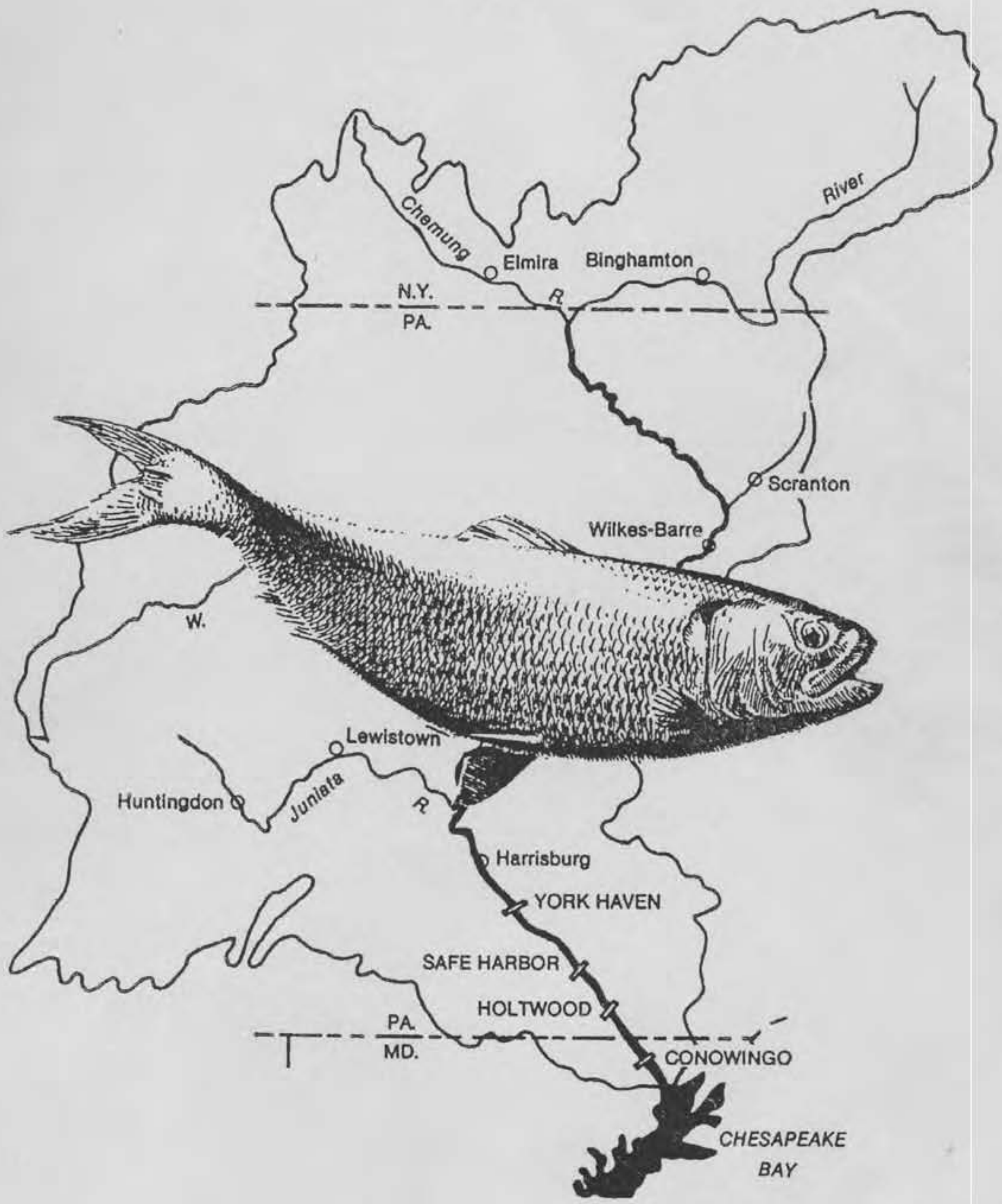
Restoration of American Shad to the Susquehanna River

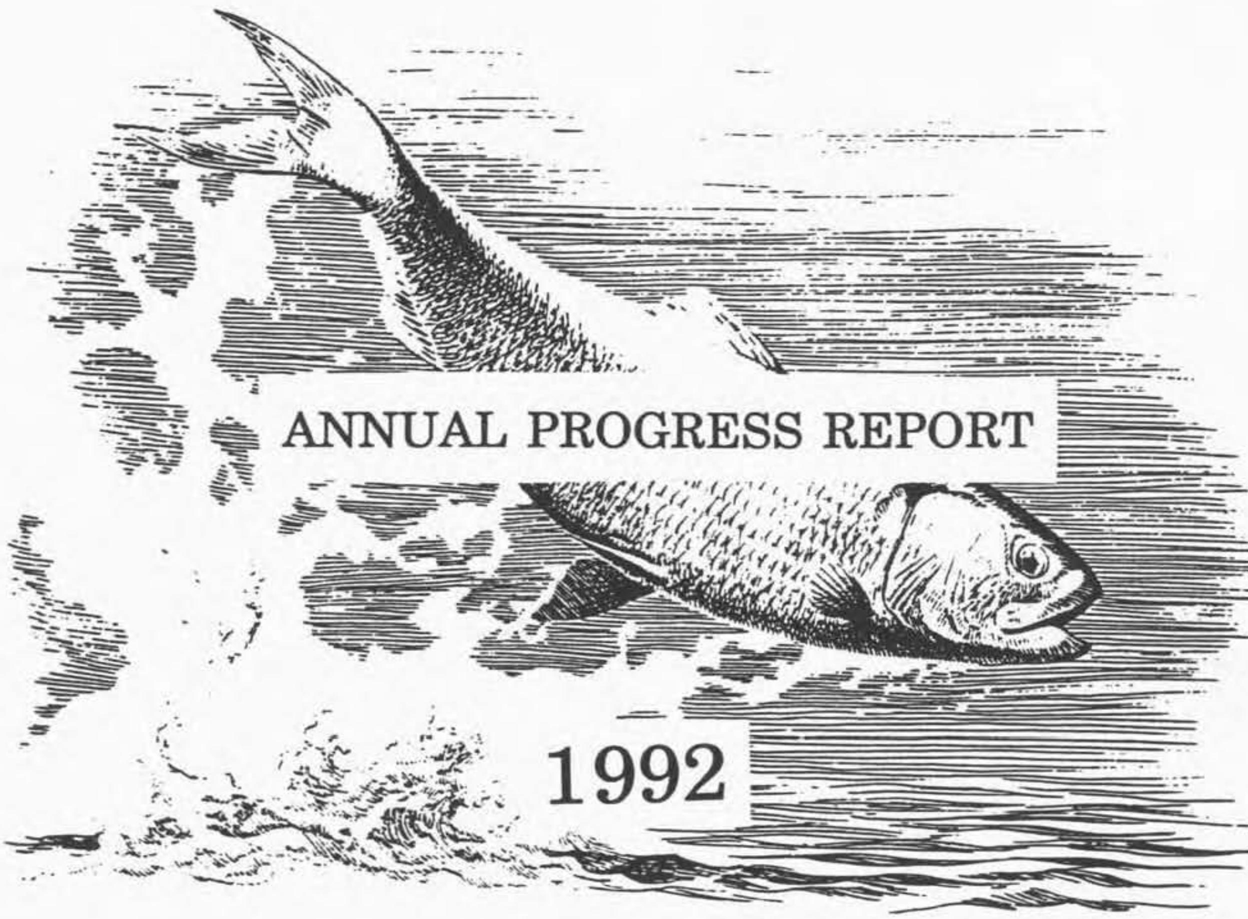
ANNUAL PROGRESS REPORT
1992



Susquehanna River
Anadromous Fish Restoration Committee

February 1993

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1992

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

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

FEBRUARY 1993

EXECUTIVE SUMMARY

The 1992 Annual Report of the Susquehanna River Anadromous Fish Restoration Committee presents results from numerous activities and studies directed at restoring American shad to the Susquehanna River. This was the eighth 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 in 1992 were also dedicated to evaluating adult shad movements in the vicinity of hydroelectric dams 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 1992 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 105,255 fish (Petersen Index). This was based on recapture of 109 shad from a tagged population of 440 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay and angling in the Conowingo tailrace. All of the tagged fish recaptured for this analysis came from the Conowingo lifts. Estimated stock size in 1992 was 25% less than the record estimate for 1991, but still 13 times greater than that of 1984.

Two lifts were operational at Conowingo Dam during the course of the migration season in 1992. Aside from an early breakdown of the West lift crowder, both facilities operated daily from mid-April through mid-June. A total of 3.954 million fish representing 42 taxa and 4 hybrids was handled. Gizzard shad comprised 96% of the total catch. Alosa species included 25,721 American shad, 34,880 blueback herring, 3,629 alewives, and 396 hickory shad.

American shad catch in 1992 was 1,506 (5.5%) fewer than in 1991 but 10,000 more than in 1990 when only one lift was operating. The average four-year capture trend in shad returns continued to improve exponentially. The West lift accounted for 10,335 American shad, 27,533 bluebacks, and most alewives and hickory shad. The new East lift took 15,386 American shad and 7,347 bluebacks. Catch per fishing hour for American shad at both lifts was 20.8, slightly lower than that recorded in 1991 (24.5).

Overall sex ratio of shad in lift collections was 0.9 to 1 favoring females. Males ranged in age from III to VII (71% @ IV-V), and females were III to VIII (75% @ V-VI). Based on scale analysis of 500 shad, 75 (15%) were repeat spawners of which 13 fish had two spawning checks. Otoliths were examined from 237 adult shad sacrificed at the fish lifts. Of these, 54 (23%) showed wild microstructure and no tetracycline tags. All remaining samples had hatchery microstructure and 164 (90%) also exhibited TC marks including single, double, triple and quadruple immersion treatments. One otolith displayed triple immersion and a single feed tag. Since 1989, the corrected hatchery component of the return population at Conowingo has ranged from 67% to 76% and the frequency of unmarked otoliths with hatchery microstructure has declined, as expected, from 48% to 7%.

A total of 15,764 American shad was transported to potential upstream spawning areas with less than 8% observed transport mortality. Most shad were stocked at the Tri-County Boat Club above York Haven Dam, with smaller numbers being released at Muddy Creek, Swatara Creek, Columbia and Pequea. A total of 12,668 river herring was stocked upstream in the Susquehanna and 9,411 were provided to Maryland DNR for release into several upper Chesapeake Bay tributaries undergoing restoration.

The most important information requirement for proper design and placement of entrances for permanent fish passage facilities at hydroelectric dams is the behavior of the targeted migratory fish as they approach the projects under normal operating conditions. In 1992, upstream licensees and SRAFRC co-funded an effort to evaluate this behavior and movement pattern of adult shad in the vicinity of tailrace and spillway areas at Holtwood, Safe Harbor and York Haven dams. Almost 300 fish (100 per project) were radiotagged and released below each project in 25 fish batches. Arrays of constant monitoring receivers and multiple antennae systems were used to document tagged fish appearance, location preferences, and frequencies of occurrence under different operational regimes.

At Holtwood, most shad entered the spillway during spilling and the tailrace during no spill conditions. At Safe Harbor, preference was generally exhibited for the west side of the powerhouse in the vicinity of the large new units. Virtually all tagged fish which reached the York Haven project were detected at the powerhouse receivers.

The Pennsylvania Fish and Boat Commission operated the intensive shad culture facility at Van Dyke and rearing ponds at Thompsontown and Upper Spring Creek. During the period 10 May to 6 June, 18.3 million shad eggs were delivered to Van Dyke from the Delaware River (9.6 M), the Hudson River (3.0 M), and the Connecticut River (5.7 M). The lower Susquehanna River was sampled for spawning fish but no eggs were collected. Overall viability of these eggs was 68.6%, the highest on record, but production amounted to only 4.29 million fry. Large unexplained mortalities occurred at the hatchery in 1992.

All fry produced at Van Dyke were distinctively marked with one to five separate 6-hour immersions in 200 ppm tetracycline (TC). About 3.04 million 18-22 day old fry were stocked in the Juniata River at Thompsontown, 1.25 million were stocked in the lower Susquehanna River at Lapidum, MD, and 356,000 were placed in the Lehigh and Schuylkill rivers. The PA Fish and Boat Commission also reared and stocked 21,800 fingerling shad. These were released at Thompsontown between 26 August and 8 October. Maryland DNR produced 24,100 shad and blueback herring fingerlings which were stocked at Havre de Grace and Elkton, MD in late September, and the Potomac Electric Power Company released 1,000 fingerling shad in the lower Susquehanna from their aquaculture facility on the Patuxent River. In order to simplify the Investigative New Animal Drug application for tetracycline with the FDA, laced feed tags were not used on fingerlings in 1992.

Considerable effort was devoted to assessing general abundance, growth, timing of migration and source of juvenile shad during summer nursery and autumn outmigration from the river. In 1992, shad were sampled with seines at several sites above and below York Haven Dam; with cast nets and a sluice net sampler at York Haven Dam; with lift nets at Holtwood; from cooling water intake strainers and screens at Safe Harbor, Conowingo and Peach Bottom; and by electrofishing in the upper Chesapeake Bay.

River flows during summer and fall months were generally above average and were characterized by frequent fluctuations related to passing storm events. Good numbers of shad were collected with seines at Marietta, Columbia and Wrightsville during July and most (72%) were naturally produced. Outmigration from the river above York Haven occurred during the first 2-weeks in October and otolith analysis of lower river seine samples noted the shift in abundance to hatchery fish (63%) in mid-October. No shad were taken from Safe Harbor strainers and only a few fish were collected at Holtwood Dam, Peach Bottom APS and Conowingo during October.

Juvenile shad grew well in the Susquehanna with wild fish showing larger mean sizes than hatchery fish at comparable age. Overall abundance of shad above Safe Harbor appeared greater than in 1991 but much lower than 1990. Number of shad collected from all sites between Safe Harbor and the Susquehanna Flats (48 total) was the lowest recorded in recent years.

Almost 400 shad from collections at York Haven Dam, Marietta, Columbia, Wrightsville, and Holtwood were returned to Benner Spring for tetracycline mark analysis. Otoliths from 152 fish (39%) were unmarked and displayed wild microstructure. This compares to 21.5% wild fish in 1991 and only 1-4% in earlier years. Rate of recovery of Hudson, Connecticut, and Delaware River fish was disproportionate to their stocking numbers. Hudson fish comprised only 19% of total fry stocked but 64% of all marked recoveries. Connecticut River fry made up 55% of the total release at Thompsontown but only 18% of juvenile returns. Delaware source fry showed an intermediate recovery (i.e. survival) rate relative to stocking numbers.

A special study was conducted to assess behavior and movements of juvenile shad as they approach Holtwood's forebay. Flow mapping and visual observations indicated that shad may orient with a surface flow component, moving downstream outside the skimmer wall toward an existing trash sluice. Insufficient numbers of shad were available to test fish reaction to underwater strobe lights at Holtwood.

American shad egg collection, hatchery culture and marking, juvenile recovery and mark analysis, downstream passage studies at Holtwood, and a portion of the adult shad telemetry were funded from the 1985 settlement agreement with upstream utilities. This funding source provided $425,250 in 1992. Upstream licensees cooperated with Philadelphia Electric Company (PECO) in separately covering 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 electrofishing in the upper Chesapeake Bay, and fingerling pond culture at Havre de Grace and Elkton.

On October 1, 1992, upstream licensees and intervener resource agencies reached an Agreement in Principle to design, model-test and construct permanent fish passage facilities at Holtwood, Safe Harbor, and York Haven dams. State-of-the-art lift facilities will be operational at the lower two projects by April 1, 1997, and at York Haven within 3 years thereafter.

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

Richard St. Pierre
Susquehanna River Coordinator

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JOB I. SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM FISH PASSAGE FACILITIES IN SPRING 1992

RMC ENVIRONMENTAL SERVICES, INC.
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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.

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 was operational by spring 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.

Funding for the 1992 operation and maintenance of the East and West Lifts was provided by Susquehanna Electric Company, a subsidiary of PECO. The trap and transport operations at the Lifts were funded by Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company.

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 1992 operation were to: (1) continue to assess the operation of the East Fish Passage Facility, (2) continue restoration efforts by the trap and transport of 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

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. Lift operation was consistent with the 1992 Susquehanna River Technical Committee Work Plan.

1.1 West Lift

Lift operation commenced on 5 April and occurred on an alternate half day (0700-1300 h) basis through 11 April. The increased collection of American shad on 11 April resulted in daily (0700 to approximately 1900 h) operation through 15 June. Equipment problems on the West Lift crowder and rewiring of the West Lift festoon harness caused the lift to be out of service from 13 April until 1300 h on 19 April. 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 1992 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 were utilized to reduce the large numbers of gizzard shad and/or common carp 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 high fish density. Second, the weir gate settings were adjusted and operation in the "Fast Fish" mode was continued until the fish density was reduced. Normal Lift operation was resumed when conditions returned to a level which did not unduly stress the collected fish. These conditions were determined by the lift supervisor.

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 high fish density and were similar to those previously reported (RMC 1986).

Minimum flow releases followed the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500, and 5,000 cfs were maintained from 1 through 30 April, 1 through 31 May, and 1 through 15 June, respectively. Generally, Units 5 and 6 were used to meet minimum flow releases in April and May. Unit 5 was used in June. The use of 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.

1.2 East Lift

Initial start-up began on 1 April, however, a mechanical problem with the crowder prohibited daily sampling until 5 April. Lift operation resumed on 5 April and occurred on an alternate half day (0700-1300 h) basis through 11 April. The increased collection of shad at the West Lift on 11 April resulted in daily operation (0700-1900 h) of the East Lift from 12 April through 15 June. Some mechanical and electrical problems were encountered and dealt with throughout the season so that uninterrupted trap/transport operations could continue with maximal fishing time.

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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.

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 in 1991 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. Matrix charts developed during 1991 were expanded upon and used during 1992. The matrix charts are based on pond and tailrace elevation and turbine unit operation, and list 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 8.0 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 from 19 through 21 May. Prior to conducting any lifts, adjustments were made to the hopper floor plate, trough entrance, and lift operation. This coupled with permitting and blocking to allow passage through the trough requires a period of approximately four hours. Fish were lifted into the trough and counted as they passed the viewing window. Refer to Section 2.9 for results. 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). Fish were either counted or estimated (when large numbers were present) at each lift and released back to the tailrace. The scientific and common names of fishes collected in 1992 (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 those sacrificed, or that died in handling and transport. Per the 1992 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 and liver tissue, scale samples, lengths, and weights from American shad were provided to researchers from East Carolina University for mitochondrial DNA analysis to determine the genetic origin (hatchery vs wild) of the those shad captured at the Conowingo Fish lifts.

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, 5,000 or more river herring were scheduled for transport to Upper Chesapeake Bay tributaries to assist MD DNR with restoration activities. As feasible any additional river herring were transported upriver. American shad and river herring were generally 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 sufficient numbers were 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 and holding and handling procedures employed were similar to those used previously (RMC 1986).

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 Conowingo Dam 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.

Shad were loaded directly into a trailer unit prior to 24 May. From 24 May through 15 June, shad were placed in a 1,000 gallon black circular holding tank in an attempt to reduce handling stress. When a sufficient number of shad were collected to facilitate a transport event, they were transferred from the holding tank to the trailer unit. 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 Conowingo 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. Two modifications of the trailer units occurred during the season to improve shad transport survival. The standpipe in each trailer unit was pinned in place to prevent it from dislodging during transport events. Flow valves were installed on water lines leading from the pump into the trailer tank to control the circulating flow but still allow the pump motor to run at normal speed.

A checklist prepared for the trailer units was 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 1973 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 1,559,822 fish of 42 taxa and 4 hybrids was caught in 64 days of operation in 1992 (Table 3). Predominant species in order of numerical abundance were gizzard shad, white perch, blueback herring, American shad, comely shiner, and channel catfish. Alosids (blueback herring, alewife, hickory shad, and American shad) comprised 2.6% of the total catch. The catch of gizzard shad was three times greater than that observed in 1991, and the highest recorded since 1987 (Table 2). Gizzard shad dominated the catch daily and comprised nearly 93% of the total catch. The daily catch of fish ranged from 280 on 7 April to 74,783 on 20 April.

2.1.1 Relative Abundance (East Lift)

In 70 days of operation at the East Lift, 2,394,583 fish of 39 taxa and 4 hybrids were caught (Table 4). Predominant species in order of numerical abundance were gizzard shad, American shad, white perch, blueback herring, common carp, and channel catfish. Alosids (blueback herring, hickory shad, alewife, and American shad) comprised 1.0% of the total catch. Twenty hickory shad were captured at the East Lift. Gizzard shad dominated the catch daily from 7 April through 15 June and comprised 98.1% of the total catch. The daily catch of fish ranged from 3 on 5 April to 156,378 on 30 April.

2.2 American Shad Catch (West Lift)

The catch of American shad (10,335) at the West Lift was the third highest recorded (Table 2); 4,586 shad were transported. There were 3,642 shad released back to the tailrace due to advanced maturation of fish and some observed incidences of hooking injury. The remainder consisted of shad transported in combined loads, MD DNR recaptures, handling and holding mortalities, and those sacrificed.

A total of 113 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 (6,972) were collected from 4 through 31 May.

As in the past, the catch per effort (CPE) of American shad varied by station generation, weekend or week day, and time of day (Tables 5 and 6). The CPE was 19.5 and 16.6 on weekends and weekdays, respectively. Generally, catches were greatest between 1100 and 1900 h with the highest catches occurring from 1500 to 1900 h.

The CPE in April was greater for periods of higher generation than for periods of two unit generation (Table 7). The May CPE during periods of two unit generation was 1.5 times higher than during periods of higher generation. Overall CPE, regardless of generation status, was four times higher in May than in April, representative of the peak abundance of shad in May.

The highest daily American shad catch (779) occurred on 30 May (Table 3), and combined with the 652 taken on 31 May represented 13.8% of the 1992 total.

American shad were collected at water temperatures of 50.1 to 75.6 F and at natural river flows of 14,000 to 93,700 cfs (Table 3 and Figure 3). Nearly 93% of the catch occurred when river flows were less than 50,000 cfs.

Over 56% of the American shad were collected at water temperatures >65 F as compared to 1991 when more than 66% were caught at water temperature <65 F (Table 8). Water temperatures during the period of peak shad abundance (4 May to 31 May) ranged from 58.8 to 70.0 F (Table 3).

2.2.1 American Shad Catch (East Lift)

During its second year of operation, 15,386 American shad were captured at the East Lift (Table 4); nearly 1,500 more captured than the 1991 total. Approximately 51% of the total shad captured were transported. A total of 4,559 shad was released back to the tailrace due to advanced maturation of fish and an observed incidence of hooking injury. The remainder consisted of shad transported in combined loads, MD DNR recaptures, handling and holding mortalities, and those sacrificed.

Only nine 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 12 April (Table 4). From 12 to 30 April, a total of 1,266 shad was collected. Most shad (11,333) were collected in May. For the period 1 through 15 June, 2,787 American shad were collected.

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. Although common carp were not as prevalent in the 1992 catch as in 1991, steps were taken to prevent their entrance into the East Lift but still allow American shad, river herring to enter. During slack periods (when American shad were not prevalent in the catch and several common carp were observed near the lift entrance) only one entrance was utilized, usually Upstream A. The weir gate was raised to increase the velocity of the attraction flow to approximately 8 fps. At times this was successful in preventing common carp from entering the lift and improving the American shad catch during certain conditions of Station generation. It is not known, however, if this method would work during extended periods of high water temperatures (>75° F) when common carp are extremely abundant as occurred in 1991.

The catch per effort (CPE) of American shad at the East Lift varied by station generation, weekend or week day, and time of day (Tables 9 and 10). The overall CPE was lower on weekdays (17.5) than on weekends (32.5). Generally, during both periods catches were greatest between 1100 and 1900 h with the highest catches occurring from 1500 to 1900 h.

The CPE in April during periods of increased generation (three or more units) was six times greater than during two unit generation (Table 11) because of increased river flow and station generation. During May, the CPE was 2.5 times higher during two unit generation than at higher generation. The overall CPE in May, regardless of generation status, was 5.5 times greater than in April.

The highest daily American shad catch (713) occurred on 17 May (Table 4), and combined with the 677 taken on 15 May represented 9% of the 1992 total, excepting the three-day trough operation.

American shad were collected at water temperatures of 51.7 to 76.5 F and at natural river flows of 14,000 to 93,700 cfs (Table 4 and Figure 4). Over 56% of the shad were collected at water temperatures >65 F (Table 8). Water temperatures during the period of peak shad abundance (4 May to 31 May) ranged from 58.1 to 70.4 F. Water temperatures from 1 through 15 June, generally increased and ranged from 68.0 to 76.5 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 1992, 4,969 shad were examined at the West Lift and 5,263 at the East Lift. The daily sex ratios are provided in Table 12. The combined male/female ratio observed in 1992 was 0.9:1. Males comprised 68.4% of the total catch in April while females comprised 52.4% and 60.0% in May and June, respectively.

2.4 Age Composition (East and West Lifts)

Scale samples from more than 600 American shad were collected in 1992. Scale samples were obtained from shad sacrificed for otolith and DNA analyses, and from transport and handling mortalities.

A total of 500 scale samples collected in 1992 was aged (Table 13). Males were III to VII years old, while females were III to VIII years old. Most males (70.7%) were IV and V years old, while most females (75.3%) were V and VI years old. Twenty-seven of 188 (14.4%) males were single repeat spawners; seven were double repeat spawners. Thirty-five of 312 (11.2%) females were single repeat spawners; six were double repeat spawners. The overall repeat spawners were 15.0%.

2.5 Tag-Recapture (East and West Lifts)

Including multiple recaptures, RMC recovered 163 MD DNR tagged American shad in 1992; 78 at the East Lift and 85 at the West Lift (Table 14). The MD DNR tagged 466 shad; 125 from pound nets in the upper Chesapeake Bay and 341 by hook and line in the Conowingo tailrace. Of the 109 first time MD DNR recaptures 100 were tagged in the tailrace and nine in pound nets. The nine from pound nets averaged 19.8 days free before capture, while those tagged and recaptured in the tailrace averaged 10.2 days free.

2.6 Other Alosids (East and West Lifts)

The combined catch of river herring (blueback herring and alewife) from both lifts was 38,538. Although the combined 1992 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 34,880 blueback herring was collected (Tables 3 and 4). Blueback herring were first collected on 21 April at the East Lift. Blueback herring were common from 19 May to 15 June at water temperatures ranging from 67.5 to 75.6 F.

A combined total of 3,629 alewife was collected, with the first taken on 5 April at the West Lift (Tables 3 and 4). More than 92% of the alewife were captured at the West Lift. Nearly 55% of the catch occurred between 14 and 17 May at water temperatures ranging from 62.9 to 65.5 F.

The hickory shad catch (396) continued to be low, although the 1992 catch represents the highest total since 1973 (Table 2). The first hickory shad was taken on 11 April at the West Lift (Table 3). Nearly 85% of the total catch was collected from 1 to 6 May at the West Lift at water temperatures ranging from 59.5 to 62.6 F.

2.7 Transport of American Shad and Herring

2.7.1 West Lift

Pre-spawned American shad were transported from 12 April through 14 June. Over 44% of the American shad catch was transported to upstream spawning areas with an overall observed stocking survival of 96.7% (Table 15). A total of 4,586 American shad was transported solely from the West Lift. Some 3,832 American shad were stocked directly to the Susquehanna River at Tri-County. Additionally, 365 shad were released at the PFBC Muddy Creek Access, 155 at the PFBC access at Swatara Creek, 133 at the Columbia PFBC Access, and 101 at Pequea Creek.

Transportation of shad occurred on 36 days and was accomplished in 56 trips (Table 15). The number of trips per day ranged from one to five; load size varied from 5 to 258 shad per trip. Trip survival ranged from 71.8 to 100%. Shad were transported at water temperatures of 59.5 to 72.5 F.

The holding facilities were utilized to maximize transport operations and release larger schools of fish. A total of 300 shad was held over in 1992; only five died in the holding tanks.

2.7.2 East Lift

Prespawned American shad were transported from the East Lift from 10 April through 14 June. Some 7,543 American shad were transported to upstream spawning areas with an overall observed stocking survival of 88.5% (Table 16). Some 7,316 American shad were stocked directly to the Susquehanna River at Tri-County, 114 stocked at PFBC Swatara Creek Access when high river flow or heavy recreational usage prevented access to Tri-County, 88 stocked at the PFBC Muddy Creek Access, and 25 shad stocked at Falmouth.

Transportation of shad occurred on 34 days and was accomplished in 64 trips (Table 16). The number of trips per day ranged from one to four; load size varied from 25 to 189 individuals per trip. Trip survival ranged from 17.5 to 100%. Shad were transported at water temperatures of 53.4 to 74.3 F.

The low survival rate of 17.5% occurred on 24 May appeared to result from an increase in water temperature combined with utilization of the transport trailer as a holding unit. Immediately after the incident occurred, a temporary holding facility was set up utilizing a circular holding tank from the West Lift facility.

Holding facilities were not utilized at the East Lift prior to the setup of a single 1,000 gal circular holding tank on 24 May. However, shad were held overnight in a transport trailer unit on 15 separate occasions. Some 614 American shad were held and 38 died in holding at the East Lift. American shad were either transported directly from the East Lift 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 a single transport unit when numbers were not sufficient to facilitate a separate transport. Some 3,635 American shad were transported upstream from combined transports (Table 17). Combined transports occurred on 25 days and were accomplished in 29 trips. The number of combined trips per day ranged from one to two; load size varied from 27 to 247 individuals per trip. Trip survival ranged from 67.1% to 100%. From these combined transports, 3,175 shad were released at Tri-County, 95 at the PFBC Swatara Creek access, 280 shad were released into Conowingo Pond at the PFBC Muddy Creek Access, and 85 were stocked at the Columbia/Wrightsville Bridge.

2.7.4 Combined River Herring Transport

During 1992, a total of 12,668 river herring (12.6% of total catch) was transported to upstream release sites in the Susquehanna River (Table 18). The transports included 243 alewife and 12,425 blueback herring. Herring were transported between 12 April and 14 June with 99.8% survival.

A total of 9,411 blueback herring was transported to Chesapeake Bay tributaries by the MD DNR. The majority of the herring collected (7,775) were stocked in the upper Patapsco River drainage, which is undergoing fish passage development, concurrent with anadromous fish reintroduction.

2.8 Delayed Transport Mortality

In 1992, a program was instituted to monitor and collect any dead shad observed at the release sites (Tri-County, Swatara Creek, etc.). This program began on 14 April and continued through 19 June. Two biologists searched the shoreline three times weekly above and below each release site for evidence of dead or dying fish. These efforts resulted in the recovery of 842 dead shad which represents 5% of the total shad transported.

Steps were taken to address the observed number of delayed mortalities. As stated in Section 1.5 of this report, the standpipes in all trailer units were pinned to prevent dislodgement during transport and flow valves were installed to control the circulating flow in the transport tanks and allow the pump motor to run at a normal speed. Soon after the flow valves were installed, the pump on Trailer #2 stalled several times during four transport events, resulting in high mortality rates for these trips. The pump was replaced and transport survival rates improved.

To reduce handling stress at the East Lift, a 1,000 gallon circular holding tank was installed on 24 May. The shad were transferred from the holding tank to the trailer unit when enough shad were available for transport. This modification improved transport survival, although a thorough assessment could not be completed due to increasing water temperatures and unavailability of prespawned shad. It is anticipated that the changes implemented in 1992 will improve transport survival.

2.9 Trough Operation

Operation of the trough at the East Lift occurred on 19, 20, and 21 May. During trough operations, a technician positioned at the viewing window recorded the species and number of fish as they passed.

During the three day trial, a total of 29,125 fish, mostly gizzard shad (27,052), American shad (1,168), and minnows (557) was observed (Table 19). An additional 348 fish of various taxa were also observed to exit the trough.

3.0 DISCUSSION

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

A combination of several factors contributed to the overall catch of 25,721 shad. The primary reasons were an increased shad population as compared to years prior to 1991, modification of station operation (Units 1 and 2 off when river flows were less than 65,000 cfs), and the operation of two lifts.

The combined American shad CPE in 1992 (19.8 fish/hr) was lower than the record observed in 1990 (27.5). However, since numerous factors affect the shad catch these data denote only general trends.

A comparison of the total catch, species composition, and CPE between the East and West Fish Lift facilities revealed some differences (Tables 3 and 4). Gizzard shad was the most abundant species comprising 98% and 93% of the total catch at the East and West Lift, respectively. Only two species, white perch and blueback herring accounted for >1.0% of the combined catch at the West Lift, while no species other than gizzard shad comprised >1.0% of the catch at the East Lift. 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, white perch, and blueback herring 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 78% of the American shad collected at the West Lift occurred when Units 1 and 2 were shutdown (Table 20). 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 slightly when Units 10 and 11 were in operation, although a greater increase was observed in 1991. More than 48% of the American shad collected at the East Lift occurred during the operation of Units 10 and 11, while nearly 43% of the East Lift American shad catch occurred when Units 10 and 11 were not operating.

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Table 1. List of scientific and common names of fishes collected at the Conowingo Dam Fish Lifts, 1972 through 1992.

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, 1973-1992.

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
NO. DAYS	62	58	55	63	61	35	29	30	37	44
LIFTS	1,527	819	514	684	707	358	301	403	490	725
EST. OPER. TIME(HR.)	996	500	307	375	413	212	187	221	275	502
FISHING TIME(HR)	623	222	189	252	245	136	123	117	178	336
# SPECIES	43	42	41	38	40	44	37	42	48	48
AMERICAN EEL	2050	91937	64375	60409	14601	5878	1602	377	11329	3961
BLUEBACK HERRING	330341	340084	69916	35519	24395	13098	2282	502	618	25249
HICKORY SHAD	739	219	20	-	1	-	-	1	1	15
ALEWIFE	144727	16675	4311	235	188	5	9	9	129	3433
AMERICAN SHAD	65	121	87	82	165	54	50	139	328	2039
GIZZARD SHAD	45668	119672	139222	382275	742056	55104	75553	275736	1156662	1226374
ATLANTIC MENHADEN	-	112	-	506	1596	-	-	16	42	-
RAINBOW TROUT	67	20	24	54	291	70	15	23	219	20
BROWN TROUT	286	483	219	427	700	261	324	258	207	219
BROOK TROUT	3	4	1	-	2	23	-	4	3	5
TROUT	-	-	-	-	-	-	-	-	2	-
RAINBOW SMELT	-	-	-	-	-	-	-	-	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-	-	-	-
CHAIN PICKEREL	1	10	-	-	1	-	-	-	1	-
NORTHERN PIKE	2	2	-	-	2	2	4	3	-	5
MUSKELLUNGE	104	9	7	12	48	14	5	27	1	4
REDFIN PICKEREL	-	-	-	-	-	-	-	-	-	-
CARPS AND MINNOWS	-	-	-	-	-	-	-	-	-	1
GOLDFISH	27	1	9	4	1	-	-	-	1	-
COMMON CARP	16362	34383	15114	6755	16256	11842	14946	8879	18313	15362
RIVER CHUB	-	-	-	-	-	-	-	1	-	-
GOLDEN SHINER	430	437	751	1622	652	221	304	35	155	92
COMELY SHINER	252	3870	2079	740	769	1152	1707	761	281	14214
SPOTTAIL SHINER	137	2036	268	1743	8107	8506	1533	849	31	315
SWALLOWTAIL SHINER	-	-	-	-	-	-	-	-	3	-
ROSYFACE SHINER	-	-	1	-	-	-	-	-	-	8
SPOTFIN SHINER	40	3011	1231	45879	7960	3751	41	314	524	622
BLUNTNOSE MINNOW	-	-	-	-	-	4	-	-	-	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-	-	2
LONGNOSE DACE	-	1	-	-	-	4	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-	-	-
SHINERS	3	-	-	-	-	-	-	-	-	6
QUILLBACK	27780	14565	8388	9882	6734	2361	5134	2929	3622	1617
WHITE SUCKER	1034	286	152	444	282	189	906	1145	1394	582
CREEK CHUBSUCKER	3	1	-	-	-	-	-	-	4	2
NORTHERN HOG SUCKER	2	-	1	5	-	3	6	13	1	-
SHORTHEAD REDHORSE	4420	434	445	1276	1724	697	2163	1394	6533	6974
WHITE CATFISH	6394	2200	6178	1451	3081	982	515	605	2199	565
YELLOW BULLHEAD	45	1	32	2	47	25	13	18	36	61
BROWN BULLHEAD	5328	1612	740	451	2416	125	284	675	531	338
CHANNEL CATFISH	55084	75663	74042	41508	90442	48575	38251	38929	55528	40941

TABLE 2 CONTINUED.

YEAR	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
NO. DAYS	29	34	55	59	60	63	51	64	64	64
LIFTS	648	519	1,118	831	1,414	1,339	1,117	1,363	1,262	1,559
EST. OPER. TIME(HR.)	299	251	542	546	639	637	539	664	685	698
FISHING TIME(HR)	224	192	421	449	532	513	457	571	551	589
# SPECIES	41	35	41	43	46	49	45	43	45	46
AMERICAN EEL	1080	155	550	364	1662	103	157	224	213	2622
BLUEBACK HERRING	517	311	6763	6327	5861	14570	3598	9658	15616	27533
HICKORY SHAD	5	6	9	45	35	64	28	77	120	376
ALEWIFE	50	26	379	2822	357	674	1902	425	2649	3344
AMERICAN SHAD	413	167	1546	5195	7667	5146	8218	15719	13332	10335
GIZZARD SHAD	950252	912666	2182888	1714441	2488618	1402565	926213	1084073	433472	1450299
ATLANTIC MENHADEN	1	-	1	-	-	-	-	-	-	-
RAINBOW TROUT	2	5	70	9	14	10	4	14	13	12
BROWN TROUT	225	141	175	65	83	85	110	63	82	127
BROOK TROUT	2	-	1	-	-	1	1	-	7	5
TROUT	-	-	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	1	1	-	-	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	1	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	1	-	6	2
NORTHERN PIKE	1	-	-	2	-	-	-	-	5	-
MUSKELLUNGE	-	-	15	-	-	1	-	2	2	10
REDFIN PICKEREL	-	-	-	-	1	-	-	-	-	-
CARPS AND MINNOWS	-	-	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	1	1	-	-	-
COMMON CARP	16273	8012	6729	2930	4607	8535	875	2761	8262	4105
RIVER CHUB	-	-	-	-	-	-	-	-	-	-
GOLDEN SHINER	216	8	292	23	40	28	5	2	7	11
COMELY SHINER	3176	871	5141	582	21199	11734	35239	5798	18816	8974
SPOTTAIL SHINER	2132	-	3525	6247	155	55	282	112	635	156
SWALLOWTAIL SHINER	-	-	-	1	-	-	-	-	-	-
ROSYFACE SHINER	-	-	-	-	-	-	-	-	-	-
SPOTFIN SHINER	501	-	2695	695	796	65	5381	135	2553	214
BLUNTNOSE MINNOW	-	-	-	-	-	65	-	-	-	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	1	-	-	-	-
SHINERS	-	-	-	-	-	-	-	-	-	-
QUILLBACK	4679	1942	957	2327	1881	1578	170	1270	2991	132
WHITE SUCKER	412	109	776	853	263	540	410	161	113	83
CREEK CHUBSUCKER	-	-	-	-	5	1	-	1	-	9
NORTHERN HOG SUCKER	-	-	-	2	4	1	1	3	-	5
SHORTHEAD REDHORSE	7558	3467	3362	2057	3583	4782	2735	4228	2871	1813
WHITE CATFISH	224	77	1094	284	917	3849	1740	560	1292	152
YELLOW BULLHEAD	10	7	21	35	41	80	445	32	25	23
BROWN BULLHEAD	179	69	461	134	163	345	402	108	263	107
CHANNEL CATFISH	12559	20479	15200	18898	11699	36212	21692	8689	10294	7070

TABLE 2 CONTINUED.

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM WEST FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1973-1992.

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FISHING TIME(HR)	623	222	189	252	245	136	123	117	178	336
# SPECIES	43	42	41	38	40	44	37	42	48	48
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	6
MADTOMS	-	-	-	-	-	-	-	-	-	1
TADPOLE MADTOM	-	-	-	-	-	-	-	-	-	1
MUMMICHOG	-	-	-	1	-	-	-	-	-	1
WHITE PERCH	647493	897113	511699	568018	224843	113164	43103	26971	83363	53527
STRIPED BASS	495	1150	174	13	1196	934	260	904.	3277	60
ROCK BASS	32	31	46	227	128	50	46	88.	381	138
REDBREAST SUNFISH	2056	1398	3040	3772	8377	4187	3466	1524	1007	1335
GREEN SUNFISH	-	4	39	81	168	25	-	16	28	91
PUMPKINSEED	2578	2579	1000	878	1687	512	323	446	306	848
BLUEGILL	1423	927	3058	2712	5442	1361	813	942	1299	1184
SMALLMOUTH BASS	298	119	153	327	701	262	374	455	881	1095
LARGEMOUTH BASS	80	23	19	33	14	22	22	41	13	20
WHITE CRAPPIE	664	4371	9290	2987	1003	673	384	100	231	303
BLACK CRAPPIE	4	25	45	86	199	103	53	15	20	39
SUNFISHES	-	-	-	-	-	-	-	-	-	-
TESSELLATED DARTER	1	4	1	-	-	1	-	-	2	-
YELLOW PERCH	1090	682	494	2904	735	526	379	373	1007	724
LOGPERCH	-	-	-	-	-	27	-	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-	1	-
WALLEYE	2734	1613	369	2267	2140	967	2491	4153	2645	504
BANDED DARTER	-	-	-	-	-	1	-	-	-	-
ATLANTIC NEEDLEFISH	-	-	1	-	-	-	-	-	2	-
LAMPREYS	-	-	-	-	-	-	-	-	-	-
SEA LAMPREY	2	-	2	29	11	1	3	1	55	56
LAKE HERRING	1	-	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	-	-	-	-	270	273	2674	39	160
TIGER MUSKIE	-	-	-	-	-	13	132	34	53	56
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-	-	-
	1300345	1617888	917043	1175616	1169161	276045	197769	372379	1353308	1403175

TABLE 2 CONTINUED.

YEAR	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
NO. DAYS	29	34	55	59	60	63	51	64	64	64
LIFTS	648	519	1,118	831	1,414	1,339	1,117	1,363	1,262	1,559
EST. OPER. TIME(HR.)	299	251	542	546	639	637	539	664	685	698
FISHING TIME(HR)	224	192	421	449	532	513	457	571	551	589
# SPECIES	41	35	41	43	46	49	45	43	45	46
MARGINED MADTOM	-	-	-	3	-	1	-	-	-	-
MADTOMS	-	-	-	-	-	-	-	-	-	-
TADPOLE MADTOM	-	-	-	-	-	-	1	-	1	-
MUMMICHOG	-	-	-	-	-	-	-	-	-	-
WHITE PERCH	23151	6402	68344	56977	29995	90651	15713	24581	14996	37521
STRIPED BASS	23	181	213	194	1337	874	357	1068	1722	2094
ROCK BASS	269	158	122	200	231	110	352	39	53	106
REDBREAST SUNFISH	401	465	3366	1433	1471	730	443	187	281	154
GREEN SUNFISH	16	7	133	15	64	19	33	17	22	35
PUMPKINSEED	228	104	1013	402	490	135	115	46	48	118
BLUEGILL	587	284	6048	1654	2436	1107	1561	446	486	813
SMALLMOUTH BASS	1003	608	1081	666	536	548	491	424	705	411
LARGEMOUTH BASS	17	8	67	75	69	117	164	48	176	211
WHITE CRAPPIE	450	59	345	199	272	125	230	33	107	74
BLACK CRAPPIE	46	6	45	51	19	42	45	22	22	23
SUNFISHES	-	-	-	-	-	-	-	2	-	-
TESSELLATED DARTER	-	-	1	-	1	1	-	-	6	2
YELLOW PERCH	387	487	2145	2267	632	815	310	124	502	127
LOGPERCH	-	-	1	1	1	2	-	2	1	2
SHIELD DARTER	-	-	-	-	-	-	-	-	-	-
WALLEYE	663	236	609	380	267	311	319	460	414	203
BANDED DARTER	-	-	-	-	1	-	-	2	10	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	2	-	5	-	3
LAMPREYS	2	-	-	-	-	-	-	-	-	-
SEA LAMPREY	8	4	164	26	21	59	94	38	34	42
LAKE HERRING	1	-	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	2	-	-	-
STRIPED BASS X WHITE BASS	355	282	1377	1713	5895	6203	5243	1172	797	359
TIGER MUSKIE	16	10	73	35	30	20	33	10	5	3
BROOK TROUT X LAKE TROUT	-	2	-	2	5	-	1	-	-	1
STRIPED BASS X WHT PERCH	-	-	-	10	19	1	3	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-	2	1
BIGMOUTH BUFFALO	-	-	-	-	-	-	1	-	-	-
	1028090	957821	2317797	1830641	2593445	1592965	1035121	1162841	534029	1559822

TABLE 3

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM WEST LIFT 5 APRIL THROUGH 15 JUNE 1992.

DATE	05 APRIL	07 APRIL	09 APRIL	11 APRIL	12 APRIL	13 APRIL	19 APRIL	20 APRIL
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	8	6	10	18	25	18	12	35
FIRST LIFT	640	620	600	606	607	626	1231	557
LAST LIFT	1200	1150	1155	1455	1729	1647	1740	1705
OPERATING TIME (HR)	5.33	5.50	5.92	8.82	11.37	10.35	5.15	11.13
FISHING TIME (HR)	5.33	5.50	5.22	7.35	9.57	9.22	5.15	9.55
AVE WATER TEMP (F)	46.0	49.4	50.1	51.0	53.1	54.6	54.2	54.7
AMERICAN EEL	5	2	2	2	4	13	-	10
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	1	6	1	-	-
ALEWIFE	1	-	-	6	63	28	3	10
AMERICAN SHAD	-	-	2	10	105	60	1	-
GIZZARD SHAD	564	270	781	11892	8052	8465	3265	74644
RAINBOW TROUT	-	-	-	-	-	-	1	-
BROWN TROUT	-	1	-	1	1	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	1	2	-	-
COMMON CARP	-	-	1	4	1	-	1	-
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	20	-	10	90	-
SPOTTAIL SHINER	-	-	-	-	155	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	2	-	-	1	-	-
WHITE SUCKER	-	-	6	13	4	15	2	3
CREEK CHUBSUCKER	-	-	-	-	-	-	5	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	6	13	39	-	3
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	1	-	-	-	-	3	1
BROWN BULLHEAD	-	-	-	-	-	-	1	1
CHANNEL CATFISH	11	2	61	78	53	122	73	84
WHITE PERCH	-	-	-	-	-	-	10	16
STRIPED BASS	-	-	-	5	1	4	-	-
ROCK BASS	-	-	-	-	2	-	4	1
REDBREAST SUNFISH	-	-	-	-	-	-	2	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	1	-	1	5	3	-	-
BLUEGILL	-	-	1	2	5	4	1	2
SMALLMOUTH BASS	-	-	2	4	13	7	-	5
LARGEMOUTH BASS	-	-	-	3	3	8	1	1
WHITE CRAPPIE	-	-	1	-	1	1	1	-
BLACK CRAPPIE	-	1	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	2	-
YELLOW PERCH	-	1	2	4	6	1	-	1
LOGPERCH	-	-	-	-	-	2	-	-
WALLEYE	-	-	-	3	2	2	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	1
STRIPED BASS X WHITE BASS	-	1	3	52	52	27	-	-
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	581	280	864	12107	8548	8815	3466	74783

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
# OF LIFTS	37	30	31	22	28	26	34	18
FIRST LIFT	602	548	557	554	556	615	600	1150
LAST LIFT	1742	1701	1730	1756	1755	1753	1750	1758
OPERATING TIME (HR)	11.67	11.22	11.55	12.03	11.98	11.63	11.83	6.13
FISHING TIME (HR)	10.35	7.48	9.55	10.48	8.48	9.72	8.95	4.67
AVE WATER TEMP (F)	53.8	54.3	53.9	56.1	57.2	59.7	57.8	54.7
AMERICAN EEL	1	1	-	2	2	1	1	-
BLUEBACK HERRING	-	41	-	4	15	-	11	14
HICKORY SHAD	-	-	1	2	4	-	2	-
ALEWIFE	24	-	13	-	-	14	-	-
AMERICAN SHAD	1	10	15	27	37	75	93	129
GIZZARD SHAD	57369	52700	24565	12950	39075	31135	69000	21400
RAINBOW TROUT	-	1	-	-	-	1	-	-
BROWN TROUT	-	1	-	-	1	-	1	1
BROOK TROUT	-	-	-	-	1	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	9	3	17	43	48	50	59	17
GOLDEN SHINER	-	-	1	-	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	2	15	32	1
WHITE SUCKER	2	4	4	1	-	4	1	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	11	8	15	18	20	29	73	10
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	1	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	1	-	-	-	-
CHANNEL CATFISH	23	11	52	57	33	183	110	99
WHITE PERCH	9	1	-	2	5	194	142	121
STRIPED BASS	1	5	1	1	2	2	6	5
ROCK BASS	1	1	1	-	-	1	1	-
REDBREAST SUNFISH	-	-	-	-	-	-	1	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	1	-	-	-	-	-	2	-
SMALLMOUTH BASS	2	7	13	4	3	10	23	8
LARGEMOUTH BASS	-	1	1	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	1	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	1	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	3	3	-	1	-	5	5	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	1	-	2	-	-	2
STRIPED BASS X WHITE BASS	-	4	11	7	4	5	10	3
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	1	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	57459	52802	24713	13120	39254	31725	69573	21812

TABLE 3 CONTINUED.

DATE	29 APRIL	30 APRIL	01 MAY	02 MAY	03 MAY	04 MAY	05 MAY	06 MAY
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	33	28	24	24	31	23	20	23
FIRST LIFT	554	615	553	553	540	601	800	604
LAST LIFT	1750	1714	1741	1800	1729	1730	1747	1738
OPERATING TIME (HR)	11.93	10.98	11.80	12.12	11.82	11.48	9.78	11.57
FISHING TIME (HR)	10.83	9.03	10.37	9.40	8.67	9.18	7.10	9.15
AVE WATER TEMP (F)	56.9	58.5	59.5	60.3	62.6	62.5	60.4	60.8
AMERICAN EEL	2	3	4	-	39	80	36	88
BLUEBACK HERRING	-	-	42	-	137	95	101	61
HICKORY SHAD	-	-	68	25	142	18	25	58
ALEWIFE	43	52	53	35	537	-	-	-
AMERICAN SHAD	102	176	47	132	256	299	136	227
GIZZARD SHAD	48100	15180	19710	24740	28600	12930	33450	11225
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	1	-	3	2	7	3	9	4
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	3	-	-	-
COMMON CARP	6	11	2	5	7	5	6	6
GOLDEN SHINER	-	-	-	-	1	-	2	3
COMELY SHINER	-	-	-	6	-	-	10	1
SPOTTAIL SHINER	-	-	1	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	14	-	-	-	1	-	-	-
WHITE SUCKER	-	-	-	3	2	1	1	2
CREEK CHUBSUCKER	-	-	-	-	-	1	-	-
NORTHERN HOG SUCKER	-	-	5	-	-	-	-	-
SHORTHEAD REDHORSE	300	54	14	48	132	91	63	26
WHITE CATFISH	1	1	1	-	-	-	3	5
YELLOW BULLHEAD	-	-	-	-	-	2	-	-
BROWN BULLHEAD	3	1	-	-	1	1	2	1
CHANNEL CATFISH	112	114	92	250	26	46	175	77
WHITE PERCH	394	636	724	338	730	930	1397	1020
STRIPED BASS	8	5	3	2	4	1	3	2
ROCK BASS	-	1	3	3	2	6	14	6
REDBREAST SUNFISH	-	-	2	-	-	5	3	2
GREEN SUNFISH	-	-	6	-	-	2	2	3
PUMPKINSEED	-	-	4	-	-	5	8	3
BLUEGILL	2	2	44	10	20	10	34	17
SMALLMOUTH BASS	28	9	12	7	48	10	7	9
LARGEMOUTH BASS	-	-	14	8	12	8	11	6
WHITE CRAPPIE	1	-	2	-	2	2	10	1
BLACK CRAPPIE	-	-	1	1	2	4	1	2
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	2	4	6	5	9	5
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	4	3	2	3	2	3	4	9
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	6	-
STRIPED BASS X WHITE BASS	1	4	-	1	1	-	3	-
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	49122	16252	20861	25623	30720	14563	35531	12869

TABLE 3 CONTINUED.

DATE	07 MAY	08 MAY	09 MAY	10 MAY	11 MAY	12 MAY	13 MAY	14 MAY
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	23	20	24	26	24	23	21	27
FIRST LIFT	602	559	602	602	605	602	602	605
LAST LIFT	1750	1748	1756	1751	1755	1800	1710	1740
OPERATING TIME (HR)	11.80	11.82	11.90	11.82	11.83	11.97	11.13	11.58
FISHING TIME (HR)	9.78	10.77	9.80	9.03	9.73	8.98	8.95	9.37
AVE WATER TEMP (F)	61.1	59.0	58.8	60.0	60.5	61.7	61.3	62.9
AMERICAN EEL	50	10	32	50	15	94	53	411
BLUEBACK HERRING	32	-	-	118	-	119	382	-
HICKORY SHAD	2	2	3	6	8	1	-	-
ALEWIFE	-	122	84	-	38	43	-	750
AMERICAN SHAD	221	17	58	358	377	234	292	216
GIZZARD SHAD	11865	6565	20500	31550	10735	38275	13820	27150
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	2	-	5	2	2	3	6	8
BROOK TROUT	-	-	-	2	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	1	-	-	-	-	-	-	-
COMMON CARP	2	3	2	-	1	106	26	66
GOLDEN SHINER	-	-	-	-	-	-	3	-
COMELY SHINER	-	-	-	15	-	170	515	1126
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	1	2	-	2
WHITE SUCKER	1	-	-	-	-	-	1	1
CREEK CHUBSUCKER	-	-	-	-	1	-	1	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	9	3	5	46	72	307	142	156
WHITE CATFISH	1	-	-	-	1	1	-	1
YELLOW BULLHEAD	-	2	1	-	-	1	-	-
BROWN BULLHEAD	6	-	-	-	-	-	3	1
CHANNEL CATFISH	23	57	24	47	22	149	147	554
WHITE PERCH	1296	1194	1417	850	1712	1535	1485	2005
STRIPED BASS	2	-	4	-	5	3	7	4
ROCK BASS	4	1	2	4	3	6	8	10
REDBREAST SUNFISH	-	1	-	2	-	1	-	8
GREEN SUNFISH	-	1	-	-	-	-	-	1
PUMPKINSEED	3	3	5	1	4	1	7	15
BLUEGILL	27	12	39	16	27	17	17	108
SMALLMOUTH BASS	6	-	-	8	5	12	11	24
LARGEMOUTH BASS	-	-	12	12	3	3	1	4
WHITE CRAPPIE	-	-	1	1	3	1	2	3
BLACK CRAPPIE	1	1	1	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	3	-	5	1	3	3	3	11
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	1	1	1	2	1	5	18	10
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	1	-	-	-	3	2	2
STRIPED BASS X WHITE BASS	2	-	2	3	1	4	2	-
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	13560	7996	22203	33094	13040	41099	16954	32647

TABLE 3 CONTINUED.

DATE	15 MAY	16 MAY	17 MAY	18 MAY	19 MAY	20 MAY	21 MAY	22 MAY
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	27	32	27	28	27	28	28	23
FIRST LIFT	606	609	635	600	602	601	604	608
LAST LIFT	1746	1750	1745	1728	1743	1759	1835	1735
OPERATING TIME (HR)	11.67	11.68	11.17	11.47	11.68	11.97	12.52	11.45
FISHING TIME (HR)	10.77	9.13	9.15	8.38	9.32	9.58	9.98	9.45
AVE WATER TEMP (F)	63.0	66.2	65.5	66.4	67.5	67.5	67.5	67.8
AMERICAN EEL	28	165	17	506	95	292	271	25
BLUEBACK HERRING	-	135	-	89	3882	1460	139	481
HICKORY SHAD	-	-	-	1	-	-	-	-
ALEWIFE	407	-	818	-	-	-	-	-
AMERICAN SHAD	244	103	196	178	276	167	154	269
GIZZARD SHAD	18690	59250	28210	48450	24175	33400	23085	9120
RAINBOW TROUT	-	1	-	-	-	-	1	1
BROWN TROUT	5	8	2	2	1	3	2	2
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	32	10	7	64	265	250	9	4
GOLDEN SHINER	-	-	-	-	-	1	-	-
COMELY SHINER	30	10	5	163	2600	255	3335	400
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	1	-	5	15	180
QUILLBACK	1	1	-	-	1	6	3	2
WHITE SUCKER	-	1	-	-	-	1	-	-
CREEK CHUBSUCKER	-	1	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	35	31	8	7	1	4	2	2
WHITE CATFISH	1	2	-	-	-	6	12	-
YELLOW BULLHEAD	-	2	-	-	-	1	-	-
BROWN BULLHEAD	3	2	2	-	2	2	3	-
CHANNEL CATFISH	111	254	99	198	413	536	175	211
WHITE PERCH	2920	1315	1265	884	1070	265	1000	570
STRIPED BASS	13	16	22	9	10	14	36	44
ROCK BASS	6	3	3	2	3	-	1	-
REDBREAST SUNFISH	6	6	7	3	8	6	8	9
GREEN SUNFISH	1	-	-	1	-	1	6	1
PUMPKINSEED	12	5	4	1	1	3	2	1
BLUEGILL	17	17	24	17	13	17	37	13
SMALLMOUTH BASS	17	11	9	5	4	2	4	3
LARGEMOUTH BASS	18	6	9	1	4	2	10	6
WHITE CRAPPIE	6	3	3	-	2	-	2	-
BLACK CRAPPIE	-	-	-	1	1	1	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	4	4	13	4	1	1	8	2
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	7	11	10	5	2	2	3	2
ATLANTIC NEEDLEFISH	-	-	-	-	2	-	-	-
SEA LAMPREY	1	4	1	4	-	-	4	2
STRIPED BASS X WHITE BASS	2	2	1	1	2	2	12	9
TIGER MUSKIE	-	-	-	-	-	-	1	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	22617	61379	30735	50597	32834	36705	28340	11359

TABLE 3 CONTINUED.

DATE	23 MAY	24 MAY	25 MAY	26 MAY	27 MAY	28 MAY	29 MAY	30 MAY
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	29	25	29	26	24	29	26	15
FIRST LIFT	601	610	607	604	605	600	604	605
LAST LIFT	1751	1742	1745	1751	1659	1739	1800	1740
OPERATING TIME (HR)	11.83	11.53	11.63	11.78	10.90	11.65	11.93	11.58
FISHING TIME (HR)	10.10	9.53	11.75	10.63	9.65	11.32	11.00	7.25
AVE WATER TEMP (F)	67.6	68.2	68.0	68.4	66.0	70.0	67.5	68.0
AMERICAN EEL	87	-	-	27	7	4	5	-
BLUEBACK HERRING	1966	1810	76	454	9	270	1604	4190
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	200	-	-	-	-	-	-
AMERICAN SHAD	55	248	122	362	234	257	241	779
GIZZARD SHAD	41300	9840	23705	14760	16720	25350	21385	10850
RAINBOW TROUT	-	1	-	-	2	1	-	-
BROWN TROUT	3	5	2	3	-	2	1	-
BROOK TROUT	-	-	-	-	-	-	1	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	1	-
COMMON CARP	1647	4	4	2	2	8	57	-
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	60	-	-	35	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	2	2	-	1	-	-
WHITE SUCKER	-	1	-	1	-	1	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	2	1	-	-	-	1	-
WHITE CATFISH	-	-	-	-	-	1	-	3
YELLOW BULLHEAD	2	-	-	-	-	-	1	-
BROWN BULLHEAD	1	1	2	-	13	-	1	-
CHANNEL CATFISH	25	9	28	118	51	25	51	7
WHITE PERCH	702	1415	1218	602	320	515	336	705
STRIPED BASS	52	70	35	78	52	44	113	30
ROCK BASS	-	-	-	-	1	-	-	-
REDBREAST SUNFISH	5	11	3	5	2	3	3	2
GREEN SUNFISH	-	2	3	-	1	1	-	-
PUMPKINSEED	1	5	-	-	-	5	-	-
BLUEGILL	11	40	6	14	6	17	11	1
SMALLMOUTH BASS	4	10	6	4	1	10	3	1
LARGEMOUTH BASS	4	4	-	2	2	17	3	-
WHITE CRAPPIE	1	1	2	4	1	2	-	-
BLACK CRAPPIE	-	1	1	-	-	-	1	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	3	2	-	1	1	1	1	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	1	7	1	2	6	4	4	3
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	2	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	2	5	3	4	8	3	3	5
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	1	-
	45934	13694	25220	16480	17439	26542	23828	16576

TABLE 3 CONTINUED.

DATE	31 MAY	01 JUNE	02 JUNE	03 JUNE	04 JUNE	05 JUNE	06 JUNE	07 JUNE
LOCATION	641	641	641	641	641	641	641	641
# OF LIFTS	29	28	25	26	22	34	33	23
FIRST LIFT	554	559	555	601	602	606	559	600
LAST LIFT	1730	1750	1749	1730	1736	1740	1740	1755
OPERATING TIME (HR)	11.60	11.85	11.90	11.48	11.57	11.57	11.68	11.92
FISHING TIME (HR)	11.47	11.27	10.17	11.22	10.08	11.43	11.50	9.90
AVE WATER TEMP (F)	68.9	68.6	69.9	67.8	68.9	-	69.4	68.9
AMERICAN EEL	4	-	6	10	-	10	7	-
BLUEBACK HERRING	966	158	66	461	744	1228	274	1090
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	652	69	52	324	44	64	63	17
GIZZARD SHAD	21850	10435	25100	19630	16352	24230	58850	18130
RAINBOW TROUT	-	-	1	-	-	1	-	-
BROWN TROUT	-	1	-	1	-	1	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	1	-	-	-	-
COMMON CARP	71	25	47	1	2	6	243	10
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	7	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	2	-	-	1	-	-	-	-
QUILLBACK	2	1	28	1	1	1	1	-
WHITE SUCKER	1	-	1	-	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	1	2	2	-	1	-	-	-
WHITE CATFISH	1	-	6	23	2	43	4	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	2
BROWN BULLHEAD	1	-	4	15	-	21	1	3
CHANNEL CATFISH	11	41	56	120	117	597	54	69
WHITE PERCH	296	617	450	205	534	1021	108	555
STRIPED BASS	27	175	90	19	86	59	127	119
ROCK BASS	-	1	-	-	-	-	-	1
REDBREAST SUNFISH	4	13	3	1	1	1	1	4
GREEN SUNFISH	-	-	-	-	-	-	-	2
PUMPKINSEED	-	4	-	-	1	-	-	1
BLUEGILL	19	22	3	11	4	-	10	18
SMALLMOUTH BASS	2	8	3	-	1	-	-	1
LARGEMOUTH BASS	2	2	1	1	1	1	1	-
WHITE CRAPPIE	1	2	1	-	1	-	-	2
BLACK CRAPPIE	-	-	-	-	1	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	2	-	-	-	-	1	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	4	7	5	1	1	-	3	4
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	-	-	-	-	1	-
STRIPED BASS X WHITE BASS	2	5	17	3	7	3	8	9
TIGER MUSKIE	-	1	-	-	-	1	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	23929	11589	25942	20829	17901	27289	59757	20037

TABLE 3 CONTINUED.

DATE	08 JUNE	09 JUNE	10 JUNE	11 JUNE	12 JUNE	13 JUNE	14 JUNE	15 JUNE	TOTALS
LOCATION	641	641	641	641	641	641	641	641	
# OF LIFTS	24	24	18	22	22	23	19	12	1559
FIRST LIFT	559	604	1022	559	602	601	603	559	
LAST LIFT	1800	1755	1740	1749	1740	1735	1517	1200	
OPERATING TIME (HR)	12.02	11.85	7.30	11.83	11.63	11.57	9.23	6.02	698.40
FISHING TIME (HR)	10.27	9.85	6.07	9.65	10.17	10.10	8.02	4.55	589.42
AVE WATER TEMP (F)	71.1	72.0	73.3	71.2	72.5	72.6	72.5	75.6	
AMERICAN EEL	5	5	7	7	9	7	1	2	2,622
BLUEBACK HERRING	469	1937	193	167	950	505	567	21	27,533
HICKORY SHAD	-	-	-	-	-	-	-	-	376
ALEWIFE	-	-	-	-	-	-	-	-	3,344
AMERICAN SHAD	286	124	342	196	126	213	125	40	10,335
GIZZARD SHAD	14150	18625	5950	12050	7160	9150	5810	4015	1,450,299
RAINBOW TROUT	-	-	-	-	-	-	-	-	12
BROWN TROUT	1	5	4	2	1	4	-	1	127
BROOK TROUT	-	-	-	1	-	-	-	-	5
CHAIN PICKEREL	-	1	1	-	-	-	-	-	2
MUSKELLUNGE	-	-	1	-	-	-	-	-	10
COMMON CARP	21	137	34	20	26	12	552	26	4,105
GOLDEN SHINER	-	-	-	-	-	-	-	-	11
COMELY SHINER	3	30	30	3	-	20	25	-	8,974
SPOTTAIL SHINER	-	-	-	-	-	-	-	-	156
SPOTFIN SHINER	-	6	-	4	-	-	-	-	214
QUILLBACK	1	-	-	-	1	-	2	1	132
WHITE SUCKER	1	-	2	-	-	-	-	-	83
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-	9
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-	5
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	-	1,813
WHITE CATFISH	9	13	2	2	2	2	3	-	152
YELLOW BULLHEAD	2	1	-	-	-	-	-	-	23
BROWN BULLHEAD	4	1	-	-	-	-	2	1	107
CHANNEL CATFISH	391	89	20	80	44	44	31	28	7,070
WHITE PERCH	128	90	80	73	61	24	9	5	37,521
STRIPED BASS	134	77	60	108	70	55	77	87	2,094
ROCK BASS	-	-	-	-	-	-	-	-	106
REDBREAST SUNFISH	1	4	-	1	1	-	4	1	154
GREEN SUNFISH	-	-	1	-	-	-	-	-	35
PUMPKINSEED	-	1	-	-	-	1	1	-	118
BLUEGILL	7	15	8	8	4	1	1	1	813
SMALLMOUTH BASS	2	-	-	1	-	-	2	-	411
LARGEMOUTH BASS	-	1	-	-	-	1	-	-	211
WHITE CRAPPIE	1	-	2	-	-	1	1	1	74
BLACK CRAPPIE	-	1	-	-	-	-	-	-	23
TESSELLATED DARTER	-	-	-	-	-	-	-	-	2
YELLOW PERCH	1	-	1	-	-	-	-	-	127
LOGPERCH	-	-	-	-	-	-	-	-	2
WALLEYE	2	-	1	5	4	1	1	1	203
ATLANTIC NEEDLEFISH	-	-	-	-	-	1	-	-	3
SEA LAMPREY	-	1	-	-	-	-	-	-	42
STRIPED BASS X WHITE BASS	6	7	0	4	5	2	10	4	359
TIGER MUSKIE	-	-	-	-	-	-	-	-	3
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-	1
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-	1
	15625	21171	6739	12732	8464	10044	7224	4235	1,559,822

TABLE 4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM EAST LIFT 1 APRIL THROUGH 15 JUNE 1992.

DATE	01 APRIL	05 APRIL	07 APRIL	09 APRIL	11 APRIL	12 APRIL	13 APRIL	14 APRIL
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	6	8	11	11	15	20	22	24
FIRST LIFT	741	620	623	545	540	619	609	614
LAST LIFT	1100	1200	1200	1157	1452	1729	1713	1745
OPERATING TIME (HR)	3.32	5.67	5.62	6.20	9.20	11.17	11.07	11.52
FISHING TIME (HR)	3.05	5.22	5.03	5.12	7.65	10.08	9.78	10.38
AVE WATER TEMP (F)	42.8	42.8	44.6	48.3	52.3	51.7	53.1	53.6
AMERICAN EEL	1	-	-	-	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	38	-	-
AMERICAN SHAD	-	-	-	-	-	82	19	19
GIZZARD SHAD	1	1	72	150	14636	8419	6434	28282
RAINBOW TROUT	-	-	-	-	-	1	-	1
BROWN TROUT	-	1	-	-	-	-	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	1	-	-
COMMON CARP	-	-	-	-	-	-	-	1
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	1	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	-	2	-	6
WHITE SUCKER	-	-	-	2	1	21	3	8
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	3	-	3
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	1	-	-	-	-	-	-	-
WHITE PERCH	-	-	-	-	-	-	-	-
STRIPED BASS	-	-	-	1	-	-	-	2
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	1	1	-	1	-	-	-	-
GREEN SUNFISH	1	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	1	-	1	2	-
SMALLMOUTH BASS	-	-	-	3	3	15	8	14
LARGEMOUTH BASS	-	-	-	-	-	1	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	1	1	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	-	-	-	-	1	-	11
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	1	-	-
STRIPED BASS X WHITE BASS	-	-	-	39	13	39	3	42
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	6	3	72	198	14654	8625	6470	28389

TABLE 4 CONTINUED.

DATE	15 APRIL	16 APRIL	17 APRIL	18 APRIL	19 APRIL	20 APRIL	21 APRIL	22 APRIL
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	36	30	21	17	11	31	28	27
FIRST LIFT	613	608	632	622	628	624	607	602
LAST LIFT	1744	1735	1730	1336	1741	1725	1755	1651
OPERATING TIME (HR)	11.52	11.45	10.97	7.23	11.22	11.02	11.80	10.82
FISHING TIME (HR)	10.37	10.20	9.95	6.50	3.25	10.82	10.50	10.68
AVE WATER TEMP (F)	54.0	53.1	54.0	54.0	53.9	53.4	53.3	52.0
AMERICAN EEL	1	-	-	-	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	3	-
HICKORY SHAD	-	-	-	15	-	1	-	1
ALEWIFE	2	3	2	3	1	3	-	1
AMERICAN SHAD	49	20	21	133	23	40	10	22
GIZZARD SHAD	56497	45160	11846	29878	20090	31063	31426	36607
RAINBOW TROUT	1	-	-	-	-	-	-	-
BROWN TROUT	-	-	1	-	-	-	-	-
BROOK TROUT	-	-	-	1	-	-	-	-
MUSKELLUNGE	3	-	-	-	-	-	-	-
COMMON CARP	3	2	-	-	-	1	2	1
COMELY SHINER	-	1	-	1	-	25	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	9	5	-	-	-	1	-	-
WHITE SUCKER	14	9	-	3	-	2	2	5
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	2	2	1	-	-	-	4	1
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	-	1	-	-	1	-	1	3
WHITE PERCH	-	-	-	-	-	-	-	-
STRIPED BASS	3	-	-	-	-	-	1	-
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	2	-	-	-	-
GREEN SUNFISH	-	-	-	-	1	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	1	-	-	-	-	-	-	-
SMALLMOUTH BASS	30	9	18	1	2	2	4	5
LARGEMOUTH BASS	-	-	-	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	1	-	-	-	-	1	-	-
YELLOW PERCH	-	-	-	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	16	35	-	1	-	-	4	-
BANDED DARTER	-	-	-	-	1	-	-	-
SEA LAMPREY	1	-	1	-	-	1	-	1
STRIPED BASS X WHITE BASS	26	50	3	2	5	2	60	24
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	56659	45297	11893	30040	20124	31142	31517	36671

TABLE 4 CONTINUED.

DATE	23 APRIL	24 APRIL	25 APRIL	26 APRIL	27 APRIL	28 APRIL	29 APRIL	30 APRIL
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	28	22	30	38	36	19	45	41
FIRST LIFT	606	602	600	612	602	1235	600	612
LAST LIFT	1743	1750	1730	1736	1741	1737	1721	1720
OPERATING TIME (HR)	11.62	11.80	11.50	11.40	11.65	5.03	11.35	11.13
FISHING TIME (HR)	10.38	10.60	10.12	10.20	10.75	4.42	10.32	10.98
AVE WATER TEMP (F)	53.8	55.4	56.7	58.1	58.3	58.1	57.6	58.5
AMERICAN EEL	-	2	-	-	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	1	-	2	-	-	-	-	-
ALEWIFE	3	15	12	14	3	16	18	-
AMERICAN SHAD	32	22	84	104	73	83	224	206
GIZZARD SHAD	25187	20526	36335	33582	75860	38355	100326	156100
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	-	1	1	-	1	2	3	2
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	2	32	21	6	3	2	2	2
COMELY SHINER	-	13	5	-	-	-	1	10
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	8	23	1	-	-	-	-
WHITE SUCKER	2	3	1	3	2	-	-	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	10	66	49	4	4	13	-	2
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	1	-	2	-	-
CHANNEL CATFISH	3	12	38	2	4	22	15	2
WHITE PERCH	-	1	-	17	1	14	4	42
STRIPED BASS	2	-	2	1	-	-	1	-
ROCK BASS	-	-	-	1	-	2	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	1	-	-	1	-	-
SMALLMOUTH BASS	3	4	6	4	7	5	40	8
LARGEMOUTH BASS	-	1	1	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	1	2	1	7	5	5	3	-
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	1	1	-	1	-	-
STRIPED BASS X WHITE BASS	3	5	4	4	9	6	-	3
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	25249	20713	36587	33753	75972	38529	100637	156378

TABLE 4 CONTINUED.

DATE	01 MAY	02 MAY	03 MAY	04 MAY	05 MAY	06 MAY	07 MAY	08 MAY
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	45	43	40	32	31	38	34	23
FIRST LIFT	612	609	612	607	605	619	710	616
LAST LIFT	1735	1715	1711	1710	1657	1715	1746	1741
OPERATING TIME (HR)	11.38	11.10	10.98	11.05	10.87	10.93	10.60	11.42
FISHING TIME (HR)	10.75	10.63	10.65	11.65	9.13	10.22	9.78	10.48
AVE WATER TEMP (F)	58.3	59.0	60.4	60.8	60.8	60.8	61.0	58.3
AMERICAN EEL	2	3	-	-	1	2	2	4
BLUEBACK HERRING	-	6	9	1	239	10	33	8
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	4	51	70	12	-	-	5	3
AMERICAN SHAD	66	375	216	647	465	323	423	26
GIZZARD SHAD	153821	75452	77810	83720	36426	38028	44311	18350
RAINBOW TROUT	-	1	-	2	-	-	-	-
BROWN TROUT	1	23	2	1	3	3	2	1
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	2	1	-	-	-	-	-
COMMON CARP	4	8	6	1	11	6	8	2
COMELY SHINER	1	-	-	1	65	1	-	55
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	5	-	-	-
QUILLBACK	-	4	1	-	-	7	1	2
WHITE SUCKER	-	-	-	-	-	-	3	-
CREEK CHUBSUCKER	-	-	2	-	-	-	-	-
SHORTHEAD REDHORSE	1	5	2	6	8	1	2	3
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	2	3	1	-	-	-	7	4
WHITE PERCH	9	80	133	62	493	89	256	56
STRIPED BASS	1	-	1	1	-	-	-	1
ROCK BASS	-	1	4	1	-	-	-	1
REDBREAST SUNFISH	-	-	1	-	-	-	-	1
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	2	5	1	1	1	-	-
SMALLMOUTH BASS	6	30	26	13	9	15	6	6
LARGEMOUTH BASS	-	3	2	-	-	-	-	-
WHITE CRAPPIE	-	1	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	5	1	-	2	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	1	2	2	3	3	-	2	1
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	1	2	-	3	2	1	2	4
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	1	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	153920	76054	78300	84476	37731	38489	45063	18528

TABLE 4 CONTINUED.

DATE	09 MAY	10 MAY	11 MAY	12 MAY	13 MAY	14 MAY	15 MAY	16 MAY
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	26	24	27	31	29	26	26	29
FIRST LIFT	612	607	613	619	614	620	615	629
LAST LIFT	1735	1616	1800	1720	1734	1744	1732	1720
OPERATING TIME (HR)	11.38	10.15	11.78	11.02	11.33	11.40	11.28	10.85
FISHING TIME (HR)	10.57	8.67	10.23	9.93	10.40	9.28	10.70	10.08
AVE WATER TEMP (F)	58.1	59.0	59.1	60.8	61.7	63.5	63.5	65.3
AMERICAN EEL	-	2	-	1	1	-	-	2
BLUEBACK HERRING	7	9	3	13	5	146	484	971
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	3	-	-	-	-	-
AMERICAN SHAD	13	548	538	354	580	233	677	161
GIZZARD SHAD	29591	33458	45160	42608	41272	51341	33553	21370
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	-	-	3	-	3	1	-	1
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	2	1	-	-	-	-	-	-
COMMON CARP	2	1	9	40	54	88	62	129
COMELY SHINER	-	-	-	-	20	140	-	30
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	26	50	12	-	3
WHITE SUCKER	-	-	-	1	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	1	-	-	18	47	10	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	-	-	-	5	4	3	15	2
WHITE PERCH	88	3	269	40	77	245	3509	2353
STRIPED BASS	1	-	1	1	-	-	1	-
ROCK BASS	-	-	-	-	2	3	-	-
REDBREAST SUNFISH	-	-	-	-	1	-	-	2
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	1
BLUEGILL	2	2	4	-	-	-	4	69
SMALLMOUTH BASS	6	2	13	17	32	15	24	19
LARGEMOUTH BASS	-	2	-	1	-	-	1	-
WHITE CRAPPIE	-	-	-	-	1	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	1	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	-	-	-	-	-	1
LOGPERCH	-	-	-	-	-	-	1	-
WALLEYE	-	-	1	1	4	1	-	2
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	1	-	2	2	1	-	1	-
STRIPED BASS X WHITE BASS	3	-	1	2	2	-	1	1
TIGER MUSKIE	-	-	-	-	-	-	1	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	1
	29717	34028	46007	43130	42156	52238	38335	25118

TABLE 4 CONTINUED.

