Restoration of American Shad to the Susquehanna River

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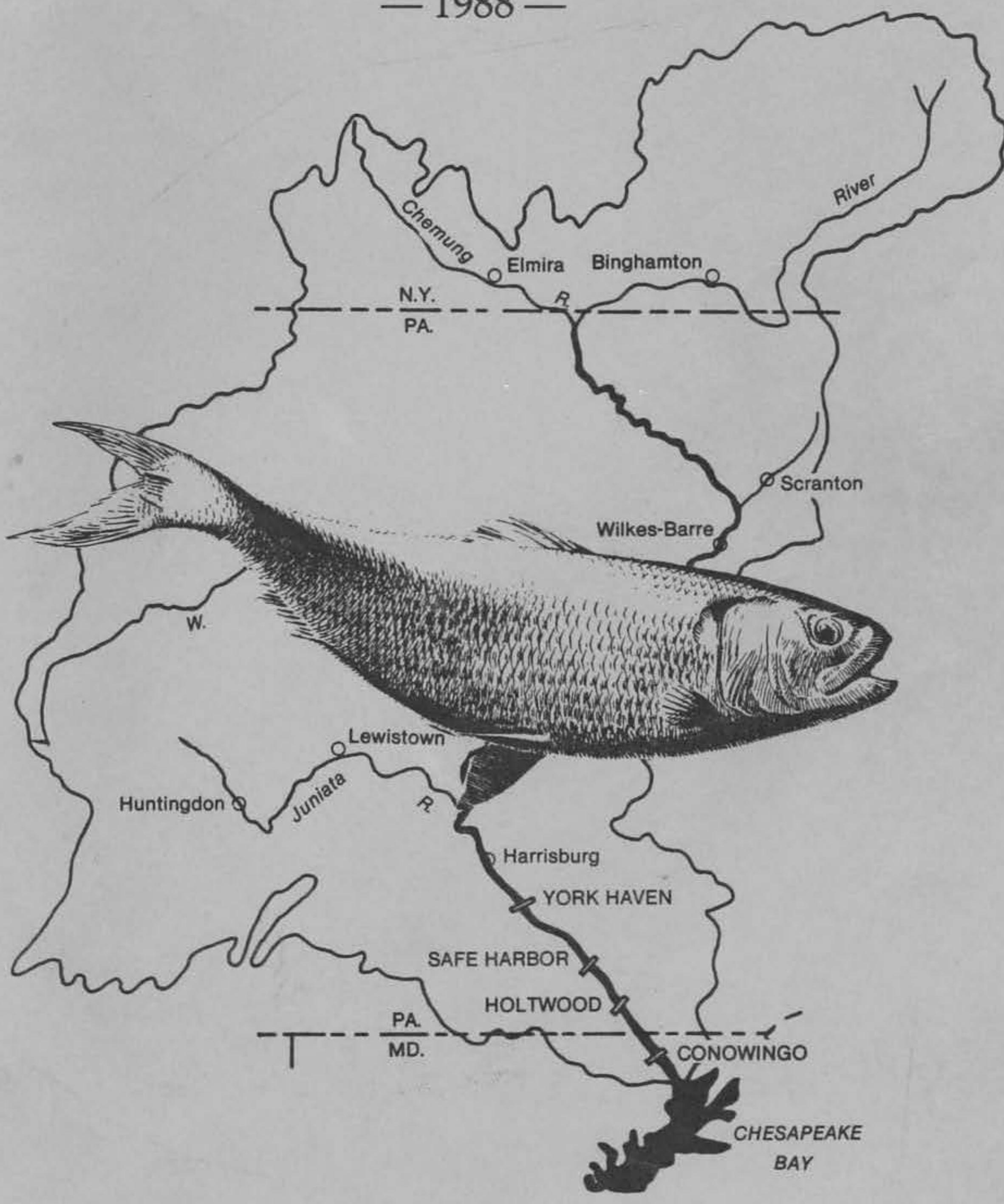
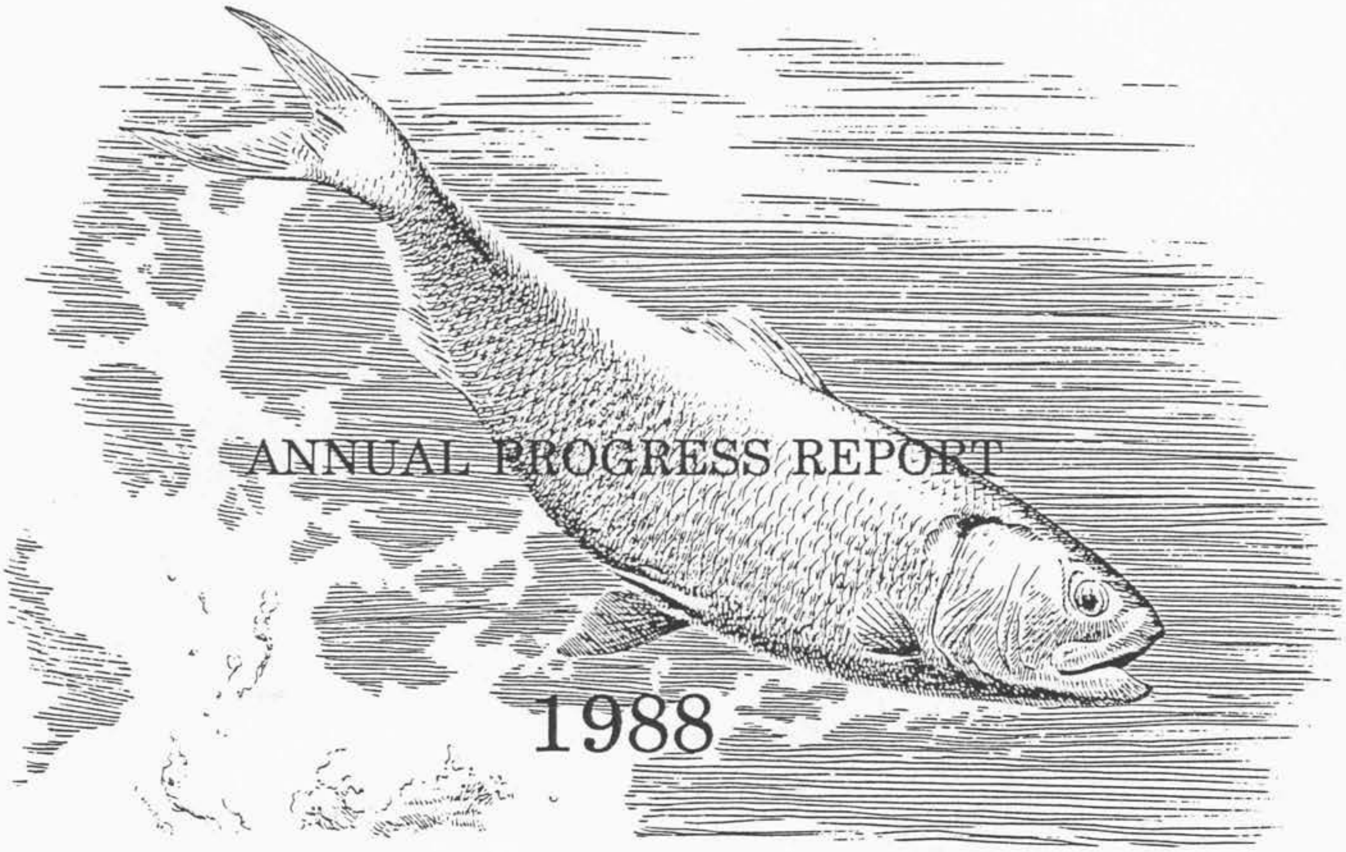


SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

FEBRUARY 1989

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

Maryland Department of Natural Resources
United States Fish and Wildlife Service
New York Division of Fish and Wildlife
Pennsylvania Power and Light Company
Safe Harbor Water Power Corporation
Susquehanna River Basin Commission
Philadelphia Electric Company
Pennsylvania Fish Commission
York Haven Power Company

FEBRUARY 1989

EXECUTIVE SUMMARY

The 1988 Annual Report of the Susquehanna River Anadromous Fish Restoration Committee presents results from numerous studies and activities aimed at demonstrating that American shad can be restored to the river. This is the fourth year of a 10-year program to rebuild stocks based on hatchery releases and natural reproduction of adult shad collected at the Conowingo fish lift and transferred upstream to spawn. Considerable efforts are also dedicated to evaluating and improving downstream migration of juvenile shad from the river. The restoration program represents a continuing commitment of state and federal fishery resource agencies and private utility companies to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1988 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 48,546 fish (Petersen Index). This was based on recapture of 38 shad from a tagged population of 364 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay (136 shad) and angling in the Conowingo tailrace (228 fish). Thirty-four of the recaptures came from the lift at Conowingo. Estimated stock size in 1988 was 82% larger than in 1987 and 13 times greater than that of 1984.

The trap and lift at Conowingo Dam (rm 10) operated for 60 days during the period 31 March through 17 June, 1988. A total of 1.62 million fish representing 49 taxa were handled. The great majority of the catch (96%) was comprised of gizzard shad, white perch and channel catfish. Alosa species included 14,570 blueback herring, 5,169 American shad, 712 alewives, and 64 hickory shad. American shad catch in 1988 was about 2,500 fewer than in 1987 even though the upper Bay population was considerably larger. Effectiveness of the trap is related to hydroproject operation and river flow conditions. A high flow event during the third and fourth weeks of May curtailed or reduced trap operations at a time generally considered to be the peak of the spawning run.

Most shad were collected during the period 23 April - 17 May and catch per effort was about 2.5 times higher during weekend (off-peak) operation. Overall sex ratio of shad in Conowingo collections was 2.9 to 1 favoring males. Males ranged in age from II to VI (71% @ IV-V), and females were IV to VII (80% @ V-VI). Only 8 of 278 fish examined were repeat spawners.

A total of 4,736 shad was transported to potential upstream spawning areas with only 10 observed mortalities. Of that total, 3,333 shad were stocked at Long Level at the head of Lake Clarke, and 1,312 were released immediately below York Haven Dam at Falmouth. Twenty-eight American shad were fitted with radiotags and released in four batches of seven each between 21 April and 2 June. The first two groups were released at Long Level and of the 12 survivors, 4 reached York Haven in 5-16 days. Two others traveled upstream to Accomac Pool above Wrightsville. With river flow increasing from 28,000 to 191,000 cfs in mid-May, all tagged fish from these stockings moved quickly downstream.

Eleven of the 14 tagged shad released at Falmouth survived for monitoring. Four of these (all female) spent 3-14 days at York Haven. Most of the remainder descended the river to Wrightsville or Lake Clarke within 3-4 days. Spawning was confirmed with shad eggs collected at York Haven, Accomac Pool and Wrightsville.

The only source of naturally reproducing shad in the river in 1988 was from fish transferred upstream from Conowingo. Out-of-basin transplants were discontinued in response to the apparent failure of those fish (mostly Hudson River) to reproduce in the Susquehanna in past years.

A second major activity related to stocking nursery waters in the Susquehanna River involves hatchery production of shad fry and fingerlings. The Pennsylvania Fish Commission operated the intensive culture facility at Van Dyke and rearing ponds at Thompsontown, Benner Spring, and Upper Spring Creek. During the period 16 April to 26 June, almost 32 million shad eggs were delivered to Van Dyke from the Pamunkey and James River, Virginia (1.97 M), the Delaware River (2.9 M), and the

Columbia River, Oregon (26.9 M). SRAFRC contractors also investigated the Cape Fear River, NC and the Hudson River, NY but were not successful in taking sufficient numbers of shad eggs to warrant delivery.

Overall viability of eggs received was 39% resulting in production of 11.05 million fry and 74,000 fingerlings. All fry produced at Van Dyke were distinctively marked with one to four separate 6-hour immersions in 200 ppm tetracycline (TC). About 6.45 million 18-day old fry were stocked in the Juniata River at Thompsontown; 3.65 million were placed in the lower Susquehanna River at Lapidum, MD; 340,400 were delivered to the Lehigh River; and 612,200 were used for fingerling production and research at various locations. In addition to immersion tags put on fish at Van Dyke, pond reared fingerlings were also marked with TC-laced feed.

Cultural research conducted by the PFC in 1988 included studies to improve egg survival and handling methods, testing of new larger incubation jars at the hatchery and overnight holding facilities at the Columbia River collection site. PFC also initiated a special study to evaluate the use of otolith microstructure to distinguish between wild and hatchery-reared shad in the Susquehanna River. Difficulties were experienced in application of some feed tags in several pond lots, and in harvesting new ponds at Upper Spring Creek.

As in past years, a considerable effort was devoted to assessing relative abundance, growth, timing of migration and source of juvenile shad during autumn exodus from the river. Shad were sampled and monitored with cast nets and hydroacoustic gear in the York Haven forebay. At Holtwood, both cast nets and lift nets were used in the forebay behind Unit 10 and meter nets in the discharge. Cooling water strainers were routinely examined for impinged shad at Safe Harbor and Conowingo, and electrofishing was conducted in the lower river below Conowingo.

Migration from the river began 2-4 weeks later in 1988 compared to prior years. This may reflect unusually low flow conditions in the basin during summer months. Shad were abundant at York Haven during late October through late November.

Side-scan hydroacoustic assessment there indicated that the overall strength of the run was slightly greater than in 1987 or 1986 and that most passage at this site occurred during late evening and early morning hours. Catch per effort in net collections was similar to 1987 and shad averaged 122 mm in length with two distinct size groups represented.

At Holtwood, sampling began in late August, but shad were not available in abundance until the third week in October. Hundreds of American shad were collected with nets in the forebay but only 61 were taken with meter nets in the discharge. Most fish collected in a live car attachment in the tailrace (15 of 18) survived turbine passage. Total juvenile American shad collections at Safe Harbor, Conowingo, and the lower river were 10, 4, and 2, respectively.

Shad from York Haven, Holtwood (forebay and tailrace), and the lower river were returned to Benner Spring for tetracycline mark analysis. As expected, all York Haven fish were tagged. At Holtwood, all fish from forebay collections were marked but 4 of 56 shad from the meter net collections were unmarked and presumed wild. One of the two lower river shad carried the double tag indicating that it was a hatchery reared fish stocked at Lapidum, MD.

Because each egg source strain of shad was distinctively marked at the hatchery in 1988, the stock composition of juveniles at various collection sites could be determined. Overall, Virginia and Delaware River fish comprised about 65% of recoveries even though they represented only 18% of fry stocked in the Juniata River. Size difference of shad in the net collections was directly related to time of stocking with Columbia River fish being the smallest. Chi square tests for homogeneity showed that Holtwood meter nets and York Haven cast nets sampled the same stock composition while Holtwood cast nets (forebay) caught a disproportional share of smaller Columbia River fish.

SRAFRC worked with the Electric Power Research Institute (EPRI) in a co-funded study of downstream passage technologies at York Haven Dam. Under contract to

EPRI, Stone and Webster researchers examined effects of underwater strobe lights and sound generators to repel shad from operating turbines, and mercury vapor lamps to attract fish to an open trash sluice. Shad were not attracted to the mercury lamps or consistently repelled by sounds. However, strobes were very effective in driving shad to and through the sluiceway. In several years of testing at numerous sites this was the most successful application of the strobe technique to date.

The final two special studies in 1988 used radio tagged juvenile shad to assess turbine mortality at Holtwood and entrainment of outmigrants passing the Muddy Run Pumped Storage Project intake. Test fish for these studies were reared in heated water at the Brunner Island Aquaculture Facility. However, fish did not grow sufficiently and temperature shock coupled with handling stress reduced their viability. Though some fish survived turbine passage at Holtwood and migration past Muddy Run, the number of tests were limited and results are inconclusive.

American shad egg collection, hatchery operations, research and marking, juvenile recovery and mark analysis, and adult and juvenile telemetry studies were funded from the 1985 settlement agreement with upstream utilities. EPRI funded about 90% of the downstream passage technology study at York Haven. Philadelphia Electric Company paid for operation of the trap and lift at Conowingo, transfer of adult shad upstream, and strainer checks at Conowingo Dam. Maryland DNR funded the adult shad population assessment and juvenile shad electrofishing survey in the lower river as part of a state-federal program.

Additional information on activities discussed in this Annual Report can be obtained from individual Job authors or by contacting the Susquehanna River Coordinator, U. S. Fish and Wildlife Service, P. O. Box 1673, Harrisburg, Pennsylvania 17105.

Richard St. Pierre
Susquehanna River Coordinator

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

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RMC Environmental Services
Drumore, Pennsylvania

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RMC Environmental Services
Drumore, Pennsylvania

JOB I. SUMMARY OF OPERATION OF THE CONOWINGO DAM FISH PASSAGE FACILITY IN SPRING 1988

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INTRODUCTION

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

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

Objectives of the 1988 operation were: (1) contribute to restoration efforts by the trap and transfer of prespawned

American shad to pre-determined upstream localities, (2) monitor relative abundance of Alosa species, (3) obtain life history information from selected migratory and resident fishes, (4) monitor species composition, and (5) assist the Maryland Tidewater Administration in assessing the American shad population in the upper Chesapeake Bay.

METHODS

Prior to the operation of the Lift, surveys were conducted to detect the arrival of alosids into the lower river area. Herring checks at the mouth of Deer Creek and at Stratford Bridge were initiated on 16 March. Water temperature during surveys varied from 40.0 to 51.8 F. Since no herring were observed and American shad were being collected at the Lift, the herring checks were terminated on 5 April.

Preparations for the operation of the Lift began during early March and included a series of steps to make the Lift reliable and operable at 120,000 cfs in accordance with the Federal Energy Regulatory Commission (FERC) order issued on January 7, 1987. The steps taken, and agreed to by the Susquehanna River Technical Committee (SRTC), are presented in Table 1.1. Lift operation was consistent with and followed 1988 SRTC and Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) work plans.

Lift operation commenced on 31 March and occurred on an alternate half-day (0700-1300 hrs) basis through 18 April. Although operation from 6 to 10 April was scheduled for an alternate half-day basis, the collection of 67 alewife on 6 April and 12 American shad on 8 April resulted in a half-day of Lift operation on 7 and 9 April, respectively. With the collection of 187 American shad on 18 April daily operation of the Lift started (0700 hr to approximately 1900 hr) and continued to 19 May. Increased river flows on 19 May (196,300 cfs) resulted in discharges in excess of 120,000 cfs at Conowingo Dam and stoppage of Lift operation at approximately 1300 hrs. Lift operation resumed during the afternoon of 24 May and was operated on an alternate half-day basis from 25 to 29 May. Due to the increased collection of shad on 30 May the Lift was operated on a daily basis through 12 June. Although the Lift was operated daily from 13 to 17 June, operation was reduced to a half-day basis due to the advanced sexual condition of the American shad collected.

Beginning in late April, SECO modified the normal pattern of station generation at Conowingo Dam to enhance Lift effectiveness when natural river flows and electrical power demand permitted. Generally, Turbine Units No. 1 and/or 2 were kept off until all others had been placed into service and were taken out of service first when going to off peak generation. This modified generation scheme was maintained through 16 June and terminated when the catch of

American shad in a post-spawned condition indicated the 1988 run of shad was over.

The mechanical aspect of Lift operation in 1988 was similar to that described in RMC (1983). Fishing time and/or Lift frequency was determined by fish abundance and the time required to process the catch. However, due to large numbers of gizzard shad, and on occasion carp, two modifications implemented in 1985 to maximize collection of American shad were utilized (RMC 1986). Operation "Fast Fish"* (RMC 1986) was employed on an as needed basis and resulted in increased fishing time during periods of heavy fish activity by reducing mechanical delays associated with normal Lift operation. On several occasions, as a result of changes in water levels and turbine discharge in the tailrace, large numbers of gizzard shad were attracted to the Lift. In an effort to maximize the collection of American shad, either weir gate 1 or 2 (Figure 1.1) was closed and fish that had accumulated were lifted rapidly within minutes. Normal operation of the Lift was resumed after most fish had been removed.

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

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

Since 1972 a continuous minimum flow of 5,000 cfs through Conowingo Dam has been maintained from 15 April through 15 June. Generally, Unit No. 6 was used in 1988 to release the continuous minimum flow. The minimum release from Unit No. 6 was based on results of 1982 and experience at other fish passage facilities which showed that passage effectiveness increased when competition was reduced between the attraction flow from the passage devices and the flow releases from other sources.

Fishes were processed as reported earlier (RMC 1983). Fishes were either counted or estimated (when large numbers were present) and released back to the tailrace. Length, weight, sex, and scale samples were taken from blueback herring, hickory shad, alewife, striped bass, and striped bass x white bass hybrid. The use of scientific and common names of fishes collected (Table 6.2) followed Bailey et al. (1970). Most life history information (i.e. length, weight, sex, spawning condition, and scale samples) were taken from American shad that were tagged and/or released back to the tailrace and those that died in handling and transport. Also, otoliths were removed from mortalities for the Pennsylvania Fish Commission.

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

Holding and Transport of Shad

Generally, transport occurred whenever 100 or more green or gravid shad were collected in a day, or at operator's discretion. Based on results of holding experiments conducted in 1986, shad were held for up to 18 days to accumulate sufficient numbers of shad for transport, thus increasing the efficiency of the transport program. Four black circular tanks (2-800 gal., 2-1,100 gal.), continually supplied with river water, were used as holding tanks. The aeration system utilized bottled oxygen and/or compressed air. Also, each tank was fitted with a cover to prevent escape and reduce stress.

American shad were transported in 1,100 gallon circular transfer units. All transfer units were equipped similarly to the system used in 1985 (RMC 1986). The holding and handling procedures employed during transport were similar to those used in previous years.

RESULTS

The relative abundance of fishes has fluctuated since 1972 (Table 1.3). Fluctuations have resulted primarily from changes in species abundance and modification to Lift and turbine operation. Prior to 1980, alosids (primarily blueback herring) and white perch dominated the catch, from 1980-1988 the catch was generally dominated by gizzard shad, white perch, and channel catfish.

In 60 days of Lift operation (31 March through 17 June, 1988) 1,620,065 fish of 49 taxa were caught (Tables 1.3 and 1.4). Predominant species in order of numerical abundance were gizzard shad, white perch, and channel catfish. Alosids (blueback herring, alewife, hickory shad and American shad) comprised less than 1.3% of the total catch.

The catch of gizzard shad (1,427,628) in 1988 was the fourth highest recorded for any species since operation began in 1972 (Table 1.3). Gizzard shad comprised 88% of the total catch and also dominated the daily catch and ranged from 988 (31 March) to 62,200 (1 May) (Table 1.4).

The large number of gizzard shad in the tailrace and operation "Fast Fish" were prime contributing factors to the high catch in 1988. Modifying normal weir gate openings, in combination with operation "Fast Fish" on 17 days when gizzard shad and/or carp numbers were excessive, also resulted in an increased catch rate of American shad on 8 of those 17 days (Table 1.5).

American Shad

The 1988 catch of American shad (5,169) at the Lift was the third highest recorded since Lift operation began in 1972 (Table 1.3). Over ninety-four percent (4,884) of the shad collected were transported. One hundred seventy-six shad were released back to the tailrace. Sixty were floy tagged. The remainder of the catch consisted of RMC tag recaptures, resource agency recaptures (Maryland DNR), handling, and holding mortalities.

A total of 44 American shad (0.9%) died during daily operation at the Lift. Mortalities resulted from mechanical operation of the Lift, handling and holding procedures. The mortality at the Conowingo Fish Lift was within the range of mortality (1-3%) observed at the Holyoke Fish Lift where handling is generally non-existent; shad swim through a flume to gain access to the area upstream of the dam.

American shad were first observed at the Lift on 31 March (Table 1.4 and Figure 1.2). Most shad (3,273) were collected from 23 April through 17 May prior to a high flow event (>196,000 cfs). Daily catch during this period indicated that the shad catch varied but reflected several peak periods of abundance. The largest collection of shad (2,003) occurred from 9 to 17 May. The other period of increased abundance occurred from 24 April to 2 May when 1,162 shad were taken.

The daily catch of American shad exceeded 175 individuals on 10 days (Table 1.4 and Figure 1.2). The largest catch in 1988 was 617 on 5 June. This represented approximately 12% of the total catch.

As in the past, the catch per effort (CPE) of American shad varied by station generation and time of day (Table 1.6). The CPE was approximately threefold higher when one unit was in operation (Table 1.7). Also, the CPE was over 2.5 times higher during weekend operation. Generally, on week days, the total CPE was greatest between 1500-1900 hrs. On weekends, catches were highest between 1100-1900 hrs.

American shad were collected at water temperatures of 51.8 to 71.9 F and at natural river flows of 10,800 to 110,600 cfs (Table 1.4 and Figure 1.2). Over sixty-three percent of the shad were collected at water temperatures ≤65 F (Table 1.8).

Water temperature during the period of peak shad abundance (23 April to 17 May) ranged from 52.7 to 65.3 F.

Transport of Adults

The trap and transport of prespawned American shad to upstream spawning areas is the primary objective of Lift operation and contributes to the American shad restoration program. Prespawned American shad were transported from 18 April through 13 June. Most American shad were stocked above Safe Harbor Dam at a public boat ramp in Long Level and the Pennsylvania Fish Commission access at Falmouth. Two loads containing radio tagged shad were stocked into Conowingo Pond at Glen Cove. One load of 148 shad was transported to the Muddy Run Laboratory on 19 May prior to the high flow event. These shad were intended for radio telemetry study, however, they died prior to the start of the study.

A total of 4,736 (92% of 1988 catch) American shad was transported to potential upstream spawning areas with an overall observed stocking survival of 99.9% (Table 1.9). Some 4,645 shad were stocked above Safe Harbor Dam. A total of 3,333 and 1,312 shad were stocked at Long Level and Falmouth, respectively. Two loads (91 shad total) containing radio tagged shad were released at Glen Cove in Conowingo Pond. Transportation of shad occurred on 23 days and was accomplished in 27 trips. Generally, individual trips to Long Level and Falmouth averaged 1.5 and 2.0 hours, respectively.

The number of trips per day varied from one to three. Load size varied from 113 to 273 fish per trip. Trip survival varied from 98.3 to 100%. Shad were transported at water temperatures between 51.8 to 71.1 F.

The transport of a large number of shad afforded the opportunity to estimate the potential contribution of these fish to the restoration program. The potential egg deposition of shad was calculated assuming an average fecundity of 200,000 eggs/female. Of the 1,387 females collected, 175 were not transported, resulting in 1,212 being stocked upstream. The estimated potential egg deposition of these 1,212 fish was 242.4×10^6 eggs. The fate of these eggs, survival to fry, and juvenile stage is unknown. In contrast, the hatchery operated by Pennsylvania Fish Commission received 31.8×10^6 eggs and released 10.1×10^6 fry and 74,000 juveniles (see Job III).

Based on 1987 results, holding facilities were utilized to allow shad collected on a given day to be held overnight or for several days, based on operator's discretion to maximize transport operations and the release of larger schools of fish. A total of 2,525 shad was held over at the Lift. Although most shad were held one night, some were held 18 days (Table 1.10). The number of shad held over varied from 1 to

140. A total of 16 shad died in the holding tanks; 5 were males and 11 were females.

Sex And Age Composition of American Shad

Visual macroscopic inspection of shad was made to determine daily and seasonal sex ratios. Generally, when daily catch exceeded 100 shad a minimum 100 fish subsample was examined. When daily catch did not exceed 100 shad generally all fish were sexed.

Three thousand three hundred seventy-five American shad were sexed in 1988. The daily sex ratio of shad collected at the Lift is shown in Table 1.11. Males dominated the catch throughout the season accounting for an overall male to female ratio of 2.9:1. Males outnumbered females from 31 March until 13 May (Table 1.12). The number of females contributing to the catch increased in late May and peaked during the first two weeks of June (Table 1.12). Generally, the distribution of males to females in relation to the catch in 1988 was similar to that observed in past years.

It is interesting to note that for a similar sampling period (May) the sex ratio (3.5:1) of shad collected at the Lift was not similar to the sex ratio (2.0:1) of shad collected in the tailrace by Maryland DNR (see Job VI).

Two hundred ninety-six scale samples were collected in 1988. Scale samples were obtained from transport and handling mortalities, and from fish tagged and/or released back to the tailrace near the end of the season. Scale sample collection did not occur randomly in regards to the entire season; therefore, age composition from these samples may not be representative of the population and is provided only to observe general trends.

Ninety-four percent (278) of the scale samples collected were aged successfully. Males ranged from II to VI years old while females were IV to VII years old (Table 1.13). Most males (71%) were IV or V year olds while the females (80%) were represented almost equally by V and VI year olds. Only five males and three females were repeat spawners. Although no multiple repeat spawners were aged in 1988, one shad tagged in 1986 by Maryland DNR and recaptured at the Lift this year would have been a double repeat spawner.

The age composition of shad released back to the tailrace was similar to that of shad which died from handling and transport and those that died at the Muddy Run Laboratory (Table 1.14).

<u>Tag and Recapture</u>

Floy tagging was limited in 1988 because the primary objective of Lift operation was to maximize the trap and transport of prespawned American shad. Shad were tagged and released to the tailrace based on operator discretion only if they had already begun spawning activities and could successfully handle the added stress from tagging.

Sixty American shad were floy tagged at the Lift by RMC in 1988. Most shad were tagged in late May and early June. Only two shad tagged at the Lift were recaptured. Both recaptures were tagged on the same day and recaptured 10 and 13 days later, respectively (Table 1.15).

The Maryland DNR tagged a total of 349 American shad in 1988; 136 from pound nets in the upper bay and 213 from hook and line in the Conowingo Dam tailrace. Of 349 tagged shad, RMC recaptured 40 at the Lift in 1988. In addition, one shad tagged by Maryland DNR in the tailrace on 2 May 1986 was recaptured at the Lift on 17 May 1988 after 715 days free.

Of 40 Maryland DNR recaptures, 37 were originally tagged in the tailrace and three in the upper bay. The three tagged in the upper bay averaged 29.6 days free before capture at the Lift, while those tagged and recaptured in the tailrace averaged 19 days free.

An interesting note was the relationship between the daily catch of shad at the Lift and the number of Maryland DNR recaptures. Most recaptures (80.5%) occurred on days when Lift catch exceeded 100 shad (Table 1.16). In addition, most recaptures were taken after a high river flow event (>196,000 cfs). The fact that most shad were tagged by Maryland DNR before the high water (see Section VI) and most recaptures occurred after the high water, suggests high water of that magnitude in mid-season did not terminate the shad run.

<u>River Herring and Hickory Shad</u>

The combined catch of river herring (blueback and alewife) and hickory shad increased from that observed in 1987 (RMC 1988), but was much lower than historic levels (Table 1.3). A total of 712 alewife was collected, with the first capture on 31 March (Table 1.4). Over 55% of the catch occurred from 7 May through 15 May at water temperatures of 57.2 to 63.5 F. Some 250 alewife (35% of total catch) were collected on 15 May.

A total of 14,570 blueback herring was collected (Table 1.3). Blueback herring typically arrive later than alewife and were first collected on 22 April. Over 82% (11,969 blueback herring) were collected between 15 and 17 May. Water temperature ranged from 63.5 to 65.3 F on these days.

As conditions permitted PECO agreed to transport up to 10,000 river herring for Maryland DNR from the Fish Lift. Three loads totaling 2,400 blueback herring were stocked into Big Elk Creek. Load size varied from 400 to 1,000 fish per trip. A total of 3 mortalities was observed.

The hickory shad catch (64) continued to be low. Hickory shad were first captured on 6 April. Most (42, or 65.6% of total catch) were caught on 24 April.

DISCUSSION

In contrast to earlier years, the total catch of shad was similar on weekends (2,579) and weekdays (2,580) (Table 1.6; Figure 1.3). However, the CPE (catch/hr) was over two fold higher on weekends. The CPE was 17.7 and 6.7 on weekends and weekdays, respectively. In comparison, the size of the catch at the Lift is primarily dictated by variations in station discharge (peak load vs reduced generation), natural river flows, and the nature of the shad run (changes in rate of immigration). Station discharge is dictated by natural river flows, peak power demand, and minimum flow requirements. On weekends since 1982 if there was little peak power demand, and if natural river flows were low, the station either shutdown (up to 14 April) or discharged 5,000 cfs. If natural river flows are high the station must discharge higher flows. Generally, peak shad collections in 1988 were coincident with weekends (Figure 1.3).

The Lift catch in 1988 did not indicate that an increased number of shad were available for capture as compared to 1987. However, it is important to note that a high flow event during the peak trapping period may have been responsible for the decrease in the 1988 shad catch. The total CPE from 1982 through

1987 (years of modified operation) was 8.3, 2.7, 2.3, 4.6, 11.9, 15.1, and 9.8, respectively (Table 1.17). The CPE in 1987 was higher than that observed in 1982, 1986 and 1988 when CPE was generally similar. The catch rates in 1983 and 1984 were similar but much lower. Excluding 1984, a high flow year, catch rates in all years were highest at station discharge less than or equal to 5,000 cfs.

Examination of the 1988 transport data showed that the major objective was satisfied; 94.5% (4,884) of the shad collected were transported. Although transport mortality was minimal (0.1%), a high spring flow in midst of the peak of trap and transport operations created a condition that warrants modification to future transport operational guidelines. Based on results of telemetry studies (see Job V) when river flows exceed 120,000 cfs it is recommended that shad be released back to the Conowingo Dam tailrace until a upriver holding facility is constructed.

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TABLE 1.1

The status of steps taken prior to 31 March 1988 to make the Conowingo Dam Fish Lift reliable and operable at 120,000 cfs.

STEPS

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1. Inspect above and below water line and perform repairs as required.

   STATUS: Completed, resulted in repairs to valve No. 5. and replacement of steel cable on hopper festoon.

2. Perform preventive maintenance including:

   a) Check out entire electrical system and replace any worn or corroded contacts;

   b) Clean out holding channel of any trash which may have accumulated over the fall and winter seasons;

   c) Calibrate weir gates to assure proper attraction flow;

   d) Recondition pumps which provide water to the fish sorting areas;

   e) Overhaul weir gate and crowder motors;
   STATUS: Items a through e completed.

3. Provide as required a crane or block and tackle system so that the weir and crowder motors can be removed when the station discharge flow goes above 120,000 cfs and subsequently reinstalled before the flow drops back down to 120,000 cfs. Additionally, the conduit to these motors will be checked for water tightness prior to operation, cracks will be sealed, and any worn junction box gaskets will be replaced. When water levels approach the level of the conduit, the conduit will be pressurized to further assure that the conduit will remain dry and that the crowder and weir gates can operate up to and including 120,000 cfs.

   STATUS: Completed. During spring a crane was made available on site as needed to install and remove the crowder and weir gate motors.

4. The licensees will also maintain on hand at the Dam various spare components and hoses. These will enable rapid repair in the event of an unforeseen breakdown of the lift.

   STATUS: Completed. Spare hoses, electrical components and a water supply pump were on hand.

TABLE 1.2

List of scientific and common names of fishes collected at the Conowingo Dam Fish Passage Facility, 1972 through 1988.

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
Salmo gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
S. fontinalis x S. namaycush	Splake
Family - Esocidae	Pikes
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Esox niger	Chain pickerel
E. masquinongy x E. lucius	Tiger muskie
Family - Cyprinidae	Minnows and carps
Carassius auratus	Goldfish
Cyprinius carpio	Carp
Nocomis micropogon	River chub
Notemigonus crysoleucas	Golden shiner

TABLE 1.2

Continued.

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

TABLE 1.2

Continued.

Scientific Name	Common Name
Family - Centrarchidae	Sunfishes
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 vitreum	Walleye
Family - Osmeridae	Smelts
Osmerus mordax	Rainbow smelt

TABLE 1.3

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1988.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979
NO. DAYS	54	62	58	55	63	61	35	29
LIFTS	817	1,527	819	514	684	707	358	301
EST. OPER. TIME(HR.)	608	996	500	307	375	413	212	187
FISHING TIME(HR)	313	623	222	189	252	245	136	123
# SPECIES	40	43	42	41	38	40	44	37
AMERICAN EEL	805	2050	91937	64375	60409	14601	5878	1602
BLUEBACK HERRING	58198	330341	340084	69916	35519	24395	13098	2282
HICKORY SHAD	429	739	219	20	-	1	-	-
ALEWIFE	10345	144727	16675	4311	235	188	5	9
AMERICAN SHAD	182	65	121	87	82	165	54	50
GIZZARD SHAD	24849	45668	119672	139222	382275	742056	55104	75553
ATLANTIC MENHADEN	-	-	112	-	506	1596	-	-
TROUTS	1	-	-	-	-	-	-	-
RAINBOW TROUT	34	67	20	24	54	291	70	15
BROWN TROUT	172	286	483	219	427	700	261	324
BROOK TROUT	1	3	4	1	-	2	23	-
TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	1	10	-	-	1	-	-
NORTHERN PIKE	-	2	2	-	-	2	2	4
MUSKELLUNGE	20	104	9	7	12	48	14	5
REDFIN PICKEREL	-	-	-	-	-	-	-	-
MINNOWS	-	-	-	-	-	-	-	-
GOLDFISH	-	27	1	9	4	1	-	-
CARP	4370	16362	34383	15114	6755	16256	11842	14946
RIVER CHUB	-	-	-	-	-	-	-	-
GOLDEN SHINER	165	430	437	751	1622	652	221	304
COMELY SHINER	5	252	3870	2079	740	769	1152	1707
SPOTTAIL SHINER	34	137	2036	268	1743	8107	8506	1533
SWALLOWTAIL SHINER	-	-	-	-	-	-	-	-
ROSYFACE SHINER	1	-	-	1	-	-	-	-
SPOTFIN SHINER	103	40	3011	1231	45879	7960	3751	41
BLUNTNOSE MINNOW	-	-	-	-	-	-	4	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	1	-	-	-	4	-
CREEK CHUB	-	-	-	-	-	-	-	-
SHINERS	264	3	-	-	-	-	-	-
QUILLBACK	7119	27780	14565	8388	9882	6734	2361	5134
WHITE SUCKER	363	1034	286	152	444	282	189	906
CREEK CHUBSUCKER	3	3	1	-	-	-	-	-
NORTHERN HOG SUCKER	-	2	-	1	5	-	3	6
SHORTHEAD REDHORSE	1097	4420	434	445	1276	1724	697	2163
WHITE CATFISH	3070	6394	2200	6178	1451	3081	982	515
YELLOW BULLHEAD	7	45	1	32	2	47	25	13
BROWN BULLHEAD	510	5328	1612	740	451	2416	125	284
CHANNEL CATFISH	61042	55084	75663	74042	41508	90442	48575	38251
MARGINED MADTOM	-	-	-	-	-	-	-	-
MADTOMS	-	-	-	-	-	-	-	-
TADPOLE MADTOM	-	-	-	-	-	-	-	-
MUMMICHOG	-	-	-	-	1	-	-	-
WHITE PERCH	50991	647493	897113	511699	568018	224843	113164	43103
STRIPED BASS	3142	495	1150	174	13	1196	934	260
ROCK BASS	66	32	31	46	227	128	50	46
REDBREAST SUNFISH	707	2056	1398	3040	3772	8377	4187	3466
GREEN SUNFISH	3	-	4	39	81	168	25	-
PUMPKINSEED	229	2578	2579	1000	678	1687	512	323
BLUEGILL	567	1423	927	3058	2712	5442	1361	813
SMALLMOUTH BASS	182	298	119	153	327	701	262	374
LARGEMOUTH BASS	82	80	23	19	33	14	22	22
WHITE CRAPPIE	4457	664	4371	9290	2987	1003	673	384
BLACK CRAPPIE	8	4	25	45	86	199	103	53
TESSELLATED DARTER	-	1	4	1	-	-	1	-
YELLOW PERCH	5955	1090	682	494	2904	735	526	379
LOGPERCH	-	-	-	-	-	-	27	-
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	1840	2734	1613	369	2267	2140	967	2491
BANDED DARTER	-	-	-	-	-	-	1	-
ATLANTIC NEEDLEFISH	1	-	-	1	-	-	-	-
LAMPREYS	-	-	-	-	-	-	-	-
SEA LAMPREY	-	2	-	2	29	11	1	3
LAKE HERRING	-	1	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	-	-	-	-	-	270	273
TIGER MUSKIE	-	-	-	-	-	-	13	132
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	241419	1300345	1617888	917043	1175616	1169161	278045	197769

TABLE 1.3

CONTINUED

YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988
NO. DAYS	30	37	44	29	34	55	59	60	63
LIFTS	403	490	725	648	519	1,118	831	1,414	1,339
EST. OPER. TIME(HR.)	221	275	502	299	251	542	546	639	637
FISHING TIME(HR)	117	178	336	224	192	421	449	532	513
# SPECIES	42	48	48	41	35	41	43	46	49
AMERICAN EEL	377	11329	3961	1080	155	550	364	1662	103
BLUEBACK HERRING	502	618	25249	517	311	6763	6327	5861	14570
HICKORY SHAD	1	1	15	5	6	9	45	35	64
ALEWIFE	9	129	3433	50	26	379	2822	357	674
AMERICAN SHAD	139	328	2039	413	167	1546	5195	7667	5146
GIZZARD SHAD	275736	1156662	1226374	950252	912666	2182888	1714441	2488618	1402565
ATLANTIC MENHADEN	16	42	-	1	-	1	-	-	-
TROUTS	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	23	219	20	2	5	70	9	14	10
BROWN TROUT	258	207	219	225	141	175	65	83	85
BROOK TROUT	4	3	5	2	-	1	-	-	1
TROUT	-	2	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	1	1
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-	1	-
CHAIN PICKEREL	-	1	-	-	-	-	-	-	-
NORTHERN PIKE	3	-	5	1	-	-	2	-	-
MUSKELLUNGE	27	1	4	-	-	15	-	-	1
REDFIN PICKEREL	-	-	-	-	-	-	-	1	-
MINNOWS	-	-	1	-	-	-	-	-	-
GOLDFISH	-	1	-	-	-	-	-	-	1
CARP	8879	18313	15362	16273	8012	6729	2930	4607	8535
RIVER CHUB	1	-	-	-	-	-	-	-	-
GOLDEN SHINER	35	155	92	216	8	292	23	40	28
COMELY SHINER	761	281	14214	3176	871	5141	582	21199	11734
SPOTTAIL SHINER	849	31	315	2132	-	3525	6247	155	55
SWALLOWTAIL SHINER	-	3	-	-	-	-	1	-	-
ROSYFACE SHINER	-	-	8	-	-	-	-	-	-
SPOTFIN SHINER	314	524	622	501	-	2695	695	796	65
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-	65
BLACKNOSE DACE	-	-	2	-	-	-	-	-	-
LONGNOSE DACE	-	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-	1
SHINERS	-	-	6	-	-	-	-	-	-
QUILLBACK	2929	3622	1617	4679	1942	957	2327	1881	1578
WHITE SUCKER	1145	1394	582	412	109	776	853	263	540
CREEK CHUBSUCKER	-	4	2	-	-	-	-	5	1
NORTHERN HOG SUCKER	13	1	-	-	-	-	2	4	1
SHORTHEAD REDHORSE	1394	6533	6974	7558	3467	3362	2057	3583	4782
WHITE CATFISH	605	2199	565	224	77	1094	284	917	3849
YELLOW BULLHEAD	18	36	61	10	7	21	35	41	80
BROWN BULLHEAD	675	531	338	179	69	461	134	163	345
CHANNEL CATFISH	38929	55528	40941	12559	20479	15200	18898	11699	36212
MARGINED MADTOM	-	-	6	-	-	-	3	-	1
MADTOMS	-	-	1	-	-	-	-	-	-
TADPOLE MADTOM	-	-	1	-	-	-	-	-	-
MUMMICHOG	-	-	1	-	-	-	-	-	-
WHITE PERCH	26971	83363	53527	23151	6402	68344	56977	29995	90651
STRIPED BASS	904	3277	60	23	181	213	194	1337	874
ROCK BASS	88	381	138	269	158	122	200	231	110
REDBREAST SUNFISH	1524	1007	1335	401	465	3366	1433	1471	730
GREEN SUNFISH	16	28	91	16	7	133	15	64	19
PUMPKINSEED	446	306	848	228	104	1013	402	490	135
BLUEGILL	942	1299	1184	587	284	6048	1654	2436	1107
SMALLMOUTH BASS	455	881	1095	1003	608	1081	666	536	548
LARGEMOUTH BASS	41	13	20	17	8	67	75	69	117
WHITE CRAPPIE	100	231	303	450	59	345	199	272	125
BLACK CRAPPIE	15	20	39	46	6	45	51	19	42
TESSELLATED DARTER	-	2	-	-	-	1	-	1	1
YELLOW PERCH	373	1007	724	387	487	2145	2267	832	815
LOGPERCH	-	-	-	-	-	1	1	1	2
SHIELD DARTER	-	1	-	-	-	-	-	-	-
WALLEYE	4153	2646	504	663	236	609	380	267	311
BANDED DARTER	-	-	-	-	-	-	-	1	-
ATLANTIC NEEDLEFISH	-	2	-	-	-	-	-	-	2
LAMPREYS	-	-	-	2	-	-	-	-	-
SEA LAMPREY	1	55	56	8	4	164	26	21	59
LAKE HERRING	-	-	-	1	-	-	-	-	-
STRIPED BASS X WHITE BASS	2674	39	160	355	282	1377	1713	5895	6203
TIGER MUSKIE	34	53	56	16	10	73	35	30	20
BROOK TROUT X LAKE TROUT	-	-	-	-	2	-	2	5	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	10	19	1
	372379	1353308	1403175	1028090	957821	2317797	1830641	2593445	1592965

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1988.

DATE	31 MARCH	02 APRIL	04 APRIL	06 APRIL	07 APRIL	08 APRIL	09 APRIL	10 APRIL
# OF LIFTS	7	8	11	12	11	20	15	16
FIRST LIFT	705	720	608	605	614	615	614	603
LAST LIFT	1300	1305	1248	1215	1150	1419	1303	1200
OPERATING TIME (HR)	5.92	5.75	6.67	6.17	5.60	8.07	6.82	5.95
FISHING TIME (HR)	5.47	5.03	4.90	4.82	4.67	6.68	5.83	5.52
AVE RIVER FLOW	69300	51900	43700	42200	43700	47100	49500	50400
AVE WATER TEMP (F)	54.8	53.6	53.6	54.5	53.6	53.6	53.6	52.7
AMERICAN EEL	2	3	3	1	4	1	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	2	-	1	-	-
ALEWIFE	38	6	33	67	44	46	6	2
AMERICAN SHAD	2	-	2	1	6	12	2	-
GIZZARD SHAD	988	6787	2547	10135	9250	30100	25550	17325
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	-	1	1	1	-	-	1	2
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	-	-	-	2	-	-	4	1
GOLDEN SHINER	-	-	-	-	-	-	-	1
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	1	4	1	-	3	1
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	1	-	-	1	-	-	-	-
WHITE SUCKER	16	4	7	28	26	31	27	7
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	18	1	1	31	3	22	11	2
WHITE CATFISH	4	2	5	1	2	1	-	-
YELLOW BULLHEAD	-	-	-	1	1	-	-	-
BROWN BULLHEAD	-	1	2	3	-	3	1	-
CHANNEL CATFISH	38	4	39	39	11	27	18	6
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	-	-	2	12	9	37	46	52
STRIPED BASS	1	-	1	2	-	-	1	-
ROCK BASS	1	-	-	3	-	-	1	2
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	-	-	-	2	1	3	12	1
LARGEMOUTH BASS	-	-	-	6	-	-	2	2
WHITE CRAPPIE	-	-	-	1	-	1	2	1
BLACK CRAPPIE	-	-	-	-	1	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	4	3	47	30	26	9	6	5
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	3	1	2	4	8	3	4	2
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	2	-	-	3	-	2	1
STRIPED BASS X WHITE BASS	5	3	5	48	13	50	8	4
TIGER MUSKIE	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	1
	1121	6818	2698	10425	9409	30347	25707	17418

TABLE 1.4

CONTINUED

DATE	12 APRIL	14 APRIL	16 APRIL	18 APRIL	19 APRIL	20 APRIL	21 APRIL	22 APRIL
# OF LIFTS	10	13	19	20	14	28	17	20
FIRST LIFT	610	618	607	614	602	609	609	606
LAST LIFT	1210	1150	1328	1802	1757	1700	1641	1800
OPERATING TIME (HR)	6.00	5.53	7.35	11.80	11.92	10.85	10.53	11.90
FISHING TIME (HR)	3.90	4.53	5.60	8.48	8.80	9.27	7.73	8.50
AVE RIVER FLOW	40700	33500	28800	25600	25500	23600	22400	21900
AVE WATER TEMP (F)	51.8	53.6	52.1	51.8	53.6	51.8	52.7	51.8
AMERICAN EEL	-	-	-	-	3	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	1
HICKORY SHAD	-	-	-	1	-	-	-	-
ALEWIFE	10	-	-	9	4	1	-	4
AMERICAN SHAD	2	1	4	187	6	7	8	10
GIZZARD SHAD	12925	29675	50350	27765	25175	35525	23002	7143
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	-	1	-	3	-	1	1	1
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	-	2	1	2	1	1	-	3
GOLDEN SHINER	-	-	1	-	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	1	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	-	-	1	2	-	-	1	-
WHITE SUCKER	3	4	6	20	4	1	6	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	6	4	13	72	4	16	2	19
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	1	-	-	-	-	-	1	-
CHANNEL CATFISH	20	21	17	5	3	-	5	13
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	20	31	75	1056	98	142	2436	1513
STRIPED BASS	4	-	1	5	3	1	1	-
ROCK BASS	1	-	-	-	-	-	-	-
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	1
BLUEGILL	-	-	1	1	-	-	2	-
SMALLMOUTH BASS	-	9	12	3	1	2	2	2
LARGEMOUTH BASS	1	-	3	-	-	2	1	-
WHITE CRAPPIE	-	-	1	1	-	-	-	-
BLACK CRAPPIE	-	1	1	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	6	7	7	41	2	2	2	5
LOGPERCH	-	1	-	-	-	-	-	-
WALLEYE	-	-	2	2	2	-	2	1
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	1	1	1	-	-	2	-
STRIPED BASS X WHITE BASS	52	39	370	39	272	142	427	11
TIGER MUSKIE	-	-	-	-	1	-	2	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	13052	29797	50867	29216	25579	35843	25903	8729

TABLE 1.4

CONTINUED

DATE	23 APRIL	24 APRIL	25 APRIL	26 APRIL	27 APRIL	28 APRIL	29 APRIL	30 APRIL
# OF LIFTS	20	22	22	19	15	30	24	28
FIRST LIFT	605	603	606	605	618	616	616	606
LAST LIFT	1806	1733	1716	1736	1622	1815	1727	1806
OPERATING TIME (HR)	12.02	11.50	11.17	11.52	10.07	11.98	11.18	12.00
FISHING TIME (HR)	9.43	9.88	7.83	7.17	6.95	9.28	8.90	9.95
AVE RIVER FLOW	20000	18400	18100	16900	18500	24100	19800	25000
AVE WATER TEMP (F)	52.7	52.7	52.7	53.6	53.6	55.4	64.5	55.4
AMERICAN EEL	-	-	-	1	-	-	-	1
BLUEBACK HERRING	7	7	-	1	1	48	-	122
HICKORY SHAD	7	42	-	1	-	-	-	2
ALEWIFE	3	2	1	-	-	9	2	4
AMERICAN SHAD	307	317	3	17	71	70	27	25
GIZZARD SHAD	1851	21173	31505	30483	20615	22550	36800	35135
RAINBOW TROUT	-	-	-	-	-	-	1	-
BROWN TROUT	1	1	-	-	-	1	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	-	-	-	-	4	3	44	1
GOLDEN SHINER	-	2	-	-	-	1	2	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	2	-	-	1	-	-	1
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	27	14	4	-
WHITE SUCKER	1	8	2	10	5	8	3	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	91	307	37	33	163	193	105	10
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	2
BROWN BULLHEAD	-	-	-	-	-	-	1	-
CHANNEL CATFISH	2	11	7	30	28	23	101	68
MARGINED MADTOM	-	-	-	-	-	-	1	-
WHITE PERCH	232	384	739	2777	4067	5016	3690	3030
STRIPED BASS	-	1	1	2	4	8	5	10
ROCK BASS	-	-	-	-	-	1	1	-
REDBREAST SUNFISH	-	-	-	-	-	1	-	1
GREEN SUNFISH	-	-	-	-	-	1	-	-
PUMPKINSEED	1	1	-	-	-	-	1	-
BLUEGILL	5	4	-	-	-	4	1	1
SMALLMOUTH BASS	-	9	2	2	6	11	8	4
LARGEMOUTH BASS	6	9	-	-	1	4	-	1
WHITE CRAPPIE	-	1	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	1	-	1	-	2
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	7	6	3	5	2	9	25	3
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	3	1	16	6	4	2	4	3
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	2	1	2	1	2	2	1
STRIPED BASS X WHITE BASS	26	62	202	472	433	203	36	268
TIGER MUSKIE	2	1	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	2552	22353	32519	33843	25433	28183	40865	38697

TABLE 1.4

CONTINUED

DATE	01 MAY	02 MAY	03 MAY	04 MAY	05 MAY	06 MAY	07 MAY	08 MAY
# OF LIFTS	44	20	25	20	23	23	30	31
FIRST LIFT	602	609	600	610	608	612	606	603
LAST LIFT	1800	1819	1800	1810	1752	1800	1755	1747
OPERATING TIME (HR)	11.97	12.17	12.00	12.00	11.73	11.80	11.82	11.73
FISHING TIME (HR)	10.60	8.78	10.08	9.38	9.35	8.12	10.15	9.73
AVE RIVER FLOW	25900	33600	38000	35900	31800	35900	36100	36600
AVE WATER TEMP (F)	55.4	56.3	57.2	57.1	55.4	57.2	57.2	57.2
AMERICAN EEL	-	1	2	-	-	4	1	-
BLUEBACK HERRING	181	15	4	2	33	16	91	83
HICKORY SHAD	1	-	-	-	-	1	2	-
ALEWIFE	9	1	1	5	2	8	38	4
AMERICAN SHAD	190	135	53	13	35	7	131	67
GIZZARD SHAD	62200	17835	22790	7755	18450	24111	48400	46270
RAINBOW TROUT	-	-	-	1	-	1	1	-
BROWN TROUT	-	-	2	-	4	4	4	3
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	1	3	4	-	-	4	32	22
GOLDEN SHINER	1	-	1	-	-	-	3	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	1	-	-
QUILLBACK	-	4	3	-	1	-	2	2
WHITE SUCKER	-	9	6	-	3	20	25	27
CREEK CHUBSUCKER	-	-	-	-	-	-	-	1
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	38	99	76	5	7	62	173	201
WHITE CATFISH	-	-	-	3	1	1	2	12
YELLOW BULLHEAD	-	-	7	-	-	-	1	-
BROWN BULLHEAD	-	-	8	1	4	5	2	8
CHANNEL CATFISH	9	34	274	96	5	151	159	226
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	2097	2832	4572	3659	2037	2435	1820	2366
STRIPED BASS	3	6	7	8	3	2	3	9
ROCK BASS	-	2	1	2	-	2	1	5
REDBREAST SUNFISH	-	-	1	1	2	5	2	9
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	1	1	-	1
BLUEGILL	6	1	2	4	4	5	17	8
SMALLMOUTH BASS	3	5	45	2	2	2	45	12
LARGEMOUTH BASS	1	-	1	1	1	1	-	4
WHITE CRAPPIE	-	-	3	4	-	-	-	6
BLACK CRAPPIE	-	-	-	1	-	-	2	4
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	5	4	10	26	4	8	8	8
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	-	-	7	2	-	2	4	9
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	2	2	-	1	3	1	4
STRIPED BASS X WHITE BASS	359	84	61	12	45	34	45	529
TIGER MUSKIE	-	-	-	-	-	-	-	3
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	65105	21072	27943	11603	20645	26896	51015	49903

TABLE 1.4

CONTINUED

DATE	09 MAY	10 MAY	11 MAY	12 MAY	13 MAY	14 MAY	15 MAY	16 MAY
# OF LIFTS	29	30	24	25	28	33	36	27
FIRST LIFT	602	602	610	610	602	800	606	601
LAST LIFT	1800	1757	1850	1806	1800	1736	1755	1710
OPERATING TIME (HR)	11.97	11.92	12.67	11.93	11.97	9.60	11.82	11.15
FISHING TIME (HR)	11.07	10.48	8.17	10.05	10.25	7.95	10.83	9.05
AVE RIVER FLOW	38700	36700	36400	32600	30400	28700	29300	25700
AVE WATER TEMP (F)	57.2	59.0	60.6	61.7	62.6	63.5	63.5	65.3
AMERICAN EEL	15	-	-	1	-	1	3	1
BLUEBACK HERRING	122	179	192	95	112	465	8425	343
HICKORY SHAD	-	-	3	-	-	-	-	-
ALEWIFE	36	23	16	14	4	8	250	-
AMERICAN SHAD	245	107	244	185	114	148	527	106
GIZZARD SHAD	34600	32240	44200	36570	35775	44480	52425	19550
RAINBOW TROUT	-	-	1	1	-	-	-	-
BROWN TROUT	1	-	4	2	1	2	6	2
BROOK TROUT	-	1	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	1
GOLDFISH	-	-	-	-	-	-	-	-
CARP	96	87	685	703	46	51	28	358
GOLDEN SHINER	1	4	-	2	-	3	2	2
COMELY SHINER	-	-	-	-	10	3	6	312
SPOTTAIL SHINER	10	-	-	-	-	1	3	1
SPOTFIN SHINER	-	-	-	-	-	-	1	-
BLUNTNOSE MINNOW	-	-	-	-	-	4	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	7	10	171	263	31	4	1	52
WHITE SUCKER	9	8	29	20	3	5	2	1
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	1	-
SHORTHEAD REDHORSE	216	134	514	440	367	153	148	260
WHITE CATFISH	3	7	28	82	44	6	12	160
YELLOW BULLHEAD	-	-	10	20	1	2	2	5
BROWN BULLHEAD	3	2	12	40	8	1	7	11
CHANNEL CATFISH	164	154	776	2262	590	24	151	1989
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	1395	2715	4482	6980	5455	901	3956	2971
STRIPED BASS	7	16	19	25	9	5	21	16
ROCK BASS	1	4	2	14	4	17	13	4
REDBREAST SUNFISH	-	4	4	16	14	45	29	46
GREEN SUNFISH	1	-	-	-	1	7	2	-
PUMPKINSEED	2	3	1	7	2	16	21	7
BLUEGILL	12	8	16	34	42	105	88	32
SMALLMOUTH BASS	37	21	22	30	42	21	41	21
LARGEMOUTH BASS	3	-	3	4	3	8	5	2
WHITE CRAPPIE	2	1	-	5	3	15	10	6
BLACK CRAPPIE	2	2	-	2	1	6	5	1
TESSELLATED DARTER	-	-	-	-	-	-	1	-
YELLOW PERCH	7	10	25	6	16	35	102	100
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	5	8	2	9	7	11	7	11
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	4	-	4	4	3	-	1
STRIPED BASS X WHITE BASS	43	74	359	311	85	244	139	24
TIGER MUSKIE	-	-	-	-	1	1	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	37045	35826	51820	48147	42795	46801	66440	26396

