly unequal sampling time. These data were graphed but no statistical tests of significance were applied because of the preliminary nature of the study. Types of behavior are defined in Table 1.

The results (Figure 1) show essentially no difference in the amount of time spent aggregating, following, or schooling between tagged and non-tagged fish. Among other forms of behavior (Figure 2), only three, Pivot, Dart, and Parallel Swim, showed notably different frequencies between the two groups. The fewer Pivots and Darts observed in tagged fish suggest that tagged fish were not able to make quick changes in orientation and swim speed. Parallel Orient and Parallel Swim are forms of behavior that lead to Schooling in shad (Ross and Backman, in press). The higher frequency of Parallel Swim in tagged fish suggests that tagged fish break out of and rejoin the school more often than non-tagged fish. Alternatively, they may associate with only a single other fish more often than non-tagged fish. I also found myself stretching the definition of "School" a bit because a greater individual space (inter-individual distance) was consistently observed around tagged fish than non-tagged fish in schools. Finally, tagged fish appeared to swim slightly more slowly than non-tagged fish, with the result that a tagged fish at the head of a school would "lose ground" and become positioned at the tail of the school some time later. Position, however, continued to alternate as the school turned. In a larger body of water, the turn rate of a school could well affect the ability of these fish to stay with the school.

It was pointed out by RMC investigators that larger fish (> 140 mm total length) are generally used for tagging. Such larger tagged fish may well be able to keep up with the school adequately.

Conclusion

Overall, these observations showed that despite a relatively large and cumbersome tag attached to the body wall of a relatively small fish, these fish resembled their non-tagged counterparts remarkably well in terms of behavior, equilibrium, and orientation. Certainly short-term movement and distributional studies on the order of minutes and hours should provide reasonably reliable information using this tagging methodology. On the other hand, there are indications of impaired ability of these fish to avoid or respond to natural predators. Over a period of days, therefore, increasingly biased results could be obtained.

References

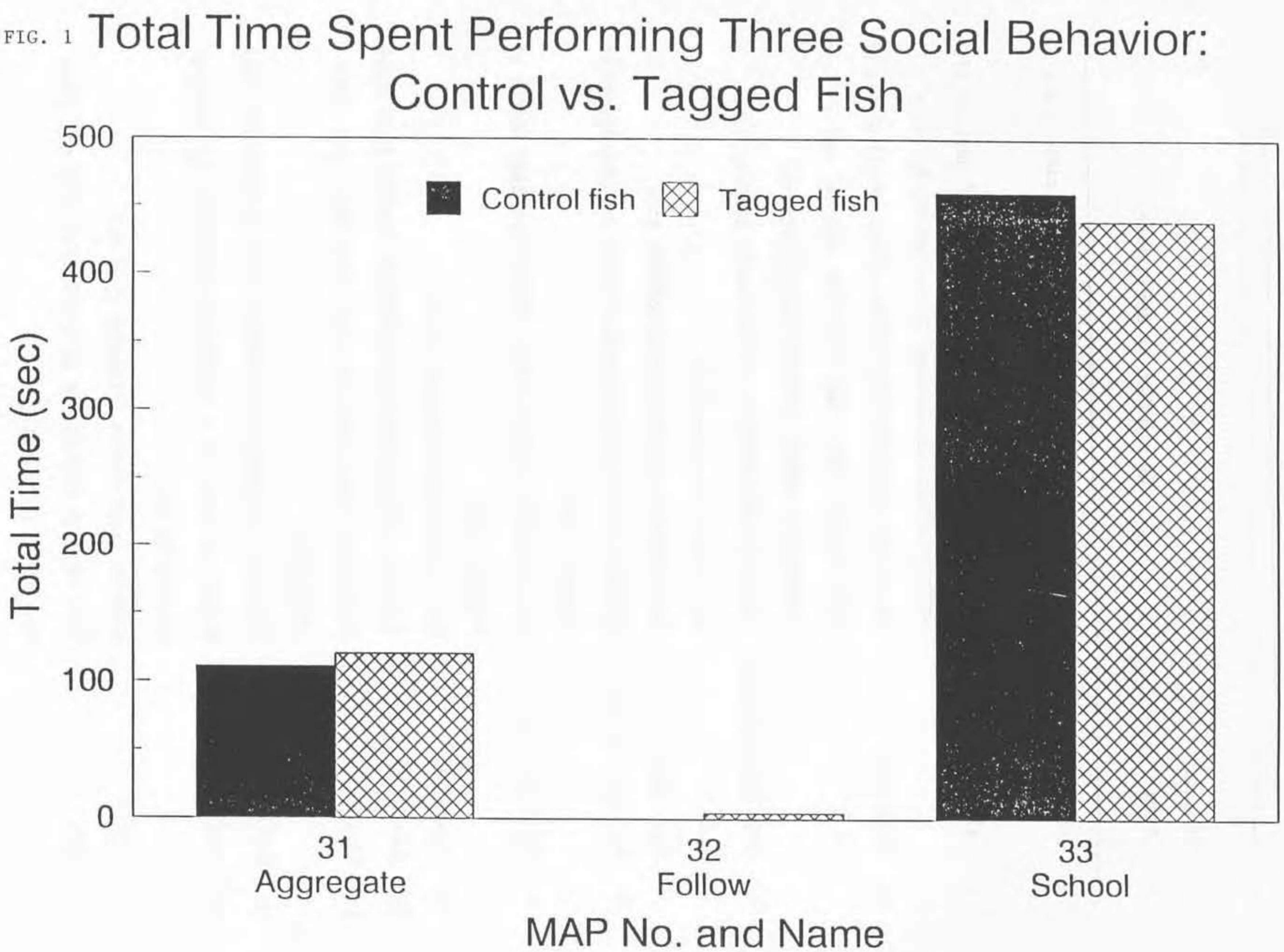
Ross, R. M. and T. W. Backman. In press. Mechanisms and function of school formation in subyearling American shad (*Alosa sapidissima*). Journal of Applied Ichthyology

St. Pierre, R. (editor). 1991. Restoration of American shad to the Susquehanna River: annual progress report 1990. Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, Pennsylvania.

TABLE 1. Modal action patterns (MAPs) or discrete types of behaviour observed in individual subyearling American shad.

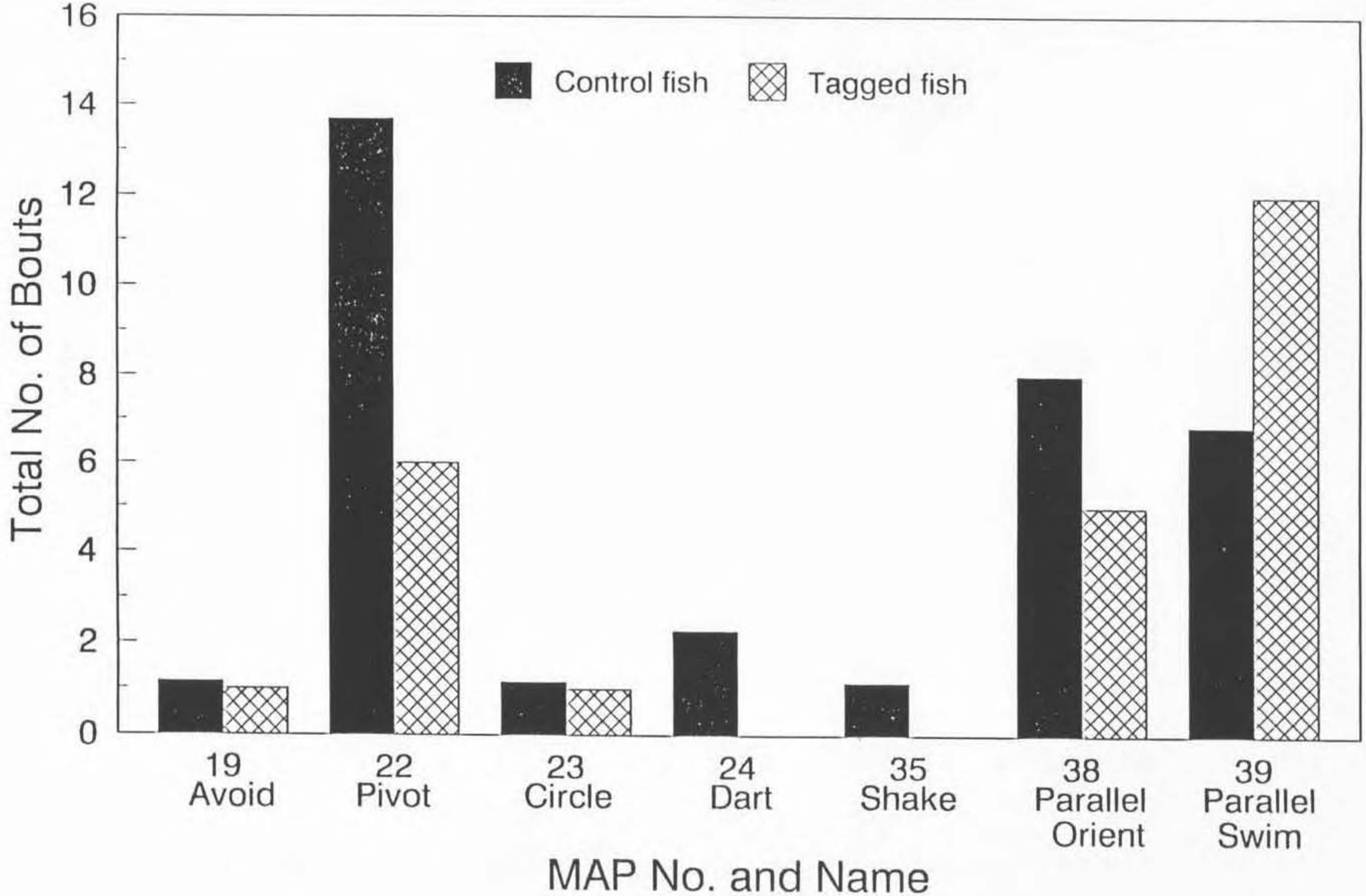
MAP No.	Name	Description or definition
1	School	Swim within one body length and in the same direction as two or more other fish
2	Follow	Swim behind and within a body length of another fish with no other fish lateral to or behind follower
3	Aggregate	Be or move to a position within a body length of two or more other fish; may involve active non-uniform swimming or merely orientation adjustments
4	Swim against tank	Actively swim while in contact with holding tank
5	Yawn	Open jaws to maximum gape
6	Bump tank	Make momentary contact with holding tank
7	Parallel orient	Align parallel, head-to-head, within one body length of another fish
8	Parallel swim	Swim parallel, head-to-head, within one body length of another fish
9	Sigmoid	Body axis forms a sigmoid curve
10	Feed	Remove particle from water column or surface with mouth
11	Bite	Open and close jaws to less than full gape (non-agonistic)
12	Avoid	Respond to proximity of another fish by swimming away
13	Pivot	Orient or swim in a different direction by turning sharply ($\geq$ 45°)
14	Circle	Swim in tight circle (diameter $\leq$ 15 cm)
15	Dart	Swim at high velocity in straight line $\geq$ 15 cm, often continuing erratically
16	Touch surface	Break water surface with any body part
17	Shake	Shudder or vibrate body

FIG. 1



Total Time Spent Performing Three Social Behavior:
Control vs. Tagged Fish
Control fish
Tagged fish
Total Time (sec)
500
400
300
200
100
0
31
Aggregate
32
Follow
33
School
MAP No. and Name

FIG. 2 Total Bouts of Various Behaviors: Control vs. Tagged Fish



JOB V TASK 4

AMERICAN SHAD STUDY: Report on 1991 Serochemical Studies on Response to Transport

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INTRODUCTION:

Basis of Study - Proposals submitted to SRAFRC for 1990 and 1991 were based on relationships that may exist between factors which induce a stress response in fish and serochemical changes which could suggest how such effects manifest as organ specific damage. 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 behavioral changes. 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.

Studies conducted in 1990 demonstrated that among 18 parameters able to be evaluated in shad, as well as two measures of reproductive status, the major serochemical responses were seen in those enzymes reflective of liver and/or muscle damage. In particular alkaline phosphatase (AP), lactate dehydrogenase (LDH), alanine aminotransferase (ALT), and aspartate aminotransferase (AST) were seen to rise following transport. Since the enzymes involved were more specific to the liver, it was felt that the primary organ affected was the liver, though it is possible that the elevated LDH values could be a combination of both liver and muscle damage.

OBJECTIVES OF STUDY:

The original proposal (1989) 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. The 1990 proposal was primarily directed towards the older west lift, however by the spring of 1991 the newer east lift was in place, and studies were expanded to include comparisons of the two lifts. The following objectives outlined in the 1990 proposal for 1991 work were met:

1. Collection and analysis of blood from shad caught at the Conowingo Dam tailrace, prior to being caught and lifted in the traps.
2. Collection and analysis of blood from shad trapped, lifted and sorted at the west lift.
3. Collection and analysis of blood from shad transported, released, or held for 24, 48, and 72 hours in a net pen at a site located in the Susquehanna River.
4. Collection, analysis and comparison of blood responses in fish collected by both the older west and newer east lift traps.

It was not possible to evaluate shad held in tanks at 24, 48, and 72 hour intervals as proposed as the studies would have interfered with the primary objectives of the lift operations. However, due to observed supersaturation of holding water at the east lift, a short study was completed to determine histological and serochemical response in shad to determine if the response seen could explain the mortalities experienced. Analysis of estrogen levels is still incomplete as the observed elevated LDH levels required diverting samples to determine the maximum levels attained in shad during the 1991 season. These studies will be complete and reported in 1992 along with other studies that will have been completed at that time.

METHODOLOGY, TECHNICAL ASPECTS:

Transport Scenario: American shad arrived at the Conowingo Dam approximately in late March and continued to be available until approximately mid to late June. Both lifts are 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 trap they are raised vertically with sufficient water and dumped into a 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. At the west lift the fish are then 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, 48, and 72 hours prior to release.

SPECIFIC METHODOLOGY:

Fish handling: American shad collected at the dam tail race were caught using hook and line, with bleeding performed within one minute after being caught, after which they were released. The remaining shad were collected by the fish trap and placed in holding tanks (west lift) or directly into transport tanks (east lift). At the west lift shad were then dipped and placed in 1000 gallon tank trucks for transport to the release site, or in the case of the est lift moved to the waiting trucks for transport. 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.

Egg Collection, and Analysis: 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 the analyses of blood taken from 250 American shad. These results must be considered preliminary since reference values are not available from shad stocks prior to entering the Susquehanna River.

Serochemical analyses were 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).

Preliminary results for 1991 are essentially the same as reported for 1990. Primary responses were seen in the enzymes ALT, AST, ALP and LDH which are indicative of liver damage. Comparisons of these values between 1990 west lift (90WL) and 1991 dam tail race (91DF), east lift (91EL) and west lift (91WL) are shown in Table 1. Blood carbon dioxide values were seen to be higher in all cases for 1991 as compared with values at the west lift in 1990. Of interest is the lower blood carbon dioxide value seen at the west lift when compared to those collected at the tail race (91DF). All parameters were seen to be higher at both the east and west lifts (note that LDH while having a lower average at the west lift, actually had a greater percentage of individuals that exceeded the detectable limits of 45,000 or greater). Blood ALT, ALP and LDH values were lower at the east lift than the west lift, suggesting that conditions may be less stressful at the east lift. Comparisons against post transport response (Table 2) indicates that all values continued to rise with the exception of AST which varied compared to east and west lift responses, however were much higher than those found at the dam tail race.

The 1991 Net Pen Study is presented in Table 2 (NPD). None of the liver values were seen to diminish as a function of time of holding as seen in NPD study set where fish were followed for 72 hours. Of interest were LDH values which remained in excess of 45,000 in all cases. Special studies were conducted to determine the maximum levels attained in fish with values in excess of 45,000 and the average level was seen to be in excess of 65,000.

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 these studies the collection of fish were at stages in their migratory pattern which would provide the greatest possibility of detecting differences if blood responses were to have occurred (See Figure 1). Since the accuracy of the tests will depend on the numbers of samples taken (See Figure 2-The number of samples will reduce the degree of variance from the mean, thereby increasing ability to resolve differences between any two populations or treatments), it is important that values from other rivers, and populations in less stressful situations be obtained.

The significance of the enzymes discussed is portrayed in figure 3 where the diagram on the left is the hexagonal model of a liver lobule or functional liver unit. In the liver thousands of such units operate to provide normal liver function. In this the center of the liver receives blood that filters between liver cells from the periphery of the lobule where concentrations of oxygen is the highest. The graph on the left shows that oxygen levels at the periportal (pp) or peripheral zones are the highest and begin to reduce as the blood moves toward the center of the lobule (cl). While blood oxygen levels are normally low in the liver, it is the degree of reduction where at some point the levels of oxygen drop below the level at which liver cell function can be held at normal limits. The lower diagram shows that membrane integrity is dependant on oxygen which provides stored energy (ATP) used to maintain that integrity. When the membranes are damaged then cellular constituents such as enzymes leak directly into the blood.

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. Figure 4 on the right, the hypothetical relationship between carbon dioxide and oxygen levels as a function of time is shown. The source of this variation is shown on the left. 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.

Preliminary results on the supersaturation problem experienced at the east lift suggests mortalities may be due to gas emboli occurring in the gills. These emboli stop blood flow, resulting in rapid onset of morbidity and eventual mortality. Histological examination of gills taken from shad, purposely exposed to supersaturation revealed gas emboli and aneurysms reflective of blood stasis. Blood carbon dioxide was also seen to rise (>25 ppm). These changes provide strong evidence for gas bubble (oxygen) formation as the cause of observed mortalities.

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

ACKNOWLEDGEMENTS:

We gratefully appreciate the assistance of the staff of RMC Environmental Services Inc. who helped in getting the fish, blood collection, and coordinating activities so that appropriate samples could be taken. The Philadelphia Electric Power Company, was very cooperative and helped facilitate completion of this phase of the project. Also, to the laboratory staff of AIP Inc., we give thanks for technical assistance and advice as well as rapid analysis. This work was conducted through funds provided by the Susquehanna Anadromous Fish Restoration Committee.