DATE	17 MAY	18 MAY	19 MAY	20 MAY	21 MAY	22 MAY	23 MAY	24 MAY
LOCATION	636	636	635	635	635	636	636	636
# OF LIFTS	24	34	22	13	14	24	28	27
FIRST LIFT	609	603	647	1000	637	938	610	611
LAST LIFT	1748	1727	1742	1726	1655	1721	1733	1655
OPERATING TIME (HR)	11.65	11.40	10.92	7.43	10.30	7.72	11.38	10.73
FISHING TIME (HR)	10.53	10.98	6.32	3.57	9.60	5.62	10.37	9.77
AVE WATER TEMP (F)	65.9	68.7	68.0	65.8	-	67.1	68.6	70.4
HERRINGS	-	-	4	-	25	-	-	-
AMERICAN EEL	1	12	1	-	-	-	15	5
BLUEBACK HERRING	100	29	2	-	-	5	948	37
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	3	-	-	-	-	-
AMERICAN SHAD	713	267	351	76	741	170	648	670
GIZZARD SHAD	37217	46720	15259	8053	4890	26930	28505	32880
RAINBOW TROUT	-	-	-	-	1	-	-	-
BROWN TROUT	-	2	1	2	1	-	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	288	1437	7	20	13	172	11	1493
COMELY SHINER	-	-	-	30	12	-	114	50
CARPS AND MINNOWS	-	-	503	-	51	-	-	
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	30
QUILLBACK	1	120	-	-	1	7	7	10
WHITE SUCKER	-	-	-	-	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	5	4	1	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	-	12	3	9	3	-	-	2
WHITE PERCH	326	193	21	12	20	8	93	10
STRIPED BASS	1	2	-	-	1	-	-	-
ROCK BASS	-	1	-	-	-	-	-	-
REDBREAST SUNFISH	2	5	5	8	7	4	9	2
GREEN SUNFISH	-	-	3	-	2	1	1	-
PUMPKINSEED	-	-	-	-	1	-	-	-
BLUEGILL	9	1	30	9	54	5	25	11
SMALLMOUTH BASS	3	12	5	1	8	2	4	9
LARGEMOUTH BASS	-	-	3	2	2	1	-	1
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	1	-	1	-	6	1	2	1
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	2	1	-	1	-	-	-
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	1	-	-	-	-	-	-
LAMPREYS	-	-	2	-	1	-	-	
STRIPED BASS X WHITE BASS	1	4	-	1	1	-	-	-
TIGER MUSKIE	-	-	1	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	38663	48825	16207	8148	5103	27307	30383	35211

TABLE 4 CONTINUED

DATE	25 MAY	26 MAY	27 MAY	28 MAY	29 MAY	30 MAY	31 MAY	01 JUNE
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	26	24	28	25	26	29	15	26
FIRST LIFT	613	612	606	616	608	605	612	606
LAST LIFT	1700	1730	1750	1730	1730	1750	1700	1740
OPERATING TIME (HR)	10.78	11.30	11.73	11.23	11.37	11.75	10.80	11.57
FISHING TIME (HR)	9.67	10.12	10.37	9.00	9.27	10.30	9.43	9.58
AVE WATER TEMP (F)	69.3	68.8	68.0	68.0	68.6	68.0	69.8	68.9
AMERICAN EEL	11	1	-	6	1	-	-	1
BLUEBACK HERRING	133	741	357	90	96	498	61	13
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	594	124	327	167	241	238	361	13
GIZZARD SHAD	15422	27390	17235	13125	12300	7792	12447	33503
RAINBOW TROUT	-	-	-	1	-	-	-	-
BROWN TROUT	1	-	1	2	1	1	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	16	64	86	14	88	982	45	610
COMELY SHINER	15	-	-	1	-	-	20	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	93	1	11	-	-	-	11	3
WHITE SUCKER	-	-	-	-	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	2	7	-	1	2	-	1	2
WHITE PERCH	16	35	12	7	6	5	3	-
STRIPED BASS	1	-	-	4	6	1	-	10
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	21	3	2	9	3	4	1	-
GREEN SUNFISH	-	-	-	-	1	-	1	-
PUMPKINSEED	6	2	-	-	-	-	-	-
BLUEGILL	35	14	14	9	6	9	1	11
SMALLMOUTH BASS	2	1	6	1	2	2	-	-
LARGEMOUTH BASS	1	-	3	-	-	-	-	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	5	-	2	-	3	-	2	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	2	-	-	4	3	3	-
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	1
STRIPED BASS X WHITE BASS	-	2	1	4	2	2	2	1
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	16374	28387	18057	13441	12762	9537	12960	34168

TABLE 4 CONTINUED.

DATE	02 JUNE	03 JUNE	04 JUNE	05 JUNE	06 JUNE	07 JUNE	08 JUNE	09 JUNE
LOCATION	636	636	636	636	636	636	636	636
# OF LIFTS	35	18	32	30	19	23	27	20
FIRST LIFT	630	642	610	613	615	615	611	645
LAST LIFT	1740	1725	1744	1714	1745	1716	1745	1730
OPERATING TIME (HR)	11.17	10.72	11.57	11.02	11.50	11.02	11.57	10.75
FISHING TIME (HR)	9.50	10.00	10.05	9.52	10.77	9.95	10.30	9.78
AVE WATER TEMP (F)	71.3	68.0	68.9	68.0	69.4	70.3	72.0	73.9
AMERICAN EEL	4	2	7	2	2	4	-	8
BLUEBACK HERRING	3	12	-	3	192	890	157	5
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	23	21	93	36	358	660	140	53
GIZZARD SHAD	44157	64225	37795	63412	46558	23890	26185	20158
RAINBOW TROUT	-	-	-	-	1	-	-	-
BROWN TROUT	-	2	-	-	1	1	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
COMMON CARP	47	6	52	21	-	17	23	12
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	20	2	3	1	-	-	1	4
WHITE SUCKER	-	-	-	-	-	1	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-
CHANNEL CATFISH	3	4	597	285	1	-	5	9
WHITE PERCH	-	20	3	90	-	-	-	-
STRIPED BASS	2	1	5	11	1	6	8	-
ROCK BASS	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	2	-	-	8	-	-
GREEN SUNFISH	-	-	-	-	1	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	11	1	-	6	5	-	1	5
SMALLMOUTH BASS	2	1	1	-	1	-	-	-
LARGEMOUTH BASS	2	-	1	-	-	-	1	-
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	-	-	1	-	-	-	-	-
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	-	7	9	-	-	3	-
BANDED DARTER	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	1	-	-	-	-	-	1	-
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
SUNFISH HYBRIDS	-	-	-	-	-	-	-	-
	44275	64297	38567	63876	47121	25477	26525	20254

TABLE 4 CONTINUED.

DATE	10 JUNE	11 JUNE	12 JUNE	13 JUNE	14 JUNE	15 JUNE	TOTALS
LOCATION	636	636	636	636	636	636	
# OF LIFTS	13	21	17	19	23	11	1774
FIRST LIFT	1031	620	605	609	612	603	
LAST LIFT	1745	1730	1745	1730	1623	1146	
OPERATING TIME (HR)	7.23	11.17	11.67	11.35	10.18	5.72	731.50
FISHING TIME (HR)	6.65	9.98	10.92	10.55	9.10	5.30	646.37
AVE WATER TEMP (F)	71.6	72.7	71.7	72.6	74.3	76.5	
HERRINGS	-	-	-	-	-	-	29
AMERICAN EEL	2	4	1	2	3	-	119
BLUEBACK HERRING	-	44	33	270	541	140	7,347
HICKORY SHAD	-	-	-	-	-	-	20
ALEWIFE	-	-	-	-	-	-	285
AMERICAN SHAD	101	112	105	429	489	154	15,386
GIZZARD SHAD	12158	12124	12778	9158	2560	3421	2,351,351
RAINBOW TROUT	-	-	-	-	-	-	10
BROWN TROUT	1	-	-	-	-	-	76
BROOK TROUT	-	-	-	-	-	-	1
MUSKELLUNGE	-	-	-	-	-	-	10
CARPS & MINNOWS	-	-	-	-	-	-	554
COMMON CARP	1	-	9	1	2	24	6,072
COMELY SHINER	-	-	-	-	39	-	650
SPOTTAIL SHINER	-	-	-	-	-	-	1
SPOTFIN SHINER	-	-	-	-	-	-	35
QUILLBACK	2	-	-	-	-	24	483
WHITE SUCKER	-	-	-	-	9	-	96
CREEK CHUBSUCKER	-	-	-	-	-	-	2
SHORTHEAD REDHORSE	-	-	-	-	-	-	278
YELLOW BULLHEAD	1	-	-	-	-	-	1
BROWN BULLHEAD	-	-	-	-	-	-	3
CHANNEL CATFISH	2	9	12	2	-	-	1,124
WHITE PERCH	1	-	1	2	-	-	8,725
STRIPED BASS	11	8	57	33	10	16	216
ROCK BASS	-	-	-	-	-	-	16
REDBREAST SUNFISH	-	2	-	1	1	1	110
GREEN SUNFISH	-	-	-	-	-	-	12
PUMPKINSEED	-	-	1	2	-	-	13
BLUEGILL	3	5	3	8	9	1	399
SMALLMOUTH BASS	-	-	-	-	1	-	494
LARGEMOUTH BASS	-	1	-	1	2	-	33
WHITE CRAPPIE	-	-	-	-	-	-	4
BLACK CRAPPIE	-	-	-	-	-	-	1
TESSELLATED DARTER	-	-	-	-	-	-	2
YELLOW PERCH	-	-	-	-	-	-	36
LOGPERCH	-	-	-	-	-	-	1
WALLEYE	-	-	-	-	-	-	150
BANDED DARTER	-	-	-	-	-	-	1
SEA LAMPREY	-	-	-	-	-	-	17
LAMPREYS	-	-	-	-	-	-	3
STRIPED BASS X WHITE BASS	1	-	13	5	-	3	413
TIGER MUSKIE	-	-	-	-	-	-	2
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	1
SUNFISH HYBRIDS	-	-	-	-	-	-	1
	12284	12309	13013	9914	3666	3784	2,394,582

TABLE 5

Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam West Fish Lift, 1992.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
APR 05	# Shad			-	0
	Hrs Fishing	0.0	0.0	5.3	5.3
	Catch/Hr Fishing	-	-	-	0.00
APR 07	# Shad			-	0
	Hrs Fishing	0.0	0.0	5.5	5.5
	Catch/Hr Fishing	-	-	-	0.00
APR 09	# Shad			2	2
	Hrs Fishing	0.0	0.0	5.2	5.2
	Catch/Hr Fishing	-	-	0.38	0.38
APR 11	# Shad	-		10	10
	Hrs Fishing	0.3	0.0	7.1	7.3
	Catch/Hr Fishing	-	-	1.41	1.37
APR 12	# Shad			105	105
	Hrs Fishing	0.0	0.0	9.6	9.6
	Catch/Hr Fishing	-	-	10.94	10.94
APR 13	# Shad			60	60
	Hrs Fishing	0.0	0.0	9.2	9.2
	Catch/Hr Fishing	-	-	6.52	6.52
APR 19	# Shad			1	1
	Hrs Fishing	0.0	0.0	5.1	5.1
	Catch/Hr Fishing	-	-	0.20	0.20
APR 20	# Shad			-	0
	Hrs Fishing	0.0	0.0	9.5	9.5
	Catch/Hr Fishing	-	-	-	0.00
APR 21	# Shad			1	1
	Hrs Fishing	0.0	0.0	10.3	10.3
	Catch/Hr Fishing	-	-	0.10	0.10
APR 22	# Shad			10	10
	Hrs Fishing	0.0	0.0	7.5	7.5
	Catch/Hr Fishing	-	-	1.33	1.33
APR 23	# Shad	15	-	-	15
	Hrs Fishing	7.9	0.8	0.8	9.5
	Catch/Hr Fishing	1.90	-	-	1.58

TABLE 5 CONTINUED.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
APR 24	# Shad	27			[illegible]
	Hrs Fishing	10.5	0.0	0.0	10.[illegible]
	Catch/Hr Fishing	2.57	-	-	2.57
APR 25	# Shad	36		1	[illegible]
	Hrs Fishing	8.0	0.0	0.5	8.5
	Catch/Hr Fishing	4.50	-	2.00	4.35
APR 26	# Shad	75		-	[illegible]
	Hrs Fishing	9.0	0.0	0.8	9.7
	Catch/Hr Fishing	8.33	-	-	7.[illegible]
APR 27	# Shad	93			93
	Hrs Fishing	8.9	0.0	0.0	8.9
	Catch/Hr Fishing	10.45	-	-	10.[illegible]
APR 28	# Shad	129			129
	Hrs Fishing	4.7	0.0	0.0	4.7
	Catch/Hr Fishing	27.45	-	-	27.[illegible]5
APR 29	# Shad	102			102
	Hrs Fishing	10.8	0.0	0.0	10.8
	Catch/Hr Fishing	9.44	-	-	9.[illegible]4
APR 30	# Shad	176			1[illegible]6
	Hrs Fishing	9.0	0.0	0.0	9.0
	Catch/Hr Fishing	19.56	-	-	19.56
MAY 01	# Shad			47	[illegible]7
	Hrs Fishing	0.0	0.0	10.4	10.4
	Catch/Hr Fishing	-	-	4.52	4.52
MAY 02	# Shad			132	1[illegible]2
	Hrs Fishing	0.0	0.0	9.4	9.4
	Catch/Hr Fishing	-	-	14.04	14.04
MAY 03	# Shad			256	256
	Hrs Fishing	0.0	0.0	8.7	8.7
	Catch/Hr Fishing	-	-	29.43	29.[illegible]3
MAY 04	# Shad			294	294
	Hrs Fishing	0.0	0.0	9.2	9.2
	Catch/Hr Fishing	-	-	31.96	31.[illegible]6

TABLE 5 CONTINUED.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
MAY 05	# Shad			136	136
	Hrs Fishing	0.0	0.0	7.1	7.1
	Catch/Hr Fishing	-	-	19.15	19.15
MAY 06	# Shad			226	226
	Hrs Fishing	0.0	0.0	9.1	9.1
	Catch/Hr Fishing	-	-	24.84	24.84
MAY 07	# Shad			219	219
	Hrs Fishing	0.0	0.0	9.8	9.8
	Catch/Hr Fishing	-	-	22.35	22.35
MAY 08	# Shad			17	17
	Hrs Fishing	0.0	0.0	10.8	10.8
	Catch/Hr Fishing	-	-	1.57	1.57
MAY 09	# Shad			58	58
	Hrs Fishing	0.0	0.0	9.8	9.8
	Catch/Hr Fishing	-	-	5.92	5.92
MAY 10	# Shad			358	358
	Hrs Fishing	0.0	0.0	9.0	9.0
	Catch/Hr Fishing	-	-	39.78	39.78
MAY 11	# Shad			377	377
	Hrs Fishing	0.0	0.0	9.7	9.7
	Catch/Hr Fishing	-	-	38.87	38.87
MAY 12	# Shad			234	234
	Hrs Fishing	0.0	0.0	9.0	9.0
	Catch/Hr Fishing	-	-	26.00	26.00
MAY 13	# Shad			292	292
	Hrs Fishing	0.0	0.0	8.9	8.9
	Catch/Hr Fishing	-	-	32.81	32.81
MAY 14	# Shad			215	215
	Hrs Fishing	0.0	0.0	9.4	9.4
	Catch/Hr Fishing	-	-	22.87	22.87
MAY 15	# Shad			244	244
	Hrs Fishing	0.0	0.0	10.8	10.8
	Catch/Hr Fishing	-	-	22.59	22.59

TABLE 5 CONTINUED.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTA[illegible] Weir Gates Open
MAY 16	# Shad			103	10[illegible]
	Hrs Fishing	0.0	0.0	9.1	9.[illegible]
	Catch/Hr Fishing	-	-	11.32	11.32
MAY 17	# Shad			196	1[illegible]
	Hrs Fishing	0.0	0.0	9.1	9.1
	Catch/Hr Fishing	-	-	21.54	21.5[illegible]
MAY 18	# Shad			178	17[illegible]
	Hrs Fishing	0.0	0.0	8.4	8.4
	Catch/Hr Fishing	-	-	21.19	21.1[illegible]
MAY 19	# Shad			276	276
	Hrs Fishing	0.0	0.0	9.3	9.[illegible]
	Catch/Hr Fishing	-	-	29.68	29.6[illegible]
MAY 20	# Shad			167	167
	Hrs Fishing	0.0	0.0	9.6	9.[illegible]
	Catch/Hr Fishing	-	-	17.40	17.4[illegible]
MAY 21	# Shad			154	15[illegible]
	Hrs Fishing	0.0	0.0	10.0	10.[illegible]
	Catch/Hr Fishing	-	-	15.40	15.4[illegible]
MAY 22	# Shad			269	26[illegible]
	Hrs Fishing	0.0	0.0	9.4	9.[illegible]
	Catch/Hr Fishing	-	-	28.62	28.62
MAY 23	# Shad			55	[illegible]
	Hrs Fishing	0.0	0.0	10.1	10.[illegible]
	Catch/Hr Fishing	-	-	5.45	5.45
MAY 24	# Shad			247	24[illegible]
	Hrs Fishing	0.0	0.0	9.5	9.5
	Catch/Hr Fishing	-	-	26.00	26.0[illegible]
MAY 25	# Shad			122	12[illegible]
	Hrs Fishing	0.0	0.0	11.8	11.8
	Catch/Hr Fishing	-	-	10.34	10.[illegible]
MAY 26	# Shad			362	362
	Hrs Fishing	0.0	0.0	10.6	10.[illegible]
	Catch/Hr Fishing	-	-	34.15	34.[illegible]

TABLE 5 CONTINUED.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gates Open	TOTAL Weir Gates Open
MAY 27	# Shad			233	233
	Hrs Fishing	0.0	0.0	9.6	9.6
	Catch/Hr Fishing	-	-	24.27	24.27
MAY 28	# Shad			256	256
	Hrs Fishing	0.0	0.0	11.3	11.3
	Catch/Hr Fishing	-	-	22.65	22.65
MAY 29	# Shad			238	238
	Hrs Fishing	0.0	0.0	11.0	11.0
	Catch/Hr Fishing	-	-	21.64	21.64
MAY 30	# Shad			779	779
	Hrs Fishing	0.0	0.0	7.3	7.3
	Catch/Hr Fishing	-	-	106.71	106.71
MAY 31	# Shad			649	649
	Hrs Fishing	0.0	0.0	11.5	11.5
	Catch/Hr Fishing	-	-	56.43	56.43
JUN 01	# Shad			66	66
	Hrs Fishing	0.0	0.0	11.3	11.3
	Catch/Hr Fishing	-	-	5.84	5.84
JUN 02	# Shad			52	52
	Hrs Fishing	0.0	0.0	10.2	10.2
	Catch/Hr Fishing	-	-	5.10	5.10
JUN 03	# Shad			324	324
	Hrs Fishing	0.0	0.0	11.2	11.2
	Catch/Hr Fishing	-	-	28.93	28.93
JUN 04	# Shad			40	40
	Hrs Fishing	0.0	0.0	10.1	10.1
	Catch/Hr Fishing	-	-	3.96	3.96
JUN 05	# Shad			64	64
	Hrs Fishing	0.0	0.0	11.4	11.4
	Catch/Hr Fishing	-	-	5.61	5.61
JUN 06	# Shad			63	63
	Hrs Fishing	0.0	0.0	11.5	11.5
	Catch/Hr Fishing	-	-	5.48	5.48

TABLE 5 CONTINUED.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	TOTAL Weir Gate Open
JUN 07	# Shad	6		11	17
	Hrs Fishing	2.0	0.0	7.8	9.9
	Catch/Hr Fishing	3.00	-	1.41	1.72
JUN 08	# Shad			286	286
	Hrs Fishing	0.0	0.0	10.3	10.3
	Catch/Hr Fishing	-	-	27.77	27.77
JUN 09	# Shad			124	124
	Hrs Fishing	0.0	0.0	9.8	9.8
	Catch/Hr Fishing	-	-	12.65	12.65
JUN 10	# Shad			342	342
	Hrs Fishing	0.0	0.0	6.1	6.1
	Catch/Hr Fishing	-	-	56.07	56.07
JUN 11	# Shad			195	195
	Hrs Fishing	0.0	0.0	9.6	9.6
	Catch/Hr Fishing	-	-	20.31	20.31
JUN 12	# Shad			125	125
	Hrs Fishing	0.0	0.0	10.2	10.2
	Catch/Hr Fishing	-	-	12.25	12.25
JUN 13	# Shad			213	213
	Hrs Fishing	0.0	0.0	10.1	10.1
	Catch/Hr Fishing	-	-	21.09	21.09
JUN 14	# Shad			125	125
	Hrs Fishing	0.0	0.0	8.0	8.0
	Catch/Hr Fishing	-	-	15.63	15.63
JUN 15	# Shad			40	40
	Hrs Fishing	0.0	0.0	4.5	4.5
	Catch/Hr Fishing	-	-	8.89	8.89
TOTAL	# Shad	659	0	9,649	10,308 *
	Hrs Fishing	71.1	0.8	517.2	589.0
	Catch/Hr Fishing	9.27	0.00	18.66	17.50

* 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 to 15 June, 1992.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	0500 - 0900	30.2	10.0	25.4	17.6	3.9	7.0	11.5
	0901 - 1100	14.4	8.0	16.5	12.0	14.4	9.7	10.8
	1101 - 1500	25.1	-	18.6	21.9	18.7	15.7	17.0
	1501 - 1900	30.9	-	25.4	5.0	14.7	25.6	24.7
MEAN WEEKDAYS		24.2	9.8	24.0	16.4	13.5	15.5	16.6
WEEKEND	0500 - 0900	3.7	7.9	13.9	0.0	0.0	0.7	8.2
	0901 - 1100	14.5	15.6	24.4	6.8	28.8	5.3	11.6
	1101 - 1500	46.2	23.4	50.7	2.3	16.3	14.3	21.6
	1501 - 1900	1.7	-	103.0	13.3	15.0	18.8	32.0
MEAN WEEKEND		27.8	13.6	39.3	4.8	16.4	12.9	19.6
TOTAL		25.5	12.6	32.1	11.6	15.1	15.0	17.5

TABLE 7

Comparison of the American shad catch and catch per effort, between discharges with one or two Francis units generating and high discharges (three or more unit generation) at the Conowingo Dam West Fish Lift, April to June 1992.

Generation Status	No. Shad Caught	Total Minutes Fished	Number of Lifts	Shad Catch per Hour
APRIL				
Two Units	1	157	9	0.38
High	842	8629	410	5.85
TOTAL for April	843	8786	419	5.76
MAY				
Two Units	1876	3348	161	33.62
High	5531	14577	624	22.77
TOTAL for May	7407	17925	785	24.79
JUNE				
One Unit	209	997	43	12.58
High	1876	7657	312	14.70
TOTAL for June	2085	8654	355	14.46
GRAND TOTAL	10335	35365	1559	17.53

TABLE 8

Catch of American shad in the Conowingo Fish Lifts (East and West) by water temperatures, 1 April through 15 June 1992.

Water Temp. (F)	Hours Fishing	CATCH		
		Number	Catch/ Effort	Percent
LE 65	646.92	10707	16.55	43.6
GT 65	588.87	13846	23.51	56.4
TOTAL	1,235.78	24553	19.87	100.0

TABLE 9

Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam East Fish Lift, 1992.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 01	# Shad						-	-	0
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	2.5	0.5	3.0
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
APR 05	# Shad				-		-	-	0
	Hrs Fishing	0.0	0.0	0.0	0.8	0.0	3.2	1.3	5.2
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
APR 07	# Shad						-	-	0
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.5	4.5	5.0
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
APR 09	# Shad				-				0
	Hrs Fishing	0.0	0.0	0.0	5.1	0.0	0.0	0.0	5.1
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
APR 11	# Shad	-					-	-	0
	Hrs Fishing	0.8	0.0	0.0	0.0	0.0	3.4	3.4	7.6
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
APR 12	# Shad						6	76	82
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	2.9	7.2	10.1
	Catch/Hr Fishing	-	-	-	-	-	2.07	10.56	8.12
APR 13	# Shad						2	17	19
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.9	8.8	9.8
	Catch/Hr Fishing	-	-	-	-	-	2.22	1.93	1.94
APR 14	# Shad				1		-	18	19
	Hrs Fishing	0.0	0.0	0.0	0.5	0.0	3.2	6.7	10.4
	Catch/Hr Fishing	-	-	-	2.00	-	-	2.69	1.83
APR 15	# Shad						6	43	49
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	2.6	7.8	10.4
	Catch/Hr Fishing	-	-	-	-	-	2.31	5.51	4.71
APR 16	# Shad				18		-	2	20
	Hrs Fishing	0.0	0.0	0.0	4.7	0.0	1.3	4.3	10.2
	Catch/Hr Fishing	-	-	-	3.83	-	-	0.47	1.96
APR 17	# Shad						-	21	21
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.0	8.9	9.9
	Catch/Hr Fishing	-	-	-	-	-	-	2.36	2.12

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 29	# Shad						3	220	223
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.4	9.9	10.3
	Catch/Hr Fishing	-	-	-	-	-	7.50	22.22	21.65
APR 30	# Shad					2	-	204	206
	Hrs Fishing	0.0	0.0	0.0	0.0	1.0	1.0	9.0	11.0
	Catch/Hr Fishing	-	-	-	-	2.00	-	22.67	18.73
MAY 01	# Shad						-	66	66
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.3	10.5	10.8
	Catch/Hr Fishing	-	-	-	-	-	-	6.29	6.11
MAY 02	# Shad	4					74	297	375
	Hrs Fishing	0.4	0.0	0.0	0.0	0.0	2.3	7.9	10.6
	Catch/Hr Fishing	10.00	-	-	-	-	32.17	37.59	35.38
MAY 03	# Shad	78					25	109	212
	Hrs Fishing	0.8	0.0	0.0	0.0	0.0	2.0	7.9	10.6
	Catch/Hr Fishing	97.50	-	-	-	-	12.50	13.80	20.00
MAY 04	# Shad						40	607	647
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.5	10.2	11.6
	Catch/Hr Fishing	-	-	-	-	-	26.67	59.51	55.78
MAY 05	# Shad	270					106	89	465
	Hrs Fishing	3.0	0.0	0.0	0.0	0.0	1.9	4.2	9.1
	Catch/Hr Fishing	90.00	-	-	-	-	55.79	21.19	51.10
MAY 06	# Shad						-	323	323
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.3	10.0	10.2
	Catch/Hr Fishing	-	-	-	-	-	-	32.30	31.67
MAY 07	# Shad						39	384	423
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.6	8.2	9.8
	Catch/Hr Fishing	-	-	-	-	-	65.00	41.74	43.16
MAY 08	# Shad						-	26	26
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.4	10.1	10.5
	Catch/Hr Fishing	-	-	-	-	-	-	2.57	2.48
MAY 09	# Shad	1		1			4	7	13
	Hrs Fishing	1.4	0.0	2.5	0.0	0.0	2.9	3.8	10.6
	Catch/Hr Fishing	0.71	-	0.40	-	-	1.38	1.84	1.23

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 18	# Shad	-					111	22	133
	Hrs Fishing	0.8	0.0	0.0	0.0	0.0	1.7	4.0	6.5
	Catch/Hr Fishing	-	-	-	-	-	65.29	5.50	20.46
APR 19	# Shad	-					-	23	23
	Hrs Fishing	0.8	0.0	0.0	0.0	0.0	0.3	2.1	3.3
	Catch/Hr Fishing	-	-	-	-	-	-	10.95	6.97
APR 20	# Shad						8	32	40
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.2	9.6	10.8
	Catch/Hr Fishing	-	-	-	-	-	6.67	3.33	3.70
APR 21	# Shad						-	10	10
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.9	9.6	10.5
	Catch/Hr Fishing	-	-	-	-	-	-	1.04	0.95
APR 22	# Shad						1	21	22
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	9.4	10.7
	Catch/Hr Fishing	-	-	-	-	-	0.77	2.23	2.06
APR 23	# Shad						1	29	30
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	8.6	9.9
	Catch/Hr Fishing	-	-	-	-	-	0.77	3.37	3.03
APR 24	# Shad						3	19	22
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	2.5	8.1	10.6
	Catch/Hr Fishing	-	-	-	-	-	1.20	2.35	2.08
APR 25	# Shad						4	80	84
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.1	9.0	10.1
	Catch/Hr Fishing	-	-	-	-	-	3.64	8.89	8.32
APR 26	# Shad					-	-	104	104
	Hrs Fishing	0.0	0.0	0.0	0.0	0.3	0.6	9.3	10.2
	Catch/Hr Fishing	-	-	-	-	-	-	11.18	10.20
APR 27	# Shad							73	73
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.0	10.8	10.8
	Catch/Hr Fishing	-	-	-	-	-	-	6.76	6.76
APR 28	# Shad							83	83
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.0	4.4	4.4
	Catch/Hr Fishing	-	-	-	-	-	-	18.86	18.86

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 10	# Shad	3					102	443	548
	Hrs Fishing	1.0	0.0	0.0	0.0	0.0	1.7	5.9	8.7
	Catch/Hr Fishing	3.00	-	-	-	-	60.00	75.08	62.99
MAY 11	# Shad						19	518	537
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.7	9.6	10.2
	Catch/Hr Fishing	-	-	-	-	-	27.14	53.96	52.65
MAY 12	# Shad						6	348	354
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	8.6	9.9
	Catch/Hr Fishing	-	-	-	-	-	4.62	40.47	35.76
MAY 13	# Shad						3	577	580
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.3	10.1	10.4
	Catch/Hr Fishing	-	-	-	-	-	10.00	57.13	55.77
MAY 14	# Shad						1	232	233
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.3	8.9	9.3
	Catch/Hr Fishing	-	-	-	-	-	3.33	26.07	25.05
MAY 15	# Shad	7					87	583	677
	Hrs Fishing	0.8	0.0	0.0	0.0	0.0	1.5	8.3	10.7
	Catch/Hr Fishing	8.75	-	-	-	-	58.00	70.24	63.27
MAY 16	# Shad	120	3	-			36	2	161
	Hrs Fishing	2.9	1.3	1.8	0.0	0.0	2.4	1.6	10.1
	Catch/Hr Fishing	41.38	2.31	-	-	-	15.00	1.25	15.94
MAY 17	# Shad	369		168			176		713
	Hrs Fishing	2.4	0.0	5.7	0.0	0.0	2.5	0.0	10.5
	Catch/Hr Fishing	153.75	-	29.47	-	-	70.40	-	67.90
MAY 18	# Shad	20					48	199	267
	Hrs Fishing	2.3	0.0	0.0	0.0	0.0	1.8	6.9	11.0
	Catch/Hr Fishing	8.70	-	-	-	-	26.67	28.84	24.27
MAY 19	# Shad						-	-	0
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.4	5.8	6.2
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
MAY 20	# Shad			-			-	-	0
	Hrs Fishing	0.0	0.0	0.8	0.0	0.0	0.8	2.0	3.6
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 21	# Shad	-					-	-	0
	Hrs Fishing	6.7	0.0	0.0	0.0	0.0	1.9	0.5	9.0
	Catch/Hr Fishing	-	-	-	-	-	-	-	0.00
MAY 22	# Shad						15	152	167
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.0	4.6	5.6
	Catch/Hr Fishing	-	-	-	-	-	15.00	33.04	29.82
MAY 23	# Shad			534			114		648
	Hrs Fishing	0.0	0.0	7.9	0.0	0.0	2.2	0.0	10.1
	Catch/Hr Fishing	-	-	67.59	-	-	51.82	-	64.16
MAY 24	# Shad	77		467			117	9	670
	Hrs Fishing	1.8	0.0	3.4	0.0	0.0	3.3	1.2	9.8
	Catch/Hr Fishing	42.78	-	137.35	-	-	35.45	7.50	68.37
MAY 25	# Shad			574			20		594
	Hrs Fishing	0.0	0.0	8.9	0.0	0.0	0.7	0.0	9.7
	Catch/Hr Fishing	-	-	64.49	-	-	28.57	-	61.24
MAY 26	# Shad			76			45	3	124
	Hrs Fishing	0.0	0.0	1.8	0.0	0.0	4.8	3.5	10.1
	Catch/Hr Fishing	-	-	42.22	-	-	9.38	0.86	12.28
MAY 27	# Shad			249			57	20	326
	Hrs Fishing	0.0	0.0	4.7	0.0	0.0	2.6	3.0	10.4
	Catch/Hr Fishing	-	-	52.98	-	-	21.92	6.67	31.35
MAY 28	# Shad			52			103	12	167
	Hrs Fishing	0.0	0.0	3.3	0.0	0.0	5.1	0.7	9.0
	Catch/Hr Fishing	-	-	15.76	-	-	20.20	17.14	18.56
MAY 29	# Shad	63		46			53	78	240
	Hrs Fishing	1.8	0.0	1.7	0.0	0.0	3.3	2.4	9.3
	Catch/Hr Fishing	35.00	-	27.06	-	-	16.06	32.50	25.81
MAY 30	# Shad	216		2			20		238
	Hrs Fishing	7.6	0.0	1.3	0.0	0.0	1.4	0.0	10.3
	Catch/Hr Fishing	28.42	-	1.54	-	-	14.29	-	23.11
MAY 31	# Shad			162			199		361
	Hrs Fishing	0.0	0.0	6.8	0.0	0.0	2.6	0.0	9.4
	Catch/Hr Fishing	-	-	23.82	-	-	76.54	-	38.40

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 01	# Shad			2			5	6	13
	Hrs Fishing	0.0	0.0	1.1	0.0	0.0	2.7	5.7	9.6
	Catch/Hr Fishing	-	-	1.82	-	-	1.85	1.05	1.35
JUN 02	# Shad						1	22	23
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.7	8.8	9.5
	Catch/Hr Fishing	-	-	-	-	-	1.43	2.50	2.42
JUN 03	# Shad						3	15	18
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	3.2	6.8	10.0
	Catch/Hr Fishing	-	-	-	-	-	0.94	2.21	1.80
JUN 04	# Shad						2	91	93
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	8.7	10.0
	Catch/Hr Fishing	-	-	-	-	-	1.54	10.46	9.30
JUN 05	# Shad						2	34	36
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	8.2	9.5
	Catch/Hr Fishing	-	-	-	-	-	1.54	4.15	3.79
JUN 06	# Shad			145			155	58	358
	Hrs Fishing	0.0	0.0	1.6	0.0	0.0	4.3	4.9	10.8
	Catch/Hr Fishing	-	-	90.63	-	-	36.05	11.84	33.15
JUN 07	# Shad			99			152	409	660
	Hrs Fishing	0.0	0.0	1.8	0.0	0.0	3.2	4.9	9.9
	Catch/Hr Fishing	-	-	55.00	-	-	47.50	83.47	66.67
JUN 08	# Shad						17	123	140
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	1.3	9.0	10.3
	Catch/Hr Fishing	-	-	-	-	-	13.08	13.67	13.59
JUN 09	# Shad						22	31	53
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	3.2	6.6	9.8
	Catch/Hr Fishing	-	-	-	-	-	6.88	4.70	5.41
JUN 10	# Shad							101	101
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	0.0	6.6	6.6
	Catch/Hr Fishing	-	-	-	-	-	-	15.30	15.30
JUN 11	# Shad						23	89	112
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	3.1	6.9	10.0
	Catch/Hr Fishing	-	-	-	-	-	7.42	12.90	11.20

TABLE 9 CONTINUED.

Date		A & B Weir Gates Open	A & DOWN Weir Gates Open	A ONLY 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 12	# Shad						48	57	105
	Hrs Fishing	0.0	0.0	0.0	0.0	0.0	6.0	4.9	10.9
	Catch/Hr Fishing	-	-	-	-	-	8.00	11.63	9.63
JUN 13	# Shad			320			102	7	429
	Hrs Fishing	0.0	0.0	2.9	0.0	0.0	2.8	4.8	10.5
	Catch/Hr Fishing	-	-	110.34	-	-	36.43	1.46	40.86
JUN 14	# Shad			400			89		489
	Hrs Fishing	0.0	0.0	7.9	0.0	0.0	1.2	0.0	9.1
	Catch/Hr Fishing	-	-	50.63	-	-	74.17	-	53.74
JUN 15	# Shad			108			43	3	154
	Hrs Fishing	0.0	0.0	2.6	0.0	0.0	2.2	0.5	5.3
	Catch/Hr Fishing	-	-	41.54	-	-	19.55	6.00	29.06
		1,228	3	3,405	19	2	2,318	7,227	14,202
		35.3	1.3	68.5	11.1	1.3	125.1	401.9	644.7
		34.79	2.31	49.71	1.71	1.54	18.53	17.98	22.03

Excludes American Shad taken in clean out lifts and flume operation.

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 to 15 June, 1992.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	0500 - 0900	8.6	33.5	16.5	35.6	3.9	9.4	10.7
	0901 - 1100	6.5	-	14.0	-	8.0	11.7	11.0
	1101 - 1500	11.0	-	28.5	58.4	4.0	14.3	14.4
	1501 - 1900	12.7	-	89.8	94.4	6.1	28.7	32.6
MEAN WEEKDAYS		9.8	33.5	54.6	59.5	5.1	16.4	17.5
WEEKEND	0500 - 0900	28.0	107.1	69.2	104.2	0.0	2.7	55.0
	0901 - 1100	18.3	86.5	95.0	43.2	14.2	3.8	25.7
	1101 - 1500	21.6	14.4	26.0	-	3.9	20.7	16.6
	1501 - 1900	18.5	-	83.7	-	14.6	47.8	43.0
MEAN WEEKEND		22.2	76.0	68.8	51.3	8.8	22.2	32.5
TOTAL		14.6	66.5	63.9	55.6	7.0	17.5	22.0

TABLE 11

Comparison of the American shad catch and catch per effort, between discharges with one or two Francis units generating and high discharges (three or more unit generation) at the Conowingo Dam East Fish Lift, April to June 1992.

Generation Status	No. Shad Caught	Total Minutes Fished	Number of Lifts	Shad Catch per Hour
APRIL				
Two Units	0	186	7	0.00
High	1266	12195	570	6.23
TOTAL for April	1266	12381	577	6.14
MAY				
Two Units	3397	2965	137	68.74
High	6768	14919	726	27.22
TOTAL for May	10165	17884	863	34.10
JUNE				
One Unit	983	887	34	66.49
Two Units	15	72	3	12.50
High	1789	7558	297	14.20
TOTAL for June	2787	8517	334	19.63
GRAND TOTAL	14218	38782	1774	22.00

Table 12. Daily sex ratio of American shad at the Conowingo Dam Fish Lifts for 1992.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
1 Apr	0	0			
5 Apr	0	0			
7 Apr	0	0			
9 Apr	2	2	2	0	
11 Apr	10	10	9	1	9:1
12 Apr	187	184	116	68	1.7:1
13 Apr*	79	79	48	31	1.5:1
14 Apr*	19	17	7	10	0.7:1
15 Apr*	49	49	34	15	2.3:1
16 Apr*	20	20	8	12	0.7:1
17 Apr*	21	21	12	9	1.3:1
18 Apr*	133	106	60	46	1.3:1
19 Apr*	24	24	13	11	1.2:1
20 Apr	40	40	25	15	1.7:1
21 Apr	11	10	7	3	2.3:1
22 Apr	32	31	17	14	1.2:1
23 Apr	47	47	32	15	2.1:1
24 Apr	49	49	39	10	3.9:1
25 Apr	121	121	81	40	2.0:1
26 Apr	179	179	112	67	1.7:1
27 Apr	166	166	99	67	1.5:1
28 Apr	212	184	122	62	2.0:1
29 Apr	326	210	117	93	1.3:1
30 Apr	382	208	130	78	1.7:1
1 May	113	113	75	38	2.0:1
2 May	507	212	128	84	1.5:1
3 May	472	205	117	88	1.3:1

Table 12. Continued.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
4 May	946	214	112	102	1.1:1
5 May	601	214	113	101	1.1:1
6 May	550	216	133	83	1.6:1
7 May	644	232	133	99	1.3:1
8 May	43	43	28	15	1.9:1
9 May	71	71	43	28	1.5:1
10 May	906	207	105	102	1:1
11 May	915	213	113	100	1.1:1
12 May	588	219	112	107	1:1
13 May	872	242	124	118	1.1:1
14 May	449	198	90	108	0.8:1
15 May	921	203	85	118	0.7:1
16 May	264	211	82	129	0.6:1
17 May	909	220	105	115	0.9:1
18 May	445	204	112	92	1.2:1
19 May*	627	26	15	11	1.4:1
20 May*	243	104	54	50	1.1:1
21 May*	895	121	61	60	1:1
22 May	439	210	71	139	0.5:1
23 May	703	158	71	87	0.8:1
24 May	918	252	94	158	0.6:1
25 May	716	201	69	132	0.5:1
26 May	486	209	85	124	0.7:1
27 May	561	206	79	127	0.6:1
28 May	424	226	108	118	0.9:1
29 May	482	258	114	144	0.8:1
30 May	1017	201	71	130	0.5:1
31 May	1013	236	81	155	0.5:1

Table 12. Continued.

Date	Daily Catch	No. Sexed	No. of Males	No. of Females	Ratio (M/F)
1 Jun	82	82	41	41	1:1
2 Jun	75	75	28	47	0.6:1
3 Jun	345	121	56	65	0.9:1
4 Jun	137	137	61	76	0.8:1
5 Jun	100	84	36	48	0.8:1
6 Jun	421	224	100	124	0.8:1
7 Jun	677	140	50	90	0.6:1
8 Jun	426	272	109	163	0.7:1
9 Jun	177	157	57	100	0.6:1
10 Jun	443	223	80	143	0.6:1
11 Jun	308	214	89	125	0.7:1
12 Jun	231	207	92	115	0.8:1
13 Jun	642	207	92	115	0.8:1
14 Jun	614	337	117	220	0.5:1
15 Jun	194	150	44	106	0.4:1
Totals	25,721	10,232	4,925	5,307	0.9:1

* East Lift trough operated 19, 20, and 21 May. West Lift did not operate from 13 April to 1300 hrs on 19 April due to mechanical problems.

TABLE 13

Age and spawning history of American shad collected at the Conowingo Dam Fish Lifts in 1992; by sex, with mean, minimum and maximum fork length (mm).

Sex	Age	N	Spawning History			Fork Lengths		
				Repeats				
			Virgins	Once	Twice	mean	min	max
MALE	III	6	6			315	280	346
	IV	40	39	1		360	300	411
	V	92	79	13		397	340	454
	VI	41	26	10	5	423	380	495
	VII	9	4	3	2	459	430	482
Subtotal		188	154	27	7	395	280	495
FEMALE	III	1	1			340	340	340
	IV	12	12			411	380	472
	V	98	86	12		432	340	495
	VI	137	119	15	3	466	409	530
	VII	60	50	7	3	502	435	558
	VIII	4	3	1		525	475	556
Subtotal		312	271	35	6	461	340	558
Total		500	425	62	13	436	280	558

Age comp sample 62% ♀

Sex ratio sample 52% ♀

Table 14. Daily capture of tagged Maryland DNR American shad at the Conowingo Dam Fish Lifts, 1992.

Date	Daily Catch East	Daily Catch West	No. of MD DNR Recaptures East	No. of MD DNR Recaptures West
9 Apr	0	2	0	0
11 Apr	0	10	0	0
12 Apr	82	105	0	0
13 Apr	19	60	0	0
14 Apr	19	0	0	0
15 Apr	49	0	0	0
16 Apr	20	0	0	0
17 Apr	21	0	0	0
18 Apr	133	0	0	0
19 Apr	23	1	0	0
20 Apr	40	0	0	0
21 Apr	10	1	0	0
22 Apr	22	10	0	0
23 Apr	32	15	0	0
24 Apr	22	27	0	0
25 Apr	84	37	0	0
26 Apr	104	75	1	0
27 Apr	73	93	0	0
28 Apr	83	129	0	0
29 Apr	224	102	0	0
30 Apr	206	176	0	0
1 May	66	47	0	0
2 May	375	132	1	0
3 May	216	256	0	0
4 May	647	299	1	0
5 May	465	136	1	0
6 May	323	227	0	0
7 May	423	221	1	1

Table 14. Continued.

Date	Daily Catch East	Daily Catch West	No. of MD DNR Recaptures East	No. of MD DNR Recaptures West
8 May	26	17	0	0
9 May	13	58	0	0
10 May	548	358	0	1
11 May	538	377	1	2
12 May	354	234	0	0
13 May	580	292	3	1
14 May	233	216	1	1
15 May	677	244	3	2
16 May	161	103	1	1
17 May	713	196	5	4
18 May	267	178	3	2
19 May	351	276	0	4
20 May	76	167	0	2
21 May	741	154	0	2
22 May	170	269	2	0
23 May	648	55	10	1
24 May	670	248	3	4
25 May	594	122	5	0
26 May	327	234	5	5
28 May	167	257	1	5
39 May	241	241	4	1
30 May	238	779	2	16
31 May	361	652	4	9
1 Jun	13	69	0	0
2 Jun	23	52	0	0
3 Jun	21	324	0	6
4 Jun	93	44	0	1
5 Jun	36	64	0	0

Table 14. Continued.

Date	Daily Catch East	Daily Catch West	No. of MD DNR Recaptures East	No. of MD DNR Recaptures West
6 Jun	358	63	3	1
7 Jun	660	17	5	1
8 Jun	140	286	1	1
9 Jun	53	124	2	0
10 Jun	101	342	1	2
11 Jun	112	196	0	2
12 Jun	105	126	0	0
13 Jun	429	213	2	2
14 Jun	489	125	2	0
15 Jun	154	40	2	0
Totals	15,386	10,335	78	85

TABLE 15

Summary of transports of American Shad from Conowingo Dam West Fish Lift, 1 April TO 15 June 1992.

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
01 MAY	47	59.5	23	MUDDY CREEK	0	100.0	8.4	12.2	58.1
02 MAY	132	60.3	124	TRI-CO MARINA	0	100.0	14.2	11.7	64.0
03 MAY	256	62.6	146	TRI-CO MARINA	0	100.0	17.2	14.8	67.6
			25	PEQUEA CREEK	0	100.0	8.3	11.4	69.8
04 MAY	299	62.5	25	MUDDY CREEK	0	100.0	14.0	11.1	61.7
			217	TRI-CO MARINA	0	100.0	11.2	14.0	62.2
05 MAY	136	60.4	24	COLUMBIA PFC	0	100.0	10.2	10.3	58.1
06 MAY	227	60.8	230	TRI-CO MARINA	13	94.3	10.4	11.8	62.8
10 MAY	358	60.0	25	PEQUEA CREEK	0	100.0	10.8	11.0	59.9
			25	MUDDY CREEK	0	100.0	10.0	10.2	59.0
			257	TRI-CO MARINA	0	100.0	11.0	12.0	59.0
11 MAY	377	60.5	26	COLUMBIA PFC	0	100.0	10.0	10.3	62.6
			258	TRI-CO MARINA	2	99.2	13.8	12.4	62.6
12 MAY	234	61.7	129	TRI-CO MARINA	2	98.4	11.8	11.4	66.0
13 MAY	292	61.3	160	MUDDY CREEK	0	100.0	12.4	12.0	66.2
14 MAY	216	62.9	49	TRI-CO MARINA	1	98.0	9.8	11.2	71.2
			137	TRI-CO MARINA	9	93.4	11.4	11.8	69.8
15 MAY	244	63.0	174	TRI-CO MARINA	49	71.8	13.0	12.6	65.3
17 MAY	196	65.5	143	TRI-CO MARINA	2	98.6	11.0	11.4	59.9
18 MAY	178	66.4	26	PEQUEA CREEK	0	100.0	15.0	10.2	66.2
			94	TRI-CO MARINA	0	100.0	13.8	10.6	62.6
19 MAY	276	67.5	13	MUDDY CREEK	0	100.0	9.3	12.0	66.2
			26	MUDDY CREEK	0	100.0	10.6	9.4	68.0
20 MAY	167	67.5	26	COLUMBIA PFC	0	100.0	10.8	10.2	68.9
			82	TRI-CO MARINA	0	100.0	10.6	10.4	68.0
21 MAY	154	67.5	112	TRI-CO MARINA	1	99.1	9.0	10.4	68.0
22 MAY	269	67.8	155	SWATARA CR.	6	96.1	12.5	11.4	68.9
23 MAY	55	67.6	27	MUDDY CREEK	0	100.0	9.3	10.9	71.6
24 MAY	248	68.2	-	MUDDY CREEK	-	-	10.9	11.0	71.6
			155	TRI-CO MARINA	7	95.5	11.6	9.8	67.1
26 MAY	362	68.4	25	PEQUEA CREEK	0	100.0	9.4	9.8	64.4
			140	TRI-CO MARINA	5	96.4	11.0	10.0	59.9
			114	TRI-CO MARINA	2	98.2	8.8	10.4	59.0
27 MAY	234	66.0	25	MUDDY CREEK	0	100.0	10.8	10.4	70.7
			98	TRI-CO MARINA	0	100.0	10.5	10.4	60.8
28 MAY	257	70.0	25	COLUMBIA PFC	0	100.0	9.4	9.5	65.3
			115	TRI-CO MARINA	0	100.0	8.9	11.2	63.0
29 MAY	241	67.5	79	TRI-CO MARINA	0	100.0	11.0	12.0	67.1
30 MAY	779	68.0	9	MUDDY CREEK	0	100.0	8.6	9.6	65.8
			5	MUDDY CREEK	0	100.0	9.0	10.6	66.2
			138	TRI-CO MARINA	16	88.4	10.8	9.8	63.5
			148	TRI-CO MARINA	0	100.0	10.6	13.2	61.2
			72	TRI-CO MARINA	0	100.0	10.4	10.0	70.7
31 MAY	652	68.9	100	TRI-CO MARINA	0	100.0	9.2	10.0	64.4

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
31 MAY	652	68.9	197	TRI-CO MARINA	26	86.8	9.0	10.0	63.0
01 JUN	69	68.6	24	TRI-CO MARINA	0	100.0	9.0	9.2	59.9
03 JUN	324	67.8	51	TRI-CO MARINA	0	100.0	11.4	10.4	66.2
04 JUN	44	68.9	6	MUDDY CREEK	0	100.0	9.0	9.6	69.8
05 JUN	64	-	10	MUDDY CREEK	0	100.0	10.8	9.8	68.0
06 JUN	63	69.4	27	TRI-CO MARINA	1	96.3	9.8	10.8	66.2
07 JUN	17	68.9	-	MUDDY CREEK	-	-	9.0	9.0	69.8
			11	MUDDY CREEK	0	100.0	11.7	9.6	69.8
08 JUN	286	71.1	35	TRI-CO MARINA	0	100.0	10.6	10.2	68.0
			92	TRI-CO MARINA	0	100.0	10.2	10.2	69.8
09 JUN	124	72.0	16	TRI-CO MARINA	0	100.0	10.6	9.9	69.8
			63	TRI-CO MARINA	9	85.7	10.4	10.2	70.2
12 JUN	126	72.5	16	TRI-CO MARINA	0	100.0	11.2	10.6	73.4
14 JUN	125	72.5	32	COLUMBIA PFC	0	100.0	9.6	9.8	78.4
SEASON TOTALS			4586		151	96.7			

TABLE 16

Summary of transports of American Shad from Conowingo Dam East Fish Lift, 1 April TO 15 June 1992.

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
15 APR	49	54.0	65	TRI-CO MARINA	4	93.8	8.4	12.4	55.4
19 APR	23	53.9	60	TRI-CO MARINA	2	96.7	13.8	9.2	49.1
20 APR	40	53.4	25	FALMOUTH	1	96.0	20.0	11.0	51.4
29 APR	224	57.6	170	TRI-CO MARINA	13	92.4	11.8	10.8	58.1
02 MAY	375	59.0	147	TRI-CO MARINA	9	93.9	14.0	12.0	59.9
			153	TRI-CO MARINA	0	100.0	12.0	14.0	65.3
			65	TRI-CO MARINA	2	96.9	14.0	12.2	63.5
03 MAY	216	60.4	105	TRI-CO MARINA	0	100.0	10.5	12.0	63.5
04 MAY	647	60.8	155	TRI-CO MARINA	9	94.2	12.8	7.3	60.8
			189	TRI-CO MARINA	9	95.2	6.0	12.0	60.8
			159	TRI-CO MARINA	3	98.1	11.8	11.0	60.6
05 MAY	465	60.8	161	TRI-CO MARINA	6	96.3	11.6	12.2	57.2
			180	TRI-CO MARINA	7	96.1	12.0	10.0	57.2
06 MAY	323	60.8	167	TRI-CO MARINA	1	99.4	13.0	12.0	56.3
			115	TRI-CO MARINA	0	100.0	10.2	13.5	56.3
07 MAY	423	61.0	159	TRI-CO MARINA	0	100.0	11.4	12.2	55.4
10 MAY	548	59.0	170	TRI-CO MARINA	2	98.8	12.0	12.5	58.6
			186	TRI-CO MARINA	2	98.9	11.8	12.2	59.4
			175	TRI-CO MARINA	0	100.0	11.8	12.8	59.4
11 MAY	538	59.1	100	TRI-CO MARINA	1	99.0	12.2	12.2	62.6
			174	TRI-CO MARINA	2	98.9	12.0	12.0	63.5
			160	TRI-CO MARINA	12	92.5	11.2	14.8	62.6
12 MAY	354	60.8	37	TRI-CO MARINA	0	100.0	11.6	11.4	-
			128	TRI-CO MARINA	11	91.4	12.4	11.9	52.0
			145	TRI-CO MARINA	0	100.0	10.6	10.3	66.2
13 MAY	580	61.7	136	TRI-CO MARINA	2	98.5	8.8	10.9	68.4
			147	TRI-CO MARINA	60	59.2	10.0	12.2	68.0
			142	TRI-CO MARINA	67	52.8	12.2	13.8	69.8
			94	TRI-CO MARINA	0	100.0	11.1	11.0	68.0
14 MAY	233	63.5	122	TRI-CO MARINA	21	82.8	11.4	13.0	69.8
15 MAY	677	63.5	162	TRI-CO MARINA	9	94.4	8.4	13.2	64.9
			147	TRI-CO MARINA	5	96.6	9.0	11.0	65.3
			150	TRI-CO MARINA	19	87.3	12.0	12.0	53.6
			158	TRI-CO MARINA	12	92.4	14.0	12.0	62.6
16 MAY	161	65.3	146	TRI-CO MARINA	11	92.5	11.0	11.6	62.6
17 MAY	713	65.9	135	TRI-CO MARINA	1	99.3	10.0	11.9	60.8
			149	TRI-CO MARINA	3	98.0	12.2	12.8	60.4
			154	TRI-CO MARINA	23	85.1	13.0	12.6	60.8
			149	TRI-CO MARINA	19	87.2	11.6	12.0	60.8
18 MAY	267	68.7	129	TRI-CO MARINA	64	50.4	8.8	10.2	64.4
			65	TRI-CO MARINA	3	95.4	10.7	10.4	63.5
23 MAY	648	68.6	120	TRI-CO MARINA	90	25.0	11.0	11.0	71.6
			77	TRI-CO MARINA	16	79.2	13.2	10.2	73.4
24 MAY	670	70.4	114	SWATARA CR.	94	17.5	10.6	10.8	72.5

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
24 MAY	670	70.4	100	TRI-CO MARINA	28	72.0	9.2	10.2	66.2
25 MAY	594	69.3	106	TRI-CO MARINA	17	84.0	11.4	11.6	62.6
			87	TRI-CO MARINA	37	57.5	9.8	10.0	60.8
26 MAY	124	68.8	34	TRI-CO MARINA	1	97.1	12.0	11.2	59.9
27 MAY	327	68.0	72	TRI-CO MARINA	7	90.3	8.9	8.6	61.7
			100	TRI-CO MARINA	17	83.0	11.2	9.6	59.9
28 MAY	167	68.0	66	TRI-CO MARINA	3	95.5	10.6	10.0	62.6
29 MAY	241	68.6	100	TRI-CO MARINA	10	90.0	10.4	10.4	67.1
30 MAY	238	68.0	96	TRI-CO MARINA	8	91.7	10.4	10.6	61.7
			92	TRI-CO MARINA	2	97.8	10.6	10.6	60.8
31 MAY	361	69.8	94	TRI-CO MARINA	0	100.0	11.2	8.2	63.5
			103	TRI-CO MARINA	13	87.4	9.6	11.0	62.6
05 JUN	36	68.0	53	TRI-CO MARINA	2	96.2	7.0	9.5	64.4
06 JUN	358	69.4	106	TRI-CO MARINA	5	95.3	8.5	10.2	63.5
			90	TRI-CO MARINA	1	98.9	12.4	10.2	64.4
07 JUN	660	70.3	89	TRI-CO MARINA	27	69.7	9.8	9.0	65.3
			88	MUDDY CREEK	3	96.6	14.8	10.0	71.6
08 JUN	140	72.0	33	TRI-CO MARINA	3	90.9	8.6	10.2	69.8
13 JUN	429	72.6	105	TRI-CO MARINA	35	66.7	8.2	8.8	70.3
14 JUN	489	74.3	83	TRI-CO MARINA	32	61.4	10.2	10.3	72.0
SEASON TOTALS			7543		866	88.5			

TABLE 17

Summary of combined transports of American Shad from both Conowingo Dam Fish Lifts, 1 April to 15 June 1992.

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 APR	187	52.4	183	TRI-CO MARINA	9	95.1	8.7	12.4	52.7
13 APR	79	53.9	76	MUDDY CREEK	0	100.0	10.7	11.5	52.7
22 APR	32	52.2	27	TRI-CO MARINA	3	88.9	9.6	9.0	57.2
23 APR	47	53.8	71	TRI-CO MARINA	2	97.2	10.2	11.0	57.2
25 APR	121	56.9	89	TRI-CO MARINA	0	100.0	15.2	11.4	57.0
26 APR	179	58.9	154	TRI-CO MARINA	2	98.7	10.2	12.2	56.3
27 APR	166	58.1	102	TRI-CO MARINA	0	100.0	11.8	10.5	55.2
			134	TRI-CO MARINA	1	99.3	4.6	13.0	56.3
28 APR	212	56.4	206	TRI-CO MARINA	0	100.0	10.0	10.8	57.2
29 APR	326	56.9	142	TRI-CO MARINA	3	97.9	11.8	9.0	58.6
30 APR	382	58.5	162	TRI-CO MARINA	0	100.0	12.4	13.4	55.9
			204	MUDDY CREEK	1	99.5	9.0	8.8	57.7
01 MAY	113	58.9	87	TRI-CO MARINA	0	100.0	10.4	12.2	60.8
03 MAY	472	61.5	164	TRI-CO MARINA	0	100.0	10.7	11.6	65.3
04 MAY	946	61.7	167	TRI-CO MARINA	25	85.0	12.2	9.2	62.6
05 MAY	601	60.6	166	TRI-CO MARINA	2	98.8	10.1	12.8	58.6
07 MAY	644	61.0	247	TRI-CO MARINA	2	99.2	10.9	11.2	56.3
			170	TRI-CO MARINA	3	98.2	8.0	12.6	56.5
09 MAY	71	58.5	109	TRI-CO MARINA	0	100.0	12.0	12.0	55.4
11 MAY	915	59.2	112	TRI-CO MARINA	2	98.2	7.4	12.8	63.5
16 MAY	264	65.7	92	TRI-CO MARINA	7	92.4	13.6	11.8	62.4
22 MAY	439	67.5	141	TRI-CO MARINA	105	25.5	11.2	11.6	70.2
03 JUN	345	67.9	75	TRI-CO MARINA	0	100.0	10.7	10.6	67.1
10 JUN	443	71.8	126	TRI-CO MARINA	0	100.0	11.6	10.0	69.8
11 JUN	308	71.9	107	TRI-CO MARINA	3	97.2	8.6	9.8	71.6
12 JUN	231	71.7	73	TRI-CO MARINA	1	98.6	8.8	9.7	73.4
13 JUN	642	72.6	95	SWATARA CR.	2	97.9	9.5	9.5	71.6
			69	TRI-CO MARINA	1	98.6	10.8	10.0	71.6
14 JUN	614	73.4	85	COLUMBIA PFC	28	67.1	11.8	9.6	78.8
SEASON TOTALS			3635		202	94.4			

Table 18. Summary of river herring transported from the Conowingo Dam Fish Lifts to upstream release sites on the Susquehanna River, 1992.

Species	Release Site	No. Trans-ported	Percent Survival
Alewife	Tri-County Marina	219	100
Alewife	Muddy Creek Access	24	100
Blueback herring	Tri-County Marina	5,520	99.7
Blueback herring	Muddy Creek Access	6,437	99.8
Blueback herring	Wrightsville Bridge	468	99.6
Total		12,668	99.8

Table 19. Species and number of fish that were passed into Conowingo Pond during trough operations on 19, 20, and 21 May 1992.

Species	Total
Eel	1
Herring	29
Blueback herring	2
Alewife	3
American shad	1,168
Gizzard shad	27,052
Minnows	557
Carp	34
Rainbow trout	1
Brown trout	2
Brook trout	2
Comely shiner	42
Quillback	1
Redhorse	6
Channel catfish	15
White perch	53
Striped bass	1
Redbreast sunfish	18
Green sunfish	6
Pumpkinseed	6
Bluegill	88
Smallmouth bass	14
Largemouth bass	7
White crappie	2
Lamprey	3
Yellow perch	7
Walleye	2
Striped x white bass	2
Tiger muskie	1
Total	29,125

TABLE 20

Summary of American Shad catch by constant generation levels (varying generation during a lift was grouped separately) at the East vs the West Lift, 1 April to 15 June 1992. Cleanout lifts and flume fish were excluded.

TOTAL DISCHARGE (X 1000 CFS)	UNIT closest to the lift	UNIT 2nd closest to the lift	EAST FISH LIFT NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	WEST FISH LIFT NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	TOTAL TIME (MINS.)
LE 5	OFF	OFF	34	887	983	66.5	43	997	209	12.6	1884
*TOTAL LE 5			34	887	983	66.5	43	997	209	12.6	1884
10-65	CHG	OFF	-	-	-	-	16	405	197	29.2	405
10-65	CHG	ON	1	30	0	0.0	-	-	-	-	30
10-65	OFF	OFF	274	6762	4605	40.9	1006	24686	7832	19.0	31448
10-65	OFF	ON	47	859	60	4.2	-	-	-	-	859
10-65	ON	OFF	123	2693	828	18.4	-	-	-	-	2693
10-65	ON	ON	735	16188	5873	21.8	14	462	0	0.0	16650
*TOTAL 10-65			1180	26532	11366	25.7	1036	25553	8029	18.9	52085
VARYING	CHG	CHG	23	740	40	3.2	4	89	15	10.1	829
VARYING	CHG	OFF	13	480	59	7.4	-	-	-	-	480
VARYING	CHG	ON	4	119	11	5.5	-	-	-	-	119
VARYING	OFF	CHG	3	180	8	2.7	-	-	-	-	180
VARYING	OFF	OFF	28	918	458	29.9	115	3114	1384	26.7	4032
VARYING	ON	CHG	24	675	311	27.6	1	20	0	0.0	695
VARYING	ON	OFF	3	95	7	4.4	-	-	-	-	95
VARYING	ON	ON	20	612	37	3.6	4	70	0	0.0	682
*TOTAL VARYING			118	3819	931	14.6	124	3293	1399	25.5	7112
+ 65	OFF	OFF	-	-	-	-	1	15	4	16.0	15
+ 65	ON	OFF	-	-	-	-	20	269	0	0.0	269
+ 65	ON	ON	368	7460	922	7.4	271	5238	665	7.6	12698
*TOTAL + 65			368	7460	922	7.4	292	5522	669	7.3	12982
			1700	38698	14202	22.0	1495	35365	10306	17.5	74063

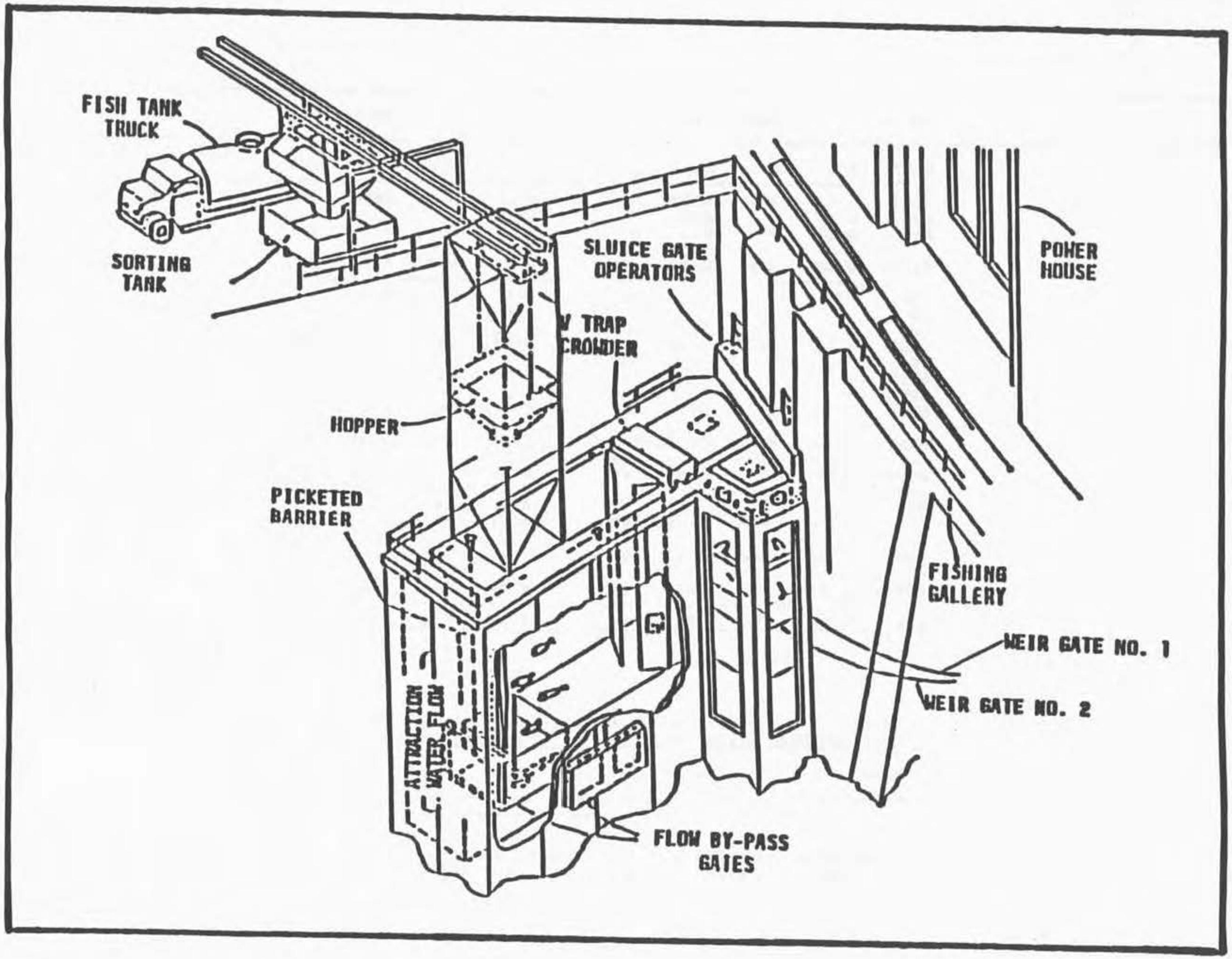


Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

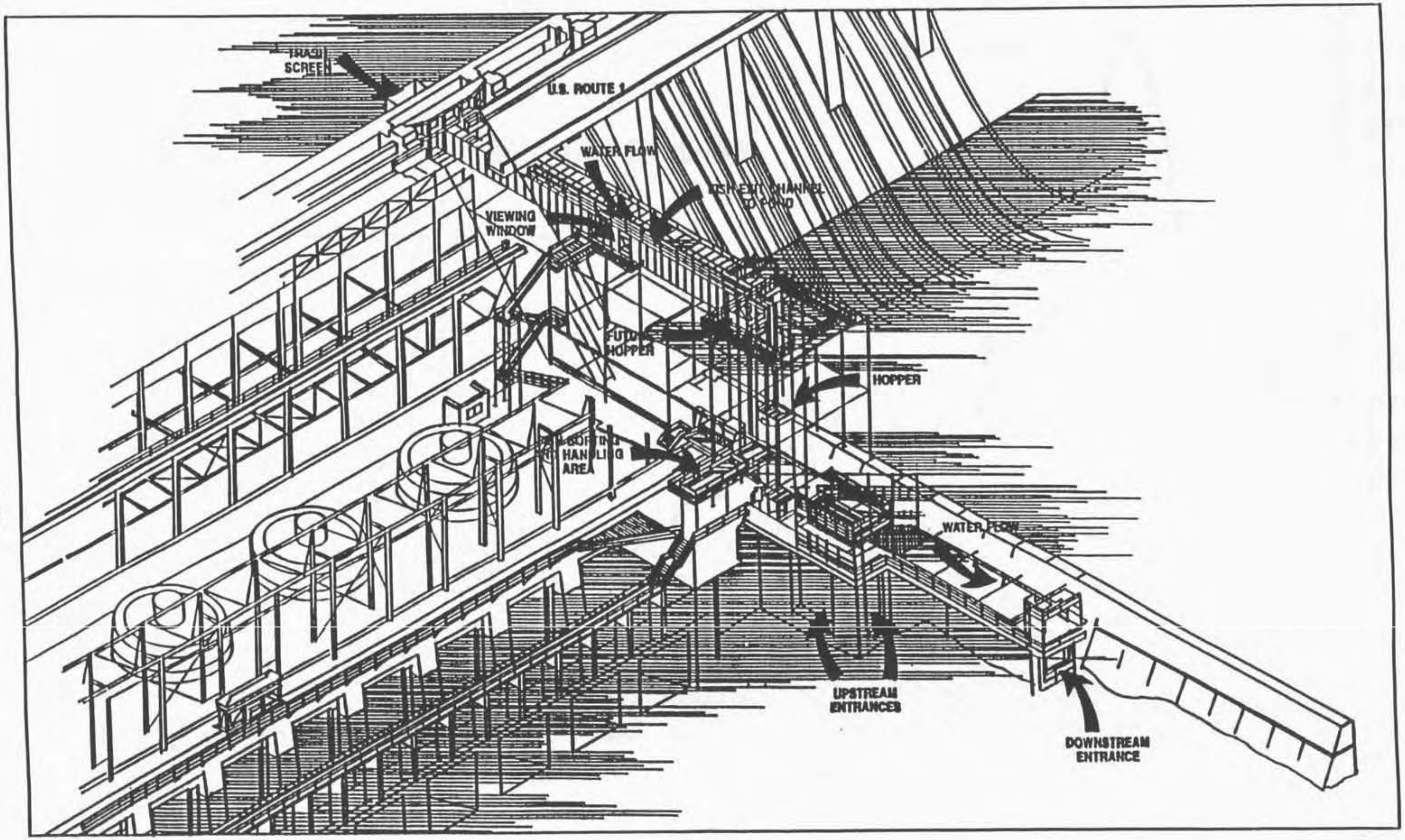
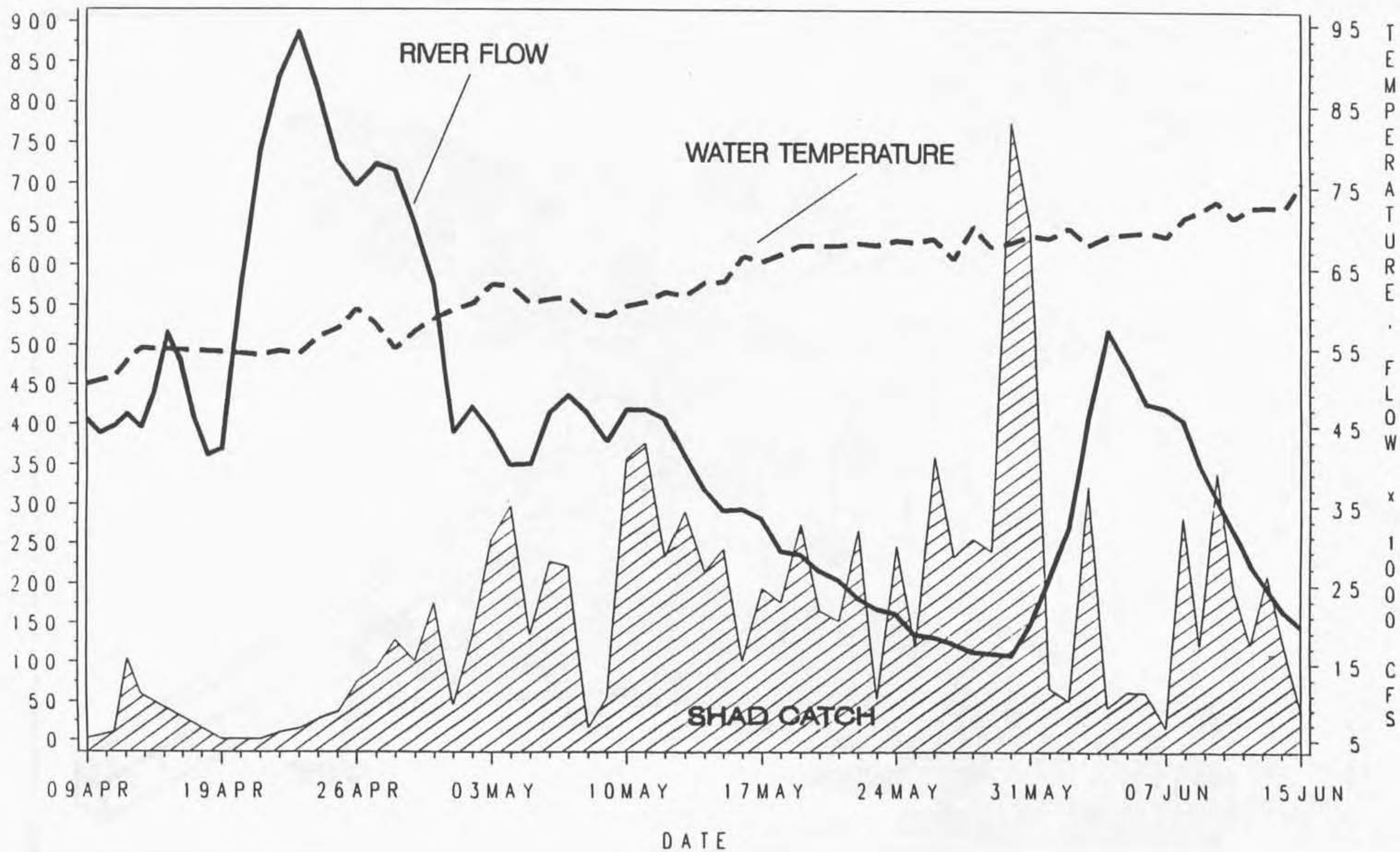


Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.



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IGURE 3

. plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch
t the Conowingo West Lift, 1992.

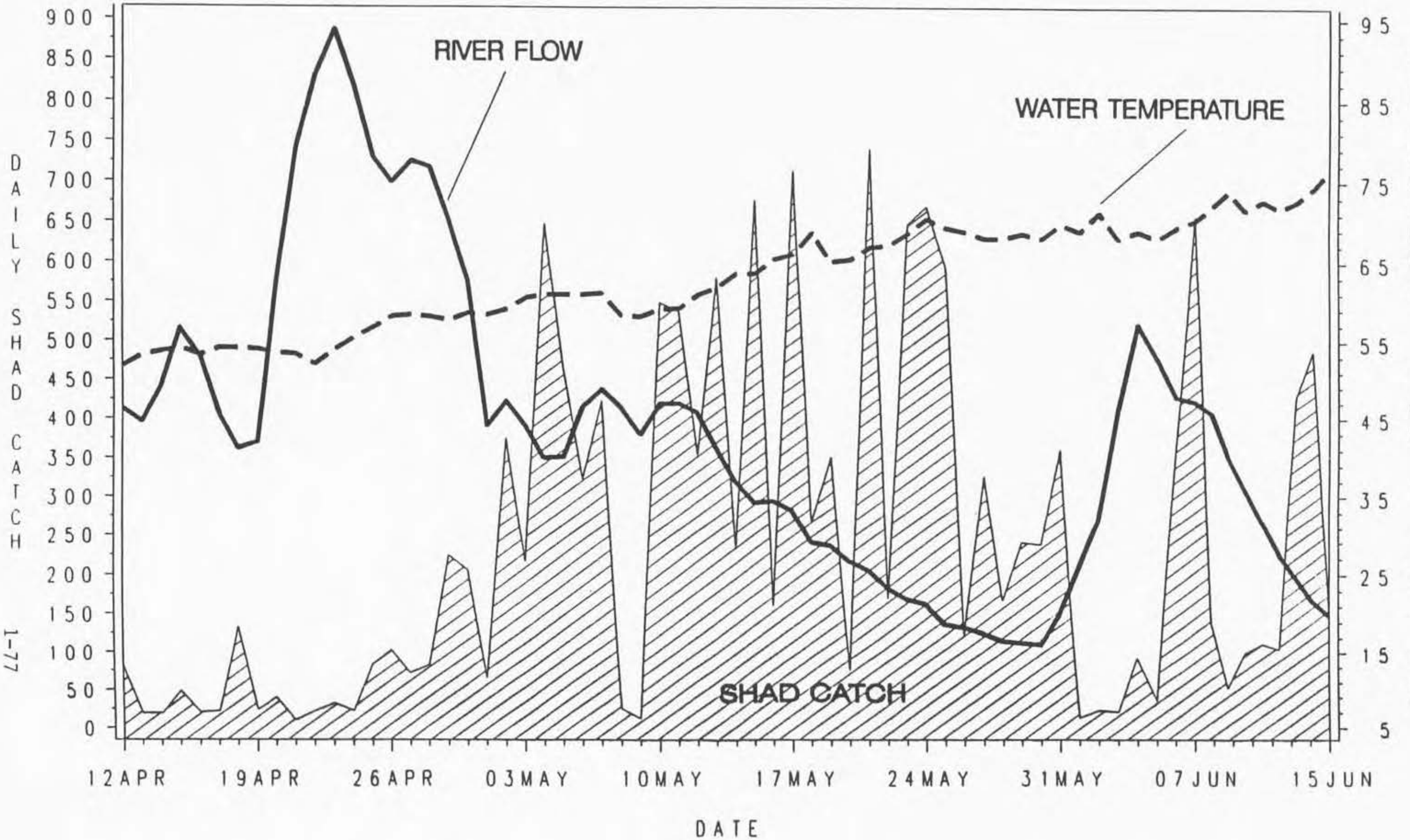

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FIGURE 4

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch at the Conowingo East Lift, 1992.

JOB II.

AMERICAN SHAD EGG COLLECTION PROGRAM

THE WYATT GROUP, Inc.