TABLE 1.4

CONTINUED

DATE	17 MAY	18 MAY	19 MAY	24 MAY	25 MAY	27 MAY	29 MAY	30 MAY
# OF LIFTS	33	29	21	9	11	12	14	24
FIRST LIFT	605	602	605	1200	605	606	556	600
LAST LIFT	1800	1750	1252	1725	1206	1158	1200	1754
OPERATING TIME (HR)	11.92	11.80	6.78	5.42	6.02	5.87	6.07	11.90
FISHING TIME (HR)	10.57	8.68	6.48	4.35	4.77	5.05	5.25	9.48
AVE RIVER FLOW	28100	38900	64700	110600	88400	68000	51300	42100
AVE WATER TEMP (F)	65.3	68.0	67.1	63.5	63.5	64.1	66.2	65.9
AMERICAN EEL	5	4	1	2	1	-	5	1
BLUEBACK HERRING	3201	137	15	242	77	46	38	102
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	1	-	-	-	-	-	-	-
AMERICAN SHAD	129	17	8	2	1	1	7	101
GIZZARD SHAD	44000	29800	35350	2750	8190	7465	17600	25525
RAINBOW TROUT	1	-	-	-	-	-	-	-
BROWN TROUT	1	1	-	2	2	1	3	7
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	430	1847	2	664	64	183	10	322
GOLDEN SHINER	-	-	-	-	-	-	1	1
COMELY SHINER	130	-	-	1	-	-	-	1760
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	1	-	-	-
BLUNTNOSE MINNOW	60	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	108	261	1	-	-	20	2	41
WHITE SUCKER	6	110	2	1	1	2	1	10
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	308	100	10	9	12	48	30	101
WHITE CATFISH	925	170	132	52	43	22	89	50
YELLOW BULLHEAD	2	2	11	-	-	-	5	-
BROWN BULLHEAD	46	6	54	4	1	-	11	3
CHANNEL CATFISH	1331	4510	3767	1268	677	458	1180	718
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	4584	3515	642	92	95	108	1400	538
STRIPED BASS	20	5	5	6	10	18	17	37
ROCK BASS	14	4	1	1	1	-	-	2
REDBREAST SUNFISH	27	37	12	6	10	5	32	31
GREEN SUNFISH	-	-	-	1	-	-	-	-
PUMPKINSEED	4	-	1	-	-	-	10	4
BLUEGILL	65	35	9	2	3	9	26	29
SMALLMOUTH BASS	35	5	-	1	-	1	2	12
LARGEMOUTH BASS	2	1	1	-	-	-	1	3
WHITE CRAPPIE	6	4	-	-	-	1	4	7
BLACK CRAPPIE	5	2	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	61	32	13	-	-	4	9	11
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	14	6	-	1	-	1	1	6
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	1	2	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	67	11	17	7	7	16	13	33
TIGER MUSKIE	1	-	1	-	-	-	-	2
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	55590	40624	40055	5114	9196	8409	20497	29457

TABLE 1.4

CONTINUED

DATE	31 MAY	01 JUNE	02 JUNE	03 JUNE	04 JUNE	05 JUNE	06 JUNE	07 JUNE
# OF LIFTS	23	25	20	19	21	21	20	21
FIRST LIFT	558	602	609	610	602	600	605	603
LAST LIFT	1755	1734	1755	1750	1745	1741	1715	1740
OPERATING TIME (HR)	11.95	11.53	11.77	11.67	11.72	11.68	11.17	11.62
FISHING TIME (HR)	9.03	9.42	8.92	8.67	10.00	10.00	9.50	9.25
AVE RIVER FLOW	40200	32700	26900	25900	25900	25200	21400	19300
AVE WATER TEMP (F)	69.7	69.9	70.2	70.0	69.9	70.7	71.1	71.3
AMERICAN EEL	3	3	2	3	-	2	2	8
BLUEBACK HERRING	17	10	26	28	11	41	1	16
HICKORY SHAD	-	-	-	-	-	1	-	-
ALEWIFE	-	-	-	-	-	1	-	-
AMERICAN SHAD	50	71	46	44	51	617	25	100
GIZZARD SHAD	15090	17170	8205	8150	15425	11125	5755	7165
RAINBOW TROUT	-	-	-	-	1	1	-	-
BROWN TROUT	4	7	-	-	2	2	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	1	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
CARP	668	331	48	10	31	120	108	420
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	245	95	110	2388	40	2555	72	170
SPOTTAIL SHINER	-	-	25	-	-	-	-	-
SPOTFIN SHINER	25	20	-	-	-	-	-	-
BLUNTNOSE MINNOW	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	110	66	2	2	1	5	-	30
WHITE SUCKER	4	10	2	1	-	-	-	2
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	76	33	2	3	-	-	1	9
WHITE CATFISH	425	284	71	77	40	62	52	182
YELLOW BULLHEAD	1	1	3	-	-	-	3	-
BROWN BULLHEAD	3	1	11	2	6	1	9	10
CHANNEL CATFISH	3326	2641	371	93	533	125	276	2431
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	790	760	235	146	101	65	62	298
STRIPED BASS	43	66	26	17	21	20	31	50
ROCK BASS	2	1	-	-	1	-	-	1
REDBREAST SUNFISH	53	55	78	20	47	7	54	20
GREEN SUNFISH	-	-	-	1	-	-	1	1
PUMPKINSEED	16	25	2	4	-	-	2	-
BLUEGILL	40	47	49	27	59	19	58	40
SMALLMOUTH BASS	9	12	3	2	6	5	1	3
LARGEMOUTH BASS	2	1	2	5	4	2	8	3
WHITE CRAPPIE	8	3	3	5	6	1	2	5
BLACK CRAPPIE	-	-	-	-	-	-	-	2
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	5	3	6	4	4	7	5	9
LOGPERCH	-	-	1	-	-	-	-	-
WALLEYE	10	8	3	8	5	3	2	30
ATLANTIC NEEDLEFISH	1	-	1	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	1	-
STRIPED BASS X WHITE BASS	32	25	4	16	11	10	30	57
TIGER MUSKIE	-	-	-	-	1	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	21058	21750	9337	11056	16407	14797	6561	11062

TABLE 1.4

CONTINUED

DATE	08 JUNE	09 JUNE	10 JUNE	11 JUNE	12 JUNE	13 JUNE	14 JUNE	15 JUNE
# OF LIFTS	22	19	22	21	24	15	18	13
FIRST LIFT	600	715	600	602	603	608	600	603
LAST LIFT	1745	1745	1740	1700	1759	1345	1300	1230
OPERATING TIME (HR)	11.75	10.50	11.67	10.97	11.93	7.62	7.00	6.45
FISHING TIME (HR)	9.17	9.25	9.98	9.32	10.40	6.17	5.95	5.67
AVE RIVER FLOW	20900	17900	19900	17800	19600	13300	13800	12000
AVE WATER TEMP (F)	70.7	70.2	69.3	70.7	68.2	69.0	70.0	69.9
AMERICAN EEL	5	4	2	-	-	2	1	1
BLUEBACK HERRING	5	-	1	4	-	1	1	5
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	112	28	85	19	169	24	7	40
GIZZARD SHAD	10766	9720	12005	9410	5550	9112	19875	6345
RAINBOW TROUT	-	-	-	-	-	-	-	1
BROWN TROUT	1	-	-	-	-	-	-	-
BROOK TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-
GOLDFISH	1	-	-	-	-	-	-	-
CARP	192	21	25	155	244	329	9	113
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	65	1	-	90	3676	5	-	-
SPOTTAIL SHINER	-	-	-	-	-	-	-	-
SPOTFIN SHINER	10	-	-	-	4	1	-	3
BLUNTNOSE MINNOW	-	-	1	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-
QUILLBACK	151	7	14	20	18	27	64	27
WHITE SUCKER	1	1	4	-	-	-	-	-
CREEK CHUBSUCKER	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	1	-	-
WHITE CATFISH	326	140	130	9	19	72	28	77
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	25	12	7	-	2	3	3	-
CHANNEL CATFISH	1929	1985	324	45	57	148	160	297
MARGINED MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	192	196	109	78	48	63	90	307
STRIPED BASS	58	40	23	18	15	32	22	65
ROCK BASS	-	1	-	-	-	-	-	-
REDBREAST SUNFISH	6	7	2	9	7	2	16	7
GREEN SUNFISH	-	1	1	-	-	-	1	-
PUMPKINSEED	-	-	-	-	1	-	-	-
BLUEGILL	37	56	9	15	20	13	26	11
SMALLMOUTH BASS	2	1	1	1	2	1	-	-
LARGEMOUTH BASS	-	1	1	-	3	1	1	-
WHITE CRAPPIE	2	1	1	-	1	-	1	1
BLACK CRAPPIE	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	-	-	-	-	-	-	-
YELLOW PERCH	2	2	1	1	3	-	-	1
LOGPERCH	-	-	-	-	-	-	-	-
WALLEYE	22	9	9	2	7	3	-	5
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	-	-
SEA LAMPREY	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	59	9	32	14	25	34	15	26
TIGER MUSKIE	1	1	-	-	1	-	-	1
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
	13970	12244	12787	9890	9872	9874	20320	7333

TABLE 1.4

CONTINUED

DATE	16 JUNE	17 JUNE	TOTALS
# OF LIFTS	13	15	1374
FIRST LIFT	608	601	
LAST LIFT	1305	1125	
OPERATING TIME (HR)	6.95	5.40	655.65
FISHING TIME (HR)	5.88	4.28	528.75
AVE RIVER FLOW	12200	10800	
AVE WATER TEMP (F)	71.9	71.6	
AMERICAN EEL	1	1	107
BLUEBACK HERRING	-	-	14,570
HICKORY SHAD	-	-	64
ALEWIFE	-	-	712
AMERICAN SHAD	17	4	5,169
GIZZARD SHAD	5950	18125	1,427,628
RAINBOW TROUT	-	-	10
BROWN TROUT	-	-	85
BROOK TROUT	-	-	1
RAINBOW SMELT	-	-	1
MUSKELLUNGE	-	-	1
GOLDFISH	-	-	1
CARP	89	48	8,672
GOLDEN SHINER	-	-	28
COMELY SHINER	-	-	11,734
SPOTTAIL SHINER	-	-	55
SPOTFIN SHINER	-	-	65
BLUNTNOSE MINNOW	-	-	65
CREEK CHUB	-	-	1
QUILLBACK	62	8	1,649
WHITE SUCKER	-	-	556
CREEK CHUBSUCKER	-	-	1
NORTHERN HOG SUCKER	-	-	1
SHORTHEAD REDHORSE	-	-	4,800
WHITE CATFISH	73	102	4,028
YELLOW BULLHEAD	-	5	85
BROWN BULLHEAD	12	20	377
CHANNEL CATFISH	327	578	37,155
MARGINED MADTOM	-	-	1
WHITE PERCH	165	50	90,866
STRIPED BASS	42	118	1,035
ROCK BASS	-	1	112
REDBREAST SUNFISH	10	15	755
GREEN SUNFISH	-	-	19
PUMPKINSEED	-	5	140
BLUEGILL	19	10	1,136
SMALLMOUTH BASS	1	1	550
LARGEMOUTH BASS	-	-	117
WHITE CRAPPIE	-	1	126
BLACK CRAPPIE	-	-	42
TESSELLATED DARTER	-	-	1
YELLOW PERCH	1	-	820
LOGPERCH	-	-	2
WALLEYE	5	4	323
ATLANTIC NEEDLEFISH	-	-	2
SEA LAMPREY	-	-	59
STRIPED BASS X WHITE BASS	35	74	6,317
TIGER MUSKIE	-	-	20
STRIPED BASS X WHT PERCH	-	-	1
	6809	19170	1,620,065

TABLE 1.5

Total catch and catch per hr of American shad by date and weir gate setting during modified lift operation at Conowingo Dam Fish Lift, 1988.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	Total Weir Gate Open
Apr 25	# Shad		3	-	3
	Hrs Fishing	0.0	0.9	6.9	7.8
	Catch/Hr Fishing	-	3.33	-	0.38
Apr 25	# Shad		-	25	25
	Hrs Fishing	0.0	0.4	9.5	9.9
	Catch/Hr Fishing	-	-	2.63	2.53
May 1	# Shad		182	7	189
	Hrs Fishing	0.0	5.3	5.3	10.6
	Catch/Hr Fishing	-	34.34	1.32	17.83
May 3	# Shad		52	1	53
	Hrs Fishing	0.0	6.6	3.5	10.1
	Catch/Hr Fishing	-	7.88	0.29	5.25
May 4	# Shad		6	7	13
	Hrs Fishing	0.0	3.0	6.3	9.4
	Catch/Hr Fishing	-	2.00	1.11	1.38
May 6	# Shad		2	5	7
	Hrs Fishing	0.0	0.7	7.4	8.1
	Catch/Hr Fishing	-	2.86	0.68	0.86
May 7	# Shad		1	130	131
	Hrs Fishing	0.0	0.5	9.6	10.1
	Catch/Hr Fishing	-	2.00	13.54	12.97
May 8	# Shad		7	59	66
	Hrs Fishing	0.0	1.1	8.6	9.7
	Catch/Hr Fishing	-	6.36	6.86	6.80

Continued

TABLE 1.5

Continued.

Date		# One Weir Gate Open	# Two Weir Gate Open	Both Weir Gate Open	Total Weir Gate Open
May 11	# Shad		14	230	244
	Hrs Fishing	0.0	1.4	6.8	8.2
	Catch/Hr Fishing	-	10.00	33.82	29.76
May 12	# Shad		10	172	182
	Hrs Fishing	0.0	0.7	9.4	10.0
	Catch/Hr Fishing	-	14.29	18.30	18.20
May 14	# Shad	4	14	130	148
	Hrs Fishing	1.0	1.5	5.4	7.9
	Catch/Hr Fishing	4.00	9.33	24.07	18.73
May 15	# Shad		116	411	527
	Hrs Fishing	0.0	1.9	8.9	10.8
	Catch/Hr Fishing	-	61.05	46.18	48.70
May 16	# Shad		2	104	106
	Hrs Fishing	0.0	1.0	8.0	9.0
	Catch/Hr Fishing	-	2.00	13.00	11.78
Jun 11	# Shad		7	12	19
	Hrs Fishing	0.0	2.6	6.7	9.3
	Catch/Hr Fishing	-	2.69	1.79	2.04
Jun 12	# Shad		10	158	168
	Hrs Fishing	0.0	3.0	7.4	10.4
	Catch/Hr Fishing	-	3.33	21.35	16.15
Jun 15	# Shad		36	4	40
	Hrs Fishing	0.0	3.2	2.5	5.7
	Catch/Hr Fishing	-	11.25	1.60	7.02
TOTAL		4	462	1455	1921
		1.0	33.8	112.2	147.0
		4.00	13.7	13.0	13.1

TABLE 1.6

Comparison of catch per effort (hr) of American shad on weekdays vs weekend days by generation (cfs) at the Conowingo Dam Fish Lift 31MAR88-17JUN88.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	10-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	MORNIN 5-9	5.4	5.2	18.0	3.5	1.6	3.3
	MID-AM 9-11	11.0	6.8	2.0	17.7	2.0	3.7
	MID-DAY 11-3	4.4	8.2	0.5	9.7	5.1	5.1
	LATE PM 3-12	15.9	13.7	10.0	39.7	12.3	16.4
	MEAN WEEKDAY	9.0	8.2	6.2	21.8	4.6	6.7
WEEKEND	MORNIN 5-9	6.3	23.8	6.9	4.8	0.7	14.7
	MID-AM 9-11	13.2	34.4	10.8	30.9	1.2	11.7
	MID-DAY 11-3	12.4	44.3	0.8	35.4	2.8	22.4
	LATE PM 3-12	9.1	24.3	7.0	0.0	59.0	19.2
	MEAN WEEKEND	10.3	31.0	6.3	24.4	3.5	17.7

TABLE 1.7

Comparison of the American shad catch, catch per effort, and effort between low (one or less unit generation) and high discharges (two or more unit generation) at the Conowingo Dam Fish Lift, 31 March to 17 June 1988.

Generation Status	No. Shad Caught	Total Minutes Fished	Number of Lifts	Shad Catch per Hour
Low	2254	6301	273	21.46
High	2915	25425	1101	6.77
TOTAL	5169	31726	1374	9.78

TABLE 1.8

Catch of American shad in the Conowingo Fish Lift by water temperatures, 31 March to 17 June 1988.

Water Temp. (F)	Hours Fishing	Catch		
		Number	Catch/ Effort	Percent
≤ 65	328.40	3293	10.03	63.7
>65	200.37	1877	9.37	36.3
TOTAL	528.77	5170	9.78	100.0

TABLE 1.9

SUMMARY OF TRANSPORTATION OF AMERICAN SHAD FROM CONOWINGO DAM FISH LIFT, 18 APRIL TO 13 JUNE, 1988.

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
18 APR	187	51.8	217	LONG LEVEL	0	100.0	14.4	16.0	51.8
23 APR	307	52.7	175	LONG LEVEL	1	99.4	14.7	14.0	56.8
			159	LONG LEVEL	0	100.0	11.8	11.0	55.0
24 APR	317	52.7	223	LONG LEVEL	0	100.0	15.0	13.5	54.5
27 APR	71	53.6	179	LONG LEVEL	0	100.0	12.4	13.0	59.0
01 MAY	190	55.4	254	LONG LEVEL	0	100.0	12.8	11.2	59.4
02 MAY	135	56.3	189	LONG LEVEL	0	100.0	20.0	14.1	59.0
07 MAY	131	57.2	235	LONG LEVEL	0	100.0	13.0	14.0	60.8
09 MAY	245	57.2	208	LONG LEVEL	0	100.0	13.2	16.2	62.6
10 MAY	107	59.0	202	LONG LEVEL	0	100.0	17.0	12.4	64.0
11 MAY	244	60.6	239	LONG LEVEL	2	99.2	18.0	20.0	64.4
12 MAY	185	61.7	180	LONG LEVEL	3	98.3	18.2	13.6	66.2
13 MAY	114	62.6	113	LONG LEVEL	0	100.0	10.7	12.2	68.0
14 MAY	148	63.5	138	LONG LEVEL	0	100.0	13.6	15.4	70.7
15 MAY	527	63.5	190	LONG LEVEL	0	100.0	12.4	16.6	71.6
			231	LONG LEVEL	0	100.0	20.0	17.0	70.7
16 MAY	106	65.3	201	LONG LEVEL	1	99.5	14.2	15.4	69.8
19 MAY	8	67.1	148	MUDDY RUN LAB *	0	100.0	20.0	20.0	-
31 MAY	50	69.7	139	FALMOUTH	1	99.3	14.0	16.6	73.4
02 JUN	46	70.2	107	FALMOUTH	0	100.0	20.0	12.6	67.1
05 JUN	617	70.7	273	FALMOUTH	1	99.6	9.6	11.8	66.2
			198	FALMOUTH	0	100.0	17.0	14.0	67.1
			152	FALMOUTH	1	99.3	12.2	16.2	68.2
06 JUN	25	71.1	44	GLEN COVE	0	100.0	19.8	16.0	72.0
08 JUN	112	70.7	155	FALMOUTH	0	100.0	13.2	17.6	72.5
10 JUN	85	69.3	136	FALMOUTH	0	100.0	12.8	14.9	64.8
12 JUN	169	68.2	152	FALMOUTH	0	100.0	11.7	12.1	72.5
13 JUN	24	69.0	47	GLEN COVE	0	100.0	12.4	15.6	76.1
			4884		10	99.8			

* 100% mortality occured in pool at lab within 10 days

TABLE 1.10

SUMMARY OF AMERICAN SHAD TRANSPORTED AND HELD OVER NIGHT AT THE CONOWINGO DAM FISH LIFT, 1988.

DATE	NO. COLLECTED	NO. TRANSPORTED	NO. HELD OVER NIGHT
31 MAR	2	0	2
02 APR	0	0	1
04 APR	2	0	3
06 APR	1	0	4
07 APR	6	0	10
08 APR	12	0	21
09 APR	2	0	23
10 APR	0	0	23
12 APR	2	0	25
14 APR	1	0	26
16 APR	4	0	30
18 APR	187	217	0
19 APR	6	0	4
20 APR	7	0	10
21 APR	8	0	18
22 APR	10	0	28
23 APR	307	334	0
24 APR	317	223	92
25 APR	3	0	95
26 APR	17	0	110
27 APR	71	179	0
28 APR	70	0	69
29 APR	27	0	96
30 APR	25	0	121
01 MAY	190	254	55
02 MAY	135	189	0
03 MAY	53	0	53
04 MAY	13	0	66
05 MAY	35	0	100
06 MAY	7	0	107
07 MAY	131	235	0
08 MAY	67	0	66
09 MAY	245	208	97
10 MAY	107	202	0
11 MAY	244	239	0
12 MAY	185	180	0
13 MAY	114	113	0
14 MAY	148	138	0
15 MAY	527	421	98
16 MAY	106	201	0
17 MAY	129	0	124
18 MAY	17	0	140
19 MAY	8	148	0
24 MAY	2	0	2
25 MAY	1	0	3
27 MAY	1	0	4
29 MAY	7	0	11
30 MAY	101	0	102
31 MAY	50	139	1
01 JUN	71	0	64
02 JUN	46	107	0
03 JUN	44	0	42
04 JUN	51	0	89
05 JUN	617	623	44
06 JUN	25	44	24
07 JUN	100	0	117
08 JUN	112	155	46
09 JUN	28	0	70
10 JUN	85	136	16
11 JUN	19	0	34
12 JUN	169	152	41
13 JUN	24	47	15
14 JUN	7	0	19
15 JUN	40	0	28
16 JUN	17	0	36
17 JUN	4	0	0
	====	====	====
	5169	4884	2525

TABLE 1.11

Daily sex ratio of American shad at the Conowingo Dam Fish Lift for 1988.

DATE	DAILY CATCH	NO. SEXED	NO. OF MALES	NO. OF FEMALES	RATIO (M/F)
31 MAR	2	2	2		2:0
02 APR	0	0			
04 APR	2	2	2		2:0
06 APR	1	1	1		1:0
07 APR	6	6	5	1	5.0:1
08 APR	12	11	10	1	10.0:1
09 APR	2	2	2		2:0
10 APR	0	0			
12 APR	2	2	2		2:0
14 APR	1	1	1		1:0
16 APR	4	4	4		4:0
18 APR	187	173	153	20	7.6:1
19 APR	6	6	5	1	5.0:1
20 APR	7	7	7		7:0
21 APR	8	8	8		8:0
22 APR	10	10	9	1	9.0:1
23 APR	307	110	95	15	6.3:1
24 APR	317	151	127	24	5.3:1
25 APR	3	3	3		3:0
26 APR	17	16	15	1	15.0:1
27 APR	71	70	67	3	22.3:1
28 APR	70	70	62	8	7.8:1
29 APR	27	27	23	4	5.8:1
30 APR	25	25	23	2	11.5:1
01 MAY	190	120	99	21	4.7:1
02 MAY	135	134	116	18	6.4:1
03 MAY	53	53	44	9	4.9:1
04 MAY	13	13	9	4	2.3:1
05 MAY	35	34	33	1	33.0:1
06 MAY	7	7	7		7:0
07 MAY	131	113	97	16	6.1:1
08 MAY	67	67	52	15	3.5:1
09 MAY	245	116	94	22	4.3:1
10 MAY	107	85	66	19	3.5:1
11 MAY	244	189	134	55	2.4:1
12 MAY	185	134	97	37	2.6:1
13 MAY	114	108	79	29	2.7:1
14 MAY	148	121	91	30	3.0:1
15 MAY	527	103	80	23	3.5:1
16 MAY	106	105	84	21	4.0:1
17 MAY	129	128	98	30	3.3:1
18 MAY	17	17	14	3	4.7:1
19 MAY	8	8	3	5	0.6:1
24 MAY	2	2	2		2:0
25 MAY	1	1	1		1:0
27 MAY	1	1		1	0:1
29 MAY	7	7	6	1	6.0:1
30 MAY	101	99	64	35	1.8:1
31 MAY	50	47	32	15	2.1:1
01 JUN	71	69	44	25	1.8:1
02 JUN	46	46	27	19	1.4:1
03 JUN	44	44	31	13	2.4:1
04 JUN	51	51	31	20	1.5:1
05 JUN	617	119	62	57	1.1:1
06 JUN	25	25	15	10	1.5:1
07 JUN	100	100	56	44	1.3:1
08 JUN	112	94	63	31	2.0:1
09 JUN	28	28	13	15	0.9:1
10 JUN	85	70	34	36	0.9:1
11 JUN	19	19	12	7	1.7:1
12 JUN	169	100	49	51	1.0:1
13 JUN	24	24	12	12	1.0:1
14 JUN	7	7	3	4	0.8:1
15 JUN	40	40	18	22	0.8:1
16 JUN	17	16	9	7	1.3:1
17 JUN	4	4	3	1	3.0:1
SEASON TOTALS	5169	3375	2510	865	2.9:1

TABLE 1.12

Sex ratio (M/F) of American shad collected at the Conowingo Dam FishLift. Season divided in approximately two week periods from 31 March to 17 June 1988.

Date	No. Males	No. Females	M/F
31 Mar-19 Apr	187	23	8.1:1
20 Apr-30 Apr	439	58	7.6:1
1 May-13 May	927	246	3.8:1
14 May-31 May	475	164	2.9:1
1 Jun-17 Jun	482	374	1.3:1
Season Total	2510	865	2.9:1

TABLE 1.13

Age and spawning history of American shad collected at the Conowingo Dam Fish Lift in 1988; by sex, with mean, minimum and maximum fork length (mm).

Sex	Age	N	Spawning History		Fork Lengths		
			Virgins	Single Repeats	mean	min	max
MALE	II	1	1		242	242	242
	III	13	13		308	284	335
	IV	37	36	1	384	340	430
	V	46	43	3	423	369	495
	VI	20	19	1	459	423	483
Subtotal		117	112	5	403	242	495
FEMALE	IV	22	21	1	409	371	439
	V	60	59	1	451	403	505
	VI	68	68		489	440	575
	VII	11	10	1	510	460	535
Subtotal		161	158	3	465	371	575
Total		278	270	8	439	242	575

TABLE 1.14

Age and Spawning history of American shad collected at the Conowingo Dam Fish Lift in 1988; by sex, with mean, minimum and maximum fork length (mm).

Sex	Disposition	Age	N	Spawning History		Fork Lengths		
				Virgins	Single Repeats	mean	min	max
MALE								
	RELEASED	II	1	1		242	242	242
		III	3	3		318	309	329
		IV	16	15	1	386	340	430
		V	25	24	1	432	371	495
		VI	15	14	1	460	440	483
	Totals		60	57	3	418	242	495
	HANDLING MORTALITY	III	2	2		299	294	304
		IV	5	5		380	360	395
		V	11	9	2	414	369	449
		VI	2	2		463	445	481
	Totals		20	18	2	399	294	481
	MUDDY RUN MORTALITY	III	8	8		306	284	335
		IV	16	16		384	357	415
		V	10	10		412	371	473
		VI	3	3		455	423	483
	Totals		37	37	0	381	284	483
Totals Sex			117	112	5	403	242	495

Sex	Disposition	Age	N	Spawning History		Fork Lengths		
				Virgins	Single Repeats	mean	min	max
FEMALE								
	RELEASED	IV	16	15	1	408	371	435
		V	42	41	1	449	403	505
		VI	44	44		491	440	575
		VII	4	3	1	510	467	535
	Totals		106	103	3	463	371	575
	HANDLING MORTALITY	IV	3	3		407	396	413
		V	10	10		457	428	493
		VI	15	15		491	445	542
		VII	4	4		526	510	534
	Totals		32	32	0	477	396	542
	MUDDY RUN MORTALITY	IV	3	3		416	394	439
		V	8	8		454	427	489
		VI	9	9		475	445	496
		VII	3	3		488	460	521
	Totals		23	23	0	462	394	521
Total Sex			161	158	3	465	371	575
Combined Totals			278	270	8	439	242	575

TABLE 1.15

Daily number of American shad floy-tagged and recaptured by RMC at the Conowingo Dam Fish Lift, 1988.

Date	Number Tagged	Number Recaptured	Days Free
10 May	1		
11 May	3		
14 May	8		
16 May	1		
18 May	1		
30 May	5		
31 May	7		
1 June	6		
3 June	1		
5 June	25		
7 June	2		
9 June		1	10
12 June		1	13
Total	60	2	

TABLE 1.16

DAILY CATCH OF AMERICAN SHAD AT THE CONOWINGO DAM FISH LIFT WHEN MARYLAND D.N.R. TAGGED SHAD WERE RECAPTURED AT THE LIFT IN 1988

DATE	DAILY CATCH	NO. OF MD DNR RECAPTURES
09 MAY	245	1
15 MAY	527	5
17 MAY	129	2
30 MAY	101	3
31 MAY	50	2
01 JUN	71	2
02 JUN	46	1
03 JUN	44	1
05 JUN	617	11
07 JUN	100	2
08 JUN	112	3
10 JUN	85	1
12 JUN	169	6
13 JUN	24	1
	2320	41

TABLE 1.17

SUMMARY OF AMERICAN SHAD CATCH BY CONSTANT GENERATION LEVELS
1 MAY TO 31 MAY, 1982; 19 MAY TO 6 JUNE, 1983; 23 MAY TO 29 MAY, 1984;
21 APRIL TO 27 MAY, 1985; 5 APRIL TO 7 JUNE, 1986; 17 APRIL TO 12 JUNE, 1987;
31 MARCH TO 17 JUNE, 1988 CLEANOUT LIFTS EXCLUDED.

TOTAL DISCHARGE (X 1000 CFS)	UNIT 1	UNIT 2	1982 NO. LIFTS	1982 TIME (MINS.)	1982 TOTAL SHAD	1982 SHAD/HR	1983 NO. LIFTS	1983 TIME (MINS.)	1983 TOTAL SHAD	1983 SHAD/HR	1984 NO. LIFTS	1984 TIME (MINS.)	1984 TOTAL SHAD	1984 SHAD/HR	1985 NO. LIFTS	1985 TIME (MINS.)
LE 5	OFF	OFF	157	4571	1179	15.5	19	495	125	15.2	1	15	0	0.0	205	4213
LE 5	OFF	ON	23	575	19	2.0	-	-	-	-	-	-	-	-	-	-
LE 5	ON	OFF	1	15	1	4.0	-	-	-	-	-	-	-	-	-	-
TOTAL			181	5161	1199	13.9	19	495	125	15.2	1	15	0	0.0	205	4213
10-40	CHG	CHG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-40	OFF	OFF	61	1937	138	4.3	33	930	70	4.5	8	165	54	19.6	150	2905
10-40	OFF	ON	46	1253	202	9.7	-	-	-	-	-	-	-	-	-	-
10-40	ON	OFF	1	30	0	0.0	-	-	-	-	-	-	-	-	-	-
10-40	ON	ON	5	171	1	0.4	4	120	4	2.0	16	155	6	2.3	11	22
TOTAL			113	3391	341	6.0	37	1050	74	4.2	24	320	60	11.3	161	2927
VARYING	CHG	CHG	14	458	34	4.5	12	330	1	0.2	5	105	3	1.7	2	32
VARYING	CHG	OFF	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VARYING	CHG	ON	-	-	-	-	3	85	1	0.7	2	60	0	0.0	-	-
VARYING	OFF	CHG	7	210	107	30.6	3	85	3	2.1	-	-	-	-	4	120
VARYING	OFF	OFF	38	1194	204	10.3	24	690	68	5.9	2	50	7	8.4	164	4509
VARYING	OFF	ON	15	405	35	5.2	-	-	-	-	-	-	-	-	1	30
VARYING	ON	OFF	4	120	19	9.5	-	-	-	-	-	-	-	-	-	-
VARYING	ON	ON	7	190	4	1.3	2	45	0	0.0	6	90	1	0.7	2	4
TOTAL			85	2577	403	9.4	44	1235	73	3.5	15	305	11	2.2	173	4695
+ 40	OFF	OFF	28	1006	46	2.7	21	600	19	1.9	-	-	-	-	283	7747
+ 40	OFF	ON	30	898	21	1.4	1	30	1	2.0	5	150	8	3.2	8	241
+ 40	ON	OFF	12	350	12	2.1	-	-	-	-	-	-	-	-	-	-
+ 40	ON	ON	36	1181	3	0.2	225	5135	88	1.0	120	2729	58	1.3	15	45
TOTAL			106	3435	82	1.4	247	5765	108	1.1	125	2879	66	1.4	306	8033
			485	14564	2025	8.3	347	8545	380	2.7	165	3519	137	2.3	845	19868

TABLE 1.17

continued

TOTAL DISCHARGE (X 1000 CFS)	UNIT 1	UNIT 2			1986				1987				1988			
			TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR
LE 5	OFF	OFF	685	9.8	103	4287	3053	42.7	246	4842	2428	30.1	257	5984	2250	22.6
LE 5	OFF	ON	-	-	-	-	-	-	-	-	-	-	16	317	4	0.8
LE 5	ON	OFF	-	-	-	-	-	-	2	28	0	0.0	-	-	-	-
TOTAL			685	9.8	103	4287	3053	42.7	248	4870	2428	29.9	273	6301	2254	21.5
10-40	CHG	CHG	-	-	-	-	-	-	-	-	-	-	1	27	0	0.0
10-40	OFF	OFF	110	2.3	153	4717	433	5.5	282	6488	2875	26.6	125	2648	642	14.5
10-40	OFF	ON	-	-	3	77	1	0.8	-	-	-	-	19	298	132	26.6
10-40	ON	OFF	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-40	ON	ON	0	0.0	3	43	0	0.0	2	30	0	0.0	25	441	66	9.0
TOTAL			110	2.3	159	4837	434	5.4	284	6518	2875	26.5	170	3414	840	14.8
VARYING	CHG	CHG	0	0.0	19	777	44	3.4	32	801	50	3.7	46	1067	100	5.6
VARYING	CHG	OFF	-	-	1	30	3	6.0	5	112	3	1.6	2	60	0	0.0
VARYING	CHG	ON	-	-	1	30	23	46.0	4	105	8	4.6	16	432	18	2.5
VARYING	OFF	CHG	6	3.0	15	483	11	1.4	7	211	10	2.8	10	269	16	3.6
VARYING	OFF	OFF	340	4.5	126	4686	651	8.3	171	4932	920	11.2	98	2547	638	15.0
VARYING	OFF	ON	0	0.0	8	470	13	1.7	1	30	2	4.0	5	158	13	4.9
VARYING	ON	OFF	-	-	-	-	-	-	-	-	-	-	1	8	0	0.0
VARYING	ON	ON	1	15.0	5	394	2	0.3	8	189	17	5.4	31	807	43	3.2
TOTAL			347	4.4	175	6870	747	6.5	228	6380	1010	9.5	209	5348	828	9.3
+ 40	OFF	OFF	377	2.9	166	5136	779	9.1	170	4955	852	10.3	125	3397	547	9.7
+ 40	OFF	ON	4	1.0	69	2345	85	2.2	30	808	66	4.9	29	832	113	8.1
+ 40	ON	OFF	-	-	7	175	0	0.0	29	629	73	7.0	3	49	0	0.0
+ 40	ON	ON	1	1.3	58	2240	38	1.0	306	6227	355	3.4	499	12385	576	2.8
TOTAL			382	2.9	300	9896	902	5.5	535	12619	1346	6.4	656	16663	1236	4.5
			1524	4.6	737	25890	5136	11.9	1295	30387	7659	15.1	1308	31726	5158	9.8

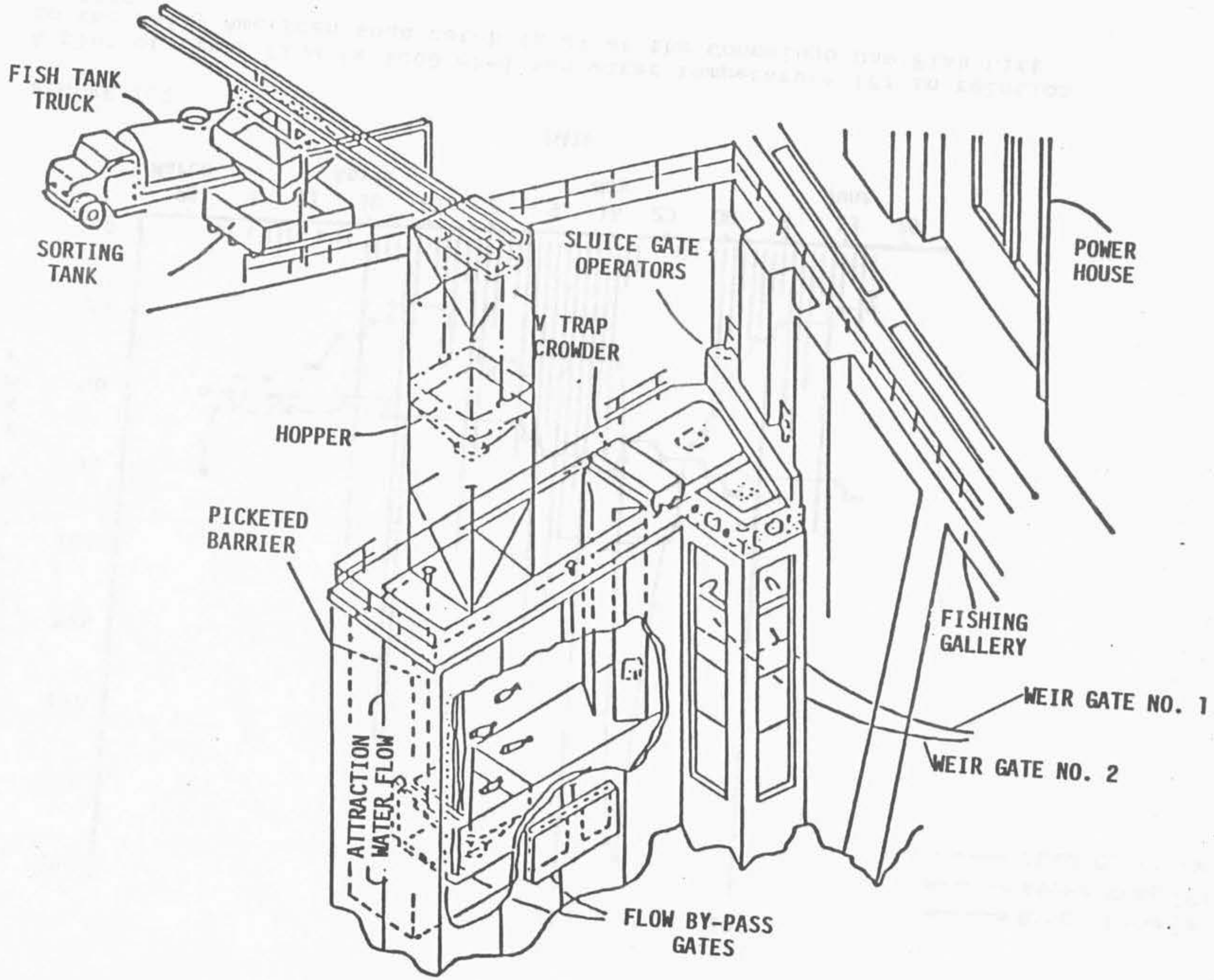

FIGURE 1.1

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

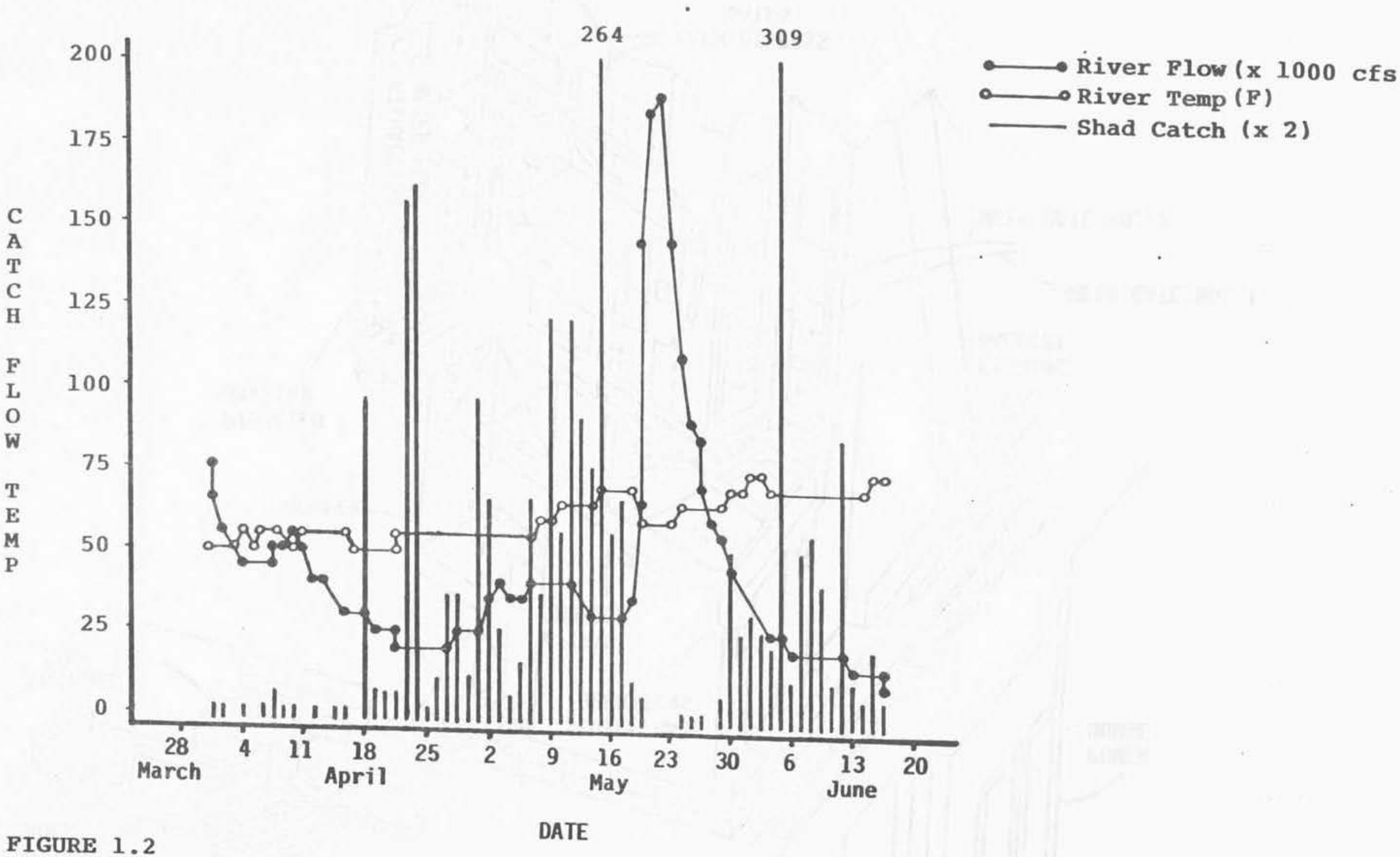

FIGURE 1.2

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch (x 2) at the Conowingo Dam Fish Lift in 1988.

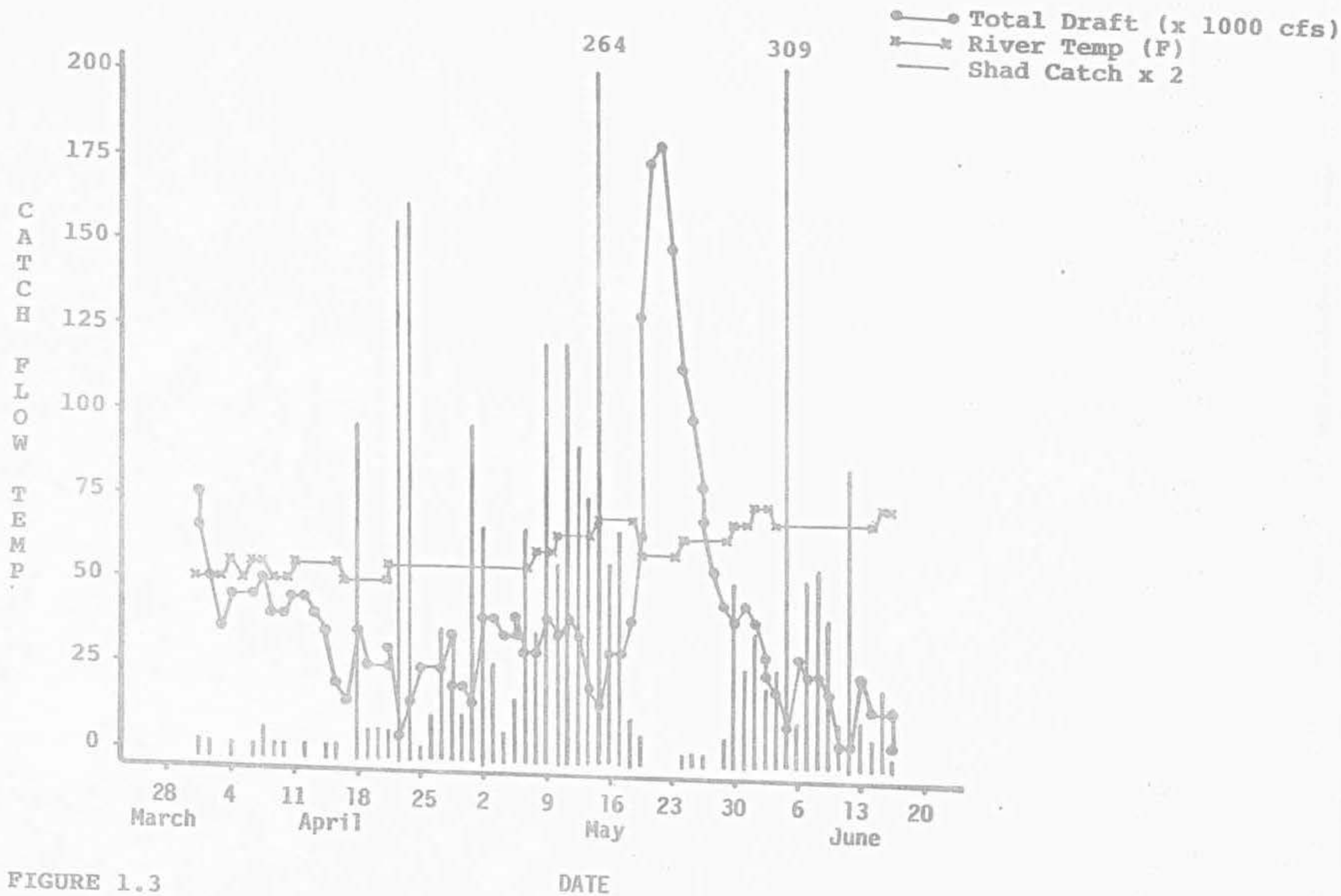

FIGURE 1.3

A plot of total draft (x 1000 cfs) and temperature (F) in relation to the daily American shad catch (x 2) at the Conowingo Dam Fish Lift in 1988. Total draft is the average during daily Lift operation.

JOB II AMERICAN SHAD EGG COLLECTION PROGRAM

National Environmental Services, Inc.
Lancaster, PA

2.1 Introduction

In September 1970, an agreement was signed between the various utilities (Philadelphia Electric Power Company, Susquehanna Electric Company, Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, Metropolitan Edison Company, the States (Maryland, Pennsylvania and New York), and the Department of Interior for the implementation of a program for restoration of the American shad to the Susquehanna River. Part of the agreement called for a program to annually obtain 50 million or more artificially fertilized American shad eggs for transplantation to areas above existing dams on the Susquehanna River. The objective was to artificially develop a population of American shad which, as adults, would return to the river with the urge to migrate upriver above Conowingo and the other hydroelectric dams. The program began in the spring of 1971 and has continued annually to date. The 1988 results are included in this report.

From 1971 through 1974 all shad eggs were transplanted to the Susquehanna River and released at various sites. Beginning in 1975 a few eggs were delivered to a hatchery for experimental culture and by 1978 virtually all eggs were delivered to hatcheries

2.1 continued

for culture and rearing.

2.1.1 Hatchery Program

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

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

2.1.1 continued

(520,000) transferred to Harrison Lake in 1976, also at the request of the Evaluation Committee.

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

2.2 Objective of Program

The SRAFRC goal for 1988 was to obtain sufficient number of shad eggs over a three month period to support the shad hatchery cultural program (Job III). From 1973 to 1986 over 400 million eggs were collected for the program. A record 52.5 million eggs (1,535.7L) were sent to the Van Dyke Hatchery in 40 shipments in 1986. In 1988, eggs were to be collected from seven rivers--Cape Fear (North Carolina), Pamunkey and James (Virginia), Delaware (New Jersey-Pennsylvania) Hudson (New York) and the Columbia (Oregon-Washington).

The collection of eggs from the Cape Fear River represented the first time that efforts would be made in North Carolina. It was the furthest south on the East Coast that it was believed that eggs could be obtained and yet coincide with hatchery operations, which begin by 1 April. Sporadic efforts have been made to collect eggs from the Hudson River, primarily from haul seine operations designed to capture shad for the adult transfer program, which was terminated after 1987. Although the Hudson River has one of the largest populations of shad, efforts by commercial fishermen have not demonstrated where spawning shad might be taken, as has been demonstrated for the Pamunkey and Columbia Rivers, for example. Thus, in 1988, NES undertook a gill-netting program to seek areas where spawning shad might be captured.

2.3 Methods

2.3.1 Egg Collection

Eggs were artificially fertilized in essentially the same method established by Kilcer (1973). A brief description of the procedure follows: Eggs were stripped from four to six spawning females into a dry collecting pan and fertilized with sperm from up to six males. After dry mixing eggs and sperm for several minutes, the eggs were allowed to set for 1-2 minutes, a small amount of water was then added to the mixing pan and the gametes stirred again. After the eggs settled, the water was drained and clean water added. The eggs were rinsed to remove dead sperm, unfertilized and broken eggs, and debris. Eggs were then poured into large plastic buckets filled with clean river water and allowed to soak for a minimum of one hour to become hardened. During this period, water was periodically drained and clean water added.

Once the eggs were hardened (about 1 hour), the water was drained and five liters each of eggs and clean water was placed in double plastic bags. Pure oxygen was put into the bag containing eggs and the bag securely tied with rubber rings. The bags were shipped in cardboard boxes with styrofoam container inserts. Each box was labeled to show river name, date, number of liters of eggs, water temperature and sex ratio of spawned fish.

On the Columbia River, although it represents a substantial source of eggs because of the large shad population, certain logistic difficulties have potentially negative impact on the shad egg collection program. The prime problem has been a relationship between time available to fish and the airline schedule for shipment of eggs back to the East Coast. 1988 was no exception. In order to get eggs to the airport in time for the flight, the shipment had to be at the airport by 11:00 P.M. Thus, all fishing and operations to fertilize and harden the eggs needed to be completed by 10:30 P.M. Depending on the success of fishing, this meant that there may not be sufficient time to process all of the eggs collected.

In past years, attempts have been made to hold the eggs in bags with oxygen in styrofoam containers and have them shipped to the East Coast on the earliest flight the next morning. The results, in terms of percentage viability, have been dissappointing; egg shipments the next morning have not had a very high viability. In 1988, in an attempt to improve the viability of eggs shipped the next morning, a holding tank was constructed when the crew was on the West Coast. NES constructed a make shift incubation tank. The incubation tank consisted of a 36 gallon oval, plastic tub (26" high x 20" wide and 42" long) screened on top to allow water overflow. Circulating water was provided by a 1/3 h.p. pump powered by 110 volts ac. Two ajustable, valve showerheads were installed in the bottom center of the tank. Water flow was directed toward the end of the tank and adjusted to keep eggs rolling without clogging the overflow screens. Eggs were removed the next morning, packed, and shipped to the East Coast.

2.3.2 Collection Areas (Table 2)

2.3.2.1 Cape Fear River, North Carolina

The 1988 program included efforts to collect shad eggs from runs on North Carolina rivers. On 9-10 March, a reconnaissance trip was made to North Carolina. Although initial thoughts were to collect on the Tar and Neuse Rivers, the description of the fisheries on these rivers by North Carolina biologists suggested it was not appropriate and that the runs were not strong enough. Additionally, the drift gill-net fisheries were not at the commercial levels from which one might expect to collect large numbers of fish. The North Carolina biologists recommended that NES sample on the Cape Fear River. It had a larger fishery, a history of larger runs, and shad were concentrated at locks and dams.

The shad egg collecting effort was concentrated at Lock #1 and Dam on the Cape Fear River (approximately 30 miles upriver from Wilmington, NC). Here, a commercial fishery existed which was made up of set-net and drift gill nets. On any one evening 5 to 10 fishermen might be present. Only occasionally did commercial fishermen go above Lock #1.

In addition to use of the commercial catch as a source, NES conducted its own drift and set gill-net operations. Two nets, 2.3.2.1 continued

300 x 8' with 5 and 5½ inch stretch mesh were used. The lock operators were required to open gates to pass shad every two hours. They co-operated with NES by not locking fish through until after NES had conducted its netting operations, from between 1600 hrs and 2300 hrs.

Collection operations began on 18 April. The collection operation was divided into two phases: (1) examination of commercial fishermen catches and (2) the NES gill-netting effort. NES gill-net operations were conducted from 19-23 April. Gill nets were first set at Lock and Dam #1. Netting also occurred within the lock system. On the 19 April NES gill-netted below Lock #1. On 20 April NES set a stake-net at Lock #2 and went upriver to Lock #3 to drift gill-nets. From 21-23 April NES moved its operation backto Lock #1 and continued drifting gill nets (several miles below the lock and dam).

On each of the days 18-23 April the commercial fishermen catches were checked. This included any commercial fisherman netting between Lock #3 and about 10-12 miles down river from Lock #1. Fishermen were also surveyed on their opinion of the strength of the run and number of spawners that they had taken in 1988.

2.2 Pamunkey River, Virginia

NES biologists began egg collection efforts on the Virginia ers on 9 April, upon confirming reports that shad had been :en by fishermen in spawning condition, and that water temper- ure had reach 58° F. Biologists worked with commercial fisher- n at Thompson's Landing, New Kent, Virginia, located approx- nately 4-6 miles upstream of Lester Manor. Up to 20 gill-nets, .75-6.00 inch mesh were set at any one time over a 2 mile stretch of river to catch adult shad. Netting was usually con- ducted between 1530 and 2200 hours, seven days per week. As fish were captured, they were shuttled to the shoreline; fish in spawning conditon were then processed.

2.3.2.3 James River

Egg Collection efforts on the James river began on 19 April at Berkley Plantation Landing. Grants Crossing was not utilized because commercial fishing operations at the landing were only conducted during the early hours of the day, a period when it would be unlikely to find any spawning shad.

Commercial fishermen using gill-nets (4.75-6.00 inch mesh x 300 feet) worked together with biologists out of small row boats during egg collection operations. Eggs were stripped from spawnin females and fertilized on the boat. Gill-netting was conducted from 1530 to 2200 hours.

2.3.2.4 Delaware River

In 1988, SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative to collect some 10 million shad eggs from the Delaware River. PFC biologists and NES biologists conducted the collection program at Smithfield Beach, 8 miles upstream from East Stroudsburg, Pa., from 15 to 25 May. Shad were captured with 200 foot long x 6 feet deep anchored gill-nets, with sections of 4.75-6.00 inch mesh, set parallel to the current. Nets were set between dusk and midnight. Spawning shad were shuttled to the shore for processing by NES personnel.

2.3.2.5 Hudson River

The effort on the Hudson river was conducted with two aims. Firstly, there was the need to find spawning shad in numbers which could justify a full effort at production levels and, secondly, if eggs could be obtained at production levels, more than 5 liters per night, to make some shipments to the Van Dyke hatchery in 1988.

NES conducted gill-net operations on the Hudson river from 16-25 May. A total of 2 nets measuring 450 x 12 ft. and 450 x 15 ft. with 5½ mesh were used. In addition to the gill-net operation, NES examined the catch in the New York State Department of Conservation haul seine operation.

The NES operation consisted of set gill-net fishing in the section of river between the Roeliff Jansen Kill (Rojan) and Catskill Creeks (near Hudson, NY) from 16-21 May. Nets were set 50 to 100 yards off shore near the edge of the shipping channel in about 10-15 feet of water. Fishing was conducted from 1600-2300 hrs. The section where fishing took place was downstream (about 1 mile) from the haul seine site which has been used in the past several years to catch adult shad. The distance between Catskill Creek and Rojan Creek is about two miles. The nets were fished and the catch checked each hour, similar to the operation conducted on the Delaware river.

In an effort to examine other areas for potential collection sites gill-netting was conducted at Imboct Bay near Cementon, NY on 23 May, the Kingston Flats off Kingston, NY on 24 May and below the Troy Dam on 25 May. At these sites fishing was conducted in shallow water such that the nets extended from the surface to the bottom.

Fishing was done in the different areas according to tide. Nets were set two hours before slack tide and fished on the ebb tide. Unfortunately, this was the tidal cycle available during the effort to collect eggs. The best fishing is done on a flood tide and the prevailing slack tide.

2.3.2.6 Columbia River

The egg collection program on the Columbia River, Oregon-Washington was initiated on 1 June. Netting for shad was conducted on the north shoreline approximately two miles upstream at the Camas-Washougal Reef (Troutdale area). Shad were captured by gill-nets, as in previous years. Net dimensions were 150 fathoms in length, tapered in depth, with sections of 4.75-5.75 inch monofiliment mesh. Typically, three 45-60 minute drifts were made nightly. Gill-netting was conducted from 1700 to 2400 hours.

2.4 Transportation

2.4.1 Pamunkey, James and Delaware Rivers

Shad eggs collected from East Coast rivers were packaged and shipped nightly by automobile to the Van Dyke Hatchery. This procedure has been conducted since 1983 with good results.

Personnel at the rivers arranged transportation and the drivers notified the hatchery nightly as to the number of liters

2.4.1 continued

shipped and the ETA of the shipment. The average delivery time from Delaware and Virginia rivers was approximately 3 and 6 hours respectively.

In 1988, as part of the transportation of eggs from the Delaware river, the adult shad were boxed and sold to a Lancaster based fish market. The proceeds of sale was donated to the Boy Scouts of America, Lancaster-Lebanon Council. This operation resulted in a productive use of the fish rather than disposal by burial or other means. Shad eggs were first delivered to Van Dyke, and then the fish were delivered to the market.

2.4.2 Columbia River

After packaging the eggs from the Columbia River, the boxes were transported by van to the Portland International Airport. Eggs were flown from Portland on United Airlines to Washington Dulles International Airport (Washington, D.C.) or Harrisburg International Airport (Harrisburg, PA). Shipments were required at the airport by 2300 hrs (Pacific Time). Upon arrival of the shipments to the East Coast, eggs were transported by van to the hatchery. Approximate shipping time for eggs which departed Portland at 2300 hours (Pacific Time) was 12-14 hours. For eggs shipped on the night of collection this means that they arrived

2.4.2 continued

at the hatchery between 1200 and 1400 hours EST. On flights which were scheduled for next morning departure from Portland, the 0630 hours flight was the first in the morning. For eggs shipped at this time, they normally arrived at the hatchery at around 1800 hours. The early morning flight eggs were shipped through to Harrisburg International Airport.

2.5 Collection Schedule

The shad egg collection schedule was based on experience gained over a 13 year period. Initiation of collection activities on any river was determined through communications with commercial fishermen and/or participation in fishing activities which documented that spawning shad were available in sufficient numbers. Collection activities usually began when water temperature reached 58-60 degrees F. East Coast egg collection operations were terminated when less than 5 liters of eggs were taken on a number of consecutive nights or it was apparent that shad had conlcuded spawning activities.

On the Columbia river the minimum of 5 liters of eggs is not the usual basis for terminating the operation. It has been extremely rare that on any night of fishing on the Columbia river that less than 5 liters of eggs are obtained. Impacting factors on the Columbia River include budget and the close of the shad fishing season for commercial fishermen. The season usually closes in the third week of June. In order to continue fishing it is necessary to get an extention and a scientific collectors permit through the Oregon Department of Fish and Wildlife. In previous years of effort this has not been done but in 1988, because of the relatively low number of eggs collected on the East Coast, the operation on the Columbia River was extended beyond the close of the commercial fishing season. The commercial fishing season closed on 24 June but an additional two days (until 26 June) were expended in order to collect more eggs.

In 1988, the colection schedule for on the East Coast was severely hampered by rain during the period of collection. This occurred from North Carolina to the Hudson River. Although collection activities began when the above criteria were met, during the period of collection, rain caused increased river flow and decreases in temperature. When such conditions prevail, it is not uncommon for a decrease in the catch of shad and therefore the availability of spawning shad. The collection schedule was most severely impacted on the Delaware River where within several days of the operation being initiated, high river flows caused a decrease in shad and eventually flood conditions which

2.5 continued

prevented any fishing at all. Several attempts were made to continue on the Delaware River after the operation had been impacted but by 16 May it was obvious that the operation would not continue to be productive, and it was terminated.

2.6 Results and Discussion

2.6.1 Cape Fear

The effort on the Cape Fear river did not produce any shipment of eggs. The run of shad according to state biologists and commercial fishermen was relatively weak in 1988. In the NES gill-netting operation at Lock #1 some 43 shad were taken on 19 April, which included 22 roe and 21 bucks. There were no spawners. An effort at Lock #2 and Lock #3 on 20 April produced 55 shad after 7 hours of gill-netting at both locations combined. No spawners were taken, although approximately 50 hard roe were netted. When NES moved its operation back to Lock #1 from 21-23 April some 250 shad were taken in 3 days. Only several spawning shad were captured.

Commercial fishermen were observed to a catch as many as 50-60 shad per night. On any one night less than 5 spawning shad were seen in the commercial catch.

2.6.1 continued

The absence of spawning shad suggested that either the operation was conducted before shad had ripened or that shad on the Cape Fear river spawned further upstream than both the netting operation and the commercial fishery. In any case, this does not look like a suitable area to attempt to collect shad eggs.