TABLE 1: Averages of Blood Values Taken from Serum of American Shad Caught, Lifted, Transported, and Held During Lift Operations at the Conowingo Dam

	LOCATION			
	90 WL	91 DF	91 EL	91 WL
PARAMETER				
CO_2	11.0	16.2	18.7	14.7
ALT	1.50	6.25	29.80	83.80
AST	228.00	125.10	653.52	607.81
ALP	59.64	51.45	74.96	96.01
LDH				
Ave:	17,155	18,584	33,573	32,636
% > 45,000	10%	20%	52%	70%

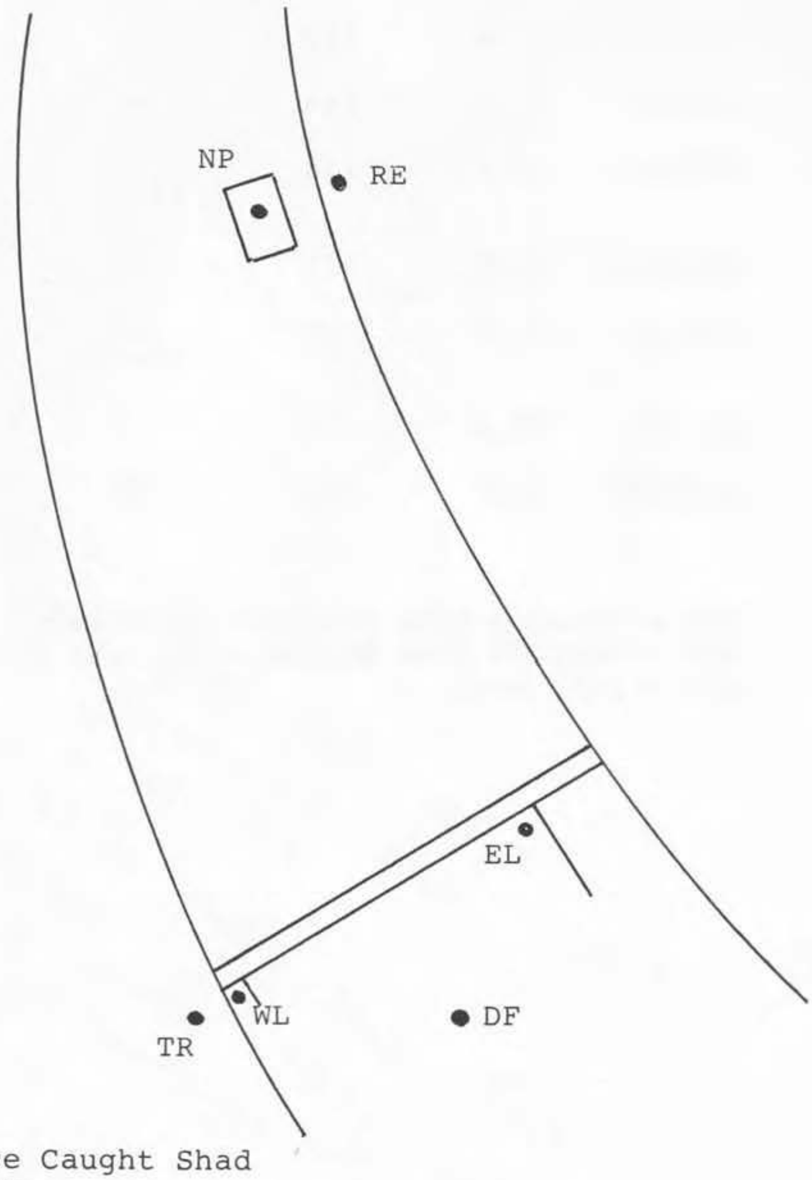
Abbreviations:
- WL = West Lift
- DF = Dam Face
- EL = East Life
- CO_2 = Serum Carbon Dioxide
- ALT, AST, ALP, LDH = Liver Associated Enzymes
- Ave = Average
- % > 45,000 = Number of Shad per Sample that Exceeded Detection Limit of 45,000 units per ml

TABLE 2: Net Pen Study, 1990 Through 1991

	DATE	CO_2	AlkPho	ALT	AST	LDH
NPA	5/23/91	23.5	152	60	1590	+45,000
	5/28/91	27.6	140.5	97	2174	+45,000
NPD	5/29/91	20.9	154	190 (272)	614 (2444)	+45,000
	5/30/91	25.7	122	116	405	+45,000
	5/31/91	24.7	116	179 (398)	591 (939)	+45,000
NPC	6/1/90	26.4	107	7	501	+45,000
	6/13/90	22.7	123	15	1586	+45,000

NPA - Release Site Bloods - No Holding
NPD - Release Site Bloods - 24, 48, 72 Hour Holding
NPC - 1990 Data

Figure 1. Sampling Points for 1990-1991 American Shad Studies



DF = Tail Race Caught Shad
EL = East Lift
WL = West Lift
TR = Trap
RE = Release Site
NP = Net Pen

Figure 2. Relationship Between Numbers of Samples [S], Blood Values [C] and Accuracy (2x) Defined as 2x the Standard Deviation About the Mean (M).

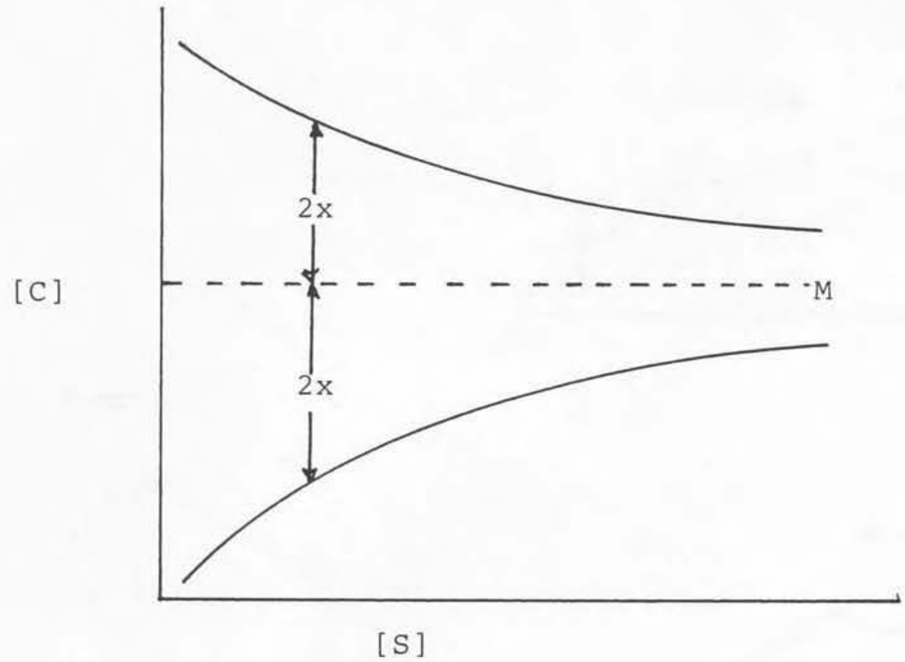


Figure 3. Dissolved Oxygen Levels $[O_2]$ (Graph A) as Function of Distance from Periportal (PP) to Centrilobular (CL) Zone, Function of Oxygen to Provide ATP or Energy for Liver Cell Function (Diagram A), and Hexagonal Liver Model (Diagram B) Showing High (H), Medium (M), and Low (L) Oxygen Zones.

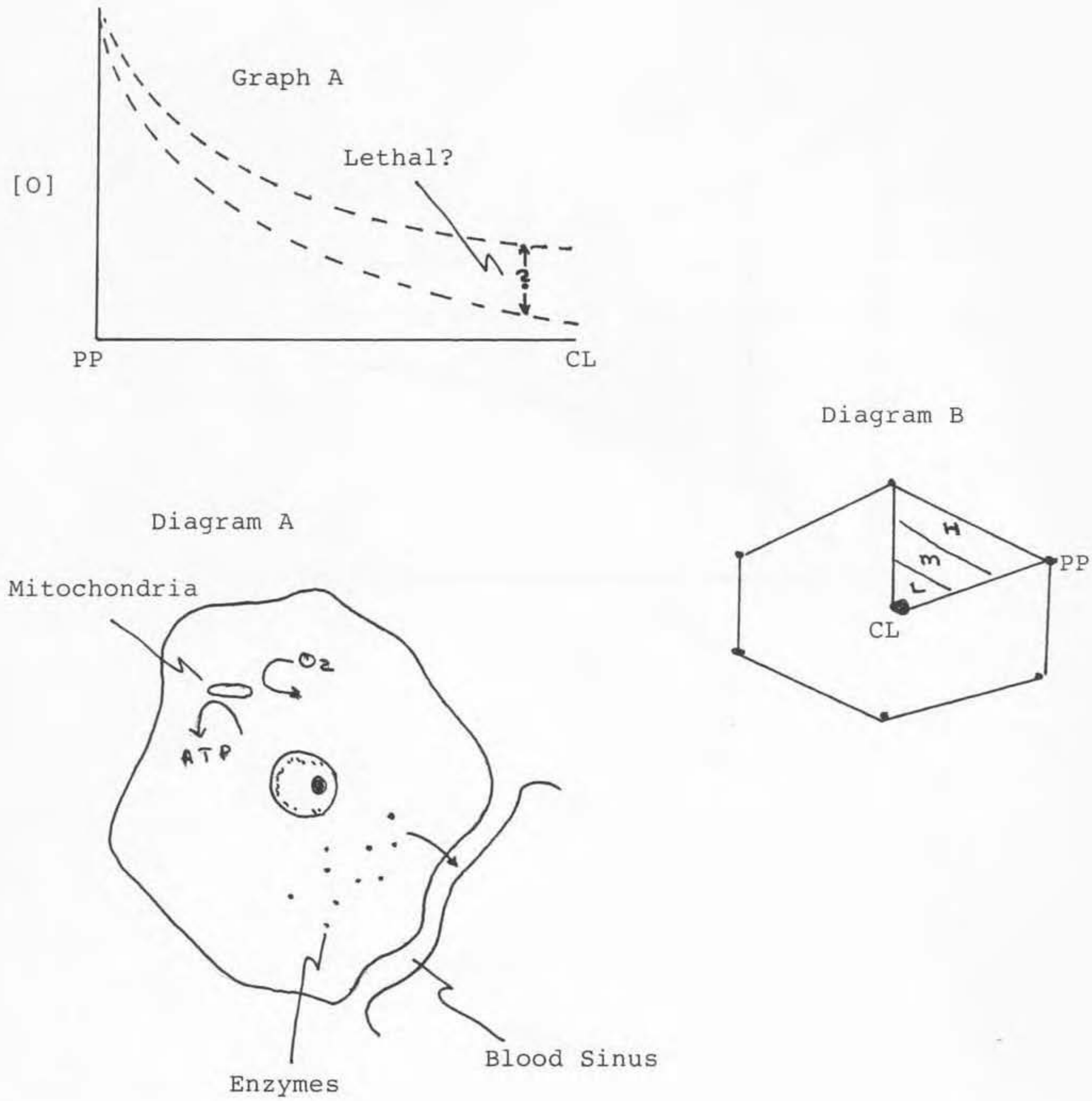
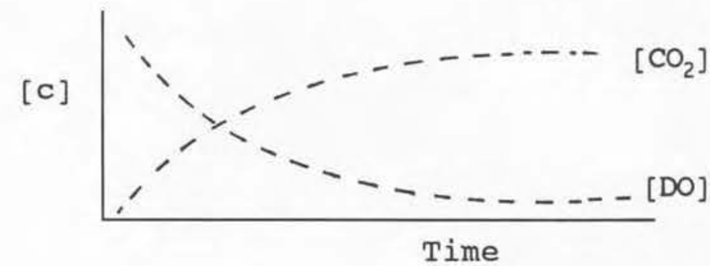
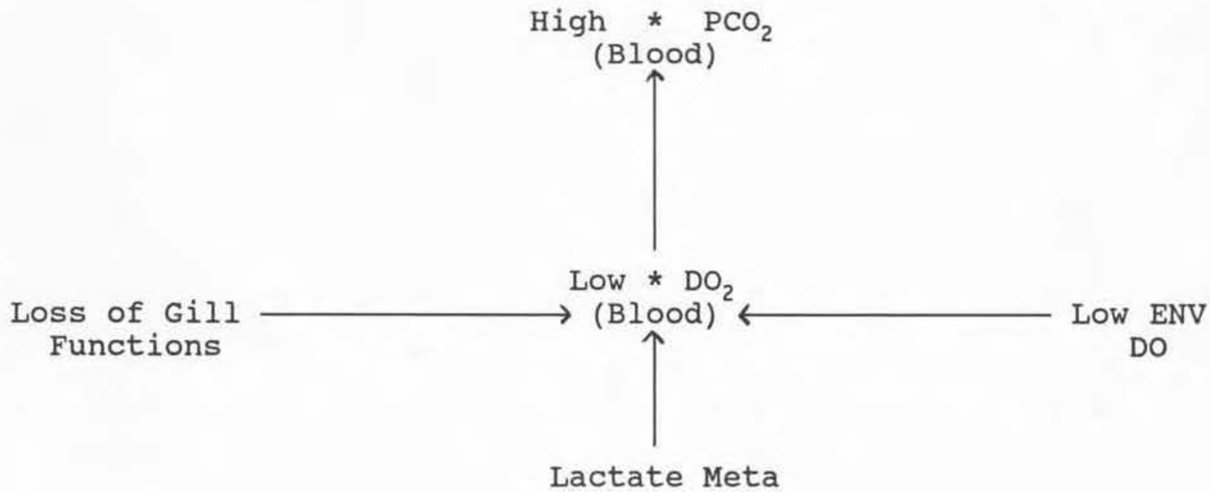


Figure 4: Causes of low blood oxygen (PO_2) as reflected by high blood carbon dioxide (PCO_2) and relationship between PCO_2 and PO_2 in blood (right).





JOB V, TASK 5.

COMPARISON OF STOCKING METHODS ON DISPERSAL BEHAVIOR OF TRANSFERRED ADULT AMERICAN SHAD IN THE SUSQUEHANNA RIVER

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ABSTRACT

Behavior and movement patterns of adult American shad (*Alosa sapidissima*) were evaluated using radio telemetry to determine if fish stocked in a net pen showed enhanced upriver movement, schooling behavior, or residency time compared to those released directly into the Susquehanna River.

A total of 52 adult American shad was radio tagged and released by RMC Environmental Services at Tri-County Marina in four groups of 15, 14, 15, and 8. Thirty fish were released directly into the river, and 22 were released into the net pen. Releases were made on 14-15 May and 21-22 May under similar conditions. Seven fish either regurgitated their tags or died.

Most fish moved downriver upon release. No enhanced upstream movement patterns or schooling behavior were observed in penned shad. This may be attributed to high water temperatures at the time of fish stocking (>70°F). American shad peak spawning temperature is 65-68° F. Fish displayed limited upstream movement. The average distance travelled by a penned fish was <10 miles upstream of the release site. Typically, a penned fish spent approximately 10 days above York Haven Dam.

not true!

Fish released directly into the river showed similar behavioral patterns. Tagged fish did not exhibit schooling behavior.

It was concluded that the net pen was not effective in enhancing the upstream movement of American shad under the prevailing water temperature conditions studied. Radio tagged shad may have spawned within a short time after release.

INTRODUCTION

The effectiveness of efforts to restore American shad (Alosa sapidissima) to the Susquehanna River is ultimately measured in terms of the number and reproductive success of trapped and transported adults that reach suitable upriver spawning grounds. In past years, American shad have been transported beyond upstream dams and stocked directly into the river. In an effort to determine if shad stocked in a net pen would benefit the restoration program, a net pen was installed at the Tri-County Marina in the spring of 1990. The purpose of holding shad in the net pen was to: (1) reduce stress from trap and transport and (2) enhance schooling behavior for increased reproduction. In a previous study (May and Koch 1991) fish held in a net pen displayed physiological signs of reduced stress, and they appeared to school initially upon release. The question still remained, how did behavior and movement of fish stocked in the net pen compare with fish released directly into the river? The objective of this study was to compare the behavior of radio tagged American shad stocked in a net pen and released directly into the river and to determine the benefits of each method. SRAFRC contracted RMC Environmental Services to accomplish this objective.

METHODS AND MATERIALS

Radio Tagging

Adult American shad caught at Conowingo Dam's west fish lift were individually removed from the sorting tank and a radio transmitter was orally inserted into the fish's stomach using a wooden cannula. The fish was then placed into a holding tank for transport.

Advanced Telemetry Systems radio transmitters used for this study measured 55 mm in length and 12 mm in diameter and weighed an average 10 g out of water. The transmitters propagated signals on 30 unique frequencies from 150.180 to 150.970 MHz at 60 or 90 ppm via a 300 mm trailing whip antenna. Tag life was estimated to be three months.

Radio tagged fish were transported along with untagged fish for release into the net pen and river. Upon arrival at Tri-County Marina, fish were released either directly into the net pen or the river. The net pen was stocked with tagged shad one day prior to shad stocked in the river. Penned shad were released at the same time of the day as those shad that were stocked into the river. Two groups of fish were released: Group I on 14-15 May and Group II on 21-22 May. Group I consisted of 29 fish, 14 released into the net pen and 15 directly into the river. Group II consisted of 23 fish, 8 released into the net pen and 15 into the river.

Monitoring

Four Lotek SRX_400 constant monitors were installed at York Haven forebay, Dock Street Dam's east shore breach, the mouth of the Juniata River, and the east side of the inflatable dam at Sunbury. Monitors were installed in areas where concentrations of shad were expected, while allowing the greatest amount of pertinent information to be obtained on upstream and downstream movements. Additionally, to monitor the vast expanse of river manual fixes by airplane were taken on three separate occasions to locate fish. Fish fixes were also made manually to survey the release site and York Haven Dam. All manual tracking was done using a Lotek SRX_400 receiver and Cushcraft four element Yagi (Model P-150-4). Aerial tracking was conducted on three occasions (May 24, May 31, and June 7, 1991) using a strut mounted Yagi antenna on a Cessna 172 aircraft. Two RMC biologists worked as a team, one tracking fish while the other plotted the locations on a map. The extent of river surveyed during each flight included the mouth of the Susquehanna River to the West Branch at Sunbury, and from the Confluence of the Juniata and Susquehanna rivers to Thompsontown.