Lancaster, Pennsylvania

INTRODUCTION

This report is a synopsis of egg collection efforts in the spring of 1992. The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) goal for 1992 was to obtain a minimum of 30 million shad eggs over a two month period (May-June). In the last 20 years (1973-1992) over 500 million eggs have been collected for the program. In the period during which the hatchery operation has become well established (1980 to the present) some 394 million eggs have been obtained (Table 1). Annual production has ranged from 11 million to 52 million eggs per year.

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 1992 schedule of collection activities is shown in Table 2. Collection is terminated on a river when either (1) the production goal for that river is reached or (2) when it is obvious that quantities of eggs obtained over several days (usually less than five liters/day) are not sufficient to justify shipments to the Van Dyke Hatchery.

Egg Collection

Every attempt is made to obtain eggs and sperm from shad as soon after capture as possible. Ability to do so varies according to the method of capture, e.g., whether or not shad are caught by, contractors (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

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.

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

Tidal Conditions

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

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

These natural events can change the times shown in tidal charts by up to 90 minutes. Thus, it is best to fish according to observation of the natural system.

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

LOCATION OF EGG COLLECTION EFFORT

Through the years since 1971, the rivers chosen each year for sampling have changed. All East Coast rivers from the Connecticut (Massachusetts) south to the Savannah (South Carolina) have been explored to determine feasibility of providing eggs. No rivers south of Virginia provided sufficient quantities of eggs to warrant continuation of efforts. The James and Pamunkey rivers (Virginia), reliable sources of eggs for 20 years, were abandoned as an egg source by 1991 due to a decline in shad populations. 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). Thus, in 1992 the program included the Delaware, Hudson and Connecticut rivers which were previously demonstrated to be a source of eggs. Also, efforts were made to collect eggs from the lower Susquehanna River (Maryland) for the first time since 1973.

Susquehanna River (Maryland)

Efforts to obtain shad eggs from the Susquehanna River were made in the vicinity of Port Deposit, MD. Drift and anchor gill-netting was done approximately 1/2 mile upstream and downstream from Spencer's Island. Fishing was conducted in the main river channel over to Port Deposit and between the Island and Lapidum. It was in this same area that shad eggs were collected in the 1960's and early 1970's.

Delaware River (Pennsylvania-New Jersey)

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

SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative (New Jersey), to collect some 10 million shad eggs from the Delaware River. Biologists from the

Pennsylvania Fish and Boat Commission and Ecology III, Inc. (Berwick, PA) conducted the collection program. Shad were captured with gill-nets set parallel to the current. Nets were set between dusk and midnight.

Hudson River (New York)

The Hudson is a relatively large estuarine system which is simple in configuration but very complex in physical and chemical characteristics. Egg collection efforts fell into two categories: collections by anchored gill-nets and haul seine. These two techniques were alternated in accordance with the changing tidal conditions; the haul seine was used during periods of low water and gill-nets were used at all other times. The 1992 efforts were concentrated in two primary areas, Rogers Island (River Mile 114) for haul seining and off Cheviot, NY (River Mile 106) for gill netting.

Connecticut River (Massachusetts)

The Connecticut River was fished in the vicinity of t e 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 Universit o

Massachusetts Cooperative Fish and Wildlife Unit. Based on 1991 experience, the 1992 effort was conducted between Turners Fall and Sunderland, MA at river miles 187 to 189. Shad were captured by drifted gill-nets.

RESULTS OF 1992 FIELD COLLECTION EFFORTS

This section provides the results of the efforts in the spring of 1992. In addition, discussion is presented when explanation is useful in describing events or in consideration of making plans for the future.

Susquehanna River (Maryland)

Efforts to collect shad eggs began on 6 May when the water temperature reached 57 °F (Table 4). A total of nine nights were expended to collect eggs. Netting was terminated on 21 May, at which time water temperature had reached 69 °F. Sampling usually began at 7 to 8 P.M. and typically terminated between 1 and 3 A.M.. Thus, the effort included a time period when Conowingo Dam operation was reduced to a minimum of two units generating (Table 5).

No eggs were obtained (Table 4). A total of 12 shad (all roe) were captured. Ripe shad were taken at water temperatures of 65 °F and higher. Striped bass were taken on all nights of netting.

Catches of up to 25 per evening occurred. All bass were released alive.

The absence of male shad in the catches suggests that smaller mesh net might be more efficient for capturing buck shad. General observations suggest that large numbers of shad were not available for capture. Evidence of spawning activity was minimal.

Delaware River (Pennsylvania-New Jersey)

A total of 10.26 million eggs was collected on nine dates (Table 6). Some 9.60 million eggs were shipped to the Van Dyke Hatchery and 0.66 million eggs were shipped to the Maryland DNR Manning Hatchery (see below). The first shipment was on 10 May and the last on 20 May. More than a million eggs were shipped on 5 of 9 collection days. Ripe shad were caught at water temperatures which ranged from 59 to 68 °F (mean = 64 °F). Up to 230 shad were captured per night. The total number of shad captured was 1,230.

Hudson River (New York)

In 1992, 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 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. Seine operations were conducted on an ebb tide, between late afternoon and dusk at a time when the tidal conditions provided a landing site where the catch could be effectively beached.

A total of 3.00 million eggs were obtained on the Hudson River (Table 7). This included 2.37 million eggs from shad captured by gill-net and 0.63 million eggs from shad captured by haul seine. The Hudson River egg collection program began on 5 May and continued until 26 May, a period of 22 days. In this time, the total effort included 14 days of gill-netting and three days of haul seining.

The Wyatt Group field crew initiated field sampling by gill-net off Cheviot, NY on 5 May when water temperature was 52 °F. On the same date in 1991 the water temperature was 56 °F. The water temperature did not reach 58 °F until 11 May, the date on which the first eggs were taken. For the next three days (12-14 May) eggs were collected at Cheviot. Then, the combination of tidal conditions and physical conditions at Cheviot required that efforts be made in other areas. Gill-netting was conducted at Catskill, Stockport and Athens, NY without success. The Wyatt Group field crew assisted Mr. Everett Nack in capturing shad by haul seine off the northwest corner of Rogers Island on 16-18. Eggs were only taken on 18 May. No eggs were taken after 18 May despite rigorous efforts at several sites.

The low production of eggs from the Hudson River is attributable to several factors. In 1992, the water temperature was not conducive to the spawning of shad until mid-May. This was in contrast to conditions of 1990 and 1991 when ripe shad were available in the first week of May. By the time that water temperature was appropriate, tidal and weather conditions affected the ability to gill-net in areas previously shown to be shad spawning sites. The combination of "full-moon" low tides accompanied by southerly winds made areas unsuitable for fishing or created conditions which affected the catch of shad. Such conditions had not been encountered in previous years shad collection efforts.

Connecticut River (Massachusetts)

Collection efforts on the Connecticut River in 1992 began on the night of 27 May and the first shipment of eggs was made on 29 May. A total of 6.19 million eggs was collected. Of these, 5.71 were delivered to the Van Dyke Hatchery and 0.48 million were provided to the Maine Department of Natural Resources. Collection was terminated on 7 June.

The effort on the Connecticut was undertaken using two fishing crews drifting gill-nets. The shad population on the Connecticut differs from other rivers in that spawning occurs only for a period of several hours (from darkness to approximately 2300 hours. Thus, using two crews increases the opportunity to collect eggs.

Water temperature and river flow influence the success of egg collection operation on the Connecticut. The difference in water temperature between 1990 and 1991 is shown in Table 9. The higher temperature in late May 1991 resulted in an earlier spawning than in 1992. Because the field crew was committed to the Hudson River, the peak of shad spawning had passed before the crew arrived in 1991. This was not the case in 1992. River flow can impact the ability to collect eggs on the Connecticut. When flows increase dramatically such as happened on 2 June (Table 9), shad spawning diminishes and egg collection drops (as seen on 3 June, Table 8).

Summary of Egg Collection

The total number of eggs delivered to the Van Dyke Hatchery in the spring of 1992 was 18.48 million eggs. An additional 1.14 million eggs were collected and provided to co-operative programs between SRAFRC and the departments of natural resources of Maryland and Maine (see below). The production goal was reached on the Delaware River. Results on the Hudson River were much less than anticipated based on previous years experience. This is attributable to a relatively cool Spring which delayed spawning water temperature (58 °F) being reached until mid-May and less than favorable collecting conditions (tidal/weather) after spawning temperature was reached. The conditions which affected the egg collection program also affected the commercial fishery. The 1992 season was characterized by relatively poor catches. Production on the Connecticut River was relatively high and the potential for obtaining 10 million eggs on an annual basis is promising.

CO-OPERATIVE PROGRAMS

Virginia

In an effort to assist with restoration of the American shad on the James River, SRAFRC agreed to rear shad from eggs collected on the James River for the Virginia Fish and Game Department. A total of 0.17 million eggs were delivered to the Van Dyke Hatchery between 14 May and 24 June (Table 9).

Maryland

In a co-operative effort to assist with restoration of American shad in Maryland waters, up to 500,000 shad eggs obtained in the Susquehanna River were to be delivered to the Manning Hatchery of the Maryland Department of Natural Resources. Shad were to be reared as part of an agreement with the Potomac Electric Power Company (PEPCO). Therefore, PEPCO provided two biologists to assist The Wyatt Group in the field program.

When it became evident that the quantity of shad eggs were not going to be obtained using the Susquehanna River as a source, efforts were made to obtain the eggs from the Delaware River program. Thus, on 20 May some 660,000 shad eggs from the Delaware were provided to the Manning Hatchery.

Maine

For several years, the Maine Department of Marine Resources has been examining the feasibility of restoring runs of the American shad to the Medomak River (near Waldoboro, ME). SRAFRC agreed to assist in this program by requesting The Wyatt Group to provide shad eggs from the Connecticut River collection program. In 1992, a total of 0.48 million eggs were provided. These were obtained on 7 June. The Maine DNR provided biologists to assist in the collection. They then transported the eggs back to Maine. Egg viability was approximately 75%. On 2 July 1992, approximately 200-300,000 fry were released along four sites on the Medomak River.

TABLE 1. Total number (millions) of American shad eggs collected from various rivers and delivered to the Van Dyke Hatchery, 1980-1992.

Year	Delaware	Hudson	Connecticut	Columbia	Other*	Totals
1980	-	-	-	-	13.56	13.56
1981	-	-	-	5.78	5.84	11.62
1982	-	-	-	22.57	3.28	25.85
1983	2.40	1.17	-	19.51	11.40	34.48
1984	2.64	-	-	27.88	10.57	41.09
1985	6.16	-	-	12.06	7.33	25.55
1986	5.86	-	-	39.97	6.69	52.52
1987	5.01	-	-	23.53	4.46	33.00
1988	2.91	-	-	26.92	1.97	31.80
1989	5.96	11.18	-	23.11	2.44	42.69
1990	13.15	14.53	-	-	0.94	28.62
1991	10.74	17.66	1.10	-	0.31	29.81
1992	9.60	3.00	5.71	-	0.17	18.48
TOTALS	64.43	53.33	6.81	201.33	68.96	394.86

*Primarily the Pamunkey River and the James River.

TABLE 2. Collecting periods for eggs of American shad, 1992.

River	Dates	Fishing Days
Susquehanna	6 May - 21 May	9
Delaware	10 May - 20 May	9
Hudson	5 May - 26 May	17
Connecticut	27 May - 7 June	10

TABLE 3. Summary of efforts to collect American shad eggs on the lower Susquehanna River, 1992.

Date	Time	Temperature (°F)	Shad Roe	Shad Buck	Striped Bass
May					
6	7-11 P	57	0	0	2
7	7-11 P	61	0	0	4
13	5-12 M	65	1	0	5
14	7-2 A	65	1	0	12
15*	-	-	-	-	-
16	7-1 A	66	0	0	10
19	8-3 A	68	5	0	25
20	8-3 A	69	3	0	25
21	8-3 A	69	0	0	10
TOTALS			12	0	93

*Effort terminated due to weather conditions.

TABLE 4. Number of units generating at Conowingo Dam during American shad egg collection efforts on the lower Susquehanna River.

Time	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300
Date May										
6	11	11	11	11	6	2	2	2	2	2
7	11	11	11	11	6	6	2	2	2	2
13	11	11	11	11	11	2	2	2	2	2
14	11	11	11	7	4	2	2	2	2	2
15	7	7	7	5	2	2	2	2	2	2
16	8	8	8	8	8	4	2	2	2	2
17	8	8	8	8	8	2	2	2	2	2
19	7	7	7	7	2	2	2	2	2	2
20	5	5	5	5	5	2	2	2	2	2
21	7	7	7	7	7	2	2	2	2	2
22	9	9	9	9	2	2	2	2	2	2

TABLE 5. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1992.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May 10	11.6	420,475	1	59	49.7
11	36.4	1,222,797	2	61	72.6
12	53.5	1,914,599	4	63	55.5
13	39.1	1,710,100	6	68	69.5
14	30.0	1,110,328	9	68	42.4
17	7.2	237,194	11	63	53.0
18	31.3	1,064,878	12	64	72.2
19	45.2	1,334,073	14	63	55.3
20	18.0	586,609	15	65	53.1
	*20.0	660,000			
Total	292.3	10,261,053	Mean =	64	60.0

* Obtained for Maryland Department of Natural Resources, Manning Hatchery.

TABLE 6. Collection data for American shad eggs taken on the Hudson River, New York, 1992.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Gear	Percent Viability
May 11	21.6	615,231	3	Gill	65.9
12	7.6	212,296	5	Gill	77.5
13	16.0	457,545	7	Gill	71.5
14	36.9	1,089,099	10	Gill	77.6
18	20.4	629,468	13	Seine	81.1
Total	102.5	3,003,639			75.0

TABLE 7. Collection data for American shad eggs taken on the Connecticut River, Massachusetts, 1992.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May 29	27.6	959,191	17	62	71.2
30	26.4	1,018,224	18	63	84.9
31	10.7	709,483	19	62	79.2
June 3	8.7	312,071	20	63	80.9
4	32.2	1,241,295	21	63	76.2
5	35.8	1,104,654	22	59	85.2
6	12.6	367,740	23	62	80.0
*7	15.0	480,000		62	74.7
Total	154.0	6,192,658		Mean = 62	78.3

*Obtained for Maine Department of Natural Resources.

TABLE 8. Numbers of American shad lifted at the Holyoke Dam, water temperature and river flow, Connecticut River, 1992.

	Shad 1992		Temperature (°F) 1992	1991	River Flow (cfs) 1992
May					
13	44,355		62	62	11,062
14	27,396		63	63	13,102
15	37,482		63	64	13,476
16	30,811		64	66	12,976
17	26,299		64	68	9,981
18	46,581		65	68	11,791
19	37,478		67	67	9,276
20	33,000		68	68	10,871
21	35,172		71	68	10,970
22	39,412		72	70	8,024
23	29,552		72	71	5,231
24	25,619		68	72	4,650
25	17,524		66	73	4,416
26	23,784		66	73	7,711
27	17,190		67	74	6,005
28	18,572		68	76	6,221
29	8,295		69	76	6,873
30	9,714		68	77	4,587
31	19,365		66	77	5,997
TOTAL	565,557	(78.4%)			
June					
1	14,543		65	78	16,618
2	10,709		66	77	27,814
3	2,468		66	76	16,426
4	14,873		67	76	14,869
5	20,077		66	72	10,740
6	12,140		66	72	16,531
7	2,006		67	75	17,116
8	5,165		70	75	16,826
9	9,187		71	76	17,116
10	7,116		72	77	16,826
11	4,505		73	77	12,268
12	5,640		73	77	10,277
13	3,159		75	75	9,015
14	1,747		77	--	7,976
15	384		77	75	3,513
16	1,009		77	77	5,142
17	243		77	76	4,281
TOTAL	116,722	(16.2%)			
GRAND TOTAL	721,369*				

*Includes shad lifted before 13 May and after 17 June.

TABLE 9. Collection data for American shad eggs taken on the James River, Virginia, 1992.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Percent Viability
May 14	0.1	5,689	8	2.6
21	0.7	26,178	16	73.9
June 15	0.4	15,054	24	0.0
22	1.2	61,431	25	36.5
24	1.0	63,513	26	29.4
Total	3.4	171,865		41.6

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1992

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INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River system. The objectives of the Van Dyke Station 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 1992 included the stocking of 10-20 million 18-day old shad fry, and 50-100 thousand fingerlings. All hatchery-reared American shad fry were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in 1992 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Research conducted in 1992 involved comparison of relative survival of American shad fry released in midstream vs controls released nearshore.

EGG SHIPMENTS

A total of 18.5 million eggs (532 L) were received in 26 shipments in 1992 (Table 1), representing the lowest total since 1981 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 68.3%, the highest since the program began. Nine shipments of eggs were received from the Delaware River (9.6 million eggs) with a viability of 60.0%. The Hudson River produced 5 shipments (3.0 million eggs) with a viability of 75.0%. Seven shipments of eggs were received from the Connecticut River (5.7 million eggs) with a viability of 79.5%. Five small shipments of eggs were received from the James River (172 thousand eggs) with a viability of 35.3%.

SURVIVAL

Overall survival of fry was 40.6%, compared to a range of 70.1% to 89.8% for the period 1984 through 1991. Survival of individual tanks followed three patterns (Figure 1). Four tanks exhibited 20d survival of approximately 90%, typical of survival in the past. Fifteen tanks suffered high mortality between 9 and 14 days of age which resulted in mean 20d survival of approximately 58%. The remaining 13 tanks exhibited 2 peaks in mortality, one between hatch and d6 and another between 9 and 14 days of age. Mean survival to 20d was approximately 20%. This group included 5 tanks which suffered almost complete mortality.

The cause of these mortalities is unknown. Large numbers of motile aeromonad bacteria were present in the gut (see Attachments) and may have caused the mortalities. An epizootic of Aeromonas hydrophila, probably brought on by very low dissolved oxygen levels, has been identified as the cause of mortality in threadfin shad and American shad in the San Joaquin River (Haley et al., 1967). The histopathology report (Attachment 2), however, did not note the tissue changes which are normally associated with bacterial pathogenesis, suggesting that the bacterial infections may have been secondary to another causal factor.

Several steps have been taken to prevent re-occurrence of these mortalities. First, all water supply plumbing, tanks, and equipment was disinfected with 200 ppm free chlorine for a minimum of 2h. The warming pond was disinfected with 10 ppm chlorine. The spring pond could not be disinfected because we cannot control its effluent to prevent release of chlorine to the environment. Second, fish culture practices have been adopted to prevent development and dispersal of bacterial pathogens. These practices will include cleaning of each rearing tank to remove egg shells within hours of hatching. In addition, all equipment (brushes, siphons, squeegees) will be disinfected before use in each tank and separate sets of equipment (hip boots, nets, etc.) will be used for pond work to prevent reinfection from effluent or natural waters. Supplemental dry feed (AP-100) left over at the end of each year will be frozen and used only if freshly prepared food runs out. It is hoped that these precautions will prevent re-occurrence of the problem.

FRY PRODUCTION

Production and stocking of American shad fry is summarized in Tables 2, 3 and 4. Total fry production was 5.1 million. A total of 3.0 million was released in the Juniata River, 1.2 million in the Susquehanna River below Conowingo Dam, 353 thousand in the Lehigh River and 3 thousand in the Schuylkill River.

TETRACYCLINE MARKING

All American shad fry produced at Van Dyke received marks produced by immersion in tetracycline (Table 5). Immersion marks were administered by bath treatments in 200 ppm tetracycline hydrochloride for 6h duration. Fry stocked below Conowingo Dam (all egg sources) received a double mark at five and nine days of age. Fry originating from Delaware River eggs and stocked in the Juniata River received a triple mark on days 3, 13, and 17. Connecticut and Hudson River fry stocked in the Juniata River received marks according to egg source river and habitat stocked. Fry stocked by boat in midstream habitat were given a single mark on day 18 (Hudson River) or a quadruple mark on days 3, 7, 11 and 21 (Connecticut River). Similar numbers of fry were given single marks on day 5 (Hudson River) and quadruple marks on days 3, 13, 17 and 21 (Connecticut River) and stocked in nearshore habitat. Fry not used in this study were given triple marks on days 5, 9 and 13 (Hudson River) or quintuple marks on days 5, 9, 13, 17 and 21 (Connecticut River).

Recent FDA rulings permitted this use of tetracycline under an "Investigational New Animal Drug" (INAD) exemption. In order to simplify the permitting process, we applied for and received an exemption only for immersion applications. Marking of pond-reared American shad fingerlings by feeding tetracycline laced feed was of a lesser priority and was eliminated from the program for 1992. Fry destined for pond culture were marked with an immersion mark based on egg source river. Consequently, fingerling releases cannot be differentiated from fry releases.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways or ponds and examining otolith samples collected during harvest. Retention of immersion marks for American shad was 100% for 10 of the 13 groups analyzed (Table 6). Ponds in Havre de Grace and Elkton contained juvenile blueback herring which probably entered the ponds via the influent. Sub-samples of these herring were examined for marks and none were found. All American shad otoliths from these ponds exhibited the expected mark.

All specimens from the remaining groups exhibited marks, however, some exhibited the wrong mark. Three specimens from Upper Spring Creek Pond 1, 1 from Pond 2, and 13 from Pond 3, exhibited an additional mark. These specimens exhibited marks on days 3, 5, 14 and 19. Two specimens from Benner Spring Raceway F2B exhibited marks on days 3, 13, 17 and 21. Five specimens from Benner Spring Raceway F1B which should have been unmarked controls, exhibited marks on days 5 and 9.

The situation with regard to Benner Spring Raceway F2B is easily explained. Because of a shortage of raceway space, we were forced to divide raceway F2 into sections A and B. Water entered via the influent in F2A, passed through a fine mesh screen into F2B, and exited via a clean-out. Raceway F2A was stocked with fish which received marks on days 3, 13, 17 and 21. Some of these must have escaped through the screen into F2B. The presence of fish with the wrong mark in raceway F1B and the Upper Spring Creek Ponds is more puzzling. We speculate that fish were inadvertently transferred from one tank to another at Van Dyke, then later transferred to the raceway or pond. It is possible that fish could be transferred between tanks on cleaning or stocking equipment. This seems improbable since 22 specimens were involved and particularly since 70% of the raceway F1B sample exhibited the wrong mark. It is more likely that a large number of fish were inadvertently transferred during mortality estimation procedures. Daily mortality is estimated in each tank by siphoning the dead fry and unused feed off the bottom of the tank into a 5 gallon bucket. Buckets are placed adjacent to each tank and all siphoning is completed before proceeding to subsequent steps. Occasionally, numbers of live shad are siphoned with the dead. This was particularly common this year as a result of large numbers of live fry lying on the bottom of the tank. These fry will swim at the surface of the bucket and are routinely water brailed back into the tank. Large numbers of fry could potentially be returned to the wrong tank at this point. It seems unlikely that this would happen, however, it is the only scenario which explains this puzzling situation.

NEARSHORE/MIDSTREAM STOCKING

Improvement of culture methods to maximize hatchery production has been the focus of much of the research conducted at Van Dyke to date. With the exception of 1992, survival of fry from hatch to stocking at 20 days of age has ranged from 70 to 90% for the last eight years. Aside from determining the cause of mortalities experienced in 1992, little improvement can be gained by directing more research effort here. Egg viability for the same period has ranged from 38% to 68% 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. In 1989, the USFWS, National Research and Development Lab, located at Wellsboro, began an investigation of predation upon newly stocked hatchery fry. For the last four years, hatchery releases have been coordinated with the USFWS to facilitate the study. The major goal of the study was 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.

Results indicated that in some years, predation has the potential to be a significant factor in survival of newly stocked hatchery fry (Johnson and Dropkin, in press). Fifteen species of predators were identified in three post-stocking samples in 1989.

Juvenile smallmouth bass had consumed a mean 345 shad larvae. In 1991, a cooperative effort was initiated to compare the success of stocking American shad fry during daytime vs. nighttime hours.

Johnson and Ringler (in review, a) found a mean of 0.3 larval shad per predator following nocturnal releases and 5.7 shad per predator following day time releases. Significant differences in mean number of shad consumed per predator were found for 3 of 4 paired diurnal releases. They concluded that nocturnal release may measurably reduce predation at the stocking site.

In contrast, results from recovery of uniquely marked juvenile shad indicated that relative survival of nighttime released larvae (1.00) was only slightly better than for daytime released larvae (0.89; Hendricks et al., 1992). The former study focused on impacts of predation at the release site only, while our study considered all mortality factors from release to recovery.

Our subjective visual observation has always been that cyprinids are a major predator on shad larvae at nearshore release sites. Cyprinids may be less abundant in midstream habitats, suggesting that midstream release has the potential to reduce predation. In 1992, we initiated a study to compare survival of uniquely marked larvae released in midstream vs. those released nearshore. Each egg shipment involved in the study was split into two groups. Procedures for splitting the shipments, incubating the eggs, and rearing the larvae were similar to those used in the day/night study (Hendricks et al., 1992). Larvae released in midstream were transferred from the rearing tank to stocking bags inside 5 gal. buckets in exactly the same manner as for the nearshore release. The bags were filled with pure oxygen and sealed. The buckets were then loaded onto a 16 ft. flatbottom boat and trailored from Van Dyke to Thompsontown Access Area. The boat was then launched and anchored in midstream just offshore from the access area. Tempering was accomplished by water brailing. When tempering was completed, the anchor was lifted and the boat allowed to drift in midstream while the larvae were released from the bags. Allowing the boat to drift alleviated problems associated with the impact of current on the bag during release, and ensured that the last larvae released were released directly offshore from the nearshore release site. Larvae released in nearshore habitats were transported to the access area via a pick-up truck and released at the mouth of Delaware Creek. Impacts of non-study releases were minimized by making study releases on days when no other releases occurred.

Three pairs of study releases were made involving a total of 1.3 million larvae (Table 7). Both Hudson and Connecticut River eggs were used for the study and each egg source received a unique set of tetracycline marks (Table 5). A total of 75 juvenile shad were recovered bearing marks from these releases (Table 8). For both egg sources, recovery rates were higher for larvae released nearshore than for those released in midstream. For the Hudson River, the recovery rate for the nearshore release was 1.52 times that for the midstream release. The Connecticut River data was similar. The recovery rate for the nearshore releases was 1.62

times that for the midstream release. This surprising result may have been caused by increased predation by yearling smallmouth bass. Johnson and Ringler (In review, b) identified smallmouth bass as the major predator on recently released shad larvae during 1991 and 1992. Smallmouth bass consumed 43% of the larvae consumed at the nearshore stocking site, 77% of the larvae consumed at a site 100m downstream, and 67% of the larvae consumed at a site 200m downstream. They were unable to capture predators in midstream.

The 1991 smallmouth bass year class was the best in recent years (Russell Burman, pers. comm.). Population estimates of yearling bass at Mifflintown ranged from 0 to 682 per hectare (mean=205) for the period 1988 to 1991. The 1992 estimate was 1,200.

These yearling bass were 4-7 inches in length and may have been more abundant in midstream habitats than in nearshore habitats, accounting for the higher survival of shad released nearshore. Since the abundance of yearling smallmouth bass in 1992 was atypical, repetition of the study might produce different results.

Among egg source river groups, recovery rates for non-study releases (presented for comparison, Table 8) are strikingly similar to those for the study releases, suggesting that survival of larvae was relatively constant between releases for each egg source. This result is somewhat surprising, since we have always speculated that survival fluctuated widely between releases due to environmental factors at the time of release. Since the Hudson River fish were released between 6/5 and 6/18 and the Connecticut River fish were

were released between 6/29 and 7/6, we cannot address whether the differences in survival were environmentally or genetically controlled.

FINGERLING PRODUCTION

American shad fingerlings were produced in the Canal Pond (Thompsontown) and Upper Spring Creek Ponds. A mark-recapture population estimate was conducted prior to the release of fingerlings from the Canal Pond. Specimens were collected for marking using a conical lift net similar to the one described by Backman and Ross (1990). The lift net was 6 feet (1.9 m) in length and measured 60 inches (1.5 m) in diameter at the top. It was tapered to 29 inches (.7 m) in diameter, 4 feet (1.2 m) from the top. The bottom 24 inches (.6 m) was tapered to fit over a 5 gal. bucket. The net was mounted on the kettle at the deep end of the pond. Juvenile American shad were attracted above the net by feeding and, using a tripod and boom, the net was lifted to capture the fish in the 5 gal. bucket. The fish were then water brailed and hand-counted from the 5 gal. bucket into a circular fiberglass tub. They were then transported by truck to the influent end of the pond where they were poured into a 5 foot diameter tank. Circular fresh water flow to the tank was established using the pond influent supply and appropriate plumbing fixtures. After approximately 16h, fish which suffered handling mortality were removed and counted. Water level in the tank was lowered to 30 inches, and 73.2g Bismark Brown was added to achieve a concentration of 53 mg/L. Pure oxygen was bubbled into the tank and after a 20 min. immersion, the dyed fish were released into the center of the pond. After waiting several hours for the dyed fish to mix with the population, recapture samples were collected by lift net and the number of marked and unmarked specimens recorded.

A total of 1,677 juvenile shad were collected in 14 marking lifts. The net appeared to work well and cause little damage or scale loss. Prior to marking, 49 dead (2.9%) were removed from the tank, leaving 1,628 fish for marking. The recapture samples included 91 marked and 710 unmarked specimens, resulting in a population estimate of 14,330 (Everhart et al., 1975). Ninety-five percent confidence interval was 11,637-17,023.

In our continuing efforts to improve survival during harvest, we used a new method of harvest. All pond boards were removed except a single set in the front of the catch basin. The catch basin was then cleared of ashes and debris. Boards were reinstalled in the rear of the catch basin with a quick release board on the bottom. The pond was then drained slowly by removing front and rear boards until five front boards remained. At this point the front five boards were removed giving the fish access to the kettle. Water depth was approximately 30 to 36 inches in front of the kettle and 54 to 60 inches in the kettle itself. Juvenile shad were then lured into the kettle using feed. When a large school of shad entered the kettle, boards were reinstalled in front of the kettle trapping the fish. The quick-release was then activated and the kettle emptied into Delaware Creek. The remaining water in the pond was held back by the front boards. The quick-release was then reset and the kettle allowed to fill with pond water. The front boards were again removed and the process repeated. The majority of the fish in the pond were released by repeating the process 5 or 6 times. Remaining fish were released by further draining of the pond and eventual quick-release to Delaware Creek. It is our feeling that this was the most successful Canal Pond harvest to date. Unfortunately, due to FDA restrictions, these fish were not uniquely marked, making evaluation impossible.

UPPER SPRING CREEK

The three Upper Spring Creek ponds were stocked with approximately 50,000 fry each on June 9, 1992. During the first week of July, when supplemental feeding was initiated, it was obvious that there were not very many fish in any of the ponds. Van Dyke had experienced severe, unexplained mortality in a number of rearing units early in the season, and this problem, whatever it was, may have affected survival of fish in the Upper Spring Creek ponds.

A total of 7,500 fingerlings were released into the Juniata River, at Thompsontown, from the Upper Spring Creek Ponds in 1992. Pond No. 3 was harvested on September 15th, and approximately 5,000 fingerlings, averaging 2.5 to 3 inches in length, were transported to Thompsontown and released into the Juniata River. On October 8, 1992, ponds 1 and 2 were harvested and an additional 2,500 fingerlings (1,500 from Pond 1 and 1,000 from Pond 2) averaging approximately 2.5 inches in length, were transported to Thompsontown and released in the Juniata River. On average, the fish were smaller this year than in previous years, and there were more small fish, (1-1.5") than seen in previous years.

A mark-recapture population estimate was conducted on Pond 2, using the same proceedings as last year (Hendricks et al., 1992). A total of 299 fish were marked. Of the 311 fish in the recapture sample, 98 were marked, giving an estimate of 1,057 fish in the pond. Ninety-five percent confidence interval was 900-1214.

SUMMARY

A total of 26 shipments (18.5 million eggs) was received at Van Dyke in 1992. Total egg viability was 68.3% and survival to stocking was 40%, resulting in production of 5.1 million fry. The majority of the fry were stocked in the Juniata River (3.0 million), with lesser numbers stocked in the Susquehanna River below Conowingo Dam (1.2 million), the Lehigh River (353 thousand), and the Schuylkill River (3 thousand). A total of 21,800 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River. An additional 32,100 American shad and blueback herring fingerlings were produced in Maryland DNR ponds at Havre de Grace and Eklton, and released directly into receiving waters.

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

Retention of tetracycline marks was 100% for immersion marks, except in cases where fry were inadvertently transferred between tanks and exhibited the wrong mark.

Mark-recapture population estimates were attempted for fingerling shad reared in the Canal Pond and Upper Spring Creek Pond 2. An estimated 14,330 fingerlings were released from the Canal Pond, and 1,099 were released from Upper Spring Creek Pond 2.

Survival of uniquely marked American shad fry stocked in nearshore was found to be approximately 1.5 times that of fry stocked in midstream for groups from both the Hudson and Connecticut Rivers.

RECOMMENDATIONS FOR 1993

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. Siphon egg shells from the rearing tank within hours of egg hatch.
7. Disinfect all hatchery equipment between use in each rearing tank.
8. Utilize separate sets of equipment for hatchery work and outdoor work (ponds, river stocking).
9. Utilize left over AP-100 only if freshly manufactured supplies run out.

10. Conduct mark-recapture population estimates for pond fingerlings prior to harvest.

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Figure 1. Survival of American shad fry, Van Dyke, 1992.

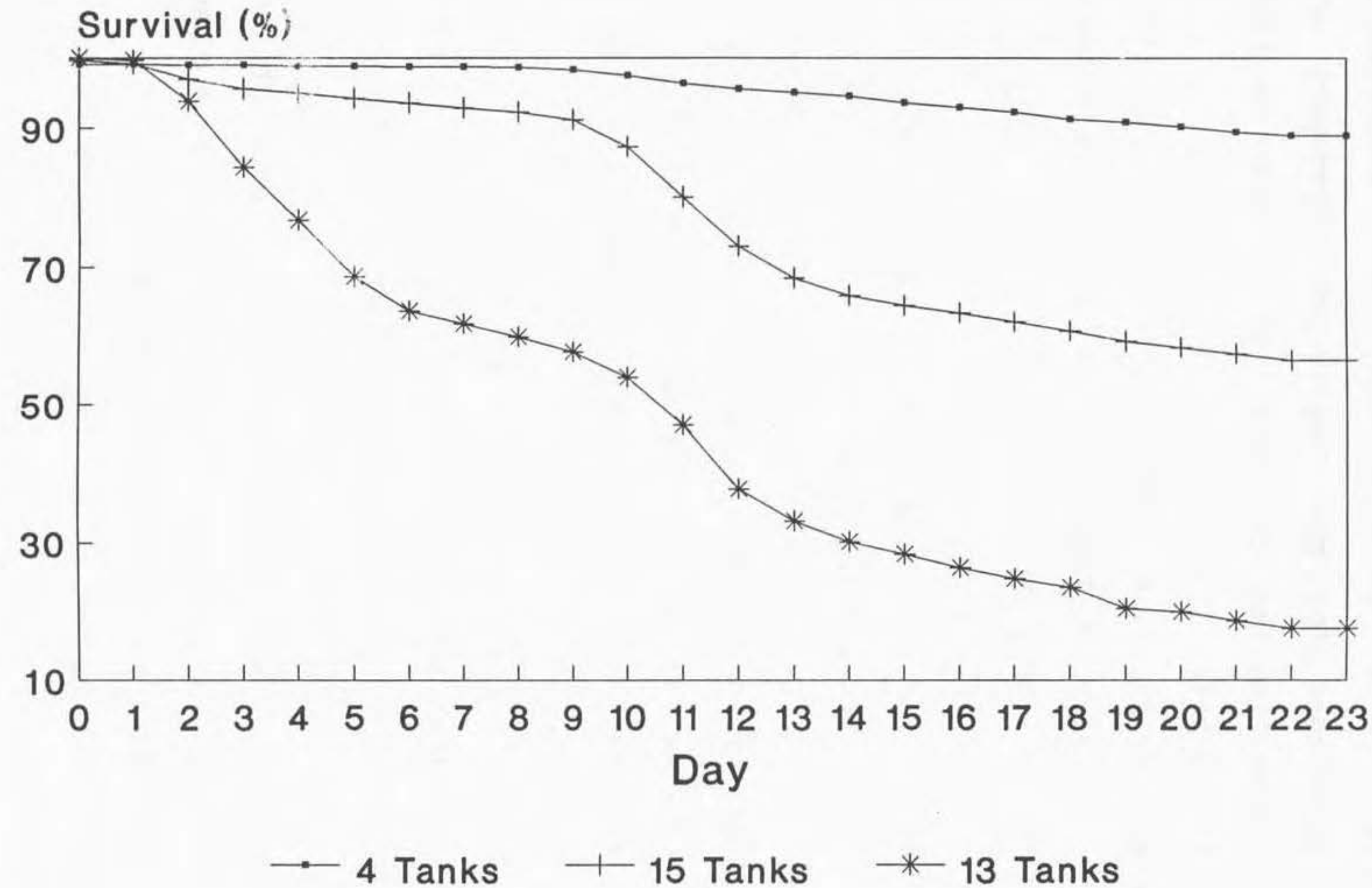

Table 1. American shad egg shipments recieved at Van Dyke, 1992.

Shipment No.	River	Date Shipped	Date Recieved	Vol. Received (L)	Eggs	Viable Eggs	Percent Viable
1	Delaware	5/10/92	5/11/92	11.6	420,475	209,149	49.7%
2	Delaware	5/11/92	5/12/92	36.4	1,222,797	887,726	72.6%
3	Hudson	5/11/92	5/12/92	21.6	615,231	405,667	65.9%
4	Delaware	5/12/92	5/13/92	53.5	1,914,599	1,063,433	55.5%
5	Hudson	5/12/92	5/13/92	7.6	212,296	164,428	77.5%
6	Delaware	5/13/92	5/14/92	39.1	1,710,100	1,189,001	69.5%
7	Hudson	5/13/92	5/14/92	16.0	457,545	327,175	71.5%
8	James	5/14/92	5/15/92	0.1	5,689	150	2.6%
9	Delaware	5/14/92	5/15/92	30.0	1,110,328	471,248	42.4%
10	Hudson	5/14/92	5/15/92	36.9	1,089,099	845,557	77.6%
11	Delaware	5/17/92	5/18/92	7.2	237,194	125,799	53.0%
12	Delaware	5/18/92	5/19/92	31.3	1,064,878	768,394	72.2%
13	Hudson	5/18/92	5/19/92	20.4	629,468	510,653	81.1%
14	Delaware	5/19/92	5/20/92	45.2	1,334,073	737,697	55.3%
15	Delaware	5/20/92	5/21/92	18.0	586,609	311,742	53.1%
16	James	5/21/92	5/22/92	0.7	26,178	19,353	73.9%
17	Connecticut	5/29/92	5/30/92	27.6	959,191	682,567	71.2%
18	Connecticut	5/30/92	5/31/92	26.4	1,018,224	864,552	84.9%
19	Connecticut	5/31/92	6/1/92	10.7	709,483	561,598	79.2%
20	Connecticut	6/3/92	6/4/92	8.7	312,071	252,617	80.9%
21	Connecticut	6/4/92	6/5/92	32.2	1,241,295	946,141	76.2%
22	Connecticut	6/5/92	6/6/92	35.8	1,104,654	941,053	85.2%
23	Connecticut	6/6/92	6/7/92	12.6	367,740	294,030	80.0%
24	James	6/15/92	6/16/92	0.4	15,054	(0)	0.0%
25	James	6/22/92	6/23/92	1.2	61,431	22,427	36.5%
26	James	6/24/92	6/25/92	1.0	63,513	18,680	29.4%
Totals		No. of shipments					
	Delaware	9		272.3	9,601,000	5,764,200	60.0%
	Hudson	5		102.5	3,003,600	2,253,500	75.0%
	James	5		3.4	171,900	60,600	35.3%
	Connecticut	7		154.0	5,712,700	4,542,600	79.5%
	Grand Total	26		532.2	18,489,200	12,620,900	68.3%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1992.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via–bility (%)	No. of Viable Eggs (exp.6)	No. of shad stocked (all rivers) Fry (exp.3)	Fing–erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.194	0.373
1977	146	6.4	46.7	2.9	969	35	1,003	0.159	0.342
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.104	0.330
1979	165	6.4	41.4	2.6	629	34	664	0.104	0.251
1980	348	12.6	65.6	8.2	3,526	5	3,531	0.283	0.431
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.177	0.393
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.196	0.548
1983	939	34.5	55.6	19.2	4,048	98	4,146	0.120	0.216
1984	1,157	41.1	45.2	18.6	11,996	30	12,026	–	0.728
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.279	0.682
1986	1,536	52.7	40.7	21.4	15,876	61	15,928	0.302	0.744
1987	974	33.0	47.9	15.8	10,274	81	10,355	0.314	0.655
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.331	0.855
1989	1,221	42.7	60.1	25.7	22,267	60	22,327	0.523	0.869
1990	897	28.6	56.7	16.2	12,034	253	12,287	0.430	0.758
1991	903	29.8	60.7	18.1	12,963	233	13,196	0.443	0.729
1992	532	18.5	68.3	12.6	4,645	34	4679	0.253	0.371

Table 3. American shad stocking and fish transfer activities, 1992. All tetracycline marks administered by 6 hour immersion in 200ppm tetracycline.

Date	Tank	Number	Mark (days)	Location	Origin	Age	Size
5/21/92	B21	5,000	None	NFRDL	Hudson	0	Fry
6/4/92	A11	190,200	3,13,17	Thompsontown	Delaware	18	Fry
6/5/92	A31	202,200	5,9,13	Thompsontown	Hudson	17	Fry
6/5/92	A31	50,000	5,9,13	Canal Pond	Hudson	17	Fry
6/9/92	A21	100,000	3,13,17	Lehigh River	Delaware	21	Fry
6/9/92	A21	150,000	3,13,17	Upper Spring Creek	Delaware	21	Fry
6/9/92	A41	252,800	3,13,17	Lehigh River	Delaware	20	Fry
6/9/92	B11	200	3,13,17	Lehigh River	Delaware	20	Fry
6/11/92	C21	109,700	5	Thompsontown – nearshore	Hudson	19	Fry
6/11/92	C21	1,000	5	Benner Spring Raceway E2	Hudson	19	Fry
6/11/92	C31	80,500	18	Thompsontown – midstream	Hudson	19	Fry
6/11/92	C31	1,000	18	Benner Spring Raceway E3	Hudson	19	Fry
6/11/92	B21	1,000	5,9	Benner Spring Raceway E1	Hudson	21	Fry
6/12/92	B21	100,000	5,9	Lapidum	Hudson	22	Fry
6/12/92	B31	200,000	5,9	Lapidum	Delaware	21	Fry
6/12/92	C11	1,000	5,9	Lapidum	Delaware	20	Fry
6/15/92	C41	3,000	3,13,17	Schuylkill River	Delaware	21	Fry
6/16/92	D31	176,300	5,9,13	Thompsontown	Hudson	20	Fry
6/17/92	D41	100,000	5,9	Elkton Ponds	Delaware	19	Fry
6/17/92	E41	50,000	5,9	PEPCO	Connecticut	11	Fry
6/17/92	D11	447,300	3,13,17	Thompsontown	Delaware	21	Fry
6/17/92	E31	9,200	3,7,17	James River	James	18	Fry
6/18/92	E11	161,100	3,13,17	Thompsontown	Delaware	21	Fry
6/18/92	E21	100	3,13,17	Thompsontown	Delaware	21	Fry
6/22/92	F21	4,000	3,7,11	NFRDL	Connecticut	15	Fry
6/25/92	E41	168,300	5,9	Lapidum	Connecticut	19	Fry
6/25/92	F11	209,200	5,9	Lapidum	Connecticut	19	Fry
6/29/92	F21	302,000	3,7,11,21	Thompsontown – midstream	Connecticut	22	Fry
6/29/92	F31	285,200	3,13,17,21	Thompsontown – nearshore	Connecticut	22	Fry
6/30/92	F41	449,300	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
6/30/92	F41	50,000	5,9,13,17,21	Canal Pond	Connecticut	22	Fry
6/30/92	F41	5,000	5,9,13,17,21	Benner Spring Raceway F1	Connecticut	22	Fry
7/2/92	G11	122,900	5,9	Lapidum	Connecticut	22	Fry
7/2/92	G41	233,400	5,9	Lapidum	Connecticut	19	Fry
7/2/92	H11	215,000	5,9	Lapidum	Connecticut	19	Fry
7/3/92	G21	337,800	3,13,17,21	Thompsontown – nearshore	Connecticut	22	Fry
7/3/92	G21	5,000	3,13,17,21	Benner Spring Raceway F2A	Connecticut	22	Fry
7/3/92	G31	232,900	3,7,11,21	Thompsontown – midstream	Connecticut	22	Fry
7/3/92	G31	5,000	3,7,11,21	Benner Spring Raceway F2B	Connecticut	22	Fry
7/3/92	H31	5,000	None	Benner Spring Raceway F1B	Connecticut	19	Fry
7/6/92	H21	64,800	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/20/92	H41	18,800	None	James River	James	21	Fry
7/20/92	I11	17,200	None	James River	James	19	Fry

Table 3 (continued).

Date	Tank	Number	Mark (days)	Location	Origin	Age Size
8/26/92	Canal Pond	14,300	5,9,13,17,21	Thompsontown	Connecticut	79 Fing.
9/15/92	Upper Spring Creek Pond 3	5,000	3,13,17	Thompsontown	Delaware	120 Fing.
10/8/92	Upper Spring Creek Pond 1	1,500	3,13,17	Thompsontown	Delaware	143 Fing.
10/8/92	Upper Spring Creek Pond 2	1,000	3,13,17	Thompsontown	Delaware	143 Fing.
9/28/92	Elkton Pond 1	7,500	*5,9	Elk River	Delaware	122 Fing.
9/29/92	Havre de Grace Pond	100	*5,9	Havre de Grace	Delaware	123 Fing.
9/30/92	Elkton Pond 3	12,500	*5,9	Elk River	Delaware	124 Fing.
10/1/91	Elkton Pond 2	4,000	*5,9	Elk River	Delaware	125 Fing.
10/22/92	PEPCO	1,000	5,9	Lapidum	Delaware	138 Fing.
10/27/92	PEPCO	7,000	5,9	Patuxent River	Delaware	143 Fing.

*Includes blueback herring which may have entered the ponds via the intakes:
Elkton Pond 1 – 2 of 23 specimens identified as American shad, 21 blueback herring
Havre de Grace Pond – 0 of 2 specimens identified as American shad, 2 blueback herring
Elkton Pond 3 – 2 of 15 specimens identified as American shad, 13 blueback herring
Elkton Pond 2 – 5 of 13 specimens identified as American shad, 8 blueback herring

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1992.

	Site	Fry	Fingerling
Releases	Juniata River		
	Nearshore	732,700	
	Midstream	615,400	
	Other	1,691,300	21,800
	Total	3,039,400	
	Susquehanna R.		
	(below Conowingo Dam)	1,249,800	32,100 *
	Lehigh River	353,000	
	Schuylkill River	3,000	
	Sub-Total	4,645,200	53,900
Transfers	Canal Pond	100,000	
	Benner Spring Raceways	23,000	
	Upper Spring Creek Ponds	150,000	
	NFRDL (Wellsboro)	9,000	
	Maryland DNR Ponds	100,000	
	Potomac Elec. Co.	50,000	
	VDGIF (James River)	45,200	
	Sub-Total	477,200	
	Total Production	5,122,400	
	Viable eggs	12,620,900	
	Survival of fry (%)	40.6	

*Includes 7,000 American shad released in the Patuxent River and a projected 20,250 blueback herring (see Table 3).

Table 5. Tetracycline marking regime for American shad stocked in the Susquehanna River basin, 1992.

Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Mark (days)	Feed mark	No. Stocked
Fry	–	Thompsontown–nearshore	Hudson	Single (5)	–	109,700
Fry	–	Thompsontown–nearshore	Connecticut	Quadruple (3,13,17,21)	–	623,000
Fry	–	Thompsontown–midstream	Hudson	Single (18)	–	80,500
Fry	–	Thompsontown–midstream	Connecticut	Quadruple (3,7,11,21)	–	534,900
Fry	–	Thompsontown–other	Hudson	Triple (5,9,13)	–	378,500
Fry	–	Thompsontown	Delaware	Triple (3,13,17)	–	798,700
Fry	–	Thompsontown–other	Connecticut	Quintuple (5,9,13,17,21)	–	514,100
Fry	–	Lapidum (Below Conowingo)	All	Double (5,9)	–	1,249,800
Fingerling	Canal Pond	Thompsontown	Connecticut	Quintuple (5,9,13,17,21)	None	14,300
Fingerling	Upper Spring Creek Ponds	Thompsontown	Delaware	Triple (3,13,17)	None	7,500
Fingerling	Havre de Grace Pond	Below Conowingo	Delaware	Double (5,9)	None	100 *
Fingerling	Elkton Pond 1	Below Conowingo	Delaware	Double (5,9)	None	7,500 *
Fingerling	Elkton Pond 2	Below Conowingo	Delaware	Double (5,9)	None	4,000 *
Fingerling	Elkton Pond 3	Below Conowingo	Delaware	Double (5,9)	None	12,500 *
Fingerling	PEPCO	Below Conowingo Patuxent River	Connecticut	Double (5,9)	None	1,000 7,000

* Includes blueback herring (see Table 3).

Table 6. Tetracycline mark retention for American shad reared in 1992.

Location	Pond/ Raceway	Attempted Mark Immersion	Day(s)	Observed Mark Immersion	Day(s)	Number Exhibiting Mark	Projected Number Stocked	Disposition
Benner Spring	Raceway E2	Single	5	Single	5	30/30(100%)	109,700	Stocked Thompsontown (nearshore)
	Raceway E3	Single	18	Single	18	30/30(100%)	80,500	Stocked Thompsontown (midstream)
	Raceway E1	Double	5,9	Double	5,9	30/30(100%)	1,249,800	Stocked Lapidum
Havre de Grace	Pond	Double	5,9	None	5,9	2/2(100%)*	100	Direct Release
Elkton	Pond 1	Double	5,9	None Double	 5,9	17/19(89%)* 2/19(11%)	6,848 652	Direct Release
	Pond 2	Double	5,9	None Double	 5,9	4/9(44%)* 5/9(56%)	2,462 1,538	Direct Release
	Pond 3	Double	5,9	None Double	 5,9	6/8(75%)* 2/8(25%)	10,833 1,667	Direct Release
–	–	Triple	5,9,13	Triple	5,9,13	Not Analyzed	378,500	Stocked Thompsontown

Table 6. (continued)

Location	Pond/ Raceway	Attempted Mark Immersion	Attempted Mark Day(s)	Observed Mark Immersion	Observed Mark Day(s)	Number Exhibiting Mark	Projected Number Stocked	Disposition
Upper Spring Creek	Pond 1	Triple	3,13,17	Triple	3,13,17	7/10(70%)	1050	Stocked
					3,5,14,18**	3/10(30%)	450	Thompsontown
	Pond 2	Triple	3,13,17	Triple	3,13,17	9/10(90%)	900	Stocked
					3,5,15,19**	1/10(10%)	100	Thompsontown
	Pond 3	Triple	3,13,17	Triple	3,13,17	16/29(55%)	2,759	Stocked
					3,5,15,19**	13/29(45%)	2,241	Thompsontown
Benner Spring	Raceway F2A	Quadruple	3,13,17,21	Quadruple	3,13,17,21	29/29(100%)	623,000	Stocked Thompsontown (nearshore)
	Raceway F2B	Quadruple	3,7,11,21	Quadruple	3,7,11,21	28/30(93%)	534,900	Stocked Thompsontown (midstream)
				Quadruple	3,13,17,21	2/30(7%)***		
	Raceway F1A	Quintuple	5,9,13,17,21	Quintuple	5,9,13,17,21	29/29(100%)	514,100	Stocked Thompsontown
	Raceway F1B	Unmarked control	–	None	–	2/7(29%)	–	Not Stocked
				Double		5/7(71%)**		
Thompsontown	Canal Pond	Quintuple	5,9,13,17,21	Quintuple	5,9,13,17,21	30/30(100%)	14,300	Stocked Thompsontown

* Identified as blueback herring which probably entered the ponds via the intakes.
Additional blueback herring were preserved in 10% formalin: Pond 1 – 4, Pond 2 – 4, Pond 3 – 7.

** [illegible] ibly [illegible] erte [illegible] rans [illegible] d fro [illegible] oth [illegible] k.

Table 7. Numbers of uniquely marked American shad fry stocked in nearshore and midstream habitats, Van Dyke, 1992. All fry were stocked at Thompsontown, Juniata River.

Egg Ship. ment	Egg source	Date Shipped	Egg Jar	Egg Jar Type	No. of Eggs	Tank	Egg Viability	Survival (hatch to stocking)	TC Mark (days)	Stocking Date	Stocking Site	Stocking Age (days)	Stocking Number
10	Hudson	5/14	307	VD	368,936	C21	80%	25.4%	5	6/11	Nearshore	19	109,700
			316	VD	175,614	C21	77%						
			308	VD	368,936	C31	76%	19.4%	18	6/11	Midstream	19	80,500
			317	VD	175,614	C31	76%						
18	Connecticut	5/30	329	VD	509,112	F21	85%	69.8%	3,7,11,21	6/29	Midstream	22	302,000
			330	VD	509,112	F31	85%	66.0%	3,13,17,21	6/29	Nearshore	22	285,200
21	Connecticut	6/4	335	VD	499,098	G21	81%	71.0%	3,13,17,21	7/3	Nearshore	22	337,800
			2	MS	121,725	G21	58%						
			336	VD	498,747	G31	79%	49.6%	3,7,11,21	7/3	Midstream	22	232,900
			1	MS	121,725	G31	62%						

Table 8. Relative survival of American shad larvae released in nearshore and midstream habitats, Thompsontown, Juniata River, 1992.

Egg Source	Tetracycline Mark (Days)	Stocking Habitat	Fry Released	Juveniles Recovered	Recovery rate	Relative Survival	No. of Releases	Release Date(s)
Study releases								
Hudson	5	Nearshore	109,700	29	0.000264	1.00	1	6/11
	18	Midstream	80,500	14	0.000174	0.66	1	6/11
Connecticut	3,13,17,21	Nearshore	623,000	21	0.000034	1.00	2	6/29, 7/3
	3,7,11,21	Midstream	534,900	11	0.000021	0.61	2	6/29, 7/3
Non-study releases								
Hudson	5,9,13	Nearshore	378,500	109	0.000288		2	6/5, 6/16
Connecticut	5,9,13,17,21	Nearshore	514,100	11	0.000021		2	6/30, 7/6

Attachment 1.

July 15, 1992

SUBJECT: Examination of Van Dyke American Shad Fry

TO: Michael L. Hendricks
Fisheries Biologist

FROM: Kenneth R. Stark (KRS)
Fisheries Biologist

On June 6, 9, 10, and 16 American shad fry from the Van Dyke Research Station for Anadromous Fish were examined. Abnormally high mortalities in these fry had been observed.

The juvenile gill structure appeared to be normal and did not exhibit signs of bacterial infection. Parasites were not observed internally or externally. No abnormalities were observed in the internal organs, except that those specimens examined on the 6th and 16th had heavy bacterial loading in their intestinal tracts. The lack of abnormal numbers of bacteria on the 9th and 10th may have been related to the condition of the fish (non-moribund?) which were available. It is believed that the specimens examined on those days, were not representative of those fish suffering the high mortalities.

On June 9 and 16, fry specimens were preserved in HBSS solution and delivered to the USFWS Lamar Fish Health Unit for viral assay. No viral activity was detected. The assay report is attached.

Bacterial samples were collected on the 5th, 9th, and 16th. Because of the size of these 10 to 11 day old fry, sampling of individual organs was not possible. A series of sampling methods were tried, but spraying the fry with 70% ethanol followed by a rinse with sterile distilled water yielded bacterial growth which was theoretically reflective of the intestinal flora and any systemic bacterial organisms. From the three specimens which were sampled in this manner, a total of twenty seven bacterial colonies were picked and transferred to pure culture for identification. Twenty six inoculated culture tubes developed bacterial growth. All were identified as terramycin resistant motile aeromonads. Of the drug sensitivities performed on these bacteria, only neomycin yielded satisfactory results. The lack of sensitivity to terramycin may be related to the use of this drug to bath tag the otoliths of these fry. The predominance of the motile aeromonads does not necessarily indicate that they were associated with the observed mortalities. These bacteria are normal inhabitants of the intestinal tract of fish; however, they can become pathogenic and cause disease.

On June 9 and 16 formalin preserved fry specimens were collected and forwarded to the U.S. Fish and Wildlife Service Leetown Fish Health Research Laboratory for histological assay. The report by Dr. Vicki Blazer, histopathologist, is attached. Her results are inconclusive. Although she observed heavy bacterial loads in some of the intestinal tracts, she did not observe tissue changes which would normally be associated with bacterial pathogenesis. Although she did note some abnormal changes in the liver and brain, how these relate to the observed mortalities is unclear.

Attachments

cc: R. Hoopes
J. O'Grodnick

United States Department of the Interior

FISH AND WILDLIFE SERVICE
NATIONAL FISH HEALTH RESEARCH LABORATORY
LEETOWN, BOX 700
KEARNEYSVILLE, WEST VIRGINIA 25430

Mr. Ken Stark
Pennsylvania Fish Commission
Benner Spring Fish Research Station
1225 Shiloh Road
State College, PA 16801-8495

July 2,1992

Dear Ken:

I'm finally getting a chance to respond to the letters of June 15 and 22, which Roger Herman passed on to me. We've done numerous sections on the shad, trying to get pieces of each tissue. I still don't know what killed them. The only obvious potential lesions were in the liver and brain. There was some fluid collection in the brain and the hepatocytes were extremely vacuolated - possibly filled with fat. In a few where we got cuts of gut, it was devoid of food. In one there were food particles and masses of bacteria as you noted grossly. However, there was no indication the bacteria were causing any direct damage - i.e. there was no necrosis, sloughing or inflammation of the epithelium. Is it possible the food could have been heavily contaminated with bacteria? There has been some work in catfish that indicates heavy bacterial loads can cause certain nutritional problems. Since the bacterial contamination may not be spread evenly throughout the feed you could get differential mortalities.

As for the muskellunge fry, the lesions I saw could certainly be consistent with a virus. The major lesions were in the kidney and gut. In both the hematopoetic and excretory kidney there was interstitial necrosis, proliferation of lymphocytes and many cells which had intracellular inclusions - these are either inclusion bodies of the virus or some other intracellular organism. In addition, this organism appears to cause proliferation of the epithelial cells of the kidney tubules - particularly the collecting ducts. There was a "blebbing" of the epithelial cells of the kidney tubules, gastric and intestinal mucosa. This appeared to be due to proliferation of these cells followed by necrosis and sloughing.

In the guts of most of these fish there were large amounts of food - possibly it was not moving through the gut very effectively. There were many bacteria associated with these areas and there were focal areas where the tips of the intestinal villi were necrotic and bacteria were present within the tissue.

If I can be of any further assistance, 'don't hesitate to contact me. I'm just about settled in!

Sincerely,

Vicki

Vicki S. Blazer

FISH HEALTH UNIT
P.O. BOX 155
LAMAR, PA 16848

6 July 1992

Ken Stark
Benner Spring Fish Research Station
PA Fish Commission
1225 Shiloh Rd
State College, PA 16801-8495

Dear Ken:

Here are results of viral assays on diagnostic case histories of American shad from Van Dyke FCS. Assays were run on CHSE-214 and FHM cell lines.

CHN	Date Received	Samples		Results
2-181	6-9-92	(E-11)		negative
2-188	6-17-92	(F-11,Sh-17)	CT River	negative
2-189	6-17-92	(E-16,Sh-16)	James R	negative

Kim

Kimball Selmer-Larsen

October 2, 1992

SUBJECT: Bacterial Identification of Van Dyke Production Waters

TO: Michael L. Hendricks
Fisheries Biologist

FROM: Kenneth R. Stark
Fisheries Biologist

On July 27, 1992, Jim Golemboski transferred bacterial specimens from bacterial count plates which Dave Truesdale had prepared with production waters from the Van Dyke Shad Restoration Station. These included UV treated spring pond water, brine shrimp dilution water, salted brine shrimp control water, and unsalted brine shrimp control water. These bacterial cultures were identified using standard biochemical procedures and Enterotube II diagnostic media. Drug sensitivities were performed on the motile aeromonads which were isolated. The results are listed below:

UV Treated Spring Pond Water

No.of Cultures	Bacterial Species
11	Gram + organisms
4	Acinetobacter lwoffii
3	Motile aeromonads (2 resistant to terramycin)
1	Pseudomonad
1	Misc.

Brine Shrimp Dilution Water

No. of Cultures	Bacterial Species
6	Gram + organisms
9	Motile aeromonads (6 resistant to terramycin)
7	A. lwoffii
1	Pseudomonad
1	Misc.

Brine Shrimp Controls

Salted		Unsalted	
No.of Cultures	Bacterial Species	No.of Cultures	Bacterial Species
16	A. lwoffii	15	A. lwoffii
4	A. anitratus	5	A. anitratus
4	Misc.	4	Misc.
1	Enterobacter spp.	1	Citrobacter spp.

The number and types of bacteria listed above should not be construed to represent the actual distribution of bacteria in the water samples. A relatively small number of randomly selected bacterial colonies were evaluated; however, there does appear to be a good correlation between the bacteria in the salted and unsalted brine shrimp controls.

Only a few motile aeromonads were detected in the pond water and dilution water samples. Approximately 66% of the motile aeromonads isolated were resistant to terramycin. In the June 16, 1992 bacterial sampling of externally disinfected moribund Van Dyke shad fry, all of the bacterial isolates were TM-resistant motile aeromonads. At that time I speculated that this predominance of drug resistant bacteria was the result of exposure to OTC during otolith tagging. The drug sensitivities of the bacterial isolates from the water samples, suggests that TM-resistant aeromonads were present in the water prior to OTC treatment. Their predominance in the fish samples may be have resulted from the elimination of OTC sensitive species during the tagging treatments.

Of the drugs which were tested (terramycin, neomycin, Romet, and triple sulfa), only neomycin appeared to be an effective control for most of the motile aeromonads in the water samples. The motile aeromonads isolated in June from the shad fry exhibited similar drug sensitivities. Unfortunately neomycin is not FDA approved for aquaculture use.

The gram negative bacteria which were identified above are typical of the bacterial flora found in culture water. Dr. Rocco Cipriano, bacteriologist at the USFWS Leetown FHRL, indicated that the Acinetobacter spp. are the most predominant bacteria found in production waters. This appears to be the case with the brine shrimp controls. He indicated that, as a general rule, the prevalence of motile aeromonads is low compared to pseudomonad and Acinetobacter spp.. Dr. Cipriano is aware of reports of shad mortalities due to motile aeromonad infections, but he could not reference those reports. Generally, infections by these organisms are considered to be secondary to some other environmental or nutritional problem. In the case of the Van Dyke shad fry, bacteria were not observed outside of the intestinal tract; therefore, the significance of the motile aeromonads which were isolated, relative to the observed mortalities, remains unclear.

Attachments

cc: R. Hoopes
T. Bender
J. O'Grodnick

JOB IV.

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

Richard St. Pierre
U. S. Fish and Wildlife Service
Harrisburg, Pennsylvania

INTRODUCTION

Juvenile American shad were collected at several locations in the lower Susquehanna River in 1992 in an effort to document timing of the migration and general 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, culture sites and nearshore versus midwater 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 1992. For their contributions to this report, appreciation is extended to Barbara Lathrop and Tim Robbins (Wyatt Group), Chris Frese (RMC), Dale Weinrich (Maryland DNR), and Mike Hendricks (PA Fish and Boat Commission). Don Torsello and Scott Rhoades (PFBC) processed most of the otoliths.

HATCHERY AND ADULT SHAD STOCKING SUMMARY

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

A total of 15,764 adult American shad were hauled from the Conowingo fish lifts during mid-April through mid-June. Most were stocked above York Haven Dam, and total observed transport mortalities amounted to 1,219 shad (see Job I). Overall sex ratio (SR) in these transfers was about one to one, a higher frequency of females than had been recorded in any earlier year. This stocking level compares with 22,083 live shad delivered in 1991 (SR 1.64 males to 1 female) and 14,792 shad in 1990 (SR 3.2 to 1 favoring males).

During the 1992 shad production season, PA Fish and Boat Commission biologists reared and released 4.29 million shad fry and 21,800 fingerlings in the Susquehanna watershed. Fry were stocked between 4 June and 6 July in the Juniata River at Thompsontown (3.039 million), and between 12 June and 2 July at Lapidum, MD (1.25 million). Fingerlings reared in Pennsylvania ponds were stocked at Thompsontown between 26 August and 8 October. Maryland DNR released an additional 24,100 fingerling shad and blueback herring from ponds at Elkton and Havre de Grace, MD between 28 September and 1 October.

The 3.04 million shad fry stocked above dams in the Susquehanna in 1992 compares to 7.218 M, 5.62 M, 13.46 M, and 6.45 M in 1991, 1990, 1989, and 1988, respectively. Shad fry stocking below Conowingo Dam in 1992 was considerably below the average of about 5 million each year during 1987-1991. Combined fingerling shad stocking from Pennsylvania and Maryland ponds of about 46,000 was only 15-25% of totals from recent years.

JUVENILE SHAD COLLECTIONS

Juvenile American shad occurrence and outmigration in the river above Conowingo Dam was assessed at numerous locations using several methods during the summer and fall of 1992 as shown below.

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

Seining was conducted by the Wyatt Group on 24 dates over 15 weeks from mid-July through late October. Most sampling occurred in late afternoon and evening and the net used measured 400-ft. x 6 ft. with 3/8" stretch mesh. The area most consistently monitored was the Columbia/Wrightsville section of the lower river (16 occasions).

Six other areas, each sampled 1-6 times, included Amity Hall on the Juniata River, Three Mile Island, York Haven, Marietta, Pequea and Holtwood. At York Haven, shad collections were also made by Stone & Webster personnel on several dates in October with a fixed 1-meter square sluiceway sampling net (1/4" mesh). A few attempts were made by Wyatt Group to take shad here with a 10-ft. diameter cast net (3/8" mesh). An 8-ft. square lift net with 1/2" mesh liner was used by RMC Environmental Services at Holtwood's inner forebay. Typically lift netting occurred twice weekly from late August through mid-November and involved 10 lifts/date.

Cooling water intake strainers at Safe Harbor were sampled three times each week by plant personnel from mid-September through November. At Conowingo, RMC checked strainers on 30 occasions (3-4 times/week) during October-November. RMC also inspected intake screen washes at Peach Bottom Atomic Power Station approximately three times weekly during mid-October through late November.

As part of their annual juvenile Alosa recruitment survey, Maryland DNR sampled for shad and herring with electrofishing gear in the Susquehanna Flats during August-October. Samples of shad from most collections were returned to PFBC's Benner Spring Research Station for tetracycline mark and microstructure analysis of otoliths. Most collecting sites used in 1992 are shown in Figures 1 and 6-2.

Seine Survey of Lower River

The principle purpose for seine sampling in the lower river during summer months is to document the occurrence of naturally produced juvenile shad resulting from transplanted adults. The occurrence and relative magnitude of the hatchery component of the juvenile stock typically becomes available to this gear as outmigration proceeds in the fall. Sampling was concentrated at Columbia, Wrightsville and Marietta since these locations proved very effective in past years.

During the period 17 July to 22 October, 169 seine hauls were made on 24 dates at eight locations. A total of 467 juvenile shad were collected. Columbia, Wrightsville and Marietta were sampled on nine dates and produced a total of 302 shad of which 216 were returned for otolith analysis. Of 138 otoliths processed from collections made during July to mid-August, 99 (72%) were wild. Samples from mid-August to mid-October from these sites were predominantly (63%) hatchery origin (46 of 73).

A one-day sampling event occurred at Amity Hall in the lower Juniata River on 29 July. The purpose was to collect a sample of shad for otolith analysis to determine if any natural reproduction occurred in this tributary. A single haul of the seine produced 115 shad and all 30 fish analyzed were produced at Van Dyke. Five sampling events at Pequea (head of Lake Aldred) in July and August produced only 2 shad, and none were taken below Holtwood on 12 August. Two shad were collected at Three Mile Island above York Haven on 19 August (one wild) and the York Haven headrace produced 52 shad (including 6 by cast net) on four sample dates between 17 September and 2 October. Otoliths from 47 of these fish were analyzed and 44 (94%) were hatchery origin.

Peak collections with seines in 1992 occurred during the first 3-weeks of the effort in July (180 shad). Late season collections were hampered by high water and frequent storms. Shad catch by date and location for all seine collections is shown in Table 1.

<u>York Haven Dam</u>

The purpose for seine and cast net collections at York Haven was to document first occurrence and relative abundance of shad here and to assist Stone & Webster in timing the start of their strobe light study at this site. Although shad were somewhat abundant here beginning in mid-September, the strobe study was delayed until mid-October because of power unit outages. Nevertheless, strobe tests were conducted and on three nights 1,835 shad were collected in sluice nets. Of these, about 60 fish were retained for otolith analysis and about 85% were determined to be of hatchery origin.

<u>Safe Harbor and Holtwood Dams</u>

Cooling water strainers in the turbine intakes at Safe Harbor Dam were inspected for juvenile American shad three times each week from mid-September through the end of November. No American shad were collected here in 1992. At Holtwood, RMC personnel initiated lift netting at the inner forebay on 20 August and continued twice weekly (usually Mondays and Thursdays) through 19 November. The first American shad was collected on 17 September; the peak day catch was 16 fish on 5 October; and the last three shad were taken on 29 October. On 24 sample dates over a 3-month period, total catch amounted to only 39 American shad, one blueback herring, 15 gizzard shad, and 113 other fish representing five species. By contrast, in 1991, a similar amount of effort at this site produced 208 American shad, 22,100 gizzard shad and about 1,000 others representing 16 species. Based on otolith analysis, hatchery shad outnumbered wild fish by a ratio of two to one. Daily catch of fish with lift nets at Holtwood during 1992 is shown in Table 2).

<u>Peach Bottom APS and Conowingo Dam</u>

With the cooperation of Philadelphia Electric Company, RMC biologists examined intake water travelling screen washes for impinged American shad at the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pond. Screen sampling occurred three times per week during 12 October through 20 November. The first and only American shad appeared at Peach Bottom on 23 October. Other fish in Peach Bottom collections included 140 gizzard shad, 169 bluegills, and 86 others representing 14 species. With similar effort in 1991, catch at Peach Bottom included 15 American shad, 116,600 gizzard shad and 3,000 others.

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged American shad twice each week during October and 3-4 times weekly through November. A total of 4 shad were collected on four sample dates between 22 October and 13 November. Other fishes in Conowingo collections included 2 bluebacks, 5 alewives, 8,583 gizzard shad, 3 shiners and 2 bluegill. In 1991, these collections produced 9 American and 46,000 gizzard shad.

Susquehanna River Mouth and Flats

Maryland DNR collected four juvenile American shad by electrofisher from the upper Chesapeake Bay during August through mid-October. No juvenile shad were taken in DNR's yellow perch trawling or striped bass seining surveys. Electrofisher collection results by location and date are provided in Table 6 of Job VI. Otoliths from the four juveniles as well as five yearling shad taken from pound nets in spring 1992 were provided to PFBC for analysis.

OTOLITH MARK ANALYSIS

Otoliths from 394 juvenile American shad taken in summer/autumn collections by The Wyatt Group, Stone & Webster, RMC Environmental Services, and Maryland DNR were successfully prepared for hatchery mark assessment. The five spring yearlings were also 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 treatments. The marking regime used by the Pennsylvania Fish and Boat Commission in 1992 is described in Job III.

Amity Hall, TMI and York Haven

Otolith analysis was completed on 140 shad provided by Stone & Webster from York Haven sluice nets (mid-October), and Wyatt Group from seine collections at Amity Hall (7/29), TMI (8/19) and York Haven (9/17-10/2). The latter sample included a few cast net caught fish. Of this group, 127 fish (91%) were hatchery produced including the entire 30 fish sample from Amity Hall. Based on river of egg origin, 80 (63%) of the sample were Hudson fish; 26 (20%) were Connecticut; and 21 (17%) were Delaware source.

Marietta, Columbia, and Wrightsville

Seine collections made during mid-July through mid-October, 1992 provided 211 shad for otolith mark analysis. Overall, 85 of the fish (40%) were marked and the remaining 126 fish (60%) were wild. Although hatchery fish were included in virtually every collection from these sites, frequency of wild fish was greater in collections made prior to mid-August (99 of 138 or 72%). Later in the season as the hatchery component made its migration past this area, otolith analysis results favored hatchery fish in the catch (46 of 73 or 63%).

Two marked fish in these collections carried error marks. One fish had a double mark on days 5 and 9, the tag combination usually reserved for fish stocked below Conowingo Dam. A double mark was detected in an "unmarked" control lot at Benner Spring but we had no record of such lots being stocked. The other fish had an unexplained triple mark on days 3, 7, and 17. Of the 83 hatchery fish in these seine collections with correctly identifiable marks, 57 (69%) were Hudson River origin; 15 (18%) were Connecticut River; and 11 (13%) were Delaware River source.

Holtwood and Peach Bottom

Of the 40 shad otoliths processed from Holtwood/PBAPS collections, 26 (65%) were hatchery origin. Eight of the 14 wild fish were taken in the earliest collections. As was the case upriver, Hudson River fish dominated the hatchery marked component with 15 fish (58%). The remainder included 9 Delaware River (35%) and 2 (8%) Connecticut River fish. The lone Peach Bottom fish was Hudson River source.

Included among the collections at York Haven and Holtwood in October were 5 shad carrying a quadruple mark on days 3, 5, 15, and 19. This was an accidental tag combination which was observed in all three Upper Spring Creek ponds. Based on frequency of that mark in the pre-stocking otolith analysis, it is estimated that of the 7,500 shad released from those ponds, 2,800 may have carried the erroneous combination.

Upper Chesapeake Bay

All five yearling shad collected on the Flats during late March to mid-May were wild. Three of the four age-0 shad provided by DNR were processed. One fish carried the day 5 and 9 double mark indicating that it was stocked below Conowingo as a fry and the remaining two fish were wild.

Otolith Summary

Otolith analysis for all collecting dates and sites is presented in Table 3. The 391 shad analyzed from collections above Conowingo Dam included samples from every week except two between 17 July and 29 October. No shad were collected during the first 2 weeks of September coincident with stormy weather and higher than normal flows. Monthly sample sizes ranged from 46 fish in August to 149 in July for all sites combined. A total of 238 fish (61%) were marked and 153 (39%) were wild. In 1990 and 1991, the hatchery components of the upriver analysis were 98% and 78%, respectively.

Hudson River fry comprised 64.4% of all correctly identifiable marked fish in collections above Conowingo Dam (152 of 236). Connecticut River fry made up 18.2% of the collections (43 fish) and Delaware fry made up the remaining 17.4% (41 fish). Ratio of Hudson: Connecticut: Delaware fish differed from this pattern only at Holtwood where percentages (based on only 25 fish) were 56% Hudson, 36% Delaware, and 8% Connecticut. Since pond-reared fingerlings were not marked with feed tags in 1992 as in past years (see Job III), recovery of these fish in downstream collections cannot be fully defined.

Of the 152 shad determined to be of Hudson River fry origin, 29 were specially marked as nearshore releases (recovery rate 0.000264), and 14 were midstream releases (recovery rate 0.000174). The remaining 109 Hudson fish were not part of this study, but based on stocking numbers, showed a recovery rate of 0.000288. Specially marked Connecticut River fry showed consistently poorer recovery rates of 0.000034 (nearshore); 0.000021 (midstream); and 0.000021 (non-study releases). This special study is further discussed in Job III.

DISCUSSION

In-Stream Movements and Outmigration Timing

Of the 302 juvenile shad collected with seines at Columbia, Wrightsville and Marietta during the July-October period, 180 fish (60%) were taken during the first three sampling dates in July. Based on analysis of 119 otoliths from July collections, 90 fish (76%) were naturally produced from transplanted adults. Considering the timing of the adult run and the condition of fish transferred upstream, it is likely that most reproduction took place in the release vicinity (above and below York Haven Dam) and that the free-flowing stretch of river from York Haven to Columbia was used as a summer nursery.

The remaining 29 shad analyzed from downstream collections in July were Hudson River origin fry stocked at Thompsontown. All Hudson releases (569,000 fry) occurred during June 5-16. Those marked fish taken at Columbia, Wrightsville and Marietta on July 17-28 made the 55-mile journey from the release site in 31 to 53 days (1.0 to 1.8 miles per day). Long-range pre-migratory movements such as this are usually associated with high flow events as was the case in 1989 (St. Pierre, 1990).

The summer and fall of 1992 was characterized by frequent rainstorms and rapidly fluctuating river flows. Figure 2 compares daily flow rates as measured at Safe Harbor for 1991 and 1992 with the long-term mean monthly record. A severe drought occurred in 1991 and this is best demonstrated by the fact that mean daily river flow in 1992 exceeded 1991 values every day from June through November. Mean monthly Susquehanna River flows for July, August and September, 1992, exceeded long-term average flow rates for those months by 30%, 86% and 57%, respectively.

Rapid downstream movement of stocked shad from the Juniata River was probably related to high flow events in early June and mid-July. It is interesting to note that 798,000 Delaware River fry were stocked at Thompsontown during June 4-18 and none were recovered in the seine survey below York Haven until 6 October. Connecticut River fry were stocked between 27 June and 6 July and first appeared in seine collections at Columbia and Marietta on 27 August. Large differences were shown for relative survival rates between the three egg sources (recapture rates as related to stocking numbers). However, the total lack of Delaware fry in July seine collections below York Haven indicates that something other than a passive response to river flow rates affects pre-outmigration movements.

Further complicating this assessment is the single day collection of 115 juvenile shad at Amity Hall on the lower Juniata River on 29 July. All 30 fish analyzed were hatchery marked and 27 (90%) were Hudson fry origin. This source of fish was simultaneously spread over at least a 47-mile river reach from Amity Hall to Columbia.

Weekly seine collections at Marietta, Columbia and Wrightsville produced only 48 juvenile shad during August through mid-September. Wyatt Group biologists indicated that water level fluctuations associated with rain events and the power generation schedule at Safe Harbor influenced effort and reduced effectiveness. With an indication of building numbers of shad in the York Haven headrace, seines were used there to collect 46 shad on 18 September and 2 October. These fish, a few taken with cast nets, and an additional 58 shad from sluice net samples at York Haven in mid-October were analyzed and it was determined that 96 of 108 fish (89%) were hatchery origin.