2.6.2 Pamunkey River

Collection efforts began on 9 April on the Pamunkey River, Virginia and continued throughout the duration of the annual adult spawning run. Water temperatures ranged from 57 to 65 degrees F (Table 4). Egg collection efforts were halted on 28 April when commercial fishermen no longer caught shad in gill-nets. A total of 1.92 million eggs was collected from the Pamunkey River in 1988.

2.6.3 James River

The normal procedure when working in Virginia is to check the progress of the run on the James river on a daily basis once efforts start on the Pamunkey river. Thus, from 9 April through

2.6.3 continued

18 April daily contact was made with the commercial fishermen on the James river. The catch of shad was low and did not contain spawning fish until 19 April. Collection of eggs on the James River occurred from 19-23 April at water temperatures of 62-64° F.

From 1974 through 1983 the James River was a consistant source of shad eggs for the program, some 64 million shad eggs were collected over that period (Table1). However, production from the James River has dropped off significantly since 1983. In 1988 only 0.05 million shad eggs (Table5) were collected. The poor catch in 1988 was a result of poor commercial harvest of shad.

2.6.4 Delaware River

Pennsylvania Fish Commission biologists and NES biologists conducted shad egg collection efforts on the Delaware river over a period of four days, beginning on 8 May and ending on 15 May. Approximately 3 million eggs (Table 6) were shipped to the Van Dyke Hatchery over that period.

2.6.5 Hudson River

On 16 May NES worked with the New York DEC at their haul seine site below the Rip Van Winkle Bridge. About 80 shad were taken in the catch but it did not include any spawners.

From the gill-net effort at the Rojan-Catskill Creek area large numbers of shad were taken, including spawners. On 17, 18 and 19 May, some 15, 12, and 8 liters of eggs were taken on the respective dates. After it was demonstrated that eggs could be collected from this area, the effort was directed toward looking at other possible areas where spawning shad might be taken. This included the efforts just downstream on Kingston Flats and Imboct Island and below Troy Dam. At these sites some 200-250 shad were taken in the gill-net operation each night but none contained sufficient spawners to collect the minimum 5 liters of eggs. With these efforts the operation was terminated. The water temperature ranged from 60-66 during the gill-netting operations.

For the first time, it has been demonstrated that spawning shad can be taken on the Hudson River. Previous experience and discussions with commercial fishermen indicated that none knew where spawning shad could be caught. The efforts in 1988 suggest that the spawning shad can be taken off the channel near the shoreline in water 6 to 15 ft. deep. The nets used in 1988 were nets that reached to the bottom and as a result, large numbers of cat fish and other fishes were taken. This made clearing the nets

2.6.5 continued

time consuming and limited the number of sets that could be made just for shad. In the future, nets 5-6 ft.deep which go just from the surface will be used so that the catch is mainly shad.

2.6.5 Columbia River

Egg collection on the Columbia river began 1 June and continued through 26 June. Water temperatures ranged from 54-64 degrees F. Some 26.9 million shad eggs (Table 7) were sent to the Van Dyke Hatchery in 19 shipments.

In the extension period of two days some 2 million eggs were collected. In all liklihood the effort on the Columbia river could continue to be productive through the end of June. Development of methods to improve viability of Columbia river eggs would be a contribution to the program. The results of the shipment of eggs held overnight is covered in the PFC report on the hatchery operation.

2.7 All Rivers Combined

The Columbia river continued to be the most productive river for shad eggs (Table 2). Some 26.9 million eggs were collected in 1988. The number of eggs obtained on the East Coast was 4.9 million, the lowest total obtained since the program began.

2.7 continued

No eggs were collected from the Cape Fear river and the Hudson river. However the Hudson river does have potential since a spawning area was found where gill-netting will produce spawning shad.

2.8 References

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

TABLE 1 Total number (millions) of American shad eggs collected from the Pamunkey, James, Delaware, Hudson and Columbia Rivers, 1973-1988.

YEAR	PAMUNKEY	JAMES	DELAWARE	COLUMBIA	HUDSON	TOTAL
1973	8.45	--	--	--	--	8.45
1974	9.75	19.20	--	8.18	--	37.13
1975	1.88	7.15	--	18.42	--	27.45
1976	--	--	4.10	54.80	--	58.90
1977	4.40	3.42	--	8.90	--	16.72
1978	6.90	10.11	--	--	--	17.01
1979	3.17	4.99	--	--	--	8.16
1980	6.73	6.83	--	--	--	13.56
1981	4.58	1.26	--	5.78	--	11.62
1982	2.03	1.25	--	22.57	--	25.85
1983	5.49	5.91	2.40	19.51	1.17	34.48
1984	9.83	0.74	2.64	27.88	--	41.09
1985	5.28	2.05	6.16	12.06	--	25.55
1986	5.62	1.07	5.86	39.97	--	52.52
1987	4.35	0.11	5.01	23.53	--	33.00
1988	1.92	0.05	2.91	26.92	0.00	31.80
TOTALS	80.38	64.15	29.08	268.52	1.17	443.30

TABLE 2 Sampling period for East and West Coast rivers for collection of American shad eggs, 1988.

RIVER	SAMPLING SCHEDULE DATES	TOTAL FISHING DAYS
Cape Fear	18 April - 23 April	7
Pamunkey	9 April - 27 April	17
James	19 April - 23 April	5
Delaware	8 May - 15 May	4
Hudson	15 May - 25 May	10
Columbia	1 June - 26 June	17

TABLE 3 Collection data of the total volume and number of American shad eggs on Cape Fear, Pamunkey, James, Delaware, Hudson and Columbia rivers, 1988.

RIVER	VOLUME OF EGGS SHIPPED (L)	TOTAL NUMBER EGGS
Cape Fear	0.0	0
Pamunkey	64.78	1,921,000
James	1.76	47,700
Delaware	105.30	2,906,800
Columbia	713.33	26,917,800
Hudson	0.0	0
TOTALS	885.17	31,793,300

TABLE 4 Collection data from American shad eggs taken on the Pamunkey River, 1988.

Date	Water Temp. (F°)	Number of Adult Shad Male	Number of Adult Shad Female	Volume Rec. at Hatchery (liters)	Total Number Eggs
Apr. 9	61	10	12	-	-
10	61	6	12	-	-
11	61	4	6	-	-
14	57	2	11	-	-
15	58	5	31	-	-
16	60	11	29	10.02	287,700
17	60	11	21	8.70	302,000
18	.60	12	23	9.85	276,500
20	58	10	13	8.10	227,400
21	59	11	22	10.02	269,100
22	60	13	20	6.33	184,300
23	60	11	22	7.08	203,900
24	62	-	-	-	-
25	62	-	-	-	-
26	62	-	-	-	-
27	65	9	16	4.68	170,100
28	65	-	-	-	-
TOTALS				60.1	1,921,000

TABLE 5 Collection data from American shad eggs taken on the James River, 1988.

Date	Water Temp. (°F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume of eggs Rec. at Hatchery (liters)	Total Number Eggs
May 19	64	2	3	0	0
20	64	2	2	0.52	15,000
21	62	4	5	1.24	32,700
22	62	0	0	0	0
23	64	0	0	0	0
TOTALS				1.76	47,700

TABLE 6 Collection data for American shad eggs taken on the Delaware River, 1988.

Date	Water Temp. (°F)	Volume of Eggs Rec. at Hatchery (liters)	Total Number Eggs
May 8		22.27	560,200
9		28.26	727,200
12		14.97	382,000
15		39.80	1,237,400
TOTALS		105.30	2,906,800

TABLE 7 Collection data for American shad eggs taken on the Columbia River, 1988.

Date	Water Temp. (F°)	Number of Adult Shad Male	Number of Adult Shad Female	Volume of eggs Rec. at Hatchery (liters)	Total Number Eggs
June 1	54	30	60	31.62	1,128,400
2	57	12	25	16.88	576,400
3	62	22	45	22.16	806,800
9	56	50	100	42.85	1,394,600
10	57	-	-	21.40	730,200
13	60	-	-	26.74	870,600
13	60	-	-	16.18	552,100
14	61	50	100	23.00	749,800
15	61	50	100	50.32	1,771,300
15	61	50	100	14.62	570,600
16	62	60	120	59.94	1,996,800
17	63	70	140	73.62	2,680,400
20	63	55	110	57.16	2,143,800
21	63	40	80	42.62	1,640,800
21/22	63	70	130	61.14	2,954,700
23	63	50	100	29.84	1,506,600
24	63	30	60	38.84	1,570,700
25	64	40	80	32.20	1,169,500
26	61	60	120	52.20	2,103,700
TOTALS				713.33	26,917,800

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1988

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INTRODUCTION

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

Production goals for 1988 included the stocking of 10-15 million 18-day-old shad fry, and 50-100 thousand fingerlings. All hatchery-reared American shad fry were marked by immersion in oxytetracycline bath treatments in order to distinguish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in 1988 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Research conducted in 1988 focused on alternative egg handling techniques, evaluation of new larger egg jars, attempts at producing sedation in fingerlings using feed laced with MS222, and a comprehensive study to determine if otolith microstructure can be used to distinguish between hatchery-reared and wild American shad. Observations on shad egg mortality as it relates to egg jar processing sequence will also be discussed, as will attempts at holding Columbia River eggs in an incubation tank overnight prior to shipping.

At this writing, the otolith microstructure study is underway but incomplete. A separate report will be submitted upon completion of the study (see Job V, Task 4).

EGG SHIPMENTS

Almost 32 million eggs (885.2L) were received in 33 shipments in 1988 (Table 1), representing the fifth largest total since the program began in 1976 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 38.7% compared to 40.9%, 40.7% and 47.9% in 1985 through 1987, respectively. The low egg viability was due in part to the complete mortality of shipment 29 and the preponderance of Columbia River eggs which traditionally exhibit lower viability. Egg viability for the Pamunkey River was 55.4% as compared to 64.5%, 62.5%, 55.3%, and 51.1% for 1984 through 1987, respectively. Egg viability for the James River was 76.9% (one shipment). Egg viability for the Delaware River was 63.4% as compared to 31.2%, 50.5%, 57.9%, and 55.4% for 1984 through 1987, respectively. Egg viability for the Columbia River was 34.8% as compared to 39.2%, 24.5%, 35.5%, and 45.7% in 1984 through 1987, respectively. Shipment 29 (Table 1) was lost in transit and arrived a Van Dyke approximately 14 to 16 hours late, resulting in complete mortality. Egg viability for Columbia River shipments excluding shipment 29 was 39.1%.

PRODUCTION

Survival, production and stocking of American shad fry are presented in Tables 2, 3, and 4. Total fry production was 11.1 million (4th highest) compared to 13.5 million, 7.9 million, 16.6 million and 11.1 million in 1984 through 1987, respectively. Of the total fry production, 6.5 million were released in the Juniata River and 3.6 million in the Susquehanna River below Conowingo Dam. Approximately 612 thousand fry were stocked into ponds for fingerling production at various sites (Table 4) and 340 thousand fry were released into the Lehigh River.

Total fingerling production for 1988 was an estimated 74,000 (Table 4) compared to 30,500, 115,000, 73,000, and 81,500 in 1984 through 1987, respectively. All fingerlings were released in the Juniata River at Thompsontown, with the exception of those reared at Brunner Island Aquaculture Facility. Fingerlings reared at Brunner Island were used in radiotelemetry studies at Safe Harbor and Holtwood Dams.

SURVIVAL

Survival of all fry was 89.8% compared to 72.8%, 76.2%, 75.6%, and 70.1% in 1984 through 1987, respectively. The increase in reported survival is, in part, due to modifications in daily mortality estimation. Research conducted in 1987 (Hendricks et al., 1987) indicated that we were overestimating mortality by a factor of 1.544. As a result, our daily mortality estimates for 1988 were divided by a correction factor of 1.544. This factor alone would account for an increase in reported survival from 75% to 83.8%. The additional 6% increase in survival over previous years was perhaps due to care and vigilance on the part of our temporary workers. For the first time since 1985 we had no major mortality episodes due to human error.

In 1987, 12 tanks of fry exhibited survivals less than 65% (77.3% if adjusted for the 1988 fry mortality correction factor). These tanks characteristically exhibited survival of less than 83% (adjusted) within the first 2 days after hatch (Hendricks et al., 1987). In 1988, only one tank exhibited overall survival less than than 77.3% (73.0%), and only one tank exhibited survival below 90% after 2 days.

EGG SURVIVAL RESEARCH

Production of American shad fry at Van Dyke is limited by the availability of fertilized eggs, the design capability for incubating eggs and rearing fry, and by survival of eggs and fry in the facility. Survival of fry from hatching to 20 days of age has ranged from 70.1% to 89.8% for the last five years. Little improvement can be expected in this area. Survival of eggs from fertilization to hatching, however, has ranged from 38.7% to 47.9% for the last four years. Mean survival of eggs and fry for all tanks in 1988 is depicted in Figure 1. Significant increases in production can be realized by relatively minor improvements in egg survival. In addition, culture methods which improve egg viability/quality would presumably produce healthier fry. Several research projects were conducted to attempt to improve egg survival and increase incubation capacity. In addition, interesting observations on egg survival were made for shipments not involved in research.

EGG HANDLING STUDIES

A complete discussion of standard operating practice for egg disinfection and enumeration at Van Dyke is needed prior to discussion of research conducted in 1988. Eggs are received from the shipper in 5 liter lots boxed in styrofoam coolers. Each lot is shipped double-bagged in clear plastic bags filled with gaseous oxygen. Dissolved oxygen concentration has been over 20ppm in every lot tested. At Van Dyke, the bags are removed from the coolers and allowed to temper a minimum of 15 minutes in a large trough in the disinfection room. After tempering, a maximum of 4 bags (20 liters) is poured into a 43 X 11 X 10 inch deep (109 X 28 X 25cm) egg net floating in a second trough filled with 4 inches of water. The egg net is then lifted from the water, allowed to drain for approximately 30 seconds, and placed in a third trough containing a solution of 80ppm Argentyne iodophore disinfectant. After 10 minutes, the net is again lifted, allowed to drain and carried to a fourth trough in the egg incubation area. Black plastic is used to shade the eggs from direct sunlight during the transfer. The egg net is floated in this fourth trough for several minutes to wash out the remaining iodophore. After several minutes, the net is again lifted and put on blocks to drain. At this point the eggs are measured volumetrically in graduated cylinders which have been screened on the bottom to allow water to drain out. Four 2 liter cylinders are currently in use. Each of the four 2 liter cylinders is filled with eggs using a feeding scoop. By the time the fourth cylinder is filled, most of the water has drained from the first. The volume of eggs in this first cylinder is then adjusted to 2 liters by adding or removing eggs, and the eggs poured into an incubation jar. This process is repeated with each of the 4 graduated cylinders until the first 4 egg jars have been loaded with 2 liters of eggs in each, and all 4 graduated cylinders are empty. The graduated cylinders are then refilled with eggs and the process repeated, filling as many incubation jars as the shipment size will allow, given that each jar must be filled later with an additional 0.5 liters for a total capacity of 2.5 liters per jar. Obviously, when each jar has been filled with 2 liters of eggs, enough eggs must be retained in the net for an additional 0.5 liters per jar. These 0.5 liter egg lots are then measured in the cylinders and poured into the incubation jars in the same manner and order as were the 2 liter lots.

After all the eggs from the first 4 bags have been put into incubation jars, the flows on the jars are adjusted and the next 4 bags (20 liters) are processed until the entire shipment has been processed.

After several hours on the egg battery, the eggs begin to layer, dead eggs on the surface and live eggs on the bottom. Dead eggs are siphoned off on the second and sixth days after fertilization (days II and VI) and enumerated using the same dry volume technique (screened graduated cylinders). Incubation jars are moved to the rearing tanks for hatch on the sixth day after fertilization. After hatch, dead eggs remain in the incubation jar and are again enumerated. This enumeration is conducted using wet volume techniques with a correction factor to convert to dry volume. The accuracy of this last enumeration is suspect due to the presence of fungus on the eggs, the fragility of the eggs, and the fact that some eggs float. For this reason, removal of all dead eggs prior to hatch is preferable.

Von Bayer enumerations (Hendricks et al., 1986) are used to determine the number of eggs per liter (dry volume). These 12-inch rule counts are done for live eggs during disinfection and for dead eggs on days II and VI. While the eggs are on the egg battery, fungus is controlled by daily 17-minute formalin treatments at 1:600. In the absence of formalin treatments, fungus forms on the dead eggs while the live eggs are hatching into the rearing tank and can contribute to mortality and enumeration problems.

Careful evaluation of the above procedure resulted in speculation that possible egg survival problems related to handling procedures could result from 1) physical stress due to handling, scooping, etc., 2) physical stress due to compacting while in the graduated cylinder or while draining in the egg net, 3) oxygen depletion while in the disinfectant solution or while draining in the egg net or graduated cylinder, 4) Dessication while the eggs are out of water. Design of experiments to independently test each of these possibilities was not considered practical. Instead, an experiment was designed to completely alter egg handling methods, effectively eliminating all 4 perceived sources of stress.

The alternative (test) handling method involved disinfection of the eggs in the shipping bag and wet volume enumeration prior to shipping, thus eliminating all draining, scooping, and compacting of eggs. After water hardening, all eggs were mixed thoroughly. Exactly 5 liters of eggs were packed in each bag, the bags filled with oxygen and shipped to Van Dyke. At Van Dyke, bags were randomly assigned to the test (alternative) or control (standard practice) methodology. Control lots were handled in the manor prescribed in the above discussion except that 5 liter lots were processed (as opposed to 20 liter lots).

Test lots were disinfected in the shipping bag at 80ppm Argentyne. In order to calculate the volume of Argentyne needed for an 80ppm solution, the volume of water in the bag had to be determined by displacement. First, the dry volume of 5.0 liters of eggs from a previous shipment was determined by displacement. Next, the volume of the eggs and water in the test shipping bag was determined by displacement. The volume of the plastic in the bag was considered negligible. The volume of water in the bag was then calculated by subtracting the volume of eggs from the volume of water and eggs. Argentyne was then added to the test shipping bag to produce a concentration of 80ppm. After 10 minutes, the entire contents of the bag were poured into 2 May-Sloan incubation jars. Incubation and dead egg removal were similar in both the test and control lots.

The experiment was replicated 3 times and the results and presented in Table 5 and Figure 2. The results of the experiment were inconsistent. Survival in test treatments exceeded that in controls for replicates 1 and 3 but not for replicate 2. Further discussion of these results is deferred until the next section.

EGG SURVIVAL AS RELATED TO JAR PROCESSING SEQUENCE

Close scrutiny of jar by jar egg survival resulted in the following observation: egg survival decreased during egg processing, resulting in the highest survivals in the first jars processed and the lowest survivals in the last jars processed. This trend is depicted in Table 6 and Figure 3. For the purposes of this analysis all 1988 egg data from May-Sloan jars were, used except for data from those shipments involved in egg research, jars which were combined, and jars loaded with less than 2.4 or more than

2.6 liters of eggs. All of the remaining 10 shipments clearly exhibit this trend. Regressions were performed on the data from each of these shipments (Figure 3) and T-tests (Ott, 1977) were used to test the slopes for significant differences from zero. Shipments 8,9, and 13 could not be tested since only 2 data points exist for each. The slopes for shipments 1, 14, 20 and 23 were significantly different from zero at the .05 level, while those for shipments 2, 22, and 24 were not.

This phenomenon is evidence that there is indeed some stress caused by our handling/disinfection/enumeration procedure and that the cumulative effects over time result in reductions in survival. The time factor may account for the inconsistent results in the previously discussed egg handling test since very little time was required to process the small 5 liter lots used for that test.

An earlier discussion listed 4 general categories as possible sources of stress during egg handling. Controlled experiments to test these theories are not practical, therefore it seems prudent to take immediate steps to: 1) expedite the egg handling process, 2) reduce compacting of eggs in the graduated cylinders, 3) and minimize the possibility of dessication and oxygen depletion during draining. This can be achieved by misting the egg net with a fine spray during handling and by replacement of the 2 liter graduated cylinders with 3 liter graduated pitchers. The 3 liter pitchers will allow measurement of 2.5 liter lots of eggs in a single step. In addition, the larger diameter of the pitcher will effectively reduce the height of the column of eggs (and therefore the pressure and compaction) from 17.1 inches for 2 liters of eggs in the graduated cylinder to 7.4 inches for 2.5 liters of eggs in the pitcher. Unfortunately, accuracy of measurement will be slightly reduced as well.

EGG JAR TESTING

Testing of a new larger egg incubation jar was begun last year (Hendricks et al., 1987) with promising results. Seventeen additional Mega-jars were constructed during 1988 and the jar re-named the "Van Dyke" jar. In 1988, the Van Dyke jars were extensively tested in controlled experiments and also occasionally used for production incubation. Data for the controlled experiments are depicted in Table 7 and Figure 4. Survival of eggs incubated in the Van Dyke jars was compared to survival of a similar volume of eggs incubated in 5 May-Sloan jars. The test was replicated 7 times and for 5 of the replicates, fry from the test and control groups were reared separately to determine if fry survival was also related to egg jar type.

Total egg survival was 56.4% for the Van Dyke jars and 39.0% for the May-Sloan jars (Table 7). Egg survival for the Van Dyke jars was higher than for the May-Sloan jars in 6 of the 7 replicates. These data were tested using Wilcoxin's signed-rank test (Ott, 1977) and found to be significant at the .05 level. Survival of fry from hatch to stocking was 91.1% for the Van Dyke jars and 85.9% for the May-Sloan jars. All five of the replicates exhibited higher fry survival for the Van Dyke jars. These data were also significant at the .05 level (Wilcoxin's signed-rank test, Ott, 1977), indicating that egg jar type continues to effect survival of fry after hatch. Overall survival (from egg delivery to fry stocking) was 56.4% for the Van Dyke jars and 32.6% for the May-Sloan jars.

If these data are reliable, use of the Van Dyke jar would result in very significant increases in numbers of fry stocked. A problem exists, however, which confuses the analysis. Water flow through the bottom screen in the Van Dyke jars was not homogeneous and resulted in "dead" spots, usually in the center of the jar, where flow was insufficient to sustain the active eggs during the hatching period. These eggs often died, clumped together, and fungused very rapidly, further blocking flow and exacerbating the problem. Increasing flow did not alleviate the problem, since additional water traveled along the path of least resistance in the spots where the eggs were already rolling.

Survival of eggs and fry incubated in the two types of jars is plotted in Figure 4. Dead eggs taken off after hatch are represented by the slope of the line from day VI to day 1. The accuracy of this dead egg enumeration is suspect due to egg fragility, fungusing and clumping, and floating eggs. A special effort was made to siphon off all dead eggs on day VI in anticipation of these enumeration problems. Therefore, we interpret the rather substantial drop in survival from day VI to day 1 (Figure 5) to be due to mortality during the last day or two of incubation. It is interesting to note that, although we do not perceive these "dead" spots in May-Sloan jars, the mortality during this critical period is similar to that in the Van Dyke jars (Figure 5). Two possibilities exist to explain this. First, dead spots may be present in the May-Sloan jars which are relatively small or perhaps subsurface and therefore not obvious. Second, our enumeration system is at its most inaccurate point and may not be able to detect these differences.

Last year we noted the presence of dead fry in the hatching jars after hatch and attributed it to death prior to exiting the jar (Hendricks et al., 1987). We now believe that these dead fry represent fully developed eggs which died in the last day or two of incubation and lost their shell at or after death. They usually appear crescent shaped and are white in color while fry mortalities are typically straight and clear. We further speculate that this mortality is due to fungus proliferation exacerbateed by "dead spots" as discussed above. This phenomenon has been observed in both Van Dyke and May-Sloan jars, and the presence of these dead fry in the egg jar confounds dead egg enumeration.

A new bottom screen, designed to create back-pressure and result in more uniform flow, will be tested in the Van Dyke jars in 1989. If this screen works, use of Van Dyke jars will become standard practice, thereby improving survival and increasing egg incubation capacity by 120%.

COLUMBIA RIVER HOLDING TANK

The availability of eggs from the Columbia River is often controlled by airline schedules rather than abundance of spawning shad. Fishing must be terminated in time to fertilize and water harden the eggs, bag them for shipping, and then arrive at the airport to catch the last flight to Harrisburg or Washington, D. C. Connecting flights involving plane changes are avoided to eliminate the possibility of missed connections. The net result is that additional eggs are available but fishing time is limited.

In 1988, N.E.S. attempted holding fertilized eggs overnight in a makeshift incubation tank, shipping them the following day. The incubation tank consisted of a 95 gal.

oval, plastic tub, 26 inches high by 20 inches wide by 42 inches long. The tank was fitted with a centrally located, screened standpipe to allow water overflow. Circulating water was provided by a one-third horsepower pump powered by 110v AC. Two adjustable, valved shower heads were installed in the bottom center of the tank. Water flow was directed towards the ends of the tank and adjusted to keep eggs rolling without clogging the overflow screens.

Fishing procedures were according to standard practice except that fishing continued after the first eggs had been sent to the airport, and the next batch of eggs collected was held in the incubation tank overnight. The experiment was replicated 2 times and the data depicted in Table 8 and Figure 6.

The first replicate was conducted on fishing date 6/13/88. The evening shipment of 6/13 (shipment 20) was typical in terms of 1988 flight schedules. It was shipped from Portland at 11:30 PM and arrived at Van Dyke at 11:30 AM on 6/14. The test shipment was held in the tank overnight, shipped from Portland at 10:30 AM on 6/14 and arrived at Van Dyke at 9:00 PM. Egg viability (% survival) was 47.2% for the evening shipment and 13.4% for the test. The evening shipment for replicate 2 followed similar flight schedules. The test shipment for replicate 2 (shipment 24) was shipped at 6:30 AM on 6/16 and arrived at Van Dyke at 8:30 PM. Approximately 30,000 live eggs from the test shipment were given to Johns-Hopkins University (Jar 122, shipment 24) for bioassay work. This jar was therefore excluded from further analysis. Egg viability for replicate 2 was 46.9% for the evening shipment and 32.4% for the test.

A third trial involved collecting eggs on 6/25 and holding them overnight. Some 32.2 liters of these were shipped at 6:30 AM on 6/26 and arrived at Van Dyke at 7:00 PM. Egg viability for this lot was 20.9%. The remainder of these eggs (8.54L) were held until 11:30 PM and shipped with the eggs collected on the evening of 6/26. Egg viability for this group was 38.1%.

Trials 1 and 2 exhibited much reduced survival for eggs held overnight 7 to 11 hours prior to shipping when compared to eggs shipped immediately after collection. Trial 3 exhibited much greater survival for eggs held 24 hours prior to shipping compared to those held 7 hours prior to shipping. There are several possible explanations for these apparently inconsistent results. First, there may indeed be a critical period of time during which shipping of eggs results in high mortality. Holding eggs 24 hours prior to shipping (trial 3) may indeed be advantageous. Unfortunately, none of the three replicates constituted a truly controlled experiment since different batches of eggs were used for test and control lots. Eggs collected early in the evening were shipped immediately while those collected later were held overnight. Differences in survivability between the early (shipped immediately) and late (held overnight) collected eggs may have been present and accounted for the inconsistent results. Thirdly, some undetected perturbation (e. g. temperature/pressure changes during flight, rough handling at the airport, etc.) may have affected survival of one of the shipments. In any case, it is clear that no conclusions can be drawn from the experiment. We recommend that the experiment be repeated in 1989 using a 2 X 3 factorial design with one empty cell. Early collected eggs should be thoroughly mixed and divided into 3 lots, one shipped that evening, one the following morning, and one the next evening. Late collected eggs should be split into 2 lots, with one shipped the following morning and one the next evening. At least 4 replicates should be attempted. In addition, PFC will construct and provide a large egg incubation tank, similar to a Van Dyke jar, which has the capability of incubating 100 liters of eggs or more.

OTC TAGGING/RESEARCH

All American shad fry and fingerlings stocked in the Susquehanna River Basin received marks produced by immersion in or feeding of oxytetracycline (Table 9). Immersion tags were administered to all fry by bath treatments at 200 ppm oxytetracycline for 6 hours duration. Fry stocked below Conowingo Dam received a double tag at 5 and 9 days of age. Fry stocked in the Juniata River were uniquely marked according to egg source river to determine relative survival of fry from the various egg sources. Fry originating from Columbia River eggs received a single tag on day 5. Delaware River fry received a triple tag on days 5, 9 and 13. Virginia River fry received a quadruple tag on days 5, 9, 13 and 17.

Fry destined for fingerling production were given the appropriate immersion tag and then tagged again, as fingerlings, by feeding feed laced with tetracycline at a rate of 40g TC per pound of food plus 0.75g glucosamine per pound of food. Fingerlings were starved for a period of 2 days and then fed the tetracycline laced feed for 3 days. Multiple feed tags were administered at least 7 days apart.

In addition to the four types of immersion tags used for fry, four unique combinations of immersion/feed tags were also produced and released (Table 9). Fingerlings reared in Benner Spring Ponds 2 and 3 were tagged with a quadruple immersion and triple feed tag combination. Fingerlings reared in the Canal Pond at Thompsontown were tagged with a triple immersion and single feed tag.

Fingerlings reared in Upper Spring Creek Pond 2 were tagged with a triple immersion and triple feed tag. Fingerlings reared at the Brunner Island Aquaculture Facility were tagged with a quadruple immersion and single feed tag. Fingerlings reared in Upper Spring Creek Pond 1 were tagged with a triple immersion and double feed tag. These were not successfully stocked.

Verification of tag retention was accomplished by stocking groups of tagged fry in raceways or ponds and examining otolith samples collected by seine, dip net, or during harvest. A total of 426 specimens was examined for immersion tags (Table 10). Thirty of these received single tags, 47 received double tags, 152 received triple tags and 197 received quadruple tags. Tag retention was 100% for all immersion tags examined. While the sample size for single tags (29) seems low, it is important to note that all double, triple, and quadruple tagged fish received a tag on day 5, increasing the effective sample size for the day 5 tag to 425. Similarly, the day 9 tag was examined on 396 specimens, the day 13 tag on 349 specimens and the day 17 tag on 197 specimens.

Tag retention for feed tags was much more complicated (Table 10). In general, feed tag retention for the production feed tag was 100% for fish reared in raceways (BSRD2 double tag, BSRD1) and fish reared in ponds

(Wellsboro, CP) where feed was spread around the pond by hand in addition to feeding by automatic feeder. In Ponds where feed was fed by automatic feeder alone, tag retention was less than 100%. For example, in Upper Spring Creek Pond 1, 23 of 25 (92.0%) otoliths examined exhibited the double feed tag, one (4.0%) exhibited a single feed tag and one (4.0%) exhibited no feed tag. Fish from this pond were not stocked due to complete mortality (see section on fingerling production). In Upper Spring Creek Pond 2, 21 of 24 (87.5%) otoliths examined exhibited the triple feed tag, 2 (8.3%) exhibited a double feed tag and 1 (4.2%) exhibited a single feed tag. An estimated 12,000 fingerlings were stocked from this pond. Extrapolating from the tag retention results, this projects 10,500 fingerlings stocked with a triple/triple tag, 996 fingerlings with a triple/double tag and 504 fingerlings with a triple/single tag (Table 10). Table 11 summarizes stockings of juvenile American shad for each tag combination as projected by tag retention (Table 10) and production estimates (Table 4). Note that the 504 fingerlings with a triple/single tag from Upper Spring Creek Pond 2 are indistinguishable from the estimated 30,000 fingerlings with a triple/single tag from the Canal Pond.

The situation with regard to Benner Spring Ponds 2 and 3 is more complex. Both ponds were scheduled to receive a double feed tag which was administered by automatic feeder only. In order to expedite tag retention analysis we sampled both ponds by seine approximately 45 days prior to harvest. Tag retention analysis on these seine sampled lots indicated 28% retention of the double feed tag in Benner Spring Pond 3 and 84% retention in Benner Spring Pond 2 (Table 10). In response to the low tag retention in Pond 3 both ponds were re-tagged with a second double feed tag. Both ponds were re-sampled at harvest and otoliths examined for tags. None of the otoliths examined exhibited the fourth (quadruple) feed tag, presumably because the fish ceased feeding between the administration of the third and fourth tag (October 5 to October 12). Temperature data for the ponds is not available, however, data for adjacent Spring Creek indicates a gradual decline in temperature during early October followed by a drastic drop in water temperature from 52F on October 5 to 47F on October 6.

At harvest, a large percentage of the otoliths did exhibit 3 of the attempted 4 feed tags (Table 10). In Benner Spring Pond 3, for example, 25 of 30 (83.3%) otoliths exhibited a triple tag, 4 of 30 (13.3%) exhibited a single tag and 1 of 30 (3.3%) did not exhibit any feed tag. The data for Benner Spring Pond 2 is similar. As a result, most of the fingerlings from these ponds were uniquely tagged, however, some exhibited no feed tags and could therefore be confused with fry stockings from the Virginia River egg source (Table 11). Our projections indicate that 1,060 such fish were released. In addition, a projected 2,933 fingerlings from Benner Spring Pond 3 exhibited a quadruple/single tag and thus were indistinguishable from fingerlings reared at Brunner Island.

Several conclusions can be drawn from this data. First, feeding by automatic feeder alone does not distribute feed to all individuals in the pond. Some individuals may reside along the periphery of the pond feeding solely on natural prey. These individuals do not receive the TC laced food and are not tagged. Second, using a seine to sample ponded fish probably selects for these un-tagged individuals resulting in biased samples with low tag retention rates (Table 10, BSP3, quadruple/double tag). Sampling during harvest provides a more representative sample of tag retention rates (Table 10, BSP3, re-tagged). Third, ponded shad appear to cease feeding due to decreasing temperature (although other causes have not been ruled out) and feed tagging should be scheduled to be completed prior to October 1.

Several experimental feed tags were administered to Benner Spring Raceway D-2. Initially, these fish were tagged with the standard double feed tag without the use of the potentiator glucosamine (Table 10). Tag retention was 100% indicating that glucosamine is not an essential component for successful feed tagging. The fish were then re-tagged by feeding TC laced feed for a single day only. Tag retention for the single day feed tag was only 12.5%

suggesting that 3 days of feeding with TC laced feed would be a preferred protocol.

FINGERLING HARVEST

American shad fingerlings from Benner Spring Pond #3 were harvested on October 25, 1988. The pond was harvested in the usual manner; fish were bucketed from the pond catch basin into the gooseneck trailer and transferred to raceways for clean-up. Due to some problems with algae, harvest was not completed until October 26. Approximately 22,000 fingerlings were stocked at the Thompsontown Access Area on October 27th (7,000) and October 28th (15,000). Total production for Pond 3 was approximately 26,900; 1,700 were lost in the pond during harvest and 3,200 mortalities were removed from the raceways prior to stocking. Approximately 82% of the fish produced in Benner Spring Pond #3 were stocked.

Benner Spring Pond #2 was harvested on November 2, 1988. This was the easiest harvest to date from a Benner Spring Pond, primarily because of the angle aluminum keyways which were installed on the lip of the catch basin, which allowed the fish to be brought into the catch basin in two lots rather than all at once. All the fish were removed in two trips and took four men about two hours. The following morning, there were only a total of 184 dead in the two raceways. Approximately 10,000 fingerlings were stocked in the Juniata River at Thompsontown on November 3, 1988. On November 3, a total of 2,145 dead, which had been lost during harvest, were picked up from the bottom of the pond. The remaining fish (approximately 7,000) were to be stocked on November 4, but immediately prior to loading, a call was received from Mr. Tim Brush, RMC, indicating that a problem with water temperature at Brunner Island may have caused the loss of their shad. He asked that we postpone stocking in the event that they needed those fish to replace Brunner Island fish. The fish were held over the weekend and by Monday, November 7, 4,000 dead were removed from the race. It was decided that the remaining fish (approximately 3,000) would be held as part of an attempt to hold fish over winter in 50F water. Approximately 51% of the fingerlings produced in Pond #2 were stocked.

Overall, the two Benner Spring ponds produced approximately 45,700 fingerlings (25.7% survival from fry). A total of 32,000 (70%) of those produced were successfully stocked. Average length for these fish was 115.8 mm and the average weight was 14.7 g.

Pond #1 at Upper Spring Creek was slowly lowered over a 4 day period and on the morning of November 8th, the influent end of the pond was de-watered and approximately 8 ft. of water remained at the effluent bulkhead. Final draw-down was begun at approximately 9:00 a.m. Fish were first observed when water was approximately 18 inches above the lip of the catch basin. At this time, the catch basin influent was turned on and the pond influent was shut off. The fish were in several large schools and appeared to be acting normally. As more fish entered the catch basin, turbidity increased and within a few minutes, a redish-black color and a foul odor was noted; at one point, a sulfur smell was noted. Almost immediately, the fish began turning on their sides and were in severe distress. An attempt was made to get a DO reading but the needle pegged on the high side of both ranges. The pond influent was immediately turned on, but it was already too late. After turning in the pond water, (DO of 9.0), an effluent DO of 6.0 was obtained, but the fish continued to die, and within a half hour, most of the fish were dead (approximately 40,000). Later that afternoon, DO's were taken in adjacent Pond #2; the influent was 9.8 and the effluent was 5.5. The DO for the effluent of Pond #1 remained at 6.0. During the past 4-6 weeks, sick fish had been observed floating on the surface of both ponds, but not in numbers that would cause concern.

In an attempt to determine the cause of the fish loss, water samples were collected on November 9, 1988 (Table 12), and DO's for Pond #2 were taken (Influent 8.4, Effluent 5.6). In addition, dying fish from Pond #2 were collected and examined by Mr. Ken Stark (PFC Pathologist). Although it is not possible to determine a single cause for the fish loss, a number of possibilities exist. The Pathology Report indicated gill fungus and necrosis of gill tissue and an absence of Flexibacteria on gills. Also, Telangiectasis in gill lamellae was observed, possibly an indication of high ammonia levels. Water quality tests indicated high ammonia nitrogen and unionized ammonia in the Pond #2 influent as well as the effluent. The water quality problems appear to be related to the Rockview discharge which enters the stream several hundred yards above our intake. In addition, water temperatures were quite low (47F-52F) during the weeks prior to harvest. Also, throughout the rearing season, the fish were fed with 2 belt feeders placed over the catch basin. It appears that unused feed collected in the deep catch basin and, judging from the odor, may have gone septic, possibly producing hydrogen sulfide. It appears that all of the above factors contributed as stressors, probably culminating with low DO in the catch basin (caused by unused feed) when fish were entering. The following steps will be taken to prevent future loss of American shad fingerlings at Upper Spring Creek:

1. Fish will be stocked before Spring Creek water temperatures reach 55F. Target date on or about October 1.

2. The large 3-acre pond will be used as an influent

supply reservoir to ameliorate intermittant water quality perturbations in Spring Creek.

3. If a dye study indicates insufficient mixing, some type of stream improvement device will be installed below the Rockview discharge so that the water is well mixed before it arrives at Upper Spring Creek intake.

4. Catch basins will be pumped clean and brushed before fish start coming in.

5. Feeders will not be placed over the catch basin.

6. DO will be monitored in the pond and stream prior to, and during pond drawdown.

7. Catch basin influent valves will remain on throughout the rearing season.

8. A portable pump arrangement will be used to provide for a water source to enhance the operation of the mechanical lift.

The harvest of Upper Sring Creek Pond #2 was begun on November 16, 1988. The catch basin was pumped and brushed clean before the pond was brought all the way down. The fish came into the catch basin very well; only 63 fish were lost on the pond bottom outside the catch basin. The fish did not appear to be in very good shape and we began to lose them in the catch basin despite a DO of 6.3 The new aluminum harvest device was used and it worked fairly well, although an electric chain hoist would be a lot better than the hand operated model used. Although the fish in the catch basin were not crowded with a crowding screen, too many fish were taken in the first few lifts. In addition, during quick release into the truck, fish blocked the hose toward the end of the discharge. A hose with running water in the lift device would probably alleviate this problem. After loading the truck, we attempted to leave by circling the pond. The truck became stuck in the mud and it took about 1 1/2 hours to free it. During that time, the oxygen supply to two of the compartments shut off and approximately 6,000 fish were lost. The remaining fish (aproximately 7,000) were released into a raceway at Benner Spring and will be held over winter as requested by SRAFRC. Additionally, we attempted to determine the effect of harvesting with the new device versus the standard bucket method. One compartment was loaded using buckets and another using the new device. The fish were placed in separate raceways. Approximately 2,000 fish were placed in each compartment. After 72 hours, 235 dead were removed from the group harvested with plastic buckets and 571 from the group harvested with the aluminum lift device. It appeared that harvesting with plastic buckets might be easier on the fish; however, since these fish were not in good shape to begin with, the test should be replicated next year. It may be possible that the first truck load can be loaded more quickly using buckets because the fish are so crowded.

On November 17, 1988, 12,000 fingerlings were harvested from USC Pond #2 and stocked in the Juniata River at Thompsontown. An additional 10,000 dead were removed from the catch basin. In total, Upper Spring Creek Pond #2 produced approximately 35,900 fingerlings (36% survival from fry) but only 12,000 (33%) of those produced were successfully stocked. Although this year's harvest was a disappointment, it was felt that we learned a lot from our mistakes, we worked a lot of bugs out of the new system, and that next year's harvest will be more successful.

Overall, 378,000 fry were stocked in the four Centre County ponds (two at Benner Spring and two at Upper Spring Creek) during the spring of 1988. Aproximately 122,500 fingerlings were reared in the ponds (32% survival from fry), but only 44,000 (36%) of the fish produced were successfully stocked. It is hoped that experience gained this year, particularly at Upper Spring Creek, will provide for a significant increase in the percentage of fish stock from those produced in 1989.

On November 17, Dr. John Mudre (IS&T) arrived at Benne Spring to go through our remaining shad, using MS222 and measuring to find fish large enough for radio-tagging. He was able to take 111 fish of suitable size back with him.

During the past summer, 20 triploid grass carp (Ctenopharyngdon idella), averaging 250 mm in length, were released into each of two ponds (Benner Spring Pond #3 and Upper Spring Creek Pond #2) to determine their effectiveness as a biological control for filamentous algae. Unfortunately, it was necessary to stock the fish at a later date than originally planned and the filamentous algae had already begun to grow. In addition, grass carp survival in both ponds was low as only four fish were harvested from each pond (20% survival). At any rate, the grass carp had no visible effect on the growth of filamentous algae in the ponds. A similar study is tentatively planned for 1989 using a larger number of grass carp per pond (30-50) stocked as soon as the ponds are filled. It is hoped that the grass carp will be able to consume the algae as soon as it begins to grow and it will not be able to get a "head-start."

SUMMARY

A total of 33 shipments (32 million eggs) was received at Van Dyke in 1988. Total egg viability was 38.7% and survival to stocking was 89.8%, resulting in production of 11.1 million fry. The majority of the fry were stocked in the Juniata River (6.5 million) with lesser numbers stocked in the Susquehanna River below Conowingo Dam (3.6 million) and the Lehigh River (496 thousand). A total of 74,000 fingerlings were produced at Thompsontown, Benner Spring and Upper Spring Creek and stocked into the Juniata River. Approximately 99 thousand fry were supplied to Brunner Island Aquaculture Facility for grow-out to fingerling size and eventual use in radiotelemetry studies.

All American shad fry were tagged by immersion in 200 ppm oxytetracycline antibiotic 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. Columbia River fry received a single tag on day 5, Delaware River fry received a triple tag on days 5, 9 and 13, and Virginia River fry received a quadruple tag on days 5, 19, 13 and 17.

All American shad fingerlings received tags administered by feeding tetracycline laced feed at a rate of 40g tetracycline per pound of food plus 0.75g glucosamine per pound of food. Tagging was accomplished by feeding the tetracycline laced food for a period of 3 days, preceded by

2 days of starvation. Fingerlings received unique tag combinations in order to distinguish fingerling rearing site. Single, double and triple feed tags were produced, in addition to the single, double, triple, and quadruple immersion tags.

Tag retention for all immersion tags was 100%. Tag retention for production feed tags ranged from 80 to 100%. Incomplete tag retention in fingerling lots resulted in the possibility that small numbers of fingerlings reared at one site were indistinguishable from fingerlings or fry reared at a different site (Table 11). Experimental feed tagging indicated that tagging without glucosamine results in successful tagging but that tagging by feeding TC laced feed for a single day is insufficient for production of acceptable tags.

Fish culture research conducted at Van Dyke in 1988 focused on improving survival of eggs from fertilization to hatch. An alternative method of handling and disinfecting eggs by disinfection in the bag and eliminating draining and compacting of eggs was attempted with inconclusive results. In an analysis of production lots of eggs, jar-by-jar egg survival was shown to be related to processing sequence. Jars processed first experienced significantly higher survival than those processed last. Additional tests of the new, larger "Van Dyke" egg incubation jar were conducted in

1988. The data indicates significantly higher egg survival in these jars over the standard May-Sloan jars. Potential flow problems were noted in the Van Dyke jars, however, and will be rectified prior to a complete shift to the Van Dyke jars for production purposes.

In an attempt to allow longer fishing times and thus collect more eggs from the Columbia River, N.E.S. held eggs overnight in Oregon prior to shipping. The data was inconclusive since extraneous variables were not controlled, however, holding eggs a full 24 hours prior to shipping may result in increased survival and warrants further testing.

RECOMMENDATIONS FOR 1989

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. Tag all production fish according to the schedule approved by SRAFRC for 1988.
4. Feed all ponded fingerlings by hand in addition to automatic feeder to ensure complete TC tag retention.
5. Continue to test "Van Dyke" incubation jars.
6. Make minor modifications to disinfection and handling procedures in an attempt to minimize handling time, egg

compaction and dessication.

7. Devise and conduct research studies to better understand early egg development and improve survival.
8. Conduct a controlled experiment to determine the feasibility of holding Columbia River eggs overnight prior to shipping.
9. Provide a large egg incubation tank and several Van Dyke jars to the egg collectors for use in incubation of production eggs after water hardening and for research as outlined in number 8 above.
10. Continue to explore methods for improving survival of fingerling shad during pond harvest.

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Table 1. Summary of American shad egg shipments received at Van Dyke, 1988.

Shipment Number	River	Date Shipped	Date Received	Vol. (L) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
1	Pamunkey	4/16	4/17	10.02	287,700	52.4	150,700	146,600
2	Pamunkey	4/17	4/18	8.70	302,000	49.7	150,000	148,900
3	Pamunkey	4/18	4/19	9.85	276,500	71.8	198,600	197,780
4	Pamunkey	4/20	4/21	8.10	227,400	27.7	62,900	62,300
5	James	4/20	4/21	0.52	15,000	75.3	11,300	11,040
6	Pamunkey	4/21	4/22	10.02	269,100	55.8	150,200	147,400
7	James	4/21	4/22	1.24	32,700	77.7	25,400	24,900
8	Pamunkey	4/22	4/23	6.33	184,300	62.2	114,700	111,100
9	Pamunkey	4/23	4/24	7.08	203,900	64.3	131,100	128,900
10	Pamunkey	4/27	4/28	4.68	170,100	62.0	105,400	104,720
11	Delaware	5/8	5/9	22.27	560,200	57.3	321,000	296,100
12	Delaware	5/9	5/10	28.26	727,200	72.3	525,800	514,700
13	Delaware	5/12	5/13	14.97	382,000	68.8	262,800	253,300
14	Delaware	5/15	5/16	39.80	1,237,400	59.2	733,000	723,300
15	Columbia	6/1	6/2	31.62	1,128,400	22.9	258,100	249,500
16	Columbia	6/2	6/3	16.88	576,400	43.5	250,600	248,100
17	Columbia	6/3	6/4	22.16	806,800	25.4	204,700	198,700
18	Columbia	6/9	6/10	42.85	1,394,600	28.8	402,000	393,500

Table 1. (Continued)

Shipment Number	River	Date Shipped	Date Received	Vol. (L) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
19	Columbia	6/10	6/11	21.40	730,200	48.9	357,300	353,300
20	Columbia	6/13	6/14	26.74	870,600	47.2	410,800	406,000
21	Columbia	6/13	6/14	16.18	552,100	13.4	74,000	73,700
22	Columbia	6/14	6/15	23.00	749,800	52.3	391,900	383,900
23	Columbia	6/15	6/16	50.32	1,771,300	46.9	830,100	811,300
24	Columbia	6/15	6/16	14.62	570,600	29.8	170,200	167,500
25	Columbia	6/16	6/17	59.94	1,996,800	33.5	667,900	640,600
26	Columbia	6/17	6/18	73.62	2,680,400	50.1	1,342,500	1,323,700
27	Columbia	6/20	6/21	57.16	2,143,800	35.8	766,900	755,400
28	Columbia	6/21	6/22	42.62	1,640,800	36.8	604,300	599,400
29	Columbia	6/21 6/22	6/24	61.14	2,954,700	0.0	----	----
30	Columbia	6/23	6/24	29.84	1,506,600	55.3	832,900	797,200
31	Columbia	6/24	6/25	38.84	1,570,700	48.8	767,200	759,300
32	Columbia	6/25	6/26	32.20	1,169,500	20.9	244,700	175,300
33	Columbia	6/26	6/27	52.20	2,103,700	37.3	784,600	742,800
	Pamunkey River		Totals	64.78	1,921,000	55.4	1,063,600	1,047,700
	James River			1.76	47,700	76.9	36,700	35,940
	Delaware River			105.30	2,906,800	63.4	1,842,600	1,787,400
	Columbia River			713.33	26,917,800	34.8	9,360,700	9,079,200
			Grand Total	885.17	31,793,300	38.7	12,303,600	11,950,240

Table 2. Annual Summary of Van Dyke production from 1976-1988.

					No. of Shad Stocked (All Rivers)				
Year	Egg Vol. (L)	Egg No. (exp.6)	Egg Viability (%)	Viable Eggs (Exp. 6)	Fry (Exp. 3)	Fingerling (Exp. 3)	Total (Exp. 3)	Fish Stocked/ Eggs Rec'd.	Fish Stocked/ Viable Egg
1976	120.3	4.0	52.0	2.1	518	266	784	0.194	0.373
1977	145.8	6.4	46.7	2.9	969	35	1,003	0.159	0.342
1978	381.2	14.5	44.0	6.4	2,124	6	2,130	0.104	0.330
1979	164.8	6.4	41.4	2.6	629	34	664	0.104	0.251
1980	347.6	12.6	65.6	8.2	3,526	5	3,531	0.283	0.431
1981	286.0	11.6	44.9	5.2	2,030	24	2,053	0.177	0.393
1982	624.3	25.9	35.7	9.2	5,019	41	5,060	0.196	0.548
1983	938.6	34.5	55.6	19.2	4,048	98	4,146	0.120	0.216
1984	1,157.3	41.1	45.2	18.6	11,996	30	12,026	-	0.728*
1985	814.3	25.6	40.9	10.1	6,960	115	7,075	0.279	0.682*
1986	1,535.7	52.7	40.7	21.4	15,867	61	15,928	0.302	0.744
1987	974.2	33.0	47.9	15.8	10,274	81	10,355	0.314	0.655
1988	885.2	31.8	38.7	12.3	10,441	74	10,515	0.331	0.855

Total Shad Stcked from 1976 to 1988 = 75,882,628
*Eggs and fish that were not used for stocking purposes were not included.

Table 3. American shad stocking and fish transfer activities, Van Dyke, 1988.

* All tetracycline tags administered at 200 ppm, 6 hour bath except feed tag administered at 40g TC/lb feed + .75g glucosamine/lb food.

** Fish transferred to ponds, raceways and other facilities.

Date	Tanks(s)	Number	Tagging days*	Location	Origin	Age (days)	Size
5/13	A3	5,000	5,9,13,17	BS Raceway D1	Pamunkey	18	Fry
5/13	A3	92,865	5,9,13,17	BS Pond 2	Pamunkey	18	Fry
5/13	A3	92,865	5,9,13,17	BS Pond 3	Pamunkey	18	Fry
5/13	A2	133,680	5,9,13,17	Thompsontown	Pamunkey	18	Fry
5/15	A1	138,650	5,9,13,17	Thompsontown	Pamunkey	21	Fry
5/16	A4	71,650	5,9,13,17	Thompsontown	Pamunkey/ James	19	Fry
5/17	B2	105,450	5,9,13,17	Thompsontown	Pamunkey	18	Fry
5/30	B3	87,580	5,9,13,17	Thompsontown	Pamunkey	30	Fry
5/30	B4	97,100	5,9,13,17	Thompsontown	Pamunkey	26	Fry
5/31	B1	98,775	5,9,13,17	Brunner Island	Pamunkey	33	Fry
5/31	B1	48,575	5,9,13,17	Thompsontown	Pamunkey	33	Fry
6/1	C1,C2	98,805	5,9,13	USC Pond 1	Delaware	16 or 17	Fry
6/1	C1,C2	98,805	5,9,13	USC Pond 2	Delaware	16 or 17	Fry
6/1	C1,C2	3,000	5.9,13	BS Raceway D2	Delaware	16 or 17	Fry
6/1	C1,C2	35,970	5,9,13	Thompsontown	Delaware	16 or 17	Fry
6/6	C4	240,920	5,9	Lapidum	Delaware	20	Fry
6/6	C3	213,410	5,9	Lapidum	Delaware	20	Fry
6/7	D1	227,260	5,9,13	Thompsontown	Delaware	18	Fry
6/9	D3	107,090	5,9,13	Canal Pond	Delaware	17	Fry
6/9	D2,D3	340,400	5,9,13	Lehigh River	Delaware	17	Fry
6/10	D4	232,440	5,9,13	Thompsontown	Delaware	18	Fry
6/27	A1,A2,A3	655,030	5,9	Lapidum	Columbia	19,18,17	Fry
7/5	A4	229,960	5	Thompsontown	Columbia	19	Fry
7/6	B1	145,070	5	Thompsontown	Columbia	20	Fry
7/7	B2	15,000	5	Wellsboro	Columbia	20	Fry
7/7	B2	323,460	5	Thompsontown	Columbia	20	Fry
7/8	B3,B4,C1	778,180	5,9	Lapidum	Columbia	18,17	Fry
7/10	C2	238,260	5	Thompsontown	Columbia	18	Fry

Table 3. (Continued)

Date	Tanks(s)	Number	Tagging days*	Location	Origin	Age (days)	Size
7/11	C3	245,940	5	Thompsontown	Columbia	19	Fry
7/11	C4,D1	406,630	5	Thompsontown	Columbia	19	Fry
7/13	D2,D3	315,180	5	Thompsontown	Columbia	20	Fry
7/13	D4	236,070	5	Thompsontown	Columbia	20	Fry
7/14	F1	435,590	5	Thompsontown	Columbia	17	Fry
7/15	E1,E2, E3,E4	1,171,740	5,9	Lapidum	Columbia	21	Fry
7/16	F2	289,570	5	Thompsontown	Columbia	19	Fry
7/17	F3,F4	571,090	5	Thompsontown	Columbia	19	Fry
7/18	G3	363,830	5	Thompsontown	Columbia	18	Fry
7/19	H1,H2	471,430	5	Thompsontown	Columbia	18	Fry
7/20	G1,G2	176,390	5	Thompsontown	Columbia	19	Fry
7/21	H3,I1	312,620	5	Thompsontown	Columbia	20,19	Fry
7/21	G4	395,460	5	Thompsontown	Columbia	21	Fry
7/22	I2,I3,I4	590,260	5,9	Lapidum	Columbia	19	Fry
7/25	H4	115,780	5	Thompsontown	Columbia	23	Fry
9/1	Canal Pond	30,000	5,9,13 Feed (91-93)	Thompsontown	Delaware	101	Fing.
10/26	Benner Spring Pond 3	7,000	5,9,13,17 Feed (114-116, 126-128, 161-163)	Thompsontown	Virginia	184	Fing.
10/27	Benner Spring Pond 3	15,000	5,9,13,17 Feed (114-116, 126-128, 161-163)	Thompsontown	Virginia	185	Fing.
11/3	Benner Spring Pond 2	10,000	5,9,13,17 Feed (114-116, 126-128, 161-163)	Thompsontown	Virginia	192	Fing.
11/17	Upper Spring Creek Pond 2	12,000	5,9,13 Feed (94-96, 106-108, 118-120)	Thompsontown	Delaware	185	Fing.

Table 4. Production and utilization of juvenile American shad at the Van Dyke Research Station, 1988.

Fry released into the Juniata River	6,450,685
Fry released into the Susquehanna River below Conowingo Dam	3,649,540
Fry released into the Lehigh River	340,400
Fry released into ponds at Van Dyke and Ancillary Facilities	107,090
Fry provided to Upper Spring Creek Ponds	197,610
Fry provided to Benner Spring Research Station	193,730
Fry provided to Brunner Island Aquaculture Project	98,775
Fry provided to Wellsboro National Fishery and Development Lab	15,000
Total Fry Production	11,052,835
Total Number of Viable Eggs	12,303,600
Survival (%) of all fry	89.8
Fingerlings Released into the Juniata River:	
From the Canal Pond (Thompsontown)	30,000
From the Benner Spring Ponds	32,000
From Upper Spring Creek Ponds	12,000

Table 5. Survival of American shad eggs disinfected in the shipping bag and measured by wet volume techniques without net handling vs controls drained in nets before and after disinfection and measured by dry volume techniques.

	Shipment	Jars	No. of Eggs	No. of Live Eggs	% Survival
Test	3	1003, 1104	118,500	88,200	74.4
Control	3	1001, 1002	118,500	85,900	72.5
Test	6	1007, 1008	115,200	60,100	52.2
Control	6	1005, 1006	115,200	69,400	60.2
Test	13	1011, 1012	114,800	96,100	83.7
Control	13	1009, 1010	114,800	75,200	65.5

Table 6. Survival of American shad eggs incubated in May-Sloan jars as a function of jar processing sequence, 1988. Jars which were combined were eliminated, as were jars with less than 2.4 or more than 2.6 liters of eggs.

Shipment	Jar No.	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
1	1	1	2.5	71,800	58.2
	2	2	2.5	71,800	56.1
	3	3	2.5	71,800	53.8
	4	4	2.52	72,300	41.5
2	5	1	2.5	86,800	79.2
	6	2	2.5	86,800	77.8
	7	3	2.5	86,800	72.1
8	16	1	2.5	72,800	64.8
	17	2	2.5	72,800	60.0
9	19	1	2.5	72,000	68.2
	20	2	2.5	72,000	60.1
13	36	1	2.5	63,800	74.3
	77	2	2.5	63,800	57.8
14	44	1	2.5	77,700	69.2
	45	2	2.5	77,700	62.0
	46	3	2.5	77,700	47.5
	47	4	2.5	77,700	51.5
	48	5	2.5	77,700	46.7
20	69	1	2.5	81,400	52.8
	70	2	2.5	81,400	55.9
	71	3	2.5	81,400	50.7
	72	4	2.5	81,400	51.2
	73	5	2.5	81,400	55.7
	74	6	2.5	81,400	51.2
	75	7	2.5	81,400	50.6
	76	8	2.5	81,400	46.6
	77	9	2.5	81,400	34.2
	78	10	2.5	81,400	38.7

Table 6. (Continued)

Shipment	Jar No.	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
22	87	1	2.5	81,500	61.2
	88	2	2.5	81,500	52.0
	89	3	2.5	81,500	43.4
	90	4	2.5	81,500	55.5
	91	5	2.5	81,500	58.8
	92	6	2.5	81,500	49.5
	93	7	2.5	81,500	55.1
	94	8	2.5	81,500	48.6
23	97	1	2.5	88,000	53.9
	98	2	2.5	88,000	55.9
	99	3	2.5	88,000	44.9
	100	4	2.5	88,000	51.7
	101	5	2.5	88,000	62.3
	102	6	2.5	88,000	41.6
	103	7	2.5	88,000	48.1
	104	8	2.5	88,000	57.6
	105	9	2.5	88,000	48.8
	106	10	2.5	88,000	30.6
	107	11	2.5	88,000	67.4
	108	12	2.5	88,000	26.8
	109	13	2.5	88,000	39.3
	110	14	2.5	88,000	40.6
	111	15	2.5	88,000	43.4
	112	16	2.5	88,000	52.1
	113	17	2.5	88,000	40.2
	114	18	2.5	88,000	40.5
24	117	1	2.5	102,700	34.6
	118	2	2.5	102,700	33.9
	119	3	2.5	102,700	36.5
	120	4	2.5	102,700	32.3
	121	5	2.5	102,700	24.8

Table 7. Survival of American shad eggs and fry incubated in Van Dyke jars vs controls incubated in May-Sloan jars, Van Dyke, 1988.