York Haven's antenna configuration consisted of a dipole antenna (ARX-2B) covering the forebay and a Yagi positioned to cover the area upstream along the spillway. The antenna at Dock Street was situated on the roof of the North Front Street Sewage Pumping Station. The Yagi antenna was oriented directly across the river just downriver of the dam. The mouth of the Juniata River was blanketed by two Yagi antennas located behind the Tool Shed. The Yagis were attached to a single pole and set at a 30° angle from one another with the bisected angle facing directly across the Juniata River. The antenna at Sunbury was located atop the red brick Municipal Building that houses the compressed air pumps for the inflatable dam. The Yagi antenna was directed across the river just downstream of the dam.

Prior to fish release, site noise floor levels were determined and receivers were calibrated to decrease background noise through RF gain reduction, global noise reduction, and noise threshold features provided in the software for the Lotek SRX_400 receiver. The scan time for the receivers was set at three seconds. When a suspected signal was received, the scan program attempted to verify the validity of the signal by measuring the duration of a preselected number of pulse intervals and statistically analyzing the differences. Data were stored as either a single event or a period of multiple events. Fish moving out of the receiver's range for more than five minutes before moving back in range were considered separate fixes. The data logged by the receiver consisted of: start date, start time, tag frequency, average pulse rate, average signal strength, interval standard deviation, number of events recorded, number of events suspect, end date and end time.

Data Retrieval

Retrieval of data was performed using a Toshiba 1200HB lap-top computer via a Packard Bell 2400 Plus External Modem. Data were stored on a three and one-half inch double sided, high density diskette.

Data were critically analyzed to determine validity. Expected pulse rate ranges were established for each transmitter and receiver. If a recorded pulse rate did not fall within this range, the record was discarded. Those fixes deemed not credible were also discarded. In addition, the remaining records were critically reviewed in terms of signal strength, and time intervals between fixes at different monitors.

RESULTS

A total of 52 radio tagged shad was released from Tri-County Marina (Figure 1). Thirty were released directly into the river and 22 into the net pen (Tables 1 and 2). Seven fish either regurgitated their tags or died after stocking and were not included in the calculations. Water temperature for both releases was 73.4°F (23°C). No substantial differences in the movement of the two release groups were noted. Upstream movement was limited. Most of the tagged fish remained near the area of release or moved downstream. Those fish moving downstream within the first six days of tagging did not show upstream movement.

Movement patterns of nine fish were unknown. Of the remaining 36 fish 16 moved upriver initially upon release. None of the tagged fish were detected at Sunbury (RM 123). However, one penned female was detected by plane between the Juniata and Sunbury monitors (RM 93); it never entered the Juniata River (Figures 2 to 4). Only six fish (16.7%) entered the Juniata River (Tables 1 and 2), an upstream movement of 25 miles. Of these, 4 (23.5%) were stocked in the net pen and 2 (10.5%) were released in river. Aerial surveys showed that none of the fish entering the Juniata River were observed more than one-quarter of a mile inside the mouth.

3 surveys!

Travel time of the six fish to the Juniata River ranged from 2 to 6 days (Tables 1 and 2). The average time it took a penned fish to reach the Juniata River was five days compared to three days for the in river fish.

Thirteen fish (36.1%), seven males and six females, moved 10 miles upstream to Dock Street Dam (RM 70). Eight of these fish were from the net pen, while five were released directly into the river.

Three other fish showed initial upriver movement and were located by plane at River Mile 65, 63, and 63 (Figure 2). Two were from the net pen and one was released in the river, respectively. All were from release Group I and all were male.

Residency time above York Haven Dam was short (Tables 1 and 2). Overall, total residency time from release to passage at York Haven Dam (RM 56) averaged 10.4 days. Residency time of Group I fish was slightly higher than for the Group II fish (12.7 days vs. 8.1 days).

At the end of the monitoring period 13 fish (36.1%) were alive and the tags of 23 fish (63.9%) were stationary (Figure 5). The exact status of these stationary could not be determined. Tags could have been regurgitated or fish may have died. The status of net pen fish was as follows, six fish (35.3%) alive, and 11 (64.7%) stationary. Status of fish released in the river was, 7 fish (36.8%) alive, 12 (63.2%) stationary.

DISCUSSION

Overall, the net pen at Tri-County Marina had little effect on the movement patterns and behavior of adult American shad. The purpose for stocking shad into the net pen was to enhance upriver movement, schooling behavior, and total residency time. After a month of tracking, evaluation of data showed in river fish fared as well as penned fish. The average upriver movement of net pen fish was less than 10 miles, comparable to that of fish released into the river. It is likely that the lack of substantial upstream movement was due to high water temperature which may have encouraged shad to spawn shortly after stocking. Observations of shad stocked in the net pen indicated that spawning occurred within three days of captivity. Unfortunately, the net pen could not be installed until the river flows decreased to less than 40,000 cfs. By this time water temperature had increased to over 70° F, past the peak spawning temperature of American shad. Thus, in order to evaluate the true benefits of penning shad using radio telemetry, fish should be released at lower water temperatures earlier in the spawning season.

Schooling behavior of released radio tagged shad was not observed. The monitors upriver of the release site never logged two or more fish simultaneously entering or leaving an area. Those fish that were logged on the same monitor did not appear to be together for a long period. Surveillance by plane confirmed the lack of schooling. Fish locations were scattered over a wide area. However, large numbers of emigrating tagged and non-tagged fish were concentrated in the intake canal of the York Haven Hydro Station. The location of stationary tags could not be precisely determined from aerial surveys to assign a specific cause and effect relationship.

A temporary malfunction of the monitor at York Haven Dam precluded determination of the exact departure times and passage routes of several fish moving downstream early in the study. Subsequent monitoring by plane failed to reveal the presence of these fish downriver to the mouth of the Susquehanna. These fish were not detected at upstream monitors indicating that they did not move upstream appreciably and if exited through the sluice they would not have been detected due to malfunction of the monitor. On 17 and 24 May, the sluice gate at York Haven Hydroelectric Station was opened for three hours during rack raking.

Water temperatures during much of the study period were 77° F, above the normal peak spawning temperature range of 65 to 68° F, which may have retarded upstream movement or stimulated spawning soon after release.

LITERATURE CITED

May, E., and T. Koch. 1991. Evaluation of serochemical markers to demonstrate stress response to transported shad, pp. 5-53 to 5-88. IN Restoration of American shad to the Susquehanna River. 1990 Ann. Prog. Rept., Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA.

Only 2 of 8 detected at Dock St.

Table 1

Summary of radio tagged adult American shad released into the net pen and Susquehanna River at Tri-County Marina on May 14-15, 1991. Water temperature was 73.4° F at the time of stocking.

Fish Number and Sex		Movement Direction	1st Fix Dock St.	1st Fix Juniata	Furthest Fix Upriver-RM	Last Fix Above York Haven	Residency Time above York Haven (Days)	Status End of Monitoring (June 10th)
				In River Release (4 above rel)				
181	Male	Unknown						Unknown
221	Female	Unknown						Unknown
321	Female	Upriver	*	May 18th	85	June 10th	25	Alive
421	Female	Upriver	*		76	May 24th	>8	Alive
441	Male	Downriver				Early Departure	<13	Alive
481	Male	Upriver	May 23rd		70	June 7th	13	Stationary
501	Female	Unknown						Unknown
521	Male	Unknown						Unknown
561	Female	Unknown						Unknown
591	Female	Stationary						Stationary
631	Female	Downriver				Early Departure	<13	Stationary
651	Male	Downriver			60	June 5th	20	Stationary
771	Male	Downriver				Early Departure	<8	Stationary
851	Male	Upriver			63	June 7th	8	Stationary
971	Female	Downriver				Early Departure	<13	Stationary
				Net Pen Release (6 above rel.)				
241	Male	Unknown						Unknown
271	Male	Upriver			65	May 31st	15	Stationary
301	Female	Upriver	*	May 20th	85	May 21st	6	Stationary
341	Male	Upriver	*	May 18th	85	June 7th	8	Stationary
361	Female	Unknown						Unknown
381	Male	Downriver			56	May 24th	8	Stationary
401	Female	Downriver				Early Departure	<8	Stationary
541	Male	Upriver			63	June 7th	>21	Alive
611	Male	Stationary						Stationary
671	Male	Upriver	*	May 21st	85	May 21st	>6	Alive
711	Male	Upriver	May 23rd		70	May 31st	15	Alive
751	Female	Stationary						Stationary
811	Female	Downriver			56	June 7th	21	Stationary
901	Female	Stationary						Stationary

* Indicates fish passed Dock Street Dam, but was not detected by the monitor.

Table 2

Summary of radio tagged adult American shad released into the net pen and Susquehanna River at Tri-County Marina on May 21-22, 1991. Water temperature was 73.4° F at the time of stocking.

Fish Number and Sex		Movement Direction	1st Fix Dock St.	1st Fix Juniata	Furthest Fix Upriver-RM	Last Fix Above York Haven	Residency Time above York Haven (Days)	Status End of Monitoring (June 10th)
					In River Release			
222	Female	Downriver			56	May 24th	1	Stationary
242	Female	Stationary						Stationary
322	Male	Downriver			56	May 30th	7	Alive
442	Male	Upriver	May 25th		70	June 7th	11	Stationary
462	Male	Downriver			56	May 31st	9	Alive
502	Female	Unknown						Unknown
542	Male	Stationary						Stationary
632	Female	Unknown						Unknown
652	Male	Downriver			60	May 29th	6	Stationary
672	Male	Downriver			56	June 6th	13	Stationary
712	Male	Downriver			56	June 1st	10	Stationary
752	Female	Upriver	*	May 25th	85	May 29th	>6	Alive
772	Female	Stationary						Stationary
812	Male	Downriver			60	June 7th	14	Stationary
902	Female	Downriver			56	May 29th	7	Alive
					Net Pen Release			
182	Female	Upriver	May 24th		93	June 5th	>14	Alive
272	Male	Downriver			56	May 24th	1	Stationary
342	Female	Upriver	May 23rd	May 29th	85	June 7th	6	Stationary
382	Female	Downriver			56	May 31st	8	Alive
562	Male	Upriver	May 27th		70	May 30th	7	Stationary
592	Female	Downriver			56	May 31st	>8	Alive
612	Male	Upriver	May 24th		70	June 7th	14	Stationary
972	Female	Downriver			56	June 7th	11	Stationary

* Indicates fish passed Dock Street Dam, but was not detected by the monitor.

LOCATION OF CONSTANT MONITORS

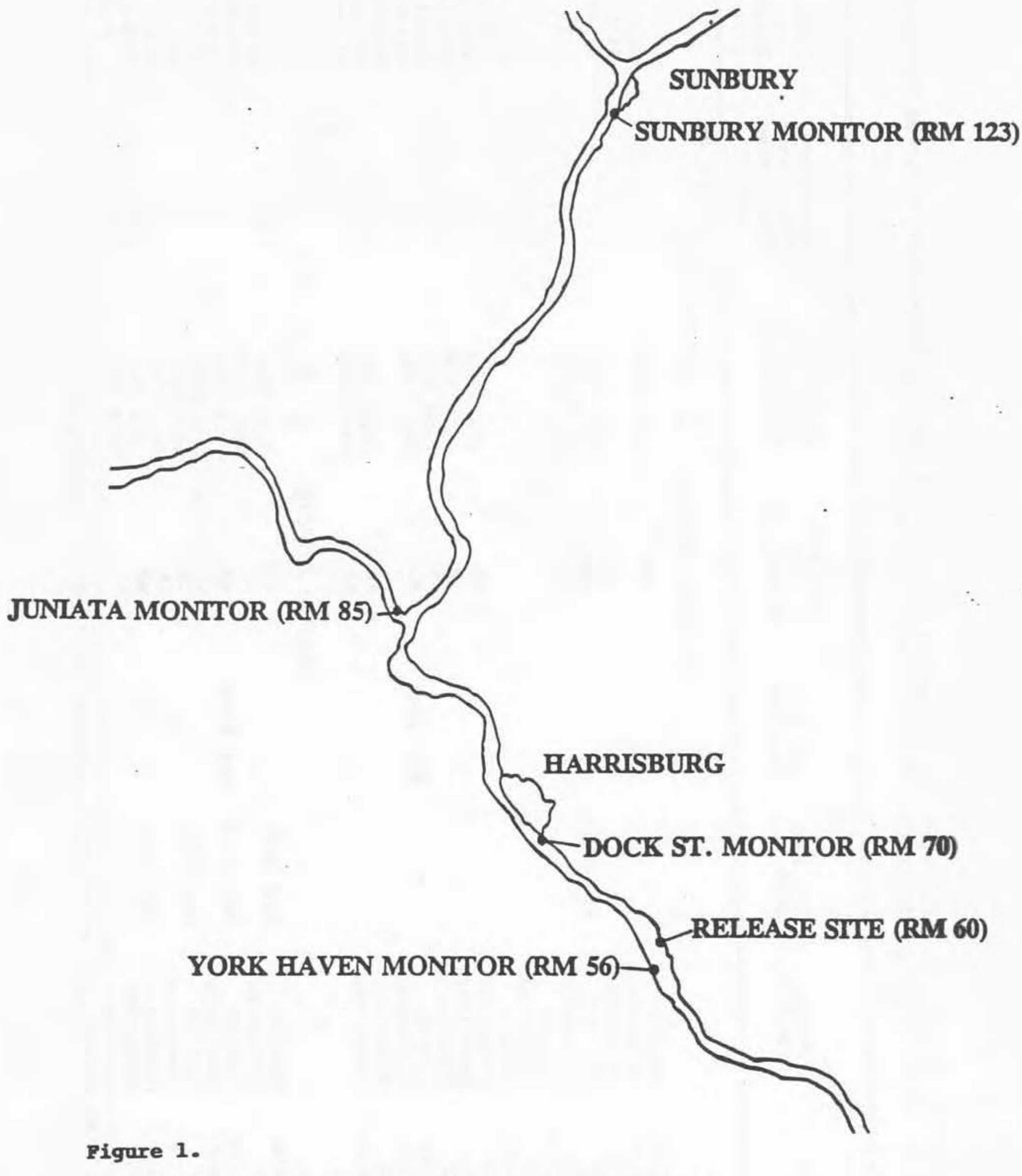
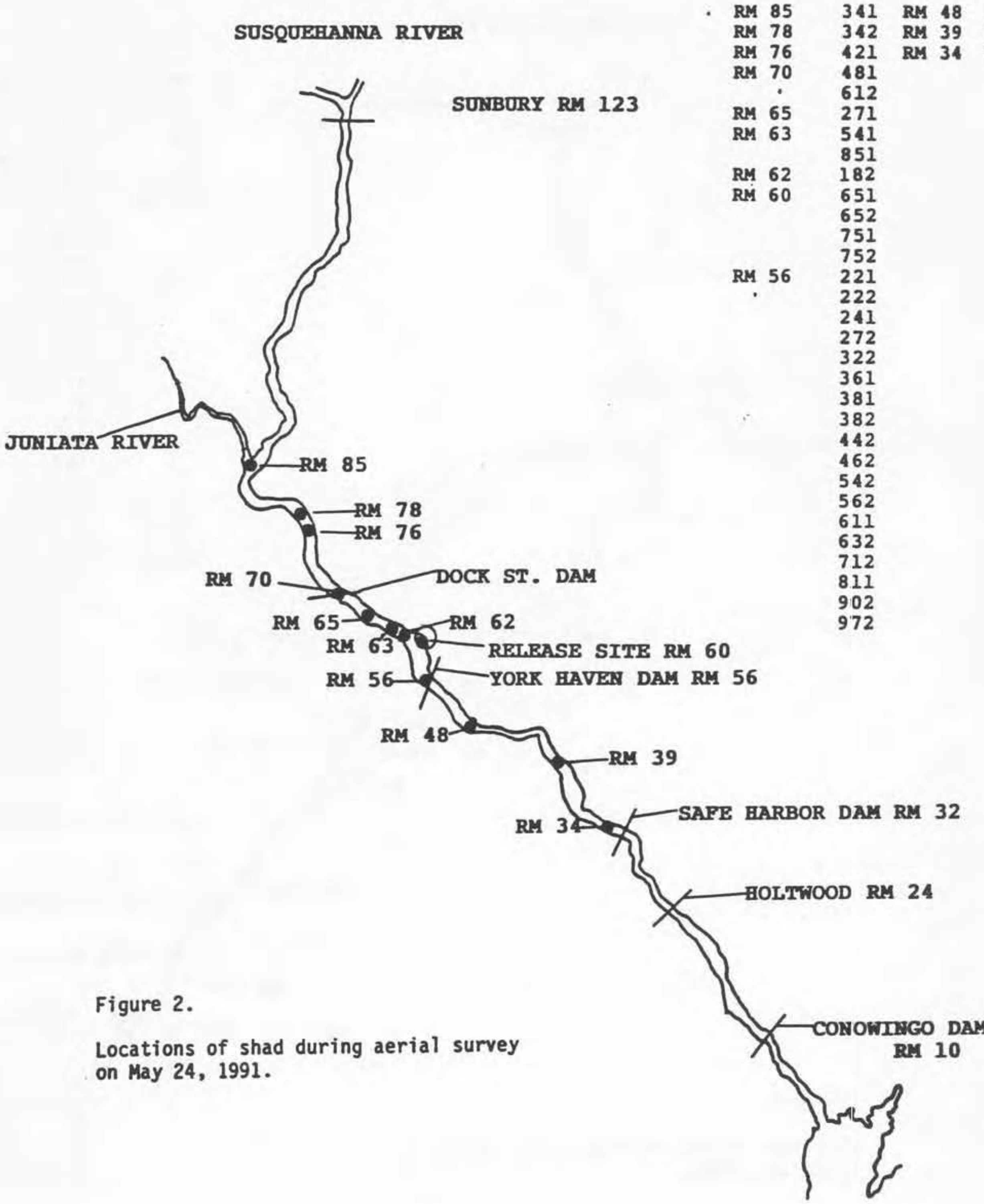


Figure 1.

Location of release site and constant monitors.



May 24, 1991-0945-1300 hr

	Fish No.		Fish No.
RM 85	341	RM 48	401
RM 78	342	RM 39	301
RM 76	421	RM 34	771
RM 70	481		
	612		
RM 65	271		
RM 63	541		
	851		
RM 62	182		
RM 60	651		
	652		
	751		
	752		
RM 56	221		
	222		
	241		
	272		
	322		
	361		
	381		
	382		
	442		
	462		
	542		
	562		
	611		
	632		
	712		
	811		
	902		
	972		

Figure 2.

Locations of shad during aerial survey on May 24, 1991.