Numbers of shad available for strobe light testing dropped off dramatically after 18 October and that study was terminated. Shad were relatively abundant in downstream seine collections on 22 September and 6 October (72 fish). Of 46 otoliths analyzed, 31 (67%) were from hatchery releases. Collections here and at York Haven coincided with a modest flow event, increasing from 10,000 cfs to 35,000 cfs, and a water temperature decline to about 15°C, typical trigger conditions for outmigration in this river stretch.

Of the 39 shad taken with lift nets at Holtwood in twice weekly sampling between mid-August and mid-November, 36 were taken on five dates during October 5-29. Otolith analysis determined that 23 shad (64%) were hatchery and remainder wild. Further definition of the timing of outmigration was hindered by lack of fish in collections at Peach Bottom and Conowingo and the termination of the electrofishing survey on the Flats on 22 October.

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 wide variation in river conditions which influence success. Excluding the Amity Hall sample, a total of 166 seine hauls were made from York Haven to Holtwood on 23 dates over 15 weeks. With a catch of 352 juvenile shad, the overall catch per unit effort (CPUE) was about 2.1. CPUE was highest during the July nursery period and at outmigration in early October. During the drought conditions of 1991, overall seine CPUE was only 0.82. Under relatively "normal" flow conditions in 1990, overall seine CPUE was 6.32. These results show no obvious relationship to either numbers of fry stocked upstream or numbers of adult shad transferred from Conowingo.

Abundance of wild shad in summer/fall collections appeared considerably greater in 1992 than in prior years. Based on otoliths analyzed from all collections above Conowingo Dam, naturally produced fish comprised 39% in 1992, 22% in 1991, and only 2% in 1990. This improvement may be partially explained by the relatively large number of adult female shad stocked in 1992 (higher female sex ratio) and suitable spawning conditions this year relative to the 1991 drought.

Cooling water strainers at Safe Harbor and Conowingo and intake screens at Peach Bottom are passive samplers. St. Pierre (1992) theorized that these should provide useful information on relative abundance since they are not influenced by vagaries of net sampling and weather conditions. In 1992, no shad were collected at Safe

Harbor, only one was taken at Peach Bottom, and four at Conowingo. This compares to 145 shad taken at the three sites in 1991, a year when seining CPUE was at it's lowest in recent years.

Weakness of the 1992 outmigration was also demonstrated by the collection of only 39 American shad with lift nets at Holtwood. Effort amounted to over 230 lifts on 24 dates between 20 August and 19 November. Similar effort produced 208 shad in 1991 and almost 4,000 shad in 1990. In addition to the paucity of American shad in downstream collections, the disappearance of juvenile gizzard shad was particularly striking. In 1992, total gizzard shad samples at Holtwood, Peach Bottom and Conowingo were 15, 8,583, and 140 respectively. Similar sampling effort in 1991, for example, produced 22,104, 116,601, and 46,460 gizzard shad at these three projects. Finally, the electrofishing collection of four shad from the Susquehanna Flats during July through mid-October, 1992 compares to 17 and 23 fish with similar effort in 1991 and 1990, respectively.

Abundance of hatchery-marked juveniles in downstream collections in 1992 was expected to be weak because of the limited numbers of fry stocked. Similarly, it was not surprising that abundance of wild juveniles was higher than in previous years due to the relatively greater numbers of females stocked above dams this year. However, the overall paucity of fish in collections from Safe Harbor to Conowingo was unexpected. With concurrent failure of gizzard shad production in lower river impoundments, it may be speculated that conditions here were not suitable for survival of young clupeids (e.g. low food availability, excessive predation). General lack of fish in strainer and screen collections and failure to record a peak of migration at Holtwood are not readily explained by flow and temperature conditions in the river during September through November, 1992.

Growth

Wild juvenile shad collected with seines at Marietta, Columbia and Wrightsville averaged 60 mm total length (TL) in mid-July (range 39-92 mm) and grew to an average 140 mm (range 117-154 mm) by late September. Wild fish growth rate during this period averaged 1.2 mm/day. Hatchery fish in these collections were consistently smaller with mean lengths improving from 52 mm in July (38-77 mm) to 117 mm in September (95-146 mm) with an average growth rate of 1.0 mm/day (Figure 3). These growth rates are similar to those recorded in 1991.

The Amity Hall shad sample from 29 July showed a mean TL of 68 mm (range 46-91 mm). Although both Hudson and Delaware River fry were stocked at about the same time at Thompsontown, Hudson fish averaged almost 20% longer (11 mm) in this collection. The hatchery cohort which remained in the Juniata River to late July were of greater size than those which made the pre-migratory movement to the Columbia-Wrightsville area.

Outmigration from above York Haven apparently occurred during the first 2-weeks of October and mean size of hatchery fish collected here with seines and sluice nets improved from 118 mm to 128 mm (Figure 3). Although few in number, wild fish in York Haven collections were consistently larger than hatchery fish. Fewer than

10 hatchery or wild fish were available from any lift net collection at Holtwood during October. For all Holtwood samples combined, hatchery fish averaged 130 mm (n = 25) and wild fish averaged 136 mm (n = 13). Compared to 1991 average lengths of shad at Holtwood during October, hatchery fish were larger and wild fish were smaller in 1992. In past years it was not uncommon to observe large shad (170-200 mm) in late season collections. In 1992, only 7 fish measured greater than 150 mm (all wild) and no juveniles exceeded 160 mm TL.

Much of the size disparity observed between wild juvenile shad and hatchery released fish in seine collections during July - September likely relates to slower growth rates experienced in the hatchery. Age of all shad in these collections seems comparable since most natural spawning probably occurred in the river during mid-May to mid-June, and most hatchery fish were released (as 18-day old fry) during the first 2-weeks in June.

Hudson and Delaware River shad eggs were delivered to Van Dyke almost simultaneously, cultured under identical conditions, and stocked during the same period at Thompsontown. Mean size of fish from these two sources measured from combined October collections at York Haven and Columbia were: Hudson - 126 mm (n=39); Delaware - 125 mm (n=21). These results differ from 1991 when Delaware fish were substantially larger than Hudson in most collections. Connecticut River shad were stocked about 2-weeks later than Hudson and Delaware fry and their mean length in October collections was 116 mm (n=25).

Stock Composition and Mark Analysis

Of the 3,039,200 shad fry stocked at Thompsontown in 1992, 1,672,000 (55.0%) were Connecticut River origin released on 4 dates between 29 June and 6 July. Delaware River shad fry made up 798,500 (26.3%) of the total Juniata River stocking in 1992, with three releases on June 4, 17 and 18. The remaining 568,700 fry (18.7%) were Hudson River origin stocked at Thompsontown on four dates between June 5-16.

Although Hudson River fish comprised the smallest percentage of total fry stocked upstream, they were the dominant component of tetracycline marked shad in most juvenile collections in 1992. Overall, Hudson fish comprised 64.4% (152 of 236) of marked shad in collections above Conowingo Dam. Broken down by collection area, Hudson shad made up 63% (80 of 127) of the marked sample above York Haven; 69% (57 of 83) of seine samples from Marietta, Columbia and Wrightsville; and 58% (15 of 26) from Holtwood and Peach Bottom. Remaining marked fish in all collections were almost equally split between Delaware River (17.4% - 41 fish) and Connecticut River (18.2% - 43 fish).

Recovery rates (number recovered/number stocked) for the three strains were 0.000267 for Hudson, 0.000051 for Delaware, and 0.000026 for Connecticut. Relative survival of Hudson fish exceeded that of Delaware and Connecticut fish by factors of 5 and 10, respectively. Numbers of shad released and recovered, recovery rates, and relative survival from various egg sources stocked in the Susquehanna River during 1988 through 1992 are shown in Table 4.

Based on otolith analysis of 391 shad from all collections above Conowingo Dam in 1992, 39% (152 fish) were naturally produced. This compares to 21.5% in 1991, and 1-4% each year during 1987-1990. As mentioned earlier, improved reproduction in 1992 probably related to favorable environmental conditions and the large numbers of potential spawning females stocked. During spring 1992, about 7,300 female shad were successfully transferred from Conowingo and released above dams. Although this is less than the estimated 8,300 females stocked in 1991, drought conditions that year may have adversely influenced reproduction. During 1987-1990, only 1,200-3,600 adult female shad were stocked each year.

A total of 1,249,800 shad fry were distinctively marked on days 5 and 9 and stocked below Conowingo Dam at Lapidum, MD on three dates between 12 June and 2 July. Stockings included 948,800 Connecticut River fish, 201,000 from the Delaware, and 100,000 Hudson fish. One of the three fish examined from the DNR electrofishing survey on the Flats carried the double tag, the other two were wild.

A total of 21,800 fingerling shad were stocked from Pennsylvania ponds into the Juniata River including 14,300 Connecticut fish from the Thompsontown canal pond on 26 August and 7,500 Delaware fish from Upper Spring Creek ponds on 15 September and 8 October. Although none of these fish were specially marked with feed tags as in past years, an accidental quadruple immersion mark was placed on an estimated 2,800 of the Upper Spring Creek fingerlings. Five of these fish were collected at York Haven and Holtwood during 9-29 October - a recovery rate exceeding that of Hudson River fry releases by a factor of 7.

SUMMARY

River flow conditions during the summer and fall of 1992 were generally higher than normal and were characterized by frequent fluctuations due to rainstorms. The haul seine was effective in taking juvenile shad at several lower river sites in July and again during late September and early October. Catch efficiency was reduced during August and early September due to frequent high flows which flooded preferred hauling areas.

The number of shad fry stocked at Thompsontown in 1992 was the smallest since 1981. Hatchery juveniles appeared in the earliest seine collections, having moved 55 miles downstream from the stocking site within 31-53 days. Shad also apparently used the lower Juniata River as summer nursery. Successful reproduction of transplanted adult shad was well documented with the collection of unmarked wild fish at all netting sites during July through October.

Outmigration at York Haven occurred during the first 2-weeks in October and, as expected, was weak compared to prior years. With collection effort comparable to past years, relatively few American or gizzard shad were collected at Holtwood, Peach Bottom, Conowingo or the Susquehanna Flats.

Hatchery released fry grew well, reaching an average size of about 130 mm within 4-months of release. Connecticut River shad in collections were about 10% smaller than Hudson and Delaware juveniles, having been stocked 2-4 weeks later. Wild shad grew at a slightly faster rate than hatchery fish and maintained a 10-20 mm size advantage (TL) throughout summer months.

Hudson River source juvenile shad were recaptured at 5-10 times higher proportions than Delaware and Connecticut River fish relative to their abundance at stocking. Small numbers of accidentally marked pond-reared fingerlings were well represented in downstream collections within weeks of release in the Juniata River.

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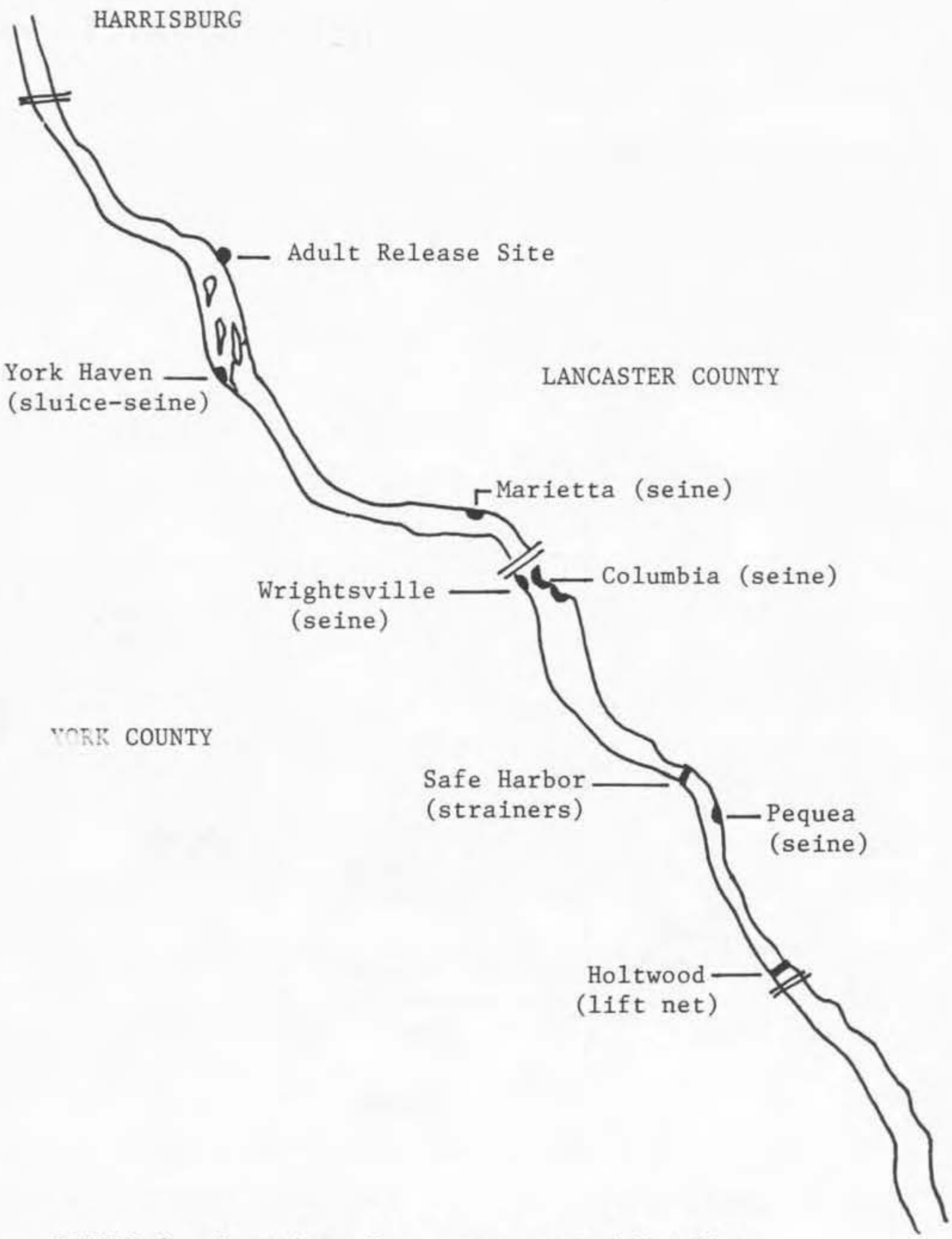


FIGURE 1. Locations for Juvenile Shad Sampling During July - October, 1992.

Fig. 2. Comparison of River Flow during June-November, 1991-1992 with Long-Term Monthly Mean Flow.

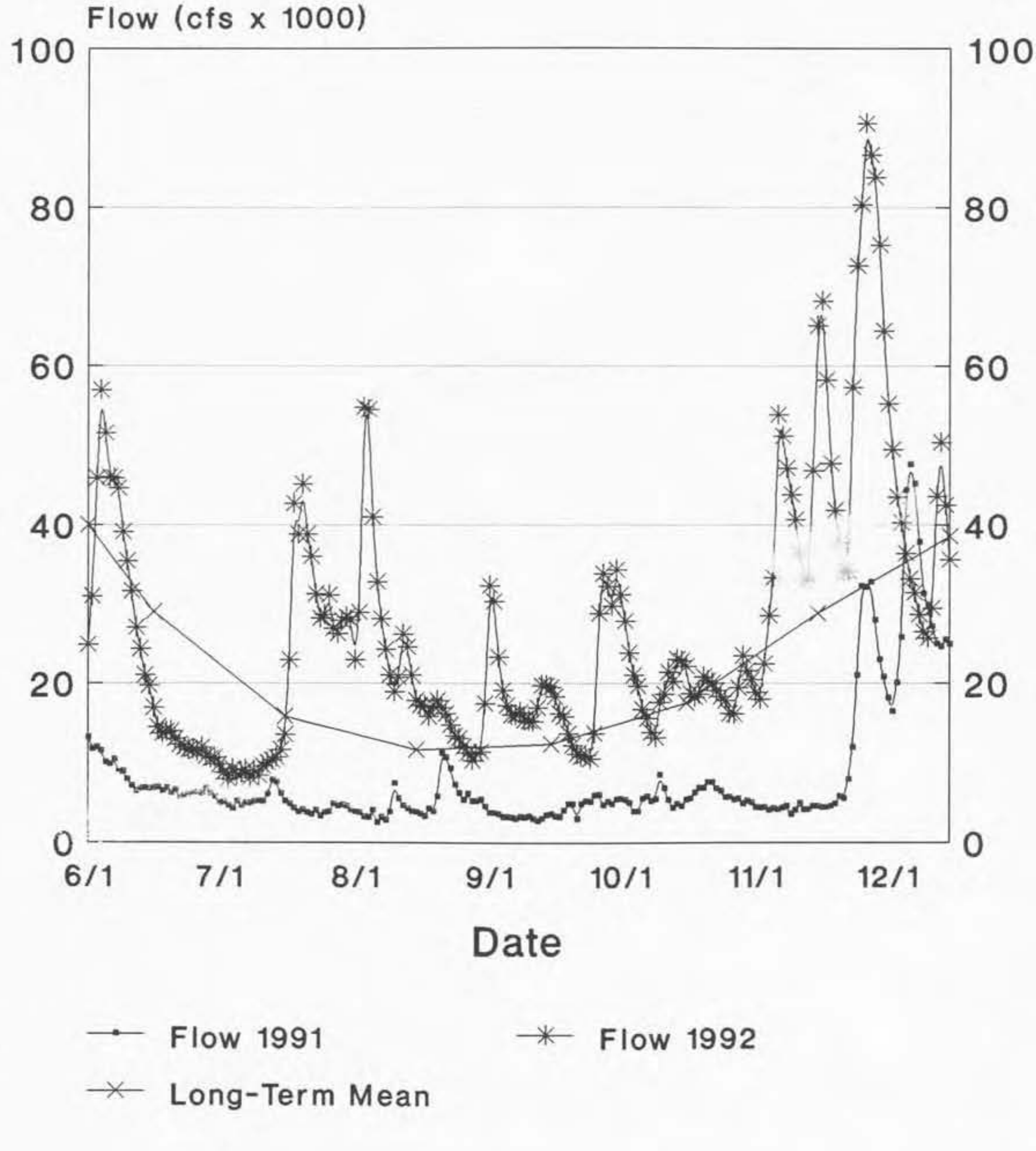
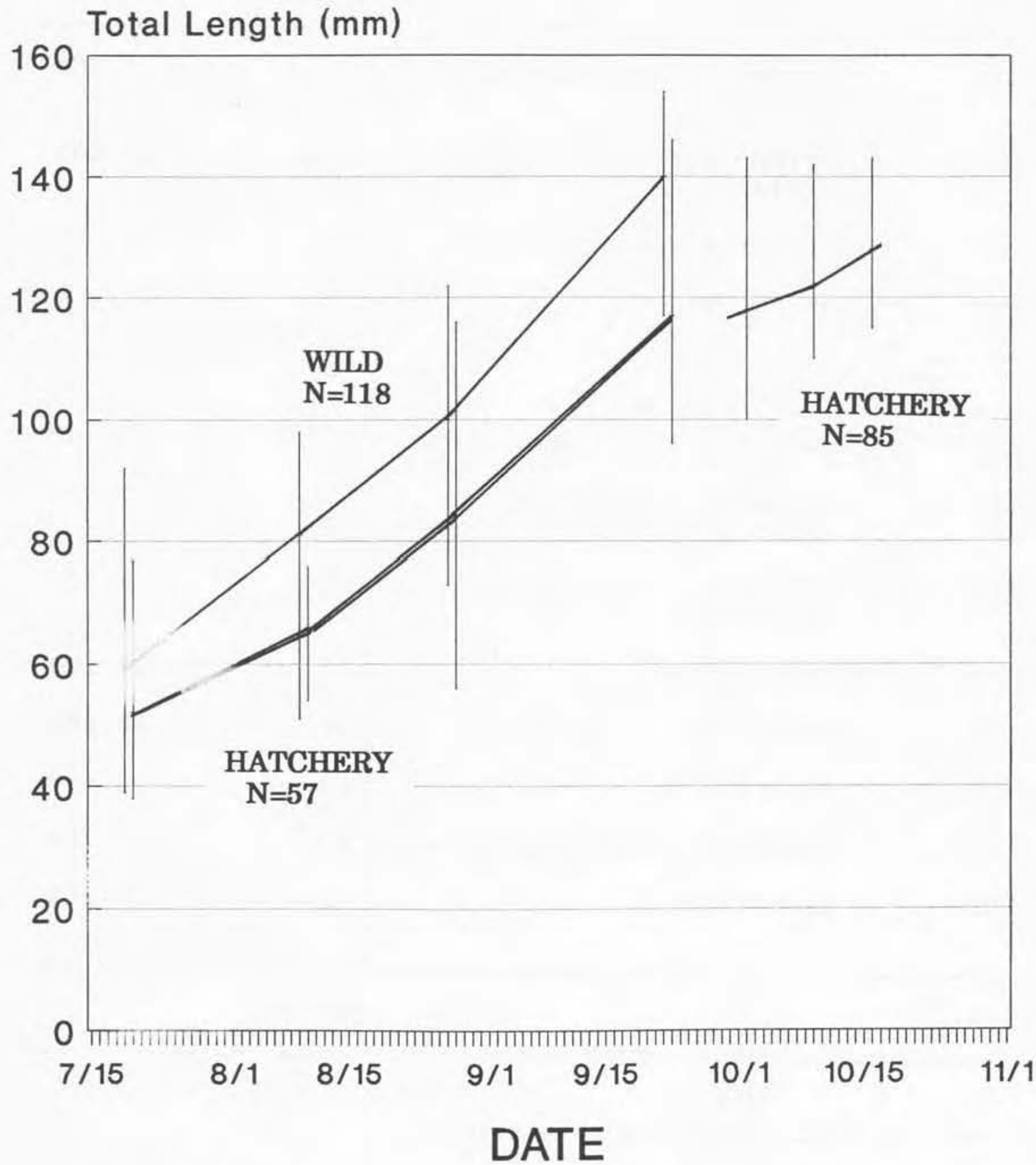


Fig. 3. Juvenile Shad Growth in the Susquehanna River in 1992.



July-Sept. data from seines below York Haven; October data from YH headrace

Table 1. **Summary of Juvenile American Shad Collected with Haul Seine in the Lower Susquehanna River, July - October, 1992.**

Date	Location	No. Shad	River Flow*
7/17	Columbia / Wrightsville	39	22,900
	Marietta	26	
7/21	Columbia / Wrightsville	81	38,800
	Marietta	28	
7/28	Columbia / Wrightsville	6	26,200
7/29	Amity Hall	115	27,900
8/6	Columbia	10	32,800
	Pequea	2	
8/11	Columbia / Wrightsville	10	20,700
8/19	Columbia / Wrightsville	2	17,100
	Three Mile Island	2	
8/26	Columbia	16	12,100
	Marietta	10	
9/18	York Haven	26	15,800
9/22	Marietta	24	10.800
10/2	York Haven	20	27,800
10/6	Columbia / Wrightsville	48	16,700
10/13	Columbia	2	20,200
Total		**467**	

* cfs as measured at Safe Harbor

Table 2. Summary of Lift Net Collections at the Holtwood Inner Forebay, August-November, 1992.

Date	Temp. (°C)	American Shad	Gizzard Shad	Comely Shiner	Walleye	Other
08/20	21.0	0	0	13	0	0
08/24	24.0	0	0	13	0	1
08/27	24.5	0	0	26	0	1
08/31	24.0	0	0	3	0	0
09/03	23.0	0	0	0	0	1
09/10	23.0	0	0	1	0	0
09/14	22.5	0	0	1	0	0
09/17	23.0	1	0	5	1	0
09/21	22.0	0	0	0	0	0
09/24	22.5	0	0	0	0	1
09/28	17.5	0	0	9	0	0
10/01	16.0	2	0	1	0	0
10/05	15.0	16	1	7	0	0
10/08	16.5	0	0	13	1	0
10/12	16.0	0	0	1	1	1
10/15	16.0	1	0	2	0	0
10/19	13.5	9	10	1	3	2
10/22	11.0	0	4	1	0	0
10/26	11.0	7	0	1	1	0
10/29	11.0	3	0	0	0	1
11/02	10.5	0	0	0	0	0
11/05	10.0	0	0	0	1	0
11/12	9.0	0	0	0	0	0
11/19	6.5	0	0	0	0	0
	TOTALS	**39**	**15**	**98**	**8**	**8**

Table 3. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1992.

Collection Site	Coll. Date	No. of fish with TC mark: Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,7,17	Days 3,13,17	Days 3,5,15,19	Days 3,7,11,21	Days 3,13,17,21	Days 5,9,13,17,21	Total Marked	Wild Micro-structure Not Marked	Total
Amity Hall	7/29/92				27		3					30		30
Three Mile Island	8/19/92				1							1	1	2
York Haven	9/17/92				1					1		2		2
	9/18/92	2	1		14		1		1	3	1	23	1	24
	9/28/92				1							1		1
	10/2/92	3			10				2	4	2	21	2	23
	10/9/92	1	1		3		6	1	3	4	2	21	3	24
	10/15/92	1	1		3						1	6		6
	10/16/92	1	1		8		8	2	1		1	22	6	28
Marrietta	7/17/92	2	1		4							7	19	26
	7/21/92		1		5							6	18	24
	8/27/92				1				1	2		4	5	9
	9/22/92	2			2				2	2	1	9	12	21
Wrightsville	7/17/92				2							2	25	27
	7/21/92	3	4		5							12	16	28
Columbia	7/17/92											0	8	8
	7/28/92	1			1							2	4	6
	8/6/92	5	2									7	2	9
	8/11/92	3										3	7	10
	8/19/92	2										2		2
	8/27/92	2			3	1				1		7	7	14
	10/6/92			1	6		9			4	2	22	3	25
	10/13/92						2					2		2

Table 3. (continued)

Collection Site	Coll. Date	No. of fish with TC mark: Day 5	Day 18	Days 5,9	Days 5,9,13	Days 3,7,17	Days 3,13,17	Days 3,5,15,19	Days 3,7,11,21	Days 3,13,17,21	Days 5,9,13,17,21	Total Marked	Wild Micro-structure Not Marked	Total
Holtwood	9/17/92											0	1	1
	10/1/92				2							2		2
	10/5/92		2		5		1	1				9	7	16
	10/15/92	1										1		1
	10/19/92				4		1		1		1	7	2	9
	10/26/92						5					5	2	7
	10/29/92							1				1	2	3
Peach	10/23/92				1							1		1
Bottom												26	14	40
Below	3/24–5/10/92											0	5	5
Cono–	8/25/92											0	1	1
wingo	9/3/92											0	1	1
	10/7/92			1								1		1
Total		29	14	2	109	1	36	5	11	21	11	239	160	399

Table 4. Relative survival of American shad fry from various egg source rivers, stocked in the Susquehanna River, 1988–1992.

Year	Egg Source	Release Dates	Fry Released Number	Fry Released %	Juveniles Recovered Number	Juveniles Recovered %	Recovery Rate	Relative Survival
1988	Va.	5/13–5/31	682,685	11	111	40	0.000163	1.00
	Del.	6/1–6/10	495,670	8	69	25	0.000139	0.85
	Col.	7/5–7/25	5,272,330	82	99	36	0.000019	0.12
1989	Va.	5/30–6/1	477,320	4	67	26	0.000140	1.00
	Hud.	6/5–6/28	2,864,720	21	94	37	0.000033	0.23
	Del.	6/16–7/7	1,644,630	12	11	4	0.000007	0.05
	Col.	6/30–7/11	8,477,980	63	80	32	0.000009	0.07
1990	Va.	5/22	178,300	3	4	1	0.000022	0.12
	Del.	5/26–6/8	1,622,800	29	19	3	0.000012	0.06
	Hud.	6/6–7/2	3,817,900	68	714	97	0.000187	1.00
1991	Del.	5/31–6/9	1,085,000	15	61	13	0.000056	0.83
	Hud.	5/30–6/18	6,098,000	84	415	87	0.000068	1.00
	Conn.	6/28	35,000	<1	0	0	0.000000	0.00
1992	Del.	6/4–6/18	798,700	26	41	17	0.000051	0.19
	Hud.	6/5–6/16	568,700	19	152	64	0.000267	1.00
	Conn.	6/29–7/6	1,672,000	55	43	18	0.000026	0.10

THE DISTRIBUTION OF TELEMETERED AMERICAN SHAD IN THE TAILWATERS AND SPILLAGE AREAS OF THE HOLTWOOD, SAFE HARBOR AND YORK HAVEN HYDROELECTRIC PROJECTS, SUSQUEHANNA RIVER, PENNSYLVANIA

VOLUME I

Client Project No. 4247

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EXECUTIVE SUMMARY

Studies of radio tagged American shad were conducted in the tailraces of Holtwood, Safe Harbor, and York Haven Hydroelectric Projects during spring 1992. The intent of these studies was to assist the owners of these facilities (Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, Baltimore Gas & Electric Company, and York Haven Power Company in finalizing fish passage designs for each of the projects. Specifically, the results of these studies should assist in siting passage facility entrance(s).

HOLTWOOD

Movement and behavior of 81 (81%) shad released downstream of the Holtwood Project were established in the vicinity of the tailrace and spillway. Initial detection indicated most fish moved into the spillway area when spillage over the dam occurred.

A total of 52 (64%) of the shad was detected in the Holtwood tailrace and 49 of these were located in the upper tailrace area near the powerhouse. Movement and behavior of these fish in the tailrace was evaluated under four generation scenarios ranging from 3,200 cfs to 32,000 cfs. Data indicate, through all scenarios monitored, the best location for a fishway entrance would be mid-powerhouse near Generating Unit No. 5. The fish may have been on the mid or far side of the tailrace out from Unit No. 5 or near this unit due to water currents associated with the two excitor (house units) located in the same general area. Exact locations need to be determined through more extensive monitoring.

Seventy-four (91%) of the shad that reached the Holtwood Project were detected in the spillway area. Of these, 55% moved to the pool area at the base of the dam. Shad behavior was monitored in this area under no spill conditions and spills ranging from 200-30,900 cfs. High residency times of some fish in the pool at the base of the dam indicates stranding in this area may occur. Additionally, the high percentage of shad (61) detected, in the upper spillway indicate a fish passage facility there may be warranted.

SAFE HARBOR

A total of 72 (73%) of 99 shad released downstream of Safe Harbor Dam was monitored in the tailrace to evaluate their location preferences under seven controlled generation scenarios.

The seven generation scenarios monitored included: (1) normal daytime generation, (2) full generation, (3) new units only, (4) old units only, (5) new units plus old Unit No. 1, (6) old units plus new Unit 12, and (7) normal nighttime generation. The amount of time each of these scenarios were monitored ranged from 36 hours of full generation to 484 hours of normal nighttime generation.

Through all scenarios monitored, data indicated three areas in the tailrace were preferred by shad including the vicinity of Unit 12, the house units and Unit 1.

During most scenarios the tailrace area near Unit 12 was preferred, a total of 70 (97%) was detected there. In addition, 69 (96%) were also detected near Unit 1 on the eastern side of the powerhouse. Based on this information, a site near Unit 12 should be selected for a fishway entrance.

YORK HAVEN

Forty-nine (51%) of the tagged shad were detected at three monitoring sites in the vicinity of the York Haven Project. The areas of the powerhouse tailrace, Main Dam, and Red Hill Dam were monitored and evaluated independently.

Shad movement and behavior patterns in the vicinity of York Haven Powerhouse were evaluated under four flows including: no spill, low (1500-10,000 cfs), moderate (13,800-23,700 cfs), and high (25,500-36,900 cfs) spill conditions. Some 48 (98%) of the fish detected in the vicinity of York Haven were monitored in the powerhouse tailrace. Fish abundance and detection, in general, was similar across the face of the powerhouse regardless of flow and spillage conditions; however, there was some preference of fish to spend time in the area downstream of Unit No. 1. This area is in the periphery of the station discharge flow. Based on the initial year of data, a fishway could be located at either end of the powerhouse due to the lack of strong preference by fish for a given area.

Twenty-five shad were detected at the Main and Red Hill dams. Of these, 8 and 7 were only detected at the Main and Red Hill dams, respectively. Although over 50% of the shad monitored in the vicinity of the York Haven Project were detected at these sites, fishways may not be warranted since all but one of these fish were detected at the powerhouse. Should a fishway be required, it could be located on either side of the East Channel at Red Hill Dam. There is no need, based on study results, for a fishway near the East shore of the Main Dam because only two fish were detected at this site.

1.0 INTRODUCTION

1.1 Background

State and Federal resource agencies entered into an agreement in 1984 with Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, Baltimore Gas & Electric, and York Haven Power Company (Licensees) the owners of Holtwood, Safe Harbor, and York Haven projects (Figure 1-1), respectively. This agreement provided for the establishment of funding by the Licensees for shad restoration efforts on the Susquehanna River. A portion of this agreement stipulated that, upon completion of fish lift facilities at Conowingo Hydroelectric Station by Philadelphia Electric Company, the Licensees would begin to finalize fish passage designs for each of the projects. The permanent east fish lift facility at Conowingo Dam became operational in spring 1991.

The Licensees contracted with RMC Environmental Services, Inc. (RMC) to conduct radio telemetry studies in 1992 to assist in finalization of preliminary fish passage facility designs. The results of these radio telemetry studies are expected to provide real time data capable of assisting the Licensees in siting the most appropriate fishway entrance(s) for successful passage of anadromous fishes, particularly the American shad at each of the powerhouses and dams. The methods, results, discussion and recommendations of the study are presented in this volume. Detailed data of all fish are presented as Appendices A through C in Volume II.

1.2 Study Objectives

The objectives of the American shad radio telemetry study at Holtwood Dam were to determine 1) the need for a spillway fish passage device, 2) the location of the tailrace fish passage facility entranceway(s), and 3) the need for a collection gallery as part of the tailrace fish passage device.

The objective of the study at Safe Harbor Dam was to determine the fish passage entrance location by testing various operational scenarios (flow releases).

The objectives of the study at York Haven Dam were to determine 1) likely fish passage entranceway(s) for a powerhouse passage facility, 2) if fish passage facilities are needed at the main and east channel dams as recommended by the resource agencies, 3) if minimum flows are needed to provide access to the main and east dam fish passage devices under low flow conditions, and 4) the effects of main and east dam spills on adult American shad movements.

1.3 Station Descriptions

Holtwood Hydroelectric Station is the second upstream hydroelectric facility on the Susquehanna River. It was built in 1910 at river mile 24. The project consists of a concrete gravity overflow dam 2,392 ft long and 55 ft high, a powerhouse with 10 turbine units, and a reservoir with a surface area of 2,400 acres. Spillway area is separated from the tailrace by the 0.9 mile long Piney Island. The project has a combined generating capacity of 102 megawatts (MW). Three of the 10 units are single Francis runner turbines; seven are double runner Francis turbines. Each unit is capable of passing approximately 3,000 cubic feet per second (cfs). Natural river flows in excess of 32,000 cfs are spilled over the dam.

Safe Harbor Hydroelectric Station is the third upstream hydroelectric facility located on the Susquehanna River. It was built in 1931 at river mile 32. The project consists of a concrete gravity dam 4,869 ft long and 75 ft high, a powerhouse with 12 turbine units, and a reservoir with a surface area of 7,360 acres. The project has a combined generating capacity of 417 MW. Seven of the 12 units are Kaplan turbines and five are mixed flow turbines. The total hydraulic capacity of the project is 110,994 cfs. Spillage is regulated with 32 gates.

York Haven Hydroelectric Station is the fourth upstream facility on the Susquehanna River. It was built in 1904 at river mile 55.6. The project consists of two dams, 20 turbine units, and a reservoir with a surface area of 2,200 acres. The main dam extends 5,000 ft diagonally upstream from the west side of the headrace to the southwestern tip of Three Mile Island. It ranges in height from 28 ft adjacent to the powerhouse, to eight ft at Three Mile Island. A second dam (eight ft high) extends 935 ft between Three Mile Island and the left bank of the river. This configuration effectively concentrates river flows at the powerhouse. The project has a combined generating capacity of 19.6

MW. Six of the 20 generating units are Kaplan turbines and 14 are Francis turbines. Each turbine is capable of passing approximately 800 cfs. River flows in excess of 16,000 cfs are spilled over the main and/or East Channel Dam(s).

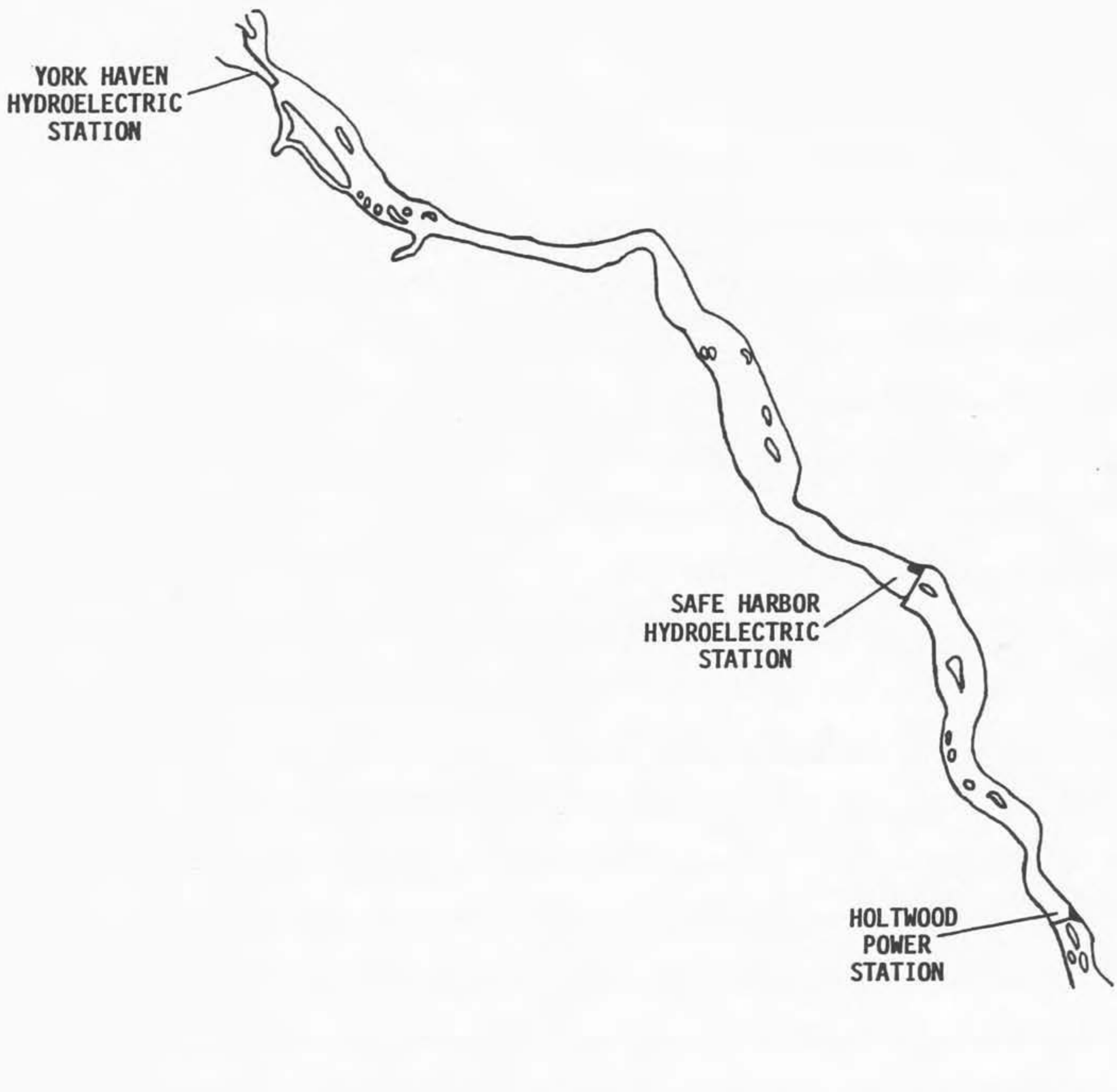


Figure 1-1

Map of the three hydroelectric stations monitored in spring 1992.

2.0 METHODS AND MATERIALS

2.1 Handling, Tagging, and Transport

Philadelphia Electric Company has operated the West Fish 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 transport of the migratory fishes is provided by the upstream licensees. The primary objective at both is 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.

The purpose of collecting shad from the West Lift for this study was twofold. First, it was believed survival would be maximized through transport in trucks versus trailers which are utilized at the new East Lift. Secondly, interference of day to day trap operation would be minimized. Migrating adult American shad were taken from Conowingo's west fish lift and radio tagged. Fish were either tagged immediately after capture or several hours later by netting them from a 800 gallon circular holding tank on site. Each specimen was individually removed from the fish lift sorting tank or holding tank and held immobile in a pre-salted water filled tagging cooler with a piece of fine mesh netting to reduce stress. A transmitter was inserted orally through the esophagus into the stomach. The transmitter's whip antenna was left to trail along the specimen's body from its mouth. The fish was sexed and placed in a temporary circular holding tank or directly into the transport tank. Fish observed swimming erratically and those that regurgitated tags were discarded and replaced.

The entire release group (approximately 25 fish) was placed into a 900 gallon circular flow transport truck and delivered to their appropriate release site. Water was circulated within the transport truck using a 3 hp centrifugal 2" pump and backup. Oxygen was provided using portable oxygen bottles and 3 ft diffuser tubes (Aerea Inc.). A 50 lb bag of Solar Salt was added to the transport tank water. Time, temperature, and dissolved oxygen were recorded throughout the tagging and transport process. Tags regurgitated during transports were returned to the fish lift. No additional fish were tagged to supplement that day's release group. The condition of the fish just prior to release was determined by drawing approximately half of the water from the tank, while maintaining the circular flow. Fish observed swimming abnormally and lying on the bottom of the tank were removed before the fish were discharged. The transport truck was backed into the water as far as feasibly and safe to provide receiving water depth $\geq$3 ft. A biologist entered the transport tank just prior to fish release to assist fish in exiting the tank if needed. Throughout the tagging, transport and stocking operations, fish were handled with utmost care and fish were subjected to the least amount of handling. Four groups of tagged fish were released at each site. This release schedule ensured a sample of fish from throughout the spring run would be monitored. Additionally, each release group was only monitored for 15 days from release to maximize data on individual fish through minimizing radio telemetry equipment scan times.

2.2 Radio Telemetry Equipment

2.2.1 Radio Transmitters

Coded radio transmitters used for the study were supplied by Lotek Engineering Inc. (Lotek) of Aurora, Ontario. Transmitters were cylindrical in shape and averaged 14 mm in diameter, 41 mm in length, and weighed 10.5 g in water. The 3.5 volt transmitters propagated signals on 20 channels with a frequency range of 149.320 to 149.920 mhz (intervals $\geq$ 20 khz) via a 455 mm whip antenna. Tag life was estimated to exceed 240 days. Each coded transmitter on any given channel generated a unique 4-pulse burst, or pulse train with intervals between 15 and 115 milliseconds.

2.2.2 Receivers

Lotek SRX_400 telemetry receivers installed with version 3.1 W16 (code log) software were manufacturer customized to identify the particular code set of tags used. Site noise floor levels were determined at each receiver location prior to release of fish. Receivers were configured to exclude background noise by utilizing several features in the receiver's software. Scan time (the length of time the receiver "listens" on each channel) was set at 6 seconds for all receivers. This time period was determined to be the minimum allowable scan time, and must be longer than the longest pulse interval of the slowest tag used. When a pulse transmission having a coded time signature within the code set is received, the scan program temporarily suspends and the signal is verified or rejected.

Verified signals were recorded as single events and stored in one of four data banks (64K bytes/bank) of non-volatile RAM memory. Data stored for each event were: date, time, channel, power level, antenna number, code, and deviation. Power level is a relative value of signal strength measured on the leading pulse of the pulse train. Deviation is a relative value interpreting the significant difference between a signal and its true coded time signature within the code set.

2.3 Site Specific Receiver/Antenna Layout

2.3.1 Holtwood Installation

Four receivers were installed at the Holtwood project (Figures 2-1 and 2-2). Receiver 1 was placed on the deflection wall and overlooked the area immediately below the spillway via two 4-element Yagi antennas (Cushcraft model P150-4). Antenna 1, coupled to the receiver through a multiple antenna switch box (Lotek model ASP-8), independently surveyed the northeast corner of the spillway from the wrecked barge to the log sluice (300 ft range). Antenna 2 viewed the entire breadth of the spillway (2,400 ft range).

Receiver 2 was located on the stoplog gallery and surveyed the upper tailrace through the use of a switch box and eight 4-element Yagi antennas. Antenna 1 was positioned just below Unit 10, facing downriver along the eastern shore (150 ft range). Antennas 2 through 8 were equally distributed along the gallery and covered the entire width (150 ft) of the tailrace, Antenna 2 was placed closest to Unit 1.

The unique physical layout of the tailrace below Holtwood dam demanded special attention when considering the time involved in a scan cycle. Holtwood's discharge, and the antenna array, is roughly perpendicular to the flow of the tailrace, this creates much quicker movement of test specimens than would otherwise be found in a parallel flow to discharge layout like those found at Safe Harbor and York Haven dams. To reduce the risk of missing the detailed movement of shad in this confined area, Receiver 2 was programmed to initially read all antennas concurrently. Upon detection of a signal, the receiver would then evaluate each antenna consecutively. If no signal was initially detected, the receiver would continue on to the next channel effectively reducing the scan cycle time.

Receiver 3 was located on the southwest quadrant of Piney Island to survey the downriver portion of the spillway. The receiver was powered by a deep cycle marine battery charged by a 30 3/4" x 20 1/2" x 3 1/4" solar panel (Solarex model 1-MSX 40). A single 9-element Yagi (Cushcraft model PLC 1429) directly linked to the receiver viewed the entire width of the spillway (2,000 ft range).

Receiver 4 was located on the southeast quadrant of Piney Island and monitored the downriver portion of the tailrace opposite Receiver 3. Similarly powered by battery and solar panel, Receiver 4 utilized two 4-element Yagi antennas, viewing both antennas as a single detection area by way of a 2 to 1 combination box. Antenna 1 was oriented just upriver of a small island in the tailrace. Antenna 2 faced just downriver of the island. The combined detection range of the two antennas covered the entire width (200 ft) of the tailrace.

2.3.2 Safe Harbor Installation

Three receivers were installed at the Safe Harbor project (Figures 2-3 and 2-4). Receiver 5 was positioned on the west side of the stoplog gallery and was coupled to eight 4-element Yagi antennas through a switch box. Antenna 1 was positioned on the end of the gallery perpendicular to flow to detect fish moving in the spillway. Detection area was from the diversion wall to an adjacent island, a range of 100 ft. Antennas 2 through 8 were evenly distributed along the western half of the gallery starting at the new units and moving east to the old units. The antennas were orientated parallel to the flow of the tailrace, and surveyed a 150 ft range downriver (Figure 2-3).

Receiver 6 covered the east side of the tailrace, and was located on the stoplog gallery. Eight 4-element Yagi antennas facing downriver were coupled to the receiver by way of a switch box. Antennas 1 through 8 were equally dispersed from the eastern shore to the middle of the gallery and had a downriver reception range of 150 ft. During analysis of the data these antennas were assigned numbers 16-9, respectively (Figure 2-3).

Receiver 7 was located on the east shore a quarter mile downriver of the release site and surveyed the entire width of the river (Figure 2-4). A 9-element Yagi antenna connected directly to the receiver pointed across river south of Weiss Island, with a range of approximately 4,000 ft.

2.3.3 York Haven Installation

Three receivers were installed at the York Haven project (Figures 2-5 and 2-6). Receiver 8 was positioned on the southwest shoreline of Three Mile Island overlooking the area immediately downriver of the main channel dam. This receiver was coupled to two 4-element Yagi antennas through a switch box and powered by a marine battery and solar panel. Antenna 1 viewed a large portion of the spillway (approximately 2,000 ft). Antenna 2 concentrated on the northeast corner of the main channel dam (200 ft range).

Receiver 9 was located on the eastern side of Three Mile Island, and was positioned immediately downriver of the Red Hill Dam. This receiver was coupled to two 4-element Yagi antennas via a switch box and powered by a marine battery and solar panel. Antenna 1 surveyed the breadth of Red Hill Dam (950 ft). Antenna 2 surveyed the west corner of Red Hill Dam (approximately 200 ft).

Receiver 10 was situated on the catwalk overlooking York Haven's tailrace and monitored the power station discharge by way of eight 4-element Yagi antennas linked by a switch box. Antennas 1 through 8 were oriented with the flow of the tailrace and spread evenly across the catwalk from Unit 20 to Unit 1. The detection area for these antennas was 100 ft.

2.4 Release Sites

Release site locations were determined based on transport time and access. Holtwood fish were released at Muddy Creek boat launch, 2.5 miles downriver of the dam on the spillway side of the river. Fish released from this point swam 1.6 miles upriver to the southern tip of Piney Island before entering the tailrace or spillway. Transport time was estimated to be 45 minutes.

Safe Harbor fish were released at Pequea Marina, 2.5 miles downriver of the dam on the tailrace side of the river. Transport time was estimated to be one hour.

York Haven fish were released at Columbia's public boat launch, 13.5 miles downriver of the dam on the spillway side of the river. Transport time was estimated to be one hour and 15 minutes.

2.5 Aerial Tracking

Aerial tracking was conducted through the use of a portable SRX_400 receiver and a 4-element Yagi antenna mounted to the wing strut of a Cessna 172 aircraft. The Susquehanna River was surveyed from its mouth to the York Haven Dam (56 miles). Five flights were flown, one per week, to determine overall fish locations under various river and generating conditions.

2.6 Discharge Scenarios Monitored

2.6.1 Holtwood

At Holtwood, there was no pre-established generation scenario to be monitored. Therefore, fish located in the tailrace were evaluated under four generation scenarios that occurred during the study including: (1) 1 to 3 unit generation (3200-9600 cfs), (2) 4 to 6 unit generation (12,800-19,200 cfs), (3) 7 to 9 unit generation (22,400-28,800 cfs), and (4) full station 10 unit generation (32,000 cfs). Each of these scenarios was evaluated independently for day and night. One to two house units typically operated when any of the generating turbines was running.

Shad movements in the spillway were evaluated under three conditions: (1) no spill, (2) spillage of 200-14,900 cfs, and (3) > 14,900-30,900 cfs.

2.6.2 Safe Harbor

A specific station operational plan was initiated for the duration of the study at the Safe Harbor Station. The Station operated according to six operational scenarios. Each scenario was conducted on a six day rotation period and was scheduled for 7 AM to 7 PM. The designed time interval was occasionally shortened because of water availability. The six scenarios were: (1) normal daytime operations; (2) full generation; (3) new units only; (4) old units only; (5) new units plus old Unit 1; and (6) old units plus new Unit 12. A seventh operational scenario was assigned to the normal station operation that occurred daily from 7 PM to 7 AM. For scenarios 3-6 generation commenced with the furtherest west new units and/or the eastern most old units. At least 3 of 5 new units were operated for scenario 3 and 5 and a minimum of 4 of the 7 old units were operated for scenarios 4 and 6. One of the two small (500 cfs) house units (No. 42 & 43) typically operated whenever any of the full sized turbines (approximately 8,500 cfs) were run.

2.6.3 York Haven

Due to the limited hydraulic capacity of the York Haven Hydroelectric Station, no specific pre-determine scenarios were chosen for shad behavior evaluation. The location of the powerhouse in relation to the river channel indicates that spill conditions could impact shad movement and behavior at all monitoring sites chosen, including the powerhouse. Therefore, four flows were evaluated, including: no spill, low (1500-10,000 cfs), moderate (13,800-23,700 cfs), and high (25,500-36,800 cfs) spill conditions.

2.7 Data Retrieval and Analysis

Data were off-loaded daily from the receivers with a portable computer and stored on 3 1/2" diskettes. Backup diskettes of all telemetry data were made prior to receiver initialization. Backups were stored in a fireproof vault.

Data were critically analyzed to determine the validity of records. Those events deemed not credible due to suspect power level, deviation, or site/time location were discarded. Fish detected concurrently (within a one minute interval) on two or more antennas set at the same detection level (gain) were assigned to the antenna site with the strongest signal strength. If a fish was detected concurrently at a site where two antennas scanned the same area, one set at high detection level and the other low, the fish's location was assigned to the antenna site with the low detection level. Three sites (Holtwood spill pool, York Haven Dam and Red Hill Dam) were set up this way. Fix locations obtained on date of release through the next 15 days were retained for analysis. Data beyond 15 days were obtained on some fish released on different dates that were tagged with transmitters having the same carrier frequency. This additional data was not used in analysis so all fish would be monitored for the same amount of time. Due to the large volume of data retrieved, Statistical Analysis System (SAS) software was used to organize and edit files.

2.7.1 Location Preference

Location preferences of shad were determined through three variables: (1) duration; (2) number of forays; and (3) the number of fish detected at various monitoring locations. Duration, defined as the amount of time fish remained in the vicinity of an antenna site, was determined by assigning a minimum time interval of 1 minute to each recorded fix. If a fish was located again at the same site within two to ten minutes after the initial fix, duration time was the difference between the two fixes. Two consecutive fixes at the same location greater than ten minutes apart were each assigned one minute. Consecutive fixes at different antenna sites, regardless of time between them, were each assigned a duration of one minute. Comparison of durations by fish at the different antenna sites was determined by ranking the time periods (total minutes) each fish was detected at each of the antennas at the respective powerhouses for each evaluated scenario. The top three sites were deemed representative of what site(s) were preferred. When preferred sites had identical duration times, the site having the longest duration time at an antenna site adjacent to it was given the higher rank. Duration times for each fish at each antenna site during different generation/flow conditions are presented in Appendices A through C (Vol. II). The median duration periods for the fish residing at each antenna site were also compared.

In order to assess frequency of movement into and out of a site the data were summarized to detect "forays". A foray was defined as an initial detection at a given site. A single foray was assigned as long as that fish was detected at least one additional time within a 5 minute time period provided it was not detected at another site. If the fish was detected a second time at the same site after 5 minutes or it was detected at another site before returning to the initial site it was assigned an additional foray. For example, if a given fish was located at 0901, 0902, 0904, 0906, and 0911 h at site 1 and 0903, 0905, 0912, and 0914 h at site 2, site 1 would be assigned four forays and site 2 would have three forays. The foray data was evaluated and compared in the same manner as the duration information. Detailed data on number of forays of each fish to different sites are presented in Appendices A through C (Vol. II).

Monitoring locations which detect the highest number of fish during various flow scenarios evaluated would ultimately represent preferred locations. Therefore, preferred locations were also based on the number of fish that were detected at least once at each antenna site.

2.8 Evaluation of Tagging and Transport Techniques

To evaluate the potential stress/mortality effects of tagging and transport, a pretest was conducted. Concern was raised over the diameter of the coded tags (14 mm) and its potential effects on specimens during tagging and transport. Fish were selected and fitted with dummy tags identical in size and shape to the coded tags. These fish were placed into a transport trailer or transport truck and their overall condition and behavior was evaluated after they had been retained at the tagging site for approximately 20 h or transported to planned release sites. Several modifications in tagging and transport procedures were undertaken to obtain >90% survival upon arrival at the release site for dummy tagged fish.

The information obtained and analysis of that information for Holtwood, Safe Harbor and York Haven stations are presented separately in Sections 4, 5, and 6, respectively. Discussion and recommendations for each project are also included with its respective section.

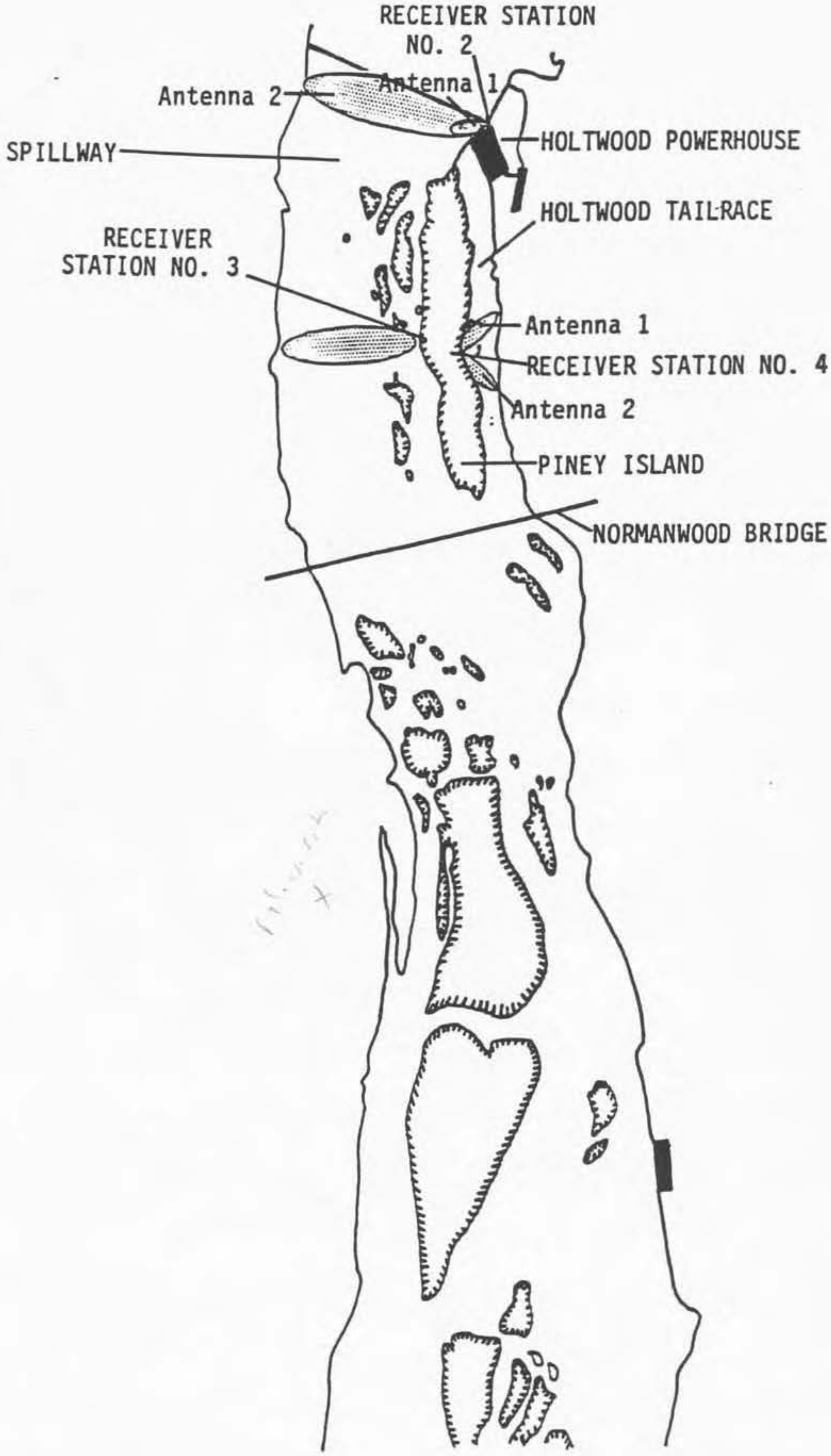


Figure 2-1

Reception areas of continuous monitor stations in the vicinity of the Holtwood Project.

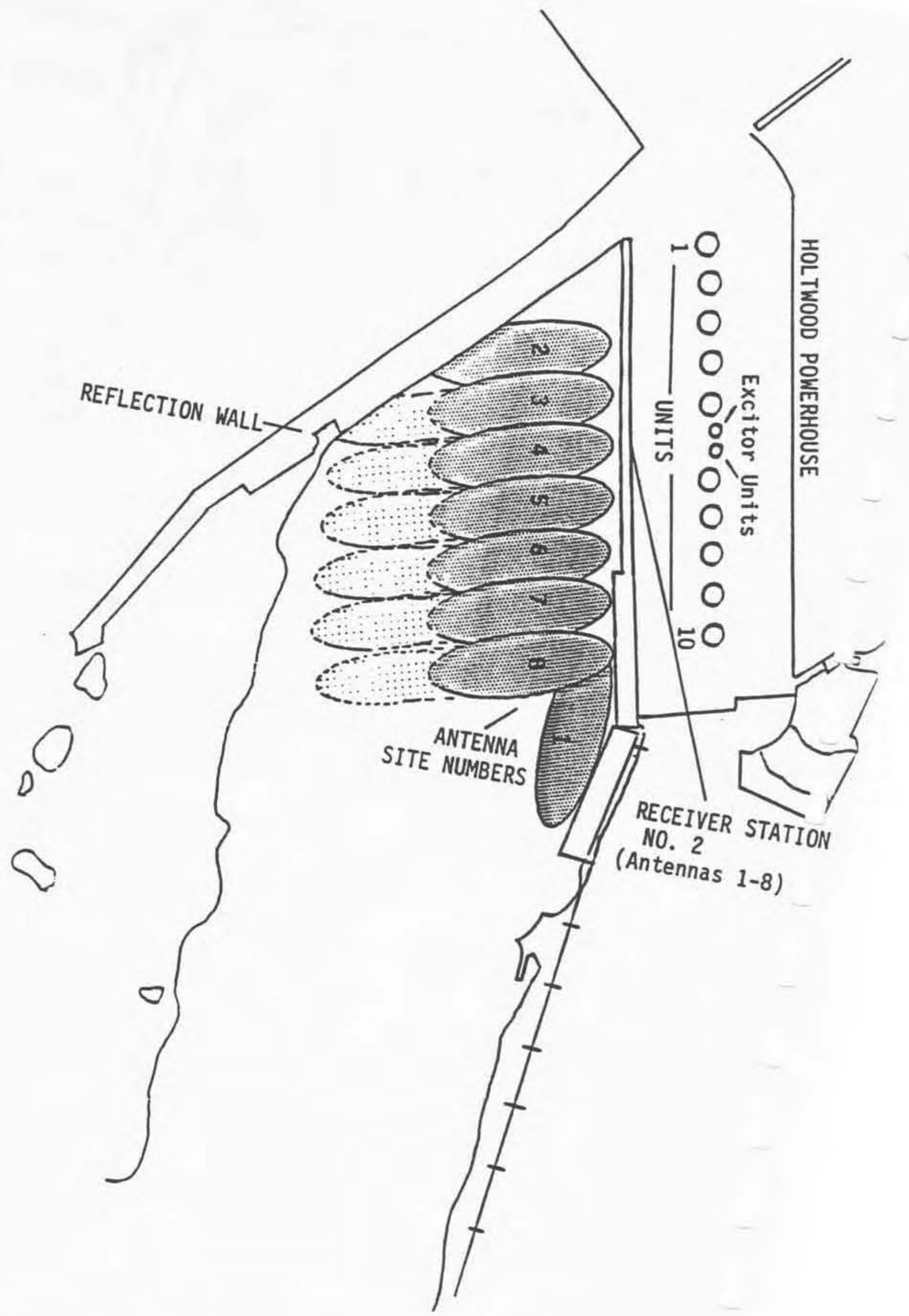


Figure 2-2

Reception areas of continuous monitor stations at Holtwood Station.

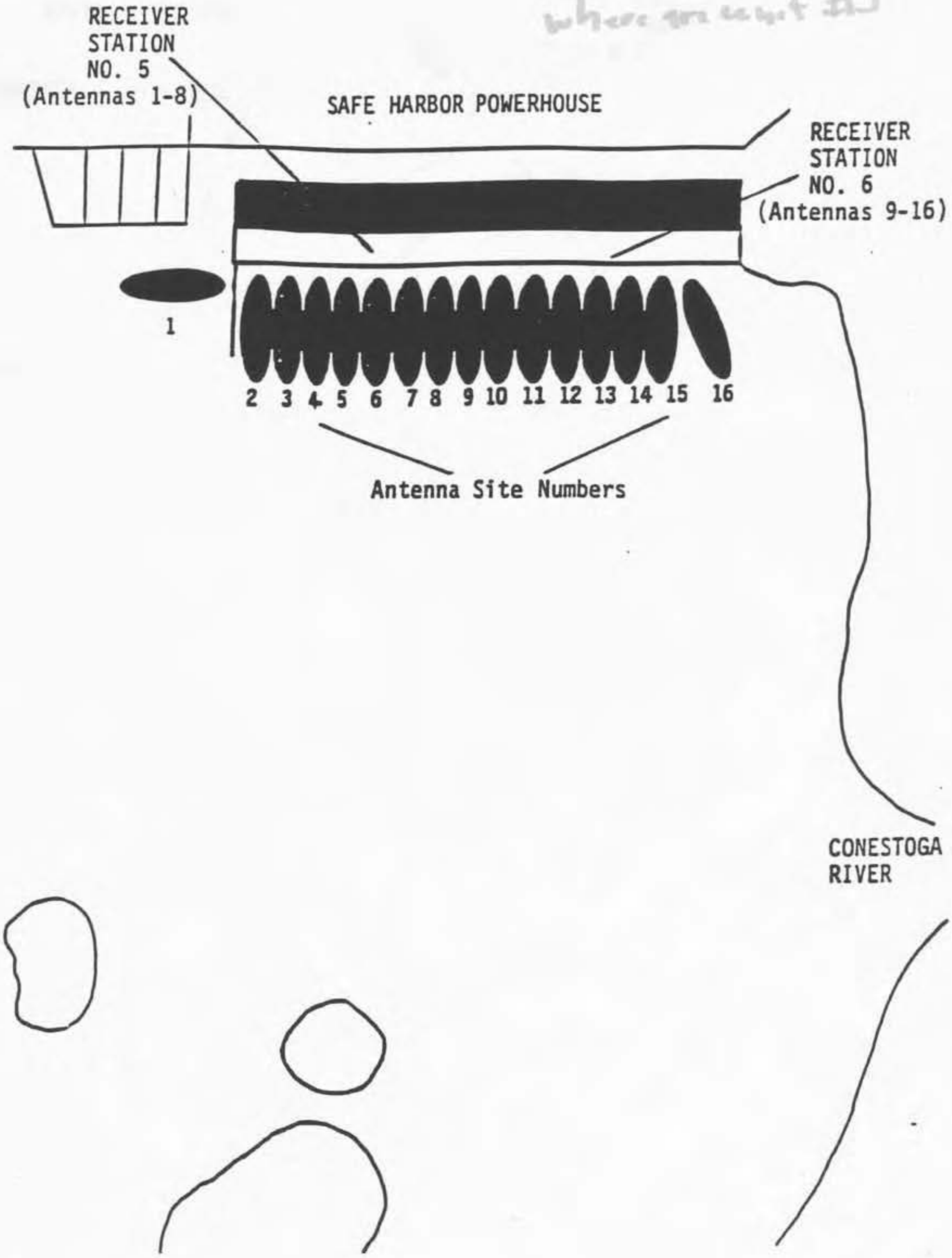


Figure 2-3

Reception areas of continuous monitor stations at the Safe Harbor Station.

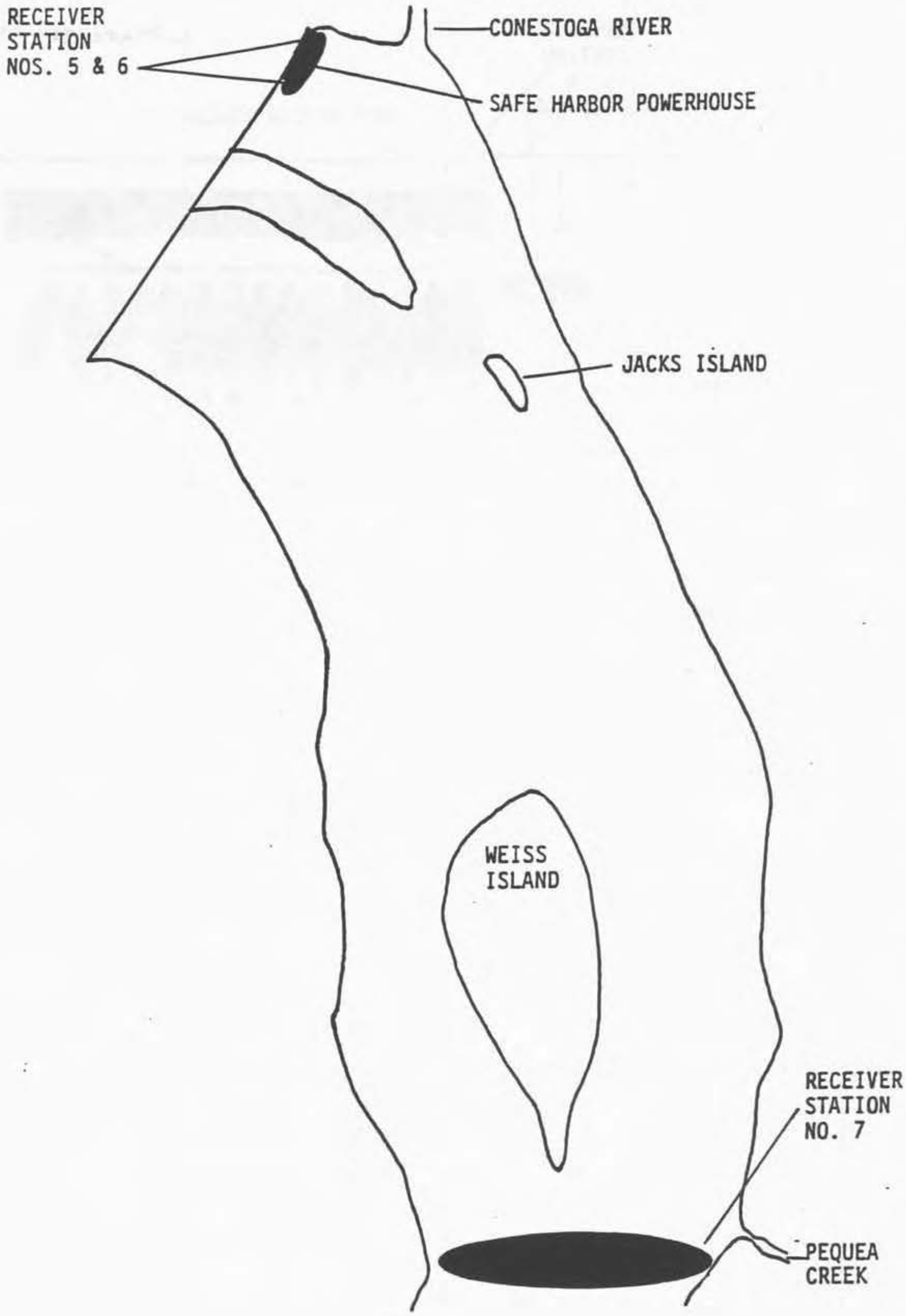


Figure 2-4

Reception areas of continuous monitor stations in the vicinity of the Safe Harbor Station.

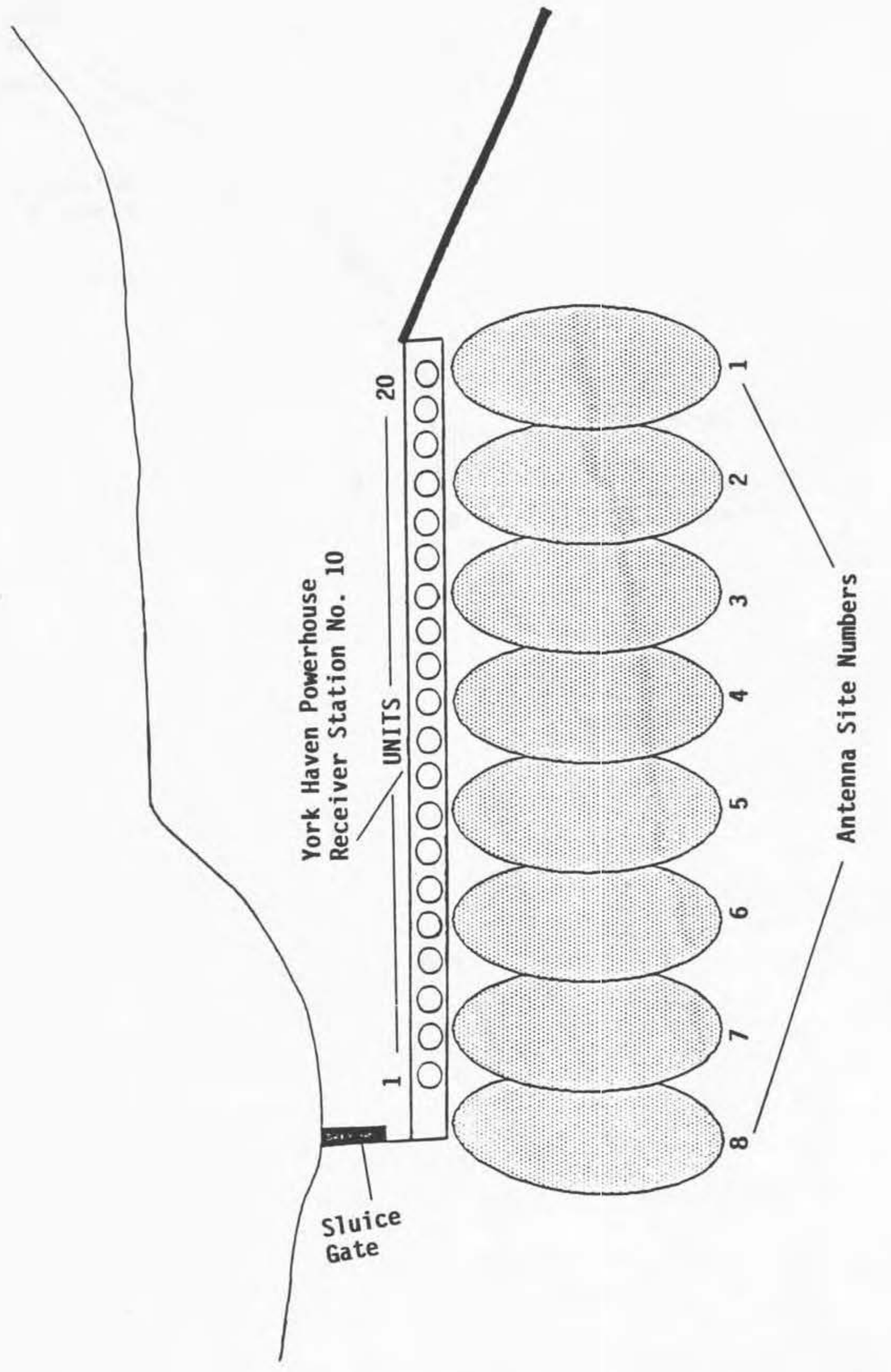


Figure 2-5

Reception areas of the York Haven Powerhouse monitor station.

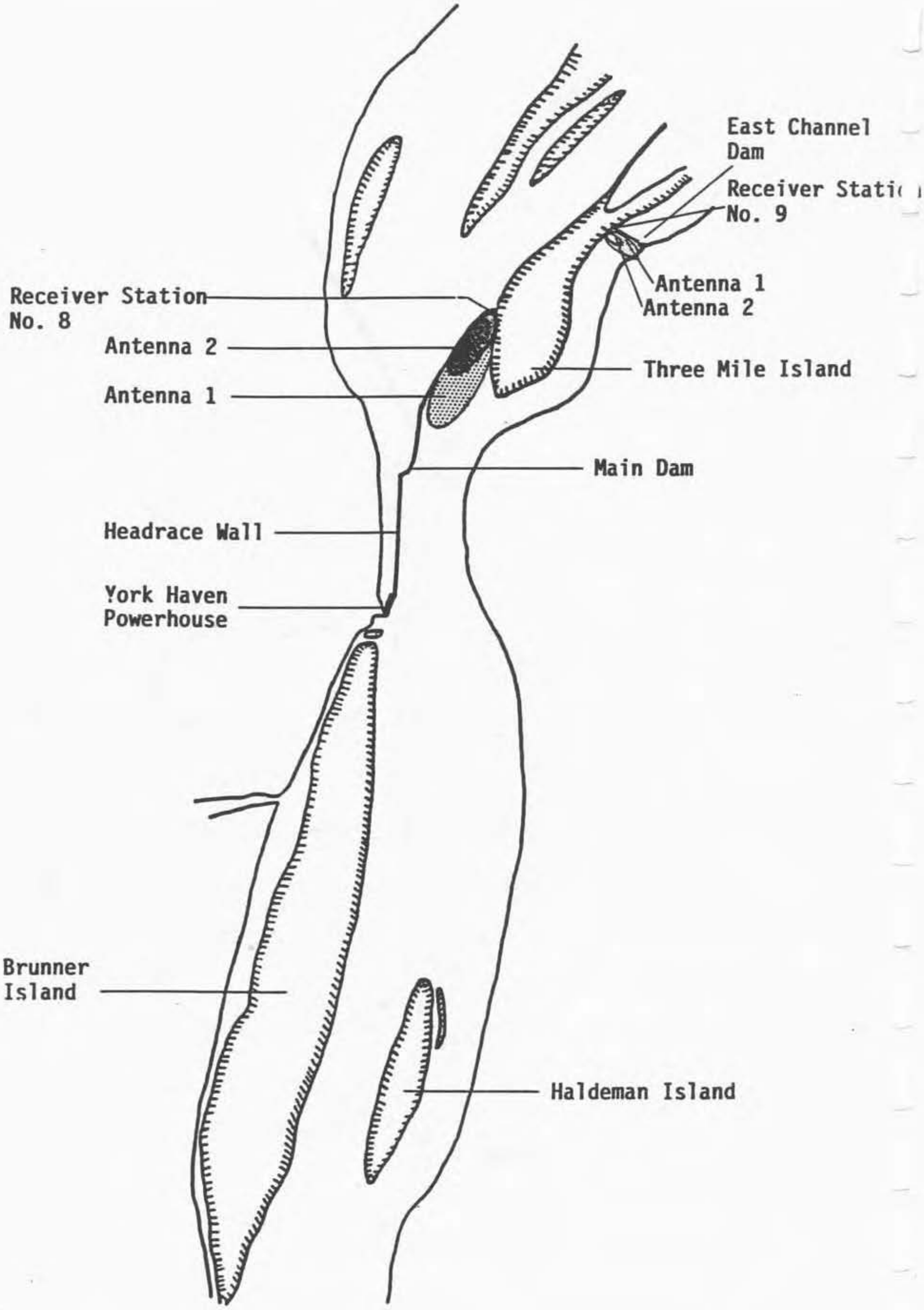


Figure 2-6

Reception areas of the Main and Red Hill Dam monitor station.