Shipment	Jar	Jar Type	Dry Vol. (L)	No. of Eggs	No. of Viable Eggs	% Survival	Tank	Fry Mortality	Fry Survival (%) From Viable Eggs	Fry Survival (%) From Eggs
11	24	MS	2.5	62,900	28,800	45.8				
	25	MS	2.5	62,900	26,700	42.5				
	26	MS	2.27	57,100	28,300	49.6				
	27	MS	2.0	50,300	25,100	49.9				
	28	MS	2.0	50,300	22,900	45.5				
Subtotal			11.27	283,500	131,800	46.5	C2	41,270	73.0	33.9
	005	VD	11.00	276,700	189,200	68.4	C1	43,150	78.6	53.8
12	29	MS	2.5	63,000	41,300	65.6				
	30	MS	2.5	63,000	44,400	70.5				
	31	MS	2.5	63,000	38,200	60.6				
	32	MS	2.5	63,000	38,500	61.1				
	33	MS	2.5	63,000	42,600	67.6				
Subtotal			12.5	315,000	205,000	65.1	N/A	-	-	-
	006	VD	12.5	314,900	260,700	82.8	N/A	-	-	-
14	39	MS	2.5	77,700	45,200	58.2				
	40	MS	2.5	77,700	47,500	61.1				
	41	MS	2.5	77,700	47,700	61.4				
	42	MS	2.5	77,700	48,100	61.9				
	43	MS	2.5	77,700	44,800	57.7				
Subtotal			12.5	388,500	233,300	60.1	D3	19,120	91.8	55.1
	007	VD	12.5	388,600	250,300	64.4	D2	16,990	93.2	60.0
15	50	MS	2.5	90,000)	52,300	29.1				
	51	MS	2.5	90,000)						
	52	MS	2.5	90,000)						
	53	MS	2.5	90,000)	62,500	23.2				
	54	MS	2.5	90,000)						
Subtotal			12.5	450,000	114,800	25.5	N/A	-	-	-
	005	VD	12.5	450,100	75,100	16.7	N/A	-	-	-

Table 7. (Continued)

									Fry Survival (%)	
Shipment	Jar	Jar Type	Dry Vol. (L)	No. of Eggs	No. of Viable Eggs	% Survival	Tank	Fry Mortality	From Viable Eggs	From Eggs
31	154	MS	2.5	101,100)	88,300	43.7				
	155	MS	2.5	101,100)						
	156	MS	2.5	101,100)	87,100	43.1				
	157	MS	2.5	101,100)						
	158	MS	2.5	101,100)	37,300	36.9				
Subtotal			12.5	505,500	212,700	42.1	H2	14,850	93.0	39.1
	015	VD	12.5	505,500	278,200	55.0	H1	4,620	98.3	54.1
32	160	MS	2.5	90,800)	36,600	20.2				
	161	MS	2.5	90,800)						
	162	MS	2.5	90,800)	38,800	21.5				
	163	MS	2.5	90,800)						
	164	MS	2.5	90,800)	20,300	22.4				
Subtotal			12.5	454,000	95,700	21.1	G2	13,780	86.1	18.0
	017	VD	12.5	454,000	101,200	22.3	G1	7,230	92.9	20.7
33	168	MS	2.5	102,700)						
	169	MS	2.5	102,700)	89,700	29.1				
	170	MS	2.5	102,700)						
	171	MS	2.5	102,700	23,800	23.2				
	172	MS	2.5	102,700	26,500	25.8				
Subtotal			12.5	513,500	140,000	27.3	I3	25,530	81.8	22.3
	007	VD	12.5	513,500	263,000	51.2	I2	23,820	90.9	46.6
TOTALS		MS	73.7	2,910,000	1,133,300	39.0		114,550	85.9	32.6
		VD	73.5	2,514,700	1,417,700	56.4		95,810	91.1	56.4

Table 8. Survival of American shad eggs held overnight in Oregon vs eggs shipped immediately after collection, or held 24 hours prior to shipping, 1988. *30,000 live eggs from jar 122 given to Johns Hopkins University resulting in artifically lower survival. Note: Not a controlled experiment. Se text for explanation.

Shipment	Fishing Date	Shipping Date/Time (PST)	Arrival Date/Time (EST)	Holding	Jar No.	Dry Vol. (L)	No. of Eggs	% Survival
20	6/13/88	6/13 11:30 p.m.	6/14 11:30 a.m.	None	69	2.50	81,400	52.8
					70	2.50	81,400	55.9
					71	2.50	81,400	50.7
					72	2.50	81,400	51.2
					73	2.50	81,400	55.7
					74	2.50	81,400	51.2
					75	2.50	81,400	50.6
					76	2.50	81,400	46.6
					77	2.50	81,400	34.2
					78	2.50	81,400	38.7
					79	1.74	56,600	24.6
					Total	26.74	870,600	47.2
21	6/13/88	6/14 10:30 a.m.	6/14 9:00 p.m.	Over-night	80	2.50	85,300)	18.1
					81	2.50	85,300)	
					82	2.50	85,300)	13.1
					83	2.50	85,300)	
					84	2.50	85,300)	
					85	2.50	85,300)	9.9
					86	1.18	40,300)	----
					Total	16.18	552,100	13.4

Table 8. (Continued)

Shipment	Fishing Date	Shipping Date/Time (PST)	Arrival Date/Time (EST)	Holding	Jar No.	Dry Vol. (L)	No. of Eggs	% Survival
23	6/15/88	6/15	6/16	None	97	2.50	88,000	53.9
		11:30 p.m.	11:30 a.m.		98	2.50	88,000	55.9
					99	2.50	88,000	44.9
					100	2.50	88,000	51.7
					101	2.50	88,000	62.3
					102	2.50	88,000	41.6
					103	2.50	88,000	48.1
					104	2.50	88,000	57.6
					105	2.50	88,000	48.8
					106	2.50	88,000	30.6
					107	2.50	88,000	67.4
					108	2.50	88,000	26.8
					109	2.50	88,000	39.3
					110	2.50	88,000	40.6
					111	2.50	88,000	43.4
					112	2.50	88,000	52.1
					113	2.50	88,000	40.2
					114	2.50	88,000	40.5
					115	2.82	99,300	43.7
					116	2.50	88,000	48.5
					Total	50.32	1,771,300	46.9
24	6/15/88	6/16	6/16	Over-	117	2.50	102,700	34.6
		6:30 a.m.	8:30 p.m.	night	118	2.50	102,700	33.9
					119	2.50	102,700	36.5
					120	2.50	102,700	32.3
					121	2.50	102,700	24.8
					122*	2.12	57,100	6.5
					Total	14.62	570,600	29.8
				Total excluding Jar 122			513,500	32.4

Table 8. (Continued)

Shipment	Fishing Date	Shipping Date/Time (PST)	Arrival Date/Time (EST)	Holding	Jar No.	Dry Vol. (L)	No. of Eggs	% Survival
32	6/25/88	6/26/88 6:30 a.m.	6/26/88 7:00 p.m.	Over-night	017	12.50	454,000	22.3
					160	2.50	90,800)	20.2
					161	2.50	90,800)	
					162	2.50	90,800)	21.5
					163	2.50	90,800)	
					164	2.50	90,800	22.4
					165	2.50	90,800)	16.9
					166	2.50	90,800)	
					167	2.20	79,900	21.5
					Total	32.20	1,169,500	20.9
33	6/25/88	6/26/88 11:30 p.m.	6/27/88 4:30 p.m.	24 Hours	176	2.50	90,800	51.0
					177	2.50	90,800	33.8
					178	2.50	90,800	34.5
					179	1.04	37,800	26.5
					Total	8.54	310,200	38.1

Table 9. Tetracycline tagging regime for American shad stocked in the Susquehanna River Basin, 1988. Immersion tag/feed tag.

Size at Stocking	Pond/ Raceway	Stocking Location	Egg Source River: Virginia	Delaware	Columbia
Fry	-	Thompsontown (Juniata R.)	Quadruple/0	Triple/0	Single/0
Fry	-	Lapidum (Below Conowingo)	Double/0	Double/0	Double/0
Fingerling	Benner Spring Ponds 2 & 3	Thompsontown	Quadruple/ Triple	-	-
Fingerling	Canal Pond	Thompsontown	-	Triple/ Single	-
Fingerling	Upper Spring Creek Pond 2	Thompsontown	-	Triple/ Triple	-
Fingerling	Brunner Island		Quadruple/ Single	-	-

Table 10. Tetracycline tag retention for American shad reared in 1988. Immersion tags all 200 ppm oxytetracycline, 6 hour bath on days 5, 5 and 9; 5, 9, and 13; or 5, 9, 13, and 17. Feed tags all 40g tetracycline/lb food plus 0.75g glucosamine/lb food, fed for 3 days after 2 days of starvation. Multiple feed tags at least 7 days apart.

* Feed tags administered without glucosamine
**Third feed tag single day only

Pond/ Raceway	Tag Immersion	/ Feed	% Exhibiting Tag Immersion	/ Feed	# Stocked	Sampling	Disposition
Wells.	Single	/ Triple	29/29 (100%)	29/29 (100%)	-		Research
VDRP	Double	/ 0	47/47 (100%)	-	-	Harvest	Research
CP	Triple	/ Single	49/49 (100%)	49/49 (100%)	30,000	Harvest	Stocked 9/1/88 T-Town
USCP1	Triple	/ Double	25/25 (100%)	23/25 (92.0%)			
		Single		1/25 (4.0%)			
		None		1/25 (4.0%)			
				25 (100%)	-	Seine	Mortality
USCP2	Triple	/ Triple	24/24 (100%)	21/24 (87.5%)	10,500		
		Double		2/24 (8.3%)	996		
		Single		1/24 (4.2%)	504	Seine/	Stocked
				24 (100%)	12,000	Dip Net	11/17/88 T-Town
BSRD2	Triple	/ Double*	30/30 (100%)	30/30 (100%)	-	Dip Net	Re-Tagged
BSRD2 (Re-Tagged)	Triple	/ Triple**	24/24 (100%)	3/24 (12.5%)			
		Double		21/24 (87.5%)			
				24 (100%)		Dip Net	Research
BIR	Quadruple	/ Single	28/28 (100%)	28/28 (100%)	945	Mortality	Turbine Mortality Studies (RMC/IS&T)

Table 10. (Continued)

Pond/ Raceway	Tag Immersion	/ Feed	% Exhibiting Tag Immersion	/ Feed	# Stocked	Sampling	Disposition
BSRD1	Quadruple	/ Double	59/59 (100%)	59/59 (100%)	-	Dip Net	Research
BSP2	Quadruple	/ Double	25/25 (100%)	21/25 (84.0%)			
		Single		3/25 (12.0%)			
		None		1/25 (4.0%)			
				25 (100%)	-	Seine	Re-Tagged
BSP2 (Re-Taggged)	Quadruple	/ Quadruple	30/30 (100%)	0/30 0	0		
		Triple		24/30 (80.0%)	8,000		
		Double		5/30 (16.7%)	1,670		
		Single		0/30 0	0		
		None		1/30 (3.3%)	330		Stocked
				30 (100%)	10,000	Harvest	11/3/88
							T-Town
BSP3	Quadruple	/ Double	25/25 (100%)	7/25 (28.0%)			
		Single		1/25 (4.0%)			
		None		17/25 (68.0%)			
				25 (100%)	-	Seine	Re-Tagged
BSP3 (Re-Tagged)	Quadruple	/ Quadruple	30/30 (100%)	0/30 0	0		
		Triple		25/30 (83.3%)	18,334		
		Double		0/30 0	0		
		Single		4/30 (13.3%)	2,933		
		None		1/30 (3.3%)	733		Stocked
				30 (100%)	22,000	Harvest	10/26-27/88
							T-Town

Key:
- Wells. - Wellsboro Ponds
- VDRP - Van Dyke Rearing Pond
- CP - Canal Pond (Thompsontown)
- USCP1 - Upper Spring Creek Pond 1
- USCP2 - Upper Sorubg Creek Pond 2
- BSRD2 - Benner Spring Raceway D-2
- BSRD1 - Benner Spring Raceway D-1
- BIR - Brunner Island Raceway
- BSP2 - Benner Spring Pond 2
- BSP3 - Benner Sprig Pond 3

Table 11. Projected numbers of juvenile American shad stocked by tetracycline tag combination, Susquehanna River Basin, 1988. Egg source River and stocking location listed for fry, rearing site listed for fingerlings. Projections based on estimates of numbers stocked (Table 3) and tag retention (Table 10). *Fish which did not retain proper tag. Refer to Table 10 for key.

	Feed Tag				
	None	Single	Double	Triple	Quadruple
Immersion Tag	(Fry Releases)	(Fingerling Releases)			
Single	5,272,330 Col. R. source Thompsontown	-	-	-	-
Double	3,649,540 All sources Lapidum	-	-	-	-
Triple	495,670 Del. R. source Thompsontown	30,000 Canal Pond	996* USCP2	10,500 USCP2	-
	340,400 Del. R. source Lehigh R.	504* USCP2			
Quadruple	682,685 VA R. source Thompsontown	945 Brunner Is.	1,670* BSP2	8,000 BSP2	-
	330* (Fingerling) BSP2	2,933* BSP3		18,334 BSP3	
	733* (Fingerling) BSP3				

Table 12. Water chemistrys at selected sites influencing water quality at Upper Spring Creek Ponds, November 9, 1988.

Parameter	Above Rockview Effluent	Rockview Effluent	Below Rockview Effluent	Pond #2 Influent	Pond #3 Effluent	Pond #3 Catch Basin Influent
pH	8.3	8.2	8.4	8.1	7.9	7.8
B.O.D. (mg/l)	1.8	735.4	2.8	2.8	6.0	1.2
NH_3-N (mg/l)	0.28	8.56	.037	.057	1.03	Interference
Unionized Ammonia (mg/l)	.0090	.2192	.0148	.0116	.0133	-
Water Temp. (C)	8.5	8.5	8.5	8.5	8.5	8.5

Figure 1. Mean survival (%) of all American shad eggs and fry incubated and reared at Van Dyke, 1988.

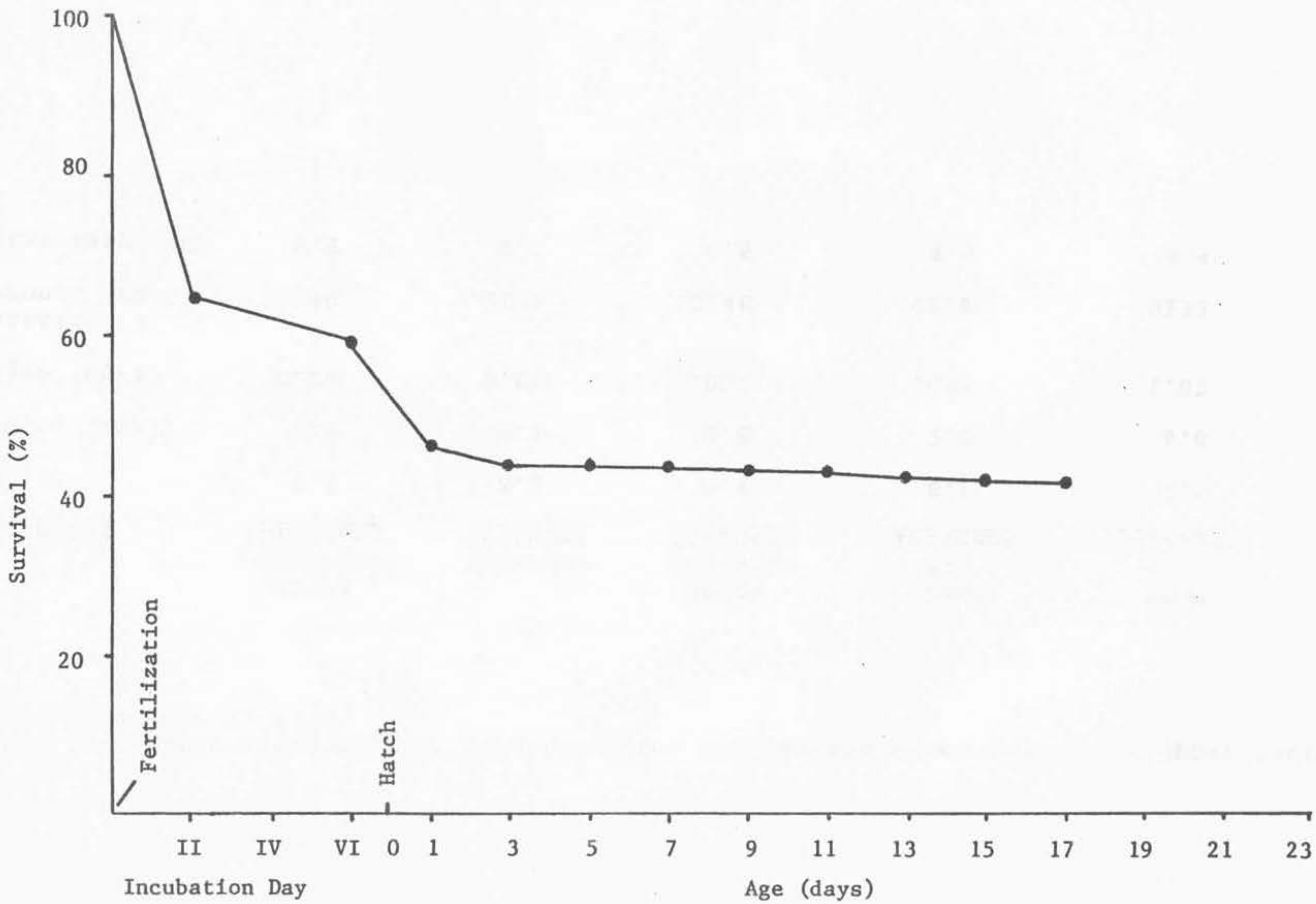


Figure 2. Survival of American shad eggs disinfected in the shipping bag and measured by wet volume techniques without net handling vs. controls drained in nets before and after disinfection and measured by dry volume techniques.

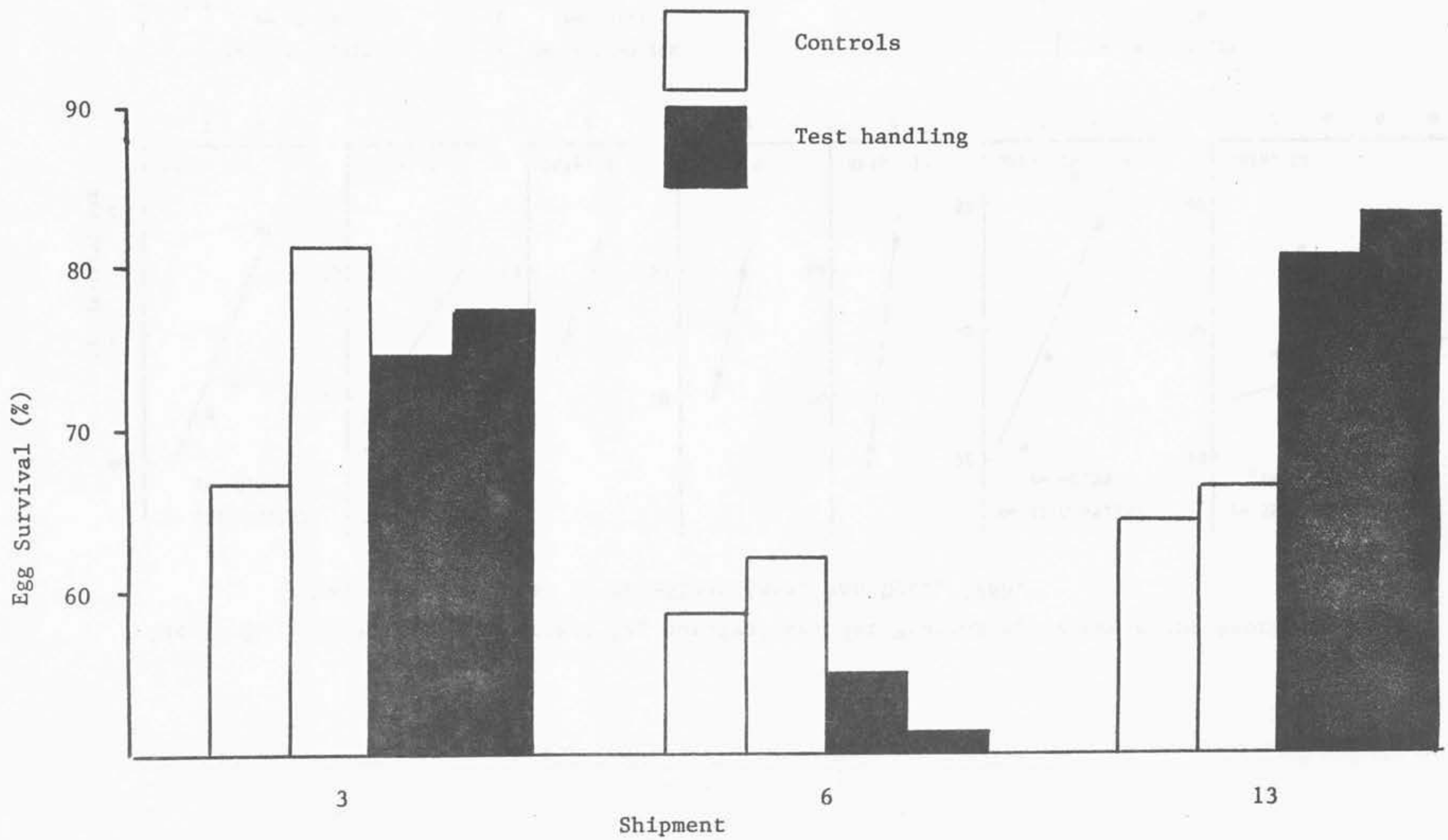


Figure 3. Regressions of Percent Egg Survival vs. Jar Processing Sequence for American shad eggs incubated in May-Sloan jars, Van Dyke, 1988.

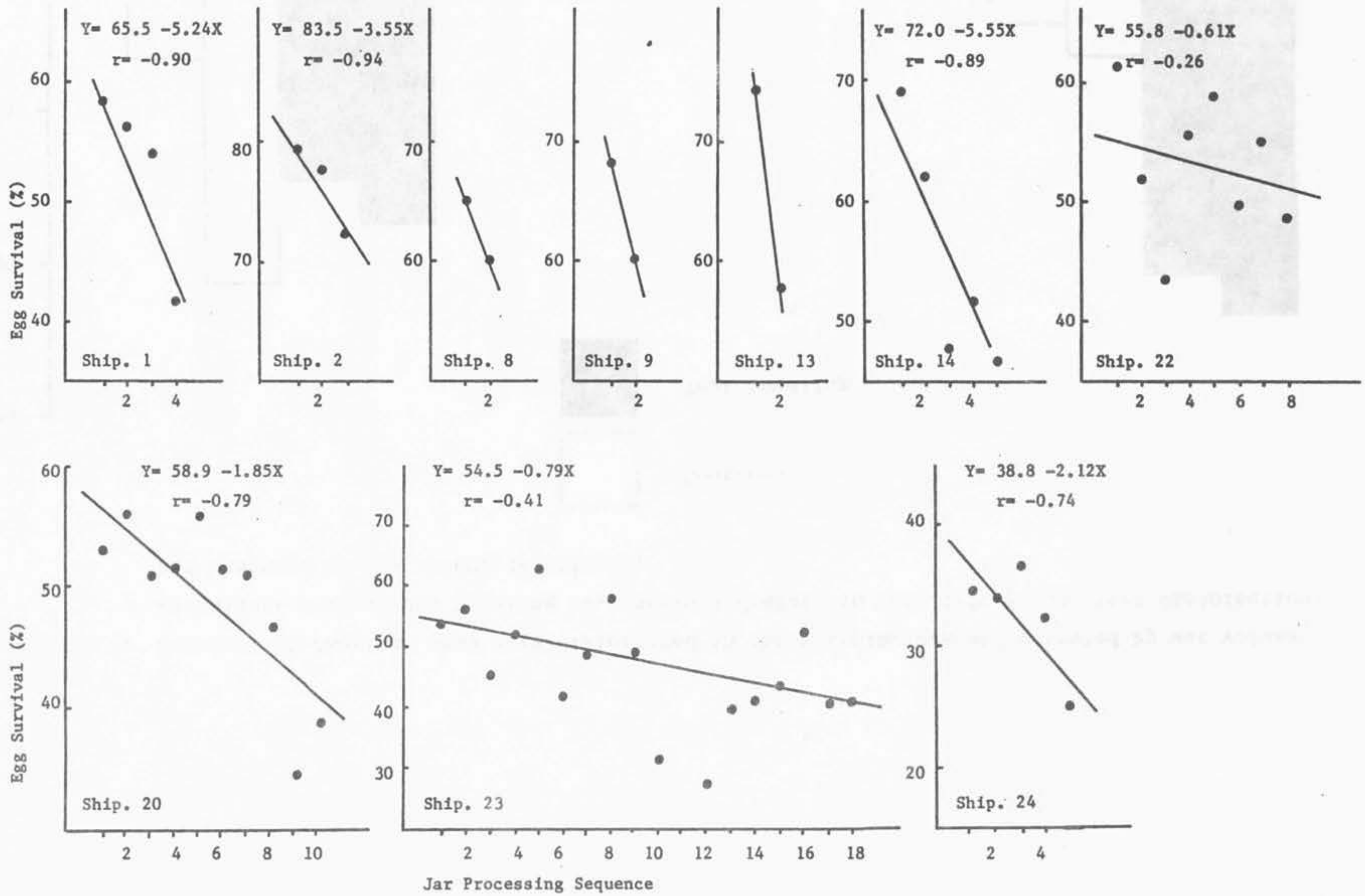


Figure 4. Survival of American shad eggs incubated in Van Dyke jars vs. controls incubated in May-Sloan jars, Van Dyke, 1988.

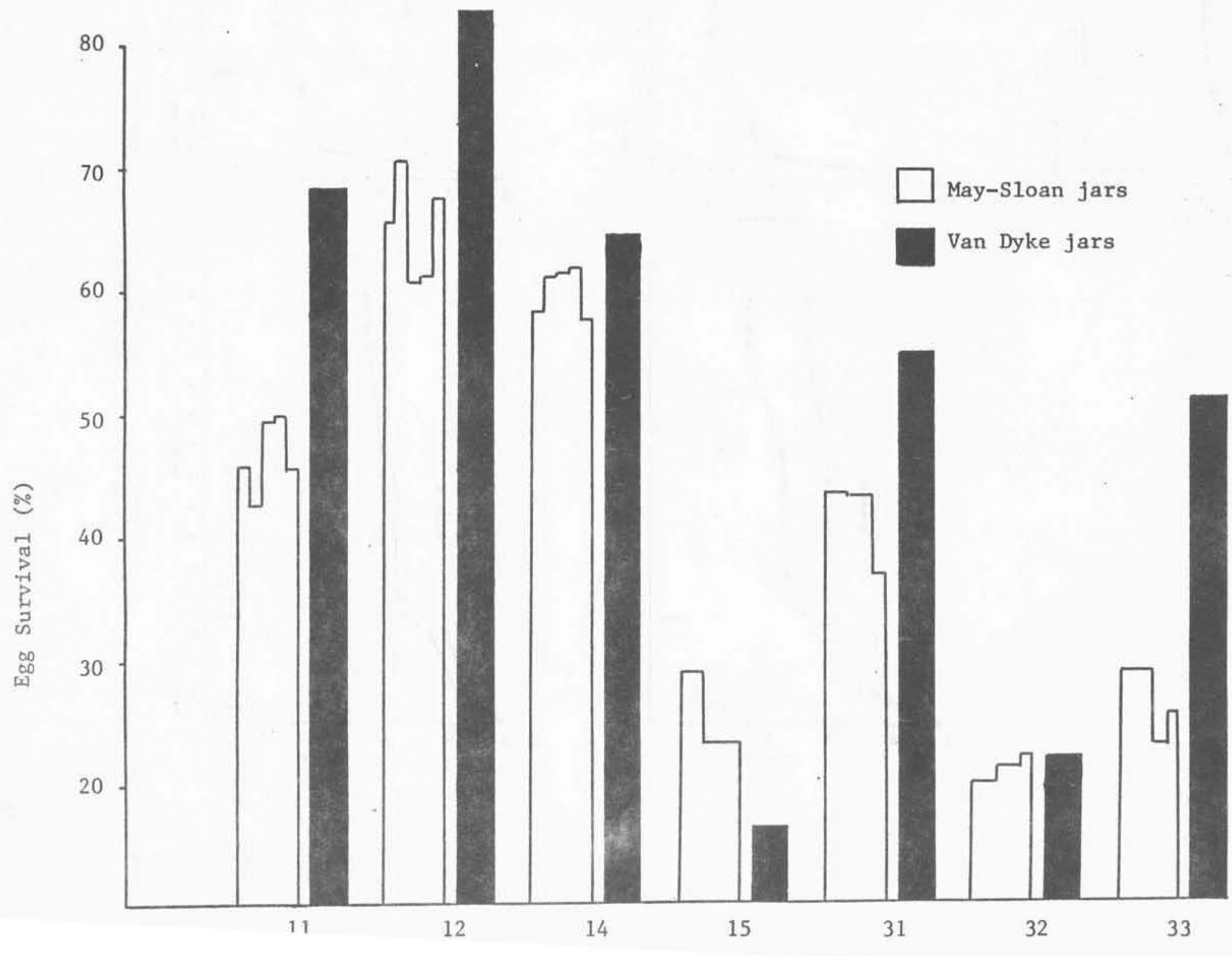
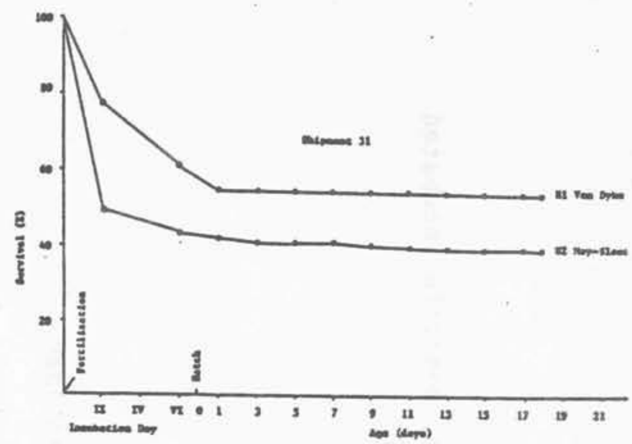


Figure 5. Survival of American shad eggs and fry incubated in Van Dyke jars vs. May-Sloan jars, Van Dyke, 1988.



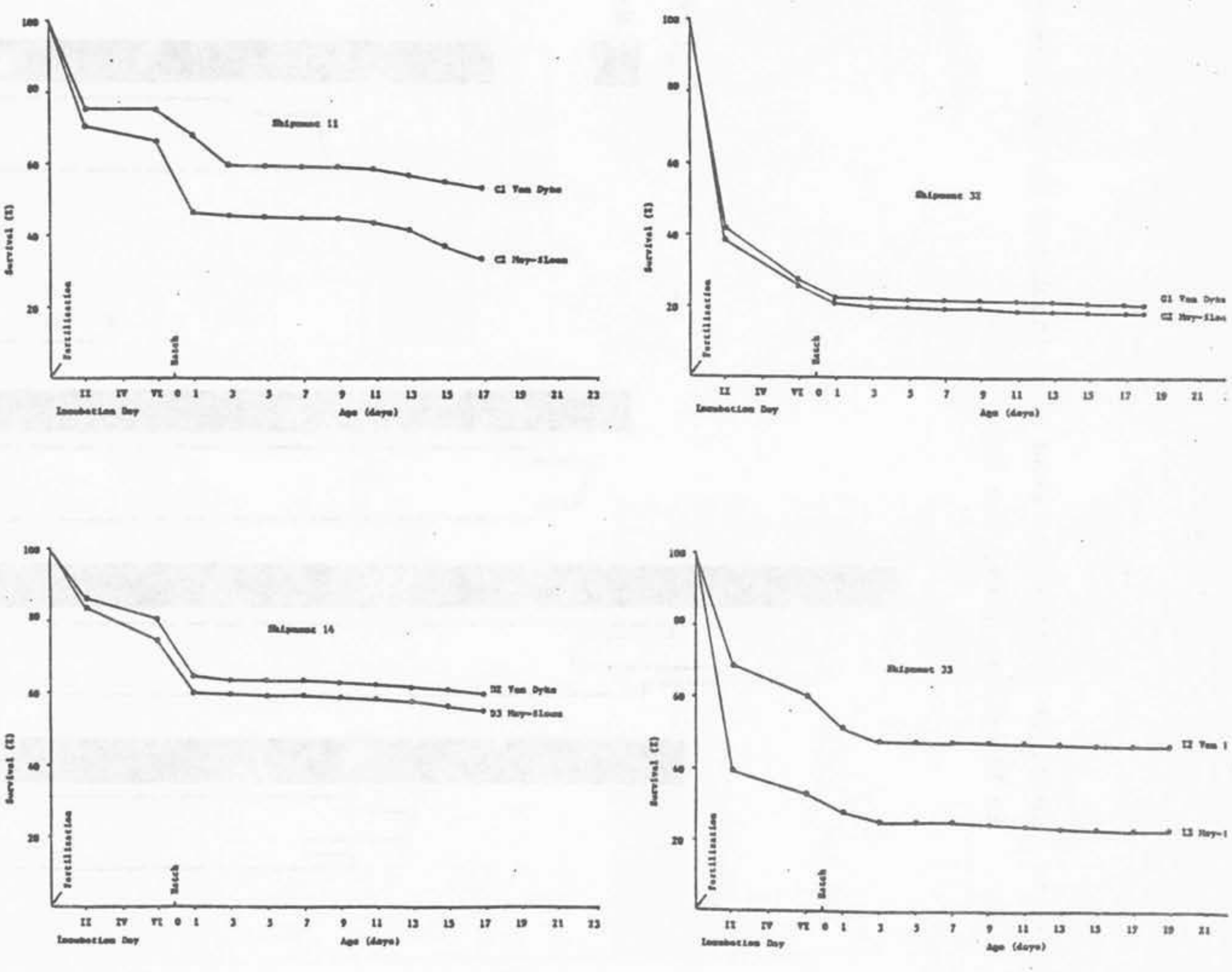
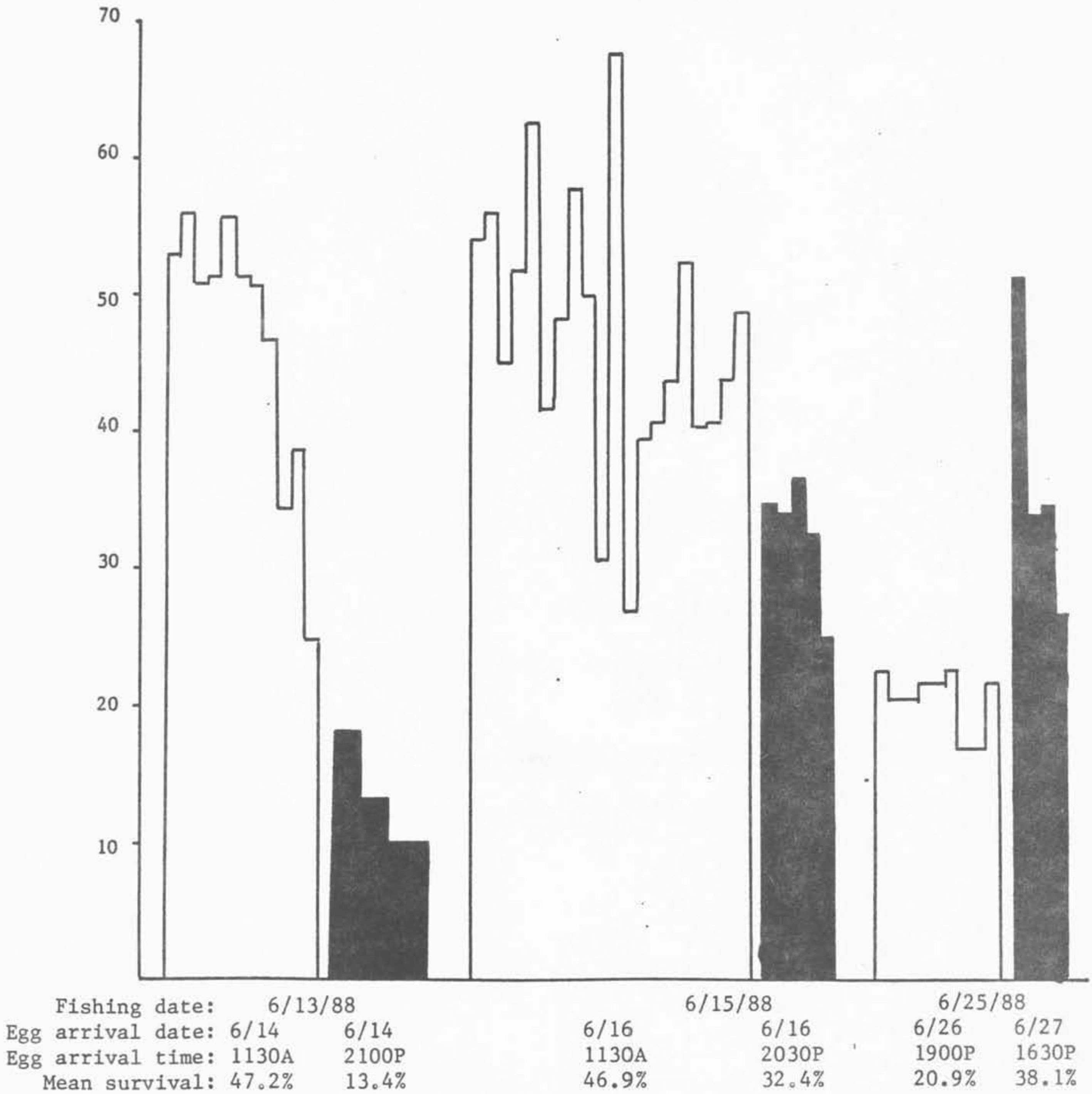


Figure 6. Survival of American shad eggs held overnight in Oregon vs. eggs shipped immediately after collection or held for 24 hours prior to shipping, 1988. Note: Not a controlled experiment. See text for explanation.



JOB IV. JUVENILE AMERICAN SHAD OUTMIGRATION ASSESSMENT

Richard St. Pierre
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INTRODUCTION

Each year SRAFRC contractors collect juvenile American shad at numerous locations in the lower Susquehanna River in an effort to document timing of the migration, growth rates and abundance. Analysis of tetracycline marks on otoliths of subsampled shad indicate what proportion of the collection is of hatchery origin. Also, because the various shad egg sources and pond culture sites were distinctively marked (see Job III), we are able to differentiate the relative contribution of each stocked strain and culture situation to the outmigrant population.

Since no adult shad were stocked above York Haven Dam in 1988, all juveniles reaching that site during emigration were from the hatchery. Therefore, seine sampling at Amity Hall near the mouth of the Juniata River was discontinued. Shad were collected with nets at York Haven and Holtwood forebays, from cooling water strainers at Safe Harbor and Conowingo hydroelectric projects, and by electrofishing in the lower river below Conowingo. A special tailrace netting study was performed at Holtwood, and hydroacoustic assessment for relative abundance was conducted at York Haven. Samples of shad from the various netting, electrofishing and strainer collections were returned to Benner Spring Fish Cultural

Research Station (PFC) for tetracycline mark analysis. All collecting sites are shown in Figures 1 and 5.

The following individuals were directly involved in these collections and analysis and the author expresses appreciation to them for supplying their data for this report: Joseph Nack (NES), Paul Heisey, Tim Brush and Chris Frese (RMC), Bob Williams and Mike Aloi (Barnes-Williams), Ted Rineer (SHWPC), Dale Weinrich (MD DNR), and Mike Hendricks and Don Torsello (PFC).

JUVENILE SHAD COLLECTIONS

York Haven Netting Survey

As pointed out in Job III, 6,450,700 shad fry were released in the Juniata River from the PFC hatchery at Van Dyke. This compares to 5.18 million and 9.9 million shad stocked upstream in 1987 and 1986, respectively. The York Haven headrace area in the vicinity of Unit 1 has been sampled for shad with cast nets for many years. In 1988, NES was contracted to make weekly collections here using a 20-ft. diameter monofilament net with 3/8-in. bar mesh. The purpose was to document occurrence of shad, to provide samples to the PFC for mark analysis, and to develop information on run timing and size of fish in the outmigrant population.

Sampling began on 5 September and continued weekly through 25 November (Table 1). Ten casts of the net were made on each sample date until fish appeared in abundance. Thereafter, the effort was restricted to that needed to collect 50 fish samples for mark analysis. In 1987, catch per effort with this gear was shown to roughly coincide with hydroacoustic assessment simultaneously conducted at York Haven (St. Pierre and B-W, 1988). However, because of the vagaries of sampling with this gear, cast net results are not considered to represent an adequate index of abundance for yearly comparison.

The first five American shad were collected at York Haven on 24 September when water temperature was 70 F. No shad were taken during the next 3 weeks but on 22 October, shad were plentiful in the sampling area. Sampling time was switched from early afternoon to late afternoon and evening when it was noticed that fish tended to congregate at dusk. Samples of 50-100 American shad were taken each week during 22 October - 19 November with very little effort. Water temperature during this period was 54-47 F. No shad were taken on 25 November and the sampling was discontinued. Fish ranged in size from 90 to 146 mm and two distinct size groups were noted. Juvenile gizzard shad appeared in collections only on 30 October and constituted about one-half of the sample. Adult gizzard shad and unidentified shiners were seen in the sample area but were not collected.

Hydroacoustic Assessment at York Haven

Another continuation of past year juvenile shad assessment at York Haven involved hydroacoustic monitoring. In conjunction with the EPRI co-funded study of fish protection devices (Job V, Task 4), Barnes-Williams Environmental Consultants was hired to monitor shad movements into the lower headrace area using acoustic techniques similar to those employed in 1986-1987. This year, the same 200 kHz 10 degree transducer was used in the same area assessed as in 1987 (Figure 2). The Koden CVS-8800 chromoscope used was also identical to that from last year, but signal processing equipment was changed to an IBM-PC compatible computer with updated and revised software.

Data were collected from 1300 hours on 12 September through 0100 on 24 November. Samples were taken during 1349 out of 1776 hours, resulting in samples being taken 76.0% of the time. Many of the missing samples were due to development of the remote data transmission system during 15-18 September and 27-30 September. Hourly mean flux densities (MFD) for the entire sampling period are filed with the Susquehanna River Coordinator in Harrisburg, PA and are summarized here. The MFD was calculated using a procedure detailed in Appendix A to this Job report. The major differences in the calculations between this year and previous years is that the conversion from volume backscatter to density was not needed.

Table 2 shows the daily average MFD (fish/m^2/hr) over the study period. Figure 3 depicts this data graphically. The main migration period was between 26 September and 11 November. The MFD during this period was 0.785 fish/m^2/hr. The MFD for the period of 12-25 September was 0.095, and for the period 12-24 November, 0.081. Values ranged from a low of 0.03 fish/m^2/hr on 12 September to a high of 2.72 fish/m^2/hr on 6 November. Compared to previous years data, the MFD was 10-15% higher. Figure 4 shows the average MFD for each hour of the day during the main migration period. Peak of movement at this project was determined to be between 9:00 p.m. and 6:00 a.m. Periods of low migration were around mid-morning. These trends are very similar to previous years (St. Pierre and B-W, 1988; BWEC, 1987).

The cross-sectional area acoustically sampled was approximately 187 m^2. Assuming a total cross-section of 645 m^2 at the monitoring site, an index value of approximately 12,150 targets (shad) per day was calculated (.785 targets/m^2/hr x 645 m^2 x 24 hr). This compares to average daily index values of 10,975 and 10,600 targets in 1987 and 1986, respectively. For the 47-day period assessed, one could calculate a total shad passage of about 571,000 fish, reflecting about 9% survival of the total fry stocked upstream. These numbers however should not be construed as absolute fish counts, but are only useful for annual comparison of relative abundance.

Safe Harbor Strainer Checks

Cooling water strainers at Safe Harbor Hydroelectric Project were examined every other day between 26 September and 4 November. No American shad were taken during these 18 sampling dates though hundreds of gizzard shad and smaller numbers of catfish and other resident species were present. A total of 10 American shad were collected from the screens between 7-24 November during daily cleanouts. These fish ranged in size from 92 to 134 mm and were taken at water temperatures of 50-42 F. Screen checks continued daily through 30 November with no additional shad taken and were discontinued thereafter.

Holtwood Netting Surveys

Three different netting surveys contributed to juvenile shad assessment at the Holtwood project in 1988. These included the 20-ft. diameter cast net used at York Haven and an 8-ft. square lift net, both fished in the forebay behind Unit 10, and 1 m diameter hoop nets fished in the tailrace.

Cast net sampling began on 27 August and continued weekly through 25 November (15 sample dates). As at York Haven, American shad were not collected until 22 October. A total of 191 shad were taken on the last six sample dates in 35 throws of the net (Table 3). Water temperature declined during this period from 53 to 43 F, and shad ranged in size from 88-144 mm.

RMC used their 8-ft. x 8-ft. lift net in the Holtwood forebay during the period 8 September through 7 December. The purpose for these collections was to provide information on timing of the shad run and to take samples for several RMC studies in the Holtwood vicinity (turbine mortality and Muddy Run entrainment - Job V; and Holtwood meter netting).

Three adult shad were netted on 3 October and one was taken on 8 November. Juvenile shad did not appear in abundance until the 26 October collection date. Between that date and 3 November, 54 lifts produced 814 American shad and over 7,000 juvenile gizzard shad (Table 4). American shad ranged in size from 71 to 150 mm fork length and the two size classes reported at York Haven were also evident here. Lift netting continued at odd intervals from 8 November to 7 December with an additional 115 American shad (and 11,000+ gizzard shad) collected in 100 lifts. Fish not retained for RMC studies were released alive and none were assessed for hatchery marks on otoliths.

Meter net sampling in the discharge at Holtwood was a special study performed by RMC Environmental Services for SRAFRC. A separate report on objectives, methods and results of this effort is provided at pages 4-39 - 4-54 of this Annual Report section. Analysis of otolith marks from those collections are reported here.

Conowingo Dam Strainers

Cooling water strainers at the Conowingo Hydroelectric Project were examined three times each week (Mon.-Wed.-Fri.) during mid-September through mid-December. Results of weekly collection totals are shown in Table 5. Only four American shad were taken; three on 16 November and one on 7 December. Over 31,000 young gizzard shad were also removed from Conowingo's strainers during this period. Otoliths from these four American shad were not analyzed.

Lower Susquehanna River

Maryland DNR juvenile American shad outmigration sampling with the Smith-Root electrofisher began on 28 September and continued through 15 November. A total of 11 sampling trips were made during this time with effort concentrated between Perryville and Port Deposit (Table 6, Figure 5). Actual electrofishing time averaged 61 minutes per trip (11.3 hours total). Because of river flows and tidal action, quantitative estimates of the finfish shocked could not be made. Table 7 lists those species observed during the sampling effort.

Two juvenile American shad measuring 92 and 109 mm were captured in the 1988 electrofishing survey. Both fish were taken just north of the I-95 bridge along the Harford County shoreline, one each on October 25-26. Numerous schools of blueback herring were observed early in the sampling,

particularly along the Garrett Island and lower Harford Coun
shorelines. However, their catch decreased by early Novemb
with falling water temperatures.

OTOLITH MARK ANALYSIS

a). York Haven

A total of 327 juvenile American shad collected with cast nets at York Haven were sent to Benner Spring for otolith mark analysis. Sixty fish from six different sampling dates were processed to determine tagging effectiveness and to differentiate relative abundance of the several strains of shad stocked in the Juniata River. All fish carried the hatchery mark as expected and the first five shad collected on 24 September were all quadruple marked indicating that they were from the Virginia egg source. Overall, the stock composition was determined to be 38% Virginia, 45% Delaware River, and 17% Columbia River (Table 8). Smallest fish in collections were those stocked latest in the season from Columbia River eggs.

b). Holtwood

All 191 shad taken with cast nets at Holtwood were sent to Benner Spring and 172 were analyzed for marks on otoliths. Again all fish were marked, but unlike the York Haven collection, 46% were from Columbia River fry plants, 36% from Virginia, and 15% were of Delaware River origin. Additionally, three fish carried the triple feed tag (Benner Spring pond) and thus were stocked as fingerlings, and one shad had a single feed tag with four immersion marks indicating that it had come from the Brunner Island hatchery. The final fish examined was double-marked and it's origin is unknown since all such fish were stocked below Conowingo. Otolith analysis data for Holtwood fish are also shown in Table 8.

Of the 61 juvenile American shad collected in meter nets in Holtwood's discharge (see part 2 of this Job report at pages 4-39 to 4-54) 56 were analyzed for TC marks. This assessment includes fish taken between 19 October and 21 November and is also displayed in Table 8.

Four unmarked and presumably wild juvenile shad were taken with meter nets at Holtwood. These appeared in collections on four separate dates (1 each) between 26 October and 7 November. One fish was a yearling. Of the remaining 52 shad examined, 26 (50%) were of Virginia fry origin, 17 (33%) were Delaware fry, and 9 (17%) were Columbia River fish.

c). Lower Susquehanna River

In addition to the two shad collected by Maryland DNR in their electrofishing survey of the lower Susquehanna River, another (51 mm) was taken with haul seine on 14 July on the Susquehanna Flats during the DNR's annual juvenile finfish survey. Otoliths from all three were analyzed by PFC for hatchery marks. One of these (the 109 mm fish from 26

...ctober) carried the double immersion tag indicating th... was stocked as a fry at Lapidum, MD. The remaining two were unmarked and presumed to be wild.

Though not related to juvenile outmigration assessment ... 1988, it is interesting to note here that nine yearli... American shad were taken from a pound net in the Flats on ... April, 1988. These fish ranged in size from 135 to 247 m... and several had an obvious or poorly defined annulus (Tabl... 9). The DNR provided otoliths from these shad and PFC researchers determined that three fish carried single immersion tags showing that they were stocked in the Juniata River as fry during the 1987 production season.

DISCUSSION

Run Timing

Juvenile shad outmigration from the Susquehanna River in 1988 occurred later than in the previous 2 years. Fish appeared in net collections at York Haven on 22 October when water temperature was 54 F. Hydroacoustic data from that site indicated that fish should have been available for capture as early as the first week in October. The run concluded during the third week of November as water temperature fell to the low 40's. By comparison, in 1987, shad were taken at York Haven on 18 September (71 F) and were not taken after 29 October (Young, 1988) - a difference of about 1 month. The 1986 run was about 2 weeks earlier than in 1988 (Young, 1987).

Similar results are shown for the Holtwood collections with the principal difference between 1988 and 1987 being that shad appeared much earlier and at higher water temperatures in 1987. Cast net sampling was initiated early at Holtwood this year in an attempt to collect wild juvenile shad produced from natural reproduction of adults transplanted upstream from Conowingo. In 1987, the early collection of unmarked juveniles indicated that these fish may precede hatchery fish in movement downstream. Shad were not collected at Holtwood until late October, 1988 when water temperature was 52 F. This temperature is considerably cooler than what has been recorded for first appearance of shad at Holtwood in prior years and supports Young's (1988) suggestion that flow rate in the river must be considered as an important determinant in triggering downstream migration of juvenile shad.

Average monthly river flows in the Susquehanna River were very low throughout the summer nursery period. During June through August, flows at Safe Harbor averaged under 11,000 cfs compared to the 70-year average of about 20,000 cfs for this 3-month period. September produced average mean flows but October dropped to only 42% of the long-term mean flow for that month, 7,500 cfs. The low river flows and accompanying higher than normal water temperatures delayed shad migration in 1988.

Abundance

As pointed out earlier, almost 6.5 million shad fry were stocked in the Juniata River from Van Dyke in 1988. Additionally, 74,000 fingerlings were released from the Thompsontown canal and other PFC production ponds. This compares to 5.2 million fry and 81,000 fingerlings in 1987. Catch per effort (CPE) with cast nets at York Haven was almost identical for the 2 years (18.9 vs. 18.2 fish/cast) during peak collection periods. The hydroacoustic assessment at York Haven was also similar (.785 vs. .709 targets/m^2/hr.) and grossly indicated that about 10% of fish stocked in the Juniata River comprised the outmigrant population.

Cast net sampling at Holtwood also produced similar results for 1988 and 1987. CPE with this gear averaged 5.5 and 5.2 fish/cast for the 2 years, respectively. Lift net catch rate however was considerably greater in 1988 for peak weeks assessed (6.9 vs. 3.1 shad/lift). Catch per effort for both gears was much higher in 1986 (40.5 cast net; 8.1 lift net) when almost 10 million fry were released from Van Dyke. Juvenile gizzard shad were much more abundant at all collecting locations in 1988 compared to earlier years. Lift net CPE at Holtwood for this species increased from 8 in 1986 to 95 in 1988. Young gizzard shad were also taken in cast nets at York Haven and adults were observed there throughout much of the fall season. Meter net sampling in the Holtwood discharge produced 25,747 gizzard shad and 61 American shad.

Similarly at Conowingo, strainer collections included over 31,000 young gizzard shad and only 4 American shad. Perhaps the hot and relatively dry summer of 1988 was conducive to gizzard shad production and survival.

Numbers of American shad taken from Safe Harbor and Conowingo strainer collections were appreciably less than last year (total of 14 fish in 1988 vs. 109 in 1987). These numbers however are too small to be useful in assessing relative abundance with confidence. The Maryland DNR outmigration survey is not comparable between years due to a change in collection gear.

<u>Growth</u>

Average fork length of American shad in net collections was greater in 1988 than in 1987, but appreciably less than in 1986. As will be pointed out later, stock composition at York Haven and meter net collections at Holtwood were not significantly different. Mean length of shad in these collections was 122 mm and 119 mm, respectively. Cast net collections at Holtwood produced smaller fish ($\bar{x}$=113 mm) with a high proportion of late stocked Columbia River shad.

Average size of shad in net collections in 1987 was 110 mm at both York Haven and Holtwood, perhaps reflecting the early migration that year. In 1986 shad averaged 135 mm and 141 mm at York Haven and Holtwood. This exceptional growth of shad has not been documented before or since 1986 and remains unexplained.

Mike Hendricks (PFC) conducted a one-way ANOVA on the mean lengths of shad in collections for the three egg source rivers. Data were pooled for all collecting sites and dates, excluding the 24 September sample. Test data were as follows:

	Mean TL	n	s.d.
Columbia River	110.1	99	10.7
Delaware River	135.9	69	7.6
Virginia Rivers	142.5	106	8.8

The resulting F value was 335.39 with F(2, 271) = 3.00. Since F exceeds the critical value, it was concluded that the differences were significant. Using Duncan's New-Multiple Range Tests to isolate the differences it was further determined that all river source samples differed from each other. This difference in growth relates directly to time of stocking and duration in the nursery zone.

Stock Composition and Mark Analysis

All hatchery reared shad in 1988 were distinctively marked with tetracycline (see Job III) to allow for assessment of the relative contribution of the various strains (egg sources) and culture situations (fry vs. fingerling and pond vs. pond). Shad collections at York Haven and Holtwood were used in this analysis. Since all adult shad from Conowingo were stocked between Safe Harbor and York Haven this year, Holtwood juvenile collections also are useful in assessing frequency of wild (unmarked) fish during outmigration.

The fact that all shad examined from York Haven were marked confirms the effectiveness of the tetracycline tagging regime employed by the PFC. Analysis of stock composition however produced surprising results. Table 10 displays numbers and percentages of shad fry released from each egg source, and recapture rates for York Haven cast nets, Holtwood cast nets, and Holtwood meter nets. Virginia and Delaware source shad comprised only 18.3% of all fry released in the Juniata River (May-June), but 64.5% of all juvenile recaptures during October and November. Conversely, Columbia River fry dominated stocking (81.7%) but only comprised 35.5% of the outmigrant population.

We have no reason to assume that shad produced from eastern egg sources should display inherent survival benefits in the Susquehanna River compared to West Coast fish, though this cannot be ruled out. Culture and handling treatments for all fish were identical except that later arriving Columbia River eggs (and fry) are exposed to warmer water conditions at the hatchery. Most likely this difference in survival rate is related to river conditions at time of stocking. Earlier stocked fry (VA and Delaware) may better adapt to cooler river water in a situation similar to what would be experienced in their native streams. Columbia fry are exposed to elevated temperature conditions considerably unlike those they would encounter in their home river.

Differential survival may also relate to food availability, competition and predation pressure which may favor early release of fry. Whatever the reasons, this analysis indicates that SRAFRC should expand early season egg collections and fry production from eastern source rivers and not rely on extensive Columbia River egg collections to meet target production levels.

It further appears from the three juvenile recovery netting efforts (Table 10) that stock composition in Holtwood cast net collections differed from that at York Haven and Holtwood meter nets. Mike Hendricks evaluated these results using Chi square tests of homogeneity (Dowdy and Wearden, 1983). Tests were conducted pairwise and fingerling releases were eliminated from the analysis. Wild fish were also eliminated from York Haven comparisons since they could not occur there.

When Holtwood cast net specimens are compared to those from York Haven or Holtwood meter net samples (i.e. forebay vs. tailrace), significant differences were noted in stock composition (X^2 = 28.32 and 28.71, respectively). Comparison of York Haven cast net stock composition against Holtwood meter net collections showed no significant difference (X^2 =

1.94). Thus, cast nets sampled a different shad population (i.e. composition) in the Holtwood forebay then was sampled at York Haven or the Holtwood discharge.

This situation is perplexing in that it indicates that either cast nets selectively over-sampled smaller Columbia River shad in the Holtwood forebay and avoided larger fish, or that the outmigrant population segregates itself at this location. Holtwood meter nets could be considered as passive sampling devices since juveniles entrained in turbine discharge cannot avoid the gear. Cast net sampling success is influenced by water depth and clarity, fishing depth (e.g. amount of rope out when pursed), weather conditions, sampling time (day vs. night) and other factors which may contribute to gear avoidance. Yet York Haven stock composition with this gear did not differ from the meter net collection. The difference therefore likely relates to conditions peculiar to the forebay area behind Unit 10 at Holtwood. Compared to other areas of the forebay, this restricted corner may offer refuge or attraction to smaller shad and concentrate them disproportional to their actual abundance. All of this is of course speculative, but it indicates that cast net sampling at Holtwood may not produce a useful relative abundance index for yearly comparison.

Since Holtwood forebay collections were not representative of the outmigrant shad population, only meter net samples from Holtwood's discharge are useful for interpreting relative occurrence of naturally produced shad in the run. Excluding the unmarked yearling, wild juveniles comprised only 5.5% of the stock at this site (3 of 55). This compares to 9% unmarked shad at Holtwood in 1987 (Young, 1988) and the difference may be attributable to the 2,000 fewer adults stocked upstream in 1988. The low percentage of wild shad in the run confirms the need to improve adult stocking conditions to concentrate spawners in suitable waters.

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Table 4.1. Juvenile American shad cast net collections in the York Haven project forebay, September-November, 1988.

Date	Shad Catch	Effort (#casts)	Catch/ effort	Mean FL (mm)	Length Range	Water Temp.
9/5	0	10	0	-	-	73
9/10	0	10	0	-	-	71
9/17	0	10	0	-	-	69
9/24	5	10	0.5	not measured		70
10/4	0	10	0	-	-	67
10/9	0	8	0	-	-	58
10/15	0	10	0	-	-	51
10/22	104	1	104	119	95-137	54
10/30	50	3	16.7	114	90-133	48
11/6	50	2	25.0	121	108-141	53
11/13	60	3	20.0	126	115-138	47
11/19	62	8	7.8	128	104-146	47
11/25	0	6	0	-	-	42
Totals	327	17*	18.9*	122	90-146	

*peak weeks only

Table 4.2
Daily Mean Flux Density
September 12 - November 24, 1988
York Haven Power Station

Date	MFD	Date	MFD	Date	MFD
Sept. 12	.03	Oct. 15	1.04	Nov. 5	1.94
13	.26	16	.43	6	2.72
14	.13	17	.37	7	1.20
19	.06	18	.29	8	.37
20	.06	19	.74	9	.44
21	.06	20	.63	10	.24
22	.12	21	.31	11	.46
23	.03	22	1.44	12	.08
24	.10	23	.63	13	.09
25	.02	24	.42	14	.11
26	.29	25	.63	15	.04
Oct. 1	.39	26	.65	16	.09
3	1.25	27	1.11	17	.17
5	.16	28	1.53	18	.12
6	.15	29	1.61	19	.05
7	.11	30	1.07	20	.05
8	.31	31	.91	21	.08
9	.30	Nov. 1	.41	22	.04
12	.62	2	1.29	23	.05
13	1.59	3	.87	24	.11
14	.71	4	1.09		

Table 4.3. Juvenile American shad cast net collections in the Holtwood project forebay, August-November, 1988.