May 31, 1991-0950-1330 hr

	Fish No.		Fish No.
RM 93	182	RM 39	272
RM 85	341		301
RM 82	342	RM 26	771
RM 63	422	RM 24	381
	442	RM 20	401
RM 60	302	RM 17	971
	711	RM 11	631
	812	RM 9	441
RM 56	402		
	462		
	481		
	541		
	591		
	612		
	712		
	772		
	811		
	851		
	901		
	972		
RM 55	271		
	382		
	611		
RM 48	222		
RM 47	902		
RM 46	562		
RM 40	652		

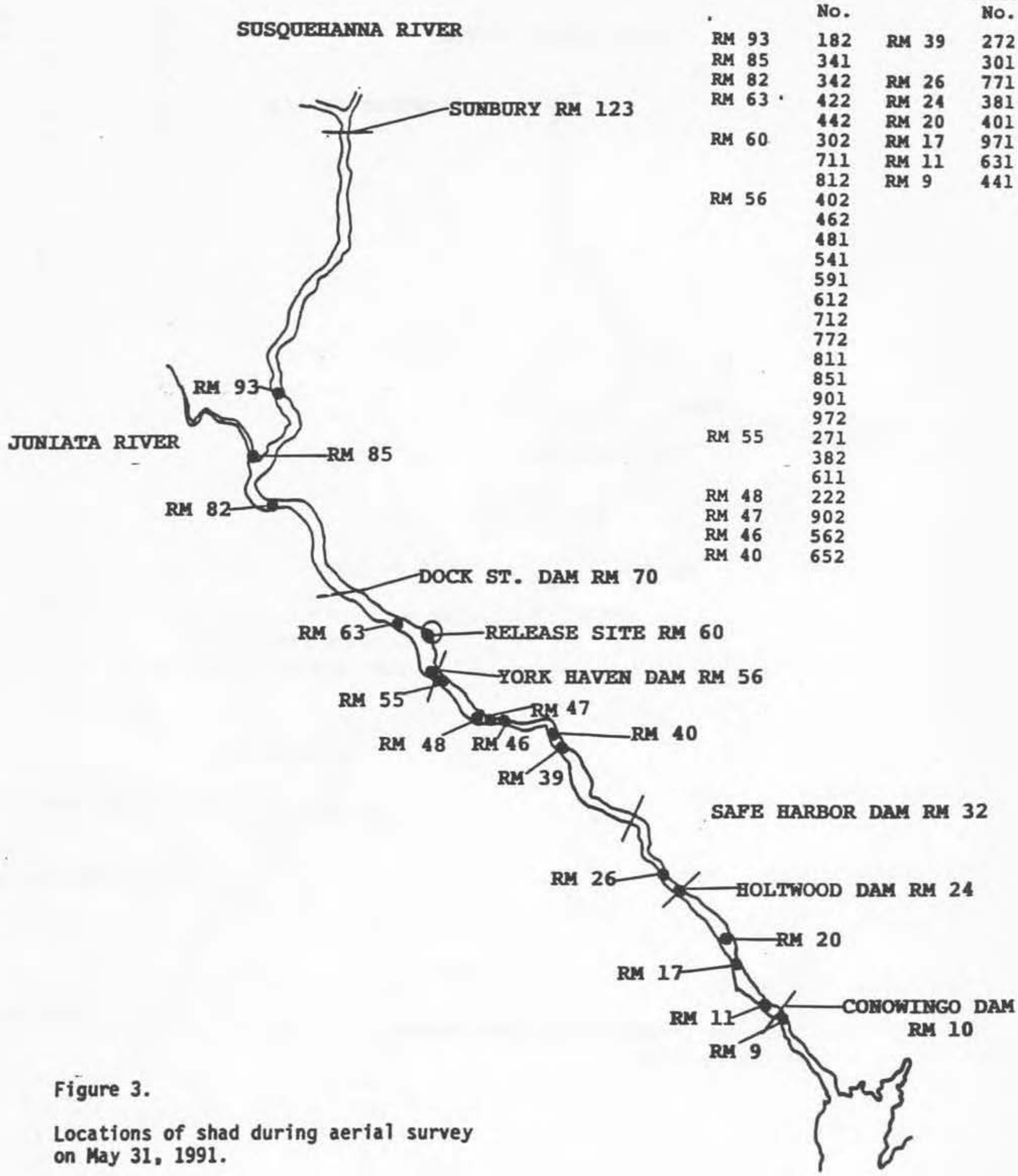


Figure 3.

Locations of shad during aerial survey on May 31, 1991.

SUSQUEHANNA RIVER

June 7, 1991-0945-1320 hr

	Fish No.		Fish No.
RM 85	341	RM 48	222
RM 82	342	RM 46	422
RM 62	541		562
RM 60	302	RM 42	462
	751	RM 40	322
RM 56	402		652
	772	RM 39	272
	851		301
RM 55	271	RM 26	771
	442	RM 24	381
	481	RM 20	401
	542	RM 10	631
	591		971
	611		
	612		
	651		
	672		
	712		
	811		
	812		
	972		

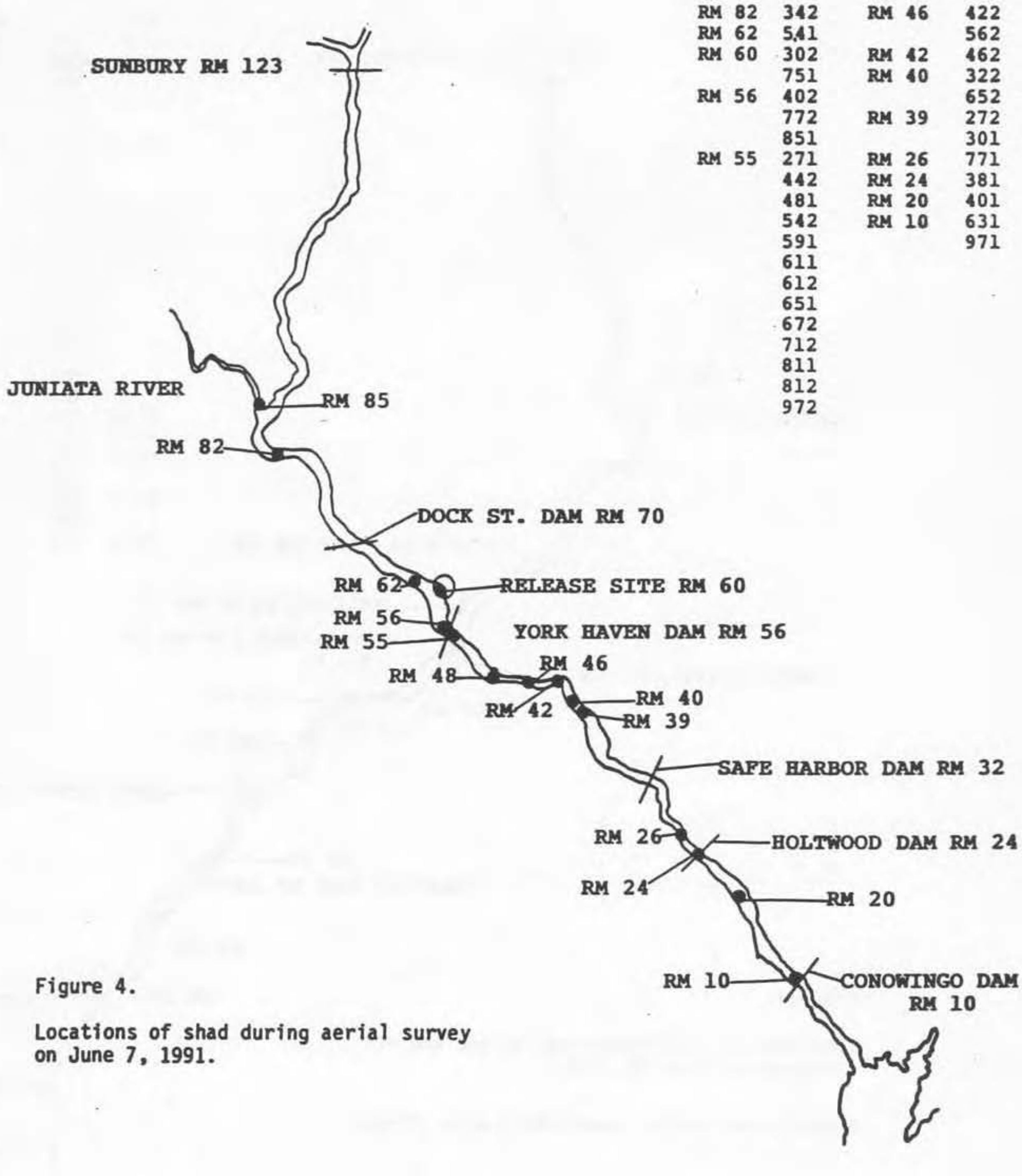


Figure 4.

Locations of shad during aerial survey on June 7, 1991.

June 10, 1991

	Fish No.		Fish No.
RM 85	341	RM 24	381
RM 82	342	RM 20	401
RM 60	*242	RM 10	631
	*751		971
RM 56	851		
	*901		
RM 55	271		
	442		
	481		
	*542		
	*591		
	*611		
	612		
	651		
	672		
	712		
	*772		
	811		
	812		
RM 48	222		
RM 46	562		
RM 40	272		
	652		
RM 39	272		
	301		
RM 26	771		

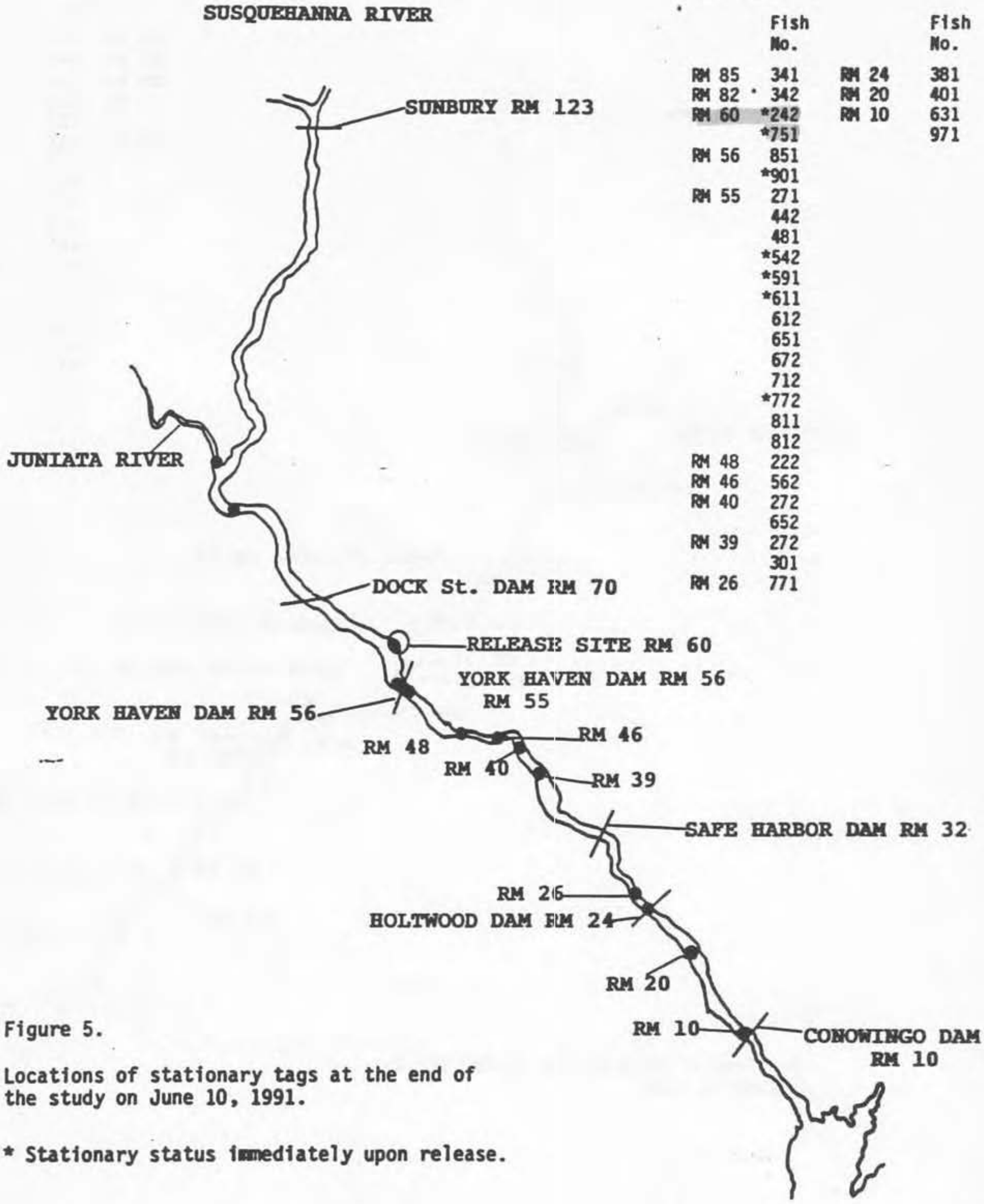


Figure 5.

Locations of stationary tags at the end of the study on June 10, 1991.

* Stationary status immediately upon release.

JOB V, Task 6. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad in the Susquehanna River.

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Introduction

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

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

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

Tetracycline marking may be of limited use for adult shad since adequate control fish cannot be maintained to determine mark retention to adulthood. Marking rates can therefore be used only to determine <u>minimum</u> contribution of hatchery-reared fish. In addition, since mark retention did not approach 100% until 1987 and Susquehanna River American shad spawn at ages 3-5, unmarked adult hatchery shad may be returning to Conowingo in numbers until at least 1992 or 1993.

In Spring 1987, it was observed that otoliths of "wild" Susquehanna River juvenile American shad (as determined by the absence of an OTC mark) appeared to have different microstructural characteristics than hatchery-reared shad. Specifically, the increments formed during the first 20 days appeared to be wider and more distinct in wild juveniles than in hatchery-reared fish. In addition, hatchery-reared fish exhibited an increase in increment width and definition somewhere around increment 20-25, possibly as a result of increased growth rate after stocking. In this study we developed a method to distinguish between wild and hatchery-reared American shad based solely on otolith microstructure. This is a final report summarizing work accomplished since 1988.

Literature Review

The following discussion of fish otoliths, their increment formation, and application to the study, while not complete, is taken largely from an excellent summary by Campana and Neilson (1985). Fish otoliths are calcium accretions consisting of calcium carbonate in the aragonite configuration and an organic matrix (Casselman, 1987; Pannella, 1971). They are located in the inner ear and function as organs of equilibrium.

The saggitae are the largest of three pairs of otoliths and are most commonly used for age and growth analysis. For many fish species studied, growth rings or increments are deposited on the otoliths with 24-hour periodicity, making possible age assessment in days (Campana and Neilson, 1985). Each increment consists of an incremental (translucent) and discontinuous (opaque) zone (Mugiya et al., 1981). The incremental zone contains both calcium carbonate crystals and an organic otolin matrix while the organic matrix dominates the discontinuous zone (Dunkelberger et al., 1980). The discontinuous zone is apparently formed around sunrise due to reduction in the deposition of calcium (Mugiya et al., 1981).

The first step in otolith microstructure aging studies is validation of daily increment formation (Campana and Neilson, 1985). This is often accomplished by chemical marking with oxytetracycline hydrochloride (OTC) which is incorporated into calcified tissues within a day of application (Wild and Foreman 1980, Campana and Neilson, 1982).

Date of formation of the first increment is also of interest to the present study. Neilson and Geen (1982) found that the first increment in chinook salmon was formed before hatching. The first increment was formed at hatch in whitefish (Eckman and Rey, 1987) and walleye pollock (Bailey and Stehr, 1988), and on the day after hatch in Atlantic cod (Radtke, 1989). Formation of the first increment occurred at the time of first feeding in anchovies (Brothers et al., 1976), and Atlantic menhaden (Maillet and Checkley, 1990).

Various environmental factors have been shown to affect increment formation and include photoperiod, temperature, and feeding. Campana and Neilson (1985) summarized the literature by describing the effects of the three variables on increment formation. Reversal of the light-dark cycle reversed the order of formation of the discontinuous and incremental zones in goldfish (Tanaka et al., 1981). Daily increments were not formed in Tilapia and mummichogs, under constant dark conditions (Taubert and Coble, 1977; Radtke and Dean, 1982, respectively). However, in many studies, daily increments were formed despite constant light conditions (Campana and Neilson, 1982; Geffen, 1982; Neilson and Geen, 1982; Radtke and Dean, 1982) or constant dark conditions (Neilson and Geen, 1982). While abnormal photoperiods have disrupted increment formation in some studies, a 1:1 correspondence between the unnatural light cycles and increment formation has never been reported (Campana and Neilson, 1985).

Daily increment formation is not inhibited by constant temperatures, provided they are high enough to promote growth (Campana and Neilson, 1985). Fluctuating temperatures can, however, induce non-daily increment formation (Brothers, 1981). Otoliths of hatchery-reared lake trout were uniquely marked in morse code by subjecting them to short-term temperature fluctuations of 8°C (Edward Brothers, pers. comm.). Neilson and Geen (1985) produced 1.56 increments per 24h in chinook salmon by fluctuating temperatures 4°C with 12 hour periodicity. Campana (1984a) and Neilson and Geen (1985) observed that a daily temperature cycle enhanced visual contrast between discontinuous and incremental zones.

Feeding regimes have also been shown to affect increment formation. Chinook salmon fed more than once per day produced significantly more increments than did those fed once daily (Neilson and Geen, 1982; 1985). In other studies (Taubert and Coble, 1977; Campana 1983a) daily increment production was not influenced by multiple daily feedings. Campana (1983a) observed that the incidence of subdaily increments apparently increased with the frequency of feeding. However, shifts in the time of feeding did not shift timing or formation of incremental or discontinuous zones in *Tilapia nilotica* (Tanaka et al., 1981). Food limitation has been implicated in lack of daily increment formation in laboratory reared fish (Siegfried and Weinstein, 1989; Radtke, 1989).