3.0 RADIO TAGGING AND TRANSPORT - PRE-TEST AND EQUIPMENT: RESULTS, DISCUSSION AND RECOMMENDATIONS

3.1 Results

Seventy-seven shad were tagged with dummy radio tags to evaluate the tagging and transport techniques and to establish a specimen size range capable of readily accepting the 14 mm diameter tag. Survival was low (40%) for the first group of 25 controls held in a transport trailer at the east side collection facility approximately 20 h. Modification in tagging and transport technique resulted in 96 and 100% survival in two subsequent pretest lots of fish transported to furthest and closest planned release sites, respectively. It was determined that specimens had to be greater than 400 mm to readily accept the 14 mm diameter tag and that fish taken from the west lift and transported on trucks were in better condition than fish from the east lift transported in trailers.

3.2 Discussion And Recommendations

3.2.1 Procedures

The procedures established for collecting, tagging, transporting, and monitoring adult shad were sufficient to meet most study objectives at the three study sites. A high percentage of the tagged fish reached each study site and resided for a sufficient time period to provide massive numbers of individual location fixes. Maintaining extreme care of the specimens during all handling procedures enhanced the probability that most fish would not drop out of the study area upon release. Collecting test fish from the west fish lift at Conowingo and transporting them in a tank truck proved to be better than using fish at the east fish lift and transporting them in trailers. Additional handling at the east fish lift and vibration in the transport trailers may have contributed to lower survival and poorer condition of the pre-test fish.

3.2.2 Equipment

Some of the telemetric equipment performed exceptionally well, while other items had some shortcomings. Lotek coded tags performed well with regards to reliability and signal transmission, however, the diameter of the tags was too large to readily pass the esophagus of specimens less than 400 mm (fork length). Consequently, little information was obtained on the smaller fish, perhaps males. The diameter of the transmitter should be decreased from the present 14+ mm to about 10 or 11 mm.

The antenna wire on the tag was also too stiff. A stiff antenna wire may affect the swimming ability of the fish since it protruded in front of the mouth rather than lie close to the fish's body. The antenna wire should be constructed from thinner, more pliable wire, similar to that on tags supplied by another manufacturer for previous adult shad telemetry studies.

The receiver/antenna array performed well in detecting fish at the projects and differentiating the specific areas approached; however, the receiver software should be modified to reduce the massive number of individual fixes. The receivers performed satisfactorily in detecting fish at the fixed sites set up in the tailraces, but different antenna arrays may be needed at some sites to obtain detailed movement patterns, particularly at potential fishway entrances.

A problem occurred when fish were monitored by airplane. Frequently, the biologist audibly detected a signal while flying but the receiver failed to decode the signal and detect the corresponding fish. Manual tracking proved to be almost impossible because of the long interval (5 seconds) between signal pulses.

The equipment performed well but several modifications are needed to ensure less stress to the fish and facilitate data collection. Signal propagation characteristics of the coded tags should be modified so these tags can be manually tracked. This could include shortening the time interval between pulses to 2 seconds or less (presently 5 seconds). Tag signal strength could also be increased without jeopardizing tag life. The present tags are designed to operate for about one year, 2-3 months would be sufficient. The receivers should be modified to better decode signals which are audible to the biologist; since the signals are coded the biologist can not identify the fish. The receiver software must also be modified to combine multiple continuous fixes on a given fish into a single record without losing any information.

4.0 HOLTWOOD: RESULTS, DISCUSSION, AND RECOMMENDATIONS

4.1 RESULTS

Radio tagged American shad were monitored in the vicinity of Holtwood Hydroelectric Station to provide biological support data on future fishway locations. Specifically, the Holtwood Hydroelectric Station tailrace and the spill area below Holtwood Dam were monitored (Figures 2-1 and 2-2. A high percentage (81%) of the fish moved to the Holtwood Project with more (74%) moving into the spill area than the tailrace (52%). Fish were strongly attracted toward an area in the tailrace near the middle of the powerhouse; however, it was not discernable if the fish were near the powerhouse, mid-channel or far shore. Many (41%) shad moved to the base of the dam and it appears a high portion remained there during non-spill periods.

4.1.1 Tagging And Transport of Test Specimens

A total of 100 tagged fish was released for the Holtwood study (Table 4-1). Fish were released in four separate groups: 25 on 4 May, 24 on 10 May, 26 on 19 May, and 25 on 27 May. Transport times to the Muddy Creek Access release site ranged from 45 to 50 min (X = 48.5 min). One additional fish tagged for the second release group regurgitated its tag during transport and was subsequently replaced in the following release group. The release site is 2.5 miles downstream of the Holtwood Project and is on the dam side of the river.

4.1.2 Shad Movement to the Holtwood Study Area

Eighty-one (81%) of the tagged shad were detected at four monitoring sites in the vicinity of the Holtwood Project: upper and lower tailrace and the upper and lower spill area below Holtwood Dam (Table 4-2 and Figures 2-1 and 2-2).

Shad movement to the Holtwood Project was high for release groups 1-3; ranging from 88% (release group 3) to 92% for release groups 1 and 2. Only 52% of the last release group were detected at any of the four Holtwood monitoring sites.

Initial detection at the Holtwood Project revealed most fish moved toward the spillway area when spillage was offered. During spillage 29 of the fish were first located in the spillway and 15 were located in the tailrace. During non-spill 12 moved initially toward the spillway while 25 moved up the tailrace.

Some 52 of 81 (64%) shad detected at the Holtwood Project moved into the tailrace. Forty-nine of these were detected in the upper tailrace area by the powerhouse. Three fish escaped detection at the lower tailrace site on their way to the powerhouse (Table 4-2). Detection along the eight powerhouse antenna sites ranged from 44 at site 1 to 47 each at sites 5 and 6 (Table 4-2). Greater than 89% of shad detected in the upper tailrace were located at all monitoring locations.

Seventy-four (91%) of 81 fish that reached the Holtwood Project were detected in the spillway area (Table 4-2). Some 45 (61%) of these fish moved to the base of the dam. Movement to the base of the dam was highest for release groups 1 and 2, with 15 and 13 fish, respectively. Nine and 7 fish in the last two groups reached the dam.

Fish did not remain exclusively in the spillway or tailrace area. Forty-five (61%) of the 74 fish that moved into the spillway also moved to the tailrace (Table 4-2). Only 5 fish were detected solely in the tailrace while 29 moved only to the spill area.

Shad residency in the Holtwood area was monitored for 15 days. Some 8 fish were only located on one of the 15 days each fish was monitored. A total of 53 fish was detected at least 5 days, and 36 were monitored in excess of 10 days.

4.1.3 Location Preference in the Tailrace Relative to Station Generation

Shad movement and behavior patterns in Holtwood tailrace were evaluated under four generation scenarios which occurred in the spring (Table 4-3). When sufficient river inflow to Holtwood is available, the station operates at maximum discharge (32,000 cfs). Because Piney Island separates the tailrace and spill areas, spillage does not increase total discharge in the tailrace. Generation at Holtwood depends on actual river flow and the generation schedule for

Safe Harbor Station. Full generation (32,000 cfs) occurred most often and was monitored for 729.9 hrs (Table 4-3). The least frequent scenario (12,800-19,200 cfs) was monitored for only 27.4 hrs.

The receiver that monitored the upper tailrace was coupled to eight Yagi antennas spaced across the stoplog gallery (Figure 2-2). Antenna 1 was positioned just downstream of Unit 10 to detect fish in the downstream peripheral area of the Unit 10 discharge. The remaining antenna sites (2-8) were evenly spaced across the discharge areas of Units 1-10 and the two house units. Due to the complexity of the Holtwood Project most data are presented independently for the monitoring stations at the tailrace and spill area.

The powerhouse locations preferred (see Section 2.7.1 for method of preference calculations) by shad at all generation scenarios are presented in Figure 4-1). Locations preferred at each generation scenario are presented in Figures 4-4 to 4-7.

4.1.4 Shad Behavior During 1 to 3 Unit Generation (3200-9600 cfs)

Generation conditions of 3200-9600 cfs, 1 to 3 units, occurred for 102.9 hrs during monitoring at Holtwood (Table 4-3). Only combinations of Unit Nos. 7-10 and the two excitor units which are located in the middle of the powerhouse were operated during this scenario. Fish from release Group 3 were monitored most for this scenario (Table 4-3). A total of 27 shad were monitored at the station. Sixteen and 25 shad were detected during day (7AM-7PM) and night (7PM-7AM) monitoring, respectively.

During day monitoring shad, in general, were detected equally ranging from 13 to 15 at all antenna sites (Table 4-4). The highest detection (15 fish) was at antenna sites 1 corresponding to Unit 10 and sites 3-5 which correspond to Units 4-6 and the excitor units. Fish spent most time in the vicinity of antenna site 5 where the median duration was 12 min. Median duration at the other sites ranged from 3-8 min. The highest number of forays also occurred at antenna site 5 (median = 8) and distribution across the other sites was similar to the duration data. Preference analysis of the duration and foray data indicated sites 4 and 5 were highly preferred (Table 4-5 and Figure 4-2).

During night monitoring, distribution of shad was also near equal as that for day monitoring, ranging from 20 at antenna site 8 to 23 at site 6 (Table 4-4). Fish again spent the most time and made the most forays at site 5. Both values were considerably higher at night with respective median values of 55 min and 30 forays. Preferred sites were 4 and 5 and they were ranked first, second or third in duration and forays for 20 to 22 fish (Table 4-6 and Figure 4-2).

4.1.5 Shad Behavior During 4 to 6 Unit Generation (12,800-19,200 cfs)

Some 23 shad were detected during 27.4 hrs of 12,800-19,200 cfs generation. A combination of all units was operated during this scenario. However, Unit Nos. 5-10 were utilized most (Figure 4-3). Release group 3 was monitored the most during this scenario at 22.1 hrs (Table 4-3). Some 16 shad were located during day monitoring and all were located at night.

During day monitoring the number of shad detected ranged from 7 at sites 7 and 8 to 12 at site 5 (Table 4-4). Maximum duration (104 min) and number of forays (38) were again observed at site 5; however, this site was not markedly better than the other sites. The respective median values ranged from 0.5-3 minutes and 0.5-2 forays. Site 5 was the primary preferred area (Table 4-7 and Figure 4-3).

A similar pattern observed during day monitoring was observed at night with most fish, 21 and 20, being detected at Units 5 and 6 (Table 4-4). The duration and forays were not concentrated at site 5 during the night, but these values were more evenly distributed over sites 4 through 10. The highest medians were at site 8 (duration of 12 min) 5 and 6 (forays of 8). However, site 5 was ranked highest in the preference analysis (Table 4-8 and Figure 4-3).

4.1.6 Shad Behavior During 7 to 9 Unit Generation (22,400-28,800 cfs)

Generation conditions of 22,400-28,800 cfs were monitored for a total of 75.8 hrs during the course of study (Table 4-3). A combination of all units was operated during this scenario.

Release groups 1 and 3 were monitored near equally at these flows for 40.4 hrs and 35.3 hrs, respectively. A total 31 fish was monitored; 29 fish during the day and 21 at night.

The number of fish detected at each antenna site during the day ranged from a minimum of 23 at site 8 to a maximum of 28 at site 6 (Table 4-4). Duration and forays were also highest at site 6. The respective median values were 19 min and 15 forays. This site was also most preferred with site 5 a close second (Table 4-9 and Figure 4-4).

During night monitoring, the maximum number of fish detected was 19 at site 5 (Table 4-4). Fish did not appear to congregate near any particular unit, as noted during most other flow scenarios. Duration and forays were not vastly different between sites. Respective median values ranged from 2 to 8 min and 2 to 7 forays. Sites 4-6 were similarly preferred (Table 4-10 and Figure 4-4).

4.1.7 Shad Behavior During 10 Full Unit Generation (32,000 cfs)

Full 10 unit generation (32,000 cfs) occurred for a total of 729.9 hrs. Each release group was monitored for a similar amount of time. A total of 49 shad was monitored. All were monitored during the day and 40 of these were detected at night (Tables 4-3 and 4-4).

During day monitoring, in general fish were detected nearly equal at all eight antenna sites but the rate of forays and duration varied greatly across the eight antenna sites (Tables 4-4 and 4-11). Highest duration and foray values were again at site 5, with 4 a close second. Site 5 was the primary preferred site (Table 4-11 and Figure 4-5).

Night monitoring indicated a trend similar to day monitoring at full generation. Fish were again detected nearly equal at the eight antenna sites. Detection ranged from 30-34 fish with the most being detected at site 8. Site 5 again recorded the most time spent (median 24.5 min) and number of forays (median 16). It was also the most preferred site (Table 4-12 and Figure 4-5).

4.1.8 Shad Movement in Spillway Area

Shad movement and behavior patterns in the vicinity of the Holtwood Dam spillway were evaluated under no spill and spillages of 200-14,900 cfs and > 14,900-30,900 cfs. This evaluation encompassed all spill events which occurred at Holtwood in spring 1992. The amount of time for each condition was 372.1, 417.9, and 143.9 hrs, respectively (Table 4-3).

In general, during spring months, spill conditions at Holtwood can frequently occur and are related to natural river flows and the generation capabilities of Safe Harbor Dam. The hydraulic capacity of Safe Harbor is 110,994 cfs which is 3.5 times greater than that of Holtwood. Therefore, it is possible for spillage to occur regardless of natural river flows. Piney Island separates the tailrace and spillway areas and excludes Holtwood Station releases from the spillway area (Figure 2-1).

Two monitoring stations detected fish movement in the spillway below the Holtwood Dam (Figure 2-1). Shad migrating to the base of the dam were detected by two Yagi antennas. One antenna was calibrated to detect signals along the length of the dam and the other only detected shad entering the Northeast corner of the dam which is closest to the powerhouse. In order to assign approximate locations of fish detected by these antennae, fish were removed from the far field (high gain) antenna when they were concurrently detected on the short range antenna. Fish remaining on the far field antenna were likely located mid to western side of the spillpool. A single high-gain antenna located approximately mid-way along Piney Island detected fish approaching and leaving the dam and those taking up temporary residence in the lower spillway area.

4.1.9 Shad Behavior During No Spill

Fish were present at both the lower spillway area and at the base of the dam during the non-spill scenario. Some 48 of the 74 fish detected in the lower spillway area were present when spillage was curtailed (Tables 4-2 and 4-13). Individual fish were detected for a minute up to 14.6

hrs (877 min) in the lower spillway with a median duration time of 14 minutes. Forays into this area ranged from 1 to 234 with a median of 9. The routes fish traveled in this area during non-spillage are not known.

Twenty-four and 10 fish were detected far field and near field, respectively in the spillpool area below the main dam (Table 4-13). Fish likely remained in pools near the base of the dam upon spillage curtailment. The time spent was much higher for fish in the mid-west spill area than along the eastern shore. Duration ranged from one minute to 104.7 hrs (6283 min) and one minute to 9.1 hrs (545 min) for the far field and near field sites, respectively. The corresponding median durations were 4.3 and 0.5 hrs. Number and range of forays were also higher for the mid-west side, but the median values were higher for the eastern corner (21 vs 4).

4.1.10 Shad Behavior During 200-14,900 cfs Spill

Fish utilization of the lower spillway area at 200-14,900 cfs spillage was similar to that observed during non-spill. The 45 fish detected in the area had a median duration time of 29 min and median forays of 8 (Table 4-13).

The highest number of fish detected at the dam coincided with this spillage. Some 29 fish moved to the mid-western spillpool area and 17 were located near the eastern shore (Table 4-13). Time spent was again considerably higher for the mid-western spill area than the eastern area. A total of 351.4 hrs (21086 min) were spent by fish in the mid-western area compared to only 38.1 hrs (2285 min)in the northeast corner. The respective median durations were 5.2 (312 min) and 1.0 (59.5 min) hrs. The total number of forays was also much higher for the mid-western area, but median values were similar.

4.1.11 Shad Behavior During 15,200-30,900 cfs Spill

The highest spillage scenario (15,200-30,900 cfs) attracted the least number of fish to both the lower spillway and near dam monitoring sites (Table 4-13). Twenty-five fish were located in the lower spillway while 13 and 6 were present at the mid-western and eastern spillpool area, respectively. Total time spent and number of forays was least at all three sites during this spill scenario. Median duration times were 9.5, 143, and 60 min for the lower, mid-western and eastern sites. The respective median foray values were 4, 18, and 9.5 (Table 4-13 and Figure 4-6).

4.1.12 Diel Movement of Shad in the Tailrace

Diel movement was examined for fish approaching the powerhouse. The number of fish monitored per hour at the powerhouse ranged from 29 to 41 (Table 4-14). Most fish (40 or 41) were detected between 2 and 5 PM. Fish were least abundant (29-32) from 9 PM until 3 AM. Intermediate numbers of fish were present at the other times.

A previous study at Holtwood revealed there was a tendency of fish to move out of the tailrace during the evening and congregate in a pool area south of Piney Island. These fish made repeated runs back to the tailrace at or near daybreak.

4.2 Discussion

4.2.1 Potential Fishway Site(s)

Based on the number of forays, time spent, and preference analysis it appears that the best location for a fishway entrance would be near mid-powerhouse (site 5). However, detection range of the seven antennas facing across the tailrace likely covered the entire width of the tailrace, not just in front of the units, as originally intended. Therefore, fish congregating at site 5 could have been near the powerhouse gallery, mid-channel or even on the far side of the tailrace channel. Based on manual fixes of tagged shad that reached the Holtwood powerhouse in 1989 (RMC 1990), many fish congregated in the mid- to far side of the channel depending on station discharge (Figure 4-7). A rock shelf approximately mid-tailrace channel is inundated when the station is near full capacity. Many of the manually tracked fish were in the main channel near the base of this shelf when the shelf was exposed. Fish were located on the shelf area at high flows. Fish may have been distributed similarly in the present study, but there is also the chance that fish were attracted toward an area of modified currents associated with the two house units. This is similar to preference observed at the Safe Harbor Station (see section 5.4.3). A more extensive antenna system and/or manual tracking is needed at Holtwood to clarify fish distribution laterally across the tailrace.

4.2.2 Utilization of Spillway Area

Detailed movement patterns and behavior of shad in the lower and upper spillway area were not readily obtainable by the monitor/antenna deployment set-up. The single high gain antenna deployed mid way along Piney Island provided general information on fish in the mid to lower spillway area; however, high duration and foray values during non-spill operations may indicate that the antenna detected fish in inundated areas beyond the desired detection zone or a high percentage of the fish remain in pools throughout the lower spillway area. Additional calibration and field observations should help clarify this issue.

The long range antenna set up to monitor the pool area at the base of the dam provided information on presence and general location of fish but was not sufficient to ascertain if the fish were near the middle or western side of the dam. A biologist fishing the area this spring observed adult shad in pools at the base of the dam. He estimated that 30 to 40 fish were in two main pools that exist in the area. (Steve Adams, personal communication). A large concrete and rock barrier separates these two pools. He also noted a few dead shad near these pools. The high duration times for some of the tagged shad supports the contention that shad can become stranded in the spillway area when spills are terminated.

The present study indicates a fishway maybe warranted for the spillway area. An open channel along the base of the dam would provide access to a passage facility sited on either shore.

4.2.3 Influence of Release Site

The spillway area was utilized to a greater extent by migrating shad than the tailrace. More than 90% of all the fish detected in the vicinity of the Holtwood Project were located in the spillway. This contrasts to only 68% of the fish moving into the tailrace. Utilization of the tailrace area was more pronounced this year than previously observed (RMC 1990) and may be related to release location. The Muddy Creek Access Area is along the spillway side of the river and is also closer than the release sites used previously (Baltimore Water Intake, Glen Cove and Peach Bottom). Tracking information from these previous fish releases indicated fish favored the mid and eastern side of the river when in the vicinity of the Muddy Creek Access (Figure 4-8).

4.3 Recommendations

4.3.1 Release Procedures

The basic tagging and transport procedures employed for the study should be repeated for an additional 100 shad in 1993. The release location should be moved to a location where the fish are likely to disperse naturally upstream. Releasing the fish too close to the spillway or tailrace sides of the river likely biases the frequency of utilization for these sites. Possible release sites could be Peters Creek or Conowingo Creek on the East side of the River and Glenn Cove on the West. Fish have been successfully released from Glenn Cove in the past. Another option would be to place fish into the east side fishway exit flume. Fish from this release point should take the most normal routes to the Holtwood Project. The chances for flume released fish to migrate to the Holtwood Project could be enhanced by removing and replacing with fresh substitutes, tagged specimens that do not voluntarily exit the flume within 24 hr. This procedure enhanced upstream migration rates for tagged shad at the Eldred L.Field Station on the Merrimack River (RMC 1988c).

4.3.2 Monitoring Site Modification

The set-up of automatic monitoring sites in the vicinity of the Holtwood Project should be changed. The tailrace monitoring site, approximately midway along Piney Island, should be redeployed just upstream of the Norman Wood Bridge. The tailrace is shallowest (< 15 ft) in this area which will ensure good radio signal detection. Monitoring should be modified and expanded in the vicinity of the powerhouse to ascertain whether fish are near the powerhouse gallery, mid-channel and/or along Piney Island and the reflector wall. Some field tests should be conducted to ascertain correct receiver/antenna placement to delineate greater resolution on fish locations. Possible antenna arrays could include a combination of short and long range antennas deployed along the powerhouse gallery coupled to one receiver. Another similar set-up could be deployed along the northeast corner of Piney Island and the adjoining reflector wall (see Figure 4-9).

Movements toward and away from the spillpool should be monitored again by a high gain antenna positioned near the lower end of Piney Island. The spillpool at the base of the dam should be monitored from both shores with a long and short range antenna combination.

4.3.3 Test Conditions

Manipulation of station and spill releases at Holtwood are not readily accomplished; however, if possible, termination of a spill event should be studied to ascertain whether there is any correlation between shad entrapment in the spillway area and rate of spill stoppage. When conditions permit, spillage could be stopped gradually or promptly. In addition to telemetric monitoring, visual inspections could be made of the primary pools at the base of the dam approximately 24 hr after spill termination.

Table 4-1

Summary of American shad releases at the Holtwood Hydroelectric Station, spring 1992.

Release Group	Tag and Release Date	Water Temperature (C) Tagging Site	Water Temperature (C) Release Site	Number of Fish Tagged	Transport Time (minutes)	Release Site	Number of Fish Released	Number of Fish Detected at Project	Number of Fish Detected Elsewhere	Number Dead or Regur-gitated After Release
						Muddy Creek Boat Launch				
1	5/4/92	17.5	16.5	25	50	"	25	23 (92%)	0	0
2	5/10/92	15.5	15	25	49	"	24	22 (92%)	0	0
3	5/19/92	21	20	26	50	"	26	23 (88%)	1	0
4	5/27/92	21	21.5	25	45	"	25	13 (52%)	5	0

Table 4-2

Listing of radio tagged American shad monitored by release group at the Holtwood Hydroelectric Station, May - June 1992.

Release Group		Powerhouse								Lower	Spillpool		Lower
(Date Released)	Fish #	1	8	7	6	5	4	3	2	Tailrace	Total	East	Spillway
1 (04May92)	1.1										x		x
	1.2										x		x
	1.3	x	x	x	x	x	x	x	x	x	x	x	x
	1.4										x		x
	1.5										x		x
	1.7										x	x	x
	1.8	x	x	x	x	x	x	x	x	x	x		x
	1.9	x	x	x	x	x	x	x	x	x	x	x	x
	1.11	x	x	x	x	x	x	x	x	x			x
	1.12	x	x	x	x	x	x	x	x	x	x		x
	1.14												x
	1.15	x	x	x	x	x	x	x	x	x			x
	2.1	x	x	x	x	x	x	x	x	x	x	x	x
	2.2		x		x	x	x	x	x	x	x	x	x
	2.3									x	x	x	x
	2.5	x	x	x	x	x	x	x	x	x	x	x	x
	2.6									x			
	2.7	x	x	x	x	x	x	x	x	x			x
	2.8	x	x	x	x	x	x	x	x	x	x		x
	2.12									x			x
	2.14	x	x	x	x	x	x	x	x	x	x		x
	2.15	x	x	x	x	x	x	x	x	x			x
	2.17												x
Total	23	12	13	12	13	13	13	13	13	16	15	7	22

Table 4-2

Continued.

Release Group (Date Released)	Fish #	Powerhouse 1	8	7	6	5	4	3	2	Lower Tailrace	Spillpool Total	Spillpool East	Lower Spillway
2 (10May92)	2.9	x	x	x	x	x	x	x	x	x	x		x
	2.10												x
	2.11										x		x
	2.13										x		x
	17.2										x	x	x
	17.3										x		x
	17.4												x
	17.5	x	x	x	x	x	x	x	x	x			x
	17.6	x	x	x	x	x	x	x	x	x	x		x
	17.7												x
	17.8										x		x
	17.10												x
	17.11		x	x	x	x	x	x	x	x	x	x	x
	18.1										x		x
	18.2					x	x						
	18.3										x	x	x
	18.4												x
	18.6										x	x	x
	18.8	x	x	x	x	x	x	x	x	x	x		x
	18.9												x
	18.10	x	x	x	x	x	x	x	x	x	x	x	x
	18.11	x	x	x	x	x	x	x	x	x	x		x
Total	22	6	7	7	7	8	8	7	7	7	14	6	21

Table 4-2

Continued.

Release Group (Date Released)	Fish #	Powerhouse 1	8	7	6	5	4	3	2	Lower Tailrace	Spillpool Total	Spillpool East	Lower Spillway
3 (19May92)	10.1	x	x	x	x	x	x	x	x	x	x		x
	10.3	x	x	x	x	x	x	x	x	x			x
	10.4	x	x	x	x	x	x	x	x	x			x
	10.5										x		x
	10.6	x	x	x	x	x	x	x	x	x	x		x
	10.8	x	x	x	x	x	x	x	x	x			x
	10.10				x	x			x	x			x
	10.11												x
	10.12												x
	10.13	x	x	x	x	x	x	x	x	x	x	x	x
	10.14	x	x	x	x	x	x	x	x	x			x
	10.15	x	x	x	x	x	x	x	x	x			x
	10.16												x
	10.17	x	x	x	x	x	x	x	x	x	x	x	x
	21.1	x	x	x	x	x	x	x	x	x	x	x	x
	21.2										x		x
	21.3	x	x	x	x	x	x	x	x	x			x
	21.5	x	x	x	x	x	x	x	x	x	x	x	x
	21.6				x			x					x
	21.7	x	x	x	x	x	x	x	x	x			x
	21.8	x	x	x	x	x	x	x	x	x			
	21.9	x	x	x	x	x	x	x	x	x	x	x	x
	21.11	x	x	x	x	x	x	x	x	x			x
Total	23	16	16	16	18	17	15	17	17	17	9	5	22

Table 4-2

Continued.

Release Group		Powerhouse								Lower	Spillpool		Lower
(Date Released)	Fish #	1	8	7	6	5	4	3	2	Tailrace	Total	East	Spillway
4 (27May92)	9.1	x	x	x	x	x	x	x	x	x	x	x	x
	9.2										x		
	9.3	x	x	x	x	x	x	x	x	x	x	x	x
	9.4												x
	9.5	x											x
	9.6										x	x	x
	9.7	x	x	x	x	x	x	x	x	x			
	9.9	x	x	x	x	x	x	x	x	x	x	x	x
	9.11	x	x	x	x	x	x	x	x	x	x		x
	9.15	x	x	x	x	x	x	x	x	x			
	25.12	x	x	x	x	x	x	x	x	x	x		x
	25.14	x	x	x	x	x	x	x	x	x			x
	25.17	x	x	x	x	x	x	x	x	x			x
Total	13	10	9	9	9	9	9	9	9	9	7	4	9
All Releases	81	44	45	44	47	47	45	46	46	49	45	22	74

Table 4-3

Number of hours four different generation scenarios and three different spill conditions were monitored for radio tagged American shad at the Holtwood Hydroelectric Station, May - June 1992.

Generation Scenario (cfs)	Release Group 1	2	3	4	Total hours *
3200-9600	2.7	36	101.8	50.4	102.9
12800-19200	5.4	14.2	22.1	12.1	27.4
22400-28800	40.5	19.7	35.3	8.6	75.8
32000	311.6	290.1	202.3	288.9	729.9

Spill Condition	Release Group 1	2	3	4	Total hours *
No spill	32.4	175.9	323.4	131.3	372.1
200-14900	263.9	164.2	18.9	114.9	417.9
15200-30900	44.8	0	0	95.9	143.9

* More than one release group was monitored during each generation scenario.

Table 4-4

Summary by station discharge (cfs) of the number of radio tagged American shad located at each antenna site in the vicinity of the Holtwood Hydroelectric Station, May - June 1992.

Generation Condition (cfs)	Time of Day	Total No. Fish Located	Powerhouse							
			1	8	7	6	5	4	3	2
3,200-9,600	Day	16	15	13	13	14	15	15	15	14
"	Night	25	21	20	22	23	22	22	21	22
"	Combined	27	23	21	22	25	24	23	23	23
12,800-19,200	Day	16	9	7	7	11	12	10	10	10
"	Night	23	15	18	19	20	21	19	16	13
"	Combined	23	15	19	20	21	22	20	17	14
22,400-28,800	Day	29	26	24	25	28	26	27	23	27
"	Night	21	12	13	17	17	19	16	14	15
"	Combined	31	26	24	26	28	27	26	23	28
32,000	Day	49	43	45	44	45	44	44	45	43
"	Night	40	31	34	32	33	33	32	32	30
"	Combined	49	43	45	44	46	45	44	45	43

Table 4-5

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during daytime generation conditions of 3,200 - 9,600 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes)				Forays (number)			
		Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	15	01:23	00:01-00:15	00:05	3	79	1--14	5	5
8	13	01:13	00:00-00:19	00:03	1	68	0--19	3	1
7	13	01:10	00:00-00:17	00:03	2	64	0--15	2	1
6	14	01:41	00:00-00:16	00:05	9	75	0--11	4	6
5	15	03:37	00:03-01:02	00:12	13	129	3--26	8	14
4	15	02:48	00:03-01:02	00:08	12	105	2--24	5	13
3	15	01:39	00:01-00:28	00:06	4	80	1--24	3	4
2	14	01:05	00:00-00:16	00:03	1	56	0--12	3	1
L Tailrace	13	04:55	00:01-01:06	00:22		44	1--9	3	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-6

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during nighttime generation conditions of 3,200 - 9,600 cfs, May - June 1992.

	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	21	05:47	00:00-01:23	00:06	1	297	0-60	5	1
8	20	03:05	00:00-00:28	00:04	1	171	0-28	4	1
7	22	07:37	00:00-01:53	00:08	4	386	0-104	8	4
6	23	18:40	00:00-02:20	00:33	19	877	0-99	21	19
5	22	42:20	00:00-05:24	00:55	21	1228	0-162	30	20
4	22	26:58	00:00-06:52	00:33	22	929	0-150	26	22
3	21	09:10	00:00-01:52	00:11	1	459	0-102	10	2
2	22	05:58	00:00-01:20	00:06	0	299	0-73	6	0
L Tailrace	19	35:46	00:02-09:03	00:32		177	1--38	5	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-7

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during daytime generation conditions of 12,800 - 19,200 cfs, May - June 1992.

	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	9	00:28	00:00-00:08	00:01	3	23	0-6	1	1
8	7	00:16	00:00-00:04	00:01	3	12	0-4	0.5	2
7	7	00:30	00:00-00:11	00:01	3	26	0-9	0.5	3
6	11	00:42	00:00-00:09	00:02	6	36	0-9	1.5	5
5	12	01:44	00:00-00:43	00:03	12	38	0-8	2	10
4	10	01:11	00:00-00:40	00:02	7	32	0-9	1.5	7
3	10	00:37	00:00-00:10	00:02	3	33	0-10	1.5	7
2	10	00:22	00:00-00:06	00:01	2	19	0-5	1	4
L Tailrace	5	01:19	00:03-00:30	00:19		4	0-3	0	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-8

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during nighttime generation conditions of 12,800 - 19,200 cfs, May - June 1992.

	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	15	02:19	00:00-00:31	00:03	1	117	0-21	2	2
8	18	03:50	00:00-00:35	00:12	8	157	0-20	7	9
7	19	03:27	00:00-00:41	00:05	9	144	0-36	4	6
6	20	04:26	00:00-00:43	00:10	12	208	0-35	8	13
5	21	06:40	00:01-01:59	00:08	16	252	1--51	8	18
4	19	07:35	00:00-03:14	00:09	14	204	0-39	6	14
3	16	03:34	00:00-00:41	00:03	3	146	0-36	3	1
2	13	01:57	00:00-00:34	00:01	0	94	0-30	1	0
L Tailrace	16	11:23	00:01-03:15	00:11		67	0-28	1	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-9

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during daytime generation conditions of 22,400 - 28,800 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
1	26	11:43	00:00-01:49	00:11	12	437	0-65	6	13
8	24	11:36	00:00-01:38	00:14	10	293	0-35	6	10
7	25	04:58	00:00-00:41	00:06	4	231	0-31	5	4
6	28	11:38	00:00-01:16	00:19	16	496	0-55	15	18
5	26	11:00	00:00-01:20	00:11	14	437	0-49	7	15
4	27	12:20	00:00-02:49	00:09	10	387	0-51	6	8
3	23	12:13	00:00-02:19	00:09	11	433	0-67	6	9
2	27	09:37	00:00-01:47	00:08	10	380	0-60	6	10
L Tailrace	23	22:21	00:02-03:44	00:30		152	0-20	4	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-10

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during nighttime generation conditions of 22,400 - 28,800 cfs, May - June 1992.

	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	12	06:30	00:00-02:05	00:03	4	236	0-66	2	3
8	13	04:28	00:00-00:51	00:06	7	174	0-38	5	6
7	17	05:37	00:00-01:16	00:02	5	244	0-50	2	3
6	17	07:49	00:00-01:47	00:08	9	307	0-62	6	10
5	19	07:36	00:01-01:24	00:07	9	328	0-54	7	11
4	16	12:11	00:00-02:09	00:08	11	357	0-62	6	12
3	14	09:56	00:00-02:39	00:05	7	324	0-68	3	8
2	15	05:11	00:00-01:17	00:07	4	219	0-45	4	3
L Tailrace	14	19:32	00:02-07:24	00:21		154	1--49	4	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-11

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during daytime generation conditions of 32,000 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes)				Forays (number)			
		Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
1	43	35:56	00:00-06:42	00:19	10	1368	0-200	14	5
8	45	41:43	00:00-04:07	00:25	17	1460	0-159	13	13
7	44	36:58	00:00-05:13	00:15	4	1620	0-214	12	9
6	45	62:12	00:00-08:37	00:32	18	2477	0-285	21.5	22
5	44	98:36	00:00-21:35	00:40	36	3107	0-300	30	35
4	44	76:42	00:00-19:31	00:37	26	2516	0-269	26	25
3	45	53:52	00:00-07:13	00:28	20	2177	0-298	20	20
2	43	37:11	00:00-04:07	00:25	6	1531	0-181	17	6
L Tailrace	47	112:02	00:01-11:38	01:28		918	1-113	8	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-12

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the Holtwood Hydroelectric Station powerhouse and lower tailrace during nighttime generation conditions of 32,000 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
1	31	09:59	00:00-01:46	00:06	3	415	0-76	4	3
8	34	27:19	00:00-04:59	00:18	18	933	0-187	9.5	18
7	32	24:38	00:00-06:52	00:10	9	979	0-239	6	9
6	33	26:10	00:00-05:08	00:14	14	1105	0-205	12	16
5	33	61:03	00:00-21:11	00:25	27	1499	0-278	16	27
4	32	45:45	00:00-18:01	00:15	20	1231	0-222	9	20
3	32	21:31	00:00-05:12	00:09	12	857	0-219	7	10
2	30	10:11	00:00-02:14	00:06	2	453	0-108	4.5	2
L Tailrace	37	127:12	00:02-13:54	02:13		1004	0-184	15	

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 4-13

Comparison of the number of radio tagged shad detected, time spent, and forays made in the spillway and spillpool at the Holtwood Hydroelectric Station during three spill conditions, May - June 1992.

Monitoring Site Description	Spill Condition	Number of Fish Detected	Duration (hours:minutes)			Forays (number)		
			Total	Range	Median	Total	Range	Median
Eastern corner (near field)	No spill	10	23:03	00:01-09:05	00:30	225	0-138	21
	200-14900	17	38:05	00:01-09:45	01:00	388	1--72	19
	15200-30900	6	08:22	00:02-04:19	01:00	87	1--52	9.5
	Combined	22	69:30	00:02-14:04	01:19	700	1-159	21.5
Mid-west (far field)	No spill	24	274:12	00:01-104:43	04:18	1117	0-308	4
	200-14900	38	351:26	00:01-47:19	05:12	1915	0-283	18
	15200-30900	13	81:32	00:10-25:22	02:23	454	0-157	18
	Combined	45	707:10	00:01-105:15	07:33	3486	1-409	40
Lower Spillway	No spill	48	60:05	00:01-14:37	00:14	849	1-234	9
	200-14900	45	93:18	00:01-15:04	00:29	1223	1-286	8
	15200-30900	25	38:32	00:01-15:41	00:10	406	1-190	4
	Combined	74	191:55	00:01-31:49	00:31	2478	1-407	11.5

Table 4-14

Hourly number of radio tagged American shad detected at the Holtwood Hydroeletric Station powerhouse, May - June 1992.

Release	Hour of day																						
Group	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	9	9	9	9	8	9	9	9	8	10	9	9	10	10	11	11	11	11	11	11	8	9	9	9
2	3	3	2	3	4	3	4	4	4	5	5	5	5	4	6	6	7	5	4	4	4	3	3	3
3	12	12	13	13	13	14	14	14	13	13	15	16	15	15	14	14	16	16	13	14	14	11	10	12
4	7	8	8	7	8	8	8	8	8	8	8	7	7	8	9	9	7	8	8	6	7	7	7	7
Total	31	32	32	32	33	34	35	35	33	36	37	37	37	37	40	40	41	40	36	35	33	30	29	31

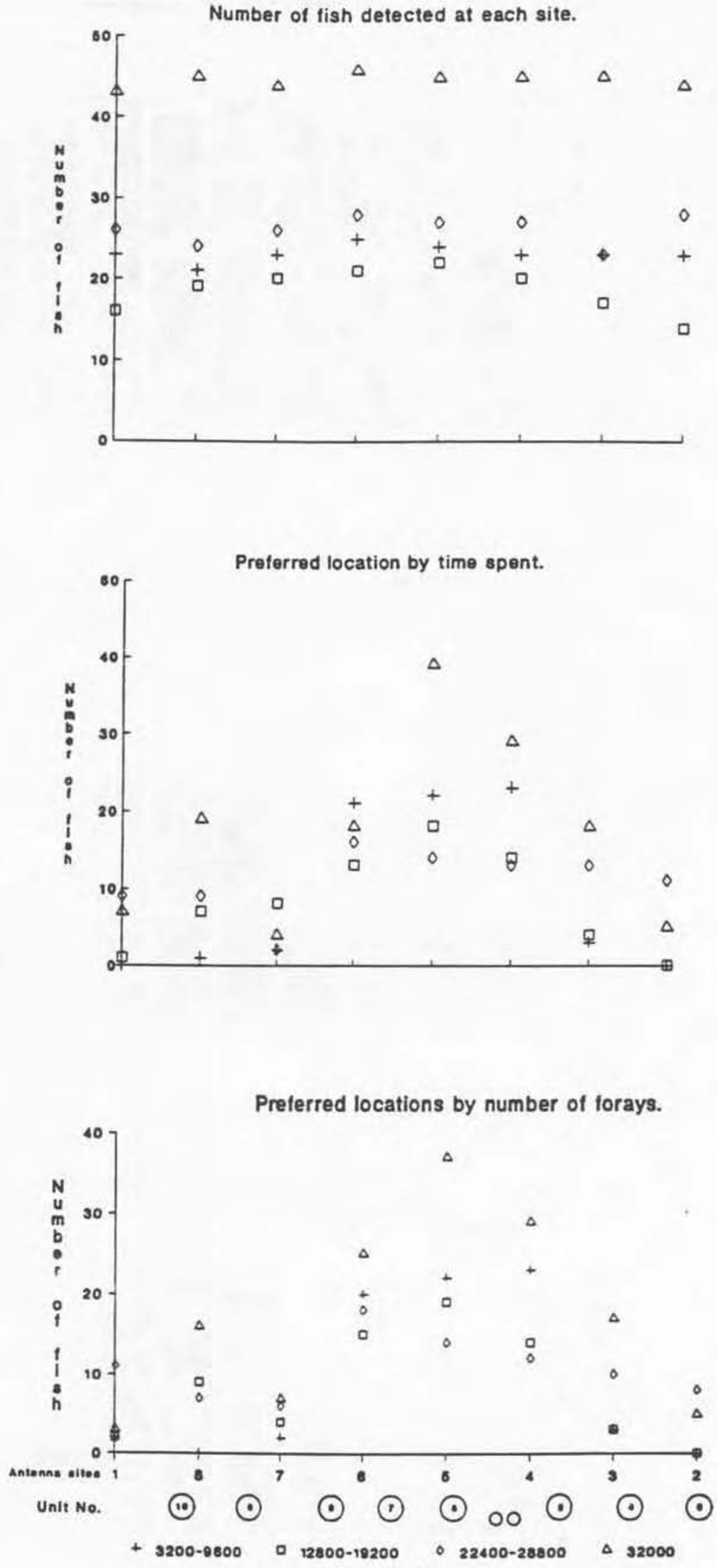


Figure 4-1

Comparison of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the Holtwood Hydroelectric Station during four generation conditons.

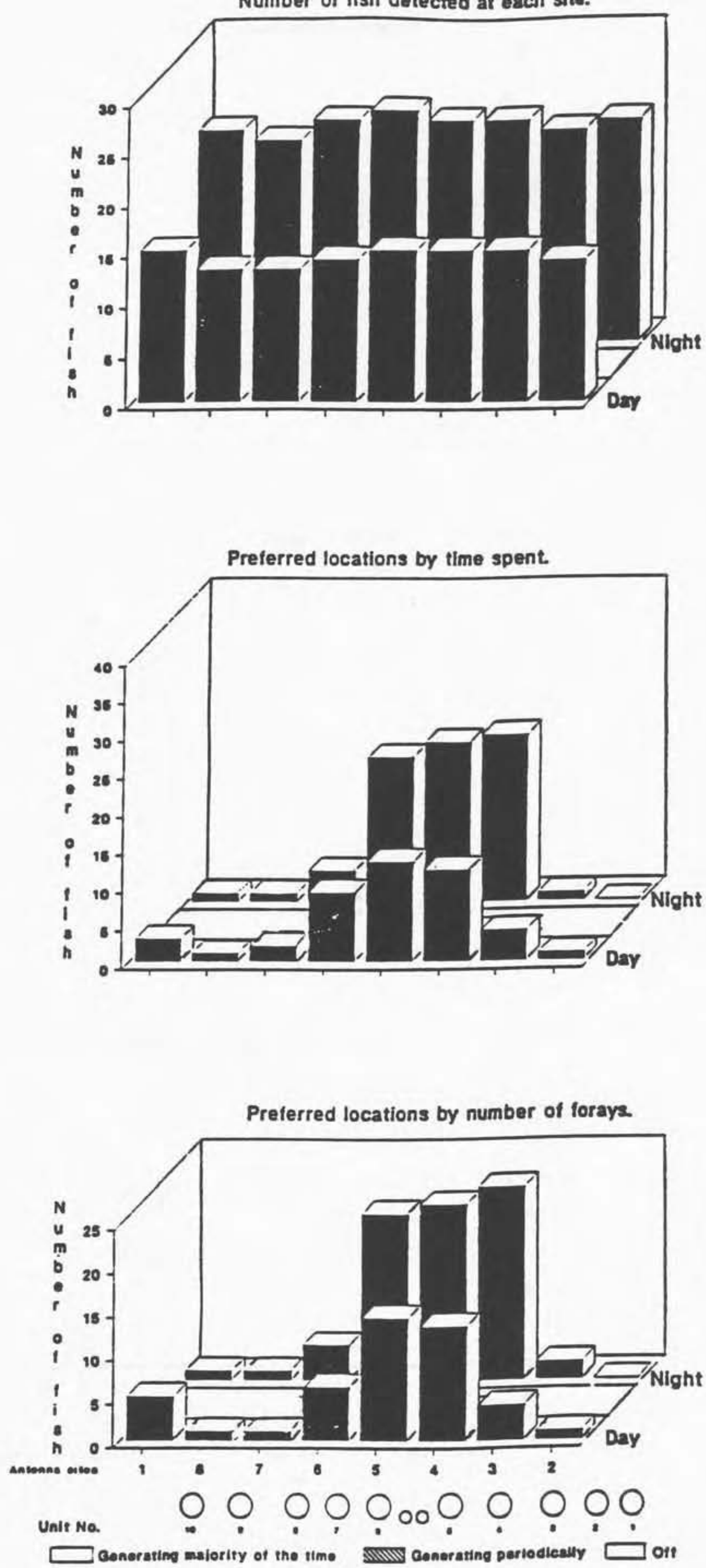


Figure 4-2

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the Holtwood Hydroelectric Station during discharges of 3,200-9,600 cfs.

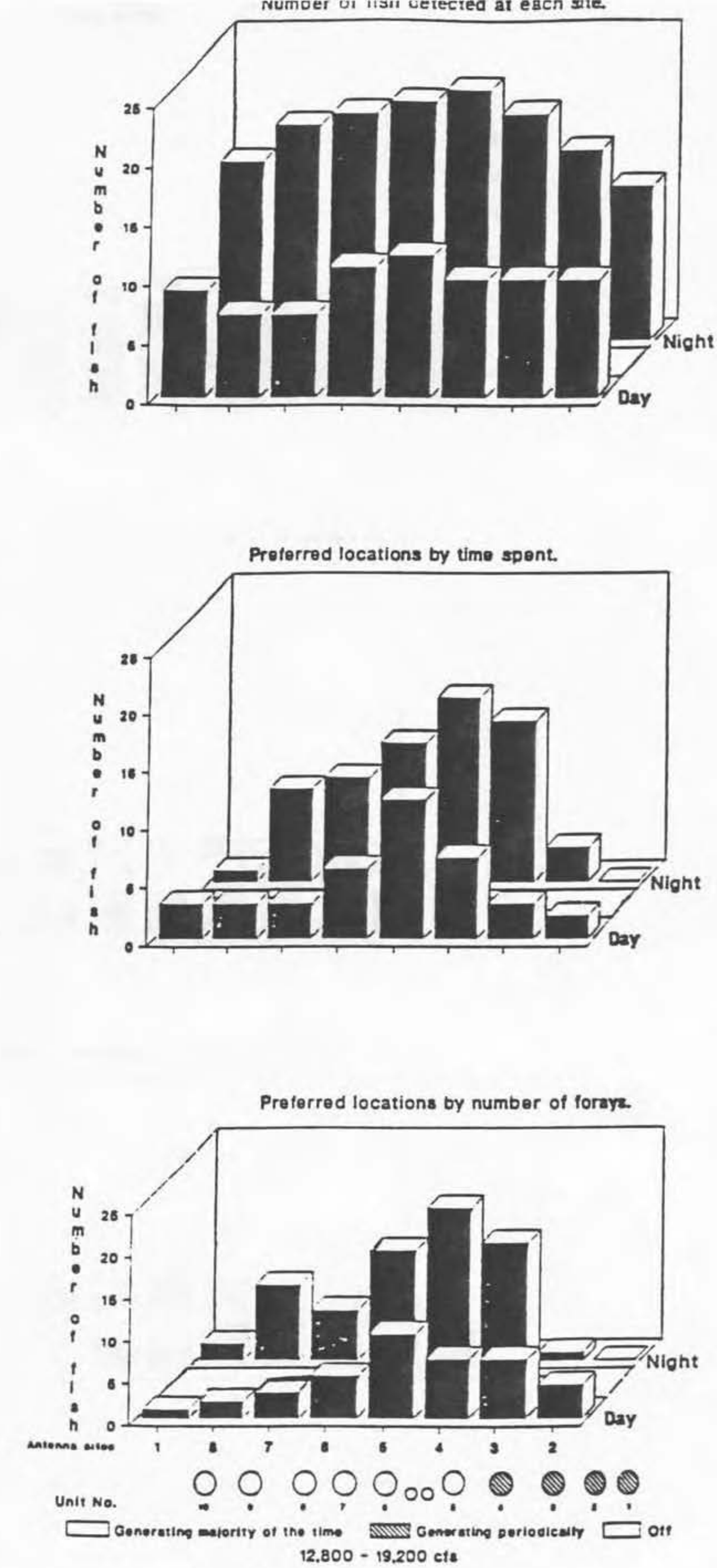


Figure 4-3

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the Holtwood Hydroelectric Station during discharges of 12,800-19,200 cfs.

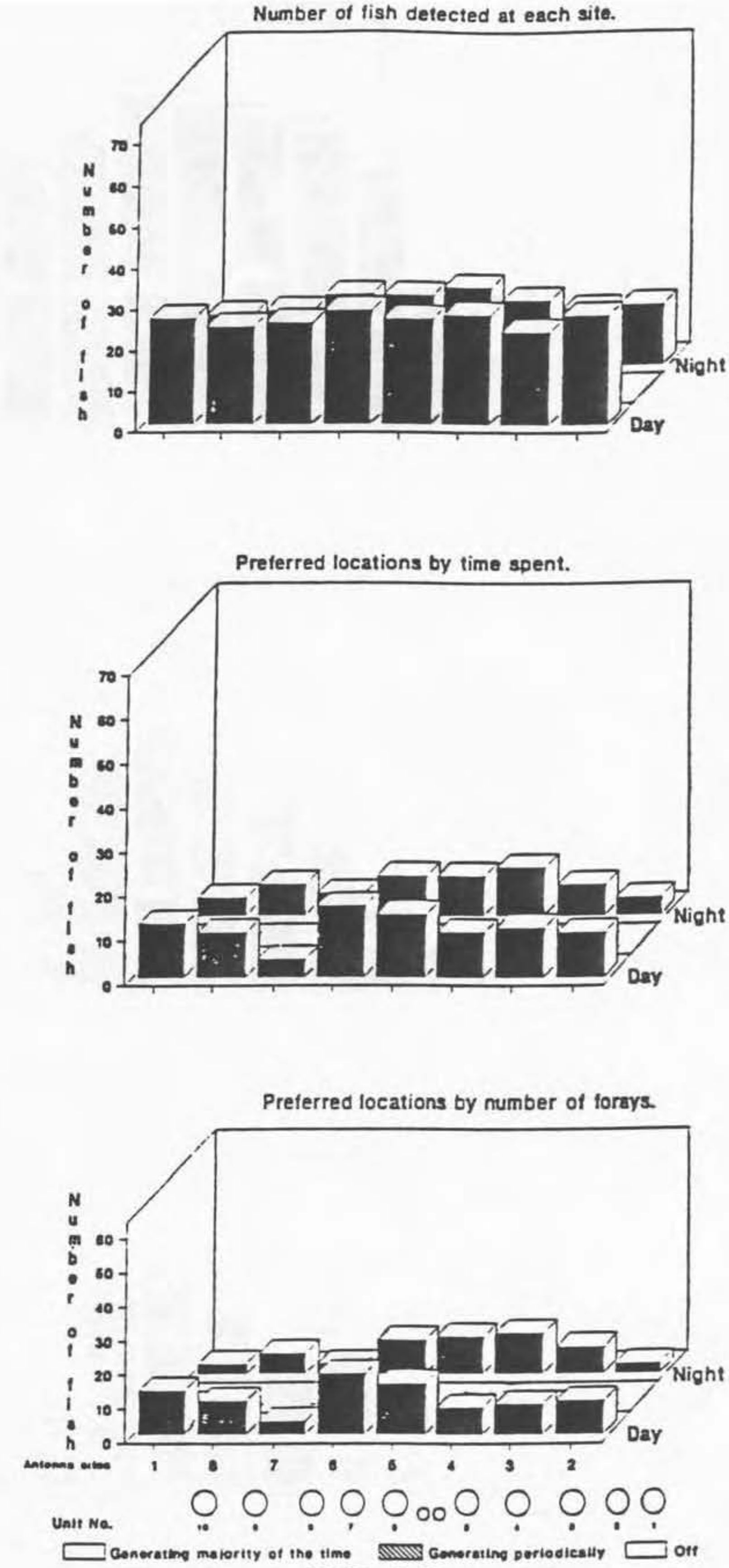


Figure 4-4

Day and night comparisons on the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the Holtwood Hydroelectric Station during discharges of 22,400-28,800 cfs.

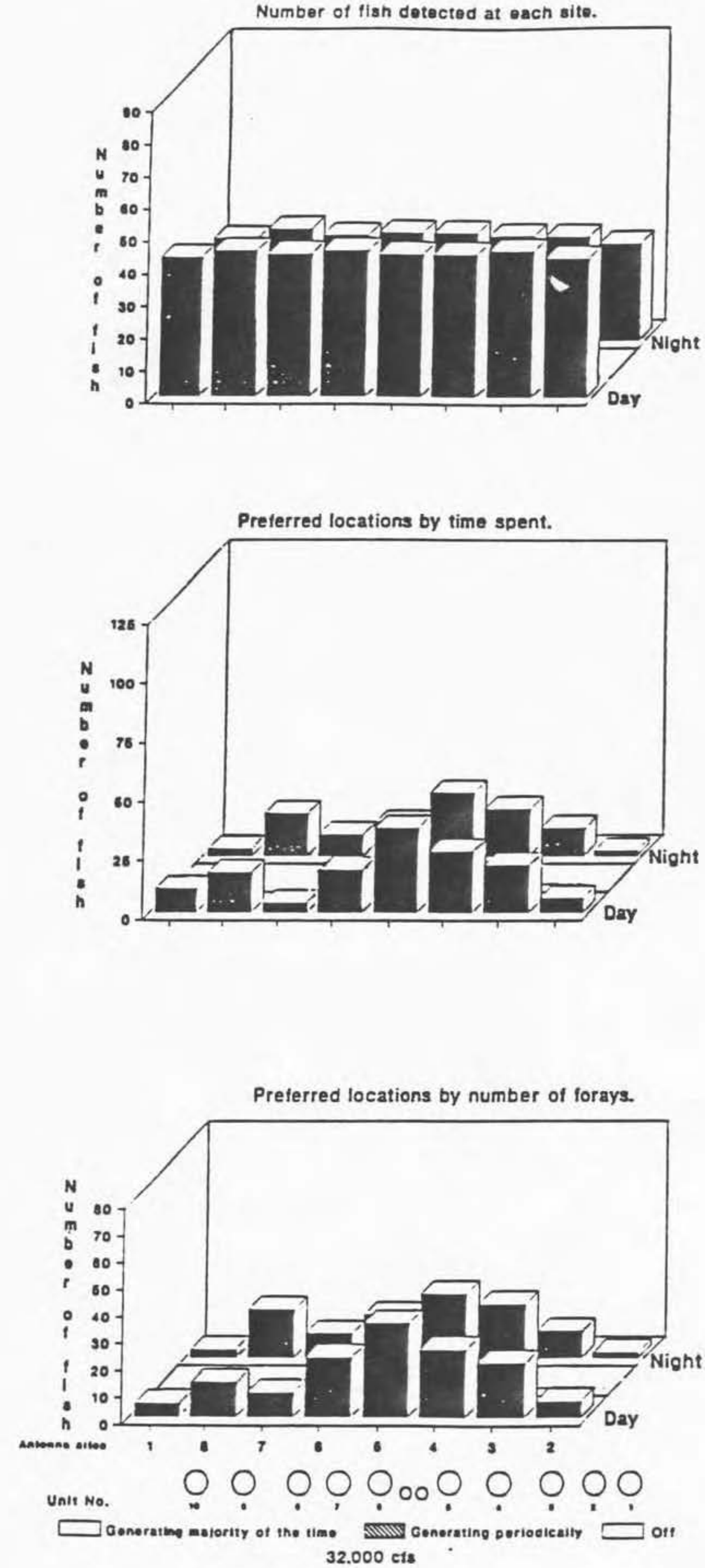


Figure 4-5

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight sites and corresponding units at the Holtwood Hydroelectric Station during full dishcarge of 32,000 cfs.

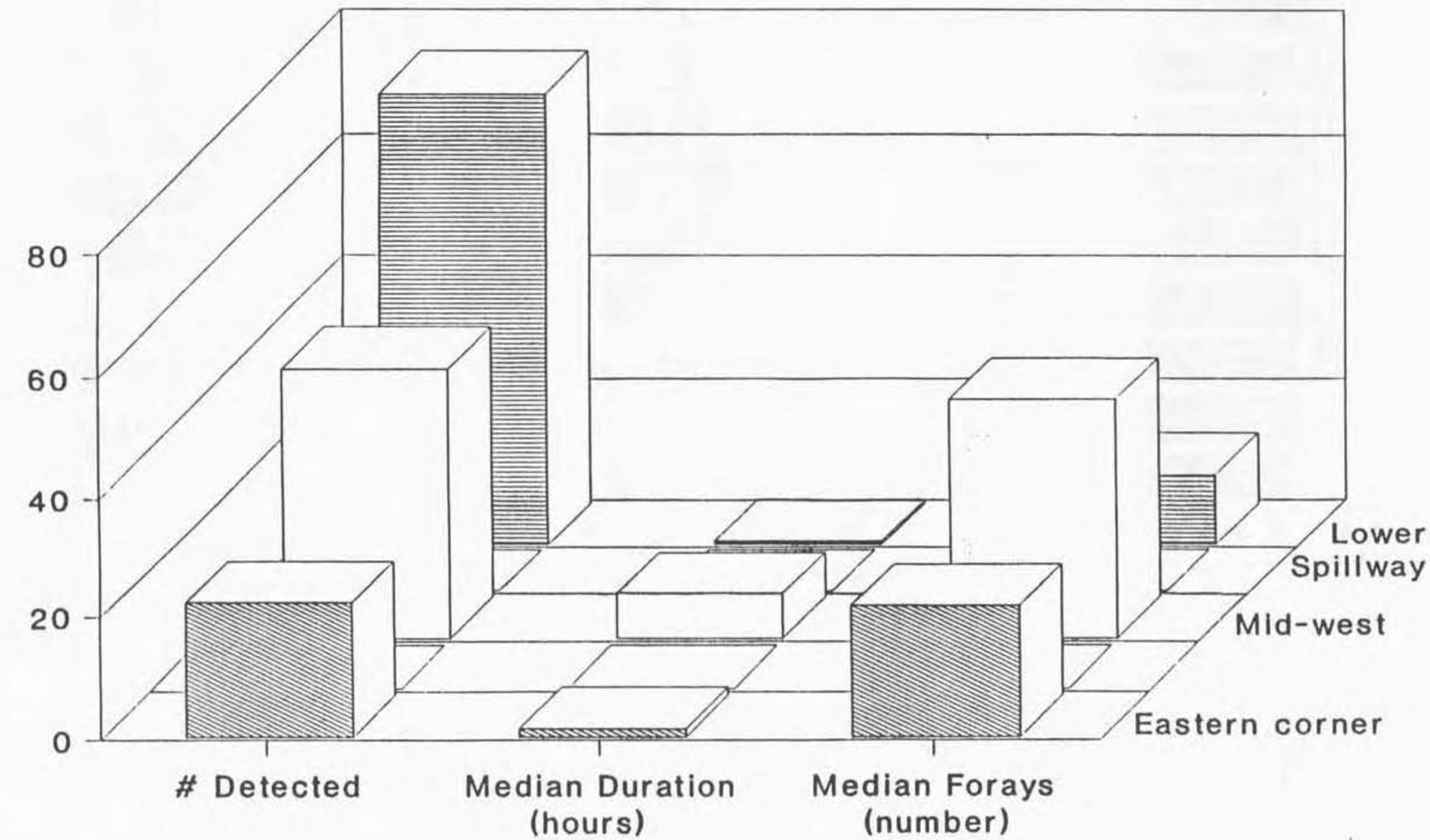


Figure 4-6

Comparison of the number, median durations, and medion forays of fish detected in the Holtwood spillway.

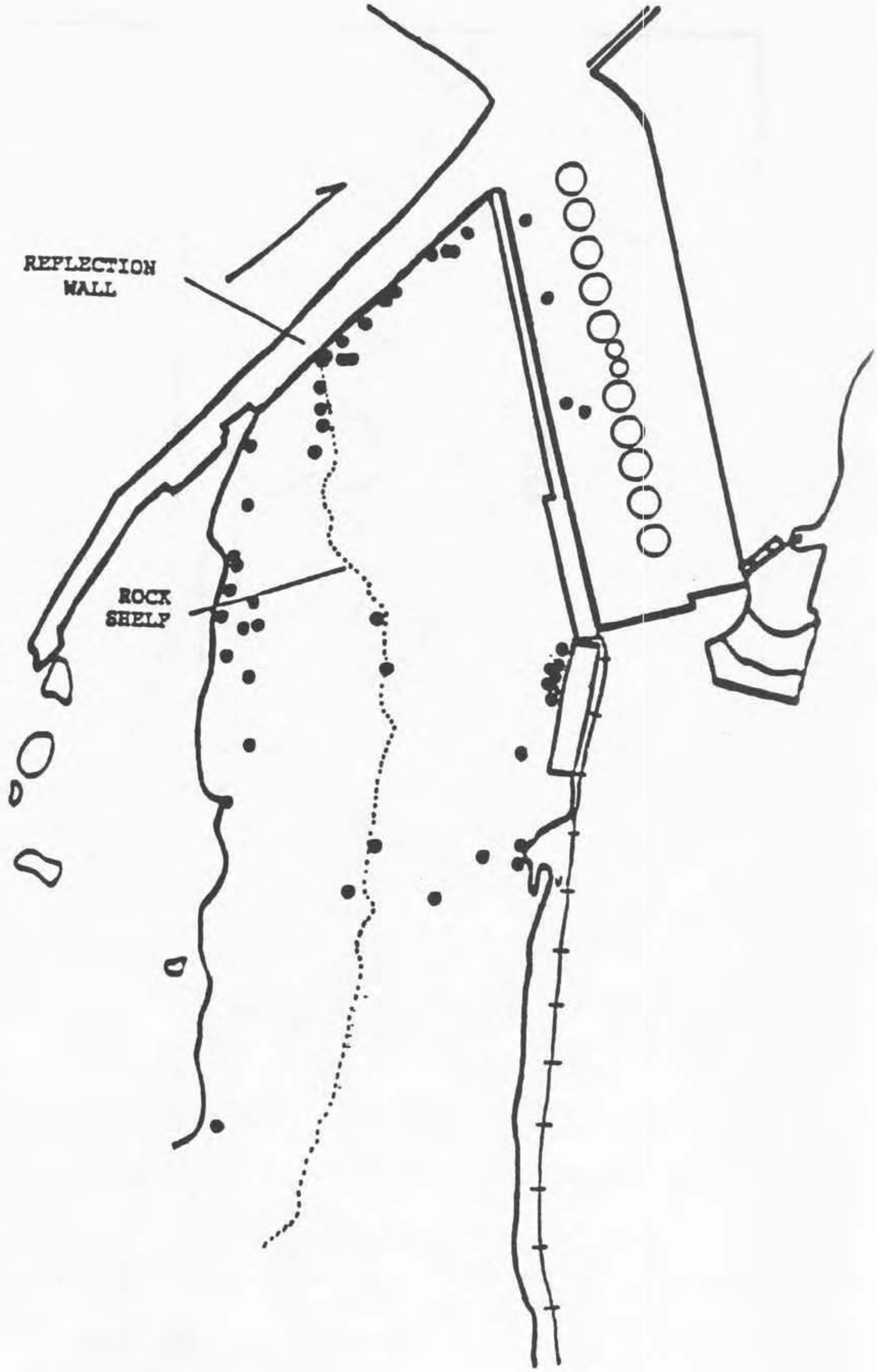


Figure 4-7

Map of Holtwood tailrace showing locations where shad were predominately located, 1989. (RMC 1990).

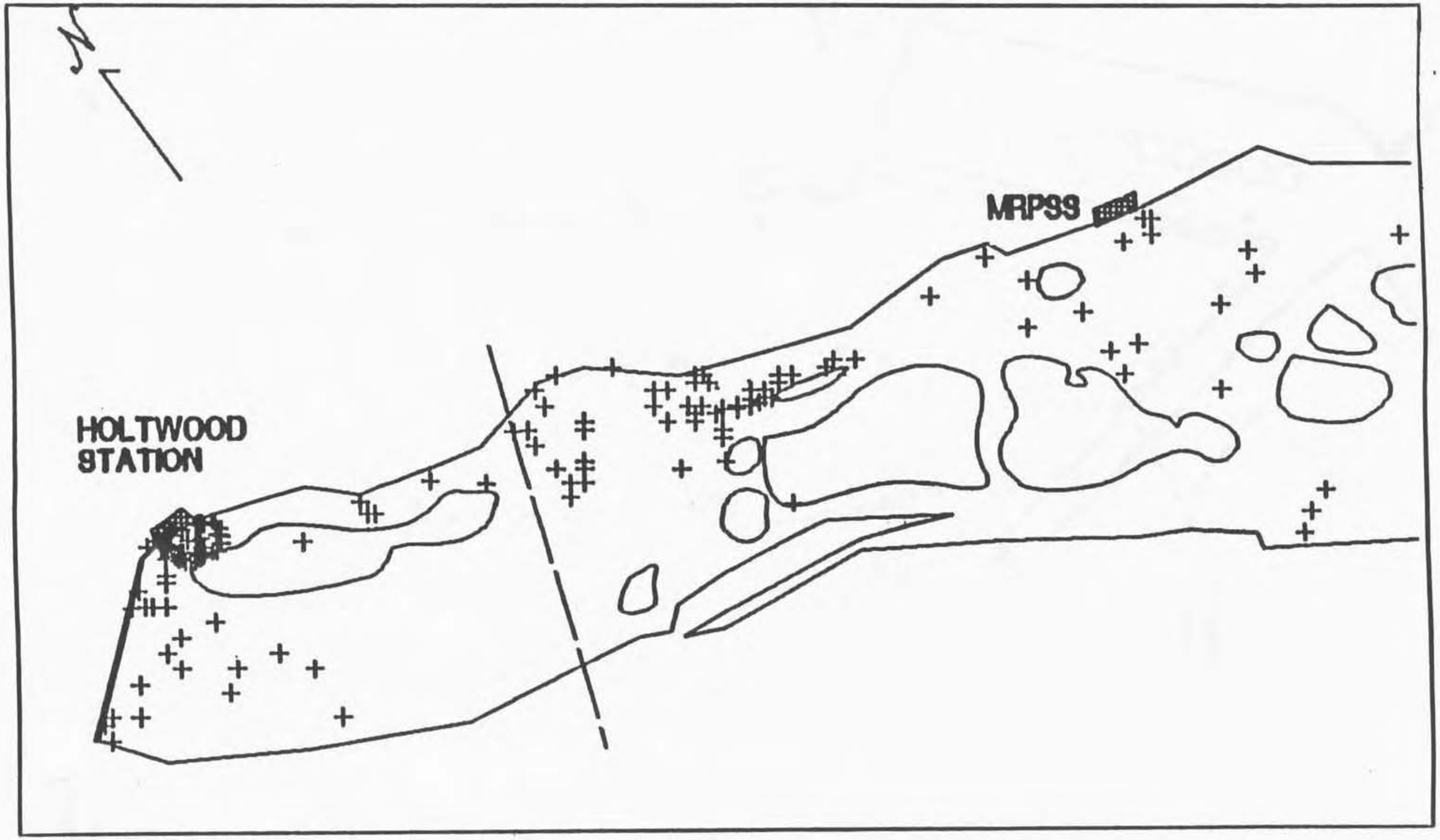


Figure 4-8

American shad locations in upper Conowingo Pond, Holtwood tailrace, and Holtwood spillway when river flows were <55,000 cfs, 1989. (RMC 1990).

what about improvements in spillway area

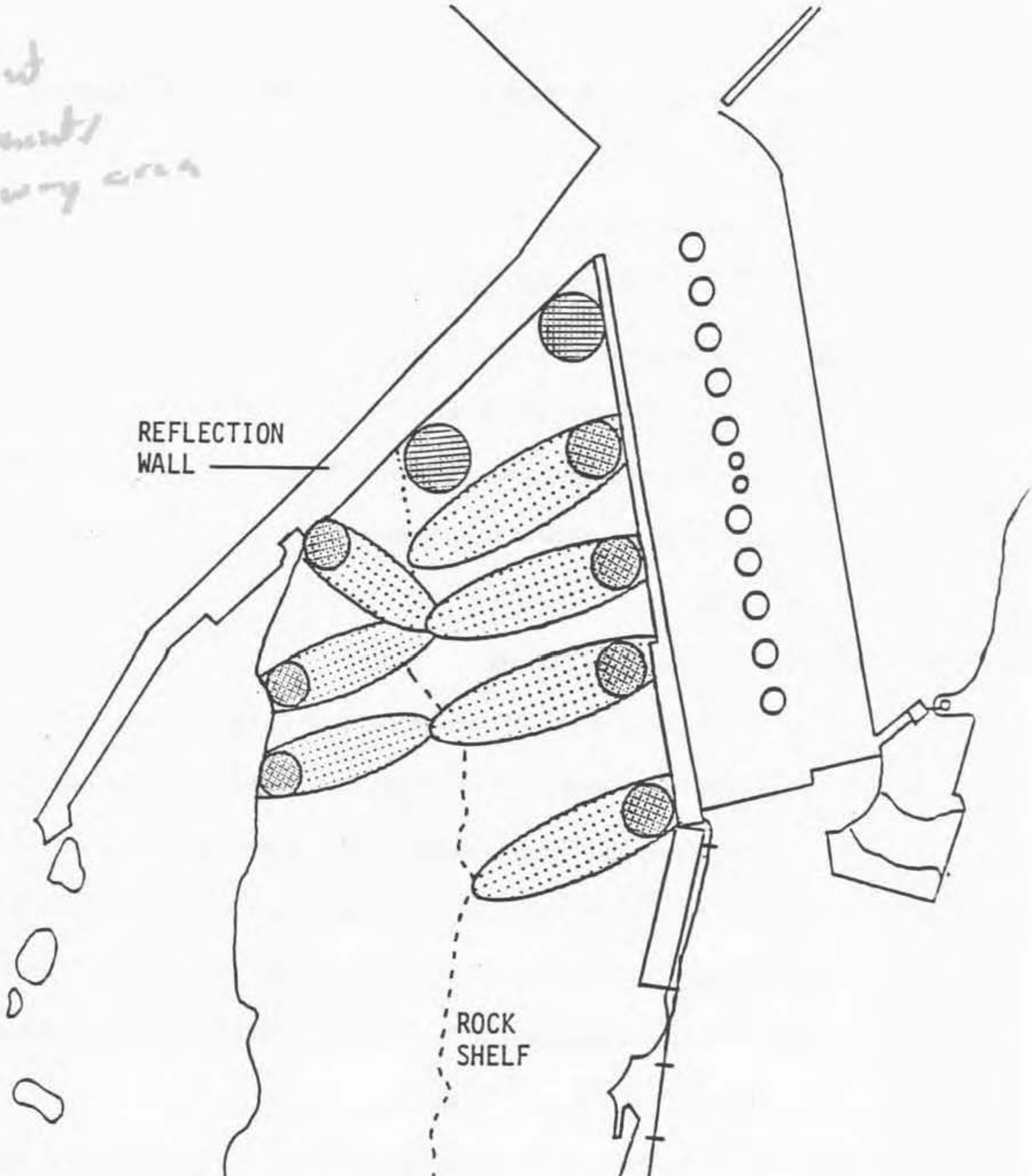


Figure 4-9

Map of Holtwood tailrace showing potential antenna placement scenario to better determine shad movement.

5.0 SAFE HARBOR: RESULTS, DISCUSSION AND RECOMMENDATIONS

5.1 Results

5.1.1 Tagging and Transport of Test Specimens

A total of 99 fish was tagged and released for the Safe Harbor study (Table 5-1). Two additional fish died or regurgitated their tags in transport. Fish were released in four separate groups: 25 on May 3rd, 24 on May 10th, 26 on May 18th, and 24 on May 26th. Transport time to Pequea Marina ranged from 51-60 min (X = 55 min, Table 5-1). Post release observations revealed one of the released fish, in group No. 3, had died or regurgitated its tag near the release site.

5.1.2 Movement to Tailrace

A total of 72 of the 99 radio tagged shad was located on at least one of the 16 antenna sites scanning the Safe Harbor tailrace (Table 5-2). Fish detected at these sites were likely within 150 ft of the powerhouse. Movement to the tailrace was high for release groups 1 and 3, 96 and 88%, respectively. Seventy-nine percent of release group 2 were detected at the station but only 29% of the last group. When the last group was released on 26 May ambient water temperature at the capture site (Conowingo Fish Lift) was 20.5° C and an increasing number of captured fish were partially spent.

Thirteen of the 28 fish (46%) not detected at the tailrace were accounted for on the monitor located along the east shore downstream of the release site and during five airplane flights. The status of the remaining 15 fish could not be ascertained.

There was variation in the residency of each fish in the tailrace. Eight fish were located only 1 of the 15 days each fish was monitored. Some 50 fish were found at least 5 days and 25 were tracked 10 or more days.

5.1.3 Location Preference Relative to Station Operations

The four different groups of tagged fish behaved similarly upon reaching the station. Fish from all groups readily moved throughout the whole monitoring zone; therefore, the four groups were combined for analysis.

Seven controlled generation scenarios were evaluated to determine location preferences in the tailrace (Table 5-3). The total amount of time each of these scenarios existed ranged from 35.7 hours of full generation (Scenario 2) to 484.7 hours of normal nighttime generation from 7 PM to 7 AM (Scenario 7). Normal generation during daylight hours (Scenario 1) was monitored for 146.7 hours. The remaining scenarios, new units only (Scenario 3), old units only (Scenario 4), new units and old Unit No. 1 (Scenario 5) and old units and new Unit No. 12 (Scenario 6) were monitored for times ranging from 58 to 68 hours.

Generally, sites near western middle and eastern side of the tailrace were preferred at all seven generation scenarios (Figure 5-1). The locations preferred by shad at each generation scenario are shown in Figures 5-2 to 5-8. Each of 16 monitoring sites at the station were not equally used by the migrating shad.

5.1.4 Normal Daytime Generation - Scenario 1

Normal daytime generation was monitored for 12 days. Generally a minimum of 4 new units, 1 house unit, and 1 old unit were run for each scheduled flow release scenario (Tables 5-3 and 5-4). The units operated most were 3, house, 8, 10, 11, and 12.

Fifty-five tagged shad were located at least once at one of the 16 monitoring sites at the Safe Harbor Station (Table 5-5 and Figure 5-2). Forty-nine and 48 of these were detected at sites 2 and 3 which monitored fish approaching the new unit number 12. Antenna sites 4 and 5 which monitored new units 11 and 10 were also visited by most of the fish (45 and 47 detected, respectively). The highest number of fish detected in the vicinity of the old units was 41 fish at Unit No. 2 (Antenna No. 14). In general, fish avoided sites 10-13. Approximately half of the fish approached these sites during normal daytime generation. These sites monitored old units 3 through 6.

The duration time fish spent at the various locations followed the trend found for number of fish detected (Table 5-6). The median time spent at the 16 different sites ranged from 0 minutes at sites 10-13 (Units 6-3) to 21 minutes at site 2 (Unit No. 12). The second highest median time was 10 minutes at Unit 11. The preference analysis indicated that most of the fish preferred the area near Unit 12 (Table 5-6 and Figure 5-2). Areas near the house units and Unit 1 were less preferred. Few of the fish preferred Units 2-6 and 8-10, and in some cases no fish were present.

The number of times fish approached the 16 locations (forays) was similar to the time spent at these sites (Table 5-6 and Figure 5-2). The longer a fish spent time at a site the greater were the number of forays to that site. Fish approached Unit 12 most often (median = 14). The median number of forays was less than 10 at the remaining units. During normal daytime generation fish approached Unit 12 the most but also preferred Unit 1 and the house units (Table 5-6).

5.1.5 Normal Nighttime Generation 7 PM to 7 AM - Scenario 7

Scenario 7 was monitored for 484.7 hours over a 37 day period and correspondingly detected the most fish, 73 (Table 5-3). A house unit and new Units 8, 10, 11, and 12 were operated most often (78%) for this scenario. The old unit operated most (59%) was Unit 3 (Table 5-4). More than 50 fish were detected at all antenna sites and corresponding units (Table 5-5). More than 95% of the fish were located in the vicinity of Units 8-12, 1 and 2. Time spent and forays made indicated fish concentrated in the vicinity of Units 12 and 1. Median time spent was 31 minutes at both units; the median number of forays was 24 and 26 at these respective units. Median time spent and forays was low (time <6 minutes, forays <5) at Units 3-7; but moderate (16 minutes, and 13 forays) at the house units which are positioned between Units 6 and 7.

Preference of the fish for the discharge from different units followed the trends observed in median time spent and number of forays made (Table 5-7 and Figure 5-3). The primary locations preferred in decreasing order were releases from Units 1, 12, and house for both duration and forays. Units 3-6 and the spillpool were not preferred by any of the fish.

5.1.6 Full Generation - Scenario 2

When river flows are high (>75,000 cfs) full generation is normal operation, but periods of high flow were minimal this spring. Consequently, this scenario was monitored for the least amount of time (35 hrs) because there was insufficient river flow to maintain full generation for desired test periods on the six days. A total of 41 fish was located at the station during full generation (Table 5-5). The highest number of fish (31) was located in the vicinity of Unit 12. At least 24 fish were also detected at the spillpool antenna and at Unit 1, house, 10, and 11. Few fish (2-6) were located near Units 3-6 (Figure 5-4).

Time spent by these fish and the number of forays made to each unit followed the trends in numbers of fish, however, the median values were low (Table 5-8). Median time spent was highest (5 minutes) in the vicinity of Unit 12 and house units. Fish made the most forays (median 4.5) to Unit 12. Median time spent and forays was ≤ 1 for the spillpool, and Units 1-9. The analysis indicated shad preference for Units 12, house, and 1 under Scenario 2; preference for Unit 12 was highest and none of the fish preferred Units 3-6 (Figure 5-4).

5.1.7 New Units Only - Scenario 3

Operation of new units is an established operating procedure at lower river flows. This operational mode could occur for several hours prior to starting old units. Operation of only the new units was studied for 68 hours over 5 days (Table 5-3). All new units except Unit 8 were operated most of the time (Table 5-4). A total of 54 fish was detected (Table 5-5). Fish concentrated in the vicinity of new Units 10-12, $\geq 94\%$ of the fish were located in the vicinity of these units. Although none of the old units were operating, fish still moved toward the eastern most old units (Figure 5-5). A total of 41 and 42 (approximately 80%) of the fish was located near Units 1 and 2, respectively (Table 5-9).