Date	Shad Catch	Effort (#casts)	Catch/ Effort	Mean FL (mm)	Length Range	Water Temp.
8/27	0	12	0	-	-	79
9/3	0	10	0	-	-	79
9/5	0	10	0	-	-	76
9/10	0	10	0	-	-	72
9/17	0	10	0	-	-	74
9/24	0	10	0	-	-	70
10/4	0	13	0	-	-	66
10/9	0	8	0	-	-	64
10/15	0	10	0	-	-	56
10/22	50	5	10.0	113	90-131	53
10/30	50	2	25.0	107	83-127	50
11/6	4	10	0.4	115	92-128	46
11/13	60	4	15.0	119	88-140	47
11/19	23	8	2.9	110	92-144	48
11/25	4	6	0.7	120	109-129	43
Totals	191	35*	5.5*	113	83-144	

*peak weeks only

TABLE 4.4

Number of juvenile American shad collected by RMC with an 8 x 8 ft lift net in the Holtwood Forebay, September-December 1988.

Date	Water Temp. (°C)	Total Lifts	Total Caught	CPE	Number Retained for Studies	Number Gizzard Shad Collected
8 Sep	21	10	0	0	0	56
3 Oct	19.5	10	0(3)*	0	0	1054
5 Oct	-	10	0	0	0	800
10 Oct	-	5	0	0	0	55
13 Oct	14.5	11	1	0.1	1	532
14 Oct	15.5	10	0	0	0	215
17 Oct	14	10	0	0	0	454
18 Oct	15	10	0	0	0	197
26 Oct	10.5	13	182**	14.0	182	258
27 Oct	11	11	59	5.4	10	77
31 Oct	-	10	102	10.2	21	547
2 Nov	9.5	10	102	10.2	13	3581
3 Nov***	8	10	369	36.9	20	2663
8 Nov	9	10	10(1)*	1.0	7	248
9 Nov	9	10	23	2.3	20	304
10 Nov	10	10	16	1.6	16	70
10 Nov***	9.5	10	42	4.2	42	838
14 Nov	8.5	10	5	0.5	5	216
15 Nov	8	10	2	0.2	2	5
19 Nov	-	10	8	0.8	0	96
21 Nov	8	10	7	0.7	7	2350
21 Nov***	8	6	0	0	0	7350
2 Dec	5.5	7	2	0.3	0	3
7 Dec	5.0	7	0	0	0	2
Totals		230	930	4.0	346	21971

* Number of adult shad in parentheses

** Fish ranged from 71-150 mm fork length; modal length of 95

*** Night time sampling

Table 4.5
Weekly summary of fishes collected in Conowingo Dam strainers in fall 1988.

Week Of	September		October				November					December		
	21	28	5	12	19	26	2	9	16	22	30	7	14	Total
Species														
American shad	-	-	-	-	-	-	-	-	3	-	-	1	-	4
Gizzard shad	191	347	72	71	36	789	1808	998	1643	3502	7903	3968	9939	31267
Comely shiner	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Channel catfish	-	1	-	-	1	5	-	1	-	-	-	-	-	8
Pumpkinseed	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Bluegill	-	-	-	-	-	-	-	-	2	-	-	-	-	2
White crappie	-	-	-	-	-	-	2	-	-	-	-	-	-	2
TOTAL	191	348	72	71	38	794	1810	1000	1648	3502	7903	3969	9939	31285

TABLE 4.6. Areas fished by date with corresponding effort and water temperatures during the 1988 Maryland DNR juvenile outmigration electrofisher sampling on the upper Chesapeake Bay.

DATE	AREAS FISHED	SHOCKING TIME (Sec.)	WATER TEMPERATURES (°C)
9/28	Garrett Is. west shore	425	17.0
10/14	Garrett Is. west shore	2004	15.0
10/19	Harford shore B&O-RT 40	370	15.5
	Garrett Is. east shore	554	15.5
10/20	Port Deposit-Logans Wharf	308	14.0
	Port Deposit to Spencer Is	468	
	Spencer Is west shore	574	
	Spencer Is to Rock Run	662	
	Spencer Is to Lapidum	500	
10/25	Garrett Is. west shore	1021	
	Harford shore I-95/Lapidum	2627	13.5
10/26	Harford shore RT 40/B&O RR	594	13.5
	Harford shore B&O/Quarry	562	14.5
	Harford shore Quarry/Lap	2030	14.0
	Spencer Is-Robert Is.	1507	14.0
	Garrett Is east shore	1210	17.0
10/31	Cecil shore RT 40/I-95	1594	13.0
	Cecil shore I-95/Logans	920	11.0
	Spencer Is/Robert Is	1273	13.5
11/3	Harford shore I-95/Quarry	664	10.5
	Quarry to Lapidum	1132	
	Lapidum to state park (mill)	1721	
	Spencer Is. west side	921	13.0
	Spencer Is to Port Dep.	703	
	Port Deposit	1050	13.5
11/7	Harford shore I-95/Lap.	2285	11.0
	Lapidum to state park (mill)	2270	12.0
11/9	Garrett Is east shore	650	11.0
	Harford shore I-95/Lap.	2270	11.5
	Spencer Is. west shore	1716	12.0

Table 4.6 Continued

DATE	AREAS FISHED	SHOCKING TIME (Sec.)	WATER TEMPERATURES (°C)
11/11	Garrett Is. west shore	1186	11.5
	Garrett Is. to I-95	1157	11.0
	Harford shore I-95/Lap	1565	11.0
	Lapidum to Port Deposit	1300	12.0
	Port Deposit-Rock Run	931	12.0

TABLE 4.7 . Scientific and common names of finfish species collected during 1988 Maryland DNR juvenile outmigration electrofishing sampling in the upper Chesapeake Bay.

SCIENTIFIC NAME	COMMON NAME
Alosa aestivalis	blueback herring*
Alosa sapidissima	American shad*
Anchoa mitchilli	bay anchovy
Anguilla rostrata	American eel
Brevoortia tyrannus	Atlantic menhaden
Carpiodes cyprinus	quillback
Catostomus commersoni	white sucker
Cyprinus carpio	carp
Dorosoma cepedianum	gizzard shad**
Ictulurus nebulosus	brown bullhead
Lepomis auritus	redbreasted sunfish
Lepomis gibbosus	pumpkinseed**
Lepomis macrochirus	bluegill**
Menidia beryllina	tidewater silverside
Micropterus dolomieui	smallmouth bass**
Micropterus salmoides	largemouth bass**
Morone saxatilis	striped bass
Notropis species	shiners
Perca flavescens	yellow perch**
Pomatomous saltatrix	bluefish
Pomoxis nigromaculatus	black crappie

*juveniles only
**juveniles and adults

Table 4.8. Analysis of tetracycline marking of juvenile American shad collected in the Susquehanna River, 1988.

Date	York Haven Forebay Cast-Net Tag	York Haven Forebay Cast-Net # Fish	Holtwood Forebay Cast-Net Tag	Holtwood Forebay Cast-Net # Fish	Holtwood Tailrace 1/2 Meter Net Tag	Holtwood Tailrace 1/2 Meter Net # Fish
8/27	-	-	-	-	-	-
9/3	-	-	-	-	-	-
9/5	-	-	-	-	-	-
9/17	-	-	-	-	-	-
9/24	Single/0	0	-	-	-	-
	Triple/0	0				
	Quad./ 0	5				
		5				
10/4	-		-		-	-
10/9	-		-		-	-
10/15	-		-		-	-
10/19	-		-		Quad./0	1
10/22	Single/0	6	Single/0	18	-	-
	Triple/0	10	Double/0	1		
	Quad./ 0	11	Triple/0	2		
		27	Quad./ 0	13		
				34		
10/26	-		-		0/0	
					Single/0	2
					Triple/0	2
					Quad./ 0	2
						7
10/28	-		-			
					Single/0	5
					Triple/0	6
					Quad./ 0	10
						21
10/30	Single/0	1	Single/0	35	-	-
	Triple/0	5	Triple/0	3		
	Quad./ 0	1	Quad./ 0	14		
		7		52		
10/31	1	-	-	-	0/0	1
					Single/0	1
					Triple/0	1
					Quad./ 0	6
						9

Table 4.8 (Continued).

Date	York Haven Forebay Cast-Net Tag	York Haven Forebay Cast-Net # Fish	Holtwood Forebay Cast-Net Tag	Holtwood Forebay Cast-Net # Fish	Holtwood Tailrace 1/2 Meter Net Tag	Holtwood Tailrace 1/2 Meter Net # Fish	Source:
11/2	-	-	-	-	Triple/0	3	
11/4	-	-	-	-	0/0 Single/0 Quad./ 0	1 1 1 3	
11/6	Single/0 Triple/0 Quad./ 0	2 2 3 7	Single/0 Quad/Single	3 1 4	-	-	
11/7	-	-	-	-	0/0 Triple/0 Quad./ 0	1 (yearling) 3 4 8	
11/9	-	-	-	-	Triple/0 Quad./ 0	1 1 2	
11/10	-	-	-	-	Triple/0	1	
11/13	Single/0 Triple/0 Quad./ 0	0 6 1 7	Single/0 Triple/0 Quad./ 0 Quad/Triple	12 16 30 1 59	-	-	
11/19	Single/0 Triple/0 Quad./ 0	1 4 2 7	Single/0 Triple/0 Quad./ 0 Quad/Triple	12 4 5 2 23	-	-	
11/21	-	-	-	-	Quad./0	1	
TOTALS	0/0 Single/0 Double/0 Triple/0 Quad./0 Quad./Single Quad./Triple	- 10 - 27 23 - - 60	0/0 Single/0 Double/0 Triple/0 Quad./0 Quad./Single Quad./Triple	- 80 1 25 62 1 3 172	0/0 Single/0 Double/0 Triple/0 Quad./0 Quad./Single Quad./Triple	4 9 - 17 26 - - 56	Wild Col. River Unknown Del. River VA River Brunner Is. BS Pond

Table 4.9. Analysis of otoliths from sub-adult American shad collected in the Susquehanna River Basin below Conowingo Dam, 1988.

Specimen #	Total Length (mm)	Capture Date	Location	Sampling Gear	Tetracycline Tag	Annulus	Year Class
1	109	10/26/88	Susq. River	Electrofisher	Double/0	Absent	1988
2	51	07/14/88	Susq. Flats	Haul Seine	None	Absent	1988
3	92	10/25/88	Susq. River	Electrofisher	None	Absent	1988
6	135	04/14/88	Susq. Flats	Pound Net	None	Absent	1987
7	151	04/14/88	Susq. Flats	Pound Net	None	Absent	1987
8	166	04/14/88	Susq. Flats	Pound Net	None	Absent	"
9	140	04/14/88	Susq. Flats	Pound Net	None	Poorly Defined	"
10	154	04/14/88	Susq. Flats	Pound Net	Single/0	Obvious	"
11	140	04/14/88	Susq. Flats	Pound Net	Single/0	Poorly Defined	"
12	140	04/14/88	Susq. Flats	Pound Net	None	Obvious	"
13	247	04/14/88	Susq. Flats	Pound Net	Single/0	Poorly Defined	"
14	143	04/14/88	Susq. Flats	Pound Net	None	Poorly Defined	"

Table 4.10. Numbers of fry released vs juveniles recovered by egg source river, Juniata and Susquehanna Rivers, 1988. Recoveries of wild fish and fish released as fingerlings are excluded.

Egg Source	Fry Released (Juniata River) No.	%	JUVENILES RECOVERED York Haven (Cast Net) No.	%	Holtwood (Cast Net) No.	%	Holtwood (Meter Net) No.	%	Total (All Sites) No.	%
Virginia R.	682,685	(10.6)	23	(38.3)	62	(37.1)	26	(50.0)	111	(39.8)
Delaware R.	495,670	(7.7)	27	(45.0)	25	(15.0)	17	(32.7)	69	(24.7)
Columbia R.	5,272,330	(81.7)	10	(16.7)	80	(47.9)	9	(17.3)	99	(35.5)
TOTAL	6,450,685		60		167		52		279	

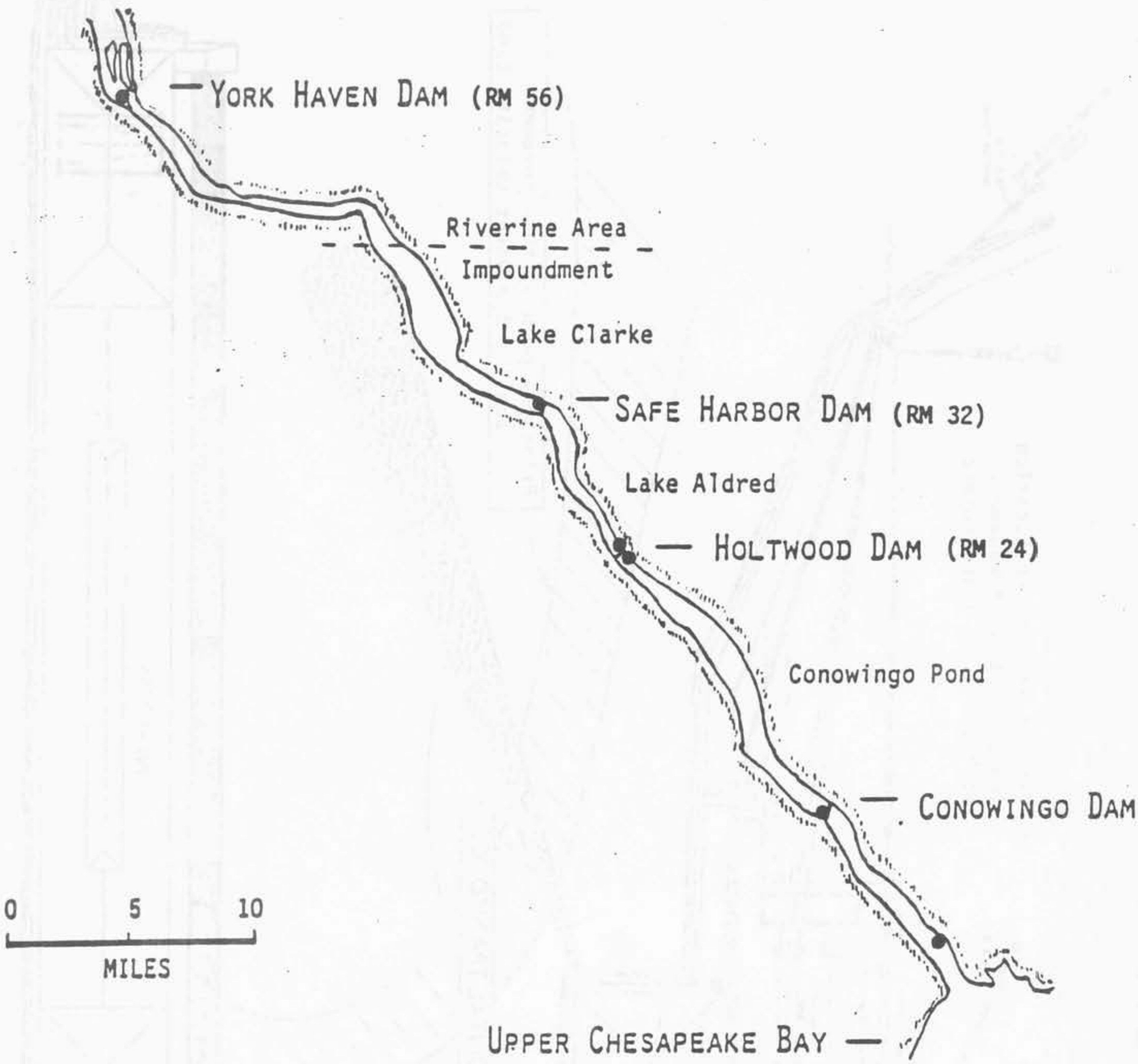


Figure 4.1. Juvenile American shad sampling locations in the Lower Susquehanna River, 1988.

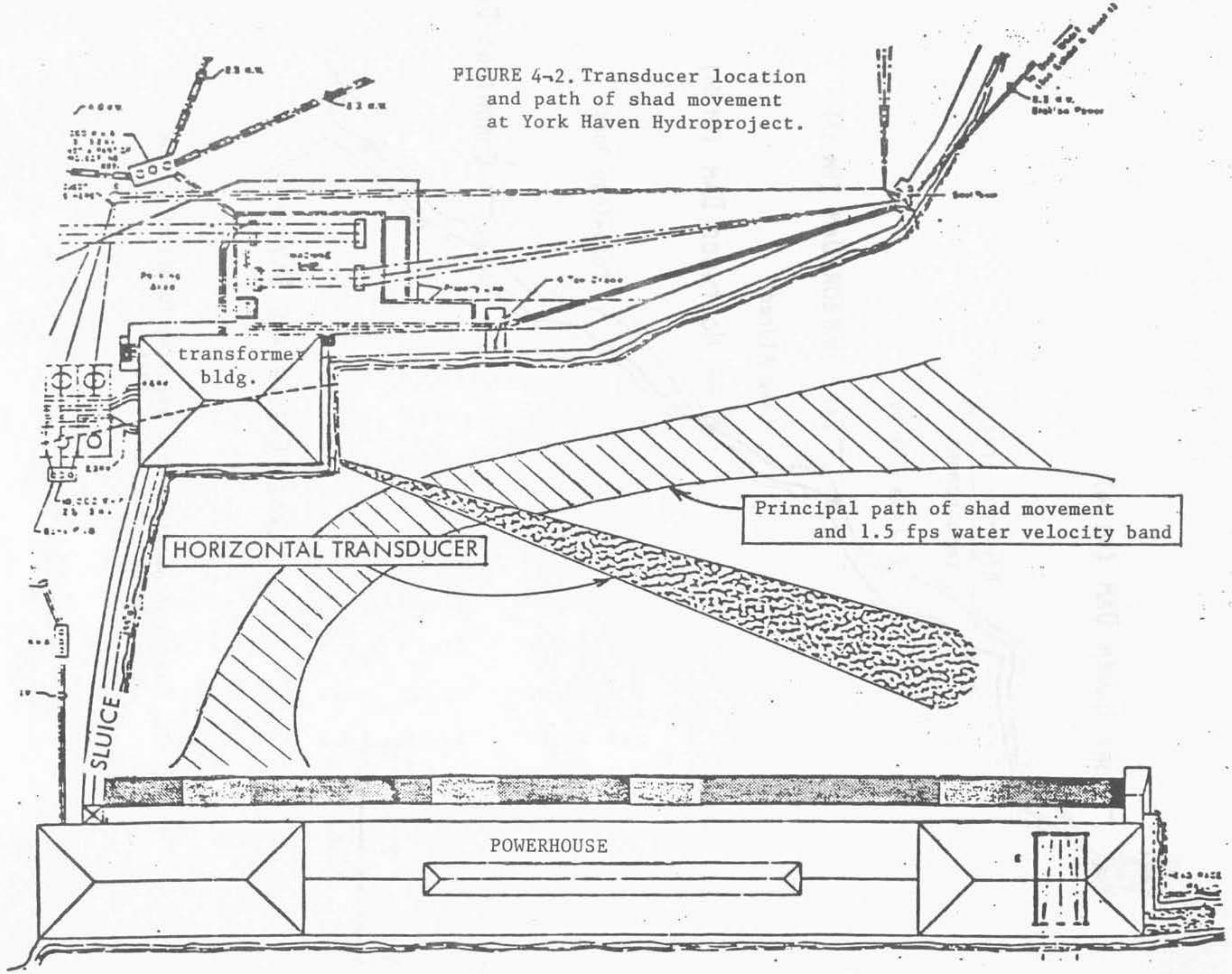


FIGURE 4-2. Transducer location and path of shad movement at York Haven Hydroproject.

Figure 4.3
Daily Mean Flux Density
Sept. 12 - Nov. 24, 1988
York Haven Side Scan Monitor Station

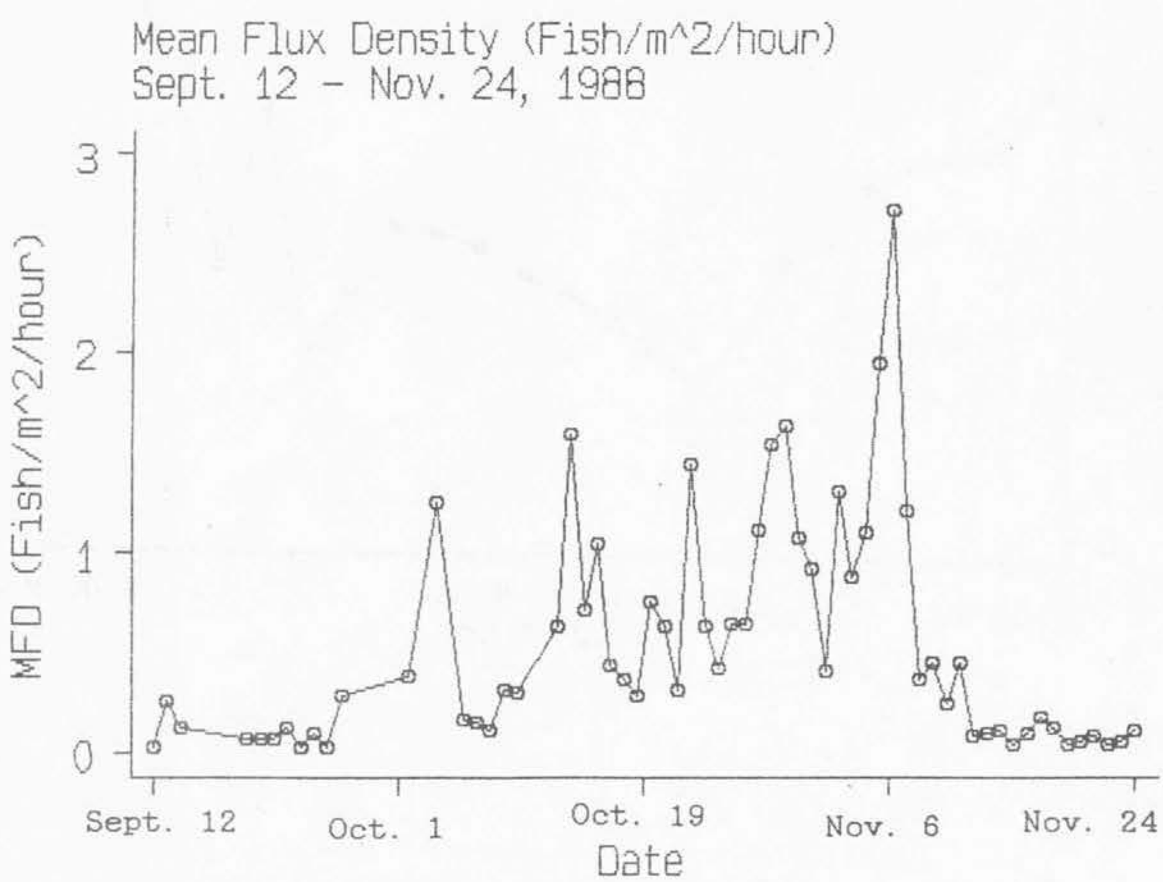
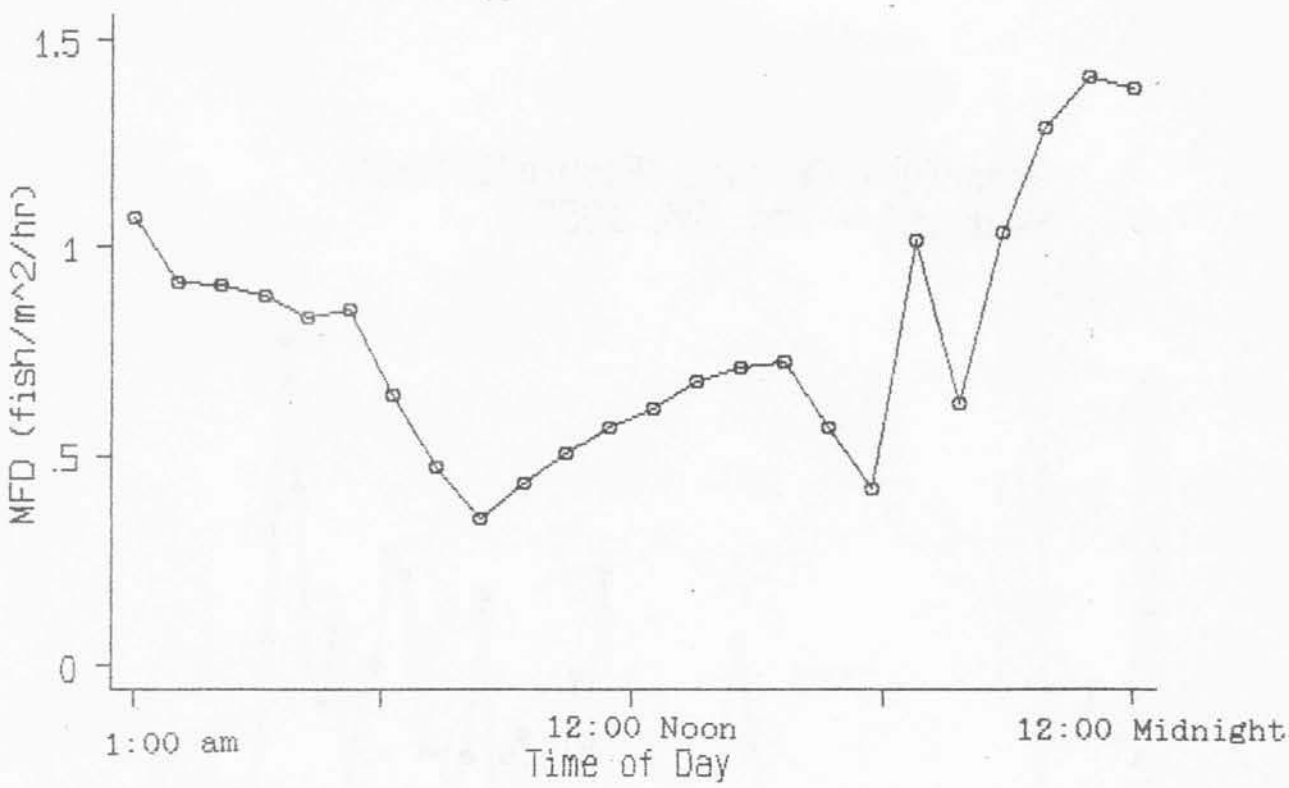


Figure 4.4
Hourly Mean Flux Density
Sept. 26 - Nov. 11, 1988
York Haven Side Scan Monitor Station



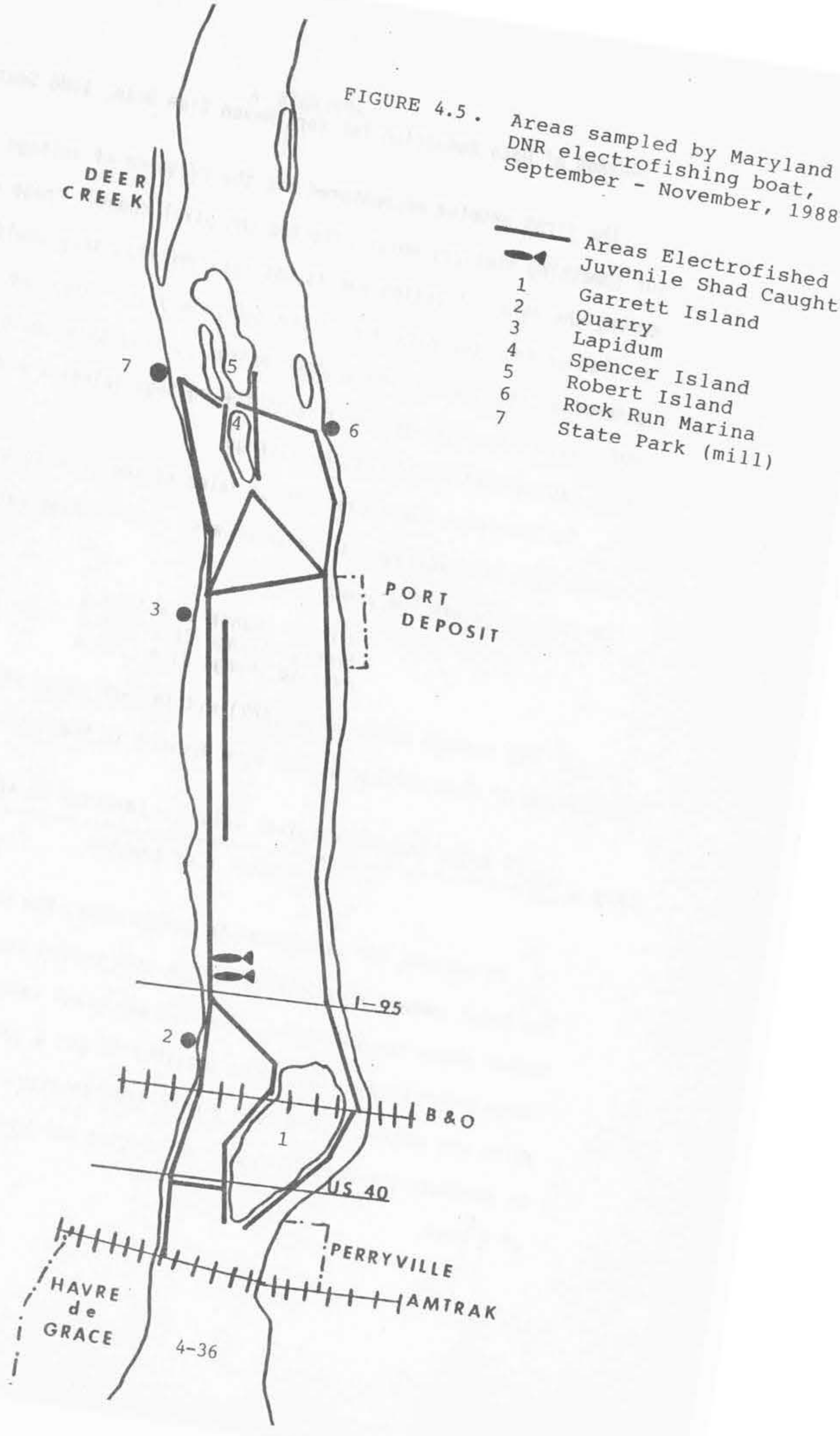


FIGURE 4.5. Areas sampled by Maryland DNR electrofishing boat, September - November, 1988.

APPENDIX A
Method of Data Reduction for York Haven Side Scan, 1988 Season

The first problem encountered was the presence of voltage spikes (or something similar) which affected the pixel count. These were seen during the data collection and it was realized that they would have to be cleaned from the data during the data analyses. Step one was to determine the value of the voltage spikes so that they could be filtered out. Once the pixel values of just the voltage spikes are determined they can be subtracted out, on average.

To determine the average pixel value of the spikes, these samples which held only voltage spikes were used. The average value at a spike in each range was computed:

Average (Range 1) = 2223.1
Average (Range 2) = 1905.4
Average (Range 3) = 712.4

The average pixel value (APV) within each range was then adjusted if one or more voltage spikes were present in the data by the formula:

$$APV = \sum \frac{(\text{\# above threshold})(\text{pixel value}) - (\text{average of spikes})(\text{\# of spikes})}{\text{total \# of samples}}$$

To account for variations in sample size, the value was divided by the total number of samples with the time period instead of just the number above the threshold. The average pixel value per sample for each range interval was then added together to get a total average pixel value per sample. To obtain a mean flux density, assumptions are needed to estimate the optimum number of samples per hour and the pixel value of a shad.

Optimum Sample Intensity:

The sample volume is figured as a two meter cylinder. To get total coverage of water volume passing the axis one sample per four seconds is needed. Therefore, sample rate is 900 samples/hour.

Pixel Volume of a Shad:

At the 20 meter scale, a ping pong ball gave a pixel value of 250 pixels. Assume this value would be 1/5 value at range scale 5x value. Thus, ping pong ball on 100 meter scale is equal to 50 pixels.

It was determined at Little Falls (1988) that an equivalent sized clupied (4-6") has a TS of 1.19 x that of a ping pong ball. Therefore, a shad has an estimated pixel value of approximately 59.5 pixels.

Mean flux density is the number of fish counted per m^2 of sample "window" per hour. The formula used to calculate MFD is:

$$MFD = \frac{\left(\frac{\text{pixel sum} * 900 \text{ samples/hr}}{59.5 \text{ pixels/shad}}\right)}{238.4 \text{ m}^2 \text{ window}}$$

$$= \frac{\text{pixel sum} * 900}{59.5 * 238.4}$$

$$= \text{shad/m}^2\text{/hr}$$

PART 2

Job IV. Assessment of Juvenile American Shad Outmigration at Holtwood Hydroelectric Station Using One Meter Diameter Hoop Nets.

By

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INTRODUCTION

This study was performed for SRAFRC as part of the 1988 juvenile American shad (Alosa sapidissima) outmigration assessment. The study was conducted in the tailrace of the Pennsylvania Power and Light Holtwood Hydroelectric Station (HHES). The Holtwood Dam is located at river kilometer 39. The HHES is a peaking power station. The powerhouse contains ten main generating units (Francis turbines) with a total discharge capacity of approximately 31,500 cfs (102 megawatt capacity). The spillway of Holtwood Dam is 16.8 m high and 729 m long, and the powerhouse is 152.5 m long (D. Runkle, PP&L, pers. comm.).

OBJECTIVES

This study had three main objectives: 1) to characterize the outmigration of juvenile American shad at HHES; 2) to address the possibility that Holtwood Dam is a bottleneck in the system to outmigration; and 3) to address the possibility of using a one meter diameter hoop net in developing an annual index of abundance for outmigrants. These objectives were met and are discussed herein.

MATERIALS AND METHODS

Young shad were captured by one meter diameter hoop nets. This gear was first used in the Susquehanna River by Carlson (1968), and further developed by RMC Environmental Services (RMC) in 1987 (Young, 1988). The nets were conical shaped hoop nets, 1.52 m long with a 1 m diameter mouth opening and 1.27 cm mesh size. In addition, an experimental live car was developed and attached to the rear of one of the nets. The live car was constructed of a plywood holding box (16" w x 28" l), PVC pipe pontoons, and a hardware cloth hatch. Fish traveled from the net to the live car through a 3' length of 4" PVC pipe.

The complex flow patterns in the HHES tailrace necessitated a two point anchoring system to hold the nets in proper fishing position (except the net fishing the Unit 10 discharge). This system consisted of one rope anchored to the stop log gallery for each net, and one long rope anchored to the retaining wall for all nets (except Unit 10). The Unit 10 net required only a single rope anchored to the stop log gallery because the discharge flow pattern was perpendicular to the stop log gallery.

Figure 1 illustrates the configuration of the HHES and the tailrace, the general flow patterns, and the lattice of ropes and general placement of nets.

The nets were fished directly behind the boil area of the discharge in the top one meter of the water column. The nets were checked periodically, and the catch identified and enumerated. The volume of water sampled was calculated using General Oceanics Flowmeters (Model 2030). Generally, sampling occurred three days each week with 2 to 5 nets. Nets were fished in the evening hours based on evidence provided by previous work by RMC (Young, 1988) and O'Leary and Kynard (1986), except for 30 September and 21 October (18.38 net hours) when the HHES generation schedule precluded evening sampling. American shad collected were examined for injury and preserved for otolith analysis, or released if alive.

A request from the SRAFRC Coordinator to determine the net efficiency was made, as a supplement to the original proposal. This was attempted by a mark-recapture technique. The experimental design was to introduce live juvenile shad through a turbine in two tests of three replicates per test. Each replicate was to include 500 - 1000 shad. This design was abbreviated due to the non-availability of required number of juvenile shad. The completed experiment involved one test of three replicates (300 shad/replicate). RMC collected and transported the shad from the PP&L Brunner Island Aquaculture Facility to holding facilities at HHES (see Job V, turbine study for description). In addition to the experiment using live shad, 239 dead shad (mortalities from previous transport from Brunner Island) were introduced through a turbine as a preliminary experiment.

The shad were stained with Bismarck Brown Y biological stain (Pfaltz and Bauer, Inc., Waterbury, CT) for approximately 15 minutes (Previous laboratory tests at RMC resulted in 100% survival, to 30 minutes, of 119 juvenile shad stained with Bismarck Brown Y.). The stained shad were introduced through a length of PVC pipe into the turbine intake (Unit 10 - live shad; Unit 8 - dead shad), downstream of the trashracks. The catch in the net downstream of the respective unit discharge was checked approximately 15 minutes after the introduction of shad.

RESULTS

Sampling occurred on 27 days from 14 September to 21 November. Sixty-one juvenile and one adult American shad were captured in the nets in 254.56 net hours of sampling. Shad were captured on ten of the 14 sampling days from 19 October to 21 November. The highest number collected in one day was 22 (28 Oct.). The highest catch per effort (CPE) was 1.84/net hour on

26 October. The mean CPE, on days when shad were captured, was 0.53/net hour. Effort varied from 2.33 to 16.70 ($\overline{X}$ = 9.43) net hours in a sampling period.

The water temperature decreased from 22.5 C on 14 September to 8.2 C on 21 November. The first shad was captured at a water temperature of 15.0 C. Fifty-nine of 61 juvenile shad were captured in eight sampling days (26 Oct. to 10 Nov.) at a water temperature range of 13.5 C to 9.0 C. An estimated 3.14 million cubic feet of turbine discharge water was sampled in the 254.56 hours of sampling. This is equivalent to approximately 0.12% of a given unit's discharge. Table 1 summarizes the sampling at HHES.

The length frequency distribution of juvenile American shad (Fig. 2) was bimodal. The neighboring length intervals 111 - 120 mm FL (Fork Length) and 121 - 130 mm FL were the modes (N = 16). The minimum length interval was 51 - 60 mm FL (N = 1), and the maximum interval was 141 - 150 mm FL (N = 3). The distribution was negatively skewed.

Eighty-three percent (15/18) of the juvenile shad outmigrants captured in the live car were alive and active. Overall, 31% (19/61) of the juvenile shad outmigrants captured were alive when the nets were checked. The mortality of the remaining 42 outmigrants was assumed to result from a combination of net mortality and turbine mortality. The exact proportions of live and dead shad cannot be determined from this study. However, lacerations were not apparent and few signs of hemorrhage were seen in captured shad. Most fish had scale loss as a result of impingement in the nets; one shad was decapitated.

The preliminary net efficiency test using dead shad was conducted on 21 October. Two of 239 stained dead shad introduced through Unit 8 were captured in the hoop net. The net efficiency experiment using live shad was conducted on 7 November using Unit 10. The catch per replicate (N = 300) of live shad was 0, 1, and 2 respectively. All of the stained shad captured in the second experiment were alive and active.

A total of 25,747 gizzard shad (Dorosoma cepedianum) was captured. Young - of - year gizzard shad dominated the catch. The modal length interval of 683 gizzard shad measured, was 51 - 60 mm FL. The lowest interval sampled was 21 - 30 mm FL and the highest interval was 121 - 130 mm FL (Fig. 3).

Eighty-seven other fish were captured in the nets. These included 11 channel catfish (Ictalurus punctatus), 62 carp (Cyprinus carpio), 1 bluntnose minnow (Pimephales notatus), 2 comely shiners (Notropis amoenus), 1 striped bass x white bass hybrid (Morone saxatilis x M. chrysops), 1 sunfish species (Lepomis sp.), 1 green sunfish (L. cyanellus), 6 bluegill (L. machrochirus), 1 largemouth bass (Micropterus salmoides), and 1 black crappie (Pomoxis nigromaculatus).

DISCUSSION

The outmigration of juvenile American shad occurs as one or more episodic events. Sampling to characterize such an outmigration must therefore encompass all episodes of movement temporally. In addition, intensive effort is necessary to assure sampling of a given episode of emigration. The sampling design attempted to encompass the outmigration by beginning early and ending as late as feasible. Intensive effort was decided to be three times per week (generally).

Previous work has indicated that juvenile shad emigration is influenced mainly by water temperature (Leggett and Whitney, 1972; O'Leary and Kynard, 1986) and possibly by river flow (Young, 1988). In 1987, shad were collected earlier than usual. RMC collected shad at HHES on 10 September (water temp. 22.0 C), the first sampling date at this location. Thirteen of 16 of the shad in this collection were naturally spawned according to otolith OTC analysis. This was the only collection of juvenile shad from Amity Hall to Conowingo Dam to have a majority of naturally spawned individuals. Only eight of the remaining 511 (1.56%) collected and examined for OTC tags (from Amity Hall to Conowingo Dam) were naturally spawned. This implied the possibility of differential emigration behavior among various stocks. A portion of the run, in particular naturally spawned shad, may have occurred prior to sampling efforts. A high river flow event (>50,000 cfs) was proposed as the reason for the relatively early episode of movement.

Sampling began on 14 September in 1988 (water temperature 22.5 C) to assure encompassing the entire emigration. The water temperature upriver (Three Mile Island) had been near or below 20 C for the previous week (RMC unpublished data). The river flow at HHES on 14 September was 9900 cfs. Sampling ended on 21 November due to hazardous working conditions caused by low water temperature (8.2 C) and increased river flow (>38,000 cfs). In addition, only one shad was captured in the last four days of sampling, suggesting the outmigration was nearly complete. Although one meter hoop net sampling did not continue past the absolute end of the run, data from RMC lift net sampling after 21 November in the HHES forebay provided a confident estimate of the end of the run (See Table 4.4, Job IV, part1).

O'Leary and Kynard contended that water temperature, not river flow, affected the emigration of juvenile shad. Although water temperature is likely an ultimate factor in stimulating emigration behavior, evidence in the Susquehanna River suggests that high river flow events are at least proximal factors. It is difficult to resolve the contribution of high river flow in effecting behavior of shad because such flow events are often coincidental with decreasing water temperature.

In 1988, there were no significant high river flow events during the outmigration period (Table 1), thus water temperature was likely the most important factor in effecting emigration.

Previous researchers (O'Leary and Kynard, 1986; Stokesbury 1986) have discussed the importance of the lunar phase in stimulating emigration. Both papers contended that movement was associated with the quarter (1st and 3rd) and new moon phases. In contrast, the two highest CPE values at HHES occurred one and three days after the full moon (26 and 28 October).

The 1988 juvenile American shad outmigration past HHES can be characterized primarily by water temperature. All captures were made within a 6.8 C water temperature range (15 C - 8.2 C), with most being captured at 13.5 C - 9.0 C. The outmigration past Holtwood Dam began in the third week of October and was likely completed by the first week of December.

Data collected during this study suggests that Holtwood Dam was not a significant bottleneck to the passage of shad in 1988. By comparing one m hoop net capture data with that from the RMC lift net (Table 4.4) it is obvious that captures by both gears occurred during the same period of time. The peak CPE for both gears occurred within a nine day period (26 October-3 November) and a 4 C range of water temperature (13.5 C-9.5 C). Comparison of absolute catch values was not appropriate because accurate estimates of the catch efficiency of each gear have not been determined. In addition, daily spills occurred from 9 November through 21 November, affording juvenile shad an alternative passage route. It appears that a previous concern for HHES being a bottleneck was likely based on collections of juvenile shad in the HHES forebay at a water temperature of 4.5 C (near lower lethal limit according to Chittenden, 1972) in 1986 (Young, 1987), and scant collections of juvenile shad in the river system below Holtwood Dam (Butowski et al., 1988).

An index of juvenile shad abundance is essential to properly evaluate the success of the restoration program. Ultimately, an index must be established below Conowingo Dam. However, useful information can be obtained by studying outmigration at each hydroelectric facility. Several techniques have been utilized to collect juvenile shad in the Susquehanna River, however no single technique has emerged that would provide the desired abundance index. Most sampling projects to date have not been intensive enough to provide a reliable index.

The only successful attempts at sampling in hydroelectric facility tailraces has been with the 1 m hoop nets in 1987 and 1988. Intensive sampling with 1 m hoop nets during the period of peak emigration is, at present, the best technique (for the available funds) to capture juvenile shad in a tailrace.

RECOMMENDATIONS

RMC recommends:

1. That the 1 m hoop net technique be further utilized as it is currently the only proven technique in the Susquehanna River to capture juvenile American shad in hydroelectric facility tailraces.
2. That, assuming an abundance index is the objective, sampling be intensive (daily) during the peak emigration period as determined by monitoring water temperature and using the RMC lift net to establish presence.
3. That net efficiency tests be repeated to obtain better estimates of catch efficiency. These tests may be approached by two methods:
   a) Mark-recapture, as attempted in this study.
   b) Use hydroacoustic and radio telemetry survey estimates of fish passing a turbine to estimate net efficiency.
4. If sampling is repeated at HHES, that semi-permanent or permanent anchoring facilities be constructed (i.e., a cable spanning the tailrace for attachment of nets).
5. That Holtwood Dam is not a singularly good index station because of the frequency and variability (across years) of spills.

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TABLE 1

Summary of 1 m hoop netting in the Holtwood Hydroelectric Station tailrace.

Date	Shad Catch	Effort (net hours/day)	CPE	Water Temp °C	River Flow (thousands cfs)	Gizzard Shad Catch
Sep 14	0	2.33	0	22.5	9.9	646
16	0	9.55	0	22.0	9.4	814
19	0	8.01	0	21.5	8.7	248
21	0	6.17	0	21.0	9.8	788
23	0	6.64	0	21.8	9.2	2072
28	0	5.80	0	21.5	8.1	970
30	0	5.05	0	21.0	6.9	88
Oct 3	0	5.63	0	20.0	7.2	2524
5	0	8.67	0	19.5	5.8	2481
7	0	5.74	0	19.0	5.5	727
10	0	5.31	0	17.0	6.2	303
12	0	9.88	0	16.5	6.8	1938
14	0	9.95	0	15.0	6.1	625
19	1	5.45	0.18	15.0	4.6	39
21	0	13.33	0	13.5	5.7	13
26	8	4.34	1.84	13.5	9.8	314
28	22	16.61	1.32	13.5	11.1	452
31	9	15.98	0.56	10.5	14.4	1332
Nov 2	3	10.32	0.29	9.5	11.5	1598
4	4	16.70	0.24	9.0	10.5	1282
7	10	9.37	1.07	9.5	11.7	191
9	3*	16.12	0.12	9.5	25.1	134
10	1	13.22	0.08	10.0	33.4	1994
14	0	16.23	0	9.0	23.6	476
16	0	10.11	0	9.3	26.2	617
18	0	11.07	0	9.5	26.4	496
21	1	6.98	0.14	8.2	38.2	2585
	61 juvs + 1 adult	$\bar{X}$ = 9.43	$\bar{X}$**=0.53			25747

* includes 1 adult

** mean of CPE when shad captured

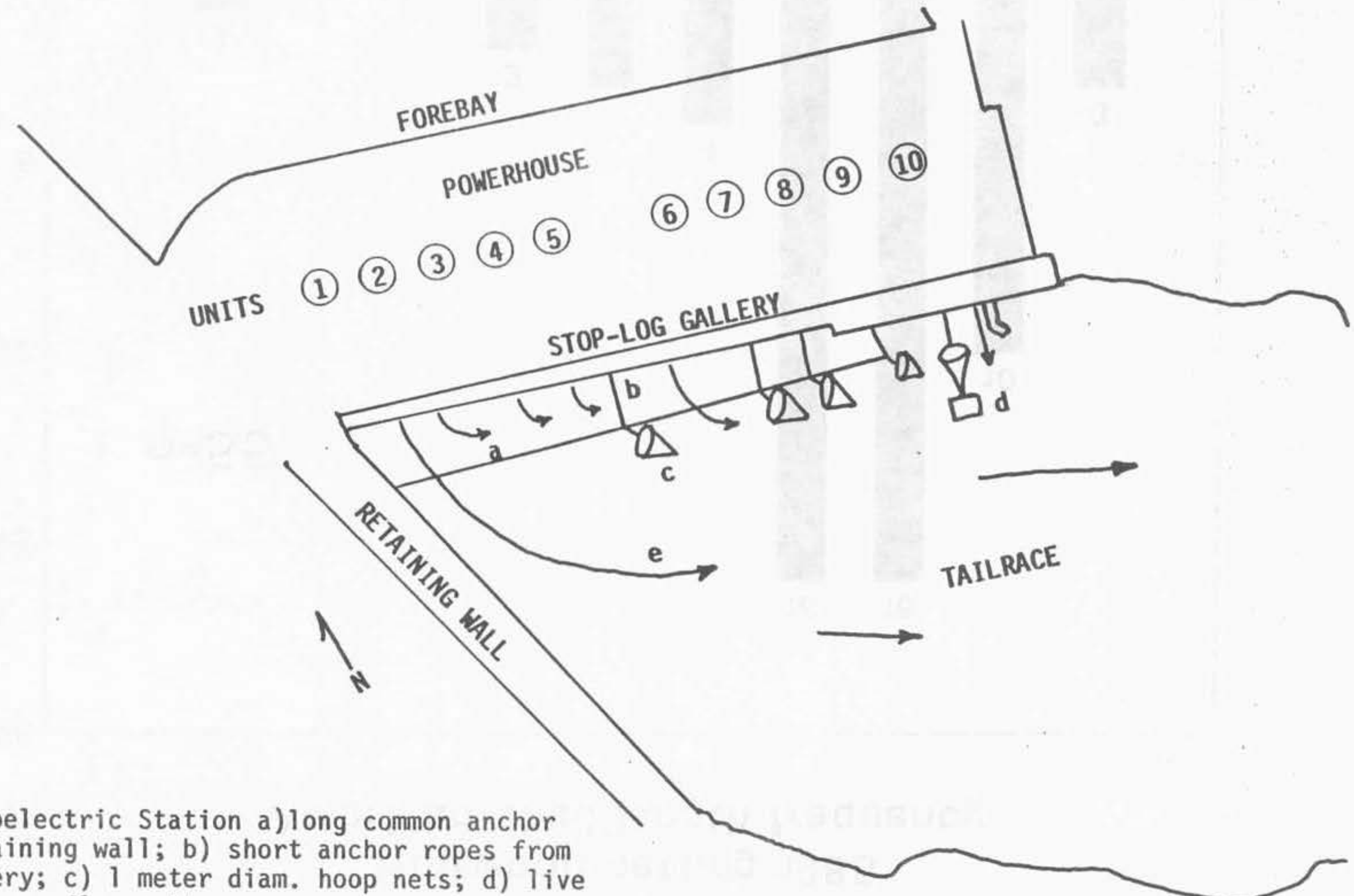

FIGURE 1

Holtwood Hydroelectric Station a)long common anchor rope from retaining wall; b) short anchor ropes from stop-log gallery; c) 1 meter diam. hoop nets; d) live car; e) discharge flow patterns.

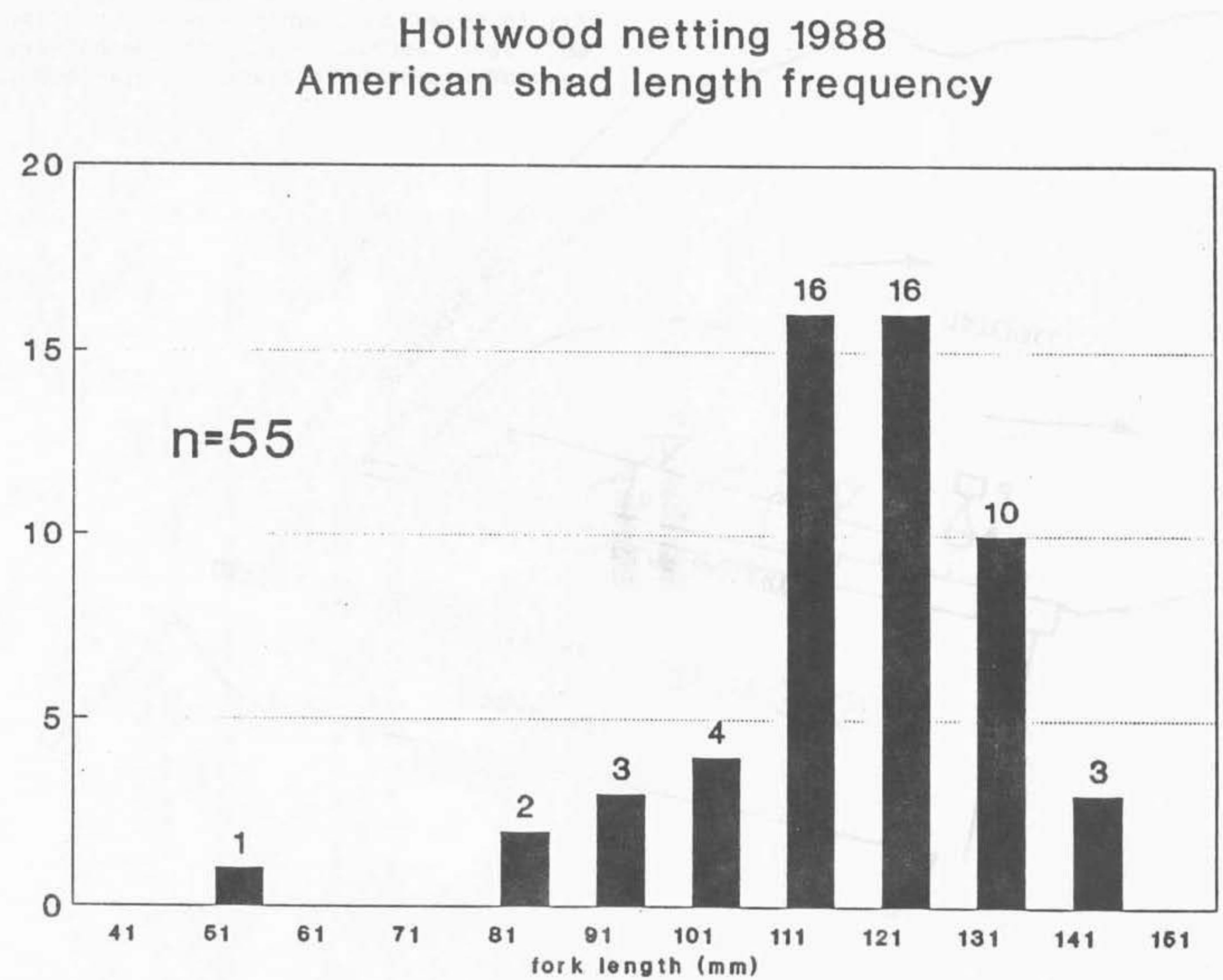

FIGURE 2

Length frequency distribution of juvenile American shad captured in the Holtwood Dam tailrace by 1 meter hoop nets in 1988.

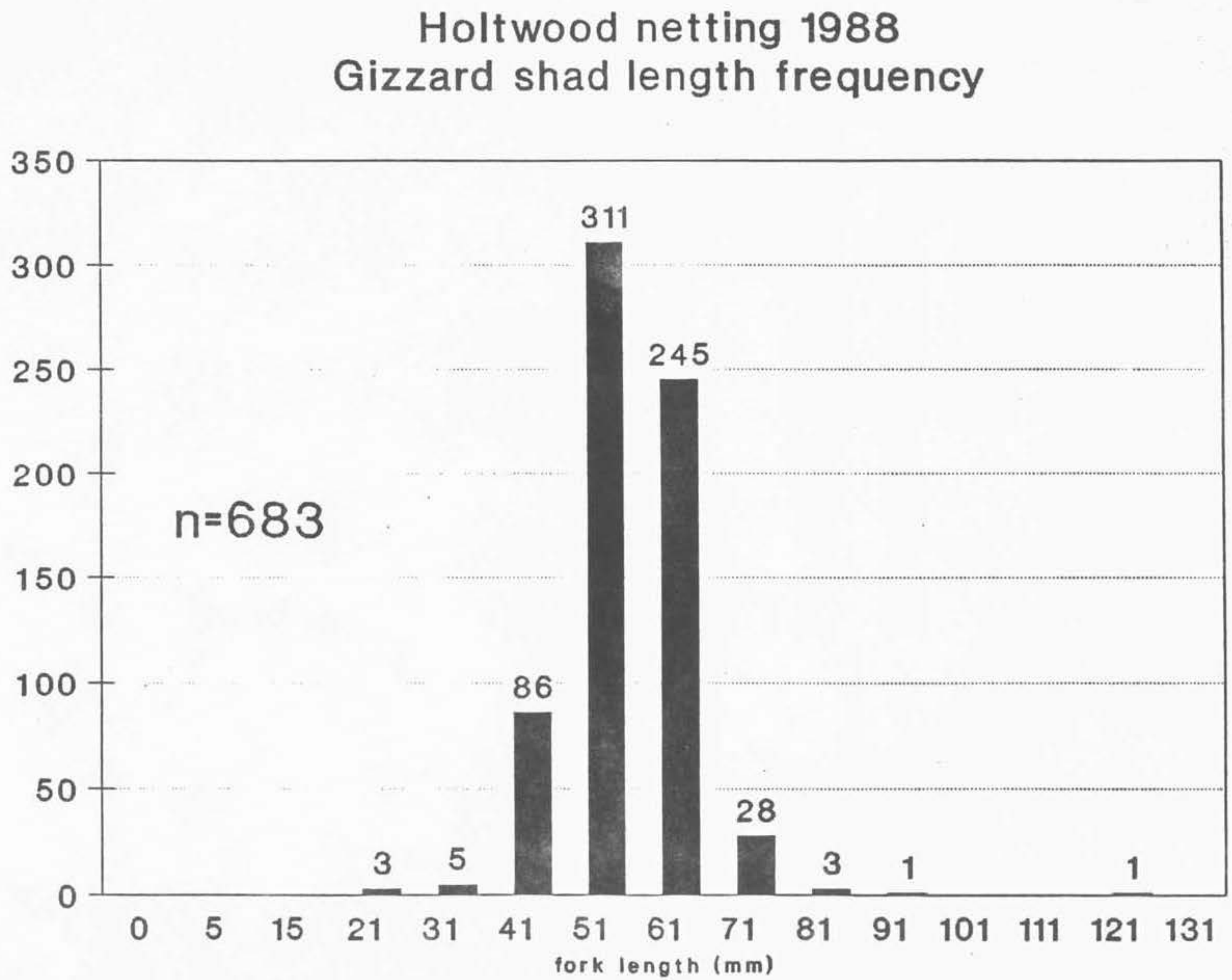

FIGURE 3

Length frequency distribution of juvenile gizzard shad capture in the Holtwood Dam tailrace by 1 meter hoop nets in 1988.

JOB V, TASK 1

DISPERSAL AND BEHAVIOR OF ADULT AMERICAN SHAD TRANSPLANTED FROM THE CONOWINGO FISH LIFT TO THE SUSQUEHANNA RIVER AT LONG LEVEL AND FALMOUTH, PENNSYLVANIA, 1988

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OCTOBER 1988

EXECUTIVE SUMMARY

The dispersal, behavior and spawning of radio tagged American shad released at two sites in the Susquehanna River above Safe Harbor Dam were investigated. Fifty-eight percent of 12 early and mid run shad released on two dates at Long Level on Lake Clarke moved at least five miles upstream to the riverine environment above Wrightsville. However, 82% of tagged shad above Safe Harbor Dam left the river quickly in mid May during a high flow event when all hydroelectric dams spilled.

Eleven late run shad were radio tagged and released in the vicinity of York Haven Dam (19 mi above Long Level) at Falmouth Access. Nine left the area within four days. Emigration of these shad past the hydroelectric dams was also accomplished quickly although no spillage occurred.

Shad spawning occurred at Wrightsville, York Haven and Accomac Pool. However, because of high flows in mid May, wild young shad captured during emigration in autumn will most likely be progeny of shad released late in the season at Falmouth. Earlier stocked shad had left the area during the high flow event.

Based on the 1988 radio tagging study it is recommended that shad transported from the Conowingo Fish Lift be stocked at Long Level when water temperatures are <60 F and at York Haven when water temperatures are ≥60 F. This would

allow shad a greater opportunity to utilize the riverine environment below York Haven for spawning.

INTRODUCTION

The behavior and spawning of radio tagged American shad, Alosa sapidissima transported to areas upstream of Conowingo Dam has been studied since 1986. These studies indicated that shad transported upstream of York Haven Dam (RM 56) dispersed over a large section of the middle Susquehanna River upstream of Harrisburg. This dispersal pattern most likely hindered spawning success and thus decreased potential juvenile production (RMC 1986). The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) suggested that shad transported upstream of Conowingo Dam in 1987 be released at Long Level (RM 37) in Lake Clarke, with the hope that York Haven Dam would act to confine upstream migrating shad in one location to increase the chances of a successful spawn. However, only 29% of radio tagged shad released at Long Level reached York Haven, 19 miles above the release site. Although tagged shad remained at York Haven for more than a month few shad eggs were collected (RMC 1987).