Checks or discontinuities can also occur in otoliths. Non-periodic check formation is usually associated with stress or sexual maturity (Pannella 1980; Campana 1983b). Hatch checks have been documented in sockeye salmon (Marshall and Parker, 1982), chinook salmon (Neilson and Geen, 1982) and whitefish (Eckman and Rey, 1987), and represent physiologically stressful events (Campana and Neilson, 1985). Checks have been documented in Atlantic cod which correspond to yolk-sac absorption, initiation of feeding, and settlement (Radtke, 1989). First feeding checks were also documented in walleye pollock (Bailey and Stehr, 1989). American eels exhibit a check which represents the transition from salt water to fresh water (Michaud, Dutil and Dodson, 1988). The viviparous dwarf surfperch exhibits a check corresponding to date of birth (Schultz, 1990). Periodic check formation has also been documented and linked to the lunar cycle (Pannella, 1980; Campana, 1984b). Weekly checks were formed in *Oreochromis aureaus* corresponding to food deprivation on Sundays (Karakiri and Hammer, 1989).

Apparent non-daily increment formation may also be attributed to limited observer resolution (Campana and Neilson, 1985). This can result from improper otolith preparation (lack of grinding), constant temperature (which reduces increment contrast), or limitations in the resolving power of light microscopy (Bailey and Stehr, 1988). Otolith increments separated by less than 0.20 um may not be resolved (Campana and Neilson, 1985).

The relationship between fish growth and otolith increment width has been addressed by many researchers, and back calculation of length at age is common practice. When this study was conceived, it was generally accepted that otolith growth represented a "running average" of fish growth (Brothers, 1981; Campana 1983a). This concept has been criticized recently due to apparent "uncoupling" of otolith and somatic growth (Mosegard, Svedang and Taberman, 1988; Wright, 1991; Wright, Metcalf and Thorpe, 1990). Evidence for "uncoupling" includes the continuation of otolith growth after somatic growth has stopped (Brothers, 1981; Marshall and Parker, 1982; Campana 1983a; Volk et al., 1984; Wright, et al., 1990) and a high correlation between otolith growth and oxygen consumption in the absence of a correlation between otolith growth and somatic growth (Wright, 1991). In addition, Mosegard et al. (1988) found that otolith growth rate responded differently to increasing temperature than did somatic growth rate. It is now suggested that otolith growth is regulated by metabolic rate, not somatic growth, (Wright, 1991; Mosegard et al., 1988).

This might be construed to have serious impacts on our study since we theorized that narrower growth increments in hatchery-reared fry were due to slower growth in the hatchery. Based on this, we designed Task 3 (to be discussed later) to describe shad growth in the hatchery and determine the relationship between fish growth and otolith growth for hatchery-reared American shad. It is important to remember that correlation does not imply cause and effect. Additionally, for rapidly growing early life history stages (such as our hatchery shad), somatic growth is often closely correlated with metabolic rate (Wright, 1991). Therefore, positive correlation between otolith growth and fish growth may be a function of otolith growth and fish growth responding similarly to metabolic rate.

Otoliths have also been used in taxonomic studies. McKern et al. (1974) used otolith nucleus diameter, otolith growth, and changes in otolith density during freshwater growth to separate summer from winter steelhead or hatchery from wild steelhead. West (1983) found significant differences among linear regressions of (ln) fork length versus (ln) total otolith length between various sockeye salmon stocks. Campana and Neilson (1985) suggest that the measurement of individual increment widths would have exhibited the same differences. Uchiyama and Struhsaker (1981) used otolith microstructure to conclude that skipjack tuna from different areas grow at different rates. A number of authors have noted that otoliths from wild fish have more distinct increments than laboratory-reared fish (Campana, 1984c; Laroche et al., 1982;

Radtke and Dean, 1982). J. Casselman (pers. comm.) routinely uses otolith microstructure to differentiate between hatchery-reared and wild walleye in Ontario. Hatchery walleye are reared in ponds, moved to raceways for a short time and then stocked into natural waters. Otolith increment widths in these fish typically exhibit fast growth initially, followed by a gradual reduction in growth as the natural forage in the pond is consumed. A "check" is formed corresponding to pond harvest and handling, followed by resumption of growth in the wild.

This study attempts to differentiate between hatchery produced and wild stocks based on otolith microstructure. Eckman and Rey (1987) suggest the feasibility of just such a study based upon their work with whitefish otoliths. They documented the formation of characteristic ring patterns which corresponded to a change from one diet to another (e.g. stocking check for American shad), alteration of water temperatures, or short starvation periods. These events produced highly reproducible patterns in otoliths within 1 to 3 days, which can then be considered intrinsic marks and used as a "basis for judging the efficacy of stocking operations".

From the above discussion, it is clear that variables such as photoperiod, temperature, feeding, fish growth, and physiological stress can play a role in increment formation and increment width. Since environmental conditions at Van Dyke differ significantly from those found in the wild, it is likely that detectable differences exist between otoliths of hatchery-reared shad versus wild shad. An understanding of environmental conditions encountered at Van Dyke is necessary for proper study design. For the purpose of this study, it would be ideal if environmental variables at Van Dyke were constant. Unfortunately, they are not.

The Van Dyke facility consists of three rearing areas: old rearing room (16 tanks), new rearing room (20 tanks), and four outdoor tanks. The old rearing room is equipped with skylights and fluorescent lighting which is kept on to permit human activity during nighttime hours; effective photoperiod is unknown. The new rearing room also has fluorescent lighting which is kept on, but has no skylights. Sunlight enters via eaves and a door which is usually open. Effective photoperiod is unknown. The outdoor tanks are protected from direct sunlight by an awning, and incandescent overhead lights are usually off. Photoperiod is governed by natural light. All tanks are 1.5 m diameter circular tanks with 1200L capacity.

Van Dyke is equipped with a furnace and heat exchanger to maintain water temperatures conducive to growth. The furnace maintains water temperatures at or above 64°F, except during extreme cold weather when the furnace is over-taxed and temperature may drop to 58°F. Breakdowns and power failures can result in even lower temperatures. Typically, during April (Virginia River egg deliveries) when the thermostat is calling for heat, temperatures fluctuate 4°F with 3 to 4 hour periodicity. During May (Delaware and Hudson River egg deliveries), daytime water temperatures reach 64°F and these 3-4 hour cycles occur only at night and on cool days.

During June, (Columbia or Connecticut River egg deliveries), the furnace is no longer needed and diel temperature fluctuations occur.

When temperatures approach 72-75°F, spring water is mixed with warming pond water to maintain temperatures at approximately 70°F. Diel fluctuations continue due to solar heating and nighttime cooling of the warming pond.

American shad fry reared at Van Dyke are fed live brine shrimp, supplemented with a finely ground dry diet. Both feeds are supplied by automatic feeders timed to feed for 5 seconds every 5 minutes, 12 hours per day. Amount of feed is determined by fish density: 12 brine shrimp per fish per day plus 62.5g dry food per 250,000 fish per day. Fish growth is slower than that reported in the wild (Wiggins et al., 1984), and may account for the apparently narrow otolith increments observed in hatchery reared fish. The primary water supply at Van Dyke is a mountain spring stream with characteristically soft water. Alkalinity ranges from 7 to 10 mg/l, hardness is approximately 16 mg/l and calcium is 8-9 mg/l. In 1986, a pump was installed in the Juniata River as a secondary source to augment spring water. The pump is utilized primarily in June and July. No data is yet available, but alkalinity and hardness are certainly increased when the pump is in operation. These factors are significant in light of studies indicating that calcium deposited in the otolith is taken up primarily via branchial pathways (Simkiss, 1974; Mugiya et al., 1981; Campana, 1983b), not dietary intake (Ichii and Mugiya, 1983). Calcium content of the culture water may play a role in apparent otolith microstructural differences between hatchery-reared and wild shad.

The Van Dyke production cycle itself may affect otolith microstructure by inducing checks associated with key events. American shad eggs are received on a daily basis from Virginia or other southern rivers in April, the Delaware and Hudson Rivers in May, and the Columbia River or Connecticut River in June. Egg incubation temperatures are regulated at 60-62°F to promote hatching in 7 days. Fry are first fed at 4 days of age, the yolk sac is absorbed between days 5 and 7, and fry are stocked at 18-20 days of age. There is a potential for checks to be formed corresponding to each of these events.

Several studies exist which utilize otolith microstructure specific to American shad on the Connecticut River (Crecco and Savoy, 1985; Crecco and Savoy, 1987; Savoy and Crecco, 1989). Crecco and Savoy (1985) used otolith increment counts to assign juvenile American shad to 5 day cohorts, and then examined the relationship between growth and survival of these cohorts to environmental factors such as water temperature, river flow and zooplankton abundance. Crecco and Savoy (1987) expanded on the previous study by relating cohort mortality rates to larval hatching density, zooplankton abundance, water temperature, river flow and larval feeding rates. Savoy and Crecco (1987) used two groups of known age American shad larvae to determine date of first increment formation, the precision and accuracy of otolith increment counts, and describe the relationship between otolith half-length and larval growth. The two groups of shad used included a group reared at 18C (USFWS, Lamar) and, of particular interest, a group reared at Van Dyke under normal production conditions (15C).

Task 1. Validation of daily increment formation for American shad reared at the Van Dyke Research Station.

Tetracycline marks administered by 6 hour immersion in 200 ppm TC, were used to mark increments 5, 12 and 19. The daily ring hypothesis was validated by counting increments between tetracyline marks and comparing the results to the known number of days between administration of the marks. The inherent assumption is that the tetracycline is laid down only in the increment formed on the day of marking. To test this assumption, we examined marks at 450x with a Reichert Microstar IV microscope under UV light. Micrometer hairlines were used to mark the width of the tetracycline mark. Under white light the hairlines were then compared to the discontinuous zones on either side of the incremental zone containing the tetracycline mark. Ten specimens were examined for the day 5 mark, ten of the day 12 mark and ten of the day 19 mark. In all 30 cases the visible fluorophore was confined to a single incremental zone, confirming that no residual is laid down the day after marking .

Validation of the daily ring hypothesis was accomplished by identifying two marks under UV light and setting micrometer hairlines adjacent to each. A white light was then switched on and the number of increments between the hairlines counted and compared to the expected number. The experiment was repeated for groups of shad from Virginia River egg sources reared under the three different lighting regimes present at Van Dyke (Table 1). The number of increments counted was identical to the number expected under the assumption of daily increment formation in 226 of 249 (91%) of the samples (Table 1). Mean counts were identical to those expected in five of the six samples from the old rearing room and outdoor areas. The sixth count (old rearing room, number of increments to day 5 tag) was within 0.04 of the expected count. The largest differences between mean counts and those expected under the daily increment hypothesis were for the new rearing room which was lighted by 24-hour fluorescent lights without skylights. Despite the lack of a natural photoperiod, mean increment counts were within 0.26 increments of the expected count. Adding across the row (Table 1) for the new rearing room, nineteen day-old fry exhibited a mean of 19.1 increments. Thus, there is no apparent deviation from daily increment formation between the three rearing areas at Van Dyke.

A similar experiment was conducted using fry from three different egg source rivers to ensure that there were no genetic differences in daily ring formation. This experiment, by necessity, also tested for differences due to ambient temperature factors since Virginia River fry are reared in late April and May, Delaware River fry in May and June, and Columbia River fry in June and July. All fry for this experiment were reared in the old rearing room. Tetracycline marks were administered on days 5, 9, 13, and 17, and the observed number of increments compared to the expected number (Table 2). The number of increments counted was identical to the number expected in 240 of 270 (89%) of the samples (Table 2). Mean counts were within 0.17 increments of the expected number and there was no apparent deviation from daily increment formation. These two experiments establish that American shad reared at Van Dyke lay down an average of one otolith increment per day regardless of egg source or hatchery lighting conditions.

This conflicts with the results of Savoy and Crecco (1987) who found that increment counts agreed closely with age for the 18C group but under-estimated age for the 15C group (Van Dyke shad) due to under-aging of older larvae (20-27d). Our methodology involved counting increments between tetracycline marks produced at 4 or 7 day intervals. Visually, this is a much easier and more accurate task than counting increments from the otolith edge to the nucleus for 20+ day old larvae. Additionally, we observed visual distortion around the edge of unground otoliths (as used by Savoy and Crecco, 1987) which could obscure narrow increments formed near the edge and result in under-estimation of age. A third explanation is that our counts were conducted on increments ranging from the hatch check to increment 19 while those of Savoy and

Crecco (1987) included 27 day old larvae (potentially 27 increments). Thus, the disagreement between age in days and increment counts between 19 and 27 days of age may be real, and may be caused by limited observer resolution (Campana and Neilson, 1985) or an actual breakdown in daily increment formation.

Task 2. Determination of the date of first increment formation.

Date of first otolith increment formation was determined using specimens from Test 1 (Tables 1 and 2). Under UV light we adjusted a micrometer hairline on a day 5 tetracyline mark. We then switched on a white light and counted incremental zones starting with the marked incremental zone and ending with the first incremental zone after the first distinct discontinuous zone. The number of increments counted was five for 132 of the 170 samples (78%). Mean number of incremental zones was within 0.26 increments of five for all samples examined.

Mugiya et al. (1981) demonstrated that the discontinuous zone in goldfish otoliths was formed at sunrise due to a cessation of calcium deposition. Our observations indicate that the first distinct discontinuous zone is wider and darker than most others. Our fry are typically force hatched between 1100 and 1500 hours. If calcium disposition were to resume between hatch and sunrise on day 1 we would expect six discontinuous zones from the first discontinuous zone to the discontinuous zone formed prior to marking (counted as number six). Since only five discontinuous zones are present and the first is wider and more distinct than the others, we speculate that the stress involved in hatching and subsequent adjustment to the tank environment may interrupt calcium deposition until normal deposition begins after sunrise on the following day. This interruption produces a wide, distinct discontinuous zone which we call the "hatch check." Sixty specimens, ten from each of the Virginia and Columbia river egg sources for each of 3 years (1986, 1987, and 1988), were examined for the presence of "hatch checks." Fifty of the sixty specimens (83%) exhibited a prominent, identifiable hatch check. The first increment of the remaining ten specimens was similar to other increments.

Task 3. Determine the relationship between fish length and otolith length and describe American shad growth at Van Dyke.

Otolith growth may be a function of metabolic rate rather than somatic growth (Wright, 1991; Mosegard et al., 1988). Since metabolic rate and somatic growth are often correlated in early life history stages (Wright, 1991), there should be a positive correlation between somatic growth and otolith growth.

To test this assumption for American shad reared at Van Dyke we regressed otolith radius against total length for shad fry from the Virginia and Columbia River egg sources. Shad were sampled at hatch and on days 6, 12 and 18 for Virginia River fry, and at hatch and on days 6, 13 and 15 for Columbia River fry. Each larva was measured to the nearest 0.1 mm using a dissecting microscope and a micrometer. Saggitae were then extracted and otolith radius measured using a micrometer at 450x. Otolith radius was plotted against total length (Figure 1). No differences were observed between the two egg sources so data were pooled. The resultant regression (y = 4.9x - 39.4) exhibited a high correlation coefficient (r = .88), indicative of a strong relationship between length and otolith radius. The slope of the regression was significantly different from 0 (t = 18.1, df = 97; Ott, 1977).

Growth of shad larvae reared at Van Dyke was plotted for two tanks of Virginia River fry and two tanks of Columbia River fry (Figure 2). These represent the environmental extremes encountered early in the season (Virginia River fry hatched in late April) and late in the season (Columbia River fry hatched in late June). Growth of wild American shad fry from the Connecticut River for the period 1979-1982 (Crecco et al, 1983) is also depicted in Figure 2 for comparison. Clearly, wild Connecticut River shad grow at a much faster rate than Van Dyke hatchery shad.

In summary, Tasks 1 through 3 have established that for hatchery-reared American shad the first increment is a prominent check, laid down at hatch (hatch check). Increments are formed on a daily basis thereafter, with the exception that an average of slightly more than one increment may be laid down in fry reared in the new rearing room. Otolith growth is proportional to growth in length, and Van Dyke hatchery-reared fry grow substantially slower than do wild fry from the Connecticut River. These findings provide the foundation for interpretation of the results in Task 4.

Task 4. Determination of key characteristics to be used to discriminate between wild and hatchery-reared American shad.

Otoliths from out-migrating juvenile American shad have been extracted from shad collected yearly in the Susquehanna River since 1986. Each fish was classified "hatchery" or "wild" based on the presence or absence of a tetracycline mark(s) on the otolith. Thus, groups of known-origin Susquehanna River fish, used for analysis of Task 4, include both hatchery and wild fish from each of four years (1986,1987,1988, and 1989). Two additional groups of known wild fish from the Delaware River were also used, including adult shad collected in 1987 and juvenile shad collected in 1990.

Each otolith section was placed under a microscope and the image projected via a video camera to the OPRS computer screen. A transect was drawn from the focus of the otolith outward through the posterior quadrant of the otolith (areas of widest incremental spacing). The OPRS then automatically measured the luminance of the image along the transect and plotted it against the distance from the focus. Peaks in luminance correspond to incremental zones while "valleys" correspond to discontinuous zones. Discontinuous zones were then automatically highlighted by red lines on the screen.

Since luminance was measured only along the transect, blemishes in the otolith could result in errors in marking discontinuous zones. These errors were corrected by manually removing marks which did not correspond to discontinuous zones and adding marks which were missed by the automatic OPRS software. Mean increment width (distance between discontinuous zones) for the first 15 increments was then calculated.

Our goal was to use 20 specimens for each of the 10 groups, however, enough wild specimens were not available. As a result, wild groups included from 10 to 24 specimens, while hatchery groups included 20 to 25 randomly selected specimens. Mean increment width for the 10 groups of wild and hatchery-reared shad are depicted in Figure 3 and Table 3. Mean otolith increment width was smallest for the 4 groups of hatchery fish and largest for the 4 groups of wild Susquehanna River fish. Wild Delaware River fish were intermediate, presumably due to slower growth as a result of intraspecific competition, different temperature regimes or simply less productive habitat. The data was subjected to one-way ANOVA to determine if significant differences exist, and Tukey's pairwise multiple comparisons to isolate the differences (Ott,1977).

Significant differences were indeed found to exist ($F9,183 = 41.866$, $a = 0.000$). Results of the multiple comparisons are depicted in Table 3. There were no significant differences between the 4 hatchery groups, and each of the hatchery groups was significantly different from the wild groups. Wild shad collected in 1989 were significantly different than all other groups. Wild shad collected from the Delaware River in 1990 were significantly different from the wild Susquehanna River fish collected in 1986 and 1987. These data support the hypothesis that hatchery-reared American shad exhibit smaller mean increment widths than do wild shad. Savoy and Crecco (1987) compared increment widths of Van Dyke hatchery-reared shad to wild shad from the Connecticut River and reached the same conclusion.