Although several fish were located near non-operating Units 1 and 2 they did not spend much time or make many forays into this area (Table 5-9). Median time and foray values were ≤ 4 compared to 19 and 17 in the vicinity of Unit 12. Median time and number of forays was low (≤ 4) for all units except 10 through 12, and spillpool. Preference analysis indicated most fish moved toward and remained for the longest time near Unit 12 when only the new units were operating (Table 5-9 and Figure 5-5).

5.1.8 Old Units Only - Scenario 4

The operation of only old units was to determine if shad would shift toward the eastern side of the tailrace. This scenario was monitored 5 days for 62 hours (Tables 5-3). The primary units operated were 1 through 5 (Table 5-4). Although no turbine flow was released on the western side of the tailrace, 47 of the 49 fish were detected there (Table 5-10). The highest numbers of fish located at operating units (no. 1 and 2) were 41 and 38. Median time and number of forays indicated fish were not preferentially attracted toward the old units. Median time was similar for old Units 1 and 2 (6-11 minutes) and Units 8-12 (8-11 minutes; Table 5-10). Additionally, although fish spent little time (median 0-2 minutes) at the remaining old units median foray values followed similar trends. Preference analysis indicated similar findings with a few more fish at Unit 1 (Tables 5-10 and Figure 5-6). However, fish also showed preference for areas near non-operating Units 12 and 8.

5.1.9 New Units Plus Old Unit No. 1 - Scenario 5

Scenario 5 was monitored 5 days for 63 hours to determine if fish would congregate near Unit 1 along the east side of the tailrace when new units were operating near full capacity (Table 5-3). Primary new units operated were 10-12 (Table 5-4). A total of 49 fish was located during this generation scenario (Table 5-5). A maximum of 36 fish was detected at Unit 1 while a range of 39 to 46 fish was near the new units. Although 78% of the fish moved into the single source attraction flow they did not spend much time or produce many forays at this site. Unit 1's median time (3 minutes) and forays (2) varied greatly with unit 12's median time 915 minutes) and forays (13) (Table 5-11). During this generation scenario the fish were attracted most to the spillpool and Units 11 and 12. Unit No. 12 was again the preferred unit (Table 5-11 and Figure 5-7).

5.1.10 Old Units Plus New Unit No. 12 - Scenario 6

Scenario 6 was tested to determine if fish would congregate in the western side of the tailrace when one new unit was operated in combination with most of the old units. This scenario was monitored 5 days for 58 hours (Table 5-3). Old units 1-4 were operated all 5 testing days (Table 5-4). A total of 41 fish was attracted to the powerhouse (Table 5-5). Fish were well distributed (30-34) at most areas (Units 8-12, house, 1 and 2). Although considerably more flow was offered from the old units, fish spent more time and made more forays at Unit 12 (Table 5-12). Median time was 8 minutes at Unit 12, the highest corresponding value was only 4 minutes at an old unit (No. 1). The trend for forays was similar, (median 3.5 at Unit 1 and 6 at Unit 12). Preference analysis indicated Unit 12 was the preferred site and Unit 1 and the house units were second and third, respectively (Table 5-12 and Figure 5-8).

5.1.11 Preferred Sites

Three areas emerged as the locations preferred by migrating shad when they approached the powerhouse. These areas were in the vicinity of Unit 12, the two house units (No. 42 and 43) and Unit 1. The intensity of activity at these sites shifted to some extent depending upon station operation (Figure 5-1). Each of the preferred areas is discussed further below.

5.1.12 Preference Near Unit 12

The area preferred by fish at most operating conditions was antenna sites 2 and 3 (Figures 5-1 to 5-8). Both of these antennas monitored fish activity in the vicinity of Unit 12. Antenna 3 was set up to monitor the discharge area directly off the unit while antenna 2 scanned the western edge of the discharge and adjacent area between Unit 12 and the wing wall which separates the tailwater and spillpool area. Generally, when Unit 12 is operational, current in this adjacent area is less than that directly off Unit 12 and some of the water returns upstream along the wing wall.

At the seven operating conditions tested, most fish were detected in the vicinity of Unit 12 (Table 5-5). A total of 70 (97%) of the 72 fish that reached the powerhouse was detected at Unit 12. Additionally, fish spent a lot of time at this unit. This unit had the maximum median time spent for all operating scenarios (Table 5-13).

Fish preferred the area near Unit 12 at most operating scenarios (Tables 5-5 to 5-12 and Figures 5-1 to 5-8). It was the area frequented by most fish in time spent and number of forays for all operating conditions except normal nighttime generation and old units only. This area was second to the area near Unit 1 for the two operating conditions. However, these operating conditions would not normally occur when fish are being lifted upstream at the Safe Harbor project. Additionally, even with no attraction flow offered during operating Scenario 4, old units only, fish still spent time and made numerous forays at Unit 12.

5.1.13 Preference Near Unit 1

Unit 1, located on the east side of the powerhouse, was another area where shad spent a lot of time and made numerous forays (Figures 5-1 to 5-8). Again, two antennas monitored this area. Antenna 15 monitored the area immediately downstream of Unit 1 while antenna 16 was set up to detect fish in the east side of Unit 1 flow and the area between Unit 1 and the eastern shore. Under most operating scenarios a back-flow toward the powerhouse was present along the eastern shore. A total of 69 of the 72 fish detected at the station was located at least once at Unit 1. Generally, more fish were attracted to antenna site 15 which monitored the area directly downstream of the unit (Table 5-5). Except for full generation, at least 75% of the fish detected during each operating condition were present at Unit 1; however, this unit never attracted the maximum number of fish.

Fish spent a lot of time and made a number of trips toward Unit 1 during night and old unit only generation (Table 5-7 and 5-10; Figures 5-3 and 5-6). Median time spent was 31 and 11 minutes and the median number of forays were 26 and 10 for these respective release scenarios. During the other scenarios both median time spent and number of forays was considerably less ranging from 1-5.

Preference data were similar to median values. Both nighttime and old units only operations had the most fish ranked highest (first, second or third). Unit 1 was preferred above all other old units for all operational scenarios.

5.1.14 House Units

The other units where fish congregated were the two house units, Nos. 42 and 43, which are located between old Units 6 and 7. Because one of the house units is normally operated whenever any of the other units are on-line, a house unit was operating during all scenarios tested. The constant 500 cfs from a house unit attracted fish toward the middle of the powerhouse in slightly lower numbers than were detected at Units 12 and 1; but in greater numbers than at most other units (Table 5-4 and Figure 5-1). A total of 66 (92%) of the fish was detected at the house units. Fish were attracted to the area most during nighttime generation; when median time spent and number of forays was 16 and 13, respectively (Table 5-7). Median values were considerably less (range 1-5) for all other operating conditions. The preference analysis indicates fish were attracted toward the center of the tailrace at all operating scenarios; however, this area was preferred less than Unit 12 for all release scenarios and preferred less than Unit 1 except during normal daytime, full and new units plus old unit 1 generating scenarios.

5.2 Discussion

5.2.1 Comparison of Release Groups

There was little evidence that the four different release groups of shad behaved differently upon arrival at the powerhouse, but the percentage that reached the station differed. The earliest release group had the best rate (96%) and the last group the worst (29%). The trend for a higher percentage of early tagged shad to move upriver has been observed in previous studies (RMC 1987, 1988a). Decreased upstream migration coincides with increased water temperature and advancement in fish's spawning condition.

5.2.2 Fish Location Versus Operating Scenarios

A total of seven station operational scenarios was studied. These included four scenarios that covered most conditions upstream migrating shad would encounter during a typical spring at the Safe Harbor Project: daytime (7AM-7PM), nighttime (7PM-7AM) full generation and new units only. The only condition which could not be studied was spillage due to low river flows; spillage occurs at river flows >110,000 cfs. Additionally, three less frequent generating conditions (old units only, new units plus old Unit 1 and old units plus new Unit 12) were studied to ascertain if fish could be concentrated at specific sites by flow manipulations. Information obtained was adequate to determine primary attraction sites at each operating scenario. Fish congregated primarily towards the far west, middle, and far east side of the tailrace during the four typical operating conditions. These respective areas were primarily in the vicinity of Unit 12, house units, and Unit 1. Fish appeared to avoid new Units 8 and 9 and old Units 3-6. Generally, fish moved toward operating units but showed a definite preference for Unit 12. Unit 12 typically is one of the first units to come on line and is operated the longest. Fish apparently were attracted to one of the two house units, which lie approximately mid-powerhouse, because it is operated whenever another unit is operational. However, generation did not always assure fish would concentrate at a specific unit. For example, fish congregated near Unit 1 when only the new units were operated; but avoided the remaining old units. Fish also avoided most of the old units except Unit 1 even though they were operational during the full generation scenario. New Units 7 and 8 were also avoided although they were operational during the full generation scenario. Factors in addition to flow such as proximity of shore and main channel, water velocities, and shadows can all influence behavior of adult migrating shad (RMC 1988b; 1988c).

The generation scenarios tested to congregate fish near the old units, Unit 12 and Unit 1, appeared to elicit the desired response only for Scenario 6 (old unit plus Unit 12). Fish were strongly attracted to the single new unit along the western side of the tailrace. Although at least four old units were operating, Unit 12 was the primary congregation site. Fish were weakly attracted to the single unit or the east side of the tailrace when the new units were operated (Scenario 5). Although operational Scenarios 5 and 6 were similar except the areas of primary and secondary flow were reversed, the corresponding areas of fish concentration did not shift. Providing flow only from the old units (Scenario 4), elicited the most unexpected response by the fish. Fish concentrated near old Unit 1 but many fish also spent a lot of time in the vicinity of all the new units, which were "off-line".

5.2.3 Potential Fishway Location

Based on the preference of tagged shad for the area around Unit 12, regardless of station operations, this site should be considered for a potential fishway entrance. The entrance may be located directly off Unit 12 (Antenna Site 3) or at the western side (Antenna Site 2) of this unit because these areas attracted the highest number of fish. However, design and placement of the fishway entrance must also consider the presently existing physical structures (wing wall, gallery, etc.) and flow pattern alterations resulting from potential new structures.

Another factor to consider in locating fishway entrance near Unit 12 is the location of the exit flume from the potential facility. The likely exit for a fishway along the eastern side of the powerhouse would be into the forebay. Fish released into the forebay, if drop-back occurs, may be subject to entrainment through operating units and the forebay wall with its submerged ports may deter fish migration upriver (RMC 1988b). The physical configuration of the powerhouse in the vicinity of Unit 12 would allow for the fishway exit to be located outside the forebay and minimize the effects of the operating units. If the exit channel is located there during periods of high river flows and spillage, the most distant spillgates could be opened to minimize drop-back.

Although this study indicates fish congregate in the general area of Unit 12, the antenna/receiver sites were not set up to ascertain detailed movements and specific preferred areas at each antenna site. Whether fish moved to within a few feet of the station or remained 50-100 feet downstream could not be determined. Nor was it determined if the fish frequented or avoided areas with specific flow, depth and/or proximal structures. Specific detailed information on behavior of shad and flow characteristics in the vicinity of Unit 12 may assist in the proper fishway placement.

5.3 Recommendations

5.3.1 Procedures

Procedures followed during the present study should be continued for any additional shad telemetry studies at the Safe Harbor Project. However, due to extensive data obtained on many fish at normal operating conditions, the number of release groups and total number of fish could be reduced to two groups of 25 fish. These fish should be released near the beginning and peak period of the run to maximize detecting fish with a strong urge to migrate upstream. Continued great care in handling all tagged shad must be exercised. If high river flows occur the distribution of fish during several days of spillage should be monitored to ascertain if fish still frequent Unit 12 and whether fish are attracted to the area of spill. Station operations should be normal except on occasions Unit 12 and other nearby units could be manipulated. The antenna/receiver deployment at the station should be changed to focus on behavior and location of shad in the vicinity of Unit 12. This could include deploying several pairs of antennas off Units 12 and 11 and the wing wall. Each pair of antenna would have one antenna set for a very limited detection range (< 10 ft) and the other would be set similar to the present study. Several activated tags should be deployed in the reception areas for the duration of the study to assist in signal strength calibration. The receiver antenna site that was deployed to monitor downstream movement should be disbanded or modified so it will have better coverage. Manual tracking and airplane over flights should only be conducted if the telemetric equipment is modified to facilitate these activities. If manual tracking is feasible and conditions are safe, detailed movement patterns of fish in the vicinity of Unit 12 should be obtained. Depth and flow characteristics should also be obtained in the vicinity of Unit 12.

Table 5-1

Summary of American shad releases at the Safe Harbor Hydroelectric Station, spring 1992.

Release Group	Tag and Release Date	Water Temperature (C) Tagging Site	Water Temperature (C) Release Site	Number of Fish Tagged	Transport Time (minutes)	Release Site	Number of Fish Released	Number of Fish Detected at Project	Number of Fish Detected Elsewhere	Number Dead or Regurgitated After Release
						Pequea Marina Boat Launch				
1	5/3/92	18	21	25	55	"	25	24 (96%)	0	0
2	5/10/92	15.5	15.5	25	51	"	24	18 (75%)	3	0
3	5/18/92	19.5	19	26	55	"	26	23 (92%)	0	1
4	5/26/92	20.5	18	25	60	"	24	7 (29%)	10	0

Table 5-2

Listing of radio tagged American shad monitored by release group at the Safe Harbor Hydroelectric Station, spring 1992.

Release Group		Antenna Number																
(Date Released)	Fish #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Downriver
1 (03May92)	7.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.3		x	x	x	x	x	x		x	x	x		x	x	x	x	
	7.4	x	x	x	x	x	x	x	x	x		x		x	x			
	7.5				x	x				x					x	x	x	
	7.7	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	
	7.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.13	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.14	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	
	7.15	x	x	x	x	x	x	x	x	x	x			x	x	x	x	
	7.16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	7.17	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	8.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	8.4	x	x	x	x	x	x	x	x	x				x	x	x	x	
	8.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	8.7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	8.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	8.10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	8.12	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	8.14	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	8.15	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Total	24	22	23	23	24	24	23	23	22	24	21	20	18	23	24	23	23	3

Table 5-2

Continued.

Release Group (Date Released)	Fish #	Antenna Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Downriver
2 (10May92)	8.2									x								
	8.6																	x
	8.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	8.13	x	x	x	x	x	x	x	x		x	x			x	x	x	
	8.16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	8.17		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	16.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	16.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	16.5		x	x					x									
	16.7	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	
	16.8		x	x		x	x				x	x				x	x	
	16.10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	16.11	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	
	15.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	15.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	15.5		x	x	x	x	x	x			x				x	x		
	15.6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	15.7	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	
	15.9	x	x	x	x	x	x	x	x	x			x		x	x	x	
Total	19	13	17	17	15	16	16	15	14	14	15	14	13	10	15	16	15	5

Table 5-2

Continued.

Release Group (Date Released)	Fish #	Antenna Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Downriver
3 (18May92)	4.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	4.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	4.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	4.7		x	x	x	x	x	x	x						x	x	x	
	4.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	4.10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	4.11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	4.12	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	4.13	x	x	x	x	x	x	x		x	x	x		x	x	x	x	
	4.16	x	x	x	x	x	x	x		x	x			x	x	x	x	
	4.17	x	x	x	x	x	x	x	x	x	x				x	x	x	x
	19.1	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	
	19.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	19.4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	19.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	19.6	x	x	x	x	x	x	x		x	x			x	x	x	x	
	19.7	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	
	19.8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	19.9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	19.10	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	19.11	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x
	15.10	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	
	15.11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Total	23	22	23	23	23	23	23	23	19	22	22	18	15	21	23	23	23	5

Table 5-2

Continued.

Release Group (Date Released)	Fish #	Antenna Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Downriver
4 (26May92)	14.2		x	x	x	x	x	x		x		x	x	x	x	x	x	
	14.5	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	14.11																	x
	5.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	5.2																	x
	5.8																	x
	5.10																	x
	5.14	x	x	x	x	x	x	x						x	x	x		
	5.15	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	5.16	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
	5.17	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Total	11	6	7	7	7	7	7	7	5	6	5	6	6	7	7	7	6	5
All Releases	77	63	70	70	69	70	69	68	60	66	63	58	52	61	69	69	67	18

Table 5-3

Number of hours seven different operating conditions were monitored for radio tagged American shad in the Safe Harbor Hydroelectric Station tailrace. Operation scenarios 1-6 were scheduled for 12 hour (7am-7pm) when conditions permitted. Scenario 7 occurred every day from 7pm-7am.

Generation Scenario	Release Group 1	2	3	4	Total hours for each Scenario *
Normal Daytime Operations - Scenario 1	56.4	33.8	33.9	67.7	146.7
Normal Nighttime Operations - Scenario 7	189.7	201.4	190.6	184.2	484.7
Full Generation - Scenario 2	12.4	14.2	8	15.3	35.7
New Units Only - Scenario 3	26.9	25.1	41.8	30.2	68.7
Old Units Only - Scenario 4	24.1	24	37.9	14	62
New Units plus Old Unit 1 - Scenario 5	25.1	24.2	25.8	25.9	63.1
Old Units plus New Unit 12 - Scenario 6	24.7	36.6	21.3	22	58.6
Totals	359.3	359.3	359.3	359.3	

* More than one release group was monitored during each generation scenario.

Table 5-4

Comparison of the number of days (%) that each unit was operated* for the seven generation scenarios at the Safe Harbor Hydroelectric Station.

Generation Scenario	# Days Tested	Units												
		12	11	10	9	8	7	House	6	5	4	3	2	1
Normal Daytime (1)	12	11 (92%)	11 (92%)	11 (92%)	6 (50%)	11 (92%)	8 (66%)	12 (100%)	2 (17%)	6 (50%)	5 (42%)	9 (75%)	2 (16%)	1 (8%)
Normal Nighttime (7)	37	30 (81%)	31 (84%)	30 (81%)	22 (59%)	30 (81%)	19 (51%)	37 (100%)	9 (24%)	13 (35%)	16 (43%)	22 (59%)	6 (16%)	5 (14%)
Full Generation (2)	6	6 (100%)	6 (100%)	6 (100%)	4 (67%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)	2 (33%)
New Units Only (3)	5	5 (100%)	5 (100%)	5 (100%)	4 (80%)	2 (40%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Old Units Only (4)	5	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (100%)	2 (40%)	4 (80%)	5 (100%)	5 (100%)	5 (100%)	5 (100%
New Units plus Unit 1 (5)	5	5 (100%)	5 (100%)	5 (100%)	2 (40%)	3 (60%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (100%
Old Units plus Unit 12 (6)	5	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (60%)	5 (100%)	2 (40%)	4 (80%)	5 (100%)	5 (100%)	5 (100%)	5 (100%

* Units that generated for the entire period or a portion of it were designated "operated".

Table 5-5

Summary by operating scenario of the number of radio tagged American shad located at each antenna site in the vicinity of the Safe Harbor Hydroelectric Station.

	Total Number of Fish Located at Station	Antenna Number and Location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		New Units							Old Units								
Generation Scenario		Spill	12	12	11	10	9	8	7	House	6	5	4	3	2	1	1
Normal Daytime (1)	55	34	49	48	45	47	40	40	40	39	24	19	19	27	41	40	40
Normal Nighttime (7)	73	57	69	69	68	69	69	67	56	61	60	53	48	56	66	67	64
Full Generation (2)	42	24	31	28	29	29	21	16	20	26	4	3	2	6	19	25	24
New Units Only (3)	54	39	48	52	49	50	45	41	35	35	21	24	23	28	42	39	41
Old Units Only (4)	49	32	46	47	45	46	44	44	15	38	34	33	24	27	38	41	39
New Units plus Unit 1 (5)	49	40	46	45	45	46	39	40	33	31	24	18	15	21	35	36	35
Old Units plus Unit 12 (6)	41	25	31	32	34	33	30	31	21	30	21	10	5	8	30	31	33

Table 5-6

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during normal daytime operations (7am - 7pm), April - May 1992.

Antenna	Monitoring Site Description	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref. **
1	Spillpool	34	16:40	00:00-02:05	00:05	16	609	0-76	3	13
2	Unit 12	49	22:25	00:00-01:24	00:21	33	941	0-56	14	31
3	Unit 12	48	20:15	00:00-01:37	00:15	34	901	0-59	12	32
4	Unit 11	45	16:28	00:00-01:49	00:10	16	728	0-71	9	17
5	Unit 10	47	14:42	00:00-01:16	00:09	5	671	0-57	8	10
6	Unit 9	40	07:01	00:00-00:42	00:03	0	337	0-34	3	1
7	Unit 8	40	06:20	00:00-00:51	00:03	0	291	0-23	2	0
8	Unit 7	40	08:15	00:00-00:54	00:03	10	292	0-25	3	8
9	House	39	16:07	00:00-02:10	00:04	17	491	0-42	4	16
10	Unit 6	24	01:16	00:00-00:08	00:00	0	71	0-8	0	0
11	Unit 5	19	01:00	00:00-00:08	00:00	0	54	0-6	0	0
12	Unit 4	19	00:41	00:00-00:05	00:00	0	39	0-4	0	0
13	Unit 3	27	01:08	00:00-00:09	00:00	1	60	0-7	0	1
14	Unit 2	41	06:40	00:00-00:50	00:02	4	308	0-37	2	4
15	Unit 1	40	10:37	00:00-01:26	00:05	11	423	0-44	4	13
16	Unit 1	40	12:24	00:00-01:36	00:05	13	497	0-47	5	14

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-7

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during normal nighttime operations (7pm - 7am), April - May 1992.

Antenna	Monitoring Site Description	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref. **
1	Spillpool	57	27:06	00:00-03:36	00:08	2	998	0-114	6	0
2	Unit 12	69	67:26	00:00-07:28	00:32	31	2875	0-262	24.5	30
3	Unit 12	69	58:02	00:00-05:15	00:31	22	2550	0-188	24	28
4	Unit 11	68	52:18	00:00-05:57	00:21	14	2301	0-172	19	13
5	Unit 10	69	50:52	00:00-06:23	00:25	14	2272	0-209	20	13
6	Unit 9	69	43:21	00:00-03:31	00:20	4	1840	0-135	15.5	2
7	Unit 8	67	36:15	00:00-02:38	00:16	3	1650	0-114	12	3
8	Unit 7	56	31:07	00:00-03:44	00:06	9	997	0-108	4	9
9	House	61	80:58	00:00-09:38	00:16	23	2549	0-245	13	16
10	Unit 6	60	08:30	00:00-00:49	00:03	0	454	0-40	3	0
11	Unit 5	53	06:58	00:00-00:43	00:02	0	359	0-39	2	0
12	Unit 4	48	05:36	00:00-00:36	00:02	0	309	0-34	1.5	0
13	Unit 3	56	11:20	00:00-00:47	00:05	0	586	0-41	4.5	0
14	Unit 2	66	57:47	00:00-04:35	00:22	19	2482	0-173	18	22
15	Unit 1	67	77:52	00:00-06:32	00:31	39	3327	0-242	26	42
16	Unit 1	64	81:13	00:00-09:25	00:27	34	3179	0-273	20	36

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-8

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during full station operation, April - May 1992.

Antenna	Monitoring Site Description	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref. **
1	Spillpool	24	04:53	00:00-01:03	00:01	12	162	0-32	1	10
2	Unit 12	31	07:12	00:00-01:52	00:05	22	260	0-46	3.5	22
3	Unit 12	28	05:18	00:00-01:21	00:02	16	217	0-43	1.5	17
4	Unit 11	29	02:52	00:00-00:26	00:02	9	130	0-17	2	13
5	Unit 10	29	02:41	00:00-00:22	00:02	7	128	0-15	1.5	9
6	Unit 9	21	01:07	00:00-00:13	00:01	0	61	0-11	0.5	2
7	Unit 8	16	00:59	00:00-00:15	00:00	2	47	0-8	0	3
8	Unit 7	20	02:37	00:00-00:41	00:00	9	97	0-20	0	8
9	House	26	06:12	00:00-01:05	00:02	15	170	0-22	1.5	11
10	Unit 6	4	00:04	00:00-00:01	00:00	0	4	0-1	0	0
11	Unit 5	3	00:03	00:00-00:01	00:00	0	3	0-1	0	0
12	Unit 4	2	00:03	00:00-00:02	00:00	0	3	0-2	0	0
13	Unit 3	6	00:07	00:00-00:02	00:00	0	7	0-2	0	0
14	Unit 2	19	00:58	00:00-00:10	00:00	3	43	0-6	0	1
15	Unit 1	25	02:06	00:00-00:21	00:01	12	99	0-14	1	13
16	Unit 1	24	03:23	00:00-00:39	00:01	10	126	0-20	1	10

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-9

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during operation of the new units only, April - May 1992.

		Number of	Duration (hours:minutes)				Forays (number)			
Antenna	Monitoring Site Description	Fish Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref. **
1	Spillpool	39	17:33	00:00-01:51	00:10	22	650	0-52	7	16
2	Unit 12	48	20:03	00:00-01:29	00:19	27	885	0-49	15	28
3	Unit 12	52	20:05	00:00-01:31	00:17	33	890	0-56	15	35
4	Unit 11	49	16:10	00:00-01:29	00:12	21	715	0-44	11	21
5	Unit 10	50	14:17	00:00-01:04	00:09	11	645	0-43	7	15
6	Unit 9	45	07:06	00:00-00:33	00:04	1	361	0-26	4	1
7	Unit 8	41	04:59	00:00-00:34	00:03	0	255	0-26	3	1
8	Unit 7	35	05:57	00:00-00:49	00:01	4	241	0-21	1	3
9	House	35	12:49	00:00-02:10	00:02	10	396	0-46	2	7
10	Unit 6	21	00:41	00:00-00:05	00:00	0	40	0-5	0	0
11	Unit 5	24	00:47	00:00-00:09	00:00	0	44	0-9	0	0
12	Unit 4	23	00:37	00:00-00:03	00:00	0	33	0-3	0	0
13	Unit 3	28	01:38	00:00-00:34	00:00	0	83	0-25	0	0
14	Unit 2	42	08:18	00:00-01:21	00:03	7	345	0-49	2	7
15	Unit 1	39	09:18	00:00-01:22	00:03	12	384	0-53	3	13
16	Unit 1	41	12:06	00:00-01:50	00:04	14	438	0-48	3	15

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-10

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during operation of the old units only, April - May 1992.

Antenna	Monitoring Site Description	Number of Fish Detected	Duration (hours:minutes) Total	Duration Range	Duration Median *	Duration Pref. **	Forays (number) Total	Forays Range	Forays Median *	Forays Pref. **
1	Spillpool	32	02:34	00:00-00:21	00:02	0	139	0-18	2	0
2	Unit 12	46	11:54	00:00-01:37	00:11	18	548	0-57	8	17
3	Unit 12	47	10:03	00:00-00:37	00:11	19	496	0-34	9	19
4	Unit 11	45	08:37	00:00-00:28	00:08	7	452	0-23	8	6
5	Unit 10	46	09:01	00:00-00:39	00:10	8	475	0-31	9	11
6	Unit 9	44	09:33	00:00-00:50	00:09	13	494	0-42	9	14
7	Unit 8	44	10:44	00:00-00:48	00:11	19	520	0-35	10	15
8	Unit 7	15	01:22	00:00-00:15	00:00	2	59	0-12	0	1
9	House	38	07:50	00:00-01:33	00:05	9	327	0-46	4	5
10	Unit 6	34	04:30	00:00-00:39	00:02	1	244	0-32	2	2
11	Unit 5	33	03:04	00:00-00:24	00:02	0	170	0-21	2	0
12	Unit 4	24	01:49	00:00-00:18	00:00	0	99	0-15	0	0
13	Unit 3	27	01:51	00:00-00:17	00:01	0	104	0-17	1	0
14	Unit 2	38	09:10	00:00-00:54	00:06	14	465	0-44	6	13
15	Unit 1	41	12:04	00:00-01:13	00:11	20	622	0-61	10	26
16	Unit 1	39	08:09	00:00-01:11	00:07	13	401	0-44	5	14

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-11

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during operation of the new units and old unit 1, April - May 1992.

	Monitoring Site	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Description	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref. **
1	Spillpool	40	14:43	00:00-01:31	00:11	19	618	0-48	8	19
2	Unit 12	46	16:33	00:00-01:22	00:15	25	795	0-73	13	32
3	Unit 12	45	14:40	00:00-01:27	00:11	28	706	0-67	10	31
4	Unit 11	45	11:43	00:00-01:13	00:11	22	603	0-64	10	23
5	Unit 10	46	10:22	00:00-01:01	00:08	21	546	0-53	7	11
6	Unit 9	39	04:29	00:00-00:36	00:03	3	230	0-22	3	2
7	Unit 8	40	04:16	00:00-00:22	00:03	4	226	0-16	3	4
8	Unit 7	33	04:17	00:00-00:23	00:01	4	197	0-20	1	3
9	House	31	03:38	00:00-00:29	00:02	7	161	0-17	1	6
10	Unit 6	24	01:03	00:00-00:11	00:00	0	59	0-11	0	0
11	Unit 5	18	00:40	00:00-00:05	00:00	0	38	0-5	0	0
12	Unit 4	15	00:36	00:00-00:11	00:00	0	34	0-10	0	0
13	Unit 3	21	00:44	00:00-00:10	00:00	0	40	0-8	0	0
14	Unit 2	35	02:37	00:00-00:19	00:02	4	138	0-15	2	5
15	Unit 1	36	03:34	00:00-00:26	00:02	4	182	0-21	2	3
16	Unit 1	35	03:21	00:00-00:24	00:03	5	154	0-15	2	4

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-12

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the units of the Safe Harbor Hydroelectric Station during operation of the old units and new unit 12, April - May 1992.

Antenna	Monitoring Site Description	Number of Fish Detected	Duration (hours:minutes)				Forays (number)			
			Total	Range	Median *	Pref. **	Total	Range	Median *	Pref. **
1	Spillpool	25	07:44	00:00-01:36	00:03	13	310	0-55	3	10
2	Unit 12	31	09:38	00:00-00:56	00:07	17	464	0-49	6	22
3	Unit 12	32	07:54	00:00-01:03	00:08	17	396	0-46	6	19
4	Unit 11	34	07:01	00:00-01:00	00:06	14	343	0-46	6	14
5	Unit 10	33	07:42	00:00-00:57	00:06	9	365	0-33	5.5	10
6	Unit 9	30	04:18	00:00-00:27	00:04	6	219	0-19	3.5	6
7	Unit 8	31	02:54	00:00-00:21	00:03	5	152	0-15	2.5	3
8	Unit 7	21	03:49	00:00-01:01	00:01	6	157	0-30	0.5	6
9	House	30	03:34	00:00-00:26	00:02	9	172	0-18	2	8
10	Unit 6	21	00:40	00:00-00:06	00:01	0	38	0-5	0.5	0
11	Unit 5	10	00:18	00:00-00:03	00:00	0	17	0-3	0	0
12	Unit 4	5	00:11	00:00-00:06	00:00	0	11	0-6	0	0
13	Unit 3	8	02:36	00:00-00:03	00:00	0	11	0-3	0	0
14	Unit 2	30	03:43	00:00-00:21	00:02	1	137	0-20	2	1
15	Unit 1	31	03:14	00:00-00:27	00:04	11	194	0-23	3.5	10
16	Unit 1	33	00:00	00:00-00:27	00:04	12	173	0-20	3	11

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 5-13

Comparison of median time spent (hours) and median number of forays made at the Safe Harbor Hydroelectric Station units frequented most by radio tagged American shad, spring 1992.

Generation Scenario	Number of Hours Monitored	All Locations *		Unit 12		House Unit		Unit 1	
		Duration	Forays	Duration	Forays	Duration	Forays	Duration	Forays
Normal Daytime (1)	146	21	14	21	14	4	4	5	5
Normal Nighttime (7)	484	31.5	26	31.5	24.5	15.5	13	31	26
Full Generation (2)	35	4.5	3.5	4.5	3.5	2	1.5	1	1
New Units Only (3)	68	19	15	19	15	2	2	4	3
Old Units Only (4)	62	11	10	11	9	5	4	11	10
New Units plus Unit 1 (5)	63	15	13	15	13	2	1	3	2
Old Units plus Unit 12 (6)	58	7.5	6	7.5	6	2	2	4	3.5

* Maximum value

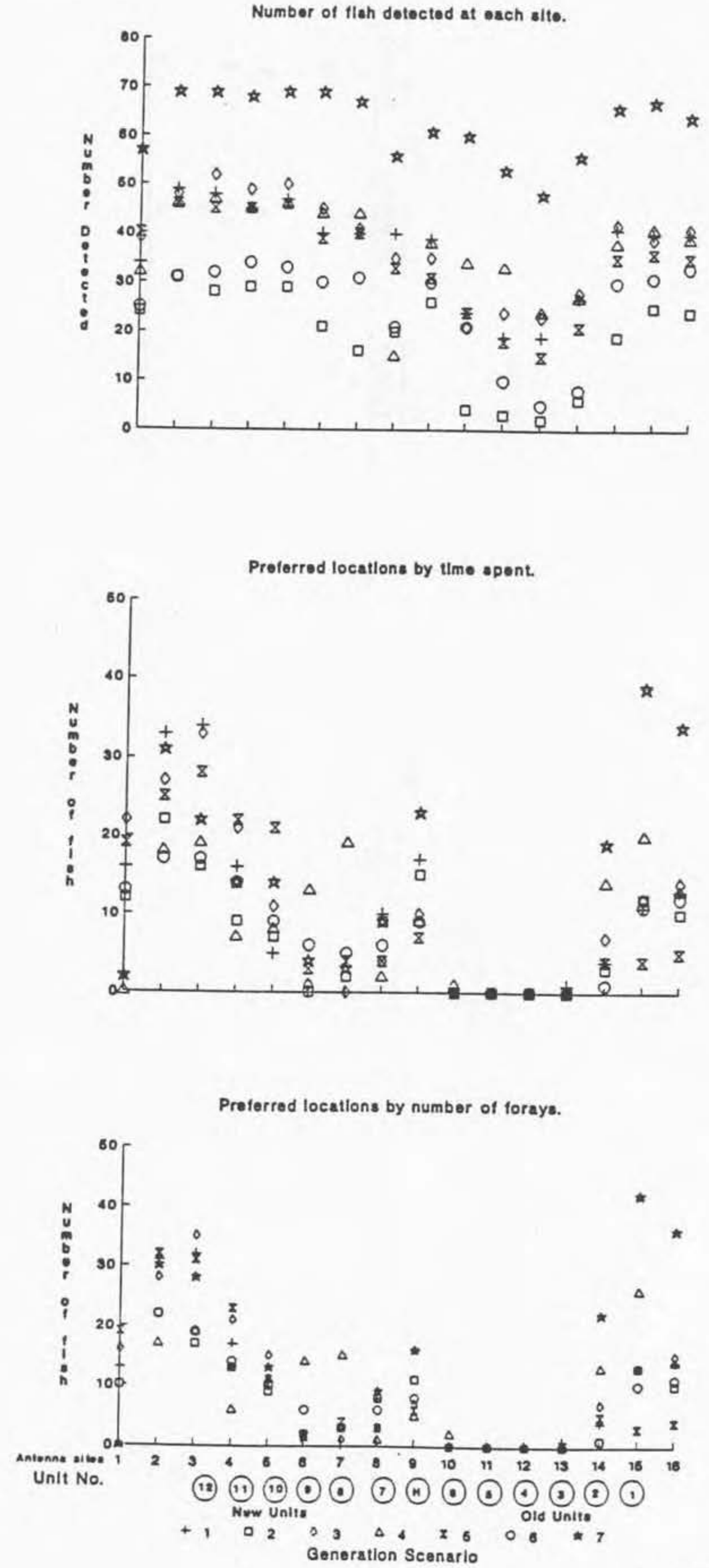
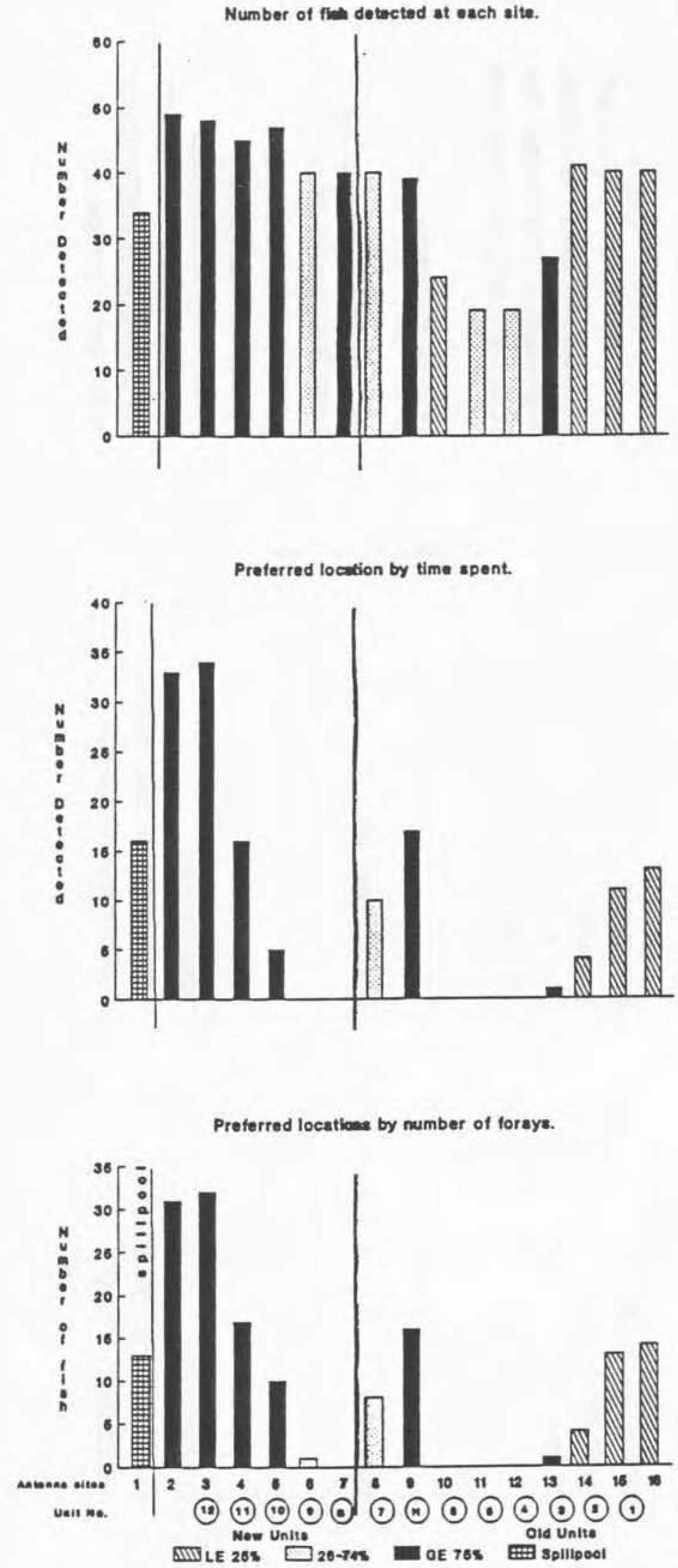


Figure 5-1

Comparison of number of fish detected, number fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during 7 generation scenarios.

Generation Scenario 1



23Oct92

Figure 5-2

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during normal daytime generation.

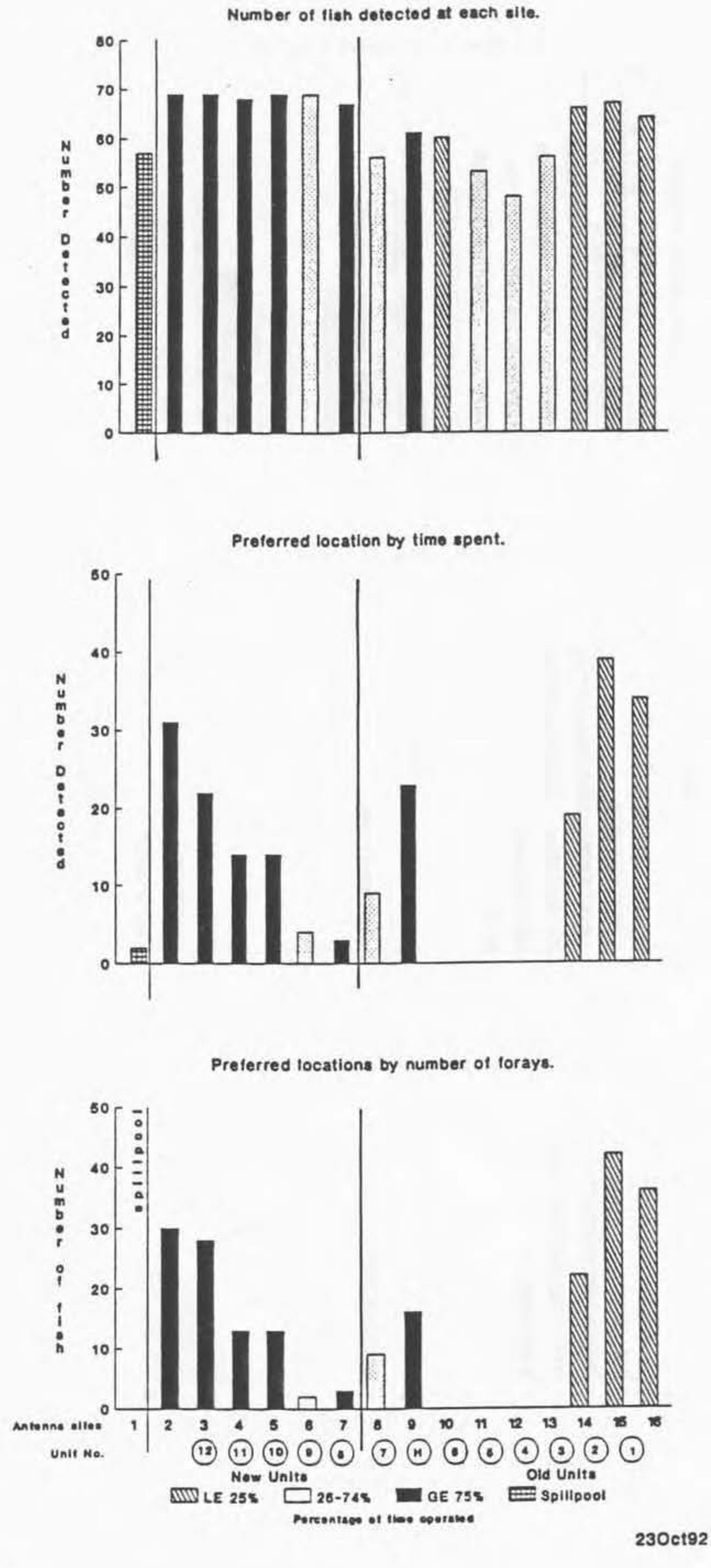


Figure 5-3

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during normal nighttime generation.

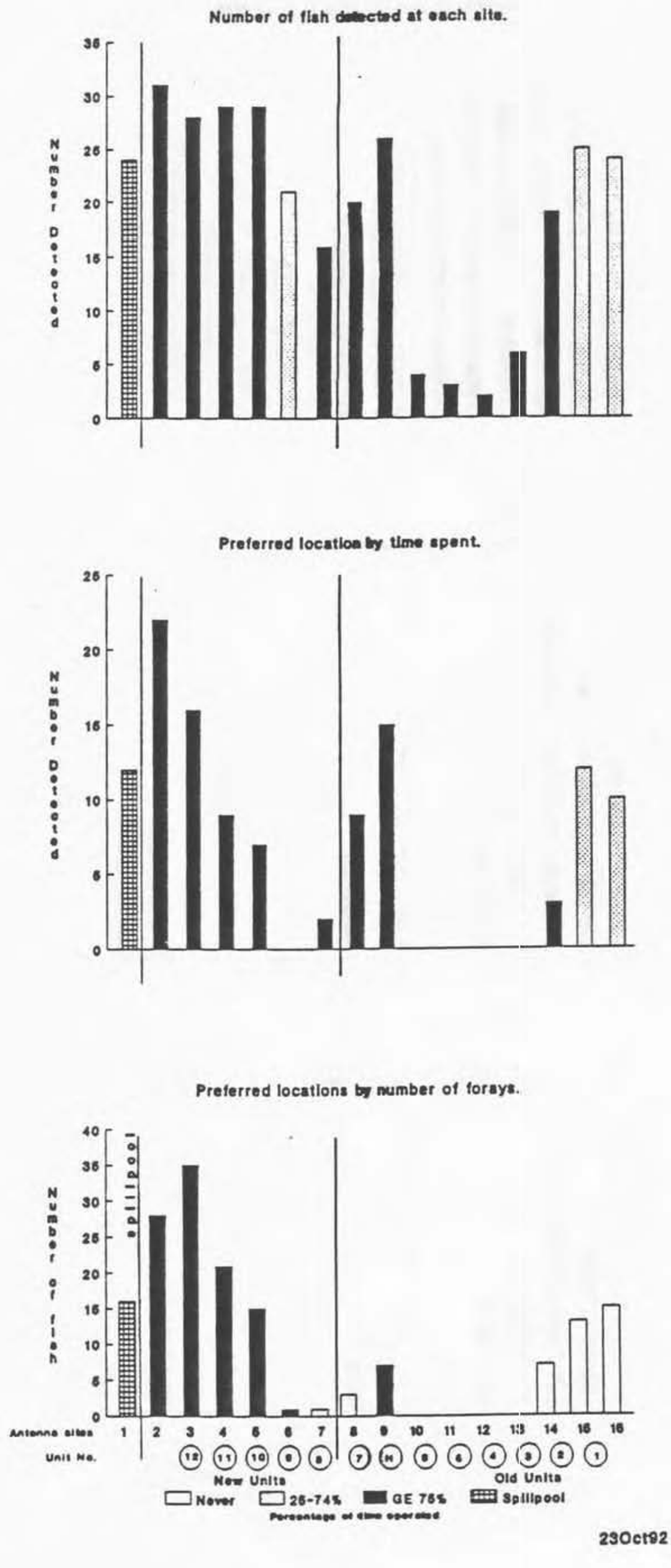


Figure 5-4

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during full generation.

Generation Scenario 3

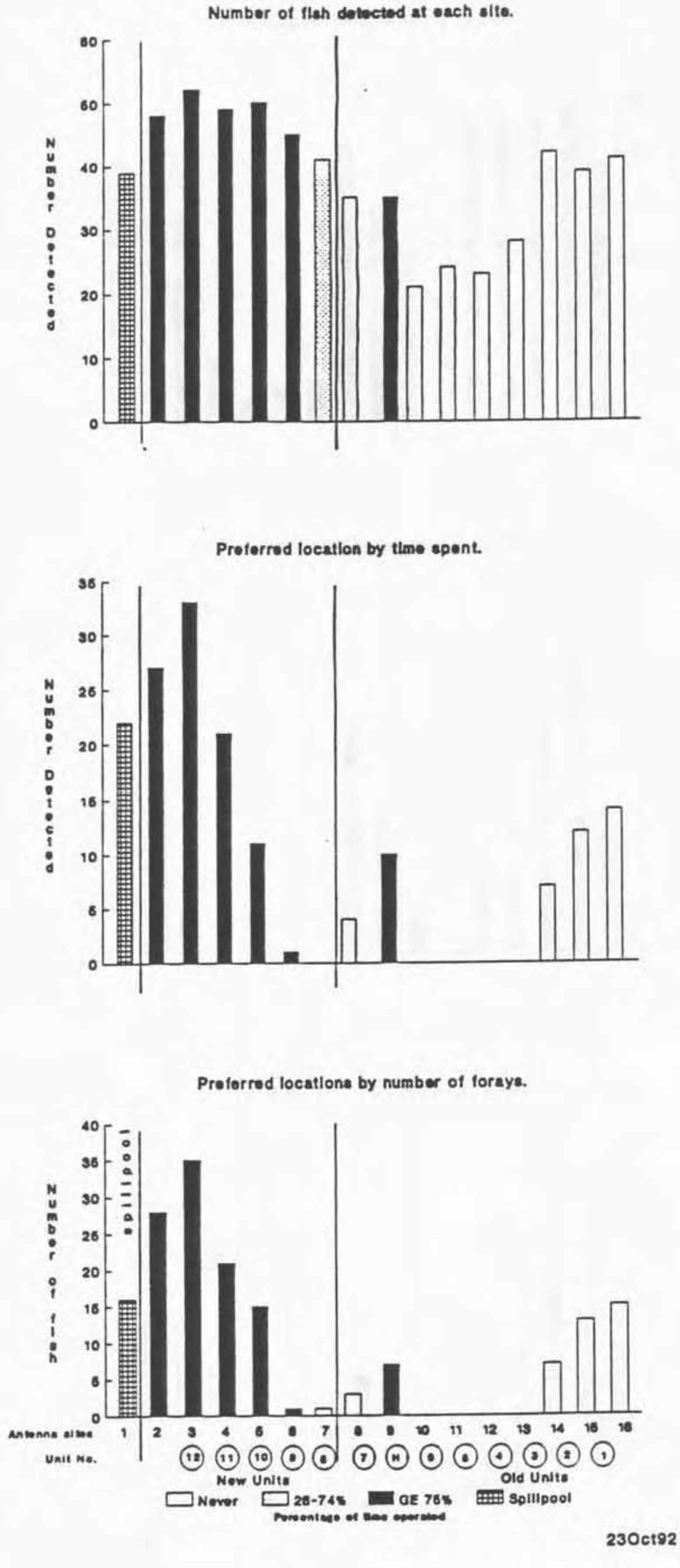


Figure 5-5

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during generation of new units only.

Generation Scenario 4

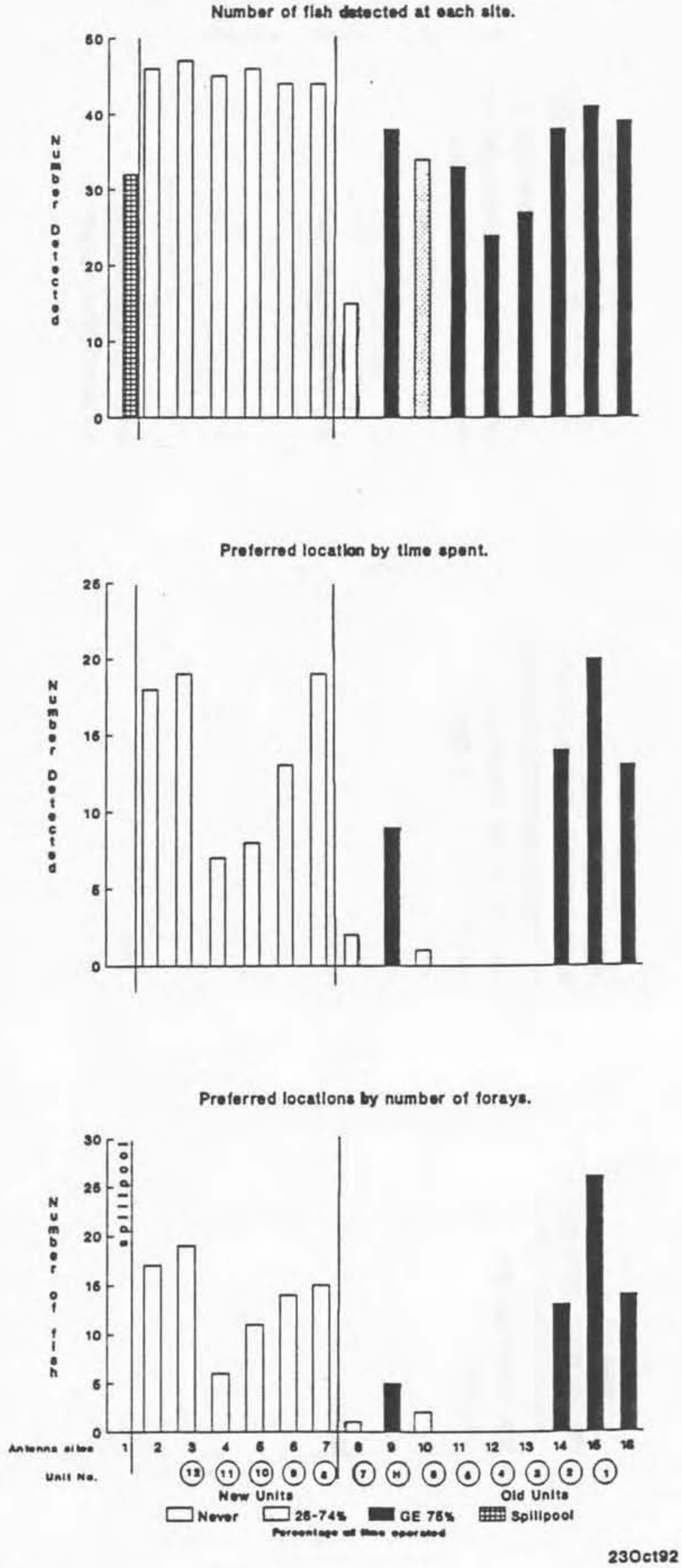


Figure 5-6

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during generation of old units only.

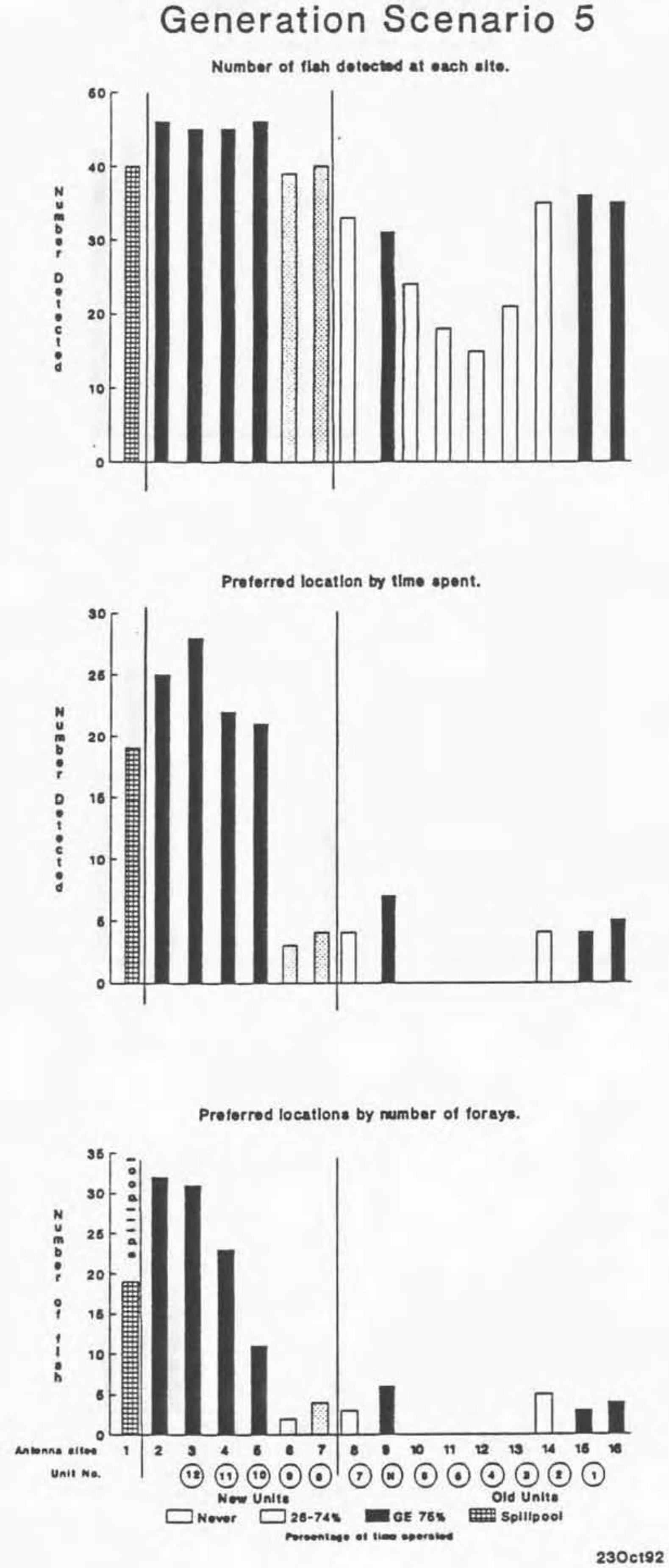


Figure 5-7

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during generation of new units plus old Unit 1.

Generation Scenario 6

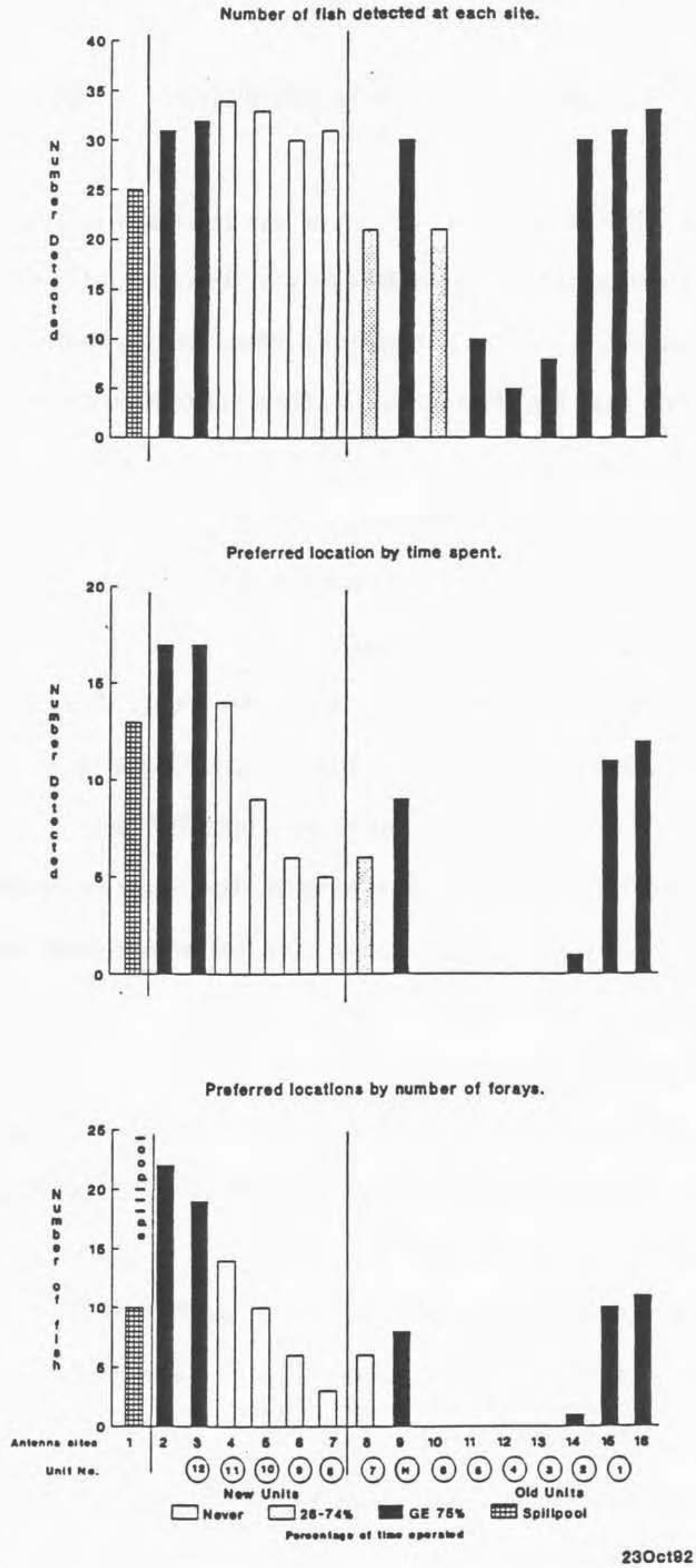


Figure 5-8

Comparison of number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the 16 antenna sites and corresponding units of the Safe Harbor Station during generation of old units plus new Unit 12.

6.0 YORK HAVEN: RESULTS, DISCUSSION AND RECOMMENDATIONS

6.1 Results

Telemetered shad were monitored at the York Haven Powerhouse and associated dams, Main and Red Hill, to ascertain the best locations for a fishway. Fish preferred both upstream and downstream sections of the powerhouse. It appears a fishway could be sited near Unit 1 or the upstream units. Only about half of the fish that reached the powerhouse moved to the dams, while only one fish was detected at the dams that did not show up at the powerhouse. This initial year of study indicates a fishway could be placed along either shoreline of the Red Hill Dam; however, this may not be necessary with a properly sited facility at the powerhouse.

6.1.1 Tagging and Transport of Test Specimens

A total of 99 tagged fish was released for the York Haven study (Table 6-1). Fish were released in four separate groups: 24 on 5 May, 26 on 11 May, 25 on 20 May, and 24 on 28 May. Transport times to Columbia's public boat launch ranged from 70-77 min ($\bar{X}$ = 74 min). Two additional fish died or regurgitated their tags in transport. Post release site observations revealed three fish, one each from release groups 1, 2, and 3, had died or regurgitated their tags and are excluded from data analysis (Table 6-1).

6.1.2 Shad Movement To The Tailrace

Forty-nine (51%) tagged shad were detected at three monitoring sites in the vicinity of York Haven Powerhouse, the Main Dam, and Red Hill Dam (Table 6-2; Figures 2-5 and 2-6). Some 48 (98%) of 49 shad were detected at the York Haven powerhouse; 42 (86%) were first detected there. Detection at each of the eight antenna sites ranged from 39 (81%; site 6) to 47 (98%; site 2). At least 90% of the fish were detected at sites 1-3 and 8. (Table 6-2 and Figure 6-1). The remaining shad was only detected at Red Hill Dam.

Twenty-five (26%) shad were detected at the Main and Red Hill dams (Table 6-2). Of these, 9 and 7 were only detected at the Main and Red Hill dams, respectively. Nine (9%) other shad were only detected away from the York Haven Project through aerial surveys. The disposition of the remaining 38 (40%) shad is unknown.

Some 60 and 58% of release groups 2 and 4, respectively, migrated to the York Haven tailrace. In contrast, 48% of group 1 and only 38% of group 3, migrated to the tailrace (Table 6-1). Overall, shad travel time from the release point to York Haven tailrace ranged from 16 hrs 11 min to 208 hrs 49 min.

Shad residency in the York Haven area was monitored for 15 days. Five fish were located only one of the 15 days each fish was monitored. Some 30 fish were found at least five days and 15 were monitored 10 or more days.

5+30+15 = 50 however, only 49 were detected!

6.1.3 Location Preference Relative To River Flows

Movement and behavior patterns of shad in the vicinity of York Haven were evaluated under four flows including: no spill, low (1500-10,000 cfs), moderate (13,800-23,700 cfs), and high (25,500-36,900 cfs) spill conditions. Due to the hydraulic capacity (16,000 cfs) of the York Haven powerhouse, spills over the Main and Red Hill dams frequently occur. Additionally, the units at York Haven powerhouse are continually operated at maximum capacity when river flows exceed 16,000 cfs. Two units (Nos. 2 and 16) were out of service during this study. The total amount of time each of these flow conditions was monitored ranged from six days at no spill conditions to 13 days at moderate conditions (Table 6-3). Additionally, low spill and high spill conditions were monitored for nine and 10 days, respectively.

The receiver that monitored the York Haven Powerhouse was coupled to eight Yagi antennas evenly spaced across the downstream side of the powerhouse. Antenna sites 1-7 covered the 20 turbine units (Figure 2-6). The remaining antenna site (#8) was located at the downstream corner of the powerhouse and detected fish in the downstream peripheral area of Unit 1 discharge. Due to the complexity of the York Haven Project and distances between the sites, data are presented independently for the monitoring stations at the York Haven powerhouse, the Main Dam, and the

Red Hill Dam. Detailed data of the amount of time and number of forays for each fish at each antenna site is presented in Appendix C.

The locations preferred (see section 2.7.1 for method of preference calculation) by shad at all flow scenarios in the vicinity of the powerhouse are presented in Figure 6-1. Locations preferred at each flow scenario are presented in Figures 6-2 to 6-5.

6.1.4 Shad Behavior During Non-Spill Conditions

Non-spill conditions were monitored for six consecutive days from 26 through 31 May (Table 6-3). A total of 11 fish was located at the powerhouse during daytime monitoring (Table 6-4). The number of fish detected was greatest at antenna sites 1-3 (Units 12-20) and 8 (Downstream of Unit 1); 11 fish at each site were recorded. Lesser numbers (8-10) were detected at sites 4-7. Preference analysis indicated antenna site 8 was highest in number of fish ranked 1, 2 or 3 in duration and forays (Table 6-5 and Figure 6-2) site 3 ranked second in preference.

The pattern of frequency of forays and time spent at each site, in general, was similar to preferred locations. Antenna sites 1-3 and 8 had the highest median values in both instances (Table 6-4). The highest median duration time, 74 min, and number of forays, 74, occurred at antenna site 8 (downstream of Unit 1). These values were nearly double those observed for sites 1-3. Median duration and number of forays was low ($\leq$6) at sites 5-7.

Some 14 shad were detected at the powerhouse during nighttime non-spill monitoring. The number of fish detected at each site ranged from 12 at sites 2, 3, and 8, to 7 at site 5, which was consistent to that observed for daytime monitoring (Table 6-4 and Figure 6-2). The median values of fish duration and number of forays was nearly equal for sites 3 and 8 (Table 6-6). This was not consistent with values calculated during daytime monitoring, where median values were nearly double at antenna site 8. The primary areas of preference were sites 2, 3 and 8 (Figure 6-2).

6.1.5 Shad Behavior During Spill Conditions of 1500-10,000 cfs

Spill conditions of 1500-10,000 cfs occurred at York Haven for nine days between 18 May and 1 June (Table 6-3). A total of 23 fish was detected at the powerhouse (Table 6-4). Twenty-one of these were monitored during daytime with all of these fish moving to sites 1 and 8. Twenty fish were at site 3. The least number (14) moved to site 7. The frequency of forays and time spent by fish at the powerhouse was highest at sites 8, 3 and 2 (Table 6-7). Sites 8 and 3 were the primary preferred sites (Figure 6-3).

During night monitoring at this spill condition antenna site 3 detected 22 of the 23 fish. Slightly fewer fish (19-20) were detected at sites 2, 7, and 8 (Table 6-4 and Figure 6-3). The median duration and forays were highest (6 for both) at antenna site 3 (Table 6-8). The preference ranking indicated site 8 was ranked as high as site 3 and this was similar to the daytime preferences.

6.1.6 Shad Behavior During Spill Conditions of 13,800-23,700 cfs

Spill conditions of 13,800-23,700 cfs occurred on 13 days throughout the monitoring period 4 May to 11 June (Table 6-3). A total of 38 fish was monitored; 30 were monitored during daytime (Table 6-4). Fish concentrated near antenna sites 1-3 and 8 during the daytime. The maximum number (30) was detected at antenna 3. Twenty-eight each were detected at antenna sites 1, 2, and 8. This is consistent with other flow scenarios where shad were more equally detected at the upstream and downstream ends of the powerhouse.

The daytime median values of duration and forays was greatest for antenna site 3 and near equal for sites 2 and 8, respectively (Table 6-9). Preference was also highest at site 3; and site 2 ranked a close second (Figure 6-4).

During night monitoring at this flow, most fish were detected at sites 1-3, with site 2 detecting 30 and sites 1 and 3 each detecting 29 (Table 6-4 and Figure 6-4). Although these sites detected the most fish, site 8 had the highest median values for duration (9 min) and number of forays (7) and was the preferred site (Table 6-10 and Figure 6-4).

6.1.7 Shad Behavior During Spill Conditions of 25,000-36,900 cfs

Spill conditions of 25,500-36,900 cfs occurred on ten days during the study period from 6 May to 7 June (Table 6-3). A total of 25 shad was detected; only 16 were monitored during daytime. Fifteen of these fish were located at antenna 2 during the daytime and 14 were detected at antenna sites 4 and 8 (Table 6-4 and Figure 6-5). Although most fish were detected at site 2, the median duration and forays was greatest for antenna site 8 at 5.5 min and 5 forays, respectively sites 8 and 2 were most preferred (Table 6-11 and Figure 6-5).

Of 21 shad monitored at night during this spill scenario, most (18) were detected at antenna site 8 (Table 6-4). Additionally, 17 were detected at both antenna sites 3 and 4. The median durations and forays were low and relatively incomparable. Sites 3 and 8 were preferred (Table 6-12 and Figure 6-5).

6.1.8 Shad Movement And Behavior at the Main And Red Hill Dam Monitoring Locations

Due to the limited generation capacity (16,000 cfs) of the York Haven Hydroelectric Station, spillage over the Main and Red Hill dams frequently occurs during the spring shad migration thus creating a potential for shad to travel into this area (Figure 2-2).

The monitoring station at the Main Dam incorporated two antennas to detect shad near field, and far field. The near field antenna detected fish near the northern-corner of the main dam, just off shore of Three Mile Island. The far field antenna monitored approximately 500 yds of the main dam of Three Mile Island (Figure 2-6). The monitoring station at Red Hill Dam was set up in a similar fashion as that for the Main Dam. The far field antenna monitored the entire width of the East Channel at the base of the dam and the near field antenna only detected fish in the west half of the channel which is closest to Three Mile Island.

A total of 25 shad was detected in the vicinity of the Main and Red Hill dams during the study. Of these, nine were detected at both locations. Some eight and seven shad were only located at the Main and Red Hill dams, respectively. Therefore, 18 shad were monitored at the Main Dam and 16 were monitored at the Red Hill Dam. Additionally, all these fish except 1 were detected at the tailrace monitoring station.

The residency time of the 18 fish near the main dam ranged from 4 min to 91 h 9 min, with a median value of 10 hrs 33 min. Only two fish were detected on the near field antenna. The sixteen shad located in the vicinity of Red Hill Dam were detected nearly equal on the east and west sides of the East Channel. All were located in the monitoring zone closest to Three Mile Island; fourteen were located on the east side of the channel. Duration time in this area ranged from 1 min to 76 hr 39 min.

6.1.9 Diel Movement of Shad

The number of fish monitored per hour at the York Haven powerhouse ranged from 21 to 33. There was a diel movement pattern observed (Figure 6-6). In general, shad were present in greatest numbers (>29) from 0500 hrs until 2100 hrs. It is likely after 2000 hrs, some fish dropped downstream out of the tailrace detection area. This tendency of fish to drop back should not be of great concern at York Haven since at least 64% (21 of 33) fish were present at all times and 94% were present during daytime hours.

6.2 Discussion

The failure of many telemetered fish to reach the York Haven Station is consistent with two previous years of data on radio tagged shad released downstream of the York Haven Station (RMC 1988a, 1988b). These fish were released about 19 miles downstream of York Haven, compared to about 13.5 miles for the present study. Only 29 and 33% of these fish were detected in the vicinity of York Haven, compared to 51% in 1992. A few specimens could have been missed in the earlier studies because continuous monitors were not deployed at York Haven. The early and present studies differ in the percentage of fish from the different release groups that were detected at York Haven. Generally, upstream dispersal was similar for early and late running shad in the present study while few or none of the late running shad reached York Haven in 1987 and 1988.

Failure of approximately half of the shad released into Lake Clarke to reach York Haven and its potential fishway may not be critical, at least initially. Earlier telemetry studies (RMC 1988a, 1988b) revealed that shad spawned in the 15 miles of riverine habitat downstream of York Haven. Shad eggs were collected at three locations, often in the vicinity of radio tagged shad. Wild juvenile shad have also been collected down river of York Haven. Timing and location of these shad collections indicated the fish were likely recruited from spawning sites below York Haven.

Generally, the number of fish detected was similar across the face of the powerhouse regardless of flow and spillage conditions. However, fish did spend more time and make more forays in the vicinity of units 13-15 and downstream of Unit 1 (antenna sites 3 and 8). The area downstream of Unit 1 is in the periphery of the main flow. Fish preference for antenna sites 3 and 8 was apparent at all flow conditions monitored, except at the higher flows (25,500-36,900 cfs spillage).

Fish abundance, was similar between day (7am - 7pm) and night (7pm - 7am) during the four different spill rates monitored, however, examination of these data on an hourly basis indicated some diurnal differences. Fish were least abundant at the powerhouse in the middle of the night (9pm - 3am). A single continuous monitor set up at the Holtwood Station found fish were least abundant between 7pm and 5am (RMC 1990). Fish at Holtwood dropped downstream about a mile to the lower end of the tailrace where it flowed into a pool. This dropping back from a power station during the night is common and should not negatively impact fishway efficiency at York Haven. Because of this phenomenon fish lifts are typically not operated at night. Fish were also least abundant at Holtwood during the night in 1992 (see Section 4.1.12).

Most fish reaching the York Haven Station should stay in the area long enough to use a properly placed fishway. Sixty-two percent of the fish were present five or more days. This is similar to 69% found for fish reaching the Safe Harbor Station (see Section 5.0). The chances for fishway utilization will also be enhanced because fish move throughout the entire tailrace.

Based on this initial year of data, a fishway could be sited on either side of the powerhouse, but a strong preference for a specific area was not evident.

Although, over 50% of the shad monitored in the vicinity of York Haven were detected at the Main and Red Hill Dams, fishways may not be warranted at these sites since all but one of these fish was detected at the powerhouse monitoring station. Should an upriver fishway be required, this initial year of data indicates it could be located on either side of the East channel at the Red Hill Dam. A fishway on the east side of the main dam does not appear warranted because only two fish were located near field in this area.

The spillage conditions monitored this spring were below normal and fish may display a different preference in the vicinity of the powerhouse, Main and Red Hill Dams during higher flows. Fish appeared to be less attracted to the spillage from the dams at the higher flows. There may be a threshold flow at which fish will avoid the spill area. This phenomenon was observed below the Holtwood Dam when spillage flows were high (>55,000 cfs). Radio tagged adult shad left the spill site and congregated in calmer water a mile or more downstream of the dam (RMC 1990).

6.3 Recommendations

An additional year of intensive monitoring of tagged shad the York Haven Station and associated dams is recommended. The same tagging and trucking procedures should be followed. The release location could be moved further upstream, possibly Bainbridge area, provided a suitable stocking location is available. Receiving waters should be at least three feet deep to minimize chance of fish striking the bottom. This additional year of intensive monitoring is needed to obtain information on fish distribution at higher river flows and detailed information on behavior in the tailwaters. River flows were below normal for most of the spring in 1992 and there were no typical high flow events (>100,000 cfs).

Basically, the same antenna/receiver deployment should be used again in 1993, except, additional antennas should be positioned at the station. Dual antennas, one near field, and one far field, should be set up at the eight antenna sites monitored in 1992. Several other antennas should be set up to monitor fish activity along the downstream periphery of Unit 1 and the adjacent trash sluice. These additional antennas are needed to determine if fish are attracted towards the main or peripheral flow, similar to that observed at Unit 12 at Safe Harbor, from Unit 1 and whether discharges from the trash sluice attract or repel fish. If fish are attracted to the sluice a similar type discharge maybe considered to direct fish towards a fishway entrance along the down river (southern) side of the powerhouse. A fishway in this area would likely empty into the southern end of the forebay. Based on previous observations of telemetered and non-telemetered shad at York Haven (RMC 1986), few shad entering the forebay should be entrained through operating units. The likelihood of fish dropping back over the dam should also diminish if the exit from the fishway is not adjacent to spillage. If feasible, we recommend the sluice be opened to one or more settings for eight hours on Monday, Wednesday, and Friday to monitor fish behavior at these conditions.

Table 6-1

Summary of American shad releases at the York Haven Hydroelectric Station, spring 1992.

Release Group	Tag and Release Date	Water Temperature (C) Tagging Site	Water Temperature (C) Release Site	Number of Fish Tagged	Transport Time (minutes)	Release Site	Number of Fish Released	Number of Fish Detected at Project	Number of Fish Detected Elsewhere	Number Dead or Regur-gitated After Release
						Columbia Public Boat Launch				
1	5/5/92	16.8	14.5	25	75	"	24	11 (48%)	1	1
2	5/11/92	16	17	26	77	"	26	15 (60%)	4	1
3	5/20/92	21	20.5	25	70	"	25	9 (38%)	4	1
4	5/28/92	22	18.5	25	75	"	24	14 (58%)	0	0

16/49 = 33%

16 at Redhill

Table 6-2

Listing of radio tagged American shad monitored by release group at the York Haven Hydroelectric Station, May - June 1992.

Release Group		Powerhouse								Main dam		Redhill dam	
(Date Released)	Fish #	8	7	6	5	4	3	2	1	1	2	2	1
1 (05May92)	12.1	x	x	x	x	x	x	x	x				
	12.2	x	x	x	x	x	x	x	x	x	x	x	x
	12.3	x	x	x	x	x	x	x	x			x	x
	12.4	x	x	x	x	x	x	x	x				
	12.8	x	x	x	x	x	x	x	x				
	12.9	x	x	x	x	x	x	x	x	x	x	x	x
	12.10	x	x	x	x	x	x	x	x				
	13.4	x			x	x	x	x	x				
	13.11	x			x	x	x	x	x				
	22.15	x	x	x	x	x	x	x	x	x		x	x
	22.16	x					x	x	x	x			x
Total	11	11	8	8	10	10	11	11	11	4	2	4	5
2 (11May92)	3.1	x	x	x	x		x	x	x	x		x	x
	3.2	x						x	x	x		x	x
	3.3	x	x	x	x	x	x	x	x	x		x	x
	3.4	x	x	x	x	x	x	x	x				
	3.5	x	x	x	x	x	x	x	x	x			
	3.7	x	x	x	x	x	x	x	x				
	3.13	x	x	x	x	x	x	x	x	x		x	x
	3.14		x			x			x			x	x
	3.17	x	x	x	x	x	x	x	x	x		x	x
	20.1		x	x	x	x	x	x				x	x
	20.2	x	x	x	x	x	x	x	x	x			
	20.7	x	x	x		x	x	x	x	x			
	20.9	x	x	x	x	x	x	x	x				
	20.10	x	x	x	x	x	x	x	x	x			
	20.11	x	x	x	x	x	x	x	x				
Total	15	13	14	13	12	13	13	14	14	9	0	7	7

Table 6-2

Continued.