Tagged shad released early in the 1987 run displayed a stronger urge to move upstream. Nearly half of these shad reached York Haven, while none released late in the run did so. This finding is believed to be related to increasing water temperatures, and led to the suggestion by SRAFRC that shad collected at the Conowingo Fish Lift at river temperatures < 68 F be transported to Long Level, and those collected at $\geq$ 68 F be transported directly to the York Haven area.

Of the 4,645 shad transported upstream from the Conowingo Fish Lift in 1988, 72% were released at Long Level, and the remainder at Falmouth Access (RM 55.8), across the river from York Haven Station (Figure 1). A subsample of each group was radio tagged and monitored to determine dispersal and movement patterns, residence time in potential spawning areas, identify these spawning sites, and evaluate the effectiveness of dual release sites for transported shad. Incidental mortality estimates of turbine passage at Safe Harbor and Holtwood dams were also obtained.

METHODS

Radio Tracking of Dispersed Shad

American shad for dispersal and movement study were taken from the Conowingo Fish Lift and radio tagged on four occasions (24 April, 15 and 31 May, and 2 June). Each batch consisted of seven shad. Radio tags and handling procedures utilized were similar to those employed earlier (RMC 1987). The first two groups were collected at water temperatures <68 F and were released at Long Level Access. The latter two groups were collected when water temperature exceeded 68 F, and were released at Falmouth Access. Each batch was released with 100 or more untagged shad.

All radio tagged shad were released in late afternoon or evening. The first batch was monitored hourly until the next morning. Each subsequent batch was monitored beginning the morning following introduction. Thereafter shad were monitored at least twice weekly by boat, truck or airplane. Exact fixes were obtained by boat, whereas general fixes were obtained by vehicle or airplane. As the number of tagged shad present in the river increased, greater reliance on monitoring by airplane resulted in improved efficiency. Most flights covered the river from York Haven Dam to the river mouth including the Susquehanna Flats.

Previous studies indicated that transported shad concentrated in the forebays of hydroelectric stations, particularly at Safe Harbor Dam (RMC 1986, 1987). Therefore, in 1988 two continuous monitors were employed to more efficiently monitor arrival and departure times of shad in the vicinity of the Safe Harbor Forebay. Each continuous monitor consisted of a data collection computer (DCC) coupled with an Advanced Telemetry Systems (ATS) programmable scanning receiver. Forebay continuous monitors utilized full wavelength underwater antennas of heavy gauge copper wire suspended vertically. The DCC's were programmed to scan each tag frequency for three seconds. When a signal was received, the DCC statistically analyzed the average time between pulses. If the pulse variance was $\leq$ 5000 the DCC considered it a valid signal and recorded day, time, frequency, pulse rate and variance in its random access memory (RAM). Data were then retrieved and stored on a disk with a Tandy 600 portable computer.

The locations and dates when continuous monitors were employed at the Safe Harbor forebay are presented in Figure 2. The DCC on the skimmer wall recorded fixes in lower Lake Clarke outside the forebay as well as shad inside the forebay. Except for a brief period from 12-15 May, at least one DCC monitored shad at Safe Harbor Dam from 23 April to 29 May, and from 20-30 June.

A third continuous monitor coupled to a 5 element YAGI antenna was deployed in upper Accomac Pool at RM 48.3 (Figure 1). It operated continuously from 9 May to 20 June except for an 18 hr period on 19-20 May. Shad ascending from Long Level, or descending from Falmouth could be monitored from this location.

Detection of Spawning

Ichthyoplankton samples were taken at night on six occasions to check for shad spawning. Radio tagged shad were located from a boat at dusk. A 1 m plankton net was set just under the surface for 10 min downstream of each shad. On one night several samples were taken above Falmouth Access where more than 600 shad had been released the previous evening, although tagged shad were not present there. Variables measured and recorded for each collection included water temperature, water depth, date, time, and location. Samples were preserved in 10% formalin, sorted and enumerated.

RESULTS

Dispersal Patterns from Long Level

Fourteen shad (8 males and 6 females) in two batches of seven were radio tagged and released at Long Level (Table 1). All shad from Batch 1 survived, whereas two shad from Batch 2 died or regurgitated their transmitters at or within one day of release.

Relatively few shad stocked at Long Level attained the York Haven area. Four of twelve Long Level shad (33%) reached York Haven in 5 to 16 days (average 11 days) (Tables 1 and 2; Figures 3 and 4). An additional two shad traveled upstream as far as Accomac Pool. Of the six shad (50%) that eventually reached Accomac Pool or above, five were from Batch 1. They remained at or above Accomac Pool an average of 17 days; however, all except one stayed from 4-18 days. One male shad from Batch 1 resided in or upstream of Accomac Pool for 49 days, and was still alive until at least 23 June, two months after release.

The maximum number of Long Level tagged shad located at York Haven was three during the period 6-13 May (Table 3). On 10 May two additional shad were located in Accomac Pool. By 15 May, all three had left the York Haven area, and only one shad remained at Accomac.

Two shad, both males from Batch 1, made multiple runs to York Haven Dam during their residence in the river (Figure 5). One (Fish No. 21) reached York Haven twice, and after each ascent remained there for 8 and 2 days, respectively. Subsequent to each run it never descended below Accomac Pool. The second shad (Fish No. 140) made four separate runs to York Haven and a fifth run to upper Accomac Pool between 29 April and 23 May. Two of these runs originated from Safe Harbor Dam, two from Long Level or Lake Clarke, and one from the Wrightsville area. The longest residency at York Haven after an ascent was five days, and averaged less than four days.

Both ascents and descents by Fish No. 140 were accomplished quickly, but downstream runs typically were of shorter duration. For example, at 0810 hr on 3 May this shad was found at RM 50.3, near the mouth of Codorus Creek in upper Accomac Pool. By 2143 hr on 3 May, the skimmer wall DCC recorded this fish in or near the Safe Harbor Forebay, 18 miles downstream. Similar descents from Accomac Pool to Safe Harbor Dam (16 miles) took 8 and 9.5 hrs each. While one ascent of 10 miles from Long Level to Accomac Pool was accomplished in 10 hr, the others generally took 2-3 days, although our estimate of the timing of these ascents was less precise.

The remaining six shad (50%) from the early and mid releases never travelled upstream past the Rt. 462 bridge at

Wrightsville, a distance of five miles. Two of these were never located upstream of the release site, and three never moved more than two miles upstream of the release site.

After the release of Batch 2 shad on 15 May several days of heavy rain increased river flow from 28,000 cfs to 191,000 cfs and caused spillage at all of the hydroelectric dams (Figure 6). Water temperature decreased from 69 to 59 F (Figure 6). Concurrently nine shad disappeared between 16-24 May. Six were later found downstream as far as Perryville, MD and three others most likely passed undetected downstream with them. After 24 May, only two radio tagged shad remained upstream of Safe Harbor Dam.

Dispersal Patterns from Falmouth Access

Fourteen shad (3 males and 11 females) in two batches of seven were radio tagged and released in the York Haven Dam area at Falmouth Access. One shad from Batch 3 and two shad from Batch 4 died or regurgitated the transmitter (Table 1).

Only four (36%) of 11 shad spent more than one day in the York Haven area (Table 2; Figures 7 and 8). These four were all females and spent 3 to 14 days at York Haven, average 8.5 days. A fifth female remained at York Haven for only one day, then dropped down to Accomac Pool and remained there for six days before leaving. Four of the remaining six shad had left the York Haven area by the morning following release. They descended to Wrightsville or Lake Clarke within 3-4 days after release.

A maximum of six shad remained at York Haven and four in Accomac Pool on 3 June, the day following the release of Batch 4 at Falmouth (Table 3). By 6 June these numbers were halved as shad rapidly left upstream areas. Once a shad left the York Haven release area it never returned. However, two and possibly a third shad dropped to the upper Accomac Pool area from York Haven and remained there for up to six days. On most days during the period 4-11 June two tagged shad were simultaneously located within the Accomac Pool (Table 3).

Residence at York Haven and Accomac Pool

Shad that ascended to or were released in the York Haven area were typically located between RM 55 and 56, particularly in the tailrace of the power station (Figure 9). Less frequent utilization of shallower reaches downstream (RM 53 to 55) was observed. However, on several occasions shad moved downstream at dusk or before midnight to below Brunner Island Station. Four shad utilized the Conewago Falls area (RM 56 to 57) but only one shad was ever located there more than once.

Radio tagged shad in Accomac Pool were typically found in the upper 2.5 mi (RM 47.5 - 50.0) of the five mile long reach. For example, Fish No. 183, released at Falmouth, spent five days between RM 47.5 and RM 48.3, and recorded nearly continuous fixes on the DCC monitor there (Figure 1). Fish No. 21 spent two months in the river, mostly near or upstream of the monitor location. In contrast, any shad located in the lower portion of the pool were usually descending rapidly.

Utilization of Safe Harbor Forebay

Ten of 12 (83%) shad released at Long Level moved downstream to Safe Harbor Dam within 1 to 25 days (Table 1). Three of seven (43%) shad from Batch 1 descended to Safe Harbor within nine days; two of these spent one day at Safe Harbor and subsequently ascended to York Haven. One of these was eventually located at Safe Harbor twice more after runs to York Haven. Four of five (80%) shad from Batch 2 moved downstream to Safe Harbor within 3 days of release. Three of these dropped to Safe Harbor by the day following release. One of these shad was subsequently located again at Safe Harbor after spending about 8 days at York Haven.

Six of 11 shad (55%) released at York Haven reached Safe Harbor Dam. They remained there for five or fewer days (Table 1). Once reaching Safe Harbor they continued downstream. In contrast, several shad stocked at Long Level moved upstream after an initial descent to Safe Harbor. Four of the five (80%) shad which did not reach Safe Harbor died upstream at Columbia or in lower Lake Clarke. The other was last located alive at Long Level.

<u>Passage at Hydrostations</u>

At least 11 (48%) radio tagged shad, eight from those stocked at Long Level and three from those released at York Haven, successfully passed Safe Harbor Dam. It is likely that three additional Long Level shad passed successfully during the period of high flows. These three had been associated with Fish 355 whose next location after the Safe Harbor Forebay was at the mouth of the river at Perryville, MD.

Passage through Lake Aldred was accomplished quickly, with the majority of the shad most likely passing during high river flows in mid May. Only three of 14 shad (11 known, 3 probable) were ever located between Holtwood and Safe Harbor dams. None of these was ever located in Lake Aldred more than once.

Only two active shad were located in the Holtwood tailrace. One eventually died there and the other was not located again. Although no shad were ever located in Conowingo Pond, two were located in tidal water below Conowingo Dam. Both passed through the impoundments during high river flows in May. One fish was located at the river mouth near Perryville, MD on 27 May, apparently shortly after passage, and the other was found at Lapidum, MD about three weeks after its last occurrence in the Safe Harbor forebay.

Spawning

Spawning was monitored in the vicinity of York Haven Station, in upper Accomac Pool and at Wrightsville . Twenty nine samples were taken during six nights downstream of eight different shad (Table 4). Samples were taken below one female on four nights, but most fish were represented in the samples once or twice. One female was sampled at York Haven and in Accomac Pool on different nights. Water temperature ranged from 66.8 to 75.2 F for all samples.

Samples at York Haven were taken below the main dam, in the tailrace, and along both shores between York Haven Station and Brunner Island Station (Table 4; Figure 9). Egg samples at Wrightsville were taken from near the west shore immediately below the Rt. 462 bridge just prior to the onset of high river flows and a subsequent 10 F decrease in water temperature. The 4.5 F difference in water temperature from samples in Accomac Pool (Table 4) was due to the influence along the west shore of the Brunner Island Steam Station discharge five miles upstream.

A total of 79 shad eggs was collected on five of the six nights sampled (Table 4). Shad eggs were collected at Wrightsville, York Haven and Accomac Pool. At York Haven, 72% of the shad eggs were taken on 6 June. Of the 60 shad eggs collected at York Haven, all but one (98%) were taken near the west shore between York Haven Station and Brunner Island Station (Figure 9).

Turbine Passage

Eleven radio tagged shad were known to have passed Safe Harbor Dam during the monitoring period in 1988. An estimate of turbine mortality may be precluded because at least six shad passed Safe Harbor during spill conditions which occurred from 1230 hr on 20 May to 2215 hr on 23 May, and from 0200-0500 on 24 May. One of these shad ceased movement downstream of the station. It is not known whether it passed through the turbines or spilled over the dam. The remaining five shad which passed Safe Harbor when no spillage occurred survived.

Nine shad were known to have passed Holtwood Dam; six of these ceased movement after passage. Of the four which passed during spillage (17 May - 2 June) two subsequently ceased movement below Holtwood. Four of five which passed before or after the spill event died and were later located in the tailrace.

Two shad were known to have passed Conowingo Dam. Both were found alive after passage during the spill event. Their exact route of passage (turbine or spill) is unknown.

DISCUSSION

Late-running shad transported directly to the York Haven area in 1988 did not reside long term in this reach. Only two shad stayed at York Haven more than four days. However, data suggest that a lengthy residence by shad at York Haven may not be a requisite to achieve spawning per se, particularly if they are transported there late in the run. Despite the fact that most radio tagged shad spent three or fewer days at York Haven a substantially larger number of shad eggs was collected in 1988 than in 1986 or 1987. Residency of three days or less may be sufficient time for shad to spawn if transported at or near their spawning temperature (≥ 65-68 F). In fact, the highest number of shad eggs was taken on 6 June, one day after the largest daily transport of shad (n = 623) to Falmouth occurred.

The percentage of radio tagged shad released at Long Level that moved to York Haven (43% of the Batch 1 release) was similar to that observed for early released shad in 1987 (41%) (RMC 1987). The percentage of shad which reached York Haven from combined early and mid-run released fish was also similar (33% in 1988 vs 38% in 1987) despite the high flow event in mid-May. However, the attainment of York Haven as a barometer of success for shad released at Long Level may be overstated. Shad eggs were collected at Wrightsville before the high flow event and at the upstream reach of Accomac Pool after this event passed. Usage of the upper

Accomac Pool by several shad was substantial in 1988. Perhaps shad need only to ascend beyond Wrightsville to reach suitable spawning areas.

Collection of shad eggs at York Haven in 1988 suggested that a spawning area may lie along the west shore between the confluence of Conewago Creek below York Haven Station and the Brunner Island Station 1.5 miles downstream. This area is relatively shallow and characterized by a gravel bottom and moderate to slow current. Although shad were normally scattered throughout the York Haven area at night, there was usually at least one tagged shad in this reach on the nights sampled. Although fewer shad eggs were taken in 1987, they were collected from the same area.

The high river flows and decline in water temperature in mid-May likely halted further spawning and eliminated any juvenile production by shad transported prior to this event. More than 3,300 shad had been released at Long Level by 16 May, nearly three-fourths of the total transported. During the high water period an estimated 82% of tagged shad above Safe Harbor left the river. If wild young shad are collected during emigration studies in 1988 they will most likely be progeny of adults transported directly to the York Haven area.

Shad transported to Long Level may range widely between York Haven and Safe Harbor dams. Two male shad made multiple ascents to York Haven in 1988. One female exhibited similar movement in 1987. This behavior was limited to shad released early in the run (April). The absence of this behavior in shad released later in the run suggests that they ripen, spawn, and emigrate quickly. This may be due to the warmer temperatures and increased numbers of shad present above Safe Harbor Dam later in the run.

Emigrating adult shad spent less time at hydrostation forebays in 1988, particularly at Holtwood. While the high flow event hastened emigration of the first two groups released at Long Level, shad released later made similarly rapid descents. No shad spent more than six days in or near a forebay.

The deployment of up to three strategically located constant monitors was invaluable for detection of shad movement. It enabled compilation of a more detailed description of shad utilization of the Safe Harbor Forebay. Rapid upstream or downstream movements of at least 16 miles in less than 10 hr were detected, largely through fixes provided by the constant monitors. The Accomac monitor provided a clearer picture of when shad departed the York Haven area. Perhaps the most significant finding was the extent of shad residency time at upper Accomac Pool, both as a result of upstream movement by shad stocked at Long Level, as well as downstream movement by shad released at Falmouth. This reach is also conducive to spawning; shad eggs were collected there in June.

Estimates of gross mortality at hydrostations were hindered by high river flows which enabled shad to bypass turbines through spillage. For the few shad which passed dams when no spillage occurred, mortality at Holtwood was much higher than at Safe Harbor. Although live shad were detected downstream of Conowingo Dam, they may have utilized spills which precluded any estimate of turbine passage mortality.

SUMMARY OF FINDINGS

1. A total of 12 early and mid-run American shad with a 50:50 sex ratio was radio tagged and released into Lake Clarke at Long Level. Seven (58%) moved upstream at least five miles, and four (33%) reached the York Haven Area. Three of the four were males.
2. Two early run male shad released in April made multiple ascents to York Haven. One shad reached York Haven four times.
3. Nine of eleven (82%) shad in the river on 16 May left during a high flow event when all hydroelectric dams spilled.
4. Radio tagged shad stocked at Long Level arrived at York Haven in 5 to 16 days and spent a maximum of eight days there. One shad released in April remained in Accomac Pool for the duration of the monitoring period after first making two trips to York Haven.
5. Eleven late run shad were radio tagged and released directly into the York Haven area. All but two were females.
6. Four (36%) of these remained at York Haven for more than one day, but only two stayed longer than four days. Six (55%) descended to Wrightsville or Lake Clarke in three days or less.
7. Radio tagged shad ascending to or descending from York Haven spent up to 20 consecutive days in upper Accomac Pool. Most shad resided there for six or

fewer days.

8. Shad eggs were taken downstream of radio tagged shad at York Haven, Wrightsville, and Accomac Pool. Most eggs were taken at York Haven the night after 623 shad were released at Falmouth Access.
9. Shad eggs collected at Wrightsville were obtained before the high flow event, but most progeny were likely lost. Emigrating feral juvenile shad, if collected in autumn 1988, will most likely be the result of late spawning shad.
10. Emigrating tagged shad from either release site moved quickly past Safe Harbor and Holtwood dams. No shad utilized either forebay for more than six days. None were located in Conowingo Pond.
11. Mortality of tagged shad due to turbine passage was higher at Holtwood Dam than at Safe Harbor Dam.
12. The deployment of constant monitors at strategic locations in the study area enhanced the quality and quantity of data obtained. In particular, rapid upstream or downstream movements were detected that otherwise may have been missed.

RECOMMENDATIONS

A persistent problem with shad transported to Long Level has been the failure of nearly half of the fish to leave Lake Clarke and move upstream. The release of fish at York Haven when captured at ≥ 68 F was considered a remedial solution. However, dispersal behavior of Batch 2 shad released at Long Level suggests further refinement of temperature criteria may be warranted. Five of seven shad from Batch 1 reached at least Accomac Pool; they were captured and released at < 55 F. Four of five batch 2 shad captured three weeks later at 63.5 F, and released when river temperature at the release site was 71.6 F had descended to Safe Harbor within three days. Higher water temperatures, the disparity between capture and release temperature, and the more advanced state of maturity of Batch 2 shad all may have contributed to the different dispersal pattern observed.

To partially overcome this problem in the future it is recommended that when the water temperature at Conowingo is ≥60 F, shad should be transported directly to York Haven. Although it is likely that "drop back" due to warmer water temperatures upstream may still occur, there are 14 mi of riverine environment below York Haven where shad may spawn. The additional distance above Safe Harbor Dam may reduce the opportunity for shad to emigrate before they can acclimate to the upstream environment. Shad captured at water temperatures <60 F may still be stocked at Long Level.

High river flows and spillage at hydro projects hastened emigration of shad. Because these events are natural and will continue to remain uncontrolled some modifications of trap-transport procedures are necessary to reduce the impact of these events. In future years upstream transport of shad should be halted if advance knowledge of these flow conditions is available. Then, shad captured at Conowingo could be either released back to the tailrace, or perhaps transported to upstream holding facilities from which they may be released after river flows subside, thus protecting the potential progeny. Upstream holding facilities may also improve acclimation of transported shad. These facilities would facilitate adjustment to water temperature differentials, provide an opportunity for shad to recover from any handling or transport stress, and allow larger schools of shad to be released with a higher female to male ratio.

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Table 1 Summary of American shad released between Safe Harbor and York Haven in 1988. Data in parentheses are best estimates.

Fish Number	Sex	Release Date	Distance Moved In 16 hr	Max. Dist. Moved Upstream	Number Of Days To York Haven	Number Of Days At York Haven	Number Of Days To Safe Harbor	Number Of Days At Safe Harbor	Number Of Days To Holtwood	Date Of Last Location	Last Location	Status
21	M	24 April	1	19	12	8,2	(>60)	-	-	23 June	Accomac	Alive
52	F	24 April	2	2	-	-	17	(6)	-	27 May	Holtwood Tailrace	Dead
70	M	24 April	3	11	-	-	24	(3)	-	27 May	Safe Harbor Tailrace	Dead
90	F	24 April	1	1	-	-	1	(2)	(4)	3 May	Holtwood Tailrace	Dead
120	F	24 April	2	19	16	1-3	3,18	1,2	-	10 June	Lapidum	Alive
140	M	24 April	2	20	5	2,5,1,1	9,15,7	1,1,0	-	25 May	Safe Harbor Tailrace	Dead
170	M	24 April	2	12	-	-	25	2	-	20 May	Safe Harbor	Alive
210	M	15 May	-5	0	-	-	1	5	-	20 May	Safe Harbor	Alive
241	M	15 May	1	1	-	-	-	-	-	16 May	Long Level	Dead
271	M	15 May	Dead	-	-	-	-	-	-	16 May	Long Level	Dead
290	F	15 May	5	5	-	-	(1-2)	-	-	19 May	Lake Clarke	Alive
319	F	15 May	1	1	-	-	3	1	-	27 May	Holtwood Tailrace	Dead
355	F	15 May	-5	0	-	-	1	(3)	-	27 May	Perryville	Alive
381	M	15 May	-5	20	12	(8)	1,19	2,0	(5)	10 June	Holtwood Tailrace	Alive
409	F	31 May	-	-	-	1	-	-	-	13 June	Columbia	Dead
441	F	31 May	-	-	-	0	-	-	-	3 June	Lake Clarke	Dead
461	F	31 May	-	-	-	(3)	(>6)	-	-	6 June	Long Level Area	Alive
490	F	31 May	Dead	-	-	-	-	-	-	10 June	Bainbridge	Dead
542	F	31 May	-	-	-	1	-	-	-	6 June	Lake Clarke	Dead
592	F	31 May	-	-	-	13	16	(5)	-	20 June	Safe Harbor	Alive
649	M	31 May	-	-	-	0	6	3	-	8 June	Safe Harbor Forebay	Alive
750	F	2 June	-	-	-	0	(9)	-	(4)	22 June	Holtwood Tailrace	Dead
808	F	2 June	-	-	-	0	(2)	0	(*2)	7 June	Holtwood Tailrace	Dead
921	M	2 June	Dead	-	-	-	-	-	-	3 June	Falmouth Launch	Dead
979	F	2 June	Dead	-	-	-	-	-	-	3 June	Falmouth Launch	Dead
110	M	2 June	-	-	-	1	-	-	-	20 June	Columbia	Dead
183	F	2 June	-	-	-	4	11	(1)	-	13 June	Safe Harbor	Alive
883	F	2 June	-	-	-	14	(>15)	(<5)	(<5)	22 June	Holtwood Tailrace	Dead

* Recorded one day upstream of Holtwood Dam.

TABLE 2

Movement patterns of radio tagged shad released at Long Level (early, mid) and Falmouth Access (late), 1988.

Time Period	Number Live Shad Released	Number (%) Moved		
		Riverine Area	York Haven	Safe Harbor/ Lake Clarke
Early 24 Apr	7	5(71)	3(43)	2(29)
Mid 15 May	5	2(40)	1(20)	4(80)
		Remained at York Haven >1 day	Remained Accomac Pool or above >1 day	Descended Wrightsville/ Lake Clarke ≤3 days
Late 31 May, 2 Jun	11	4(36)	5(45)	6(55)

TABLE [illegible]

Number of active radio tagged shad in the vicinity of York Haven, Accomac Pool, forebays of Safe Harbor and Holtwood, and in Conowingo Pond in 1988.

Date	York Haven Tailrace	Accomac Pool	Safe Harbor Forebay	Holtwood Forebay	Conowingo Pond
April					
25	-	-	1	-	-
26	-	-	1	-	-
27	-	-	0	-	-
28	-	-	1	-	-
29	1	0	0	0	0
30	1	0	-	-	-
May					
1	-	-	0	0	-
3*	0	1	1	0	0
6	2	1	0	0	0
7	2	1	-	-	-
8	0	0	-	-	-
9	-	0	-	-	-
10	3	2	0	-	-
11	1	2	1	-	-
12	-	-	1	-	-
13	2	1	1	0	-
15	-	1	-	-	-
16	0	2	5	-	-
17	0	1	3	-	-
18*	-	1	4	-	-
19	-	-	2	-	-
20	0	1	3	-	-
21	-	-	0	-	-
22	-	-	0	-	-
23	1	1	0	-	-
24*	-	1	1	-	-
25	1	1	0	-	-
26	-	0	0	-	-
27	2	0	0	0	0
28	-	0	0	-	-
29	0	0	0	-	-
30	-	0	0	-	-
31	0	0	0	-	-
June					
1	5	0	0	-	-
2	3	1	0	-	-
3	6	4	0	0	0
4	-	2	0	-	-
5	-	2	0	-	-
6	3	2	1	1	0
7	-	2	1	0	0
8	-	1	1	0	0
9	-	2	0	0	0
10	2	1	0	0	1
11	-	2	0	-	-
12	-	0	0	-	-
13	2	1	1	0	0
14	-	0	0	-	-
15	-	0	0	0	1
16*	1	2	0	0	0
17	-	0	0	-	0
18	-	0	0	-	-
19	-	0	0	-	-
20	-	0	0	-	-
21	-	-	0	-	-
22	-	-	0	0	0
23	-	1	0	-	0
24	-	-	0	-	-
25	-	-	0	-	-
26	-	-	0	-	-
27	-	-	0	-	-
28	-	-	0	-	-
29	-	-	0	0	0
30	-	-	0	-	-

* Same shad found at each location

TABLE 4

Shad eggs collected by a 1-meter plankton net at three locations between the Safe Harbor and York Haven dams, 1988.

	Wrightsville	York Haven Area				Accomac Pool
River Mile(s)	42.4	55.7,55.4	55.7,54.3	56.1,55.9,54.3	54.8,55.8	49.2,49.5,47.5
Date	16 May	1 June	2 June	3 June	6 June	9 June
Number of Samples	2	4	4	7	6	6
Times	2120 2150	2159 2217 2245 2259	2210 2227 2304 2317	2122 2140 2156 2211 2301 2340 2354	2133 2148 2222 2238 2321 2339	2116 2132 2200 2239 2255 2309
Water Temperature	68.0	75.2	66.8	67.1,68.0	70.7	72.5,68.0
Number of Shad Eggs	8	0	9	8	43	11
Number Possible Shad Eggs	3	0	0	2	7	0
Other	2	1	0	10	4	0
Radio Tagged Shad* in Area	170(M)	542(F) 592(F)	592(F) 381(M)	110(M) 183(F) 592(F) 381(M)	883(F) 592(F)	21(M) 183(F)

* Listed by Tag Frequency (sex)

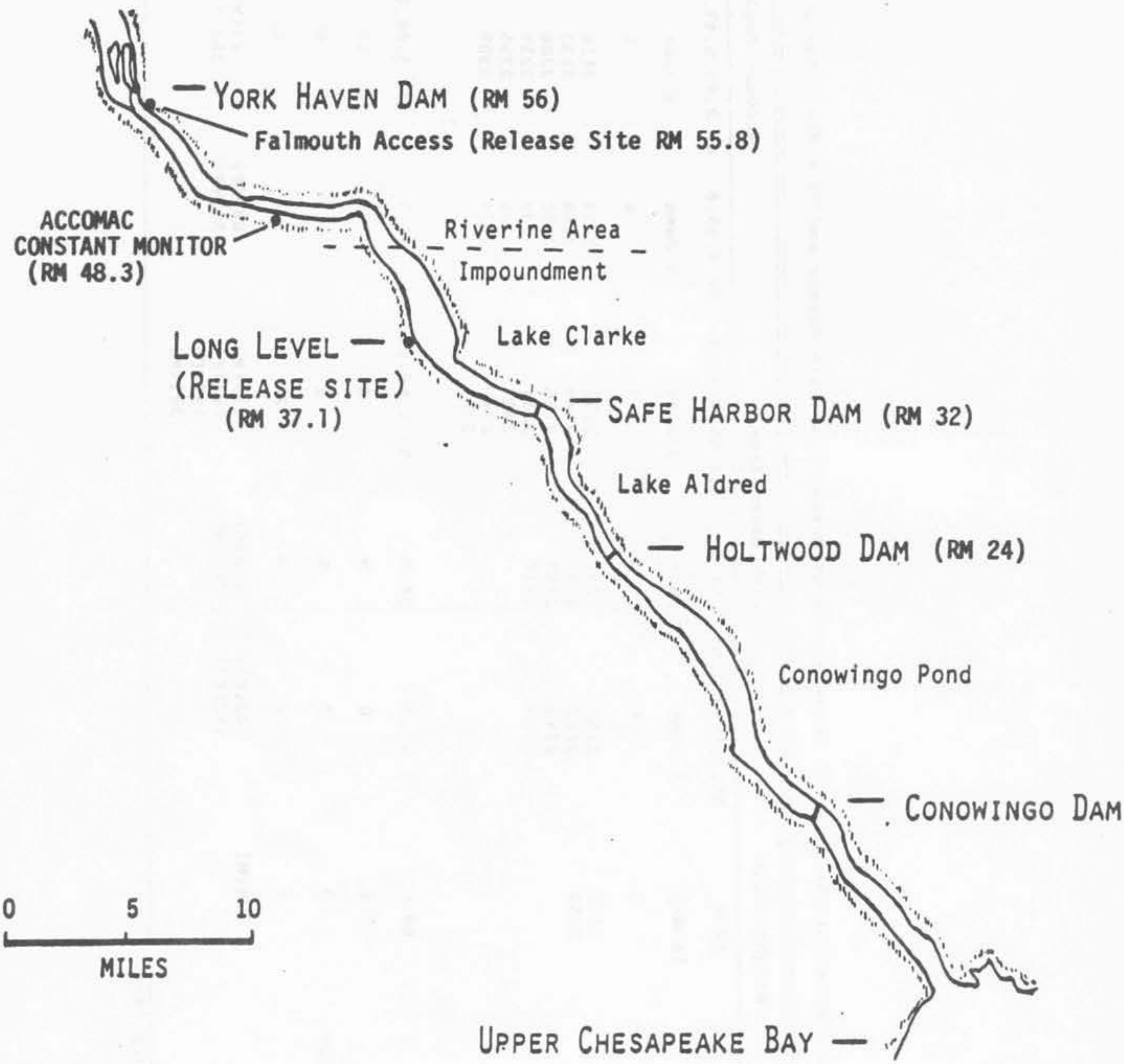
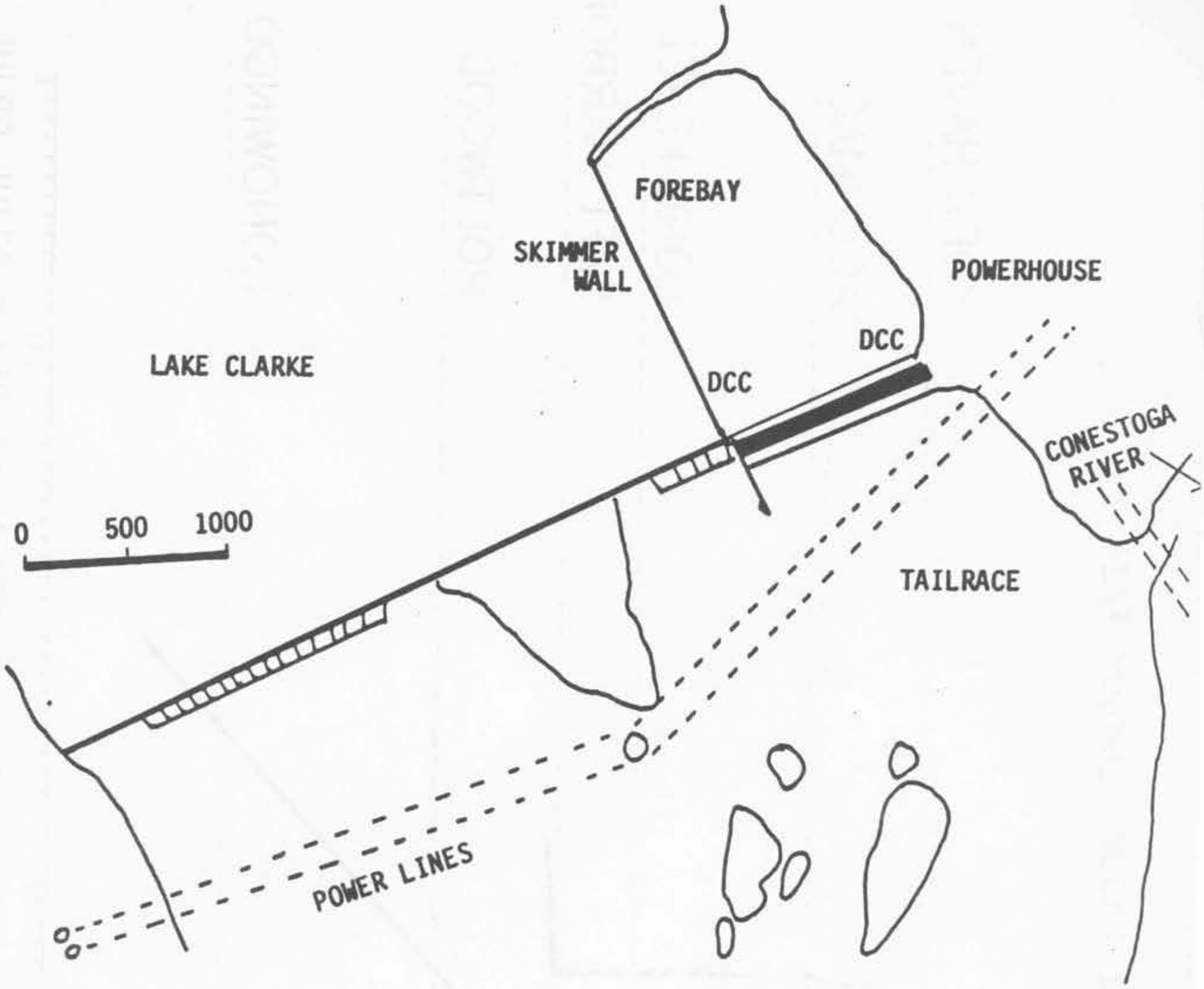


FIGURE 1

Areas monitored for radio tagged shad, 1988.



LOCATION	DATES DEPLOYED
Skimmer Wall	23 April - 12 May
	15 - 20 May
	26 - 29 May
	20 - 30 June
East Forebay	16 - 29 May

FIGURE 2

Location and dates of constant monitors (DCC) used at Safe Harbor Dam during radio telemetry study of American shad, spring 1988.

RELEASE GROUP =_GROUP 4/24

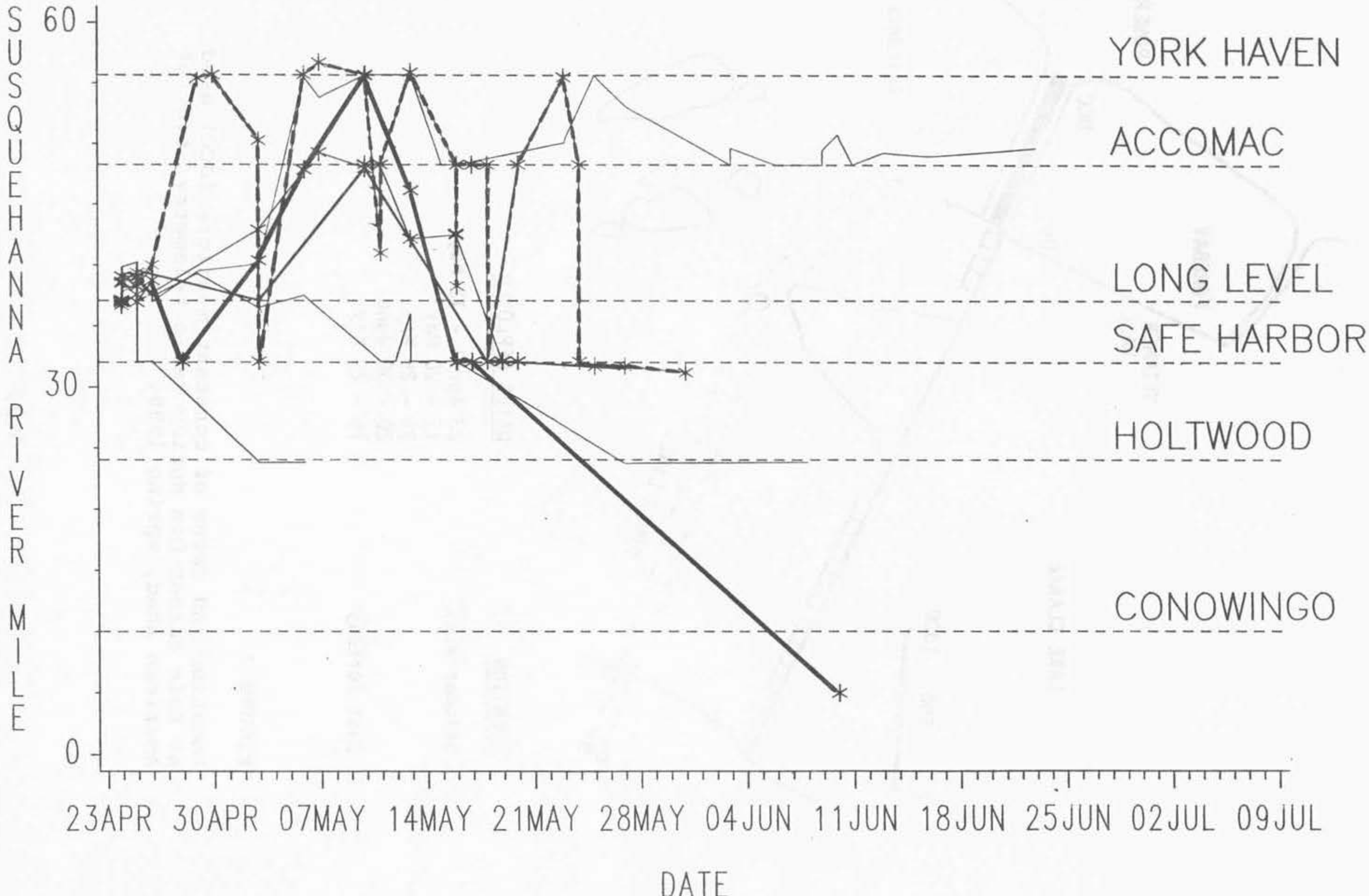


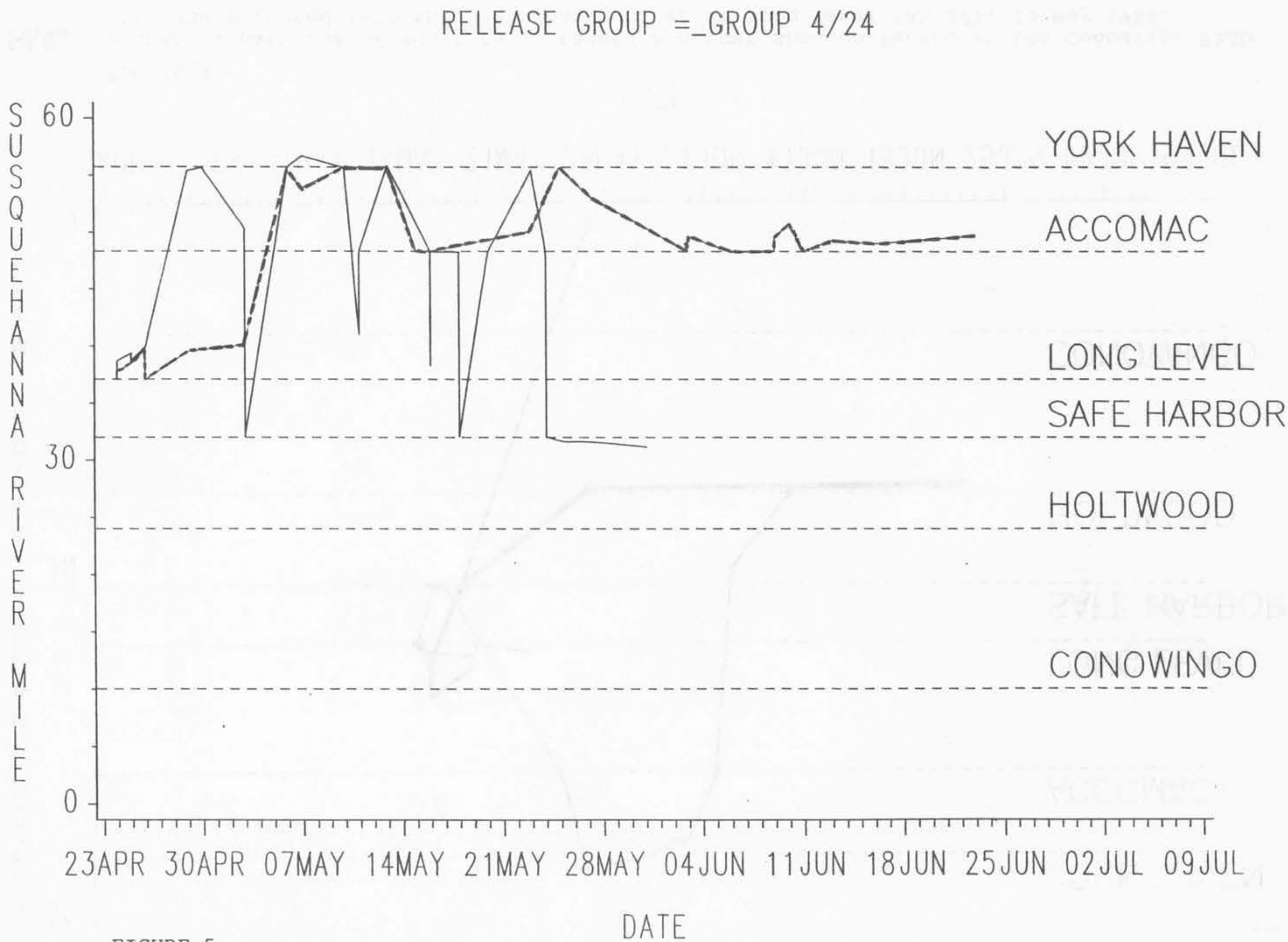
FIGURE 3

RMC Dispersal patterns of adult radio tagged American shad collected at the Conowingo Fish Lift and released into the Susquehanna River at Long Level (RM 37), 24 May 1988.

RELEASE GROUP =_GROUP 5/15

FIGURE 4

RMC Dispersal patterns of adult radio tagged American shad collected at the Conowingo Fish Lift and released into the Susquehanna River at Long Level (RM 37), 15 May 1988.



5-32

FIGURE 5

RMC

Movement of two radio tagged American shad between Safe Harbor Dam and York Haven Dam during spring, 1988. Both shad were released at Long Level (RM 37) on 24 April. Fish No. 21 = red line; Fish No. 140 = green line.

MEAN DAILY RIVER FLOW AND TEMPERATURE, 1988

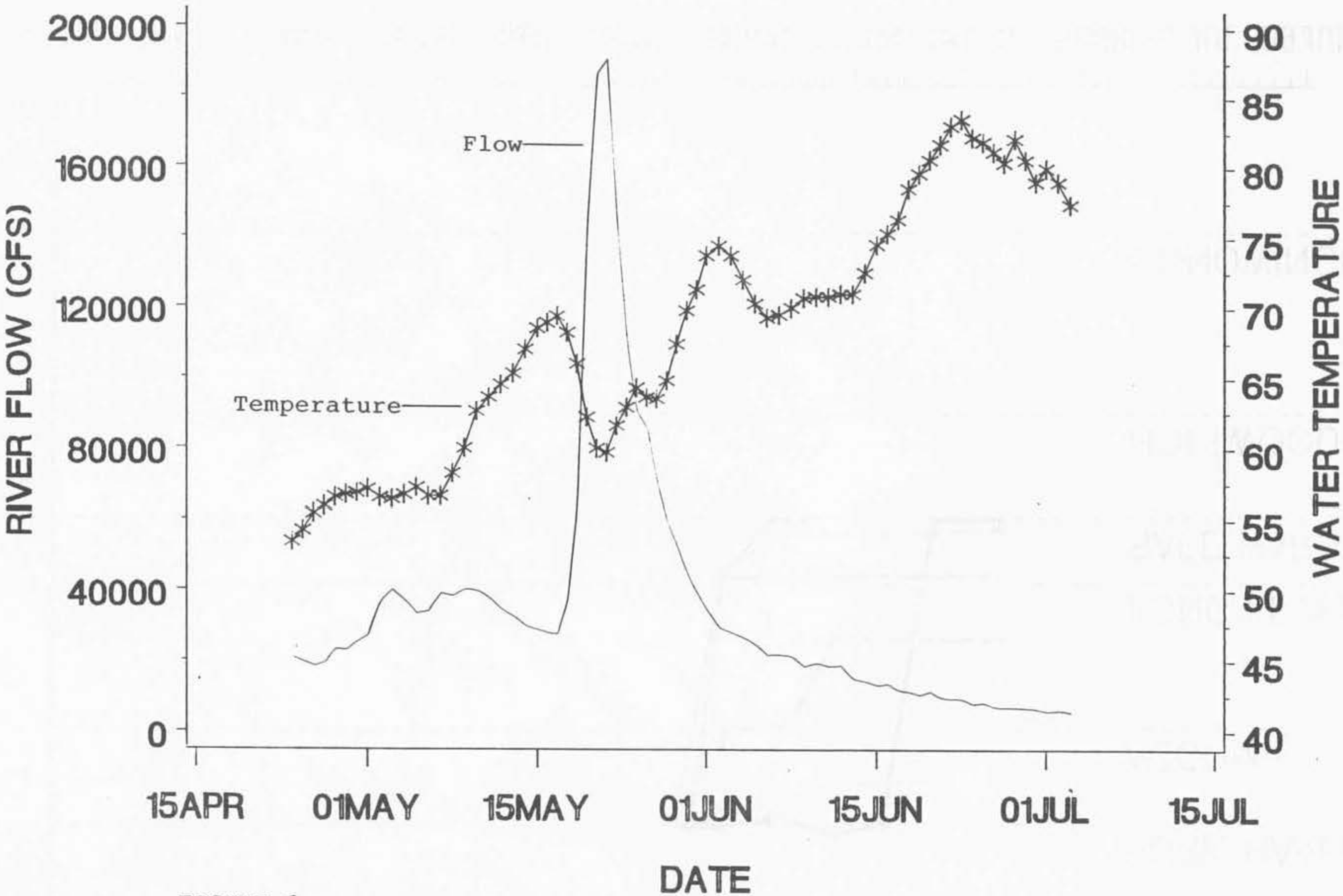


FIGURE 6

Mean daily river flow (cfs) and water temperature at Holtwood Dam during the study period, 1988.

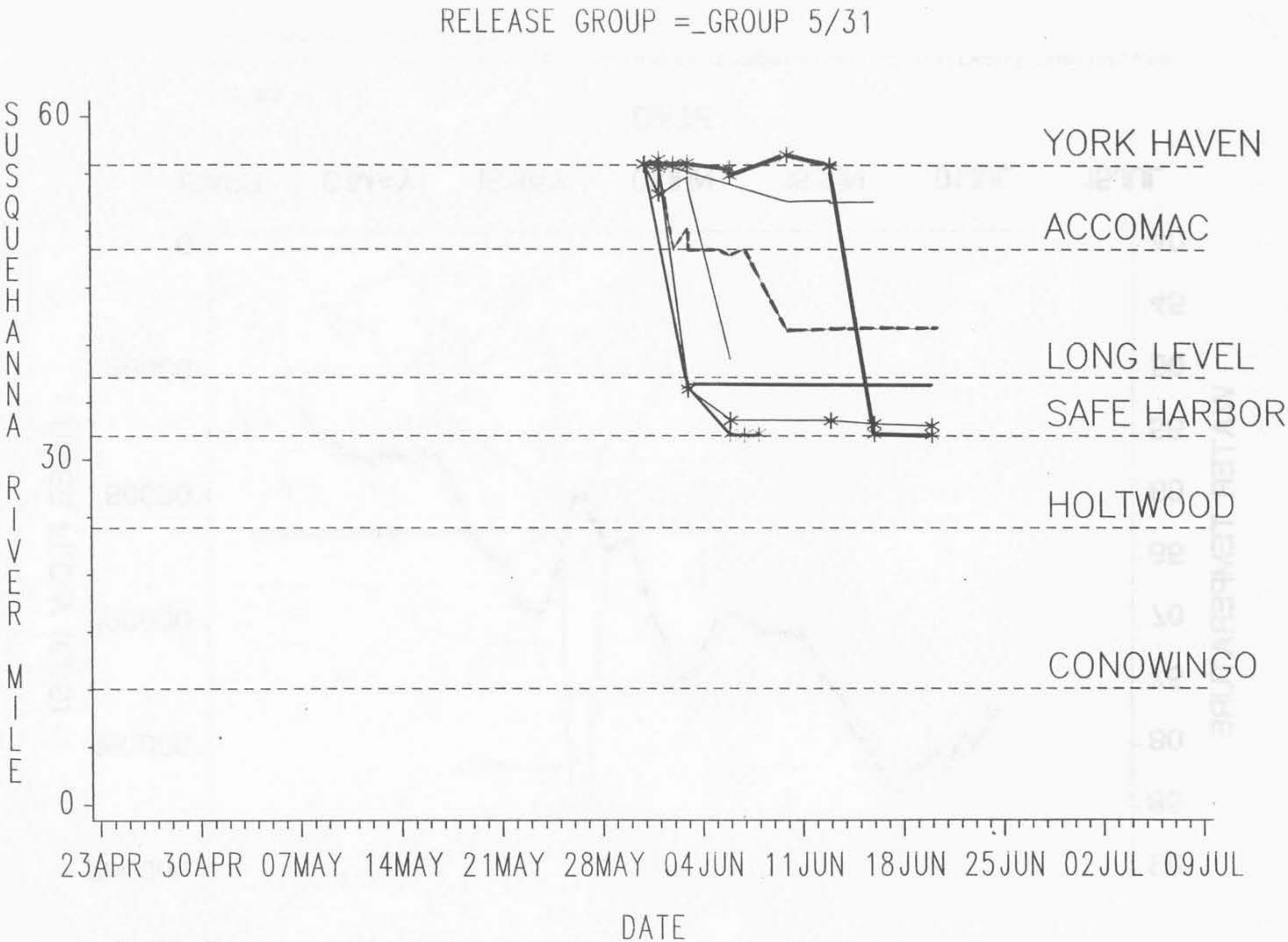


FIGURE 7

RMC Dispersal patterns of adult radio tagged American shad collected at the Conowingo Fish Lift and released into the Susquehanna River at Falmouth (RM 55.8), 31 May 1988.

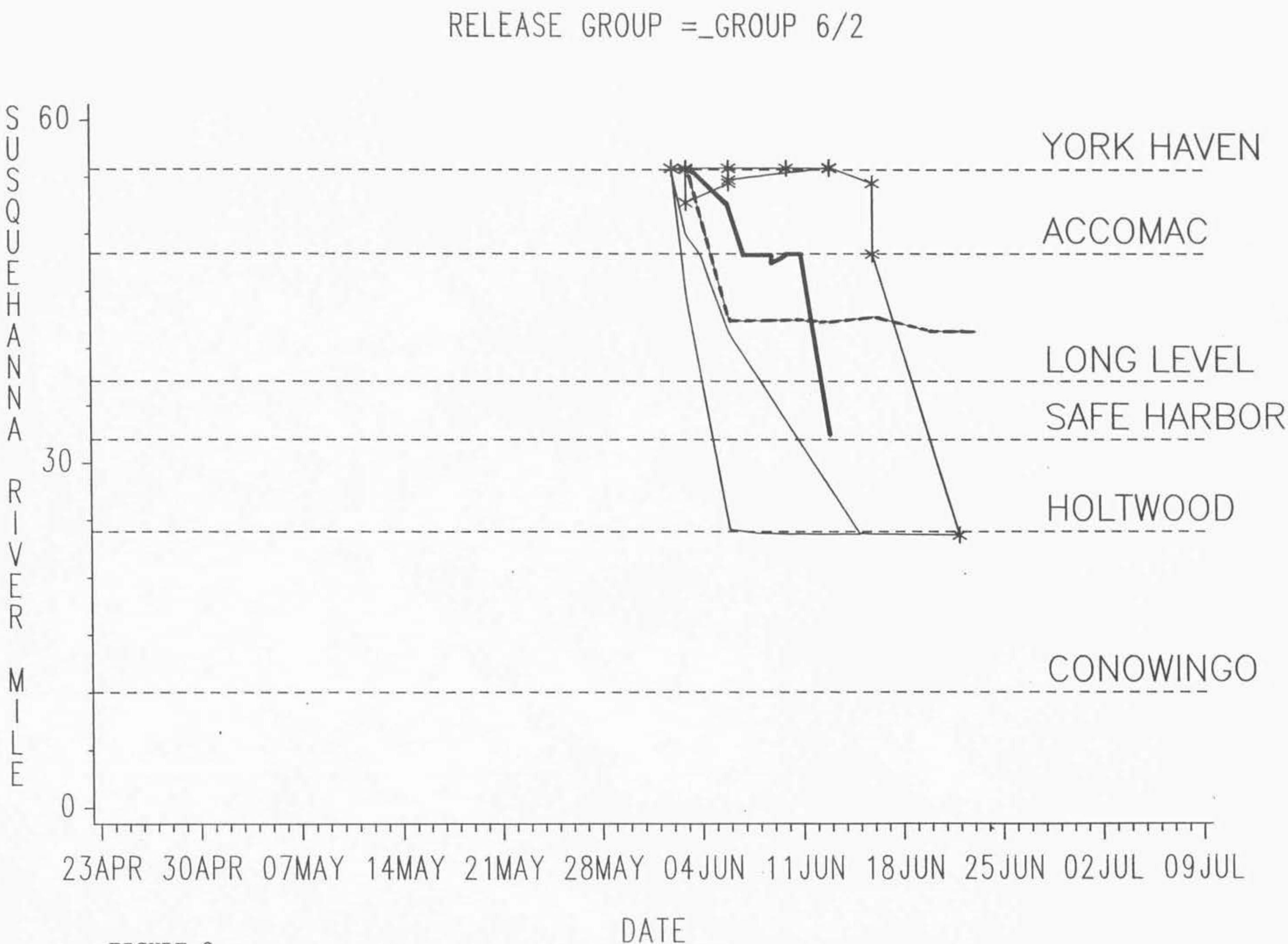


FIGURE 8

RMC Dispersal patterns of adult radio tagged American shad collected at the Conowingo Fish Lift and released into the Susquehanna River at Falmouth (RM 55.8), 2 June 1988.

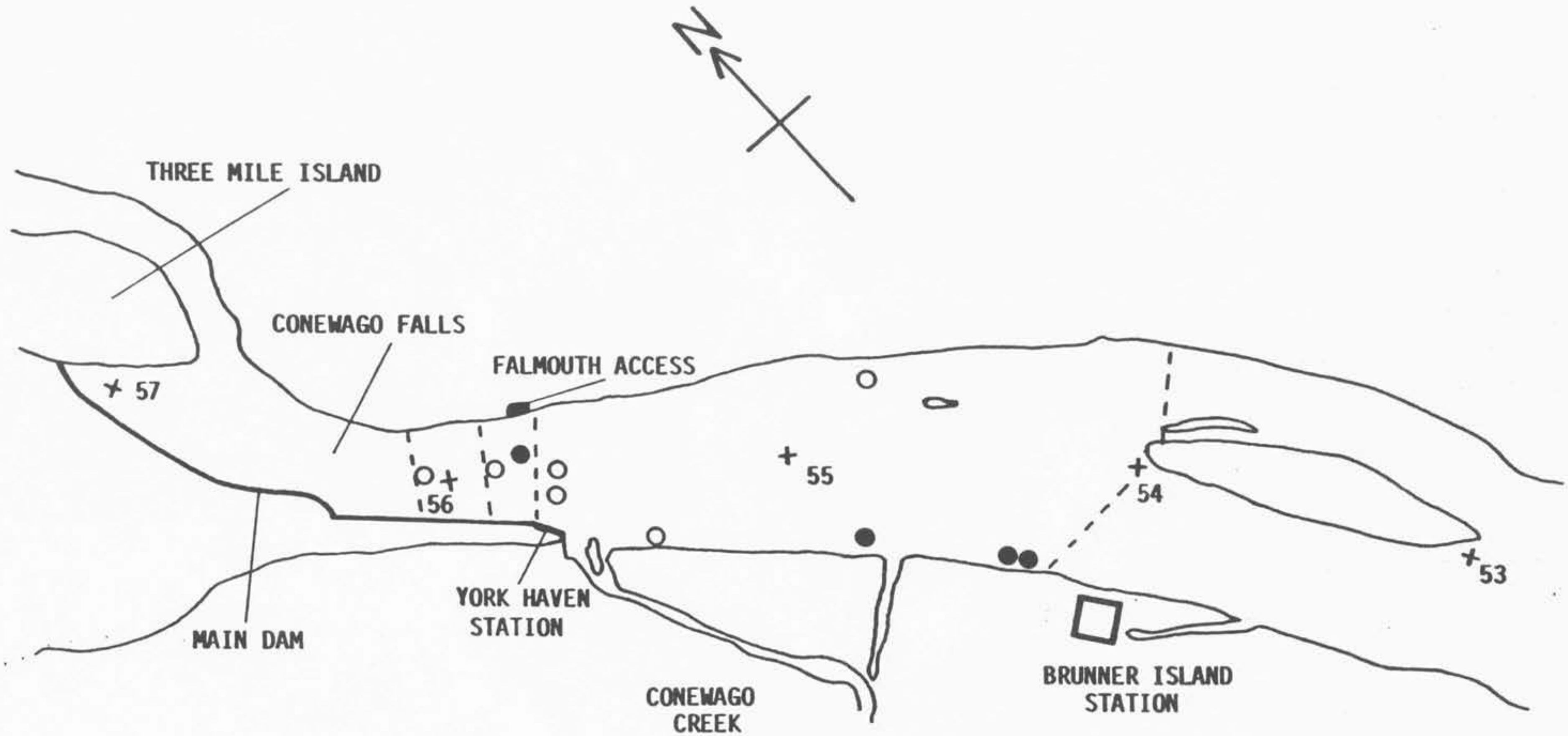


FIGURE 9

Map of York Haven area, river mile 53-57. Circles indicate locations sampled for shad eggs. Filled circles show where shad eggs were taken.

JOB V - ASSESSMENT OF THE EFFECTS OF MUDDY RUN PUMPED
TASK 2 STORAGE STATION OPERATION ON THE EMIGRATION OF JUVENILE AMERICAN SHAD, 1988

By
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EXECUTIVE SUMMARY

Juvenile American shad, Alosa sapidissima were radio tagged and released near the Muddy Run Pumped Storage Station (MRPSS) to assess feasibility of determining entrainment and behavior at this station. Fourteen tagged shad were released near MRPSS while the station was in a pumping phase. Eight passed the station with minimal delay, two remained near the release site, two were presumed entrained, and two entered eddies along shore for extended periods of time.

INTRODUCTION

Muddy Run Pumped Storage Station (MRPSS) is on the Susquehanna River 2.5 km downstream of Holtwood Hydroelectric Station and 19 km upstream of Conowingo Dam. MRPSS pumps water from the river into Muddy Run Pumped Storage Pond (MRPSP) overnight. Water is then discharged back into the river during hours of peak energy demand.

The Susquehanna River Anadromous Fish Restoration Committee has expressed concern about possible entrainment mortality of emigrating juvenile American shad (*Alosa sapidissima*) at MRPSS. Studies conducted by Heisey and Mathur (1980) and Snyder (1975) indicated that ichthyofauna in MRPSP originated from the Susquehanna River and that little mortality occurred during routine operations. The objectives of the present study were to determine: (1) if radio tagged juvenile shad could be tracked near MRPSS, (2) behavior patterns of shad passing MRPSS during the pumping phase and (3) if radio tracking can be used to assess juvenile shad entrainment at MRPSS.

METHODS AND MATERIALS

Juvenile shad were collected in the inner forebay at Holtwood Hydroelectric Station using a 2.4 m square lift net (RMC 1987). Shad were concentrated in a water filled bucket in the center of the net, transferred to a 91-l circular tub filled with 5 ppt salt-river water solution and transported to a holding facility at Muddy Run Ecological Laboratory (MREL).