<u>Visual Classifications</u>

A second approach to Task 4 involved a blind study in which classification of otoliths was based solely on visual observations. An independent researcher removed all identifying information and assigned a random number to each known origin otolith specimen. Two experienced researchers then independently classified these otoliths based on microstructural characteristics including increment width, increment distinctness, presence of a "stocking check," and presence of a "hatch check." Data was then compared, and when the two researchers disagreed, the specimen was re-evaluated to attempt to reach consensus through discussion of otolith microstructure. Final classification was then compared to the known origin.

Three preliminary 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 4) 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 trial (Table 4). Of those, 244 (89%) were classified correctly, 26 (9%) incorrectly and on 5 (2%) the researchers disagreed. Visual classification for hatchery specimens was more reliable than for wild specimens.

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.

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. The relatively poor results for Delaware River fish are explained by the fact that mean otolith increment widths for this group are intermediate between wild and hatchery fish from the Susquehanna River (Table 3). Excluding Delaware River otoliths, 64 (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. Overall, excluding Delaware River specimens, 92% of the otoliths in the trial were classified correctly, thereby validating visual microstructural classification methodology.

Task 5. Determination of the origin of adult American shad collected at the Conowingo Dam.

Representative samples of adult shad from the Conowingo Dam have been obtained since 1989. Every 50th (1989) or 100th (1990,1991) shad to enter the West tailrace fish trap was sacrificed. The East Fish Lift was sampled similarly in 1991. Otoliths were removed on site by consultants and stored in microcentrifuge tubes. Otoliths were delivered to Benner Spring Fish Research Station where they were mounted on microscope slides and ground to produce a thin sagittal section. Otoliths were then viewed under white light at 450x and classified wild or hatchery, based on visual observation of otolith microstructure. As in Task

4, classification was made by two independent researchers, followed by an attempt to reach consensus if the researchers disagreed. After classification according to microstructure, the otolith was examined under UV light for the presence of tetracycline mark.

Results from 1989 and 1990 were reported in Hendricks et al. (1990) and Hendricks et al. (1991). Some 84% of the adults returning to Conowingo in 1989 were classified as hatchery while in 1990, 73% were classified as hatchery.

Results from 1991 are depicted in Table 5. Of 269 specimens processed in 1991, 16 otoliths were broken, poorly ground or missing. Some 253 otoliths were read, 68 (27%) of which exhibited wild microstructure. The remainder (73%) were classified hatchery. Of the 185 total hatchery otoliths, 122 (66%) exhibited tetracycline marks. By contrast, 55% and 28% of the otoliths with hatchery microstructure exhibited marks in 1990 and 1989, respectively. This is to be expected, as marked year classes become fully recruited into the fishery.

Summary

Hatchery reared American shad lay down their first otolith increment, a prominent "hatch check," at hatch. Increments are formed on a daily basis thereafter. Otolith growth is proportional to linear growth in length, and Van Dyke hatchery-reared fry grow slower than do wild fry from the Connecticut River. Mean otolith increment width for hatchery shad was significantly smaller than that of wild shad for the first 15 increments. Using visual observation of otolith microstructural characteristics, we correctly classified 92% of the otoliths from Susquehanna River hatchery and wild groups from the years 1986, 1987, 1988 and 1989. Otoliths from wild Delaware River fish were problematic, presumably due to their intermediate increment width. Seventy-three percent of a sample of 253 otoliths from adult shad caught in Conowingo Dam Fish Lifts in 1991 were classified as hatchery. Sixty-six percent of these exhibited tetracycline marks.

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Figure 1. Otolith radius vs total length for American shad fry reared at Van Dyke, 1989.

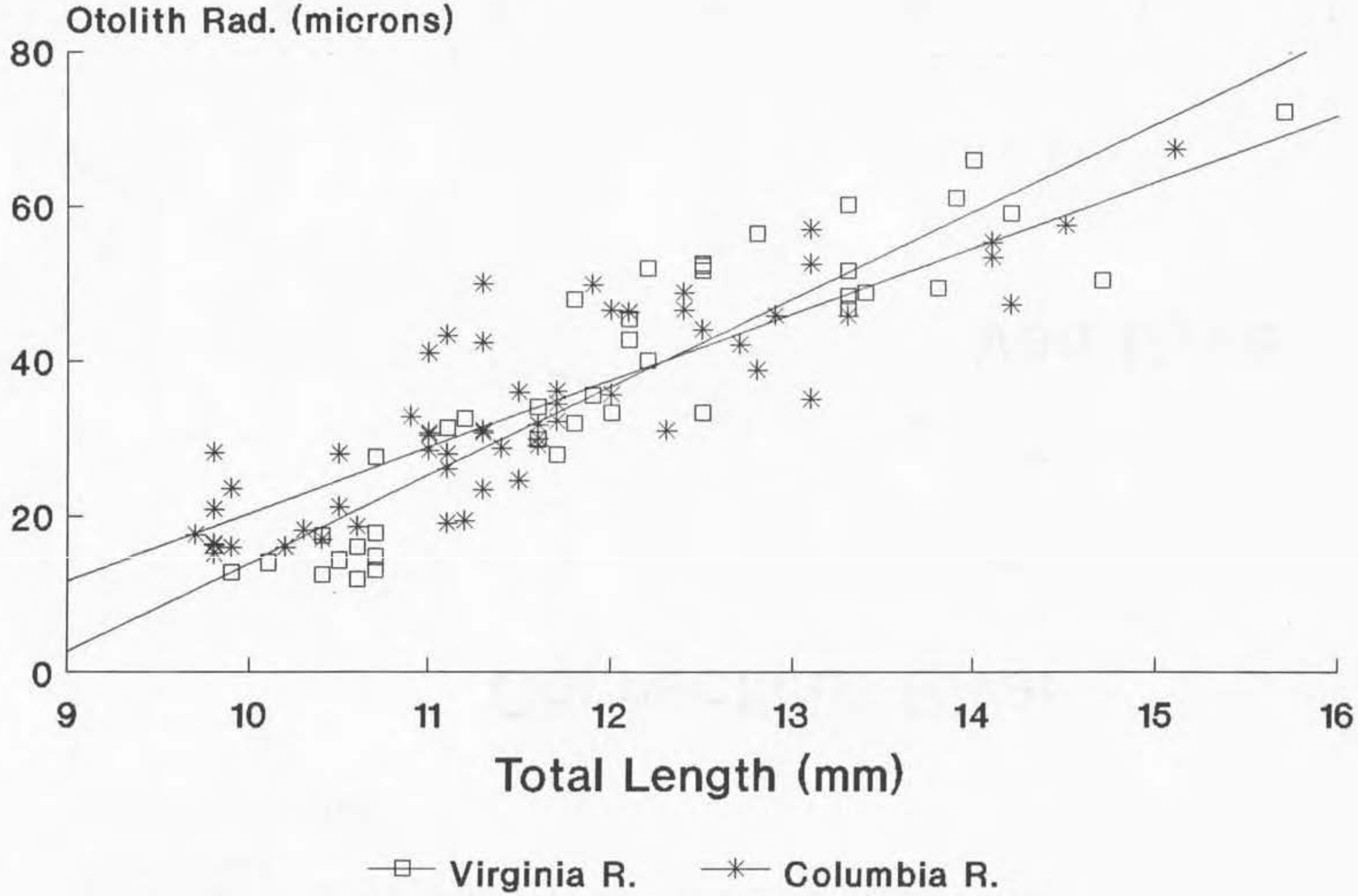
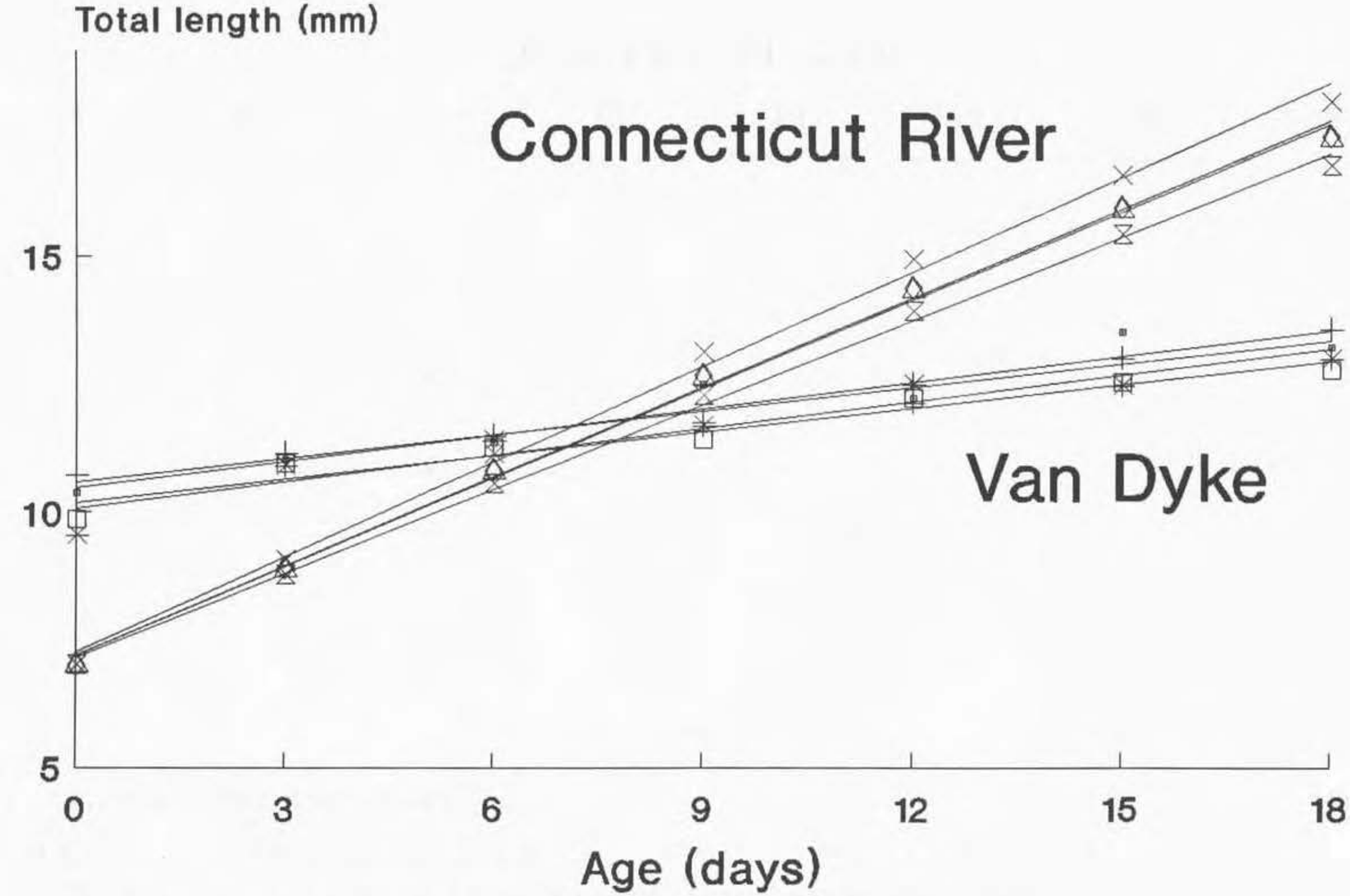


Figure 2. Growth of American shad fry reared in 4 tanks at Van Dyke, 1989, vs. wild fry from the Connecticut River, 1979-1982.



Connecticut River data from Crecco et al. (1983).

Figure 3. Mean otolith increment width and 95% confidence intervals for groups of known origin otoliths, 1986-1989. Increments 1 through 15 only.

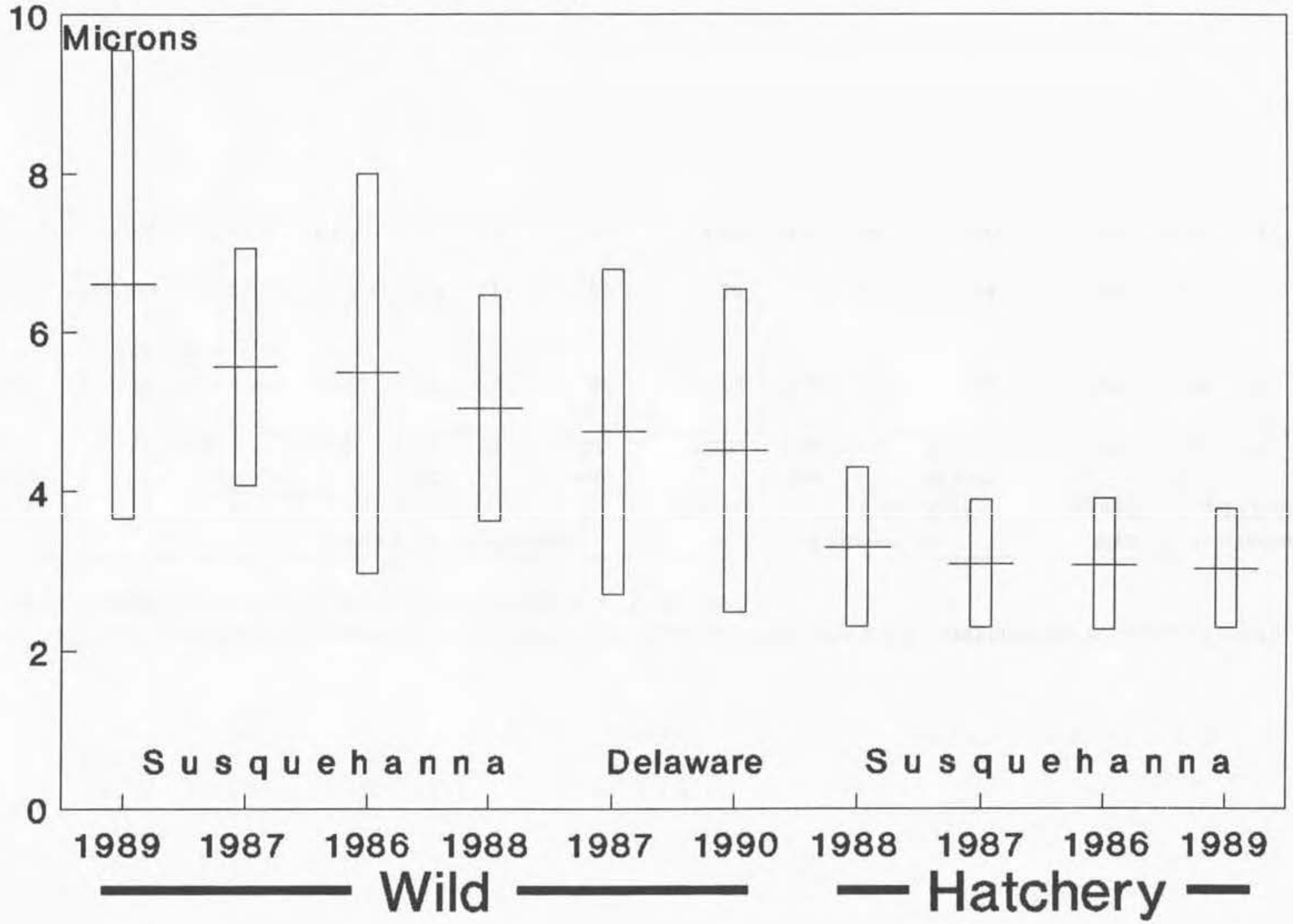


Table 1. Number of otolith increments observed from the hatch check to the day 5 tetracycline mark and between subsequent marks, for American shad fry reared in three areas with different lighting, Van Dyke, 1987.

			Mean # of increments to day 5 mark				Mean # of increments between 5 and 12 day marks				Mean # of increments between 12 and 19 day marks			
Tank	Rearing Area	Lighting	Obs.	Std. Dev.	N	% with 5 inc.	Obs.	Std. Dev.	N	% with 7 inc.	Obs.	Std. Dev.	N	% with 7 inc.
B1	Old room	Fluorescent- 24h +Skylights	4.96	0.43	28	82	7.00	0.00	28	100	7.00	0.00	27	100
F3	New room	Fluorescent- 24h	5.26	0.63	31	65	6.94	0.25	31	94	6.90	0.09	31	90
J1	Outdoor	Natural	5.00	0.30	24	92	7.00	0.00	25	100	7.00	0.00	25	100

Table 2. Number of otolith increments observed from the hatch check to the day 5 tetracycline mark and between subsequent marks, for American shad fry from three different egg source rivers, Van Dyke, 1988.

		Mean # of increments to day 5 mark				Mean # of increments between 5 and 9 day marks				Mean # of increments between 9 and 13 day marks				Mean # of increments between 13 and 17 day marks			
Pond	Egg Source River	Obs.	Std. Dev.	N	% with 5 inc.	Obs.	Std. Dev.	N	% with 4 inc.	Obs.	Std. Dev.	N	% with 4 inc.	Obs.	Std. Dev.	N	% with 4 inc.
BSP2	Virginia	5.10	0.40	30	83	4.07	0.37	30	97	4.00	0.37	30	87	4.03	0.32	30	90
USCP1/ USCP2	Delaware	5.17	0.59	30	73	3.97	0.18	30	97	4.07	0.25	30	93	-	-	-	-
VD	Columbia	5.11	0.42	28	82	4.00	0.00	30	100	-	-	-	-	-	-	-	-

Table 3. Mean otolith increment widths for known origin American shad collected in the Susquehanna and Delaware Rivers, 1986-- 1990. Includes the first 15 increments only. Susquehanna River fish were juveniles and Delaware River fish were juveniles or adults.

Group	River	Mean Otolith Increment Width (microns)	Standard Deviation	N	Tukey's Multiple Comparison
Wild 1989	Susquehanna	6.61	1.50	14	A
Wild 1987	Susquehanna	5.57	0.76	19	BC
Wild 1986	Susquehanna	5.49	1.28	24	BC
Wild 1988	Susquehanna	5.05	0.72	10	BCD
Wild 1987	Delaware (adults)	4.75	1.04	14	BCD
Wild 1990	Delaware (juv.)	4.51	1.03	21	CD
Hatchery 1988	Susquehanna	3.30	0.51	25	E
Hatchery 1987	Susquehanna	3.09	0.41	20	E
Hatchery 1986	Susquehanna	3.08	0.42	24	E
Hatchery 1989	Susquehanna	3.03	0.38	22	E

Table 4. Visual classification of juvenile American shad otoliths by two researchers based on microstructure laid down during the first 30 days after hatch. 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 1990.