Release Group (Date Released)	Fish #	Powerhouse 8	7	6	5	4	3	2	1	Main dam 1	2	Redhill dam 2	1
3 (20May92)	11.1	x	x	x	x	x	x	x	x	x			
	11.3	x	x	x	x	x	x	x	x				
	11.14	x	x	x	x	x	x	x	x	x			
	27.13	x	x	x	x	x	x	x	x				
	27.14	x	x	x	x	x	x	x	x				
	27.17	x	x	x	x	x	x	x	x				
	28.15												x
	28.17	x	x		x	x	x	x	x	x			
	29.12	x	x	x	x	x	x	x	x	x			
Total	9	8	8	7	8	8	8	8	8	4	0	0	1
4 (28May92)	23.12	x	x	x	x	x	x	x	x				
	23.14	x	x		x	x	x	x	x				
	23.16	x	x	x	x	x	x	x	x				
	24.16	x	x	x	x	x	x	x	x				
	24.17	x	x	x	x	x	x	x	x				
	29.13	x	x	x	x	x	x	x	x			x	x
	29.17	x	x	x	x	x	x	x	x				
	30.12	x	x	x	x	x	x	x	x			x	x
	30.13	x	x	x	x	x	x	x	x				
	30.14	x	x		x	x	x	x	x				
	30.15	x	x	x	x	x	x	x	x	x			
	30.16	x	x	x	x	x	x	x	x				
	31.15	x			x	x	x	x	x			x	x
	31.16	x	x	x	x	x	x	x					
Total	14	14	13	11	14	14	14	14	13	1	0	3	3
All Releases	49	46	43	39	44	45	46	47	46	18	2	14	16

Table 6-3

Number of days four different spill conditions were monitored for radio tagged American Shad at the York Haven Hydroelectric Station, May - June 1992.

Spill Condition (cfs)	Release Group 1	Release Group 2	Release Group 3	Release Group 4	Total Days * for each Condition
No spill	0	0	6	4	6
1,500 - 10,000	2	8	7	1	9
13,800 - 23,700	7	5	1	6	13
25,500 - 36,900	6	2	1	4	10
Totals	15	15	15	15	

* More than one release group was monitored during each spill condition.

Table 6-4

Summary by spill condition of the number of radio tagged American shad located at each antenna site in the vicinity of the York Haven Hydroelectric Station, May - June 1992.

Spill Condition (cfs)	Time of Day	Total No. Fish Located	Powerhouse							
			8	7	6	5	4	3	2	1
No spill	Day	11	11	8	8	10	10	11	11	11
"	Night	14	12	8	8	7	11	12	12	10
"	Combined	12	12	9	11	10	11	12	12	11
1,500 - 10,000	Day	21	21	14	16	16	18	20	19	21
"	Night	23	19	20	15	18	16	22	19	17
"	Combined	23	22	20	19	21	21	23	22	22
13,800 - 23,700	Day	30	28	18	16	22	24	30	28	28
"	Night	35	27	22	18	23	24	29	30	29
"	Combined	38	35	27	23	29	31	35	36	37
25,500 - 36,900	Day	16	14	8	8	11	14	13	15	13
"	Night	21	18	10	9	12	17	17	14	15
"	Combined	25	12	5	8	7	10	11	9	11

Table 6-5

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during daytime non-spill conditions, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
8	11	27:04	0:04-8:41	1:14	11	1611	4-517	74	11
7	8	1:17	0-0:35	0:05	1	77	0-35	5	1
6	8	0:41	0-0:11	0:03	0	41	0-11	3	0
5	10	1:17	0-0:18	0:06	0	76	0-18	6	0
4	10	3:13	0-0:37	0:19	2	193	0-37	19	2
3	11	11:21	0:08-2:58	0:47	9	679	8-178	47	9
2	11	12:07	0:01-3:34	0:34	5	727	1-214	34	5
1	11	9:19	0:05-2:14	0:35	5	558	5-134	35	5

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-6

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during nighttime non-spill conditions, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
8	12	7:49	0:02-3:15	0:15	11	451	2-184	15	11
7	8	0:52	0-0:15	0:03	3	51	0-14	3	3
6	8	0:25	0-0:11	0:01	0	25	0-11	1	0
5	7	0:24	0-0:08	0:01	0	24	0-8	1	0
4	11	1:03	0-0:15	0:03.5	1	63	0-15	3.5	1
3	12	3:38	0:01-1:09	0:13.5	9	217	1--69	13.5	8
2	12	3:18	0:02-0:59	0:09	10	198	2--58	9	10
1	10	2:32	0-0:42	0:07.5	2	152	0-42	7.5	3

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-7

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during daytime spill conditions of 1,500 - 10,000 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
8	21	23:09	0:02-3:42	0:39	16	1376	2-222	39	16
7	14	6:45	0-1:39	0:03	3	405	0-99	3	3
6	16	5:20	0-1:09	0:07	3	318	0-68	7	3
5	16	7:12	0-1:03	0:16	4	427	0-63	16	4
4	18	13:52	0-6:44	0:20	5	794	0-369	20	5
3	20	16:31	0-3:44	0:23	17	983	0-219	23	17
2	19	12:06	0-2:10	0:21	11	725	0-129	21	11
1	21	8:12	0:01-1:14	0:14	4	491	1--74	14	4

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-8

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during nighttime spill conditions of 1,500 - 10,000 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Duration Range	Duration Median *	Duration Pref. **	Forays (number) Total	Forays Range	Forays Median *	Forays Pref**
8	19	6:26	0-1:01	0:10	15	381	0-61	9	16
7	20	2:28	0-0:31	0:02	10	142	0-31	2	11
6	15	1:06	0-0:22	0:01	5	66	0-22	1	5
5	18	1:37	0-0:29	0:02	4	94	0-28	1	3
4	16	2:46	0-0:36	0:03	6	161	0-36	3	5
3	22	6:06	0-1:11	0:08	16	363	0-71	8	15
2	19	3:35	0-0:40	0:03	10	214	0-39	3	11
1	17	2:07	0-0:24	0:03	2	127	0-24	3	2

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-9

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during daytime spill conditions of 13,800 - 23,700 cfs, May - June 1992.

	Number of Fish	Duration (hours:minutes)				Forays (number)			
Antenna	Detected	Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
8	28	29:34	0-6:04	0:23.5	16	1127	0-245	15	14
7	18	3:41	0-0:53	0:02	1	163	0-43	2	0
6	16	1:43	0-0:39	0:01	0	92	0-31	1	0
5	22	6:42	0-1:51	0:03.5	6	281	0-57	3.5	5
4	24	10:02	0-2:01	0:11	10	447	0-81	9	12
3	30	22:05	0:01-4:07	0:17.5	24	908	1-147	12	25
2	28	14:57	0-2:12	0:21.5	21	758	0-100	17	22
1	28	10:39	0-1:22	0:09.5	9	586	0-71	9.5	10

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-10

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during nighttime spill conditions of 13,800 - 23,700 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes)				Forays (number)			
		Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
8	27	14:07	0-2:36	0:09	23	428	0-74	7	23
7	22	2:39	0-0:38	0:01	11	103	0-25	1	9
6	18	0:36	0-0:08	0:01	3	31	0-5	1	4
5	23	1:45	0-0:24	0:01	4	85	0-14	1	4
4	24	3:23	0-0:42	0:02	11	149	0-26	2	11
3	29	7:41	0-1:19	0:04	16	321	0-48	4	14
2	30	5:42	0-0:59	0:05	18	264	0-43	5	19
1	29	5:41	0-0:59	0:04	16	274	0-44	4	18

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-11

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during daytime spill conditions of 25,500 - 36,900 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes)				Forays (number)			
		Total	Range	Median *	Pref. **	Total	Range	Median *	Pref**
8	14	5:50	0-2:34	0:05.5	10	279	0-128	5	9
7	8	1:03	0-0:18	0:00.5	3	35	0-10	0.5	2
6	8	0:25	0-0:12	0:00.5	2	22	0-9	0.5	3
5	11	1:06	0-0:20	0:01.5	4	42	0-11	1.5	5
4	14	2:10	0-0:22	0:04.5	8	83	0-13	3.5	7
3	13	4:01	0-1:30	0:07.5	4	150	0-36	5	4
2	15	2:37	0-1:05	0:04	9	150	0-60	4	10
1	13	2:07	0-0:41	0:03	7	119	0-41	2.5	7

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-12

Comparison of the number of radio tagged shad detected, time spent, forays made, and preference at the York Haven Hydroelectric Station powerhouse during nighttime spill conditions of 25,500 - 36,900 cfs, May - June 1992.

Antenna	Number of Fish Detected	Duration (hours:minutes) Total	Range	Median *	Pref. **	Forays (number) Total	Range	Median *	Pref**
8	18	0:20	0-0:50	0:02	11	140	0-29	1	10
7	10	1:23	0-0:38	0	3	51	0-26	0	3
6	9	0:26	0-0:09	0	3	25	0-9	0	4
5	12	0:54	0-0:20	0:01	6	40	0-15	1	6
4	17	2:03	0-1:12	0:02	6	88	0-46	2	7
3	17	2:16	0-0:37	0:02	14	92	0-20	2	13
2	14	1:10	0-0:15	0:01	6	59	0-12	1	7
1	15	1:14	0-0:16	0:02	8	63	0-10	1	8

* Zero values included in calculation, all fish had equal access to all sites.

** Number of fish ranked 1st, 2nd, or 3rd in time spent (duration) or number of forays to site.

Table 6-13

Comparison of the number of radio tagged shad detected, time spent, and forays made at the Main and Red Hill Dams during four spill conditions, May - June 1992.

Monitoring Site Description	Spill Condition	Number of Fish Detected	Duration (hours:minutes)			Forays (number)		
			Total	Range	Median	Total	Range	Median
Main Dam	No spill	1	52:29			533		
	1500-10000	11	177:58	0:05-77:09	6:08	868	4-244	50
	13800-23700	10	207:48	0:04-52:27	17:54.5	656	4-231	45
	25500-36900	6	73:02	0:18-29:30	10:33.5	141	5--57	19
	Combined	18	511:17	0:05-91:09	10:33	2198	4-781	58
Red Hill Dam	No spill	0						
	1500-10000	5	128:19	0:01-74:43	15:49	581	1-244	70
	13800-23700	12	226:24	0:52-39:51	14:14	912	1-245	58
	25500-36900	7	127:17	5:23-44:47	13:10	473	8-124	52
	Combined	16	482:00	0:01-76:39	28:22.5	1966	1-332	96

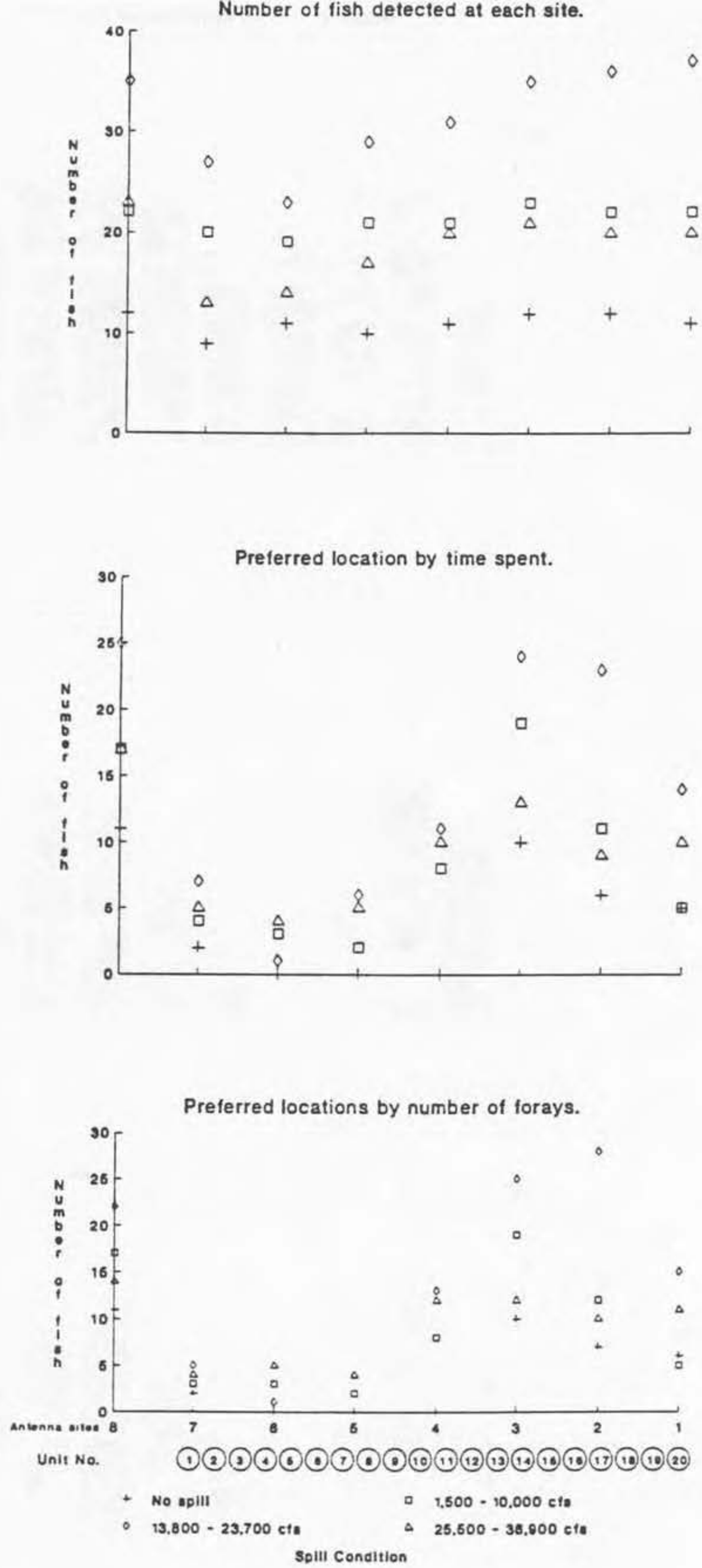


Figure 6-1

Comparison of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the York Haven Hydroelectric Station during four spill conditions.

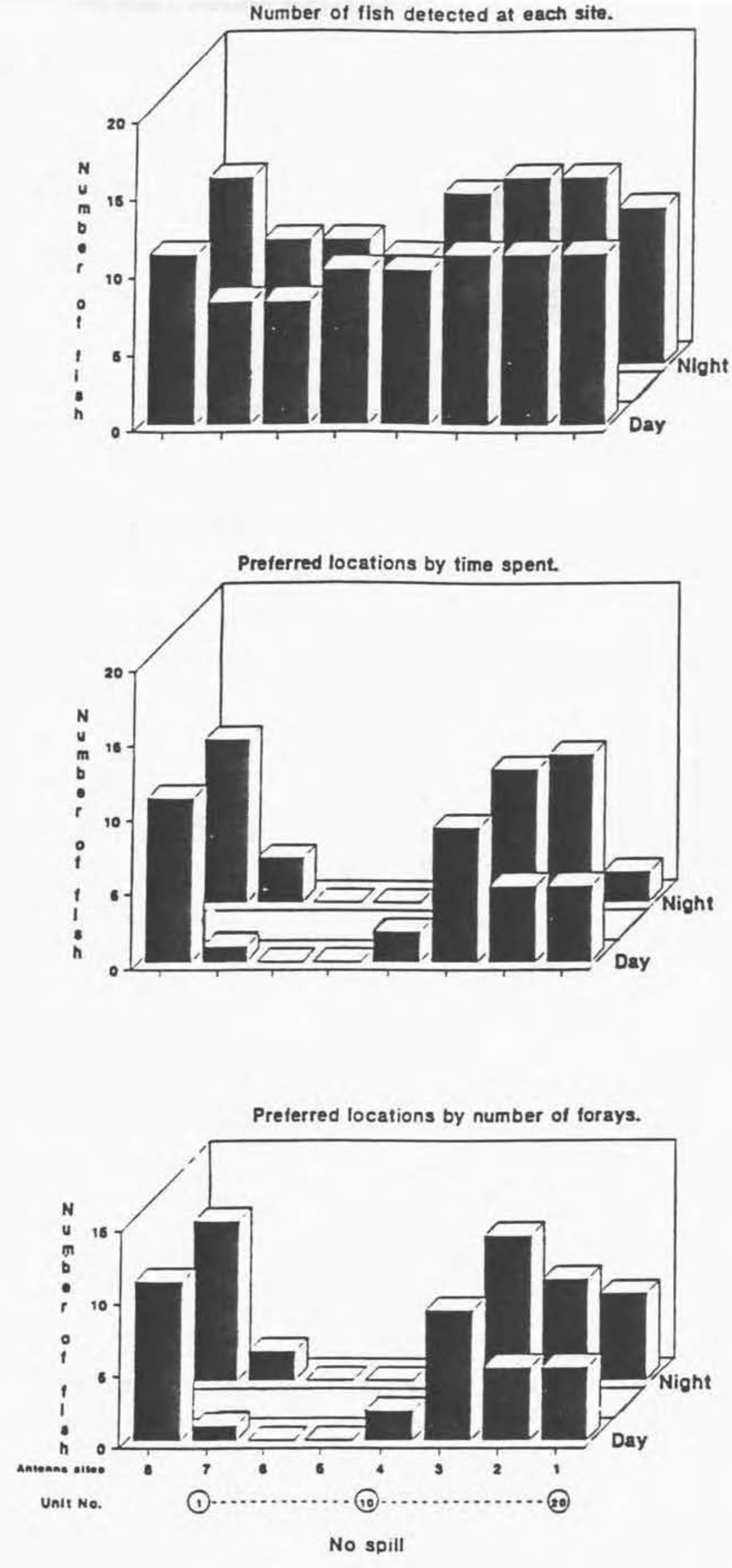


Figure 6-2

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the York Haven Hydroelectric Station during non-spill conditions.

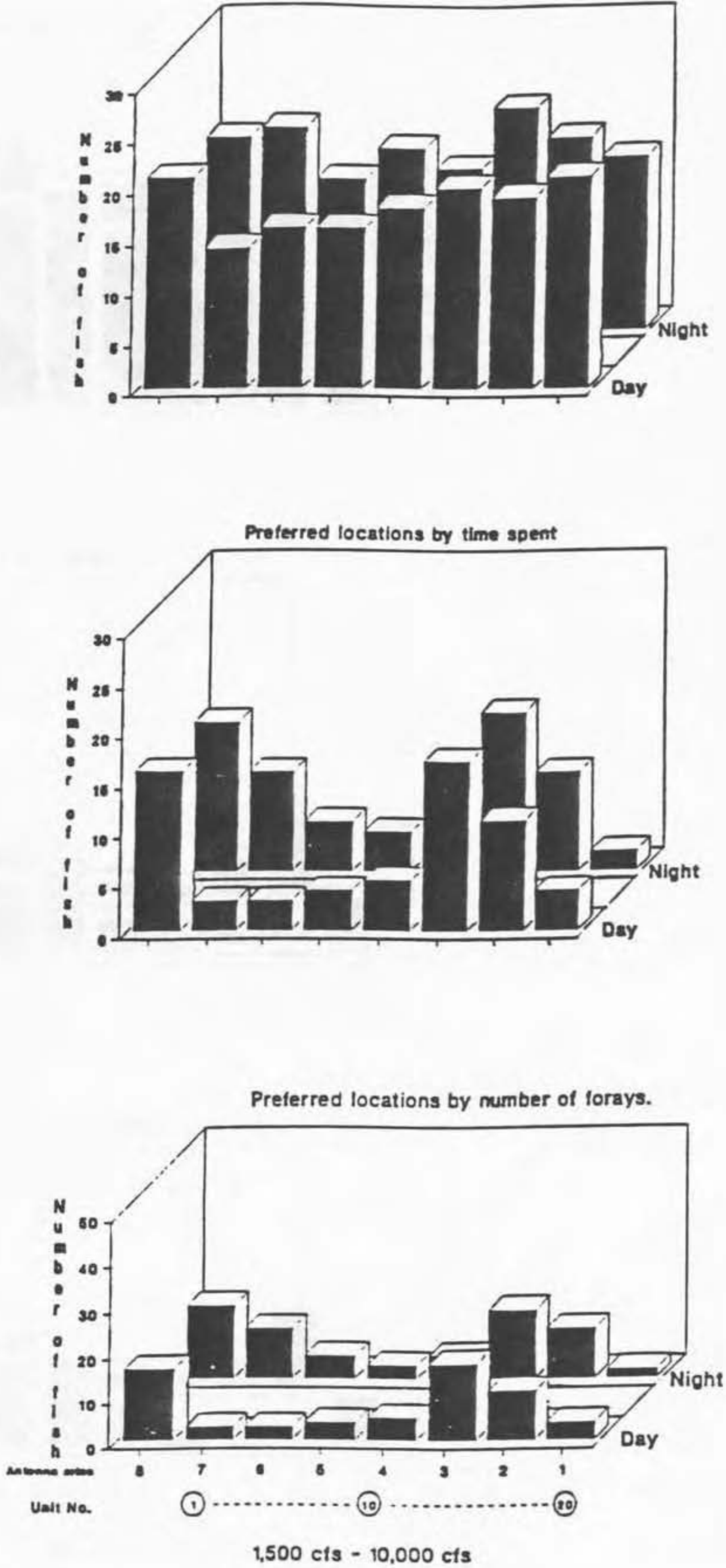


Figure 6-3

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the York Haven Hydroelectric Station during spill conditions of 1,500-10,000 cfs.

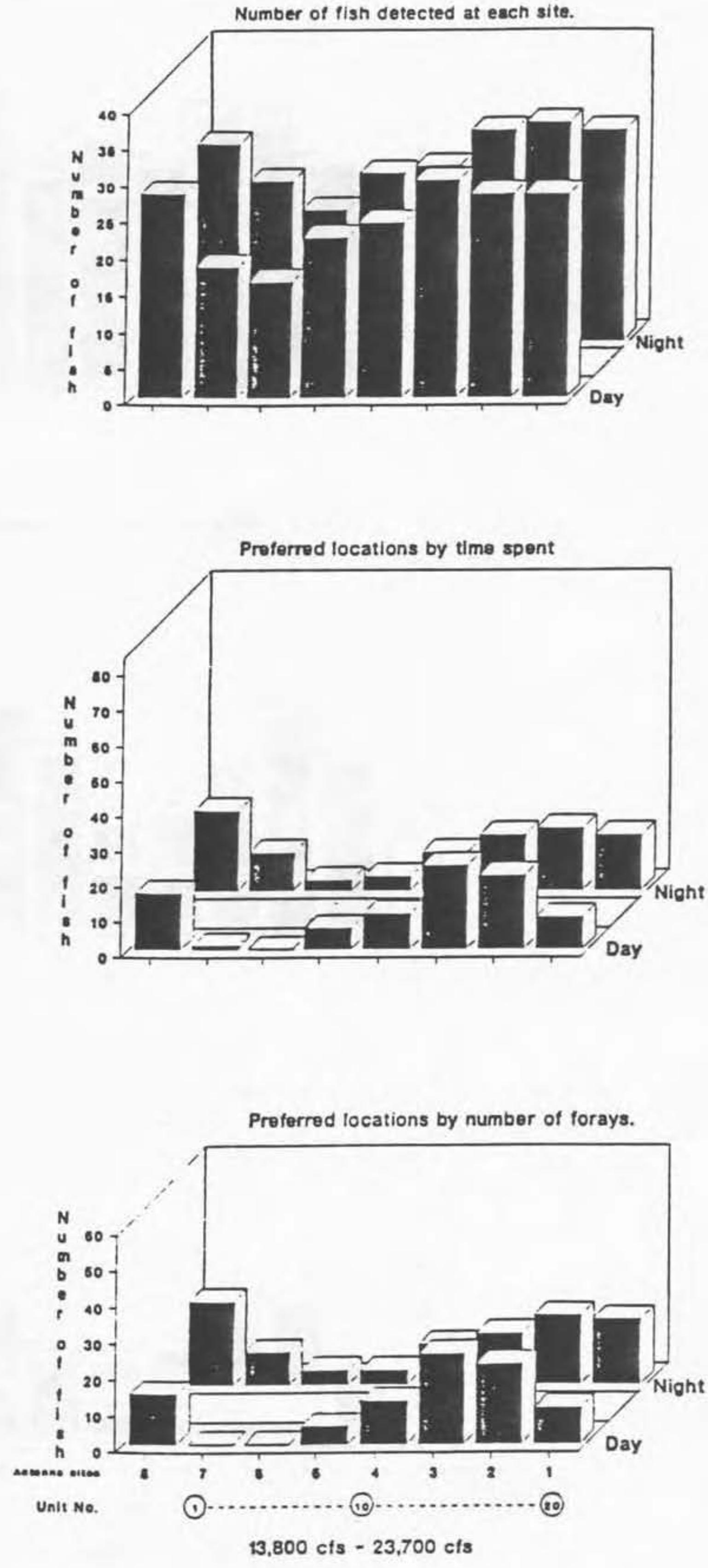


Figure 6-4

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the York Haven Hydroelectric Station during spill conditions of 13,800-23,700 cfs.

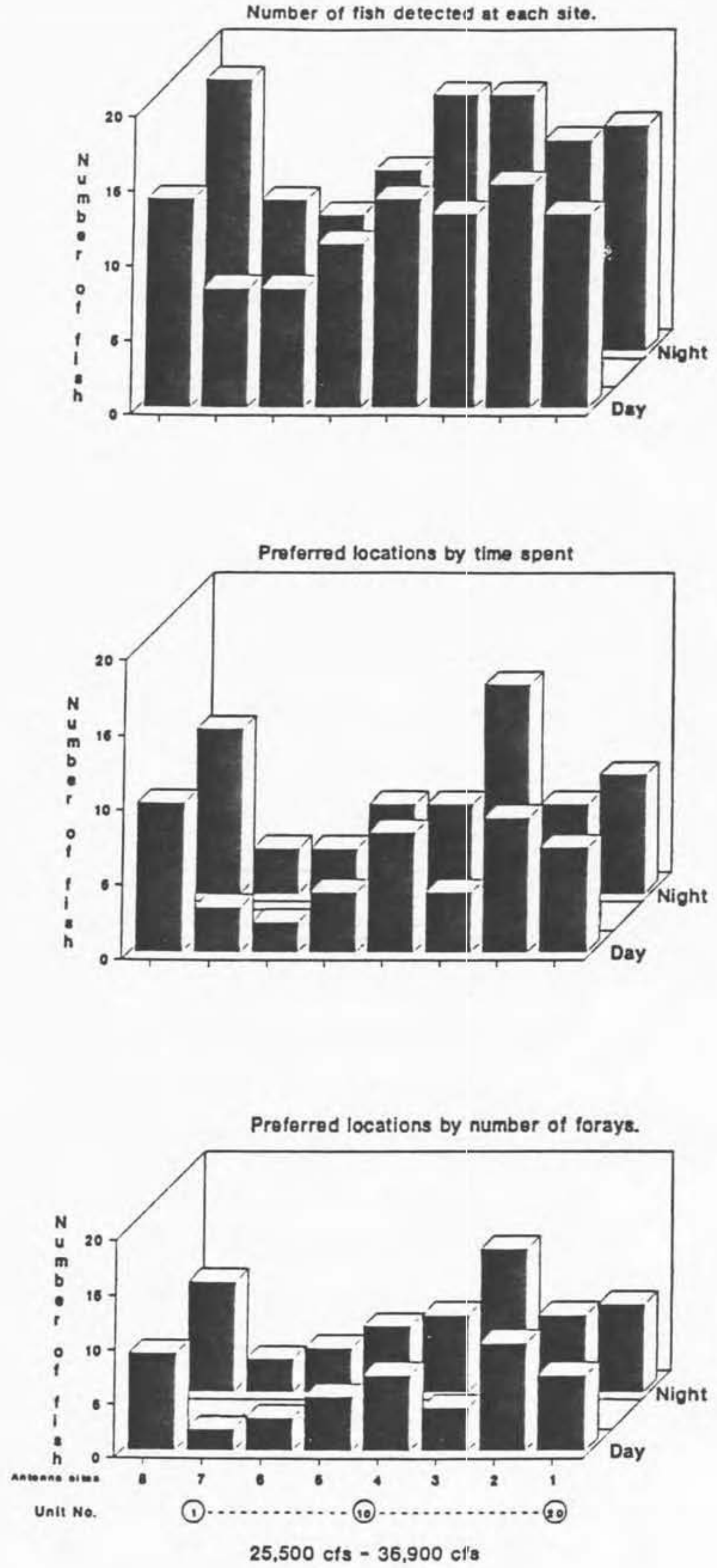


Figure 6-5

Day and night comparisons of the number of fish detected, number of fish ranked 1, 2 or 3 in time spent and forays at the eight antenna sites and corresponding units at the York Haven Hydroelectric Station during spill conditions of 25,500-36,900 cfs.

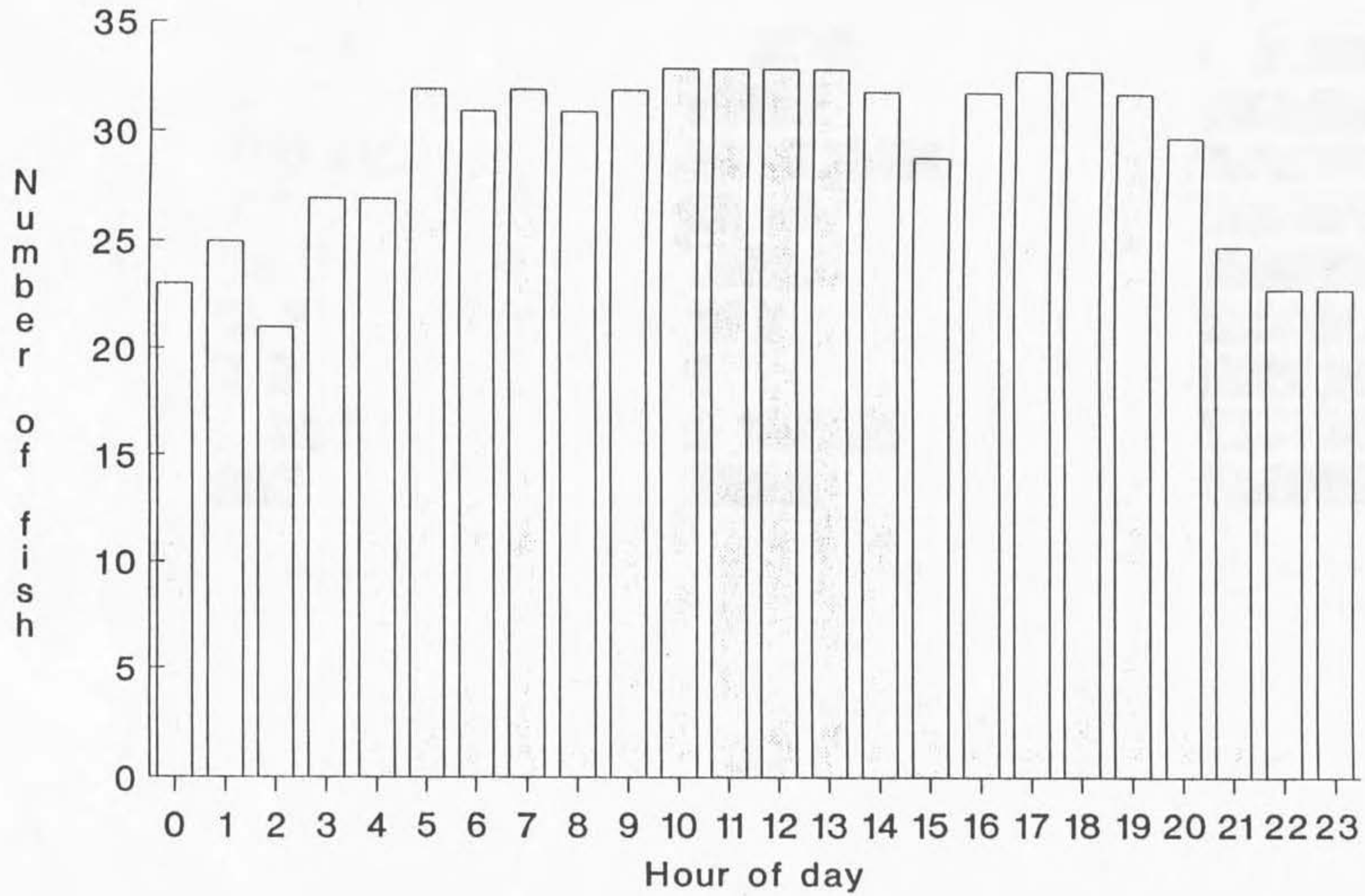


Figure 6-6

Number of fish monitored by hour at the York Haven Powerhouse, Spring, 1[illegible]

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Job V., Task 2. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1992

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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 (Lorson and Mudrak, 1987: 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 minimum 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. Hendricks, et al (1992) developed a method to distinguish between wild and hatchery-reared American shad based solely on otolith microstructure. This report represents a continuation of that work, focusing on evaluation of otoliths from adult American shad collected in 1992.

<u>Hatchery and wild sources of adult American shad returning to Conowingo Dam</u>

Methods:

As in previous years, a representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 100th shad to enter each lift. Each sampled fish was sexed, measured and the otoliths were extracted on site by RMC personnel. Otoliths (sagittae) were delivered to Benner Spring, mounted on microscope slides and ground on both sides to produce a thin sagittal section.

Under white light, each otolith specimen was classified hatchery or wild based upon microstructural characteristics. The classifications were done by 2 experienced researchers. If the researchers disagreed, characteristics were discussed to attempt to reach consensus. If consensus was not reached, the otolith was classified as "microstructure unknown." After microstructure classification, the white light was turned off and the specimen examined under UV light for the presence of a tetracycline mark.

Results:

A total of 246 shad were sacrificed in 1992. For 9 of those, otoliths were broken, not extracted, or had unreadable grinds, leaving 237 readable otoliths (Table 1). A total of 23% of the otoliths exhibited wild microstructure, and 77% had hatchery microstructure. Of those with hatchery microstructure, 90% exhibited tetracycline marks and 10% did not exhibit marks. Ten of the 18 unmarked otoliths with hatchery microstructure exhibited autofluorescence which may have obscured a mark, if it were present. Single, double, triple and quadruple immersion marks were identified and one specimen exhibited a triple immersion mark and a single feed mark (Table 1).

Discussion:

Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. It is possible to estimate hatchery and wild contributions to the population of adult shad entering the lifts by applying a correction factor based on the error rates achieved in the blind trials (Hendricks et al., 1992):

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

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

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

The blind trials (Hendricks et al., 1992) included a group of Delaware River fish for comparison. If we exclude Delaware River fish, which would not be expected to enter the trap, a total of 2.4% of the hatchery fish were classified incorrectly (E_h = 0.0240) while 17.7% of the wild fish were classified incorrectly. If we include the 1.3% of the wild fish on which we disagreed, the error rate for wild fish is 19.0% (E_w =0.190). Using these correction factors, estimates of hatchery contribution to the adult population entering the Conowingo Dam fish lifts during 1989-1992 ranged from 67% to 76% (Table 2, Figure 1). The percentage of fish with hatchery microstructure which also exhibited tetracycline marks was 28% in 1989, 54% in 1990, 66% in 1991 and 90% in 1992. This is expected, as unmarked hatchery cohorts constitute a decreasing proportion of the population over time. The percentage of fish with hatchery microstructure which also exhibit a tetracycline mark should reach an asymptote corresponding to mark retention to adulthood. We have no reason to believe that marks retained to 100d would not be retained to adulthood. Mark retention is likely to be more a function of our ability to produce consistently good grinds than it is actual loss of the mark.

Mitochondrial DNA Study

Introduction:

Dr. Bonnie Brown of Virginia Commonwealth University is conducting a genetic investigation of the resurgence of the American shad in the Susquehanna River using electrophoretic techniques. The study involves the description of genotype frequencies for baseline populations of shad which might contribute to Susquehanna stock. Six genotypes found in the Susquehanna are statistically compared to the baselines to determine maximum likelihood estimates of stock composition (Chapman and Brown, 1991).

Methods:

The sample consisted of 50 males and 50 females collected at the Conowingo Dam fish lifts on June 11, 1992. Otoliths from those 100 fish were extracted, given a blind number and delivered to us for analysis.

Results:

A total of 95 of the 100 otoliths in the sample were readable (Table 3). The proportion of fish exhibiting wild microstructure and no tetracycline mark was 23% for the sacrificed fish and 8% for the DNA sample. The proportion of fish exhibiting a single tetracycline mark on d5 or days 5-8- 5-9 was 77% for the sacrificed fish and 41% for the DNA sample. This suggests that the composition of the samples is different.

We tested this using a X^2 test of independence (Ott, 1977). For the analysis, groups of fish with a single mark on days 5-8 or 5-9 were combined with those with a single mark on d5, since we are uncertain of our ability to distinguish between the 2 types of marks. Groups of fish with single marks on days 15-18 or 15-19, d12, and d15 were combined with those with single marks on d18 for similar reasons. Since the Chi-square test requires that no expected value is less than 1 and that no more than 20% are less than 5, (Ott, 1977), we also combined fish with both triple marks and feed marks (1 fish) with fish which had triple marks only. The results of the test indicated that the composition of the catch was dependent upon the sample ($X^2 = 51.4$, df=7, $P < 0.005$). Thus, the DNA sample may not be representative of the entire population entering the lift. It is unclear whether this is because the sample was collected on a single day or because an artificial 50:50 sex ratio was selected. The reader is referred to Dr. Brown for further information.

Virginia Coastal Intercept Fishery Study

Introduction:

A drift gill net fishery for American shad has developed in nearshore Virginia coastal waters. This intercept fishery is of concern to fishery managers because of the potential for harvest of shad from depleted stocks, including the Susquehanna. Dr. Roman Jesien of the University of Maryland, Center for Environmental and

Estuarine Studies, is investigating the stock composition of the fishery by tagging adult shad to determine their eventual destination (Maryland DNR, Tidewater Administration, Contract No. F267-92-008). He has also collected tissue samples for stock identification using mitochondrial DNA. That analysis is being conducted by Dr. Bonnie Brown of Virginia Commonwealth University.

Methods:

In addition, otoliths were collected from the same adult shad and delivered to us to identify any hatchery-reared Susquehanna River shad based on tetracycline marking. Our trials, and those of Dr. Brown, were blind trials: only a specimen number was included with the sample.

Results:

There were a total of 328 shad in the sample. For 15 of the shad we received no otoliths. For 3 shad, both otoliths were destroyed during grinding. Good data was obtained from the remaining 310 otoliths. A total of 308 (99%) of the remaining otoliths exhibited no tetracycline marks and typical wild microstructure. One fish (#8), had microstructure which was typical of hatchery shad: slow initial growth (narrow increments), a check at about 16d of age, and faster growth (wider increments) after the check. It did not exhibit a tetracycline mark.

Discussion:

We believe it likely that this was a wild fish and probably not from the Susquehanna River for several reasons. First, the percentages are against it being an unmarked hatchery fish. Ninety percent of the adults collected at Conowingo, which exhibited hatchery microstructure, also exhibited a mark (Table 1). Second, the fact that this fish was collected offshore, makes it likely that it was a wild fish which grew atypically slowly and exhibited narrow increments. A second fish (#280), exhibited no mark and had early growth increments which were intermediate between typical hatchery and typical wild fish. Again, this is very likely a wild fish with somewhat atypical early growth. For further information on this study the reader is referred to Dr. Roman Jesien.

Summary

A total of 246 adult American shad were sacrificed for otolith analysis at the Conowingo Dam fish lifts in 1992. Of the 235 readable otoliths, 23% exhibited wild microstructure and 77% had hatchery microstructure. Ninety percent of the otoliths with hatchery microstructure also exhibited tetracycline marks. Estimates of hatchery contribution to the population of adults entering the lifts ranged from 67% in 1990 to 76% in 1992.

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Figure 1. Estimated composition of fish lift catch at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1992.

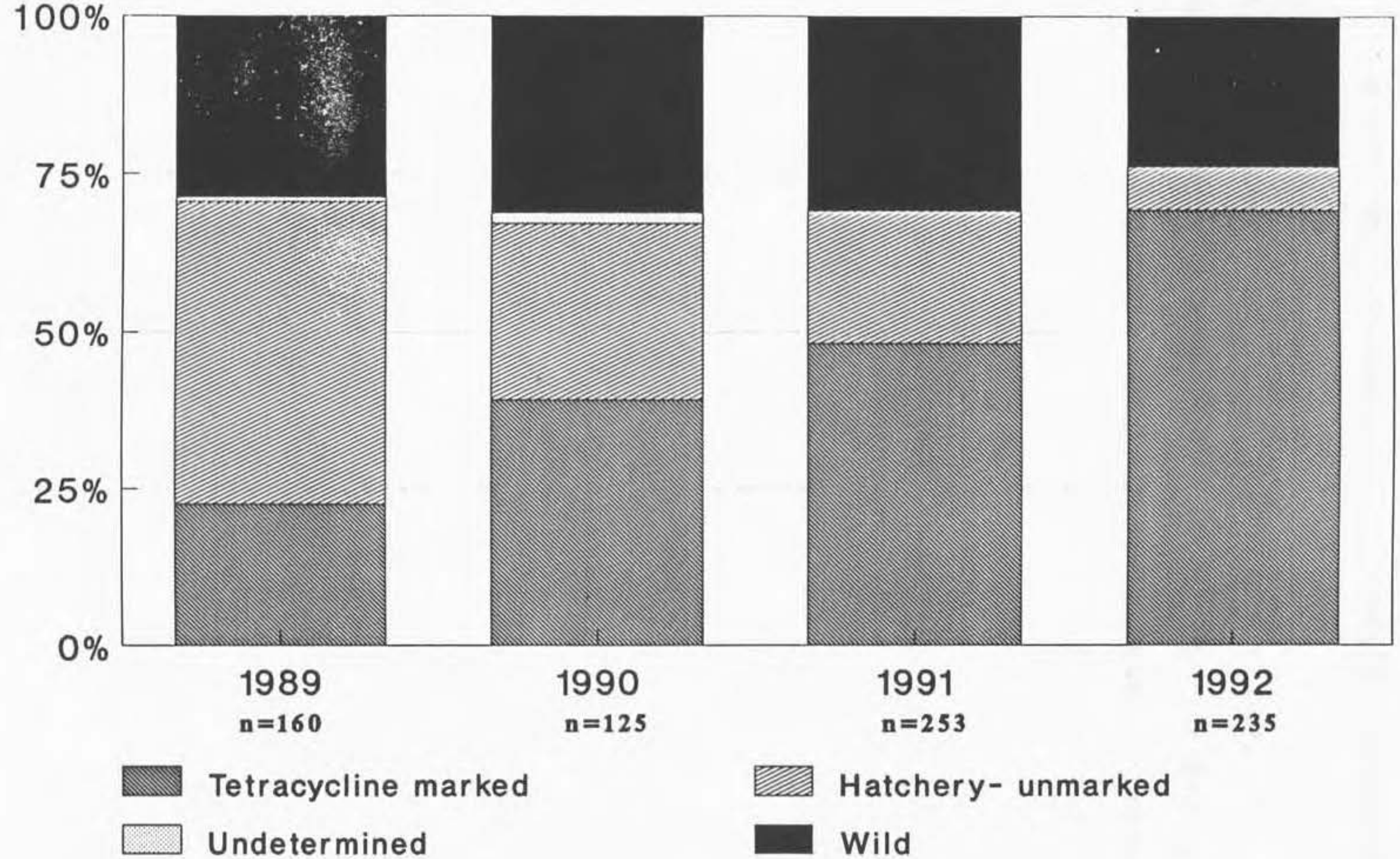


Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts, 1992. One of every 100 fish to enter each lift was sacrificed.

			Sex		Total	
			M	F	N	%
Wild Microstructure, No TC Mark			15	39	54	23%
Hatchery Microstructure	No TC Mark*		10	9	19	8%
	Single TC Mark	Day 5	35	41	76	32%
		Days 5−8 or 5−9	6	15	21	9%
		subtotal	41	56	97	41%
		Day 12				
		Day 15				
		Day 18	3	9	12	5%
		Days 15−18 or 15−19	4	14	18	8%
		subtotal	7	23	30	13%
	Double TC Mark	Days 5,9	7		7	3%
		Days 5,12		1	1	
	Triple TC Mark	Days 5,9,13	11	3	14	6%
	Quadruple TC Mark	Days 5,9,13,17	10	3	13	5%
	Feed Marks	Days 5,9,13,17+	1			
		3d feed mark			1	0%
		Days 3,13,17 +	1			
		3d feed mark			1	0%
		Total Hatchery	88	95	183	77%
		Total readable otoliths	103	134	237	
		Unreadable Otoliths**	6	3	9	
		Total	109	137	246	

*Includes 10 otoliths in which autofluoresence may obscure mark.
**Includes missing, broken, and poorly ground otoliths.

Table 2. Composition of the catch of adult American shad at Conowingo dam fish lifts, based on microstructure classification and tetracycline marking, 1989–1992. Estimates of population proportions were derived from sample classifications corrected based on error rates from a blind classification trial.

	1989			1990			1991			1992		
	Sample n		Population	Sample n		Population	Sample n		Population	Sample n		Population
Wild Microstructure:	29	18%	29%	32	26%	31%	68	27%	31%	54	23%	24%
Microstructure unknown	1	1%	1%	2	2%	2%	0	0%	0%	0	0%	0%
Hatchery Microstructure No Tetracycline mark:	94	59%	48%	42	34%	28%	63	25%	21%	19	8%	7%
Tetracycline marked	36	23%	23%	49	39%	39%	122	48%	48%	164	69%	69%
Total Hatchery	130	81%	71%	91	73%	67%	185	73%	69%	183	77%	76%
Total	160			125			253			237		

Table 3. Microstructure classification and tetracycline marking of adult American shad for two samples collected in the Conowingo Dam Fish Lifts, 1992. One of every 100 fish to enter each lift was sacrificed. The DNA sample included 50 males and 50 females collected on 6/11/92.

			Sacrificed		DNA sample	
			N	%	N	%
Wild Microstructure, No TC Mark			54	23%	8	8%
Hatchery Microstructure	No TC Mark*		19	8%		
	Single TC Mark	Day 5	76	32%	71	75%
		Days 5-8 or 5-9	21	9%	2	2%
		subtotal	97	41%	73	77%
		Day 12			1 **	1%
		Day 15			1	1%
		Day 18	12	5%		
		Days 15-18 or 15-19	18	8%	2	2%
		subtotal	30	13%	4	4%
	Double TC Mark	Days 5,9	7	3%	6	6%
		Days 5,12	1		3	3%
	Triple TC Mark	Days 5,9,13	14	6%	1	1%
	Quadruple TC Mark	Days 5,9,13,17	13	5%		
	Feed Marks	Days 5,9,13,17+ 3d feed mark	1	0%		
		Days 3,13,17 + 3d feed mark	1	0%		
		Total Hatchery	183	77%	87	92%
		Total readable otoliths	237		95	
		Unreadable Otoliths***	9		5	
		Total	246		100	

*Includes 10 otoliths in which autofluoresence may obscure mark.
**Specimen with wild microsructure and tetracycline mark.
***Includes missing, broken, and poorly ground otoliths.

Job V, Task 3

PROGRESS REPORT
1992 PRELIMINARY STUDY OF FISH PROTECTION METHODS
HOLTWOOD HYDROELECTRIC PROJECT

PREPARED FOR

PENNSYLVANIA POWER & LIGHT COMPANY
SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

PREPARED BY
STONE & WEBSTER ENVIRONMENTAL SERVICES

JANUARY 1993

INTRODUCTION

In mid-1992, Stone & Webster and Pennsylvania Power & Light Company (PP&L) met to discuss various approaches that PP&L could take to obtain an understanding of the movement patterns of American shad juveniles into the plant area at the Holtwood Project and to use that understanding to identify methods for effectively bypassing the outmigrating fish safely around the project. Stone & Webster has been conducting an extensive evaluation of a strobe light and bypass system for preventing migrating shad from passing through the turbines at Metropolitan Edison's (Met-Ed) York Haven Project. These studies have demonstrated that strobe lights strongly repel shad and can be used to guide this species to the sluiceway bypass at that site. A major advantage of a strobe light system over other mechanical types of fish protection systems is that the strobes are effective when operated only periodically, thereby eliminating the need for continuous spilling through a bypass. Given the behavior of American shad outmigrants, it appeared possible that fish could be effectively bypassed at Holtwood with short spilling periods (several minutes) several times each night.

Stone & Webster reviewed the design and operation of the Holtwood Project and believed that the site layout (Figure 1) is similar enough to York Haven to warrant a preliminary evaluation of strobe light technology. Accordingly, Stone & Webster developed a Scope of Work for this preliminary evaluation of strobe lights which was approved and performed in the fall of 1992. The study was funded by the Susquehanna River Anadromous Fish Restoration Committee and is presented in this report.

PURPOSE

The purpose of the 1992 preliminary study program was to develop an understanding of fish behavior at the Holtwood Project, the basic behavioral response of American shad to strobe lights, and to identify or quantify important structural and hydraulic features of the project which could influence fish behavior. In previous studies conducted by Stone & Webster at Met-Ed's York Haven Station, strobe lights have been shown repeatedly to divert American shad through a trash sluice bypass.

The scope of work called for several tasks to be completed relative to evaluating fish behavior and passage at Holtwood:

TASK 1 Determine the migratory pathway that the fish follow and the behavioral characteristics of the fish in the vicinity of the skimmer wall;

TASK 2 Measure critical environmental and hydraulic parameters that influence fish movement and behavior and can effect the selection of potentially effective fish protection measures;

TASK 3 Conduct small-scale pilot tests with strobe lights at the downstream end of the skimmer wall near the sluiceway.

The rationale behind each task is presented below.

RATIONALE

Task 1: Fish Behavior - Stone & Webster has demonstrated at York Haven, as well as many other sites, that the success of a behavioral system in protecting fish is dependent upon an understanding of the behavior of those fish as they approach the area of hydraulic influence of a hydroelectric facility. Migratory fish, such as American shad, follow ambient river currents as they move downstream and avoid hydraulic conditions which signal danger. Most fish avoid the acceleration in flow and turbulence which typically exists as water passes through trash racks. Further, surface-oriented fish such as shad tend to sound and pass under structures such as skimmer walls only if no other route of egress exists, and then only after some period of delay in downstream movement. The skimmer wall configurations at the Holtwood Project are shown on Figures 2 and 3. Under normal pool elevation, the skimmer walls extent into the water column about 12 feet. Therefore, it is likely that surface-oriented shad will resist passing under these walls.

The physical and hydraulic conditions appear ideal at Holtwood for natural movement of shad along the skimmer wall toward the debris sluice. With the plant operating, there is a perceptible current moving along the wall in a downstream direction. It is possible that shad move with this current and accumulate in front of the sluice gate (which is normally closed) for some period of time before sounding under the wall and entering the plant forebay.

At low river flow conditions, the hydro plant is not typically in operation at night when shad are actively migrating. Under this condition, shad may mill upstream of the skimmer wall for extended periods until the units come on line in the early morning.

Under either operating condition, the skimmer wall will act as a barrier for at least a short period of time. A behavioral repelling system, such as strobe lights, offers the potential for taking advantage of this avoidance response and concentrating the shad near the existing sluice gate (or a new or modified fish bypass). The potential effectiveness of such a system would be better defined if the migration patterns and behavior of the shad in the area of the skimmer wall were understood.

Task 2: Environmental and Hydraulic Measurements - As discussed above, the behavior of migratory fish is dictated by the physical and hydraulic conditions that they encounter as they move downstream. It is important to document these conditions in order to understand the patterns of fish movement and their tendency to congregate in selected areas when confronted with a structure such as a dam and hydroelectric facility. With this understanding, it is possible to explain fish response to ambient conditions and to predict how they might respond to artificial stimuli such as strobe lights.

Task 3: Strobe Light Pilot Tests - While strobe lights have been shown to effectively repel American shad at York Haven, possible differences in water quality and physical/hydraulic conditions at Holtwood warranted an investigation of the basic behavioral response of shad to the lights at Holtwood. Therefore, small-scale pilot tests were proposed for 1992 to verify the response of shad at Holtwood. The information obtained would provide a baseline for future development of a strobe light system for protecting American shad at this site.

MATERIALS AND METHODS

The equipment used to achieve the three study tasks included scanning sonar, strobe lights and velocity and turbidity meters. Each type of equipment is described below.

Scanning Sonar

Two WESMAR Model SS390 scanning sonar systems were use during the study. One unit was deployed from the floating ice boom (Figure 4) to monitor, on a continuous basis, the outmigration of American shad. Data was collected 24 hours/day and was also used to determine the behavior and distribution of fish in space and time. The second sonar system was used during the strobe light evaluation to record the response of fish upon light activation. The sonar was deployed from the bow of a PP&L barge that was used as a work platform during the strobe light study (discussed later).

Each sonar system included a control console, a sounddome and preamplifier with connecting cables, a time lapse video recorder, a color video monitor and a power supply (Photograph 2). The range, gain and transducer angles of the sonar units were calibrated throughout the study using fixed mechanical targets with known acoustic backscattering characteristics. Data was recorded using time lapse VCR's in the VHS format. The VCR's provided date and time information on-screen which was also recorded for documentation.

Strobe Lights

Two strobe lights floats (Photograph 1) were designed and constructed to be easily installed as test units at any location. The floats were mounted from the bow of the PP&L barge, as shown in Photographs 3 and 4. A single strobe light was suspended from each float, at a depth of six feet, via a PVC mast. The strobe light equipment used was manufactured by Flash Technology, Inc. and was recently developed specifically for underwater applications.

Supplemental Sampling

Supplemental sampling was conducted to obtain the following information:

- hydraulic conditions to which fish approaching the hydroelectric plant are exposed
- turbidity
- bottom bathymetry

Current velocities in the study area were taken in a grid pattern using a Swoffer velocity meter. Turbidity measurements were obtained using a Hach Turbidimeter, model 2100P. Bottom bathymetry was mapped using the WESMAR SS 390 scanning sonar.

RESULTS

The results of each task are presented separately below:

Fish Behavior - On September 18, 1992, a scanning sonar unit was attached to the downstream ice boom (Figure 4) at PP&L's Holtwood Hydroelectric project to monitor fish activity. PP&L employees monitored the sonar system and the time lapse VCR, changing tapes daily. The tapes were initially reviewed by PP&L and then shipped overnight to Stone & Webster in Boston, Ma. Fisheries biologists at Stone & Webster reviewed the tapes to note the frequency of targets appearing in the vicinity of the study area and the densities of these targets.

On October 13, the sonar data indicated that fish were present in the Holtwood area. Scanning sonar at York Haven also indicated the movement of fish. The study team immediately mobilized and was on-site for testing the next night, October 14. Unfortunately, in the short time that was required for mobilization, fish abundance dropped dramatically and did not increase again throughout the study period. Sonar monitoring continued until November 11. The lack of targets observed, coupled with the minor number of shad collected by RMC in a collection net at Holtwood, led to a decision to terminate monitoring.

While sonar data was limited, visual observations of fish dimpling upstream of the skimmer wall and sonar data indicate that fish approach the wall along the flow streamlines that exist in this area (Figure 5). Further, it appears that fish tend to move toward the downstream end of the wall. These observations will need to be verified in 1993, since few fish were available for close observation in the sluicegate area during the study period.

Environmental and Hydraulic Measurements - Velocity profiles were obtained at ten locations along the skimmer wall (Figure 6). The scanning sonar was used to obtain bottom bathymetry data along transects immediately upstream of the skimmer wall and lateral transects from the skimmer wall to a distance of several hundred feet into the river.

Table 1 presents the velocity data obtained at the locations shown on Figure 6. It was determined that the velocities approaching the wall increase from the upstream floating sections to the downstream solid sections and also increase with depth. Velocities with eight units running at full capacity ranged from about 0.5 ft/sec at the surface to greater than 2.0 ft/sec at a depth of 30 feet (see Figures 7 through 16). Visual observations indicated that the surface flow approaches the wall at an angle and that there is a noticeable flow along the wall in a downstream direction toward the sluice gate.

Bathymetric measurements taken along the skimmer wall and for several hundred feet into the river from the wall at Holtwood show that the river bottom is relatively flat in the area upstream of the wall. Several hundred feet upstream of the wall, the bottom drops steeply as the flow dives under the wall. It is in this area that the highest velocities were measured (in excess of 2 ft/sec).

One additional discovery was made during the October testing period. Both the bottom bathymetric survey and the scanning sonar data indicate the presence of an underwater structure that extends outward from the upstream end of the concrete skimmer wall toward the dam. This structure interfered with the detectable range of the sonar. Discussions with plant personnel indicate that a submerged railway structure exists that was left after original construction (Figure 17). This potential problem will have to be taken into consideration in future studies.

Strobe Light Pilot Tests

Due to the limited number of fish in the area during the study period, little information on the response of shad to the strobe lights was obtained. While it has been clearly proven that American shad juveniles strongly avoid strobe lights at York Haven, it was hoped that some data would be obtained at Holtwood to verify such a response under the environmental and hydraulic conditions at this site. Fortunately, the feasibility of mobilizing strobe lights and sonar on one of the available work barges was demonstrated. This approach proved so simple and effective that it is proposed for additional testing in 1993.

DISCUSSION

There is strong reason to believe that the hydraulic and physical conditions existing at Holtwood tend to "guide" fish toward the sluicegate. Fish were not present in sufficient abundance during the study to determine 1) the behavior of fish immediately upstream of the wall or 2) where and when the fish ultimately "sound" and pass under the wall. However, with the baseline data collected this year, it has been possible to formulate a plan for additional studies with reasonable assurance of successful completion.

Hydraulic measurements taken along the skimmer wall show that the velocities are higher approaching the downstream length of the wall and increase from surface to bottom. The apparent skew in the distribution of fish toward the downstream area would appear to result from a behavioral response to physical and hydraulic conditions in the river where the bottom is relatively uniform and shallow (about 20 feet deep) and along the wall. Similar behavior of American shad outmigrants has been well documented at the York Haven project. Velocity measurements taken throughout the York Haven forebay show that juvenile shad have a preferred flow velocity in the range from 1.0 to 1.5 ft/sec that they will tend to stay in as they move downstream. It appears that the fish follow the relatively low velocity river flow downstream to the dam area at Holtwood while avoiding moving into the increasing velocity areas approaching and passing under the skimmer wall. This type of behavior is optimal for using behavioral devices to further enhance movement of fish toward the existing sluiceway or future bypass.

CONCLUSION

The results of the 1992 preliminary study have yielded interesting data that will be of significant value in planning the future efforts of a fish diversion and bypass that could be developed for installation at Holtwood Hydroelectric Project. Fish were not present in sufficient abundance during the study to determine their response to strobe lights. However, the quantitative and qualitative data obtained allow the following conclusions and observations to be made:

- There is strong reason to believe that the hydraulic and physical conditions existing at Holtwood tend to "guide" fish toward the sluicegate.
- Strobe lights can be easily deployed at Holtwood; the strobe light system used in 1992 was functionally effective and should be adequate for all future testing needs

While it is believed that the strobe lights will effectively repel shad at Holtwood, additional studies will be required to determine the optimum design and location of a system for repelling American shad to a bypass.

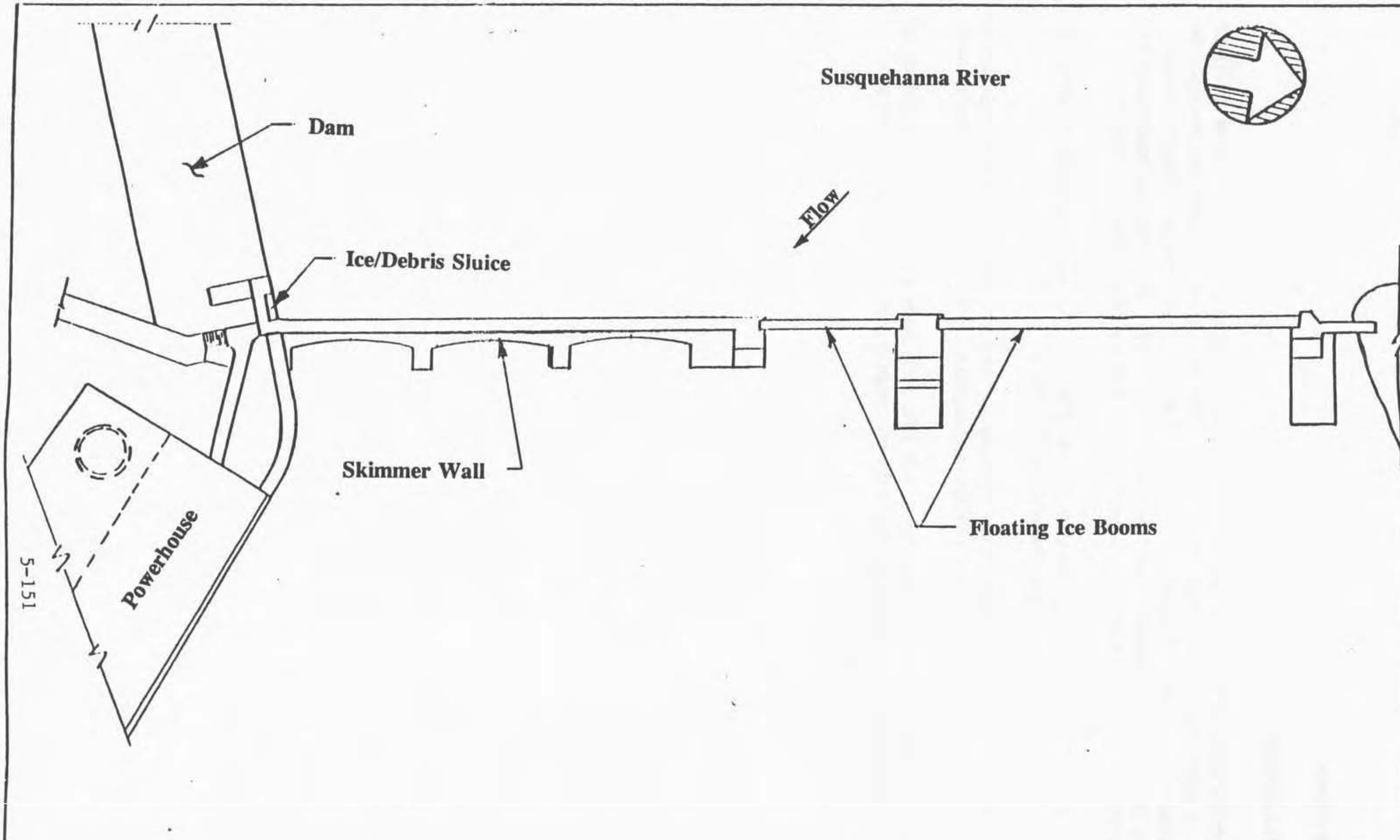


Figure 1
Project Layout
Holtwood Project

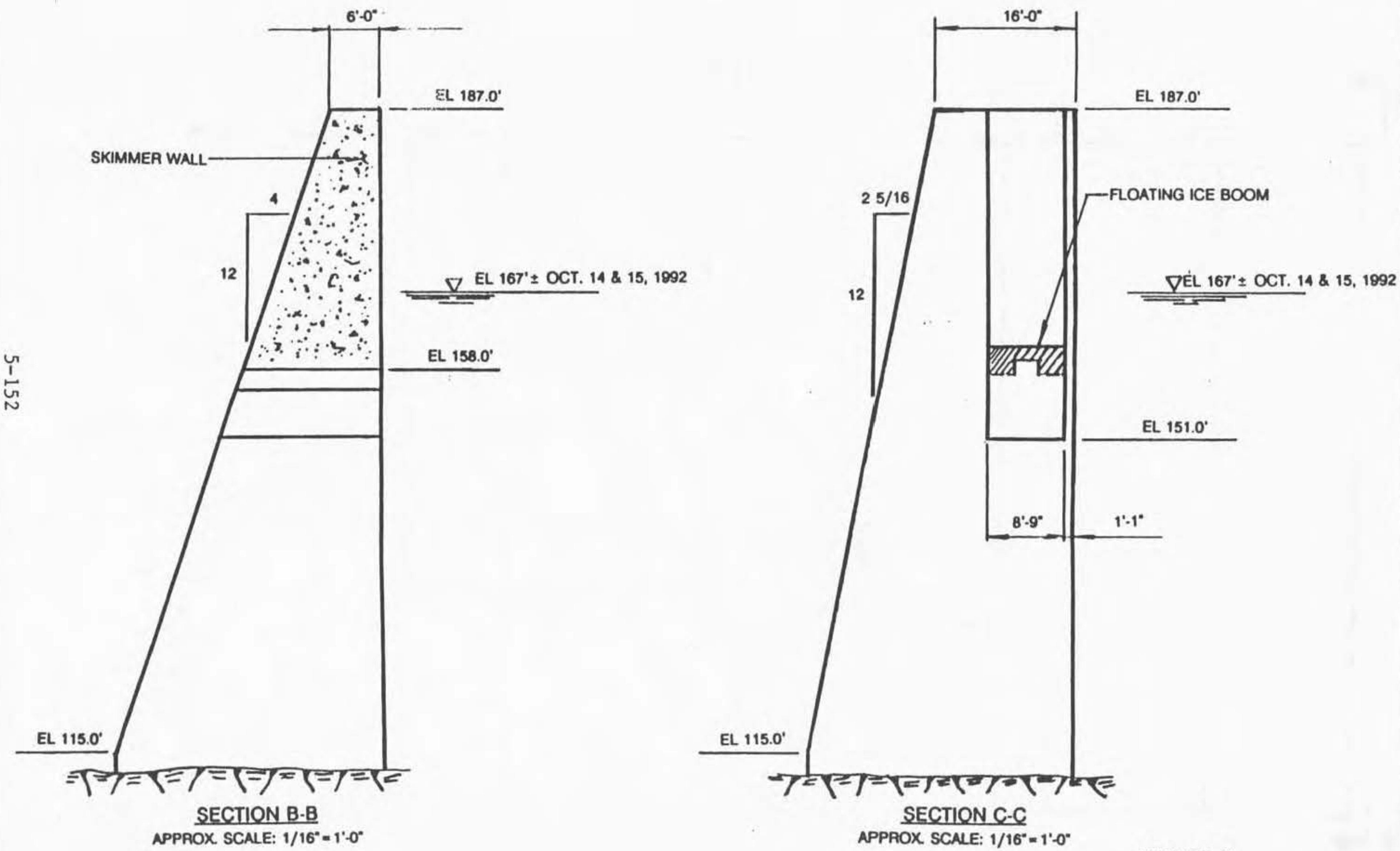
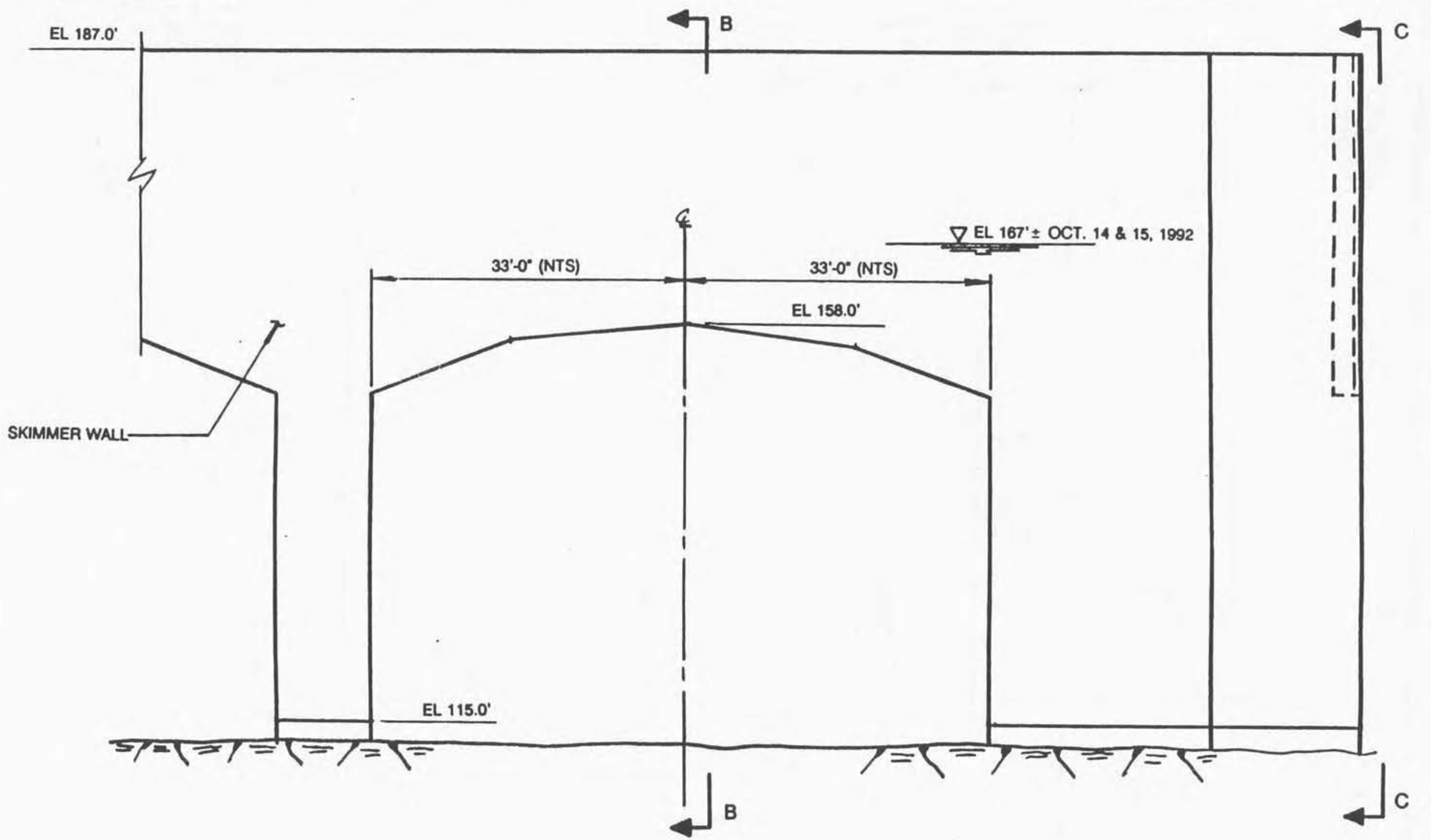


FIGURE 2
SECTIONS THROUGH SKIMMER WALL
HOLTWOOD HYDROELECTRIC PROJECT



SECTION A-A
APPROX. SCALE: 1/16" = 1'-0"

FIGURE 3
ELEVATION OF SKIMMER WALL
HOLTWOOD HYDROELECTRIC PROJECT

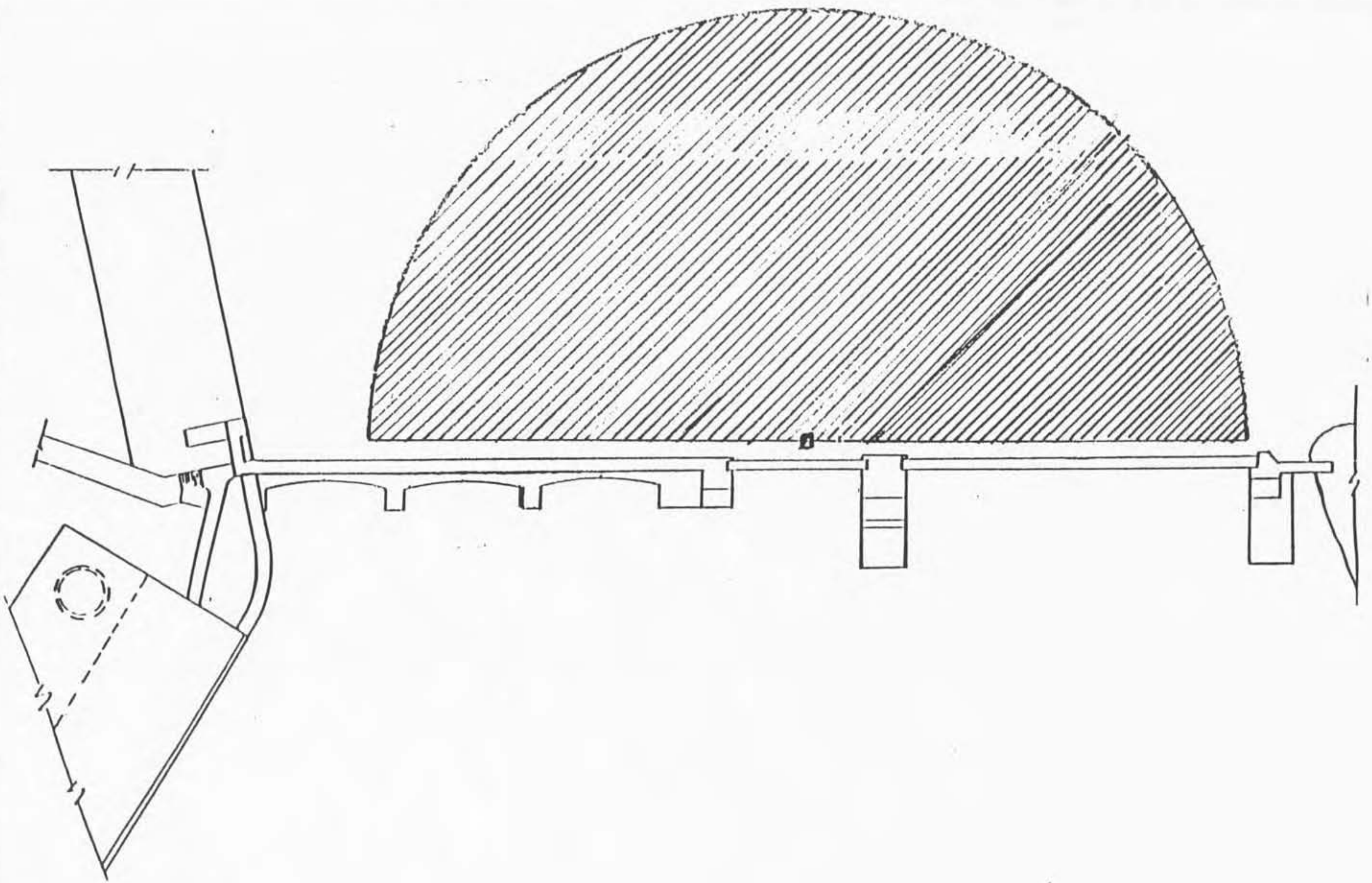
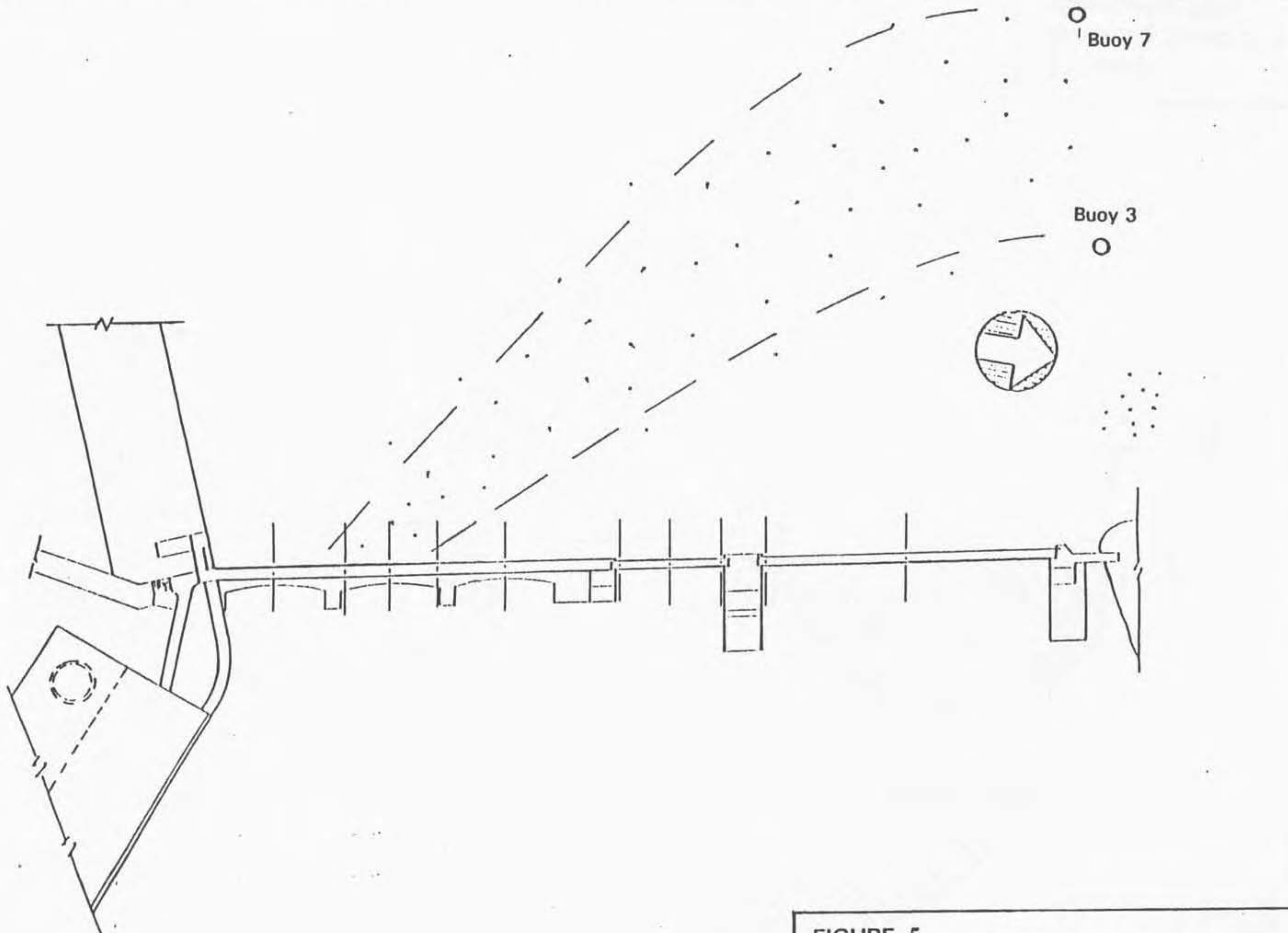


Figure 4
Scanning Sonar For
Monitoring Fish



.FIGURE 5
Visually Observed Dimpling Pattern of American Shad in 1992 Strobe Light Study