Shad were tagged at MREL with cylindrical radio transmitters supplied by Advanced Telemetry Systems, Isanti, MN. On the average, tags measured 6 x 25 mm, weighed 1.2 g, and had 280 mm antennas. Transmitters had a life span of three days and transmitted between 48 and 50 MHz. They were modified for external attachment on young shad by encapsulation in a No. 2 gelatin capsule coated with "tool grip". Air trapped inside the capsule provided bouyancy. A No. 6 fish hook was attached to monofilament line protruding from the capsule.

Shad were tagged by inserting the hook through the musculature just posterior to the dorsal fin. Shad >120 mm were tagged and placed into the transport container filled with a 5 ppt salt water solution and transported to Wissler's Run by truck and to the release area by boat (Figure 1). They were released into the river once MRPSS began pumping operations.

Advanced Telemetry programmable scanning receivers and 5-element yagi antennas were used to locate shad. Locations were estimated from landmarks and plotted on field maps. Fish were continuously tracked at least two hours. Monitoring generally was discontinued if they moved downstream of Wissler's Run (500 m downstream of MRPSS) or remained in an area longer than 4 h.

RESULTS

Fourteen juvenile shad were radio tagged and released near Deepwater Island, in Holtwood tailrace, and downstream of MRPSS on four occasions (Table 1). Eight shad successfully passed the station, two remained near the release site, two were presumed entrained and two entered and remained in eddies for extended periods of time.

The first four fish were released when discharge from Holtwood was less than the pump rate at MRPSS. Two shad released at Deepwater Island remained there 4 h (Figure 2 and 3). Because these two fish did not move downstream rapidly, the other two shad were released downstream of MRPSS into current moving upstream caused by the pumping mode. Within 9 min one shad entered an eddy at the south end of MRPSS and remained there for 50 min (Figure 4). The fish was deemed dead and monitoring was discontinued. The other fish moved upstream along the station for 19 min until it was entrained in Unit #2 (Figure 5).

Ten shad were released when Holtwood discharge exceeded MRPSS pump rate (Table 1). One shad displayed movement behavior which indicated it was preyed upon after release. The other nine shad exhibited three general behavior patterns as they approached MRPSS. They either continued uninterrupted past the station, proceeded west from the station or were delayed near the station.

Five shad passed MRPSS uninterrupted. Upon release, all reached the station within 20 to 35 min and then continued passed the intakes within 26 min. Two of these came within 10 m of the intake structure; one was released in the Holtwood tailrace (Figures 6 and 7). The other three passed at least 100 m away (Figures 8, 9, and 10). Times to reach Wissler's Run varied from 53 min to 2 h 25 min.

Two radio tagged shad proceeded west after they approached MRPSS. They reached the area of the station in 18 and 19 min after release. One of these moved west 130 m in 3 min from approximately 40 m off the intakes. It then proceeded downstream to the lower tip of Lower Bear Island (Figure 11). The other approached to within 80 m of MRPSS then traveled 75 m west in 4 min. It also moved toward Lower Bear Island (Figure 12).

Two tagged shad remained in the area between MRPSS and Turkey Island for 45 to 52 min. One circled in this area for 45 min before moving 100 m downstream of the facility. It then returned upstream to the station before proceeding back downriver (Figure 13). The other circled within this area twice for 52 min before being entrained into Unit #8 (Figure 14).

The remaining fish moved to the station within 36 min of release. It remained in the area between the station and the south end of Turkey Island for one hour until it's behavior changed. It proceeded back to the north end of

MRPSS in 7 min and traveled upstream for 200 m in 13 min indicating fish predation. It entered an eddy downstream of a large emergent boulder near shore for more than 2.5 hours (Figure 15). The signal varied when the tracking boat was positioned over the tag, indicating that the transmitter moved.

DISCUSSION

The limited data collected during this study indicate that operation of MRPSS should not substantially impede emigration of juvenile American shad. At least 8 of 14 shad released passed the station successfully and only two were presumed entrained. The fate of two shad which remained near the release site is unknown. The other remaining two fish exhibited behavior uncharacteristic of emigrating shad and may well have been preyed upon.

Of the eight shad which successfully passed the station, most swam directly downstream. Two passed near enough to the facility to be in the direct influence by the intake currents. They were drawn close to the intakes and moved down the face of the station. Upon passing MRPSS they swam back offshore and continued downriver indicating young shad have the ability to resist strong intake currents.

The extent of the station influence on the remaining six shad is not readily discernable but it did not appear to directly affect their movement. Shad which moved west upon approach to MRPSS may have been influenced indirectly by station operation. The combination of water drawn into MRPSS and water flowing downstream from Holtwood created a deflection current to the west. One shad circled the area between Turkey Island and the station twice before monitoring was terminated south of the station. The others continued their migration west to Lower Bear Island.

Four of the remaining six shad did not pass MRPSS successfully; two were entrained and two entered eddies. The remaining two stayed near their release location. One of the entrained shad and the shad which entered an eddy at the south end of the station were released into a swift current 50 m from the station. Effects of the station on these shad may not be representative of that expected during natural emigration. These shad were probably disoriented and had not recoverd prior to reaching the station. Consequently, one was entrained by MRPSS and the other entered an eddy. The amount of time it remained in the eddy was indicative of mortality or predation. The remaining shad presumed entrained by MRPSS, circled the area between Turkey Island and MRPSS twice within 52 min. Upon approach to the south end of MRPSS, turbulent currents may have disoriented the shad causing it to be entrained. The shad which remained in an eddy upstream of MRPSS was believed to have been taken by a predator. The rapid upstream movement of this signal and the presence of the signal in an eddy for an extended period of time are uncharacteristic of juvenile shad. Monitoring of the other two shad released when MRPSS pumping exceeded Holtwood discharge was terminated because they did not migrate substantially after 2 h.

Although two shad were believed entrained, their fate could not be determined. Their signals were not received during limited monitoring of MRPSP after they were lost at the intakes below. However, signals were lost so abruptly, it was assumed these shad were entrained. If these shad had moved into deeper water signals would have faded away gradually.

RECOMMENDATIONS

We recommend conducting a study of this nature using a larger sample size. Shad should be released and tracked during both high and low flow releases from the Holtwood Station. The extent of the downstream influence of the MRPSS should be assessed by releasing and monitoring shad downstream of the intake area. Shad entrained by the MRPSS should be monitored in the MRPSP to determine their fate.

REFERENCES

Heisey, P. G., and D. Mathur. 1980. Summary of ecological studies of fishes in Muddy Run Pumped Storage Pond, Pennsylvania. In J. P. Clugston (ed.), Proceedings of the Clemson workshop on environmental impacts of pumped storage hydroelectric operations, pp. 80-94. U. S. Fish and Wildlife Service, Clemson, S.C.

RMC. 1987. Progress Report III - Study for determination of flow needs for downstream migrant American shad at the Conowingo Hydroelectric Station, 1986. RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, Pennsylvania. 33 pp.

Snyder, D. E. 1975. Passage of fish eggs and young through a pumped storage generation station. J. Fish. Res. Board Can. 32:1259-1266.

TABLE 1

Summary of fourteen juvenile American shad radio tagged and released near Muddy Run Pump Storage Station.

Fishnum	Release Date	Release Time	Time Last Located	Last Location	Flow Conditions
88100929	3 Nov.	2234	0301	Remained near release site off S end of Deepwater Is.	Holtwood 6000 cfs until 2400 hr then 3000 cfs Leak approx. 2000 cfs, No spill Muddy Run Pump Storage Station Updraft 24000 by 2325 hr
88100318	3 Nov.	2234	0300	Near S end of Deepwater Is.	
*88100393	4 Nov.	0100	0119	Fish drawn up unit #2	
88100268	4 Nov.	0100	0150	In eddy at S end of station	
88100368	10 Nov.	2238	0157	South of Pump Storage Station	Holtwood 30000 cfs until 2400 hr then 27000 cfs Leak approx. 2000 cfs, Spill approx. 6150-7780 cfs Muddy Run Pump Storage Station Updraft 28000 by 2220 hr
88200393	10 Nov.	2236	0357	Sicily Island	
88200368	11 Nov.	0212	0410	Wissler's Run	
88300368	11 Nov.	0045	0343	Lower Bear Is., W of station	
88100023	16 Nov.	2304	0339	Possible victim of predation	Holtwood 27000 cfs Leak approx. 2000 cfs, Spill 860-1660 cfs Muddy Run Pump Storage Station Updraft 24000 by 2320 hr (21000 between 0224-0245 hr)
88100053	16 Nov.	2304	0320	South of Wissler's Run	
88100098	17 Nov.	0214	0341	Wissler's Run	
*88100971	17 Nov.	0123	0247	Fish drawn up unit #8	
88100058	22 Nov.	2312	0030	South of Wissler's Run	Holtwood 27000 cfs Leak approx. 2000 cfs, Spill 23390 cfs Muddy Run Pump Storage Station Updraft 28000 by 2345 hr
88200968	22 Nov.	2312	0125	SW of Pump Storage Station	

* Fish drawn up Muddy Run Pump Storage Station

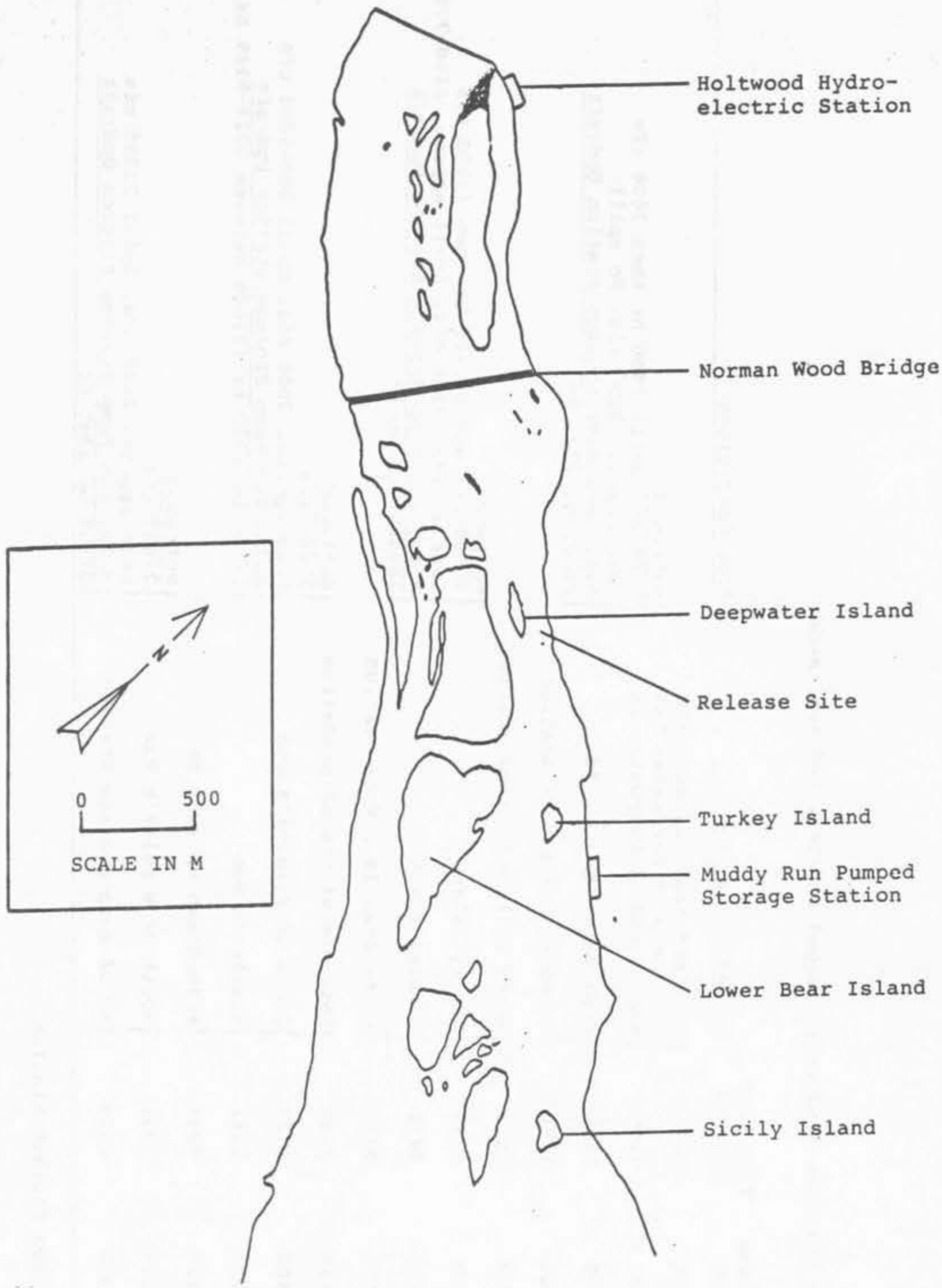

FIGURE 1

Study area near Muddy Run Pumped Storage Station, November 1988.

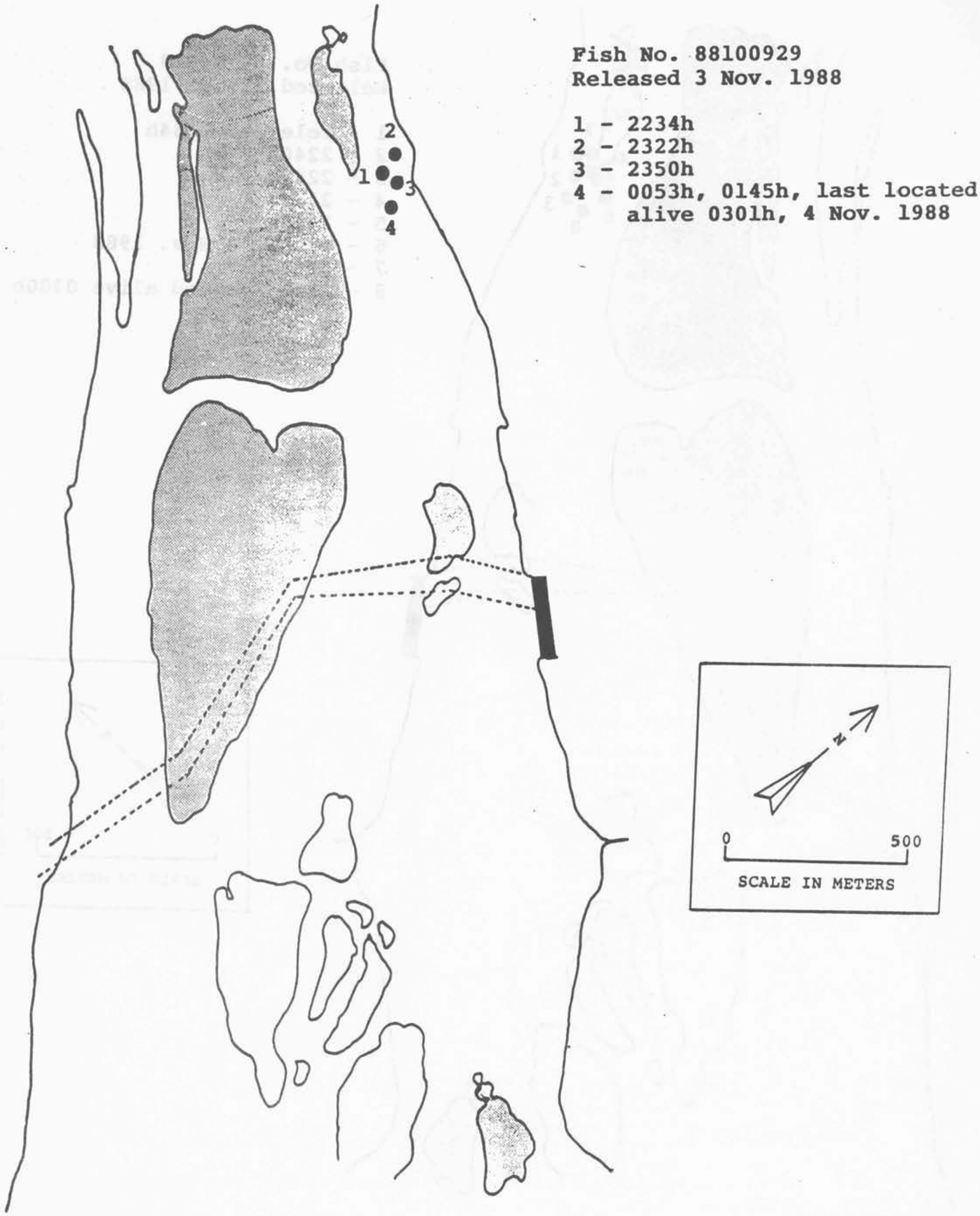

FIGURE 2

Movement of shad No. 88100929 released at Deepwater Island during period of low flow from Holtwood, November 1988.

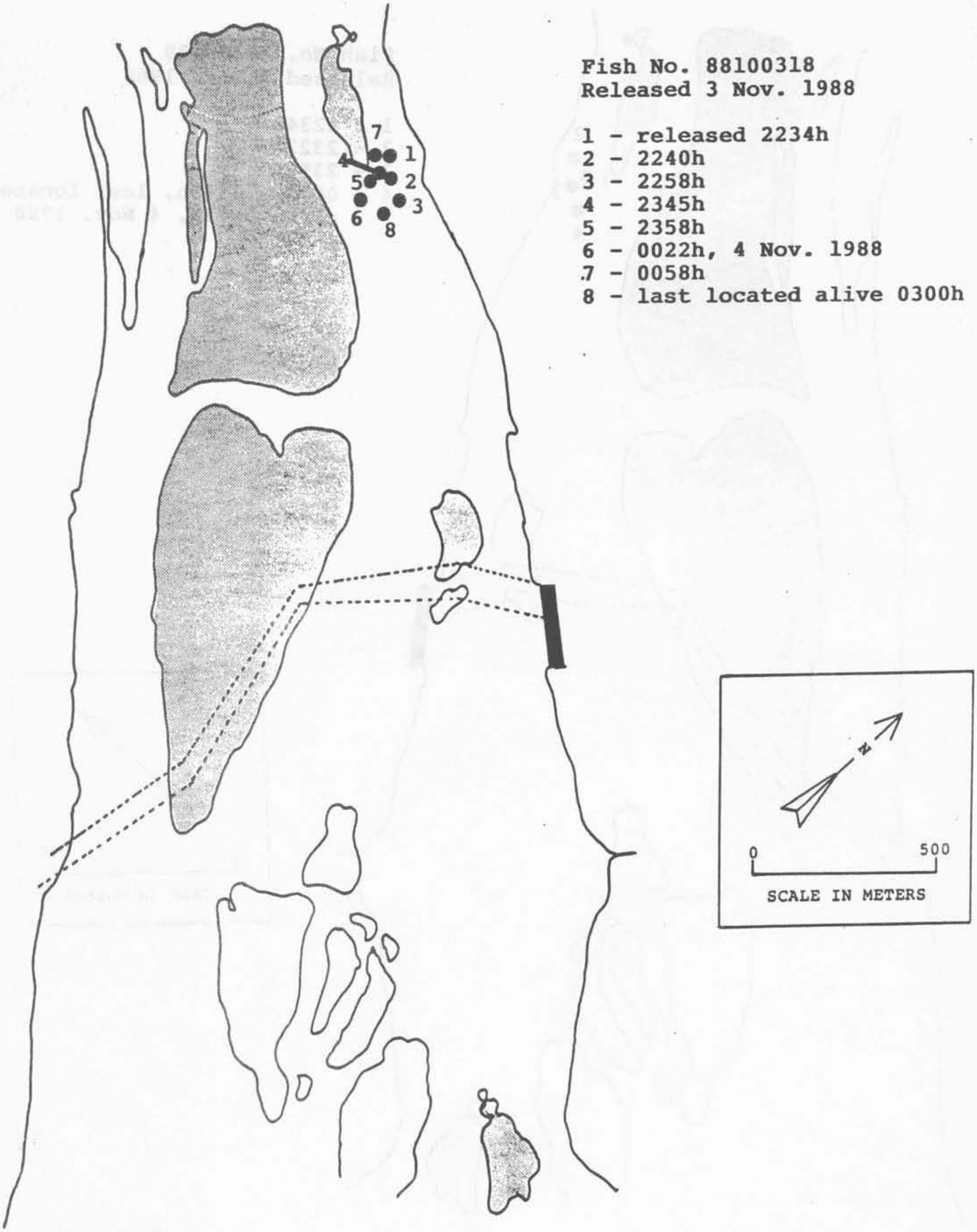

FIGURE 3

Movement of shad No. 88100318 released at Deepwater Island during a period of low flow from Holtwood, November 1988.

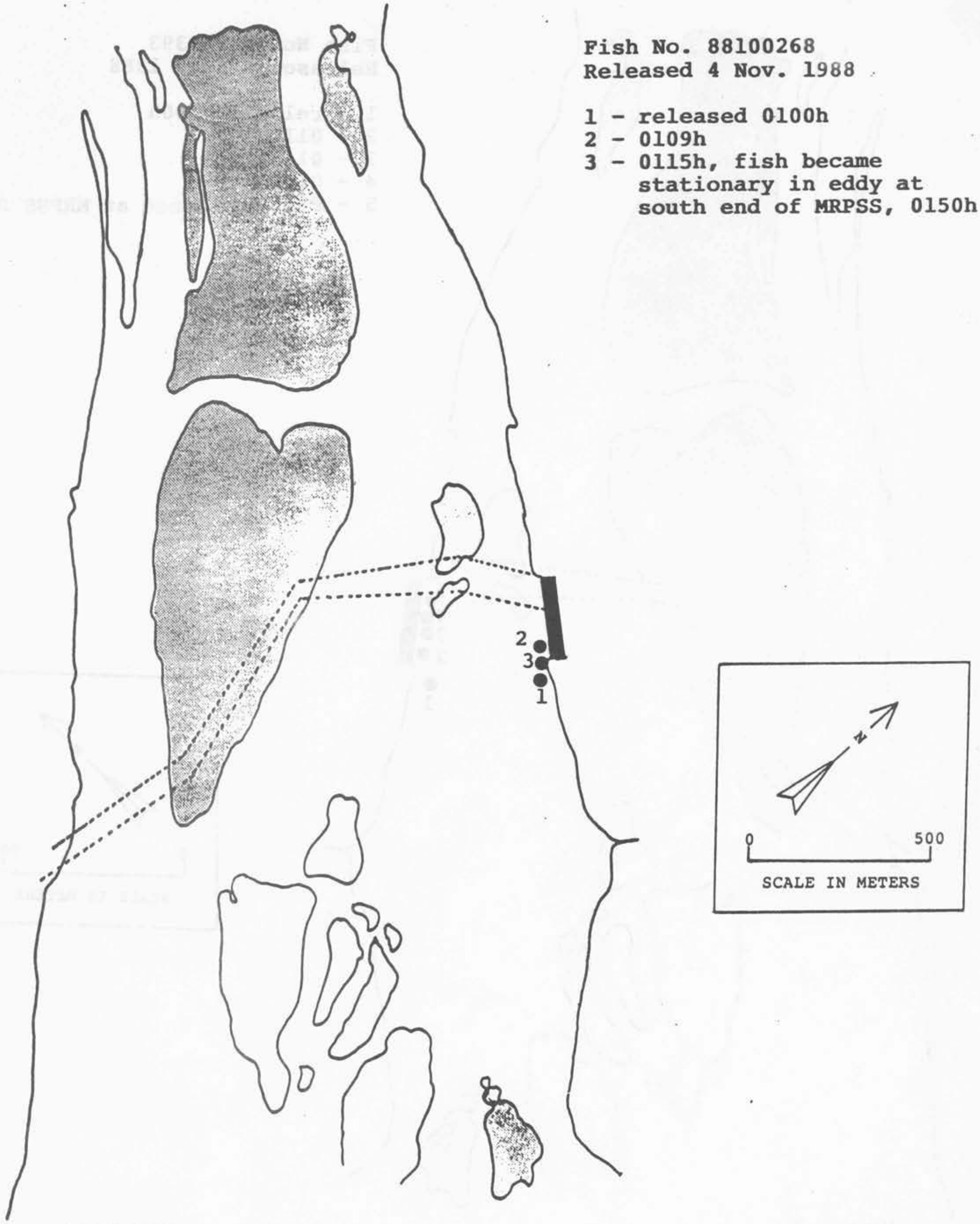

FIGURE 4

Movement of shad No. 88100268 released downstream of MRPSS during a period of low flow from Holtwood, November 1988.

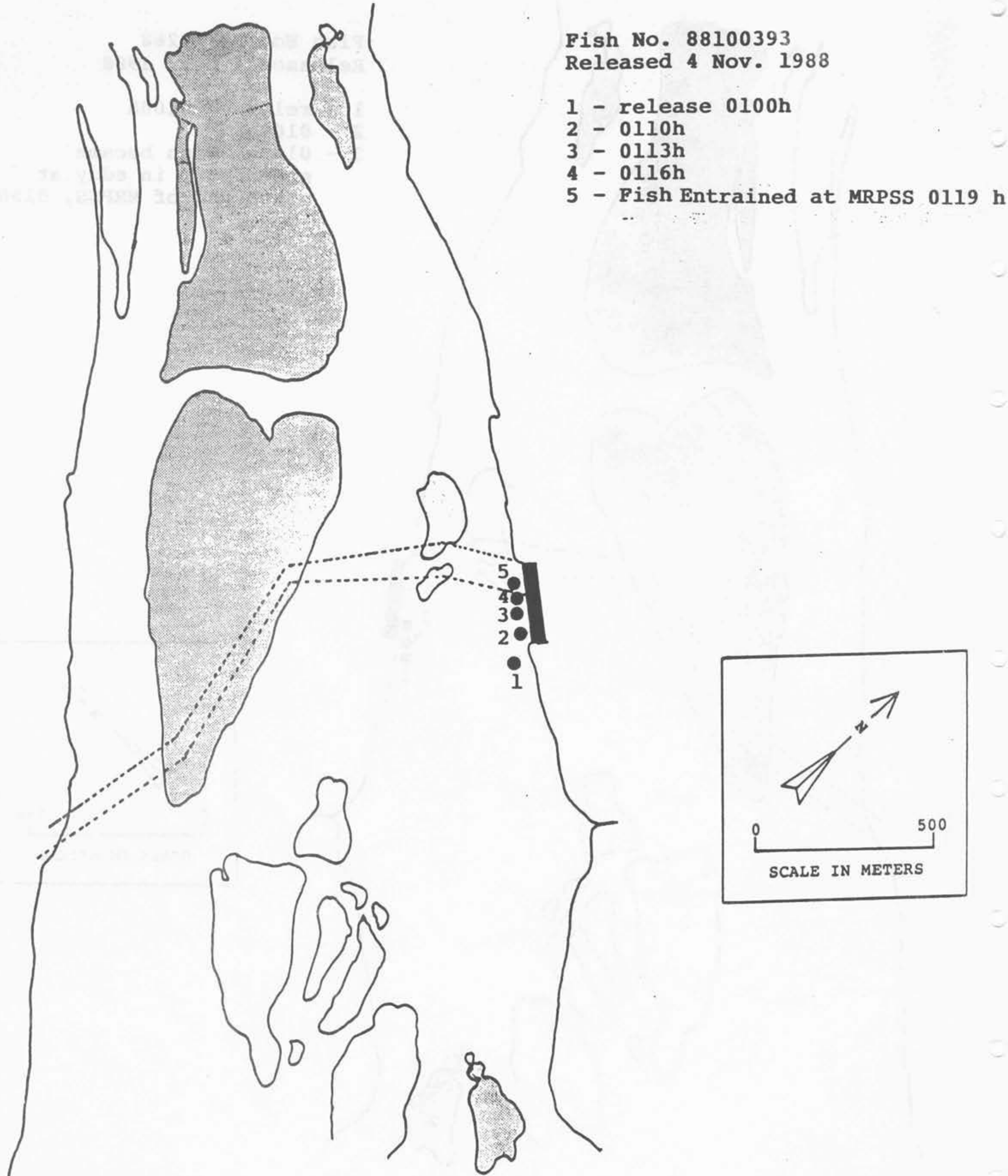

FIGURE 5

Movement of shad No. 88100393 released downstream of MRPSS during a period of low flow from Holtwood, November 1988.

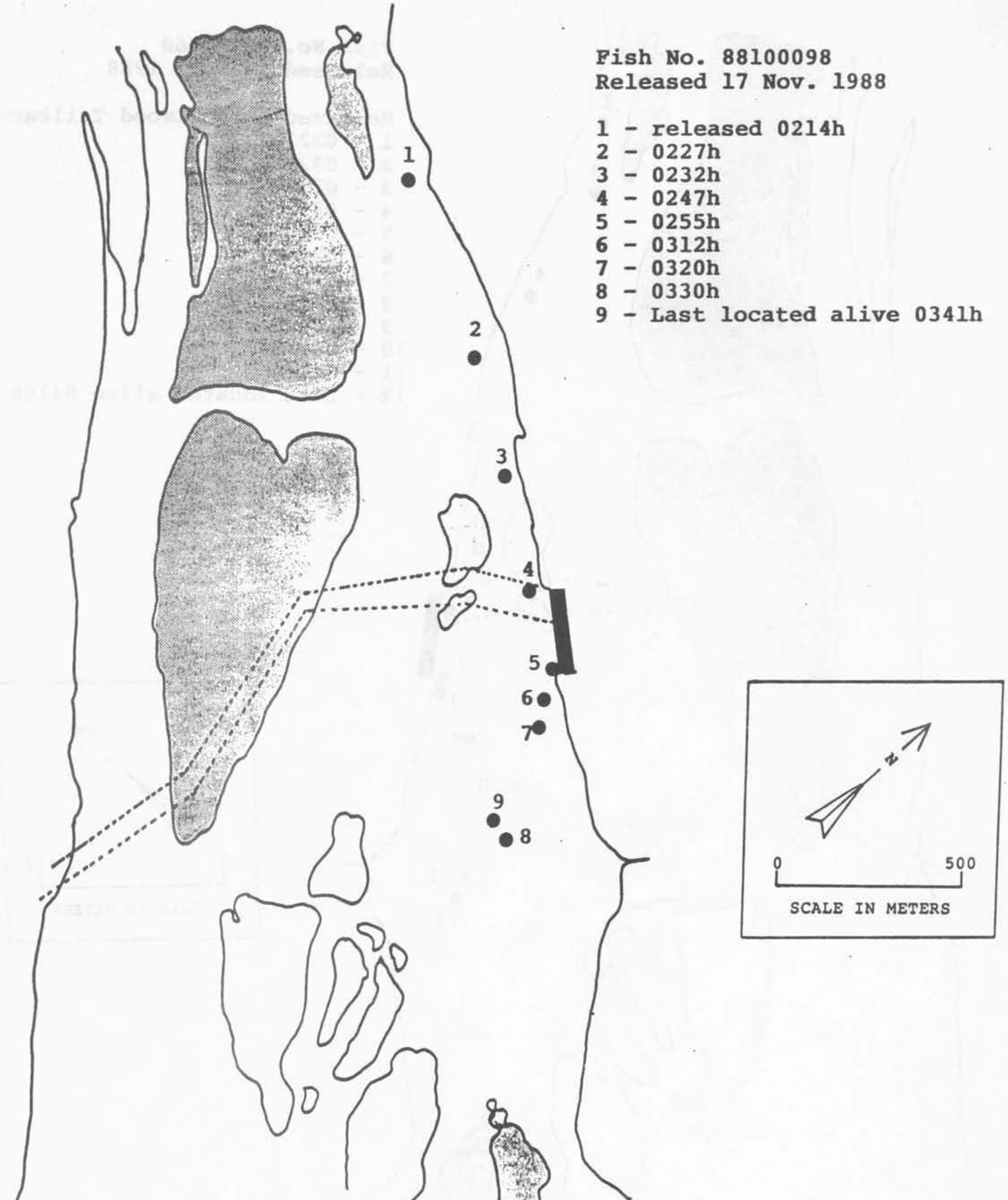

FIGURE 6

Movement of shad No. 88100098 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

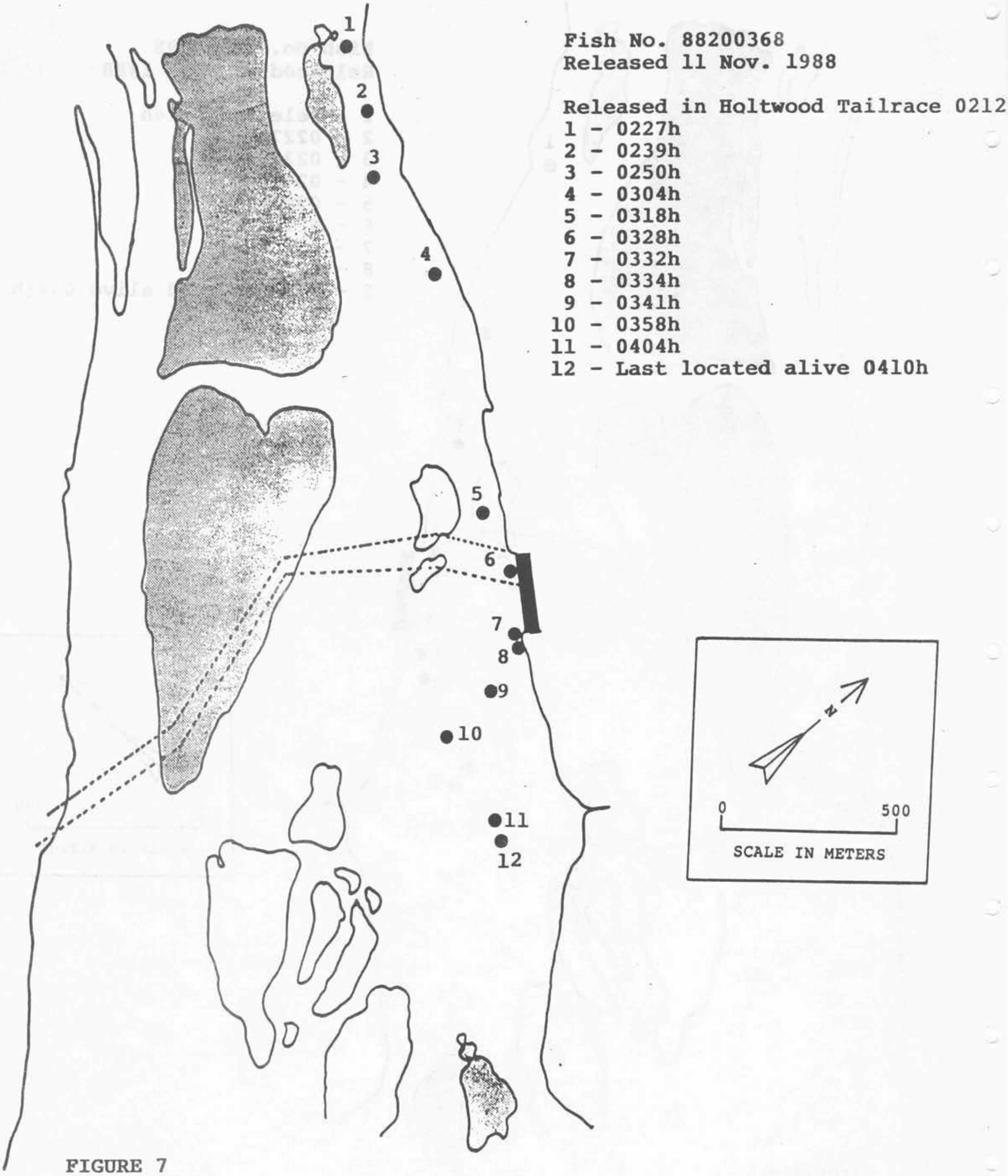

FIGURE 7

Movement of shad No. 88200368 released in Holtwood Tailrace when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

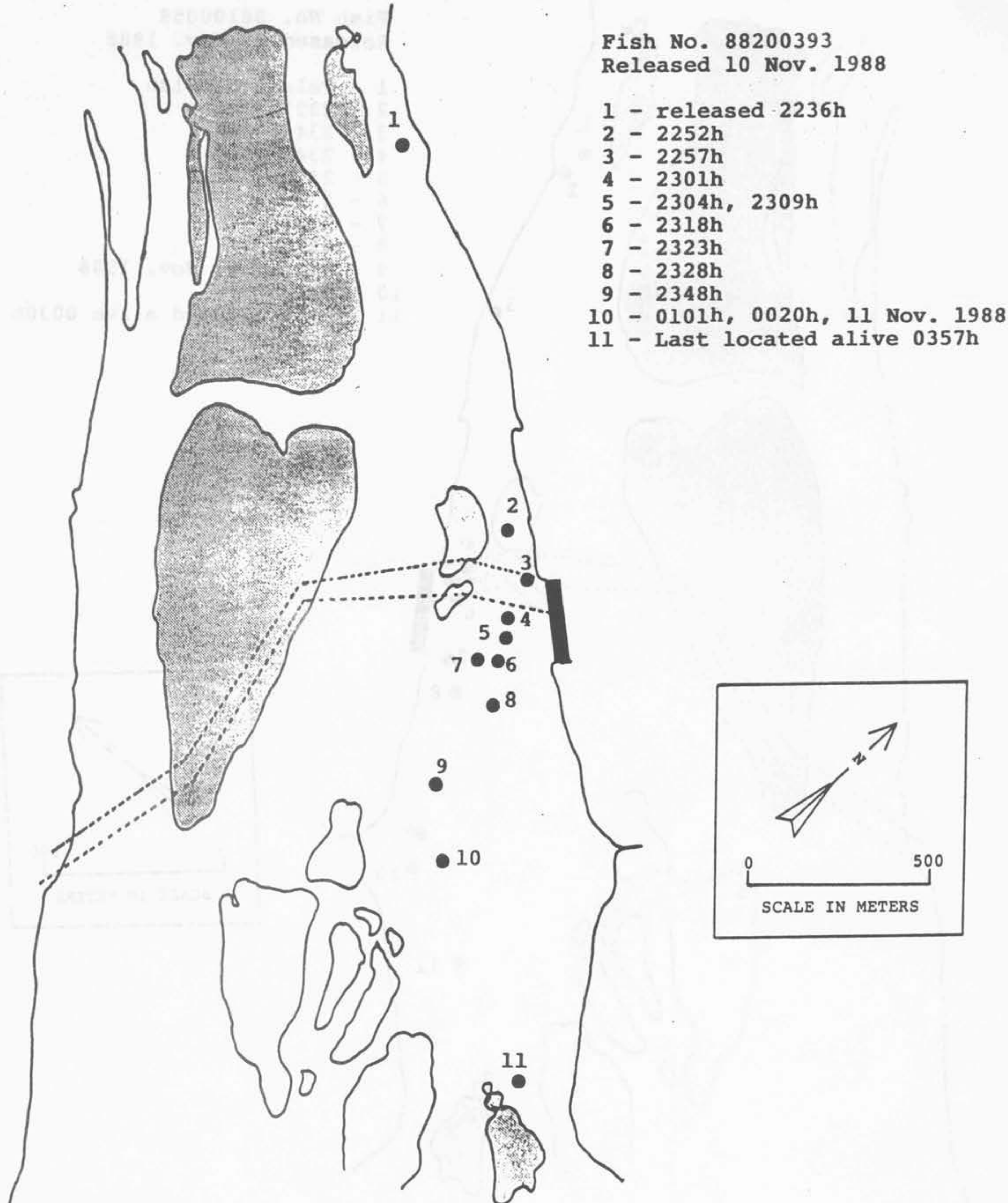

FIGURE 8

Movement of shad No. 88200393 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

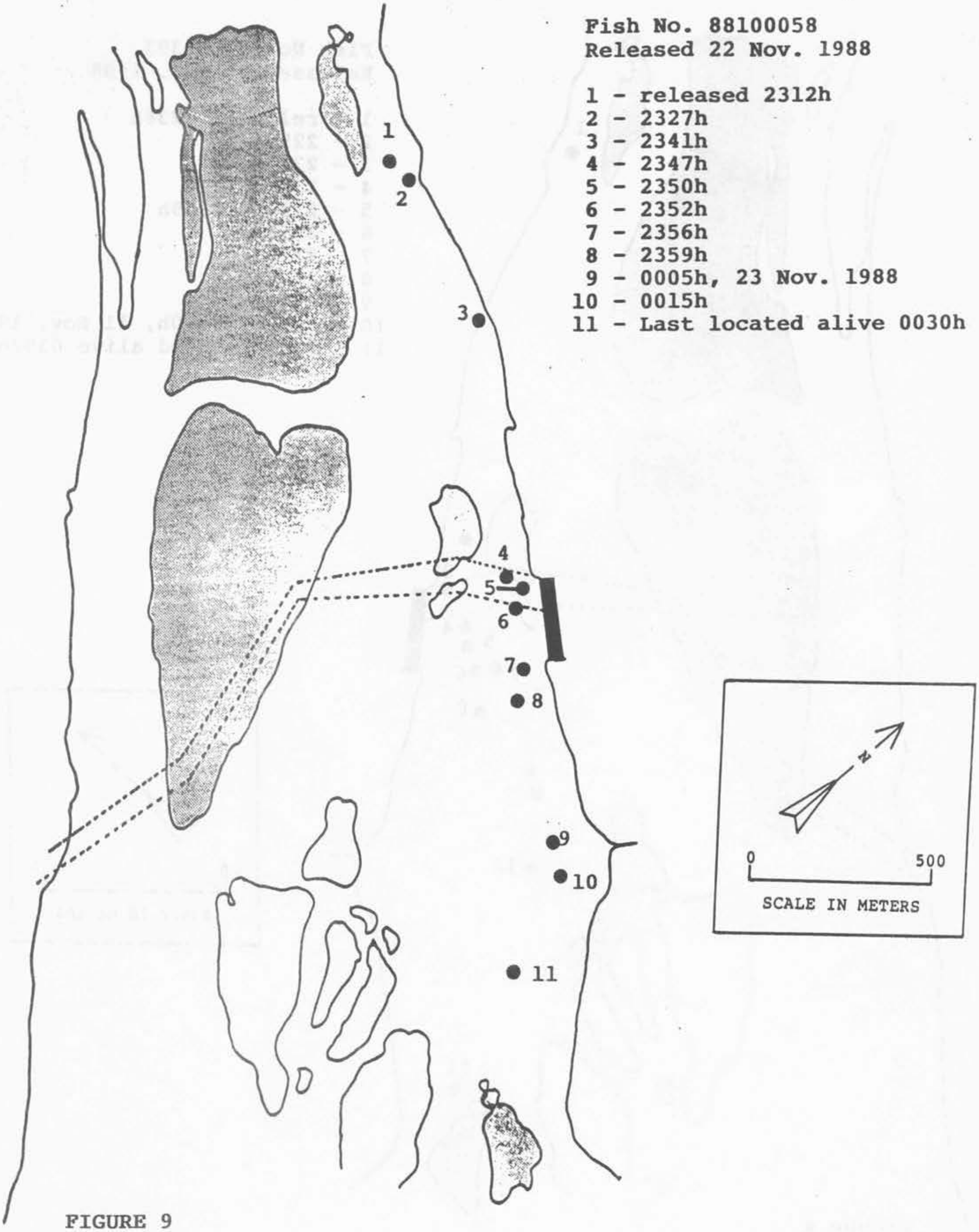

FIGURE 9

Movement of shad No. 88100058 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

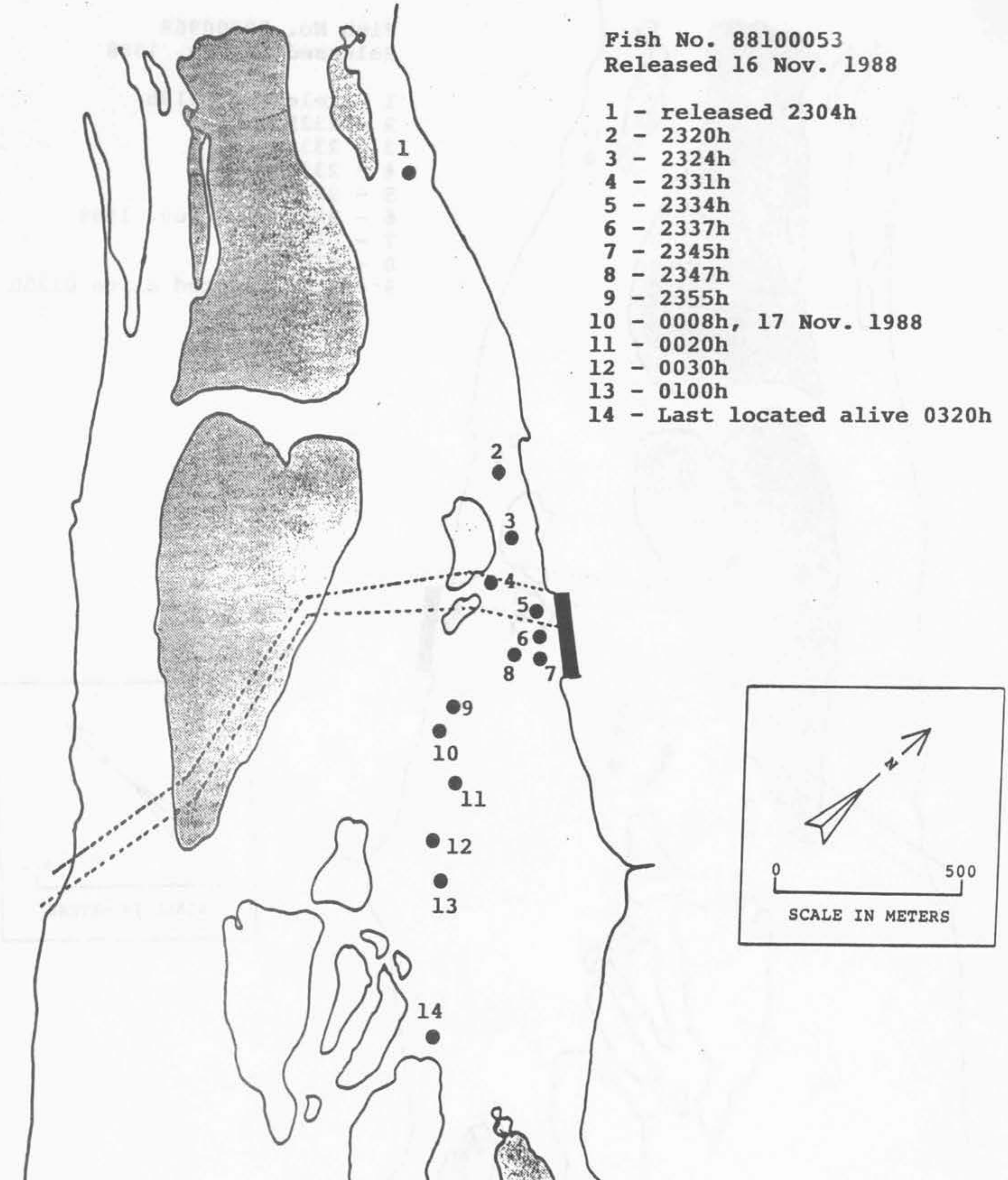

FIGURE 10

Movement of shad No. 88100053 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

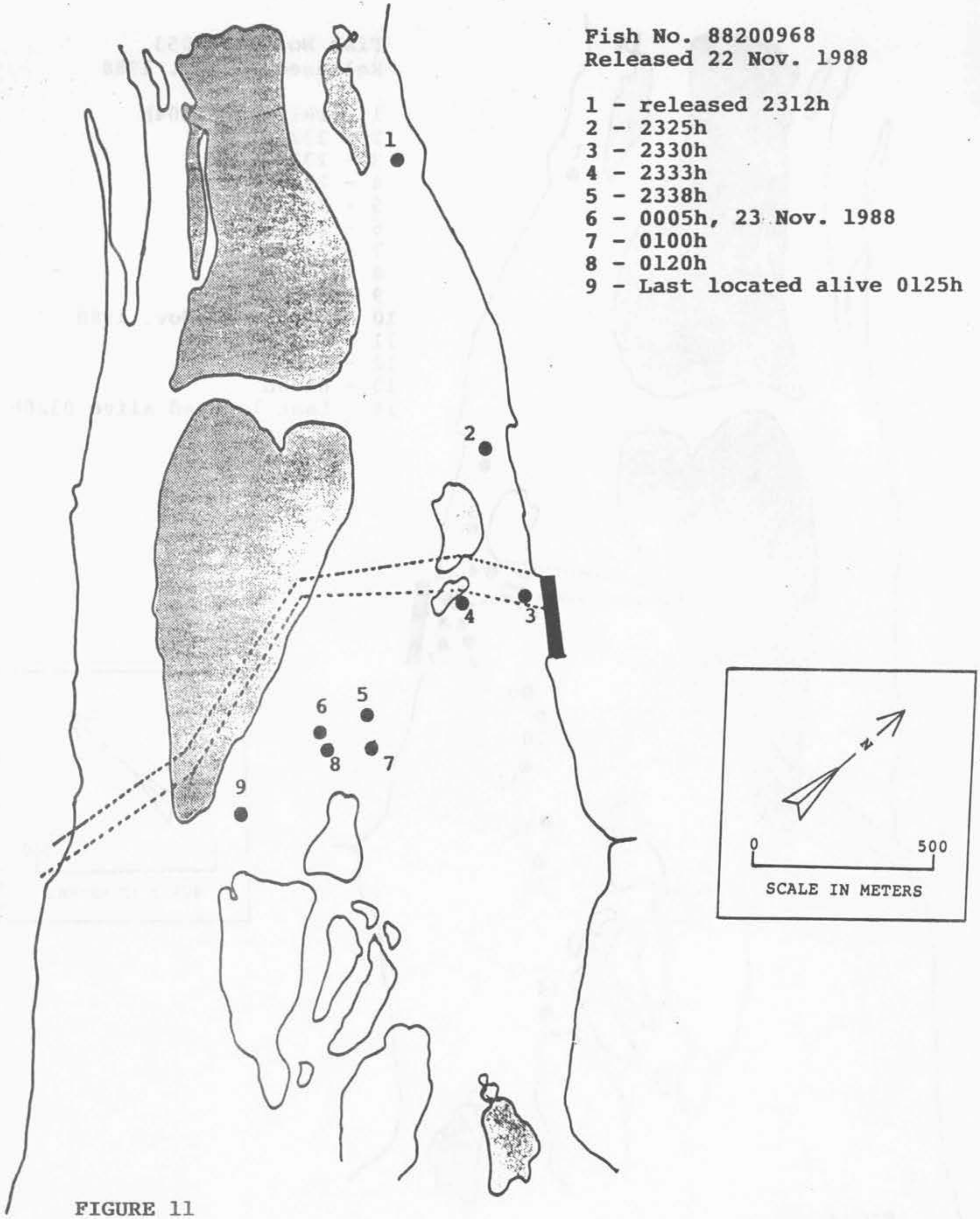

FIGURE 11

Movement of shad No. 88200968 released at Deepwater Island when flow from Holtwood was greater than pum volume at MRPSS, November 1988.

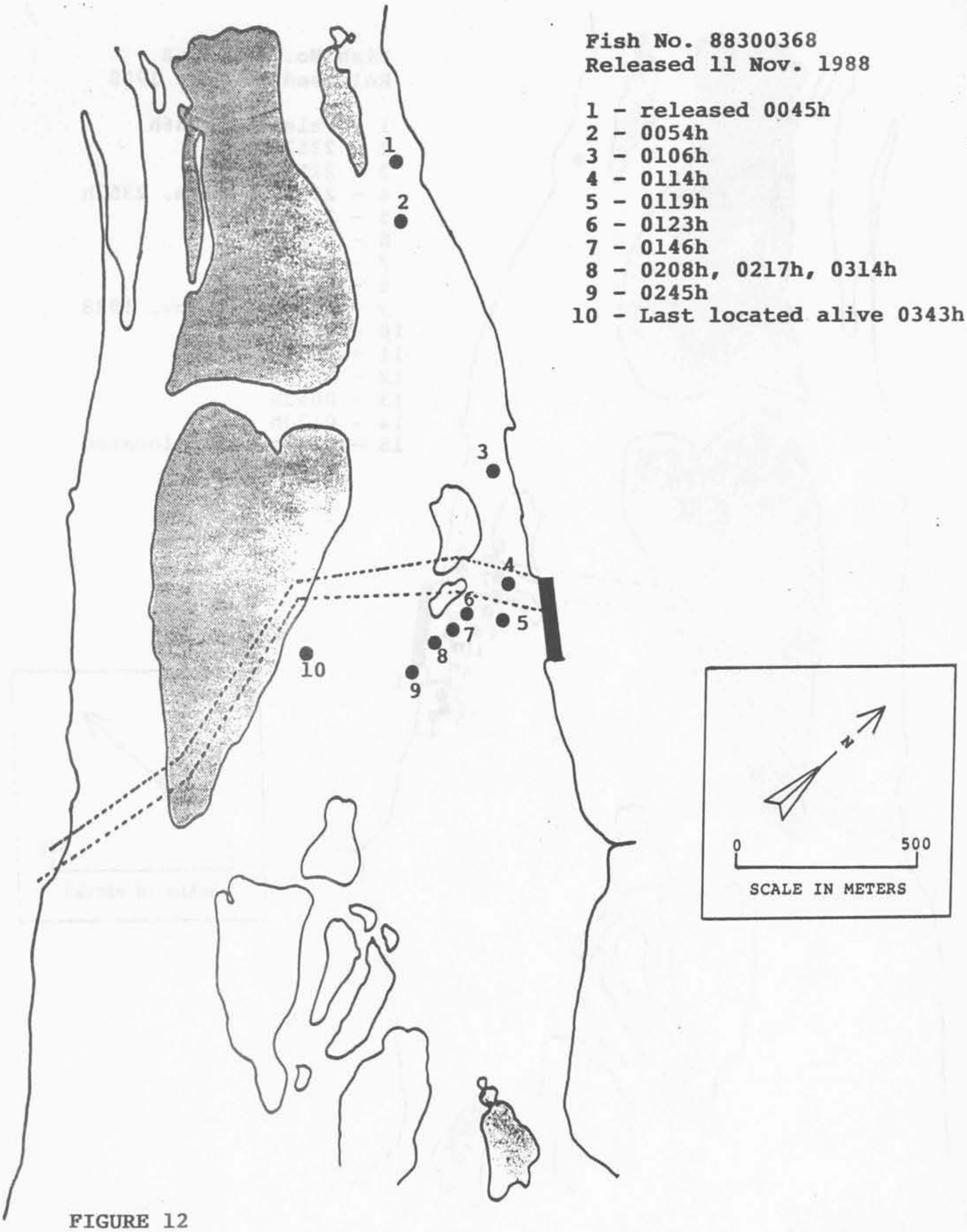

FIGURE 12

Movement of shad No. 88300368 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

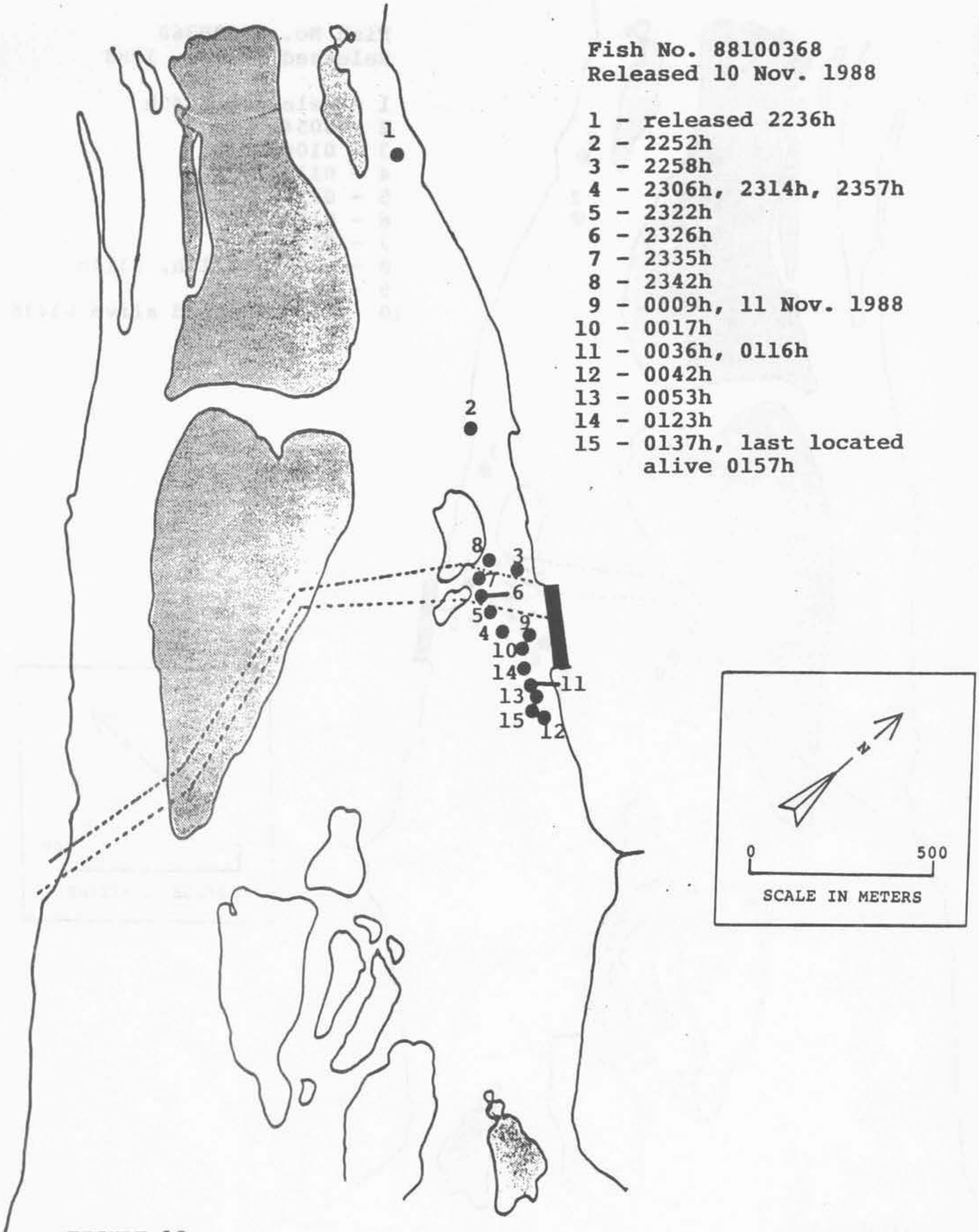

FIGURE 13

Movement of shad No. 88100368 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

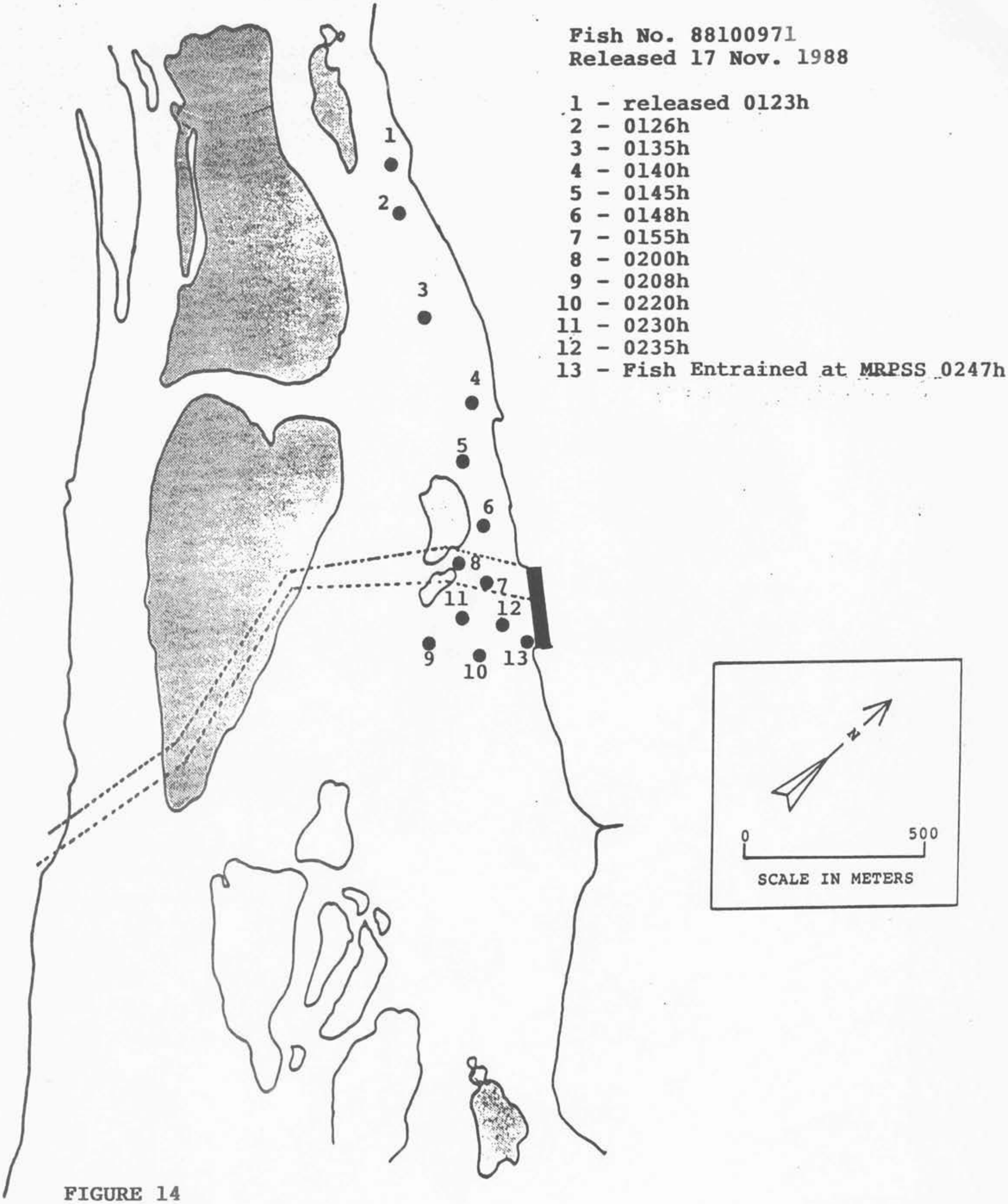

FIGURE 14

Movement of shad No. 88100971 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

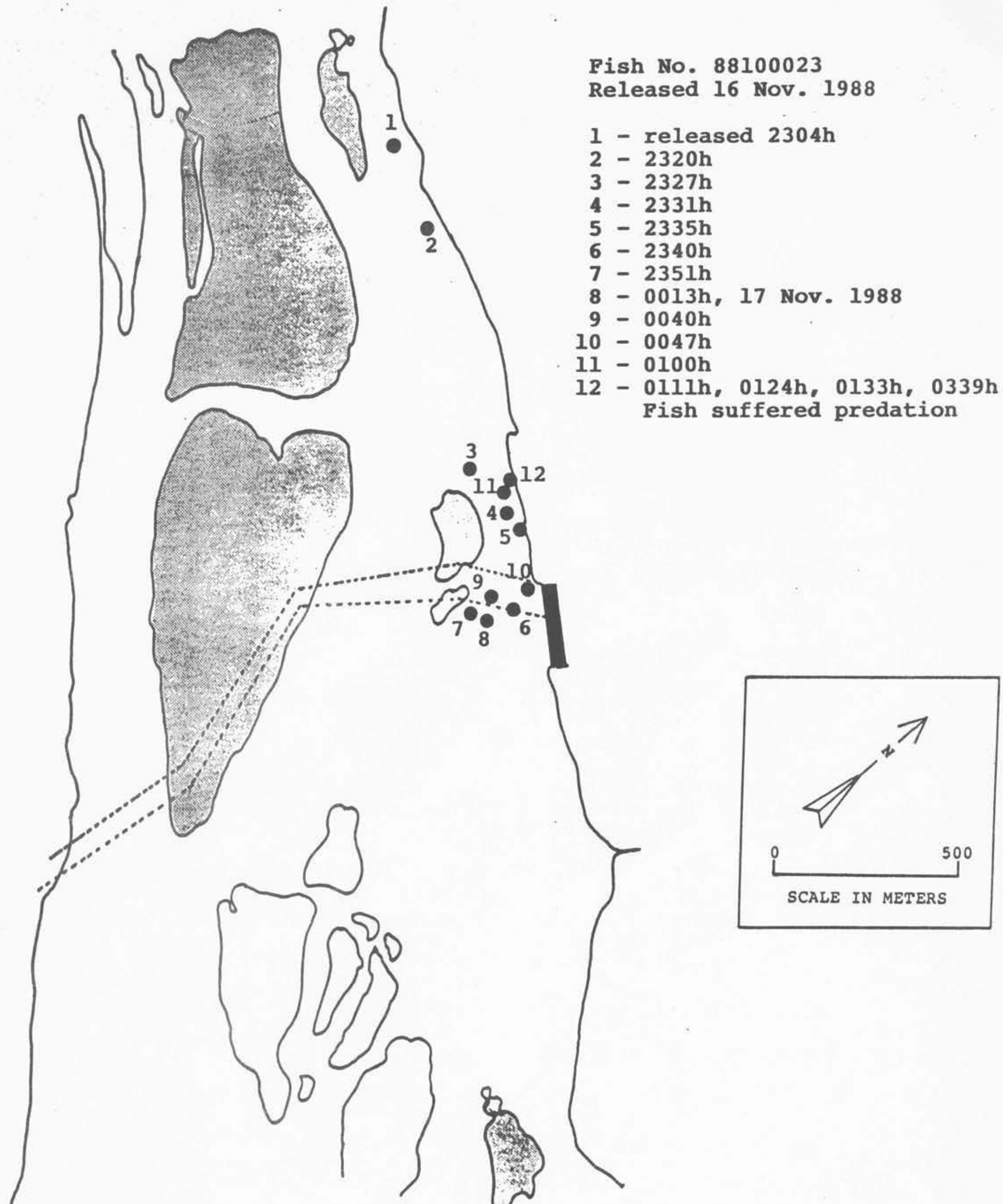

FIGURE 15

Movement of shad No. 88100023 released at Deepwater Island when flow from Holtwood was greater than pump volume at MRPSS, November 1988.