Known Origin:		Hatchery (marked)				Wild (unmarked)			
			Classification				Classification		
Year	Source	N	Hatchery	Wild	Disagreed	N	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%)

	N	Correct	Incorrect	Disagreed
Grand Total	275	244(89%)	26(9%)	5(2%)
Grand Total (Del. excluded)	246	227(92%)	18(7%)	1(<1%)

Table 5. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts, 1991. One of every 100 fish to enter each lift was sacrificed. Holding and transport mortalities are not included.

			Total
Wild Microstructure			68(27%)
Hatchery Microstructure	No TC Mark		63(25%)
	Single TC Mark	Day 5	65(26%)
		Day 12 or 13	2(0%)
		Day 15	19(8%)
		Days 5-8 or 5-9	5(2%)
		Days 15-18 or 15-19	14(6%)
	Double TC Mark	Days 5,9	4(2%)
		Days 5,12	1(0%)
		Days 5,19	1(0%)
		Days 5-8 or 5-9, 15-18 or 15-19	2(0%)
	Triple TC Mark	Days 5,9,13	4(2%)
	Quadruple TC Mark	Days 5,9,13,17	2(0%)
	Feed marks	Days 5-8 or 5-9 +7d feed mark	1(0%)
		Days 5,12,19 + 3d feed mark	1(0%)
		Days 9,13 or 12,17 or 13,19 + 3d feed mark	1(0%)
		Total Hatchery	185(73%)
		Unreadable Otoliths*	16
		Total	269

*Includes broken, missing and poorly ground otoliths.

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

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INTRODUCTION

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

METHODS AND MATERIALS

Collection procedures for adult American shad assessment in 1991 were nearly identical to those in 1990, the only difference being the addition of the Bohemia River pound net site at Ford Landing (Figure I). Hook and line sampling in the Conowingo tailrace continued unchanged from 1990. 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, 1989 and 1990. 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 mid-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 1991.

RESULTS

Pound net tagging for 1991 began on 21 March and continued until 13 May while hook and line effort commenced on 11 April and ended 22 May. Of the 1,491 adult American shad captured, 1,037 (70%) were tagged and 204 (14%) subsequently recaptured (Table 1). Of these 204 recaptures eight occurred outside the upper Bay system and four were from tailrace anglers. The 204 total also does not reflect the 74 multiple recaptures, two incorrectly recorded numbers, and 11 fish tagged prior to 1991 collected by RMC from the two traps. Consequently, for the Petersen estimate an R value of 192 was utilized.

Recapture data for the 1991 season is summarized as follows:

a. 183 fish recaptured by the Conowingo Fish Lift
   (does not include 74 multiple recaptures)
   4 fish recaptured by pound net
   6 fish recaptured by hook and line from tailrace

8 fish recaptured outside the system

b. 120 fish recaptured originally caught by hook and line

81 fish recaptured originally caught by pound net

c. 124 fish recaptured in the same area as initially tagged

79 fish recaptured upstream of their initial tagging site (includes 7 recaptures from the Delaware River)

1 fish recaptured downstream of their initial tagging site (from the Potomac River)

d. shortest period at large: 1 day

longest period at large: 63 days (1990 fish only)

mean number days at large: 16.2

e. number of pre-1991 tagged fish recaptured: 11

number of multiple recaptures: 74

The population estimate for adult shad in the upper Chesapeake Bay for 1991 using the Petersen Index was 139,862 (Table 2). Since 8 recaptures occurred outside the upper Bay an emigration factor was calculated in order to adjust the number of fish marked (M) in the Petersen statistic but lost and unavailable for later recapture (Table 3). The Petersen estimate for those fish captured, marked and recaptured only from the Conowingo tailrace (angling and fish trap) was 84,122 (Table 4). The 1991 estimates were the highest recorded to date for both the upper Bay and tailrace and represent 13% and 42%, increases, respectively' over 1990 (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 1991 and comparison with previous years is presented in Table 5. Catch per angler hour increased to over 5 1/2 fish in 1991 a slight increase over 1990. The shad catch per pound net day for all nets combined increased sharply in 1991 over the previous year. Excluding the Bohemia River net which was set for the first time in 1991, the CPUE's increased 14% and 324% for the Rocky Point and Cherry Tree nets, respectively, over 1990. The combined catch per pound net day for both these nets in 1991 represents a 120% increase since 1989.

A total of 1,069 adult American shad (347 hook and line, 722 pound net) were examined for physical characteristics by DNR biologists in 1991 (Table 6). Of the males examined, 94% were ages IV, V, and VI with age group V predominating in both gear types (Table 6). The overall incidence of repeat spawning in male shad increased from 2.7% in 1990 to 17.2% for 1991. Nearly 83% of the 505 female shad examined in 1991 were V and VI year old fish with age group VI slightly predominating (Table 6). As with their male counterparts, the incidence of repeat spawning in females increased in 1991 with 12.7 % of non-virgin female recruits returning as opposed to only 2.6% the previous year.

Juvenile alosid sampling in the upper Bay during 1991 produced fewer numbers of young-of-the-year American shad than the previous year. Table 7 presents results from 1991 haul seine and otter trawl sampling arranged by catch, catch by site, and associated CPUE. Comparison of 1991 results with previous years (Table 8) indicates a decline in the juvenile shad and alewife herring CPUE by both gears, but substantial increases in blueback herring, white perch, and striped bass production over 1990 for haul seine.

Supplemental haul seine sampling for the Department's juvenile striped bass survey in 1991 captured 8 young-of-the-year American shad, a decrease of 11 fish from 1990. All 8 fish were collected from Carpenter Point on July 17.

Numbers of juvenile shad collected by electrofisher also decreased in 1991 to 17, six fish less than the previous year. Electrofisher sampling procedures established in 1990 were continued in 1991. 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 DURING 1991

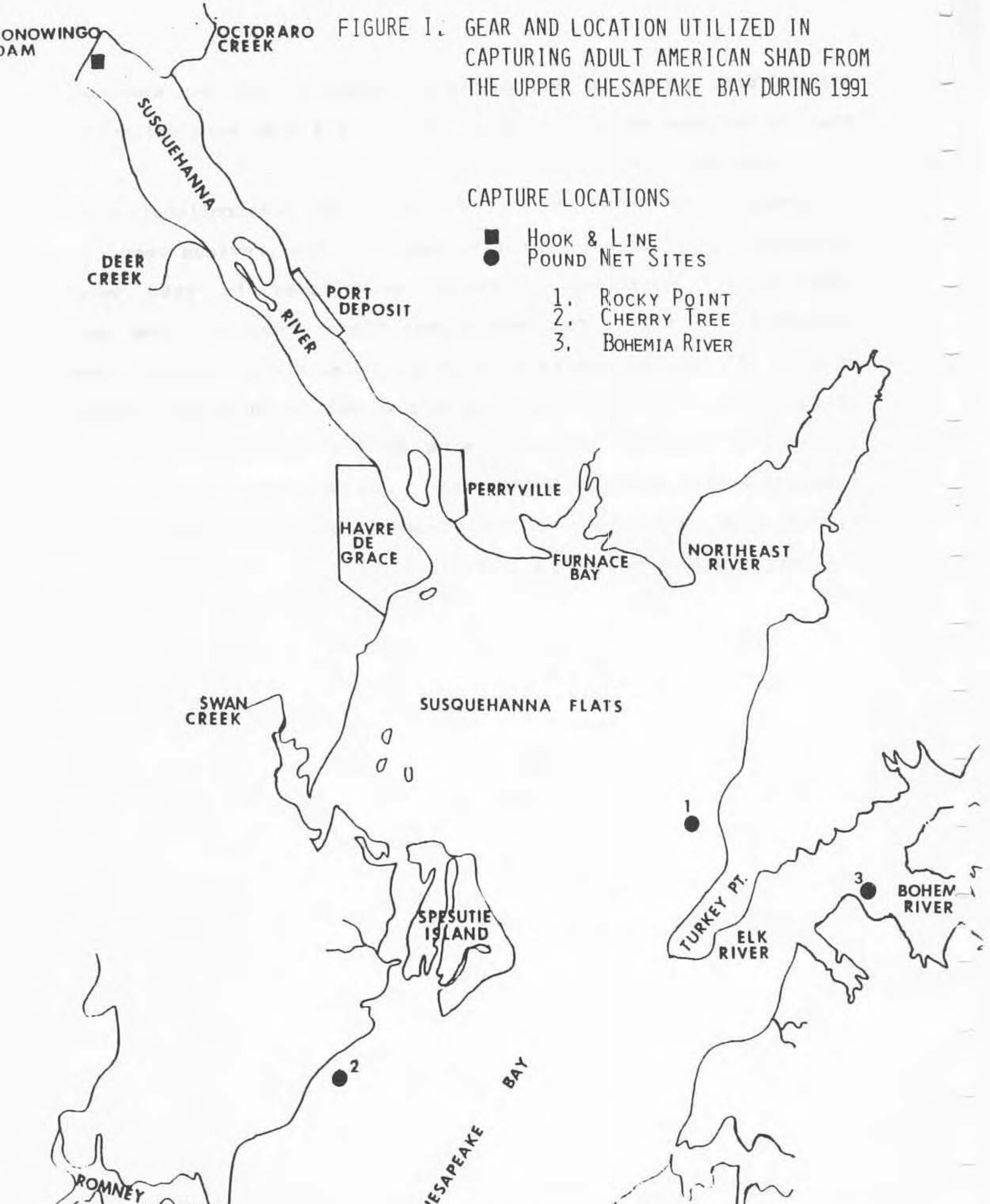

FIGURE II. SEINE AND TRAWL SITES SAMPLED DURING THE 1991 JUVENILE RECRUITMENT SURVEY.

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

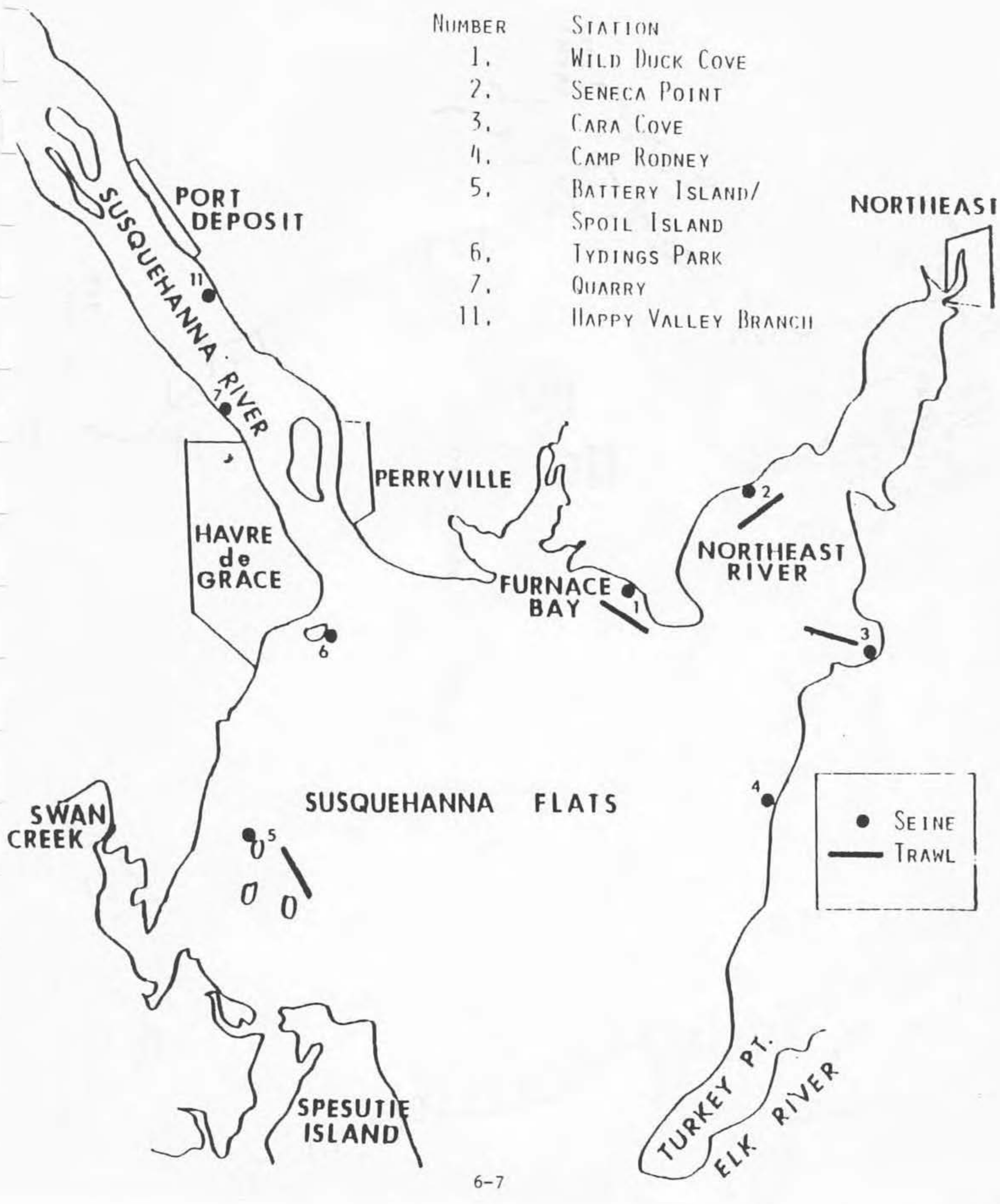

FIGURE III. UPPER CHESAPEAKE BAY ELECTROFISHING SITES SAMPLED DURING THE 1991 JUVENILE RECRUITMENT SURVEY.

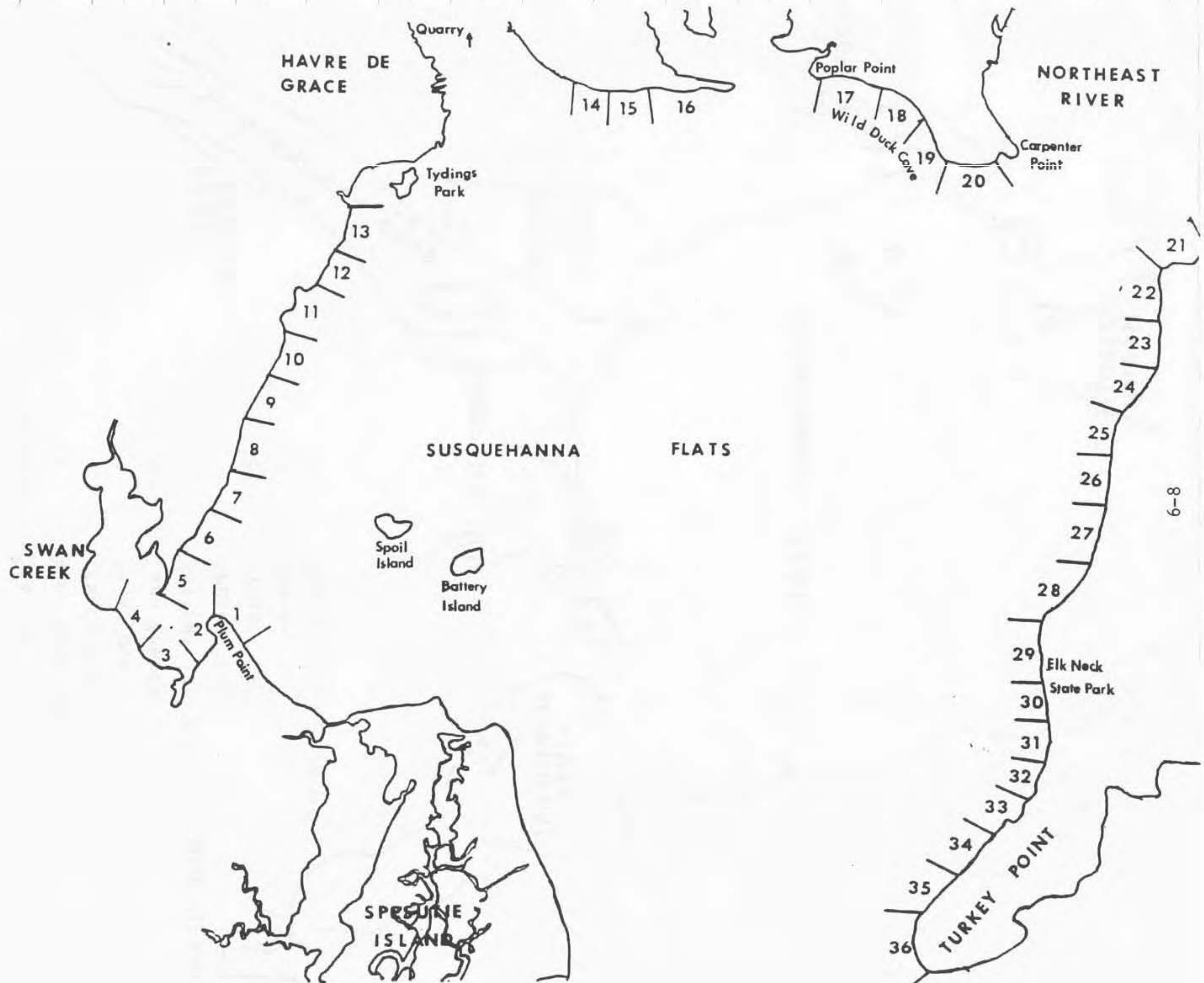

Figure IV. Yearly comparisons of the adult American shad population estimates in the upper Chesapeake Bay.