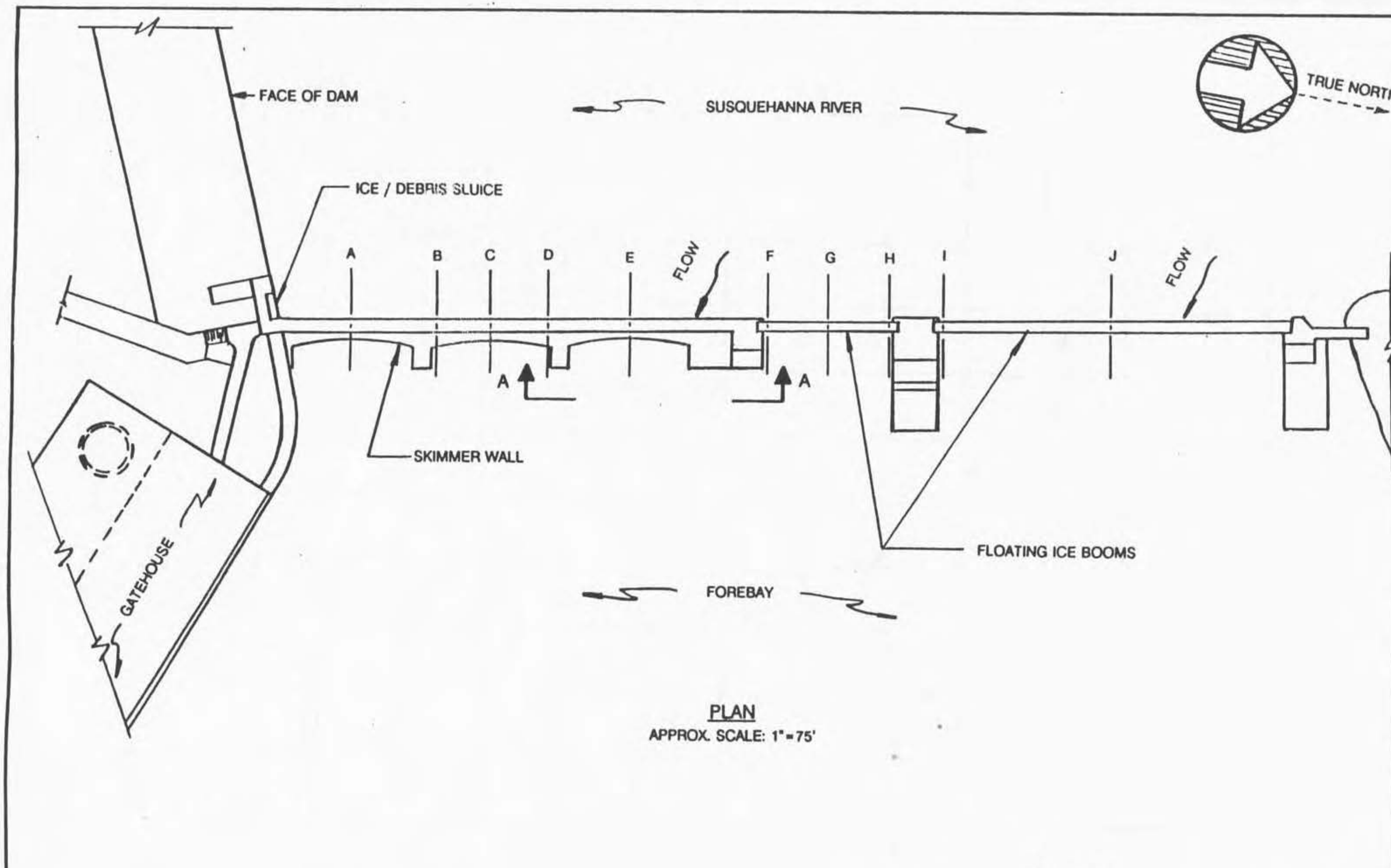


FIGURE 6
PLAN SHOWING LOCATION OF VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

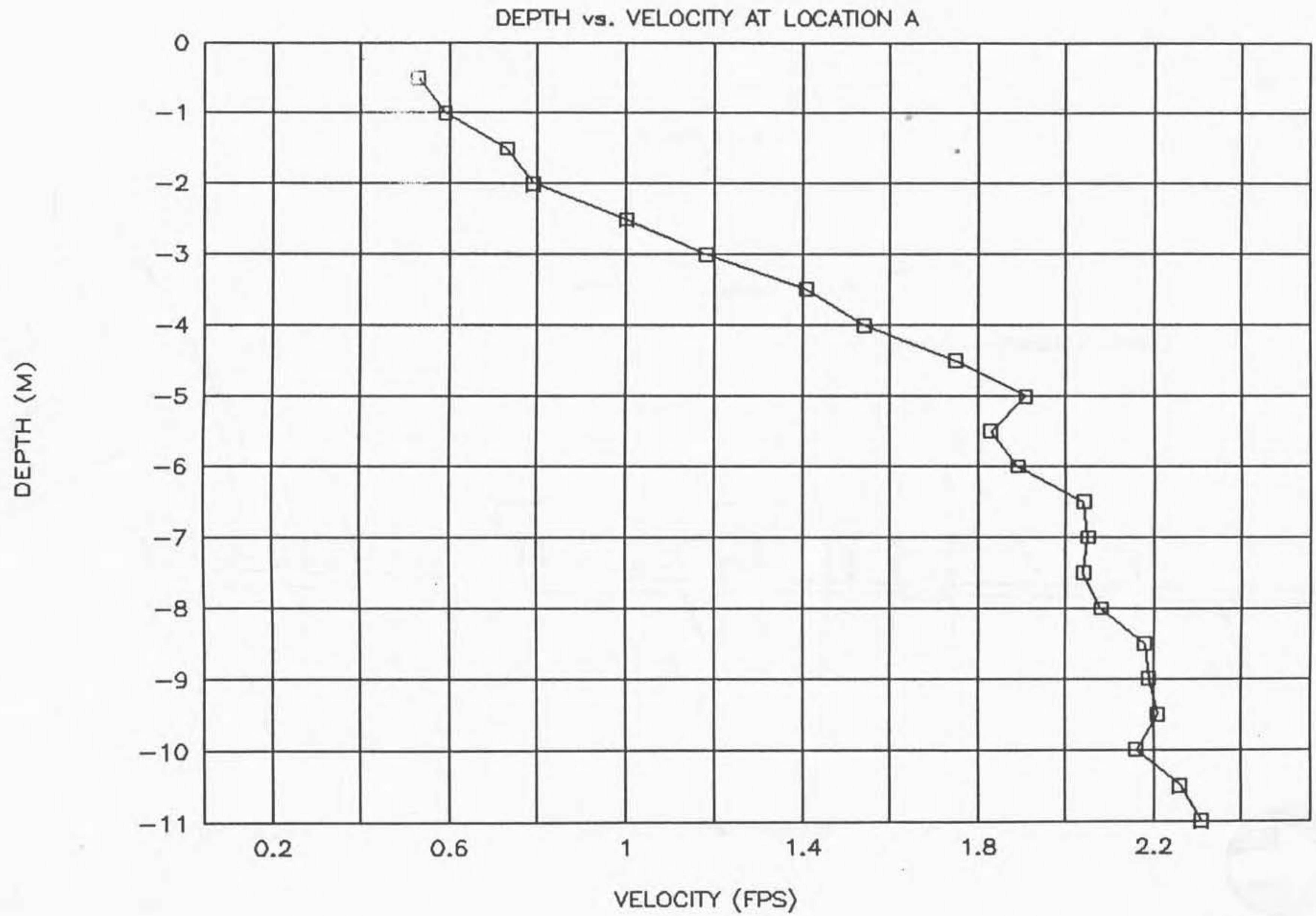


FIGURE 7
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

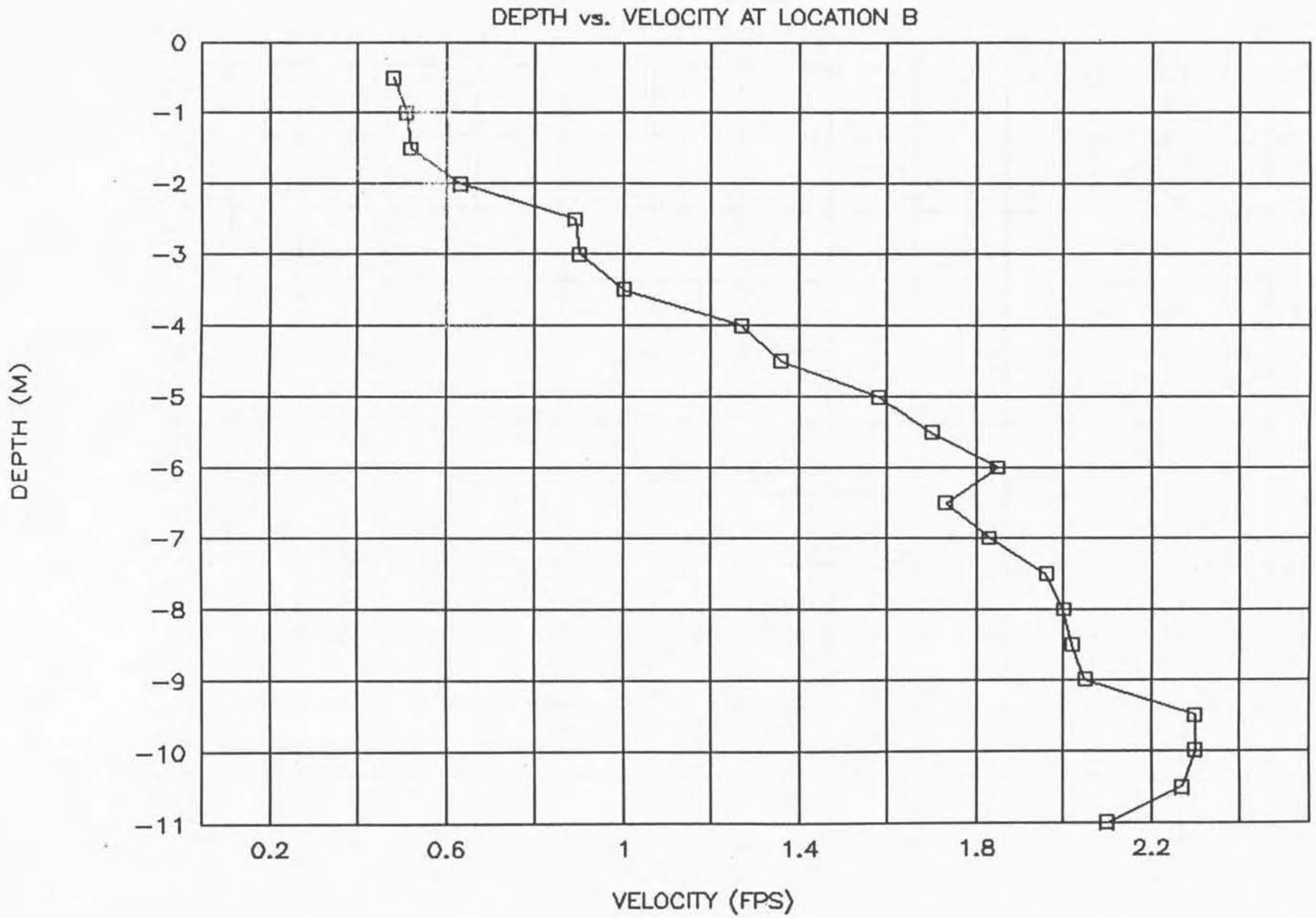


FIGURE 8
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

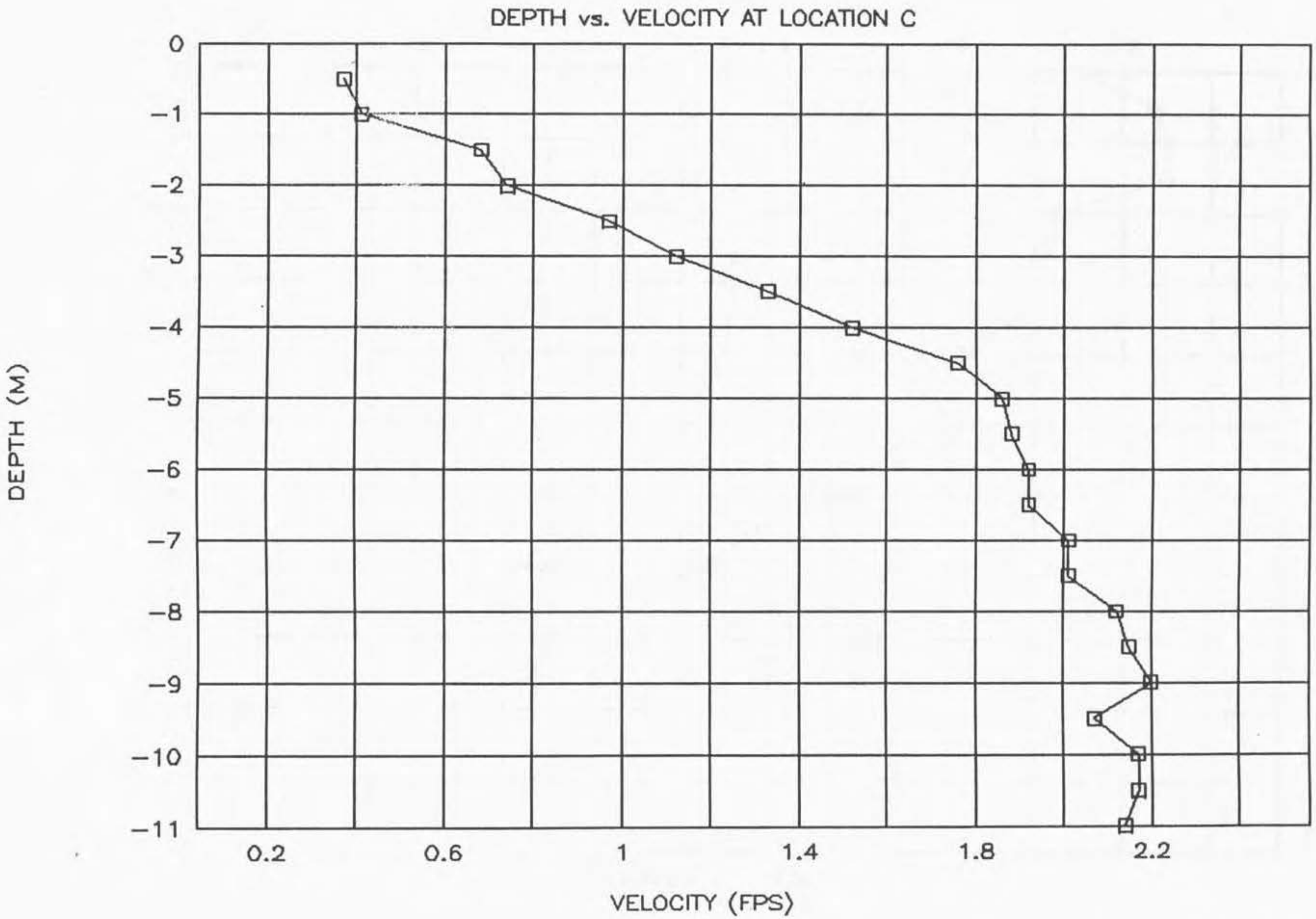


FIGURE 9
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

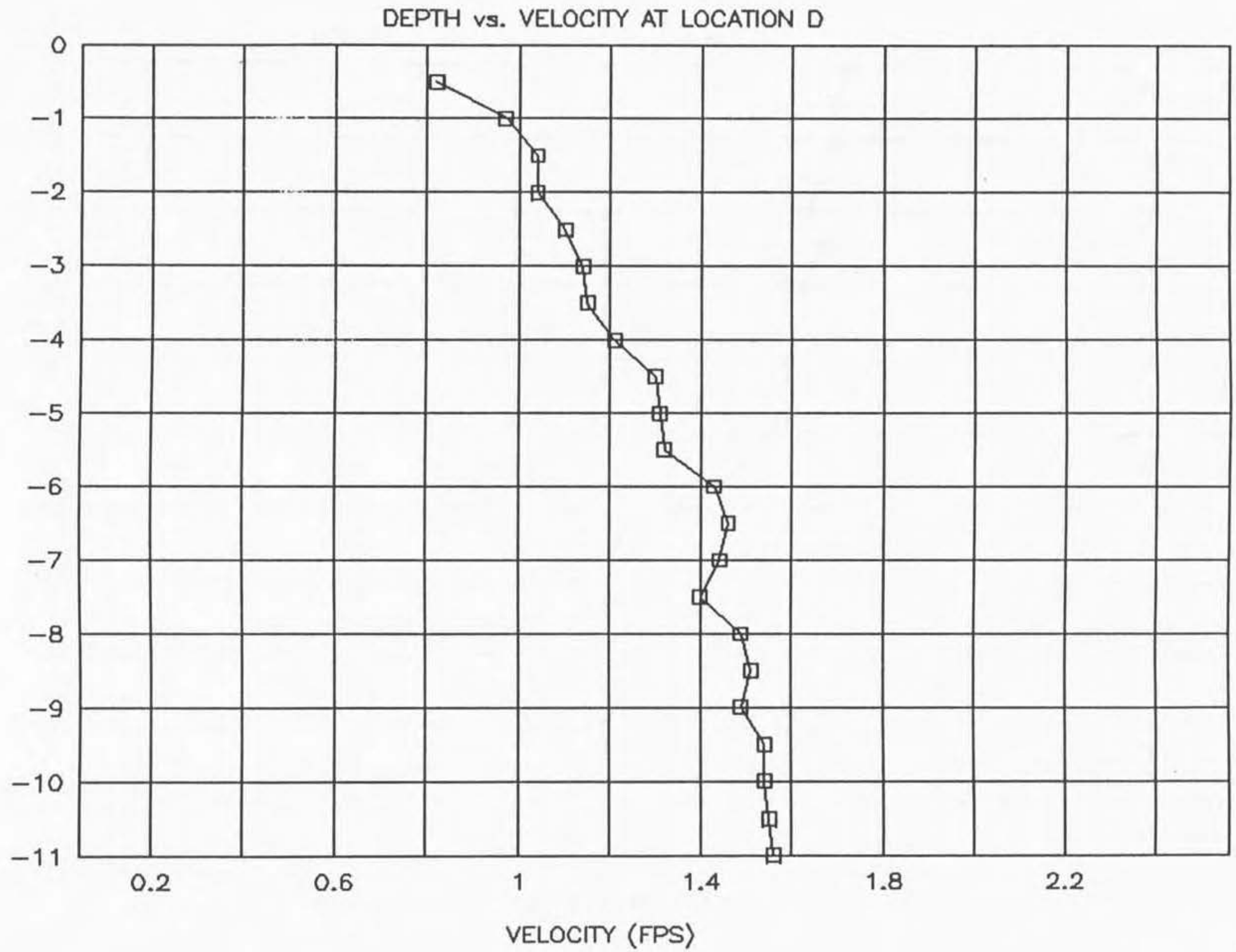


FIGURE 10
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

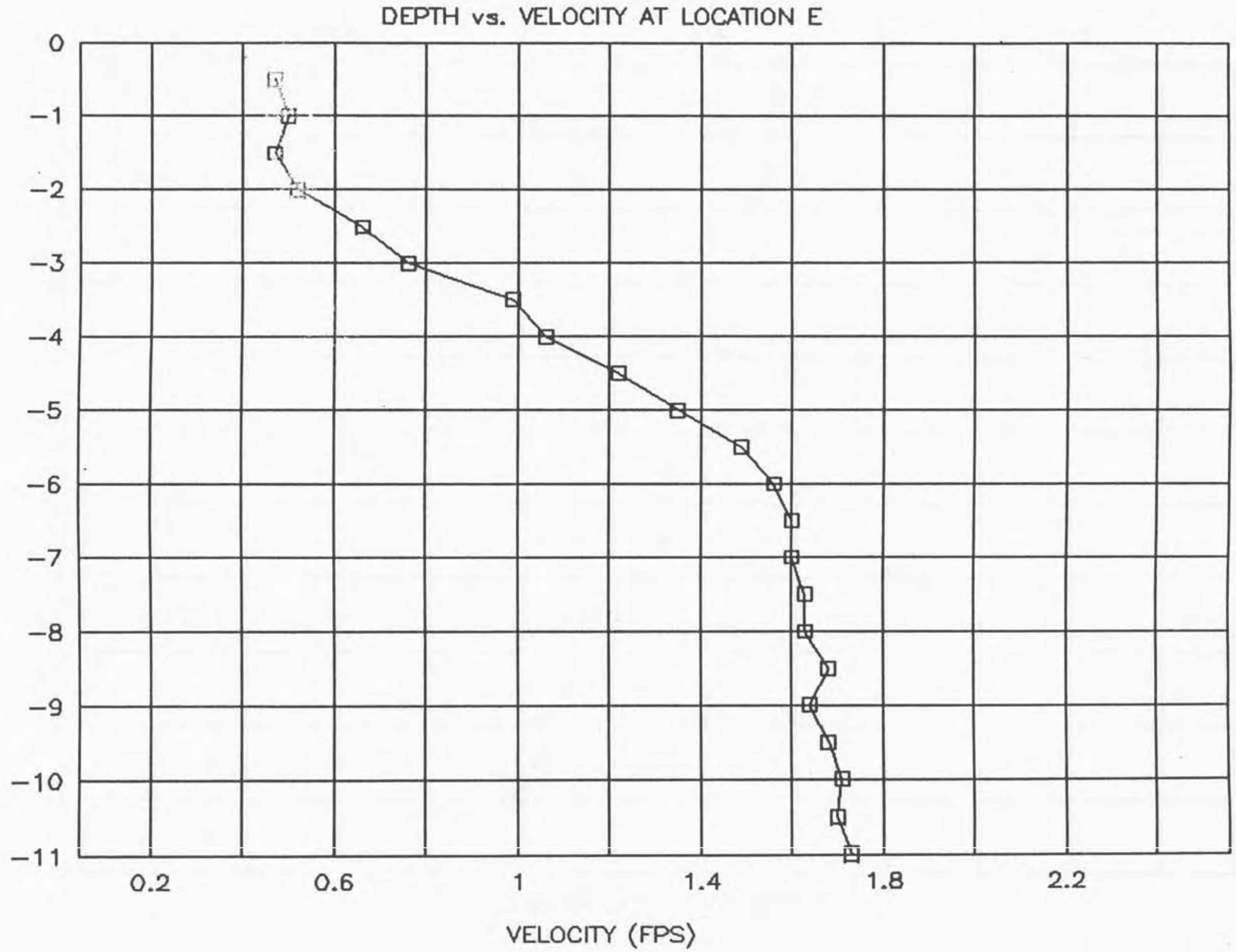


FIGURE 11
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

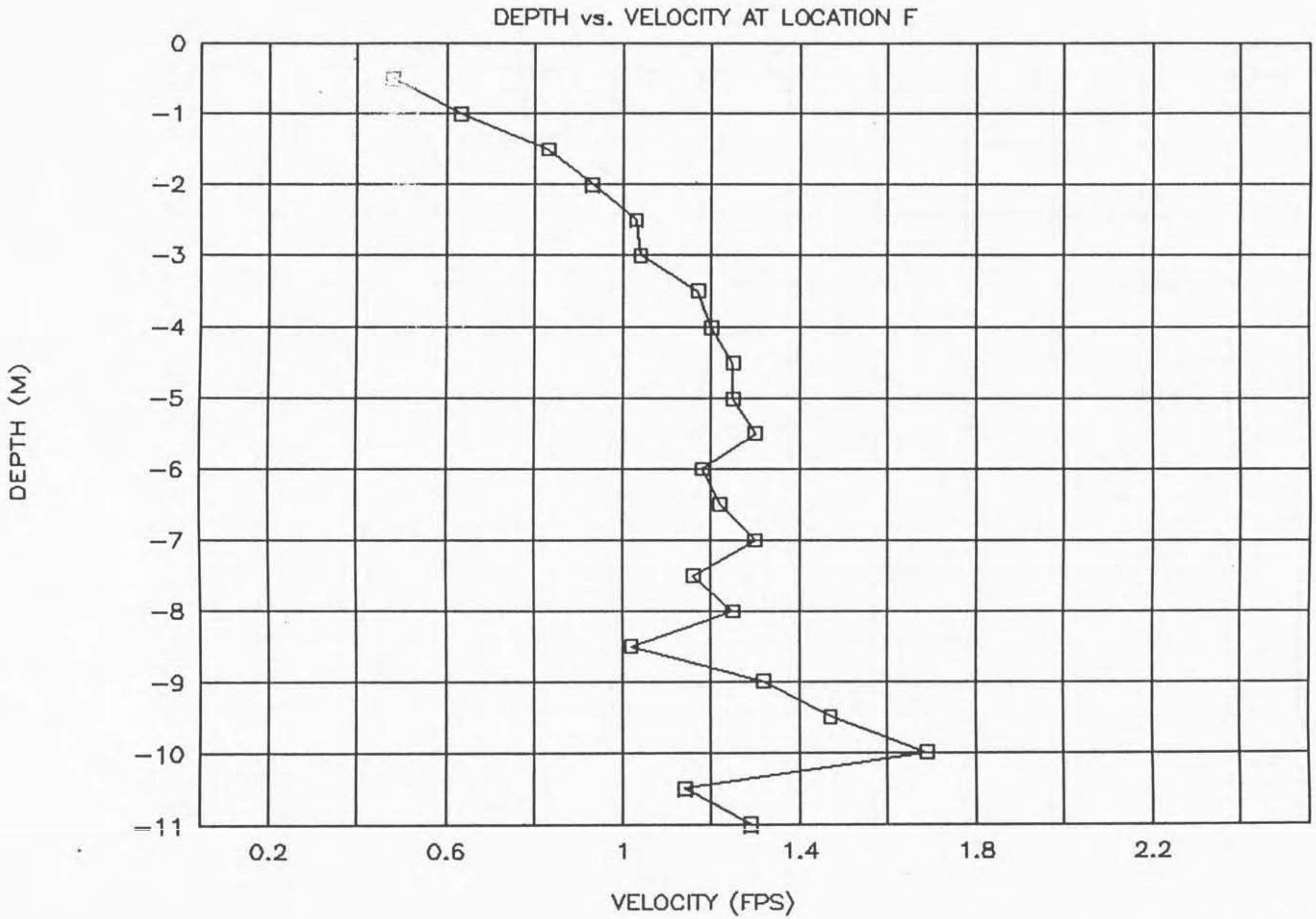


FIGURE 12
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

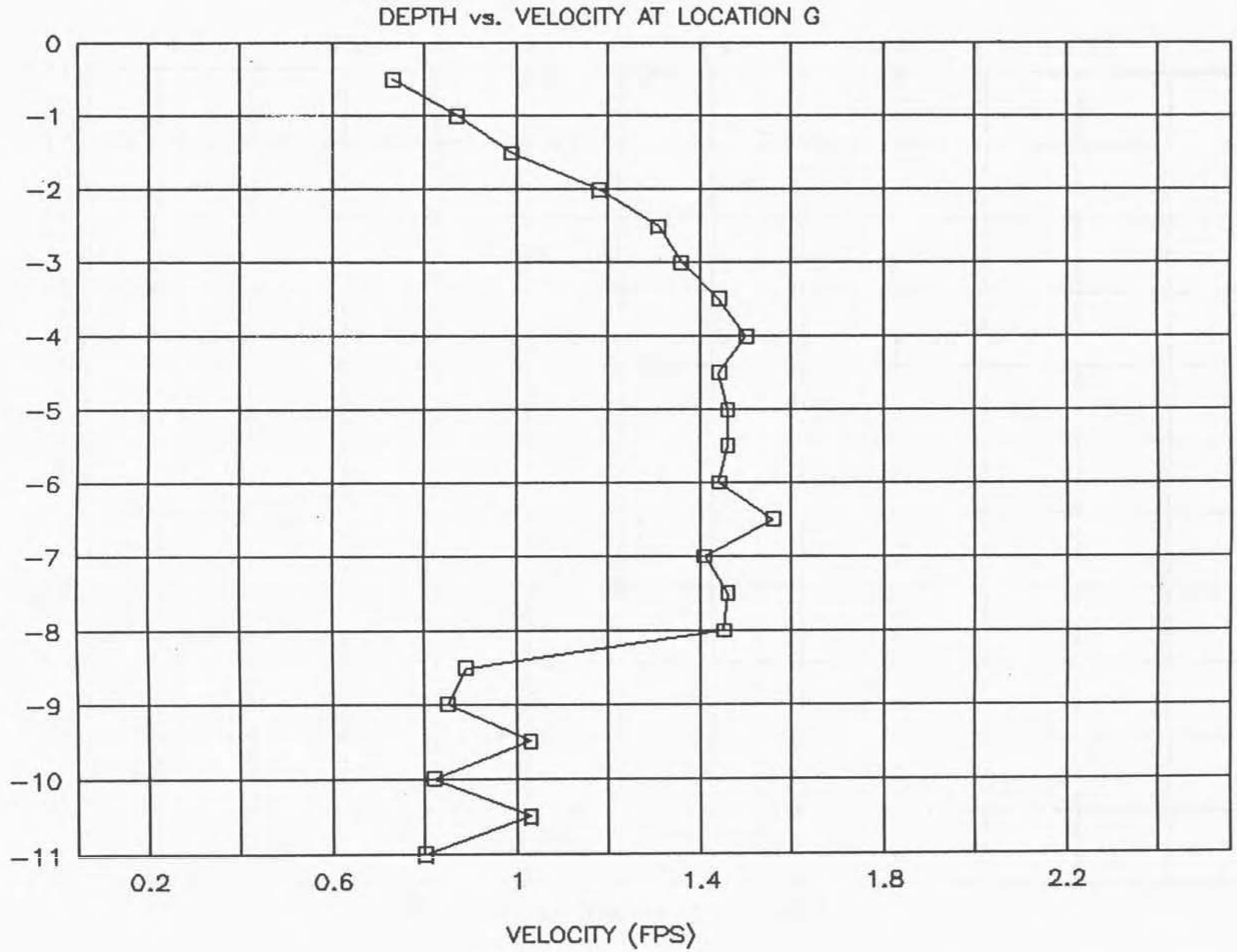


FIGURE 13
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

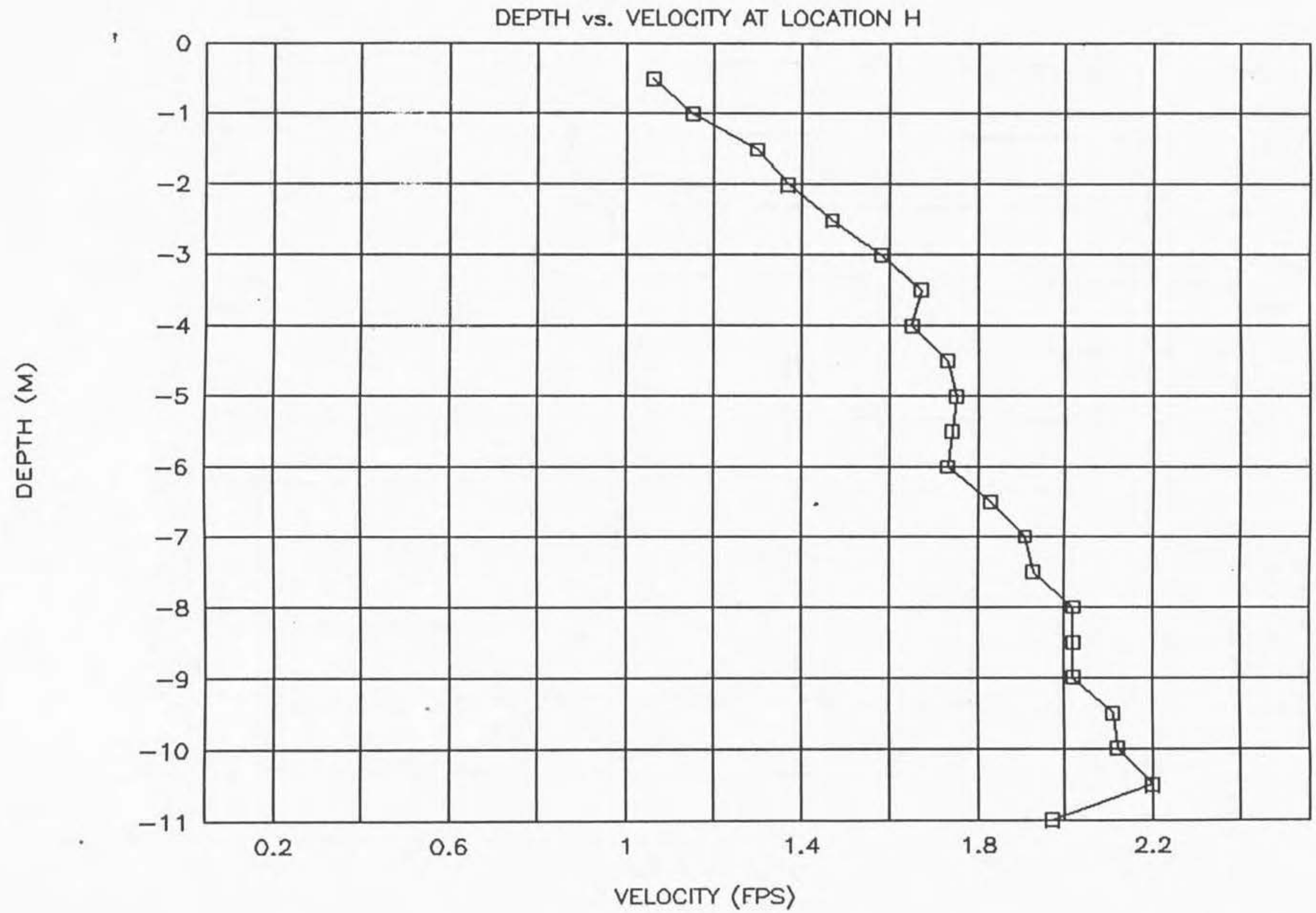


FIGURE 14
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

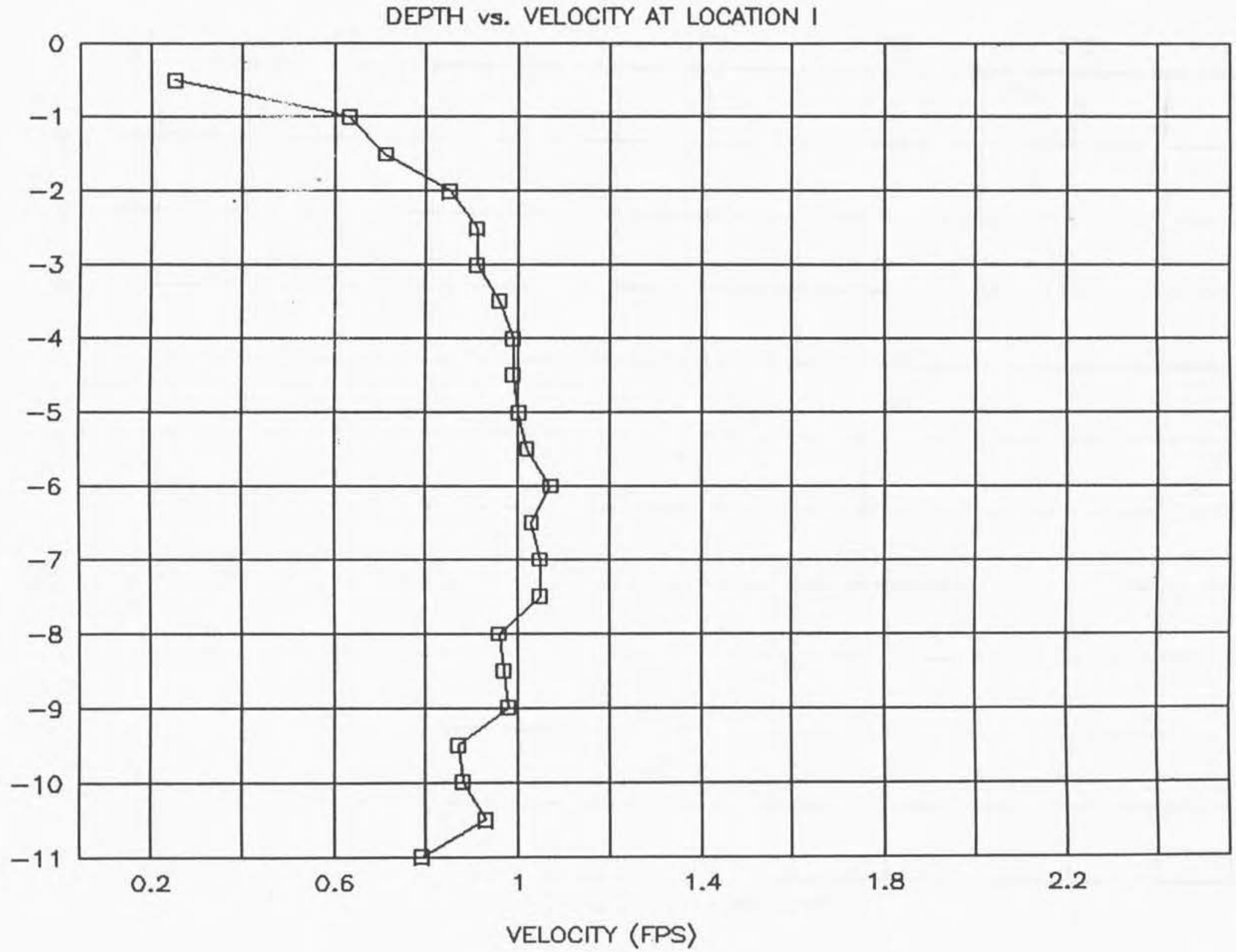


FIGURE 15
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

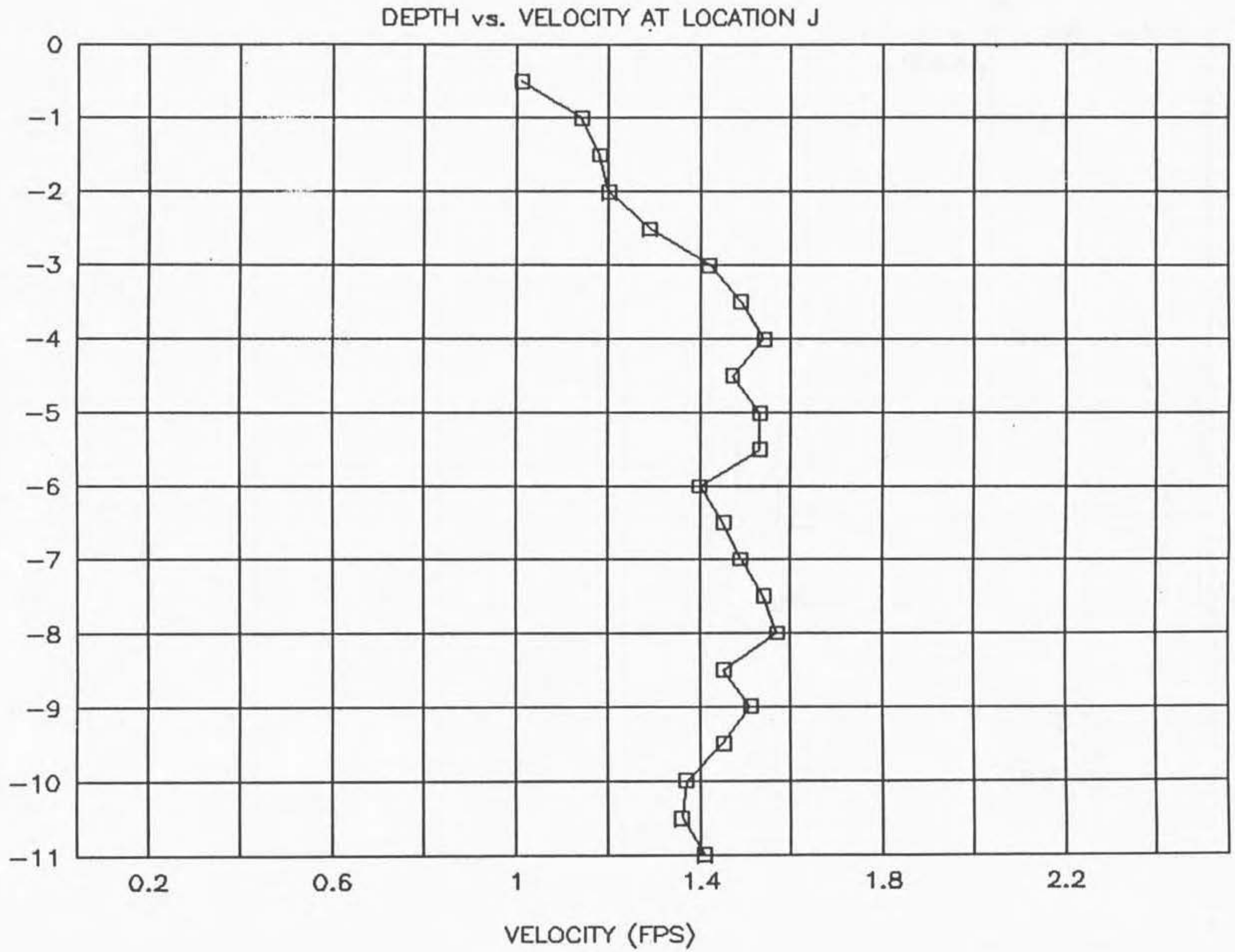


FIGURE 16
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

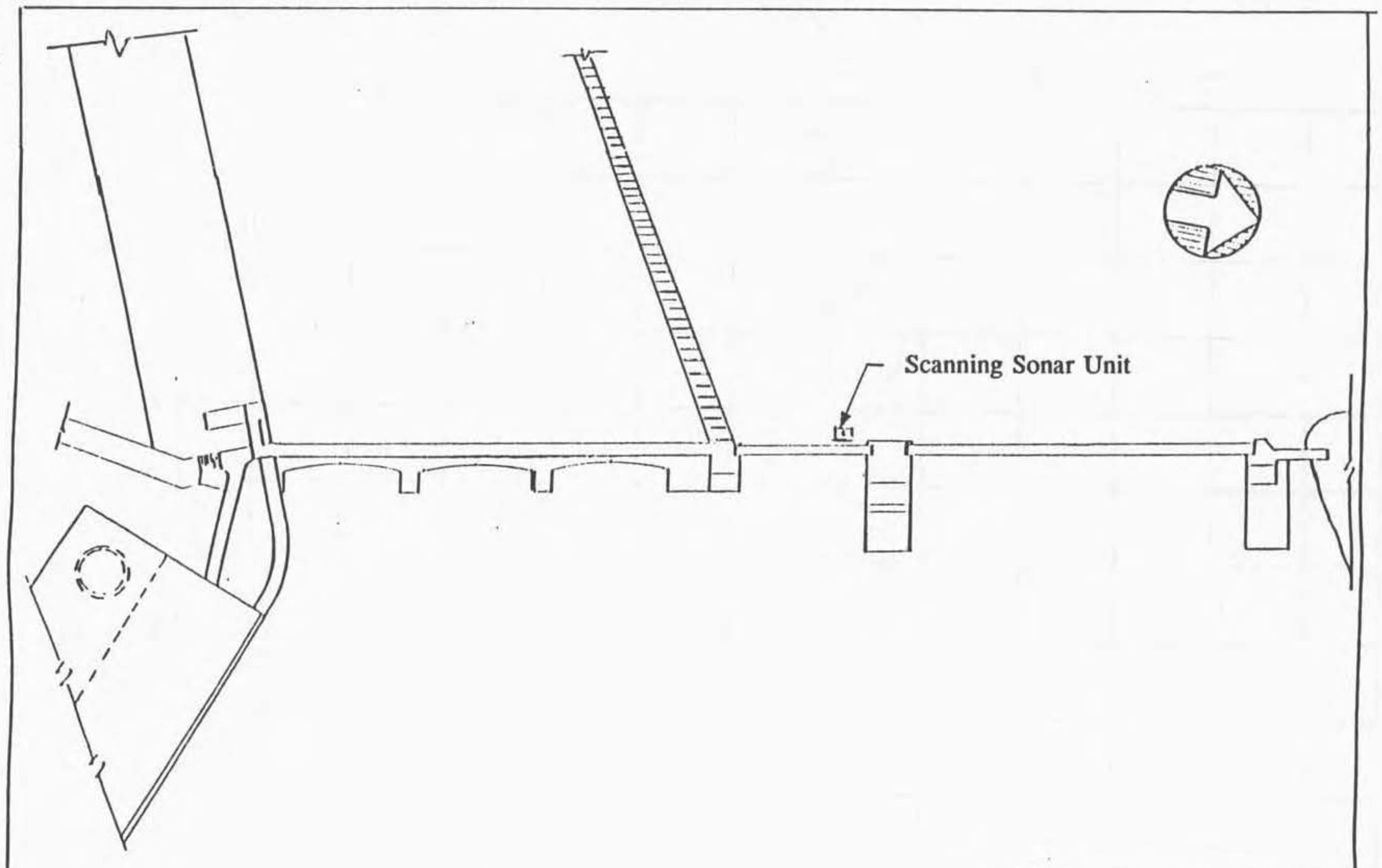


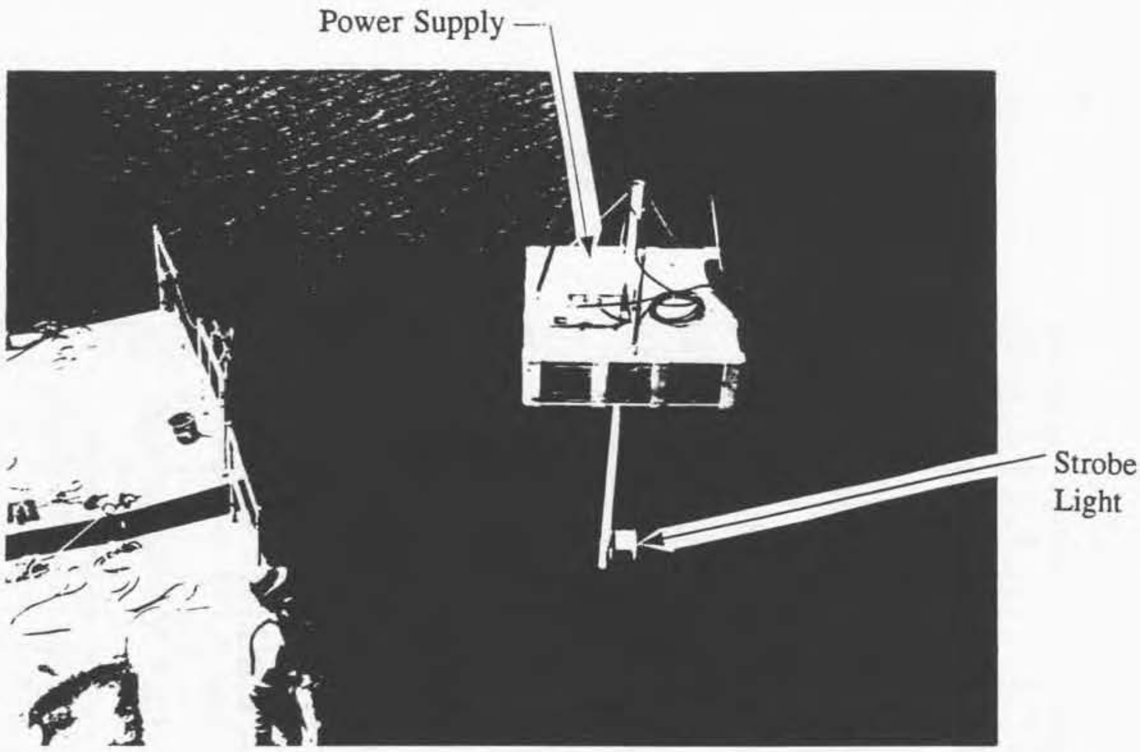
Figure 17
Location of Submerged Rail Structure
Holtwood Project

TABLE 1
SKIMMER WALL VELOCITY MEASUREMENTS
HOLTWOOD HYDROELECTRIC PROJECT

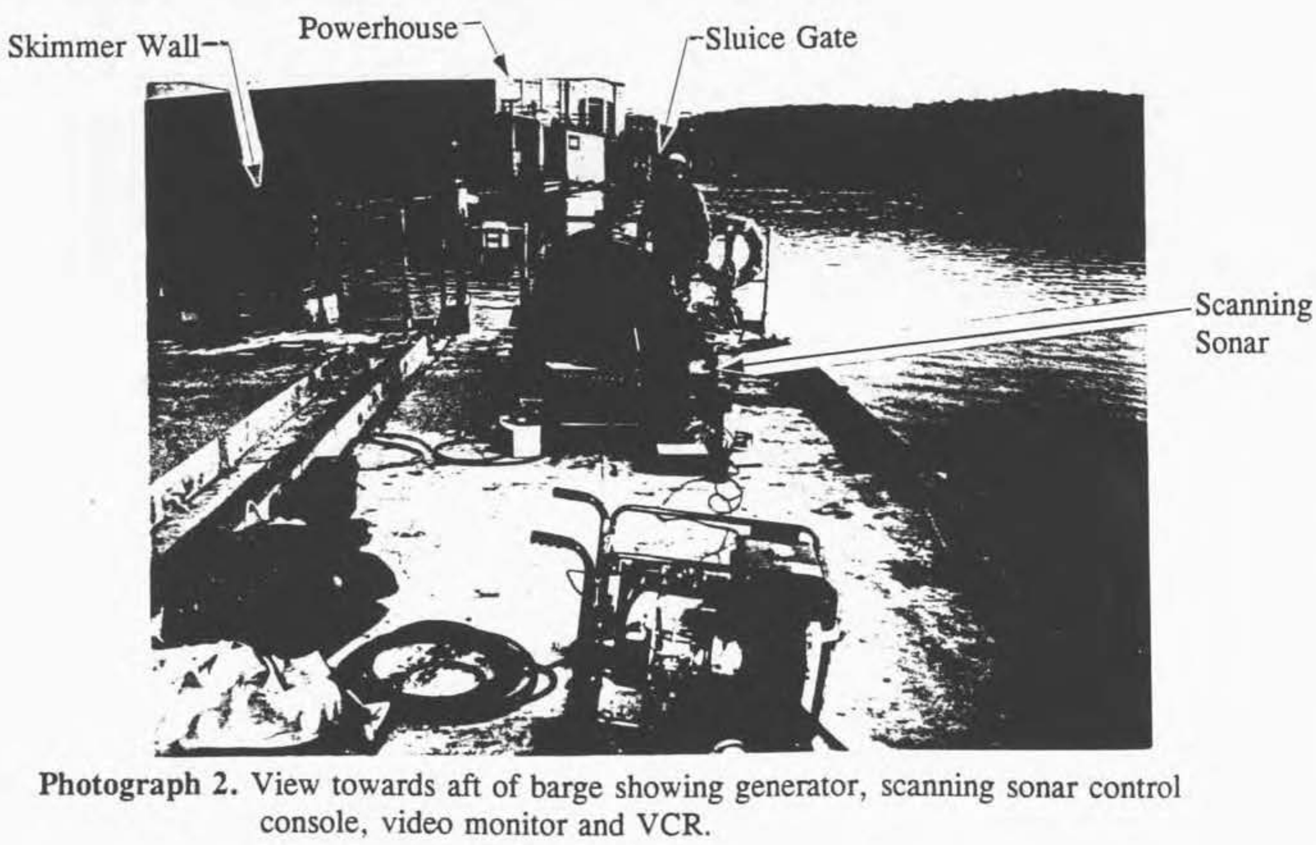
DEPTH	VELOCITY (FPS) AT LOCATION (SEE FIGURE 2)									
(M)	A	B	C	D	E	F	G	H	I	J
-0.5	0.53	0.48	0.37	0.82	0.47	0.48	0.73	1.06	0.25	1.01
-1.0	0.59	0.51	0.41	0.97	0.50	0.63	0.87	1.15	0.63	1.14
-1.5	0.73	0.52	0.68	1.04	0.47	0.83	0.99	1.30	0.71	1.18
-2.0	0.79	0.63	0.74	1.04	0.52	0.93	1.18	1.37	0.85	1.20
-2.5	1.00	0.89	0.97	1.10	0.66	1.03	1.31	1.47	0.91	1.29
-3.0	1.18	0.90	1.12	1.14	0.76	1.04	1.36	1.58	0.91	1.42
-3.5	1.41	1.00	1.33	1.15	0.99	1.17	1.44	1.67	0.96	1.49
-4.0	1.54	1.27	1.52	1.21	1.06	1.20	1.50	1.65	0.99	1.54
-4.5	1.75	1.36	1.76	1.30	1.22	1.25	1.44	1.73	0.99	1.47
-5.0	1.91	1.58	1.86	1.31	1.35	1.25	1.46	1.75	1.00	1.53
-5.5	1.83	1.70	1.88	1.32	1.49	1.30	1.46	1.74	1.02	1.53
-6.0	1.89	1.85	1.92	1.43	1.56	1.18	1.44	1.73	1.07	1.40
-6.5	2.04	1.73	1.92	1.46	1.60	1.22	1.56	1.83	1.03	1.45
-7.0	2.05	1.83	2.01	1.44	1.60	1.30	1.41	1.91	1.05	1.49
-7.5	2.04	1.96	2.01	1.40	1.63	1.16	1.46	1.93	1.05	1.54
-8.0	2.08	2.00	2.12	1.49	1.63	1.25	1.45	2.02	0.96	1.57
-8.5	2.18	2.02	2.15	1.51	1.68	1.02	0.89	2.02	0.97	1.45
-9.0	2.19	2.05	2.20	1.49	1.64	1.32	0.85	2.02	0.98	1.51
-9.5	2.21	2.30	2.07	1.54	1.68	1.47	1.03	2.11	0.87	1.45
-10.0	2.16	2.30	2.17	1.54	1.71	1.69	0.82	2.12	0.88	1.37
-10.5	2.26	2.27	2.17	1.55	1.70	1.14	1.03	2.20	0.93	1.36
-11.0	2.31	2.10	2.14	1.56	1.73	1.29	0.80	1.97	0.79	1.41

NOTES:

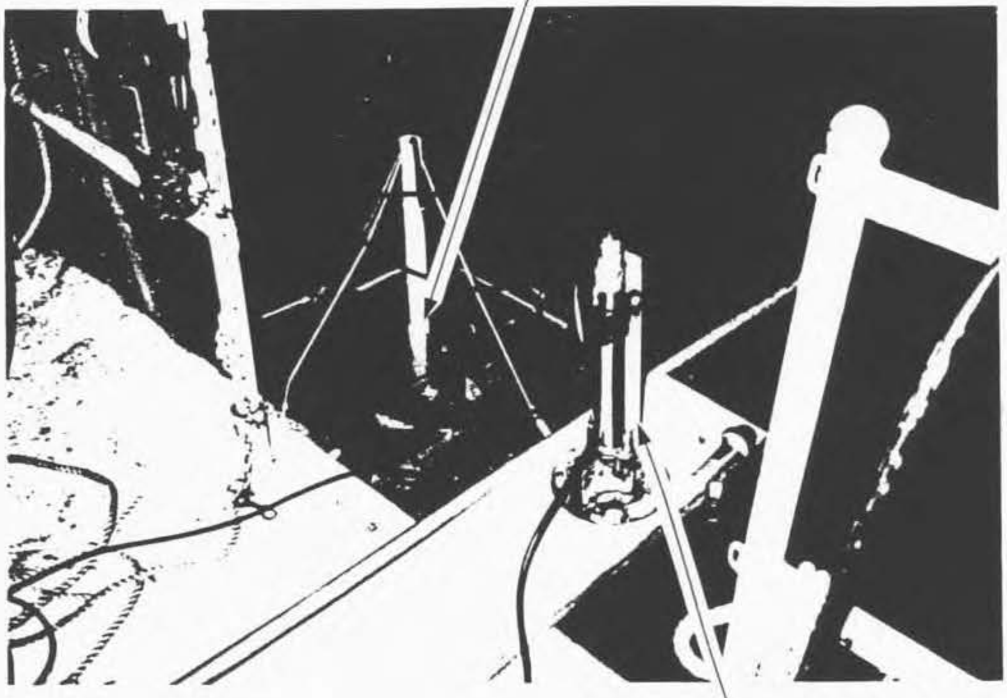
1. VELOCITY MEASUREMENTS OBTAINED ON OCTOBER 14 & 15, 1992.
2. WATER LEVEL AT EL 167'+/-.
3. 10 UNITS TOTAL; UNITS 1,2,3,4,5,7,8,10 AT FULL CAPACITY; UNITS 6 AND 9 OFF.



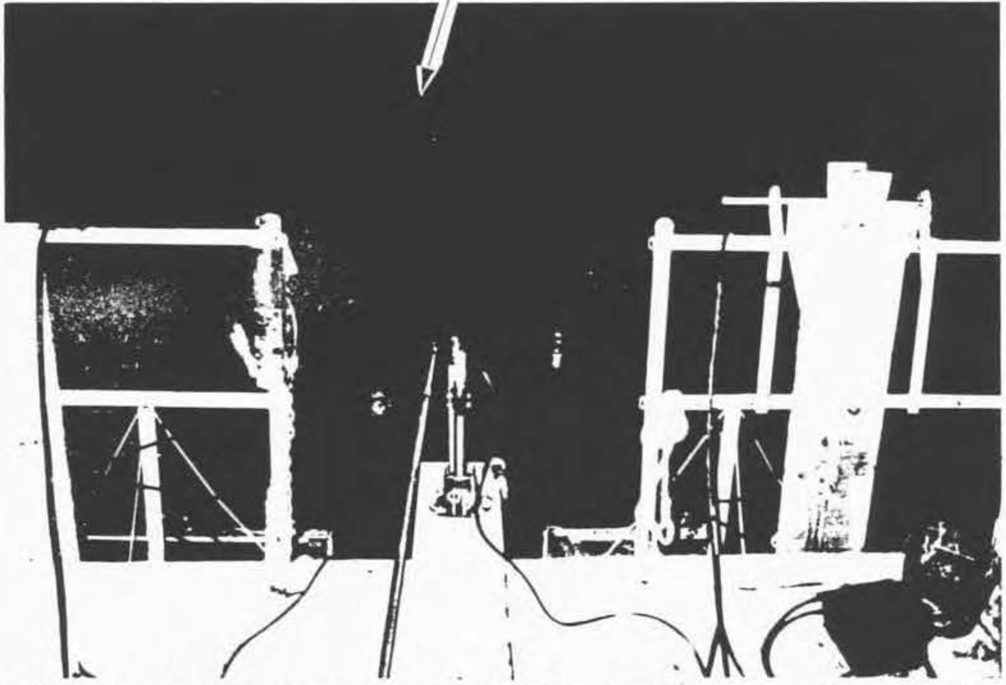
Photograph 1. Strobe light float being deployed at Holtwood Hydroelectric Station.



Photograph 2. View towards aft of barge showing generator, scanning sonar control console, video monitor and VCR.



Photograph 3. Close up of barge bow showing a strobe light (left) and the mast supporting the scanning sonar transducer (right).



Photograph 4. Bow of barge with two strobe light floats mounted on each side of the sonar transducer support mast.

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

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301 Marine Acadamy Drive Stevensville, MD 21116

INTRODUCTION

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

METHODS AND MATERIALS

Collection procedures for adult American shad in 1992 were nearly identical to those in 1991, the only difference being the elimination of the Rocky Point pound net site in the Susquehanna Flats (Figure I). Hook and line sampling in the Conowingo tailrace continued unchanged from the previous year. Tagging procedures and data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Juvenile production in 1992 was monitored by project personnel with only the Smith-Root electrofisher. The Susquehanna Flats shoreline area was gridded off into 36 separate cells approximately 2,000 feet long (Figure II). 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 sampling was conducted the following week on nine randomly chosen sites from cells 19 to 36. This procedure was then repeated during subsequent weeks. 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 1992.

RESULTS

Pound net tagging for 1992 began on 24 March and continued until 19 May while hook and line effort commenced on 17 April and ended 29 May. Of the 573 adult American shad captured, 467 (82%) were tagged and 109 (23%) subsequently recaptured (Table 1).
Of these 109 recaptures two occurred outside the upper Bay system; one from the Delaware River near Portland, PA and one below Holtwood Dam. The 109 total does not reflect the 43 multiple recaptures, four unverifiable tag numbers, and 7 fish tagged prior to 1992 collected by RMC from the two fish lifts.

Recapture data for the 1992 season is summarized as follows:

a. 109 fish recaptured by the Conowingo Fish Lift (does not include 43 multiple recaptures, 7 pre-1992 tagged fish, and 4 fish with unverifiable tag numbers)
   0 fish recaptured by pound net
   0 fish recaptured by hook and line from the tailrace
   2 fish recaptured outside the system

b. 102 fish recaptured originally caught by hook and line
   9 fish recaptured originally caught by pound net

c. 101 fish recaptured in the same area as initially tagged
   10 fish recaptured upstream of their initial tagging site (includes one recapture from the Delaware River and one from the Susquehanna below Holtwood Dam)
   0 fish recaptured downstream of their initial tagging site

d. shortest period at large: 1 day
   longest period at large: 43 days (1992 fish only)
   mean number days at large: 11.1

e. number of pre-1992 tagged fish recaptured: 7
   number of 1991 tagged fish recaptured: 5
   number of 1987 tagged fish recaptured: 2
   number of multiple recaptures: 2

The population estimate for adult shad in the upper Chesapeake Bay for 1992 using the Petersen Index was 105,255 (Table 2). Since one recapture was recorded from the Delaware River an emigration factor was calculated in order to adjust for the number of fish marked (M) in the Petersen statistic but lost and unavailable for later recapture (Table 3). Even though the 1992 estimate represented a 25% decrease from the previous year (Figure III) the overall trend still continues to indicate an increasing population for the upper Bay stock ($r^2 = 0.71$, $p = 0.0003$).

Effort, catch, and catch-per-unit-of-effort (CPUE) by gear type for adult American shad in the upper Bay during 1992 and comparison with previous years is presented in Table 4. Catch per angler hour increased to over 6 fish in 1992 while the shad catch per pound net day for all nets combined decreased sharply in 1992 over the previous year. Possible reasons for this sharp decline in pound net catch include elimination of the Rocky Point net, a colder than normal spring featuring strong east winds, and fewer adults available for capture.

A total of 533 adult American shad (371 hook and line, 162 pound net) were examined for physical characteristics by DNR biologists in 1992 (Table 5). Of the males examined, 79% were ages IV and V with age group V predominating in both gear types (Table 5). The overall incidence of repeat spawning in male shad decreased from 17.2% in 1991 to 8.2% for 1992. Nearly 76% of the 290 female shad examined in 1991 were V and VI year old fish with age group V slightly predominating (Table 5). As with their male counterparts, the incidence of repeat spawning in females decreased in 1992 with 9.0 % of non-virgin female recruits returning as opposed to 12.7% the previous year.

Juvenile alosid sampling in the upper Bay during 1992 produced fewer numbers of young-of-the-year American shad than the previous year. Supplemental haul seine and otter trawl sampling for the Department's juvenile striped bass and yellow perch surveys in 1992 captured no young-of-the-year American shad as opposed to 8 in 1991. Numbers of juvenile shad collected by electrofisher decreased to 4 in 1992, 13 fish less than the previous year. Table 6 provides a breakdown by cell and date of the juvenile shad collected by electrofishing from the upper Bay during 1992.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1992.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	147	88
	Bohemia River	43	26
	Total	190	114
Hook and Line	Conowingo Tailrace Susquehanna River	383	353
Fish Lift	Conowingo Tailrace Susquehanna River	25,721	
	TOTALS	26,294	467

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1992 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1991 survey -

C = 26,253
R = 109
M = 440*

Therefore -

$$N = \frac{(26{,}253 + 1)\ (440 + 1)}{(109 + 1)}$$

$= \mathbf{105{,}255}$

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)

$$\text{Upper } N^* = \frac{(26{,}253 + 1)\ (440 + 1)}{90.36 + 1} = 126{,}725$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(26{,}253 + 1)\ (440 + 1)}{131.48 + 1} = 87{,}396$$ @ .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 (1980-1992), the number of those fish recaptured, the number recapture 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
1992	114	9	1	0.111	13

Table 4. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad by hook and line and pound net during the 1980-1992 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
1992	62.8	383	6.10	0.16	105,255

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
1992	Cherry Tree	56	147	2.63	
	Bohemia R.	47	43	0.87	
	1992 Total	103	190	1.80	105,255

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

Table 5. Catch (N), age composition (%), number and percent of repeat spawners, and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1992 upper Chesapeake Bay operation.

	MALE				**FEMALE**			
AGE GROUP	N(%)	RPTS.	MEAN	RANGE	N(%)	RPTS.	MEAN	RANGE
A. **Hook & Line**								
II	1(1)	0	275		0	0	-	-
III	18(10)	0	317	278-345	0	0	-	-
IV	52(29)	0	375	340-410	9(5)	0	408	395-422
V	90(50)	6	405	365-470	88(46)	1	435	390-476
VI	16(9)	2	428	380-480	66(34)	5	454	400-505
VII	2(1)	0	475	470-480	28(15)	7	497	450-535
VIII	0	0	-	-	1(1)	0	535	
% Repeat Spawners		4.5				6.8		
B. **Pound Net**								
III	1(2)	0	360	330-440	0	0	-	-
IV	19(30)	0	375	340-400	5(5)	0	404	385-420
V	31(48)	4	406	360-450	30(31)	0	433	400-485
VI	9(14)	4	434	400-455	37(38)	7	463	425-520
VII	4(6)	4	439	425-460	25(26)	6	494	460-545
VIII	0	0	-	-	1(1)	0	545	
% Repeat Spawners		18.8				13.3		
C. **All** gears combined								
II	1(<1)	0	275		0	0	-	-
III	19(8)	0	319	278-440	0	0	-	-
IV	71(29)	0	375	340-410	14(5)	0	407	385-422
V	121(50)	10	406	360-470	118(41)	1	434	390-485
VI	25(10)	6	430	380-480	103(35)	12	457	400-520
VII	6(3)	4	451	425-480	53(18)	13	496	450-545
VIII	0	0	-	-	2(1)	0	540	535-545
% Repeat Spawners		8.2				9.0		

Table 6. Juvenile American shad captured by date and cell and associated catch-per-unit-effort during the 1992 upper Chesapeake Bay **electrofishing** survey.

CELL	AUGUST				SEPTEMBER					OCTOBER				SHOCK TIME	*
NO.	6	11	19	25	3	9	16	28	30	7	14	22	CATCH	(SEC.)	CPUE
1			0		0				0				0	1500	0.0
2	0				1		0						1	1500	2.4
3	0		0		0		0						0	2000	0.0
4	0						0		0		0		0	2000	0.0
5	0				0				0				0	1500	0.0
6			0				0		0		0		0	2000	0.0
7			0		0								0	1000	0.0
8	0				0		0				0		0	2000	0.0
9			0		0						0		0	1500	0.0
10							0						0	500	0.0
11			0		0				0				0	1500	0.0
12	0						0				0		0	1500	0.0
13	0						0				0		0	1500	0.0
14									0				0	500	0.0
15	0		0								0		0	1500	0.0
16			0		0		0		0		0		0	2500	0.0
17	0		0						0		0		0	2000	0.0
18									0				0	500	0.0
19				0		0		0		2		0	2	2500	2.9
20								0				0	0	1000	0.0
21		0						0					0	1000	0.0
22		0				0				0			0	1500	0.0
23				0						0			0	1000	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		0		0		0	0	3000	0.0
28								0				0	0	1000	0.0
29		0		1						0			1	1500	2.4
30		0		0						0			0	1500	0.0
31		0		0		0				0		0	0	2500	0.0
32				0		0						0	0	1500	0.0
33						0				0			0	1000	0.0
34				0		0		0					0	1500	0.0
35		0						0					0	1000	0.0
36		0		0		0						0	0	2000	0.0
TOTL	0	0	0	1	1	0	0	0	0	2	0	0	4	54000	0.3

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

Figure 1. Gear and locations utilized in capturing adult American shad from the upper Chesapeake bay in 1992.

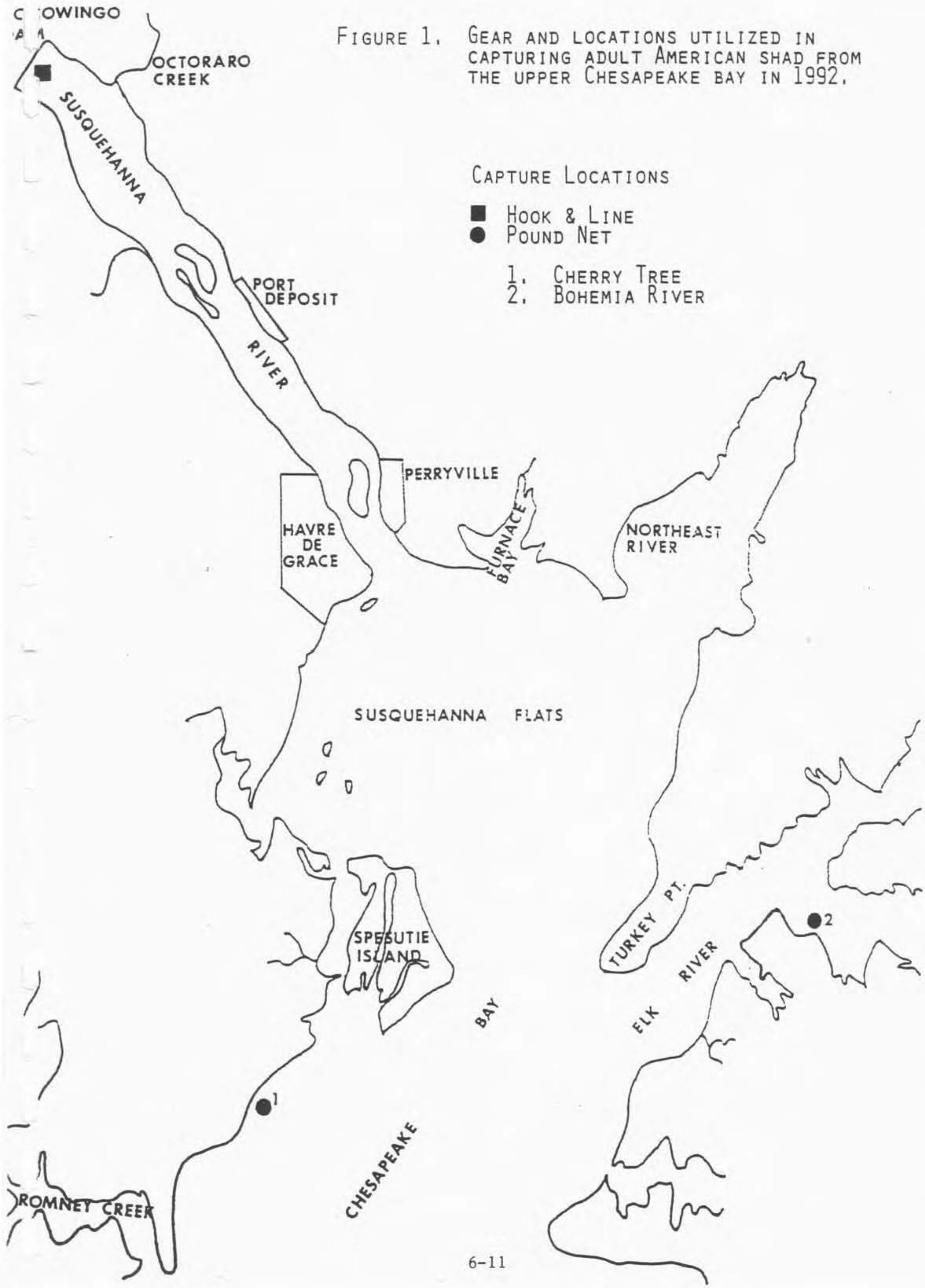


FIGURE 2. UPPER CHESAPEAKE BAY ELECTROFISHING CELLS SAMPLED DURING THE 1992 JUVENILE RECRUITMENT SURVEY.

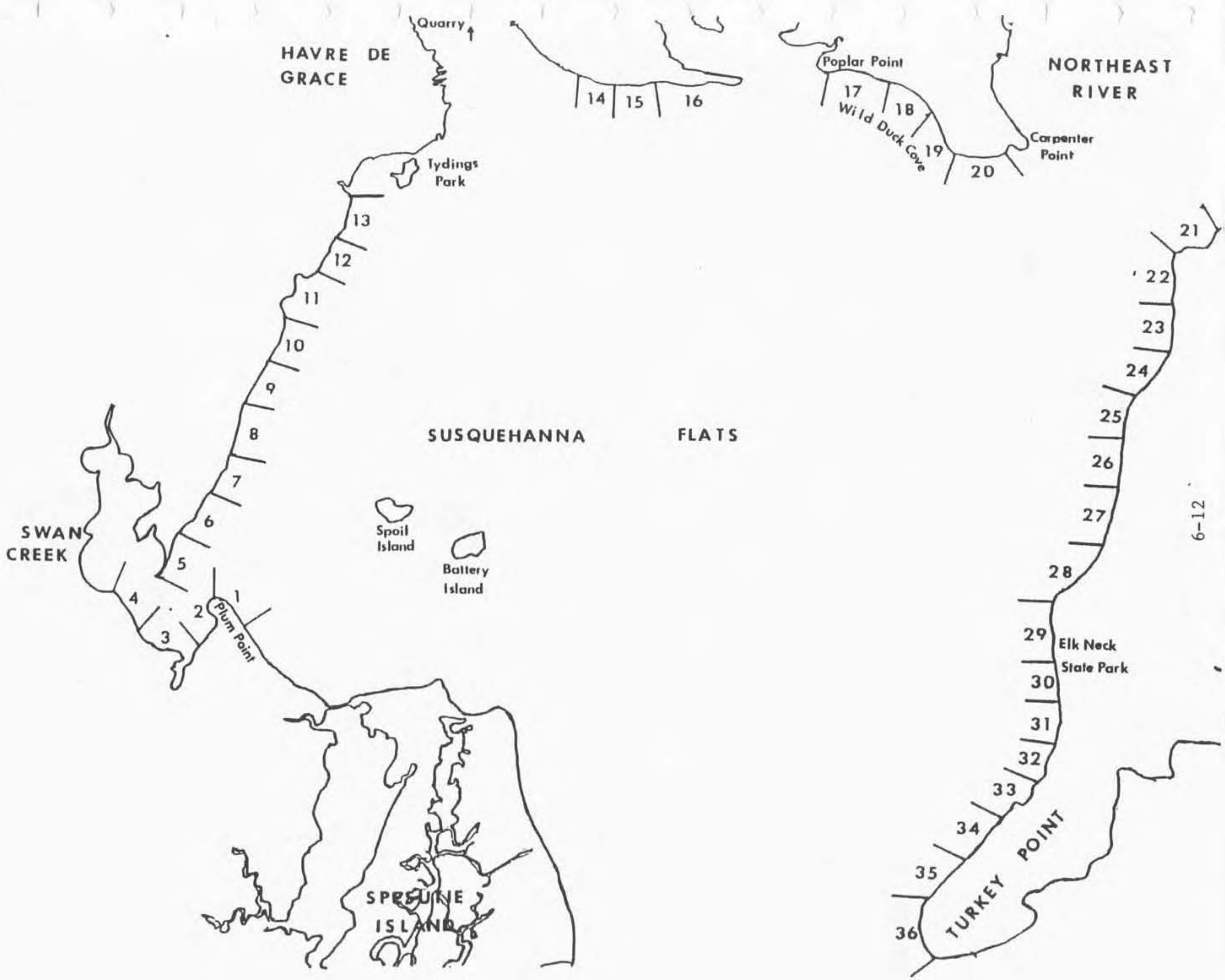
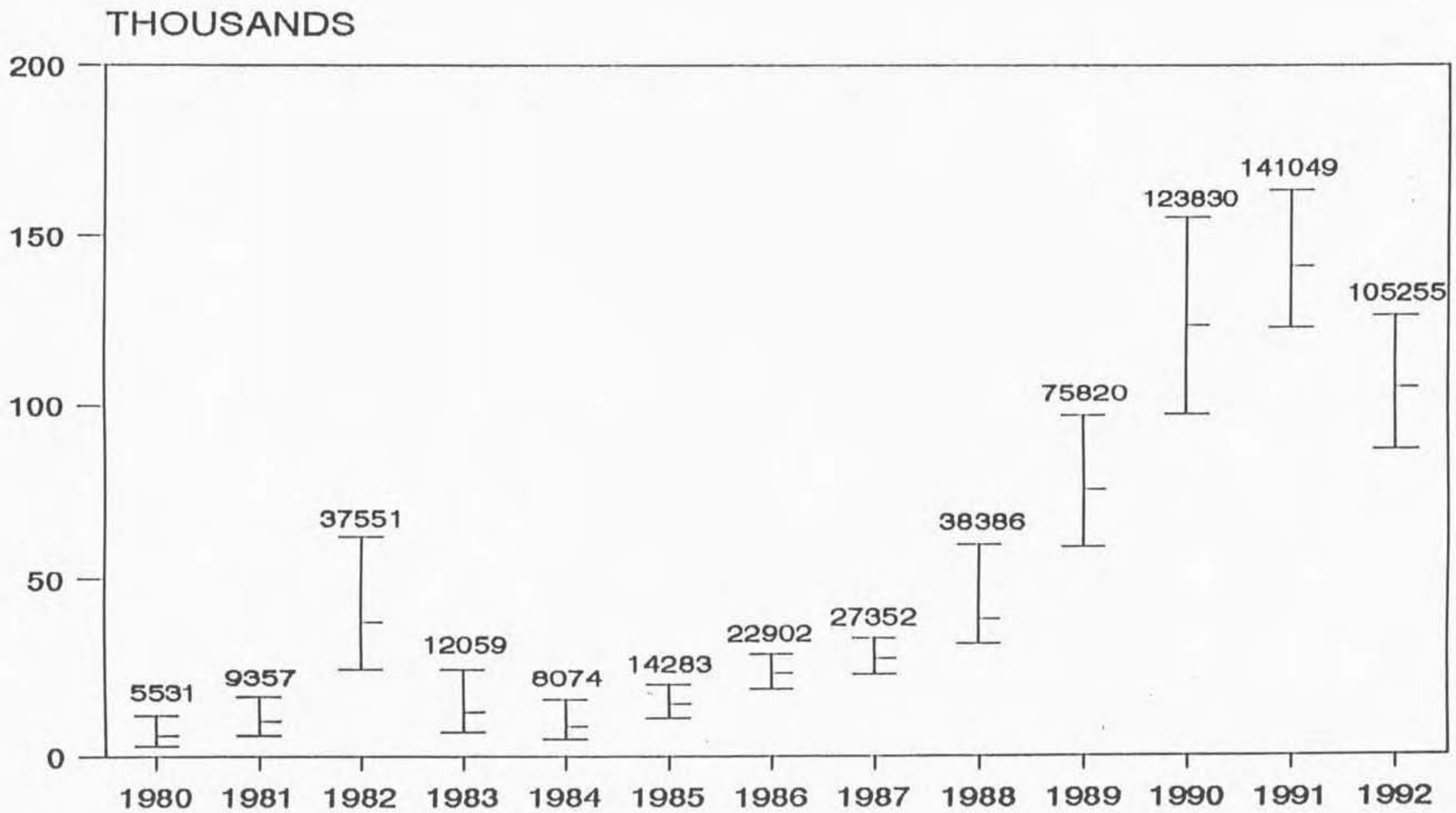


FIGURE 3. Yearly comparisons of the adult American shad population estimates in the upper Chesapeake Bay.



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