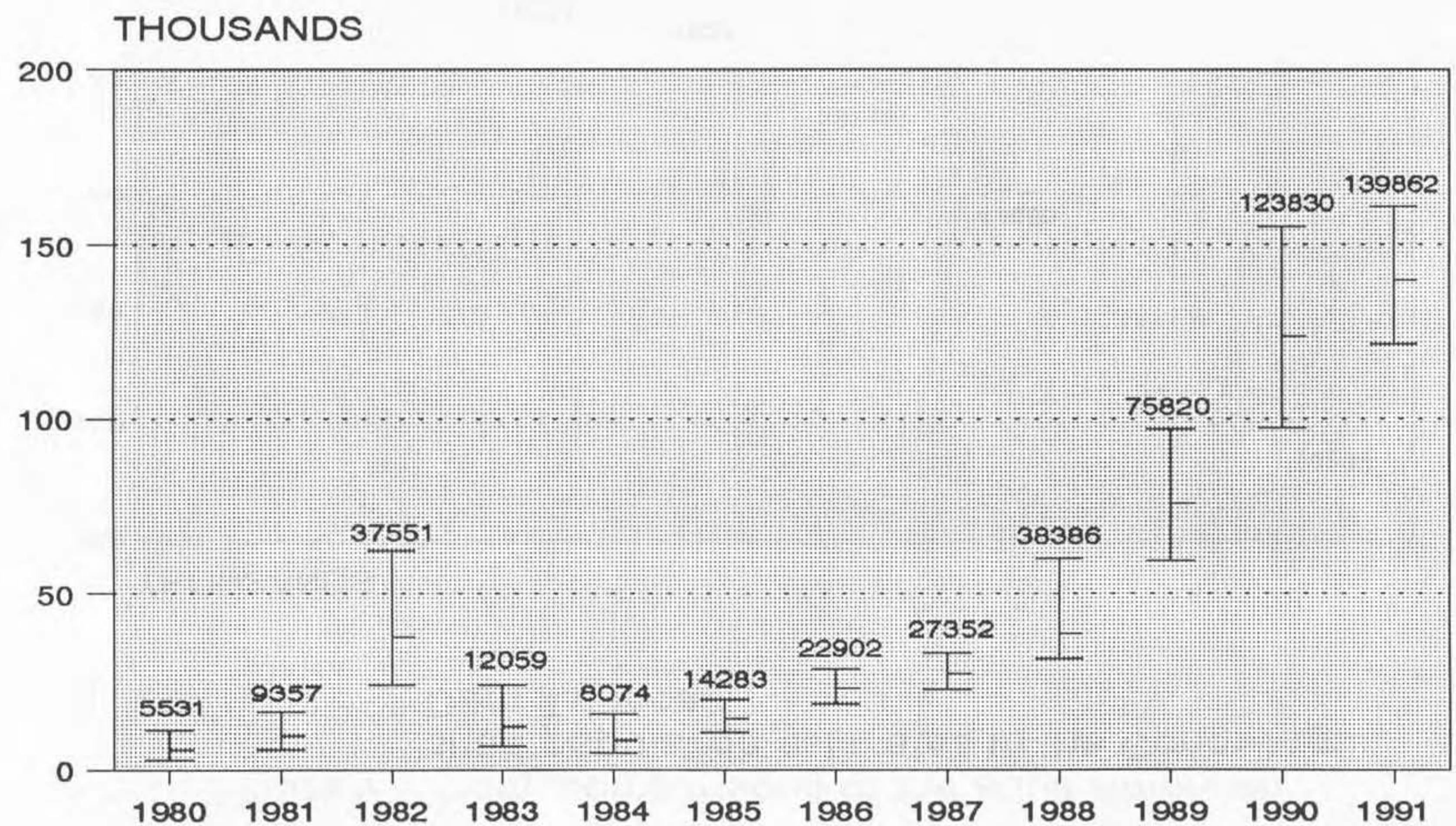

Figure V. Yearly comparisons of the adult American shad population estimates in the Conowingo Dam Tailrace.

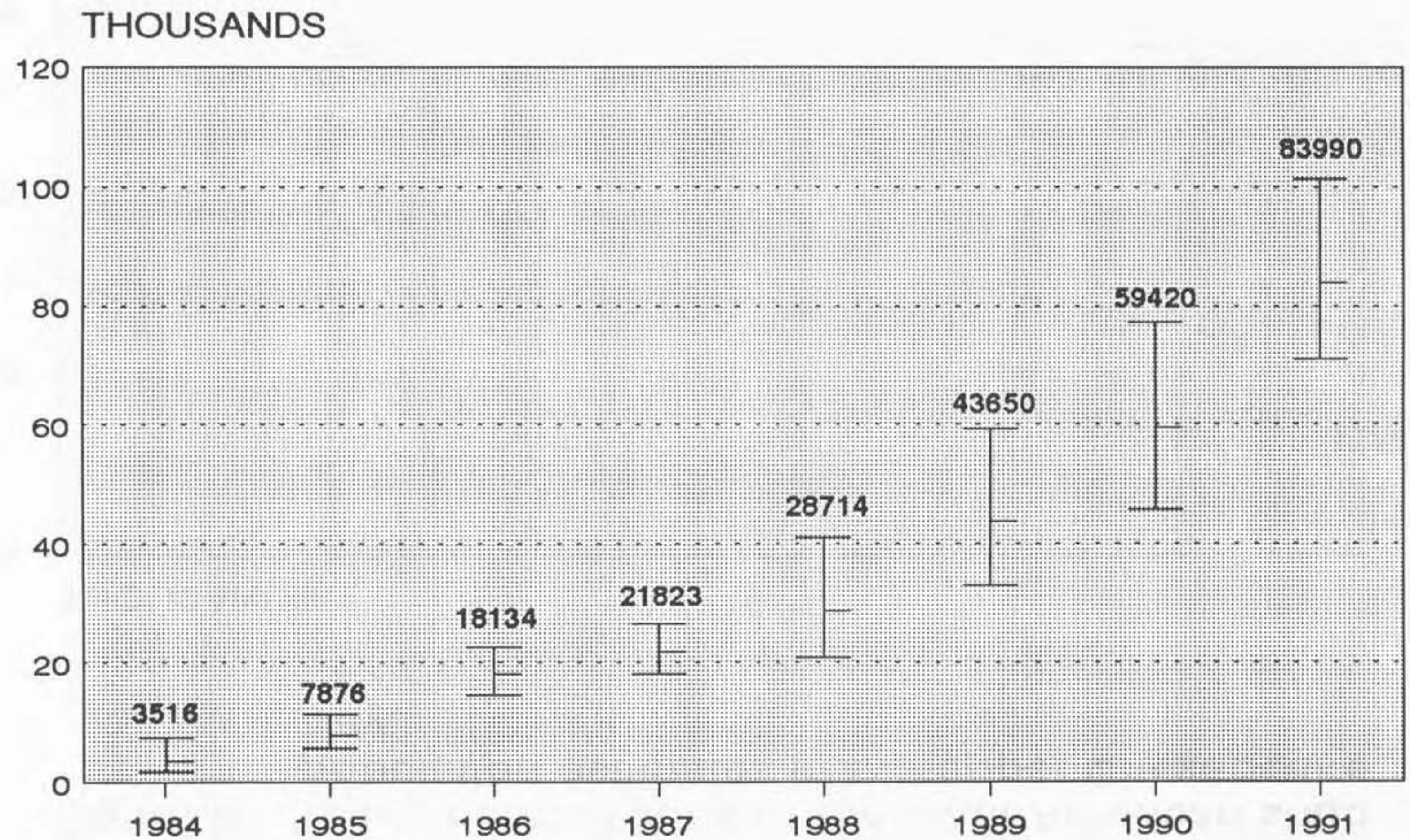

Table 1. Number of American shad captured and tagged by location and method of capture, **upper Chesapeake Bay**, March-June 1991.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	594	308
	Rocky Point	209	169
	Bohemia River	251	164
	Total	1,054	641
Hook and Line	Conowingo Tailrace Susquehanna River	437	396
Fish Lift	Conowingo Tailrace Susquehanna River	27,227	
	TOTALS	28,718	1,037

Table 2. Population estimate of adult American shad in the **upper Chesapeake Bay** during 1991 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1991 survey -

C = 28,624
M = 192
R = 942*

Therefore -

$$N = \frac{(28624 + 1)\ (942 + 1)}{(192 + 1)}$$

$$= 139,862$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(28624 + 1)\ (942 + 1)}{166.69 + 1} = 160,972$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(28624 + 1)\ (942 + 1)}{221.15 + 1} = 121,510$$ @ .95 confidence limits

* M adjusted for emigration and 3% tag loss

Table 3. Number of adult American shad tagged from anchor gill nets (1980-1982) and pound nets (1980-1991), the number of those fish recaptured, the number recaptured outside the upper Chesapeake Bay, and the calculated emmigration factor and associated number of fish lost.

YEAR	NUMBER TAGGED	NUMBER RECAPTURED	NUMBER OUTSIDE	EMMIGRATION FACTOR	NUMBER LOST
A. Anchor Gill Nets					
1980	65	4	-	-	-
1981	185	13	-	-	-
1982	178	15	3	0.200	-
B. Pound nets					
1980	89	9	2	0.222	20
1981	65	5	1	0.200	7
1982	76	7	1	0.143	11
1988	136	7	3	0.429	58
1989	298	16	1	0.063	19
1990	286	19	2	0.105	30
1991	641	78	8	0.103	66

Table 4. Population estimate of adult American shad in the **Conowingo tailrace** during 1991 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1991 survey -

C = 26,927
M = 120
R = 377*

Therefore -

$$N = \frac{(26927 + 1)\,(377 + 1)}{(120 + 1)}$$

$$= 84{,}122$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(26927 + 1)\,(377 + 1)}{100.36 + 1} = 100{,}422$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(26927 + 1)\,(377 + 1)}{143.48 + 1} = 70{,}451$$ @ .95 confidence limits

* M adjusted for emigration and 3% tag loss

Table 5. Catch, effort, and catch-per-unit-effort (CPUE) for adult **American shad** by hook and line and pound net during the 1980-1991 tagging program in the upper Chesapeake Bay.

A. **HOOK & LINE**

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

B. **POUND NET**

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POP. EST.
1980	Rocky Pt.	26	50	1.92	5,531
1981	Rocky Pt.	38	50	0.86	9,357
1982	Rocky Pt.	27	62	2.29	37,551
1985	Rocky Pt.	10	30	3.00	14,283
1988	Rocky Pt.	33	87	2.64	
	Cherry Tree	41	75	1.83	
	Romney Cr.	41	8	0.20	
	1988 Total	115	170	1.48	38,386
1989	Rocky Pt.	32	91	2.84	
	Cherry Tree	62	295	4.76	
	Beaver Dam	11	14	1.27	
	1989 Total	105	400	3.81	75,820
1990	Rocky Pt.	38	221	5.82	
	Cherry Tree	71	178	2.50	
	1990 Total	109	399	3.66	123,830
1991	Rocky Pt.	38	251	6.61	
	Cherry Tree	56	594	10.61	
	Bohemia R.	54	209	3.87	
	1991 Total	148	1,054	7.12	139,862

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

Table 6. Catch (N), age composition (%), number and percent of repeat spawners, and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1991 upper **Chesapeake Bay** operation.

	MALE				**FEMALE**			
AGE GROUP	N(%)	RPTS.	MEAN	RANGE	N(%)	RPTS.	MEAN	RANGE
A. Hook & Line								
III	8(4)	0	339	330-345	0	0	-	-
IV	49(27)	0	377	340-410	18(11)	0	409	380-435
V	93(51)	11	408	370-455	76(46)	2	434	400-470
VI	30(17)	8	447	400-480	65(39)	4	467	405-520
VII	2(1)	1	453	450-455	6(4)	0	503	400-580
% Repeat Spawners		10.9				3.6		
B. Pound Net								
II	2(<1)	0	250	220-280	0	0	-	-
III	14(4)	0	350	328-363	0	0	-	-
IV	91(24)	0	379	335-417	20(6)	0	409	390-423
V	165(43)	31	414	348-467	115(34)	8	439	400-488
VI	98(26)	40	446	403-495	158(46)	40	476	422-528
VII	11(3)	5	481	460-507	41(12)	9	519	467-562
VIII	1(<1)	0	530	-	6(2)	1	549	530-575
% Repeat Spawners		19.9				17.1		
C. All gears combined								
II	2(<1)	0	250	220-280	0	0	-	-
III	22(4)	0	345	328-363	0	0	-	-
IV	140(25)	0	378	335-417	38(8)	0	409	380-435
V	258(46)	42	411	348-467	191(38)	10	437	400-488
VI	128(23)	48	447	400-495	223(44)	44	472	405-528
VII	13(2)	6	467	450-507	47(9)	9	511	400-562
VIII	1(<1)	0	530	-	6(1)	1	549	530-575
% Repeat Spawners		17.0				12.7		

Table 7. Total catch and catch-per-unit-effort () by **gear** type and sampling station for five juvenile species during the 1991 upper Chesapeake Bay juvenile recruitment survey.

STATION	American Shad	Blueback Herring	Alewife Herring	White Perch	Striped Bass
A. HAUL SEINE					
1	1 (0.1)	1065 (118.3)	48 (5.3)	366 (40.7)	23 (2.6)
2	0 (0)	31 (3.4)	13 (1.4)	499 (55.4)	11 (1.2)
3	0 (0)	0 (0)	5 (0.6)	410 (45.6)	0 (0)
4	2 (0.2)	5 (0.6)	8 (0.9)	204 (22.7)	19 (2.1)
5	0 (0)	6 (0.7)	0 (0)	148 (16.0)	36 (4.0)
6	2 (0.3)	325 (36.1)	0 (0)	1014 (112.7)	34 (3.8)
7	2 (0.3)	1105 (138.1)	1 (0.1)	0 (0)	0 (0)
11	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	7 (0.1)	2537 (36.2)	75 (1.1)	2641 (37.7)	123 (1.8)
B. OTTER TRAWL*					
1	1 (0.1)	0 (0)	0 (0)	220 (31.4)	0 (0)
2	0 (0)	0 (0)	3 (0.4)	483 (69.0)	0 (0)
3	0 (0)	0 (0)	3 (0.4)	556 (79.4)	1 (0.1)
4	NA	NA	NA	NA	NA
5	1 (0.1)	1 (0.1)	1 (0.1)	225 (32.1)	10 (1.4)
6	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA
11	NA	NA	NA	NA	NA
TOTAL	2 (0.1)	1 (0.04)	7 (0.3)	1484 (53.0)	11 (0.4)

* 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 during the years 1980-1991* in the upper Chesapeake Bay juvenile recruitment survey.

YEAR	American Shad	Blueback Herring	Alewife Herring	White Perch	Striped Bass
A. HAUL SEINE					
1980	0 (0)	108 (0.6)	194 (1.1)	1315 (7.2)	55 (0.3)
1981	0 (0)	2 (0.02)	108 (0.8)	174 (1.3)	8 (0.1)
1982	0 (0)	130 (0.8)	14 (0.1)	1631 (10.0)	235 (1.4)
1983	0 (0)	1 (0.01)	4 (0.03)	208 (1.5)	8 (0.1)
1984	0 (0)	40 (0.3)	11 (0.1)	914 (7.2)	22 (0.2)
1985	0 (0)	96 (0.7)	99 (0.7)	228 (1.6)	8 (0.1)
1986	8 (0.1)	3484 (24.2)	175 (1.2)	1686 (11.7)	60 (0.4)
1987	0 (0)	40 (0.3)	6 (0.1)	101 (0.8)	6 (0.1)
1989	12 (0.2)	538 (7.8)	35 (0.5)	1124 (16.3)	44 (0.6)
1990	13 (0.2)	1320 (19.1)	552 (8.0)	1833 (26.6)	70 (1.0)
1991	7 (0.1)	2536 (36.2)	75 (1.1)	2641 (37.7)	123 (1.8)
B. OTTER TRAWL**					
1980	0 (0)	27 (0.2)	38 (0.4)	1453 (14.4)	8 (0.1)
1981	0 (0)	0 (0)	35 (0.4)	347 (3.8)	0 (0)
1982	1 (0.01)	8 (0.1)	19 (0.2)	3973 (37.8)	49 (0.5)
1983	0 (0)	2 (0.02)	6 (0.1)	553 (5.5)	2 (0.02)
1984	0 (0)	17 (0.3)	49 (0.7)	2410 (35.4)	10 (0.2)
1985	1 (0.02)	16 (0.2)	171 (1.7)	1014 (10.1)	1 (0.01)
1986	6 (0.1)	1988 (18.9)	241 (2.3)	3028 (28.8)	37 (0.4)
1987	3 (0.03)	3 (0.03)	13 (0.1)	457 (4.6)	1 (0.01)
1989	16 (0.6)	96 (3.4)	15 (0.5)	3125 (111.6)	18 (0.6)
1990	6 (0.3)	280 (12.7)	377 (17.1)	1276 (58.0)	89 (4.1)
1991	2 (0.1)	1 (0.04)	7 (0.3)	1484 (53.0)	11 (0.4)

* 1988 was not sampled
** Data provided by Maryland estuarine fisheries yellow perch project

Table 9. Juvenile American shad captured by date and cell and associated catch-per-unit-effort during the 1991 upper Chesapeake Bay **electrofishing** survey.

CELL	AUGUST			SEPTEMBER				OCTOBER						SHOCK TIME	*
NO.	15	22	29	5	11	18	24	2	8	16	22	30	CATCH	(SEC.)	CPUE
1	0		0		0				1		0		1	2500	1.4
2			0						0				0	1000	0.0
3	0						1						1	1000	3.6
4	0				0				0		0		0	2000	0.0
5							0						0	500	0.0
6													0	0	0.0
7	0		0		0		0						0	2000	0.0
8			0				0		0		0		0	2000	0.0
9			1		1								2	1000	7.2
10													0	0	0.0
11	0		0				0				0		0	2000	0.0
12	0				2		1		0				3	2000	5.4
13			0		0				0		0		0	2000	0.0
14									0		0		0	1000	0.0
15	0		0		0		0		2		0		2	3000	2.4
16	1				0		0		4		0		5	2500	7.2
17					0		0						0	1000	0.0
18	0		1								0		1	1500	2.4
19		0		0				0		1			1	2000	1.8
20		0				1							1	1000	3.6
21		0		0		0				0			0	2000	0.0
22								0				0	0	1000	0.0
23						0		0				0	0	1500	0.0
24										0			0	500	0.0
25		0								0		0	0	1500	0.0
26								0		0		0	0	1500	0.0
27				0		0							0	1000	0.0
28		0		0		0				0			0	2000	0.0
29		0						0		0		0	0	2000	0.0
30								0				0	0	1000	0.0
31				0				0					0	1000	0.0
32		0		0		0				0			0	2000	0.0
33						0		0					0	1000	0.0
34		0		0						0			0	1500	0.0
35				0		0		0					0	1500	0.0
36		0		0		0							0	1500	0.0
TOTL	1	0	2	0	3	1	2	0	7	1	0	0	**17**	52500	1.2

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

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