JOB V - RADIO TELEMETRY MORTALITY ASSESSMENT
TASK 3 OF JUVENILE AMERICAN SHAD AT HOLTWOOD HYDROELECTRIC STATION, 1988

By

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EXECUTIVE SUMMARY

Juvenile American shad, Alosa sapidissima were radio tagged and released at Holtwood Hydroelectric Station to determine whether: (1) radio tagged shad suffer mortality during turbine passage and (2) developed telemetry techniques are feasible for utilization in the Holtwood tailrace. Some 12 freshly dead control, 14 live control, and 25 live test juvenile shad were released at Holtwood Station. The dead controls and live test shad were passed through generating Unit #10. The remainder was released into the boil of Unit #10. All dead controls settled in the upper and mid-tailrace. Of the 14 live control shad, 4 (19%) were confirmed alive >30 min; 2 (14%) ≥90 min. Eight (57%) became inactive in the tailrace or near Deepwater Island shortly after release. Two were lost soon after release. Seven (28%) of the 25 live shad passed through Unit #10 were alive >30 min. Two of these were monitored ≥2 h. Eleven (44%) shad became stationary in the tailrace or near Deepwater Island. Five (20%) shad signals were lost after release and the remaining two (8%) were preyed upon by a bird and fish.

INTRODUCTION

Field and laboratory studies have demonstrated that juvenile American shad, *Alosa sapidissima*, can be internally radio tagged for acute turbine mortality experiments (RMC 1985, 1986, 1987a,1987b, 1988; Royer et al. 1988). Signal reception of miniature radio tags is adequate up to a depth of 8-9 m. Although shad >160 mm are preferred for tagging, smaller shad have been successfully tagged for laboratory experiments and survived for time periods adequate for performing acute mortality studies.

Concern has been expressed by the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) regarding turbine mortality of emigrating juvenile American shad at Holtwood Hydroelectric Station. SRAFRC provided funding to RMC Environmental Services to undertake a preliminary mortality study at Holtwood Station prior to a larger scale study needed to delineate turbine mortality there. The primary objectives of this study were to determine whether: (1) radio tagged shad suffer mortality during turbine passage, and (2) existing radio telemetry procedures and equipment can be utilized in the Holtwood tailrace.

METHODS AND MATERIALS

Juvenile shad cultured at Brunner Island Aquaculture Facility (hatchery) and shad collected from the Holtwood forebay were utilized for this study. Shad taken from the hatchery were gently water brailled from raceways into 187 l transport containers filled with an oxygen saturated 10 ppt saline solution. Transport water temperatures were based on Brunner Island Steam Electric Station (SES)discharge water temperature, and varied throughout the study period (Table 1). Shad were transported to Holtwood Hydroelectric Station and placed into a temporary holding facility. The holding facility consisted of four galvanized tanks with volumes of 884, 686, 636, and 1228 l. Water was supplied equally to all tanks with a 3/4 hp (79 lpm) submersible pump placed in the inner forebay. All water was passed through a 30 watt in-line ultra violet sterilizer prior to entering tanks. Differences in temperature between transport water and ambient river water supplied to the holding facility required tempering of shad. This was done by draining a holding tank and gently pouring all the transport water and shad into the tank. The water supply to the tank was then turned on to allow the shad and water to gradually decrease in temperature.

Feral shad were collected from Holtwood forebay with an 2.4 m lift net using methods previously described by RMC (1987b).

Shad were generally transported on each day of study to eliminate any delayed stress which may occur from transport and acclimation to lower temperatures. Most test and control shad were tagged internally by methods developed previously by RMC. Each tag was gently inserted into the fish's stomach with a wooden rod. One control shad was tagged externally by methods described in Job V, Task 2. Transmitters were supplied by Advanced Telemetry Systems Inc., transmitted in the 48 to 50 MH_z range, and had a life expectancy of 3 days. Each cylindrical tag averaged 6 x 24 mm, weighed 1.2 g and had a 200 mm whip antenna constructed of thin pliable cardiac pacemaker wire. Dummy transmitters, used for control shad, were constructed to similar dimensions using scotchcast potted in gelatin capsules.

Three types of controls were utilized to quantify turbine mortality: (1) passing freshly dead tagged shad through an operating unit, (2) releasing live tagged shad into the discharge boil below the station, and (3) dummy tagging and holding of shad for 2 h.

Freshly dead tagged shad were passed through Unit 10 at both single unit generation and full generation (10 units) to determine locations where shad killed during passage might settle. Live tagged shad were released into the turbine boil to discern any mortality factors other than station passage. Control shad were also tagged and held in tanks for 2 h to estimate mortality associated with handling and tagging. Individual controls were tagged immediately after test shad were released.

Tagged shad (both live and dead) were released into the operating unit by lowering a 11 l bucket into the gate well and upending the bucket to pour the shad into the water. Turbine draw was sufficient to pass shad through the station. Control shad were released off of the station gallery using similar techniques.

Fish were tracked with Advanced Telemetry Systems programmable scanning receivers connected to boat mounted 5 element Yagi antennas. Tracking was initiated immediately upon release of shad. A boat was also stationed in a shallow area of the tailrace (near Norman Wood Bridge) to locate any shad reaching this point if the signals were lost soon after release. Water depths in this area were only 3-5 m. Shad were tracked up to 2 h, until signals became stationary, or until signals were lost. Locations of each signal were recorded and plotted on maps.

RESULTS

Approximately 2200 shad were transported to Holtwood Station from Brunner Island for this study and a netting/mortality study (Job IV). Initial transport and handling mortality was low. However, mortality increased markedly within 24-48 h. Shad in holding tanks displayed erratic behavior and rapid swimming bursts just prior to death. The average water temperature difference between Brunner Island raceways and ambient river temperature at Holtwood increased from the time test shad were first introduced (16-18 Nov) and until control shad and the remainder of the test fish were used (19-23 Nov.; Table 1). When the first test fish were passed through the station, the average temperature difference was 7.6 C. This temperature difference was relatively low because of a shutdown of units at Brunner Island SES. However, a restart of the Brunner Island SES on 19 November and a decrease in ambient river temperature created a greater difference (15.9 C) during the remainder of the study.

Twelve freshly dead radio tagged control shad were passed through Unit #10. Ten were released when only Unit #10 was operating. Nine of the 10 became stationary within 200 m of the powerhouse; the other signal was lost shortly after release (Figure 1). The remaining two shad were released through Unit #10 with Holtwood Station at full generation (10 units). These shad settled in mid-tailrace (Figure 2).

Twenty-five live tagged shad were passed through Unit #10 at full generation (Table 1). Seven (28%) were confirmed alive at least 30 min after release. Two of these were tracked $\geq$2 h; the remaining five were alive when their signals were lost within 30 to 81 min. These shad were last located between the area just above Deepwater Island and Muddy Run Pumped Storage Station (MRPSS) (Figure 3). Eleven (44%) shad were confirmed stationary after passage. Two of these settled in the upper tailrace, 6 in mid-tailrace, 2 in the lower tailrace, and 1 near Deepwater Island (Figure 4). One shad was subjected to fish predation and another to avian predation. Both events occurred near Norman Wood Bridge. During test days, several thousand gulls were observed feeding in this area. Five (20%) shad signals were lost within 2 to 65 min and their status could not be determined. One of these was lost in the upper tailrace; four others were lost near Deepwater Island (Table 2;Figure 5).

Fourteen live tagged control shad were released directly into the boil of Unit #10 (Table 1). Two were wild shad collected at Holtwood. One wild shad was externally tagged. The rest were tagged internally. Four (29%) were located alive after 30 min. Two of these (both wild shad) traveled from Holtwood tailrace to below Sicily Island into Conowingo Pond within 90 min. The remaining two were last located alive between Deepwater Island and MRPSS after 34 and 68 min, respectively (Figure 6). Eight (57%) control shad became inactive shortly after release. One settled in the upper tailrace, 4 in mid-tailrace, 2 in the lower tailrace, and 1 near Deepwater Island (Figure 7). The remaining two (14%) shad signals were lost <3 min after release. Their status could not be determined (Table 2;Figure 8).

Thirty-nine control shad were internally tagged with dummy or inactive tags and held for 2 h. Thirty-two (82%) survived >2 h. The size of controls ranged from 113-147 mm FL; X = 131 mm. Survival of shad >130 mm was 100% (Tables 1 and 2).

DISCUSSION

Although immediate shad transport mortality from Brunner Island to Holtwood was low, high delayed mortality created some problems in coordination and implementation of the study. It was preferred to bring all study specimens to the holding site prior to the start of tests to allow recovery and eliminate stress after transport.

Specific causes of delayed holding mortality are unknown. Periodic dissolved oxygen monitoring indicated no depletion occurred. Since shad were not being fed, metabolite build up did not appear to be a factor. However, extreme fluctuations in hatchery water temperature over a relatively short period of time is a likely cause for mortality. Wild shad collected concurrently from the Holtwood Forebay and held in the same facilities and at similar conditions did not display the erratic swimming behavior and sudden death within a day or two of stocking in the tanks. Facility design, location, and time constraints (i.e., days) prohibited preferred gradual tempering of shad. If shad cultured in warmer water are used for future studies, methods to gradually temper them should be initiated at the hatchery site prior to transport to maximize survival.

Tag reception of dead controls passed through the station was most encouraging. Only one signal was lost. The shad had settled into a known deep pocket of water (>60 ft). Since all shad released at one unit generation settled in the same area, it was believed that acute mortality, when these operating conditions exist, could readily be identified.

High river flows prevented conducting the live shad mortality test at a preferred one unit generation. Near capacity generation at Holtwood caused many tagged shad, whether live or dead, to travel quickly down the tailrace. Shad which were injured and/or in a lethargic state required longer time periods to become stationary. Field observations indicate that most injured and dead fish passed through the station at low generation will settle more quickly in the upper section of the tailrace.

All shad (test and control) known alive >30 min had attained Deepwater Island, downstream of the tailrace, before their signals were lost in deeper water. One shad signal lost in this area was located about 3 h later just a few hundred meters downstream of its last location.

It is believed all live shad whose signals were lost in the tailrace expired. The signal of any shad passing Norman Wood Bridge would have been located by the tracking boat stationed there. Most shad (both test and controls) that became stationary did so in the tailrace. Signals from shad that remained alive >90 min were usually strong indicating they were traveling in the upper portion of the water column.

Although releasing live control shad into the station boil was not initially proposed, this portion of the study was decided upon after high mortality of tagged shad released through the station was observed during initial testing. Factors other than turbine mortality were thus assumed to cause shad to become stationary.

The exact reason(s) for higher mortality of control shad (57%) released into boil #10 versus that of test shad (44%) is not known. Shad used for this study may have been in a weakened condition from temperature fluctuations caused by the Brunner Island SES shutdown and start-up. They were transported to Holtwood the day after the power plant started operation again. Water temperature decreased from 19.2 C to 11.1 C, and then increased to 21.4 during 17 to 19 November. The combination of transporting, tagging, and releasing shad after experiencing 3 days of fluctuating temperatures may have caused higher mortality.

The survival of control fish held for 2 hours was high. However, it is also evident that survival was better for controls tagged early in the study (16-18 Nov) when lower temperature differences were observed. Previous observations by RMC indicated shad survival after tagging is higher when conducted at temperatures >10 C. High survival of relatively small control shad indicated shad as little as 130 mm FL can be used for acute mortality studies. However, larger size shad would be preferred to minimize influence the tag may have on behavior of the shad.

Both objectives of the study were addressed; however, only one of the objectives was fully met. Juvenile shad can be tracked in the Holtwood tailrace to determine acute mortality caused by turbine passage. A high mortality rate of control shad released into the boil, and small sample size precluded definitive estimates of turbine mortality.

RECOMMENDATIONS

1. In the event large juvenile shad can not be collected from the river, the Brunner Island Aquaculture Facility appears feasible for the culture of shad. However, RMC recommends obtaining the earliest possible shad egg lots to ensure availability of adequately sized shad (>160 mm). Adequate time should be provided to allow gradual

acclimation of shad (i.e., several days) to ambient river water temperatures prior to transporting them for testing.

2. RMC recommends conducting future studies when water temperatures are 10-15 C which should coincide with periods of natural emigration. Previous laboratory studies indicated higher survival of tagged shad at these temperatures.

3. Single unit operation allowed RMC to determine a definite area where dead shad settle after station passage. We recommend conducting future studies at single unit generation. If an increase in river flows occur (as happened this year) arrangements may have to be made to permit low generation.

4. If wild fish of sufficient size are present at Holtwood, RMC recommends that these fish be given priority in any mortality study.

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TABLE 1

Summary of radio tagged juvenile American shad released at Holtwood Station, November 1988.

Date	Fish Number	Turbine/ Boil	Last Location	Tracking Time	Status	Control Status After 2 Hr	Control Size (mm)	Holtwood Water Temp (C)	Brunner Is. Water Temp (C)	Δ Temp. (C) Holtwood and Brunner Is.
Nov 16	1-093	T	Deepwater Isl.	25 min	Lost(unknown)	Alive	130	9.3	19.2	9.9
Nov 17	1-114	T	Lower tailrace	69 min	Dead	Alive	130	8.7	19.2	10.5
Nov 17	1-108	T	Upper tailrace	2 min	Lost(unknown)	Dead	132	8.7	19.2	10.5
Nov 17	1-978	T	Lower tailrace	33 min	Dead	Alive	143	8.7	19.2	10.5
Nov 18	1-988	T	Below Norman Wood Bridge	2 h	Alive	Alive	130	8.7	11.1	2.4
Nov 18	1-003	T	Deepwater Isl.	65 min	Lost(unknown)	Alive	137	8.7	11.1	2.4
Nov 18	1-002	T	Turkey Isl.	4 h 49 min	Alive	Alive	128	8.7	11.1	2.4
Nov 18	1-979	T	Deepwater Isl.	21 min	Lost(unknown)	Alive	138	8.7	11.1	2.4
Nov 18	1-013	T	Deepwater Isl.	51 min	Lost(unknown)	Alive	137	8.7	11.1	2.4
Nov 18	2-013	T	Deepwater Isl.	38 min	Alive(Lost signal)	Alive	128	8.7	11.1	2.4
Nov 18	2-988	T	Mid-tailrace	30 min	Dead	Alive	136	8.7	11.1	2.4
Nov 18	1-973	T	Deepwater Isl.	29 min	Alive(Lost signal)	Alive	115	8.7	11.1	2.4
Nov 18	2-953	T	Upper tailrace	58 min	Dead	Alive	132	8.7	11.1	2.4
Nov 18	2-093	T	Below Norman Wood Bridge	72 min	Avian predation	Alive	123	8.7	11.1	2.4
Nov 18	1-958	T	Turkey Isl.	81 min	Alive(Lost signal)	Alive	137	8.7	11.1	2.4
Nov 18	1-103	T	Mid-tailrace	45 min	Dead	Alive	135	8.7	11.1	2.4
Nov 18	1-993	T	Mid-tailrace	23 min	Dead	Alive	135	8.7	11.1	2.4
Nov 19	1-078	B	Mid-tailrace	18 min	Dead	Dead	130	8.8	21.4	12.6
Nov 19	1-043	B	Lower tailrace	40 min	Dead	Dead	130	8.8	21.4	12.6
Nov 19	1-063	B	Mid-tailrace	43 min	Dead	Dead	125	8.8	21.4	12.6
Nov 21	2-933	B	Upper tailrace	12 min	Dead	Alive	130	7.7	24.4	16.7
Nov 21	1-064	B	Mid-tailrace	40 min	Dead	Alive	127	7.7	24.4	16.7
Nov 21	1-087	B	Upper tailrace	<1 min	Lost(unknown)	Alive	131	7.7	24.4	16.7
Nov 21	1-083	B	Lower tailrace	2 h	Dead	Alive	131	7.7	24.4	16.7
Nov 21	1-054	B	Deepwater Isl.	33 min	Dead	Alive	122	7.7	24.4	16.7
Nov 21	1-073	B	Turkey Isl.	68 min	Alive(Lost signal)	Alive	129	7.7	24.4	16.7
Nov 21	1-924	B	Upper tailrace	3 min	Lost(unknown)	Dead	116	7.7	24.4	16.7
Nov 21	1-968	B	Mid-tailrace	52 min	Dead	Alive	140	7.7	24.4	16.7
Nov 21	1-938	B	Deepwater Isl.	34 min	Alive(Lost signal)	Alive	128	7.7	24.4	16.7
Nov 23	2-971	T	Turkey Isl.	1 h	Alive(Lost signal)	Alive	135	6.5	25.0	18.5
Nov 23	2-948	T	Mid-tailrace	16 min	Dead	Alive	134	6.5	25.0	18.5
Nov 23	2-958	T	Mid-tailrace	30 min	Dead	Alive	138	6.5	25.0	18.5
Nov 23	1-943	T	Mid-tailrace	51 min	Dead	Alive	147	6.5	25.0	18.5
Nov 23	1-068	T	Lower tailrace	61 min	Fish predation	Alive	131	6.5	25.0	18.5
Nov 23	3-933	T	Deepwater Isl.	31 min	Dead	Alive	125	6.5	25.0	18.5
Nov 23	1-948	T	Deepwater Isl.	50 min	Alive(Lost signal)	Alive	130	6.5	25.0	18.5
Nov 23	2-924	T	Upper tailrace	54 min	Dead	Alive	127	6.5	25.0	18.5
Nov 23	2-073*/**	B	Below MRPSR	90 min	Alive	Dead	113	6.5	25.0	18.5
Nov 23	2-938**	B	Below MRPSR	90 min	Alive	Dead	126	6.5	25.0	18.5

* Externally tagged
** Shad collected from Holtwood inner forebay

TABLE 2

Numbers and status of radio tagged American shad released at Holtwood, November 1988.

	Number	Survival After 30 min	Survival After 1 h 30 min	Shad Lost <30 min	Shad Which Became Stationary	Shad Known Subjected to Predation
Tagged Shad Released Through Unit #10	25	28%(n=7)	8%(n=2)	20%(n=5)	44%(n=11)	8%(n=2)
Control Shad Released Into #10 Boil	14	29%(n=4)	14%(n=2)*,**	14%(n=2)	57%(n=8)	0
Control Shad Held for 2 h	39	-	82%(n=32)	-	-	0

* Both wild shad collected at Holtwood
** One of these was externally tagged

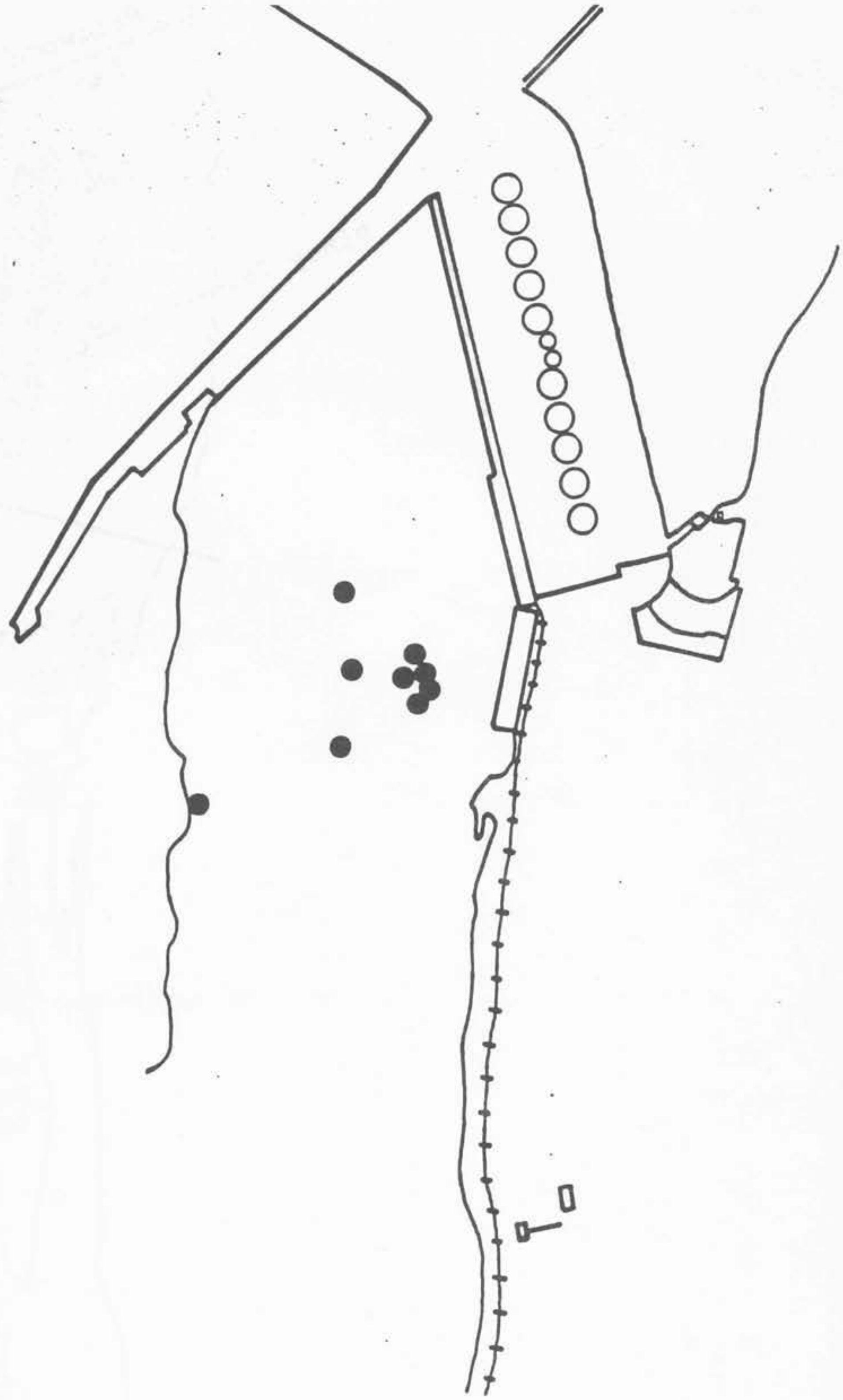

FIGURE 1

Settling locations of dead tagged control shad passed through Unit #10 of Holtwood Station at single unit generation (n=9); November 1988.

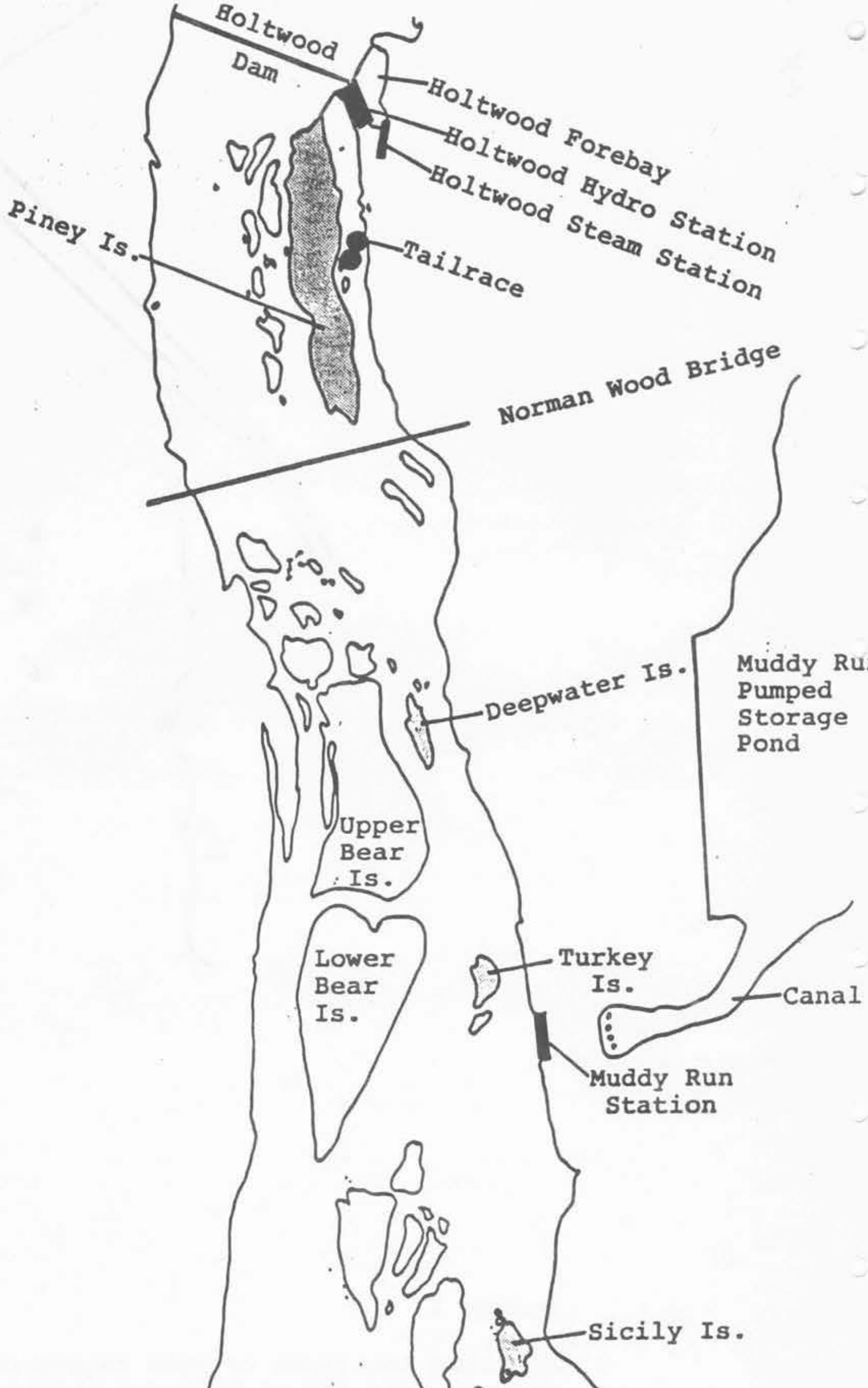

FIGURE 2

Settling locations of dead tagged control shad released through Unit #10 of Holtwood Station at full station generation (n=2); November 1988.

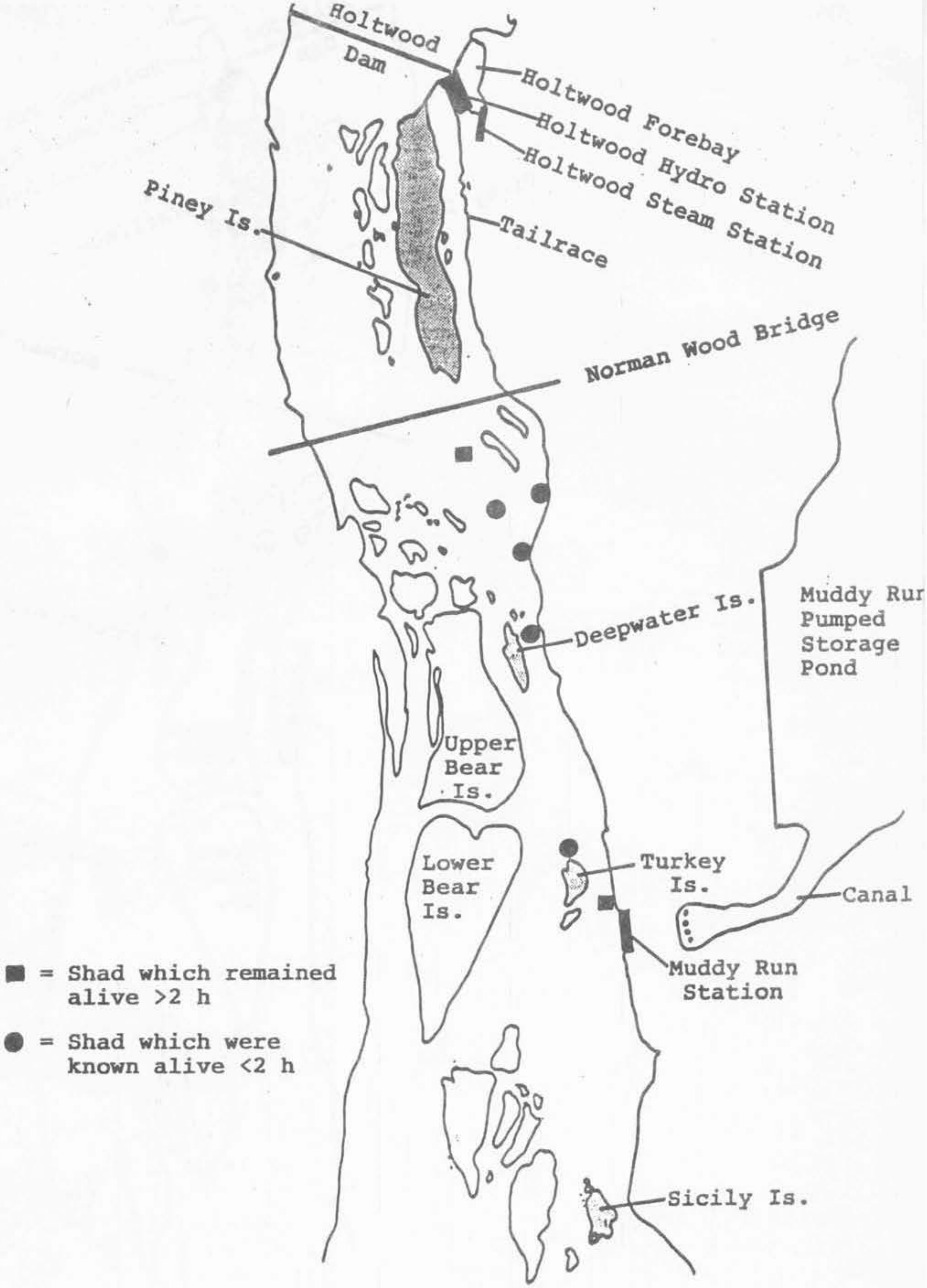

FIGURE 3

Final locations of shad which remained alive after passage through Unit #10 (n=7).

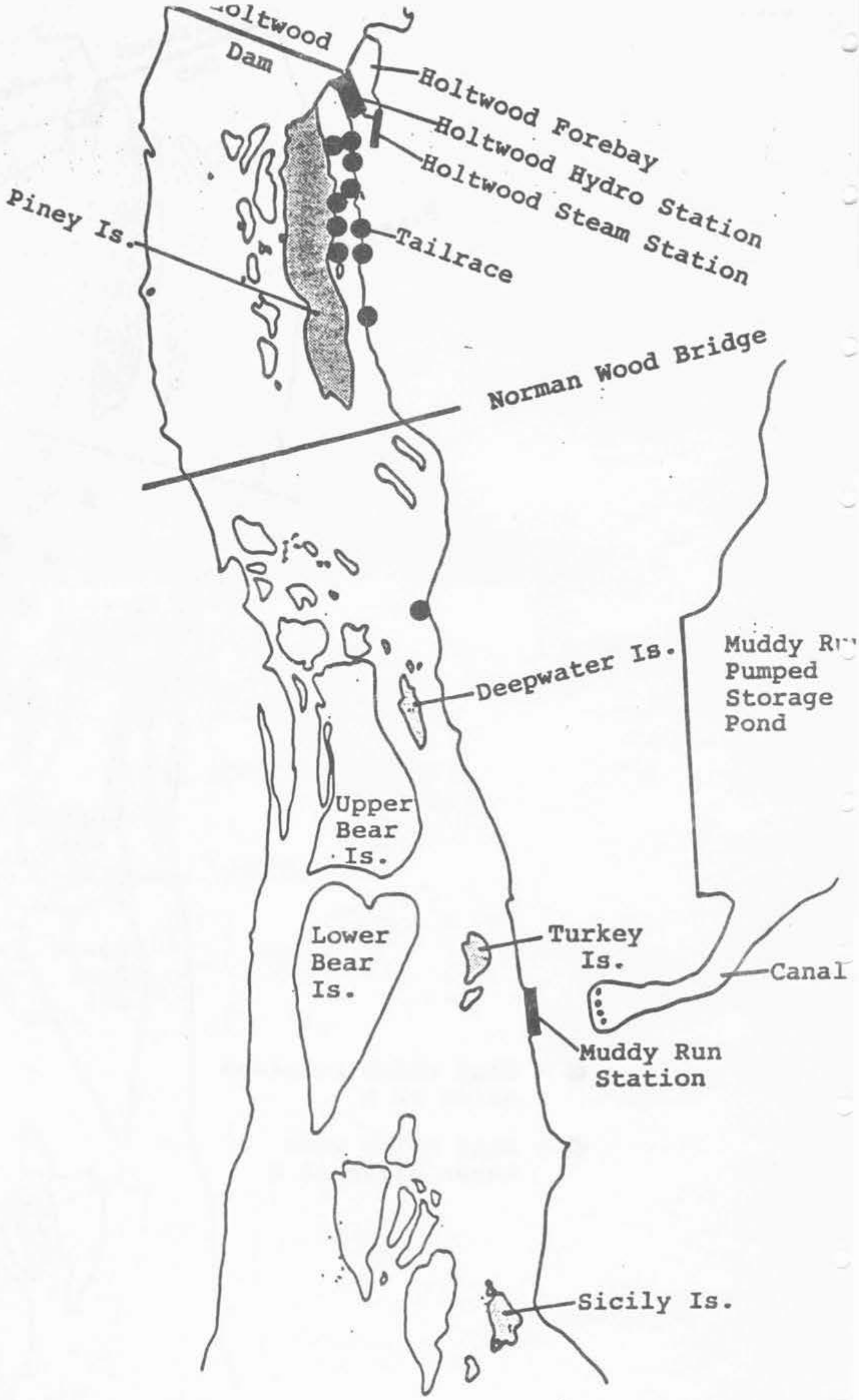

FIGURE 4

Final locations of shad released through Unit #10 of Holtwood Station which became stationary (n=11); November 1988.

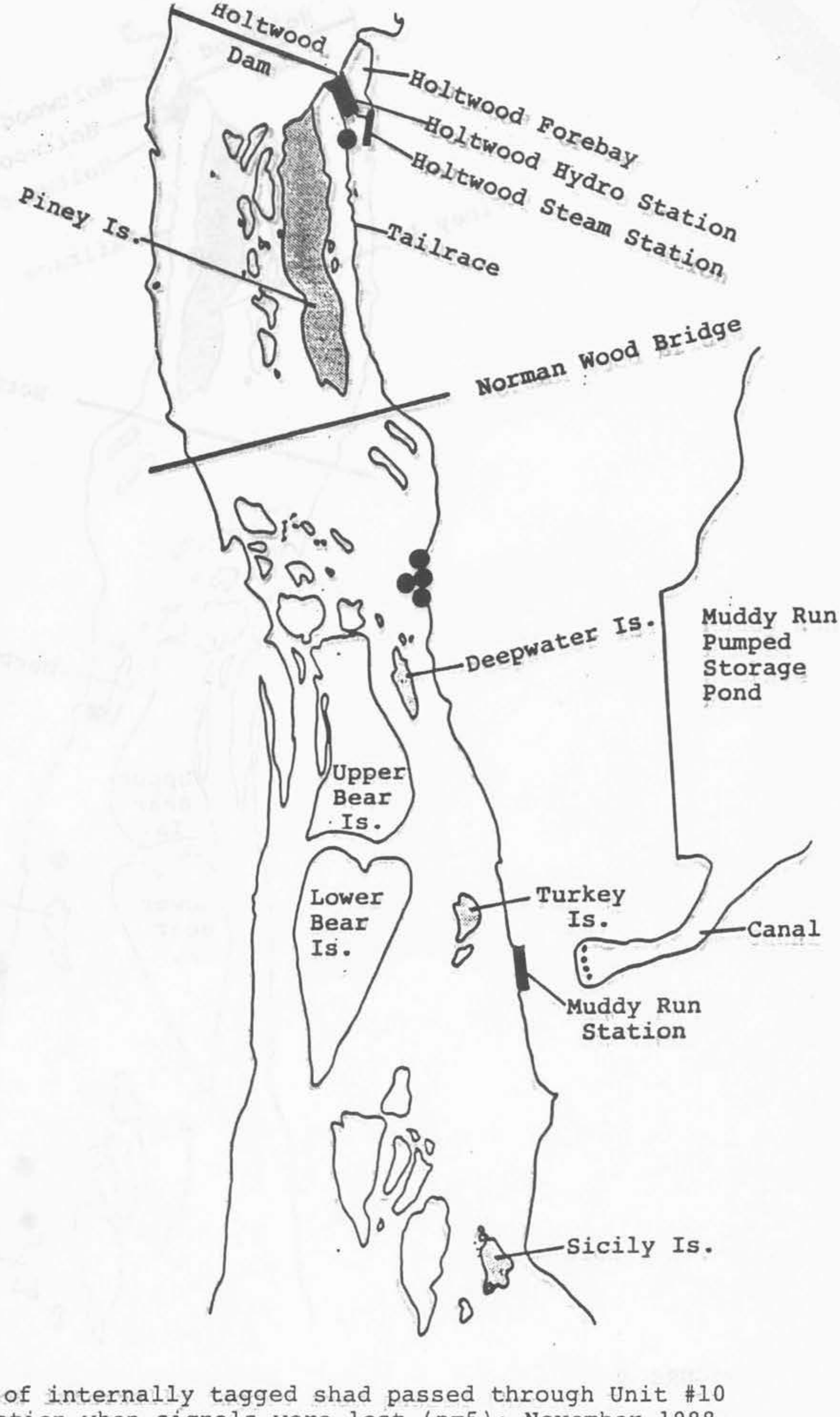

FIGURE 5

Last locations of internally tagged shad passed through Unit #10 of Holtwood Station when signals were lost (n=5); November 1988.

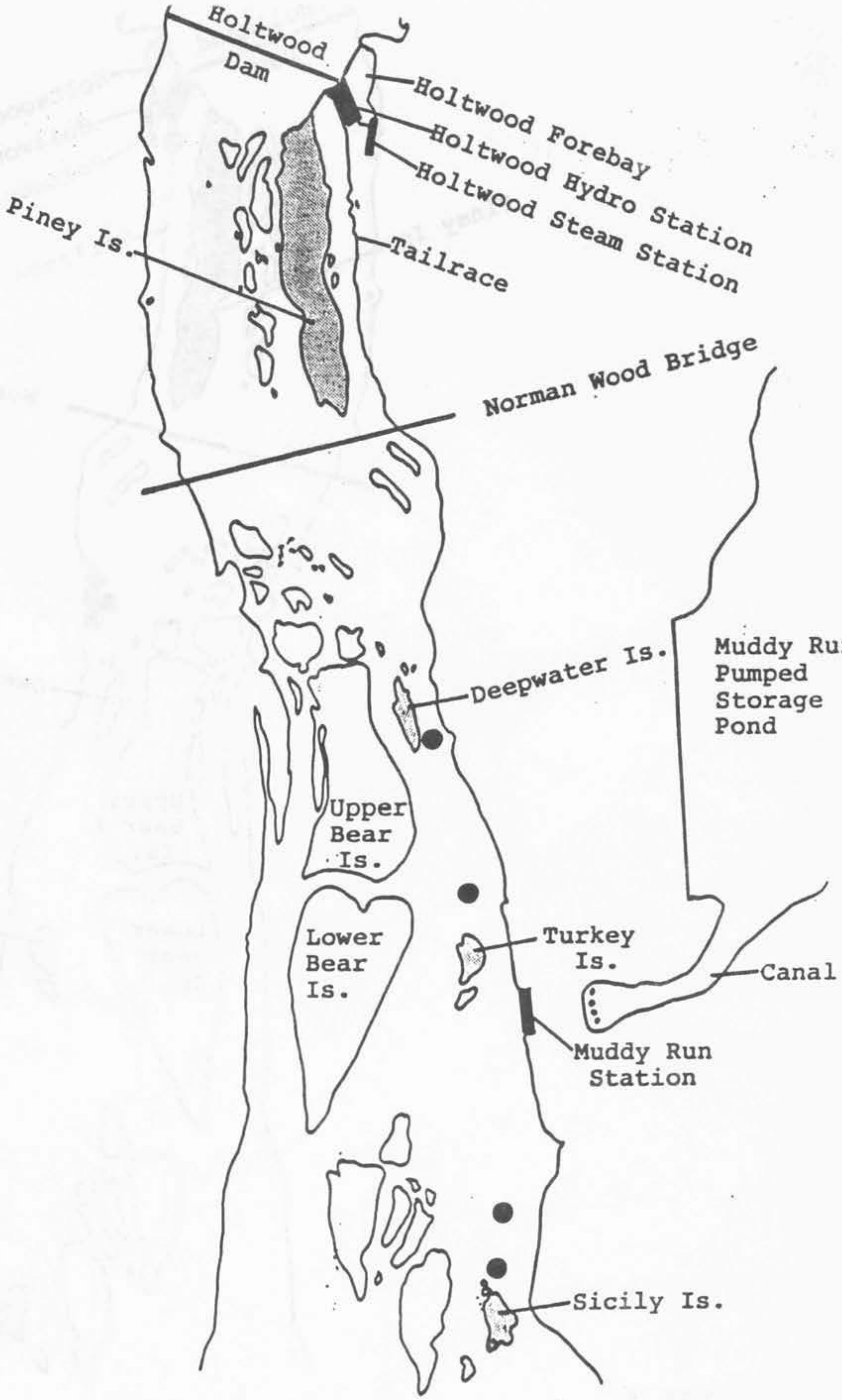

FIGURE 6

Final locations of shad which were known alive after release into boil #10 of Holtwood Station (n=4); November 1988.

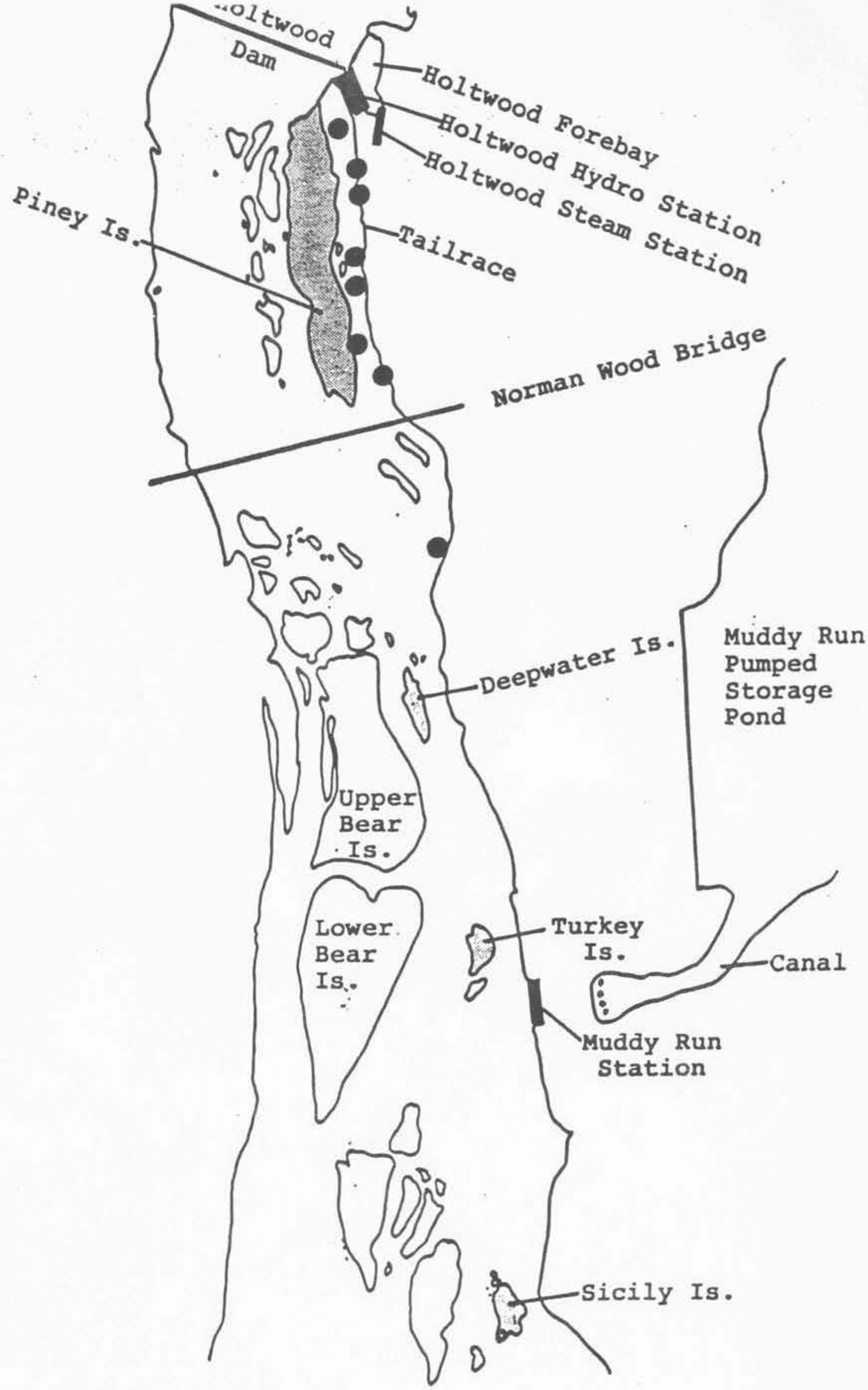

FIGURE 7

Final locations of internally radio tagged juvenile American shad released in boil #10 of Holtwood Station which became stationary (n=8); November 1988.

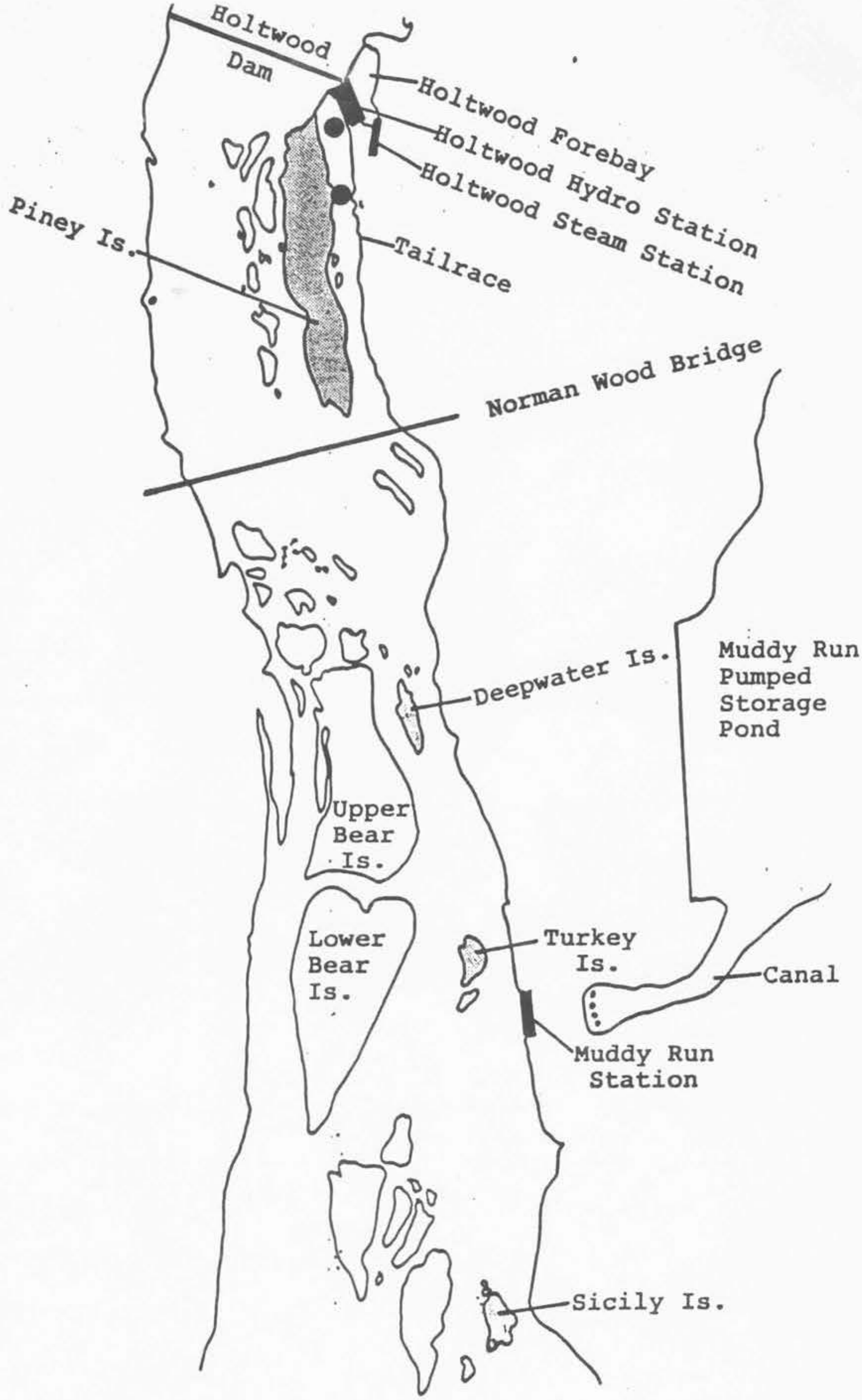

FIGURE 8

Last locations of internally tagged shad released into boil #10 of Holtwood Station when signals were lost (n=2); November 1988.

Job V, Task 4. Use of Otolith Microstructure to Distinguish Between Wild and Hatchery-Reared American Shad in the Susquehanna River

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INTRODUCTION

Efforts to restore American shad to the Susquehanna River are being conducted by the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC). Funding for the project is provided by a settlement agreement with the three upstream utilities. The restoration project consists of two programs. First, trapping of pre-spawn adults at Conowingo Fish Lift and transfer to areas above dams. Second, planting of hatchery-reared fry.

In order to evaluate and improve the program it is necessary to know the relative contribution of these two programs to the overall restoration effort. Toward that end, the Pennsylvania Fish Commission developed a physiological bone tag which could be applied to developing fry prior to release. The tag utilizes immersion in tetracycline antibiotics to mark the otoliths of hatchery-reared fry. Analysis of otoliths of outmigrating juveniles allows discrimination of "wild" vs hatchery-reared fish. The first successful application of tetracycline tagging at Van Dyke was conducted in 1984. Tagging on a production basis began in 1985, but was only marginally successful. Beginning in 1986, refinements in the tagging procedures produced tag retentions for juveniles which approached 100%. 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 resulting from out-of-basin or trap and transfer restoration efforts which are of upstream origin, 3) hatchery-reared fish originating from stockings in the Juniata River and 4) hatchery-reared fish originating from stockings below Conowingo Dam. The latter group are fish which received a "double" tetracycline tag and were first planted below Conowingo Dam in 1986.

There is a potential that tetracycline tagging rates will be of limited use for adult shad since adequate control fish cannot be maintained to determine mark retention rates. Tagging rates can therefore be used only to determine minimum contribution of hatchery-reared fish. In addition, tetracycline tagged adult males cannot be expected to return to Conowingo in numbers prior to 1989 (1990 for females).

This study was designed to develop a method to distinguish hatchery-reared adult shad from "wild" shad utilizing otolith microstructure. The possibility that such a study was feasible became apparent in Spring, 1987 when it was observed that otoliths of "wild" Susquehanna River juvenile American shad (as determined by the absence of an OTC tag) appeared to have different microstructural characteristics than hatchery-reared shad. Specifically, the increments formed during the first 10-15 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.

The study contains five jobs. Job I validates the daily ring hypothesis for American shad reared at Van Dyke under the different lighting regimes (photoperiod) used and for the various temperature regimes encountered during the rearing season. Job II determines the date of first increment formation for fry from Virginia rivers, Delaware River and Columbia River. Job III examines the correlation between fish length and otolith length and describes growth of shad fry at Van Dyke from the different egg source rivers. Job IV attempts to determine the key differences between otoliths of wild and hatchery-reared shad using known origin samples from 3 production years (1986-1988) including both hatchery and wild individuals. Job V applies these key characteristics to adult shad returning to Conowingo Dam in 1988. As such, these two jobs are the crux of the study. Jobs 1, 2, and 3 establish the background for the study in terms of increment formation and will aid in interpretation of the results obtained in Job 5.

Status

At this writing Jobs I and II are complete. Job III is 90% complete. Jobs IV and V have not yet been started. Preparation of specimens for Jobs IV and V should be complete by February, 1989. At that time, specimens will be delivered to Wellsboro National Fishery Research and Development Lab. Analysis for Jobs IV and V will be done using their newly acquired Biosonics Optical Pattern Recognition System. A separate report of results of the study will be completed as soon as possible after completion of Job V.

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JOB V, Task 5. SUMMARY OF 1988 YORK HAVEN STUDIES
METROPOLITAN EDISON COMPANY
ELECTRIC POWER RESEARCH INSTITUTE

SITE DESCRIPTION

The York Haven Hydroelectric Project is operated by Metropolitan Edison Company. The plant is located on the West bank of the Susquehanna River about four miles south of Harrisburg, Pennsylvania. An 8,000 foot long dam angles downstream from the East bank of the river to the project forebay.

The powerhouse consists of six Kaplan and fourteen Francis units each capable of passing about 1,000 cfs. The station is capable of generating 19.6 megawatts of electricity with a head of 23 feet. The forebay and site layout are shown in Figure 1. The corner of the forebay between the powerhouse and the cableway contains a gate which is typically used to sluice floating debris past the plant. Water velocities approaching the trash racks are between 1.5 and 4 fps and are typically highest through the downstream-most units (Units 1-5) (Barnes-Williams, 1987).

Juvenile American shad (Alosa sapidissima) move downstream past this project between late September and early November. During this period, river flows are usually low and most of the river water moves through the powerhouse and most typically through units 1 through 10. Past studies have shown that the majority of downstream migrating shad move along through the forebay and accumulate in great numbers in front of Units 1 to 3.

The purpose of this study was to determine if strobe or mercury lights or an underwater sound system could be used to move these aggregations of migrating fish to or through the gate.

MATERIALS AND TEST EQUIPMENT

Hydroacoustic Monitoring Equipment

The locations and orientations of each fixed-head transducer as discussed below are shown in Figure 2. A fixed, single beam transducer was mounted on the northeast corner of the Metropolitan Edison office building on the West bank of the forebay. This transducer was oriented across the forebay and looking slightly upstream toward Unit 20 on the powerhouse building on the opposite side of the forebay. The computer for this hydroacoustic system was equipped with a modem and was programmed to send data summaries to Stone & Webster's office in Boston every 24 hours. The purpose of this system was to act as a long-term monitoring device to determine the beginning of the outmigrating period for the 1988 season and to provide a measure of relative size of the season's outmigration compared to previous years.

A 10 by 14 foot foam-ballasted wooden raft was used as a moveable platform for the test devices and some additional hydroacoustic monitoring equipment. The raft was positioned about 20 feet off the face of the trash racks and about 50 feet upstream of the sluice gate. This position was determined to be just upstream of the greatest aggregation of fish based upon a scanning hydroacoustic survey during the first night of testing.

On the upriver side of the raft, two different types of hydroacoustic transducer heads were mounted. One was connected to a scanning sonar system and video recording system which was installed in a storage shed mounted on the raft. This system was powered by an on-board portable generator, and was used to record and qualitatively assess the behavioral response of fish to the test devices.

A second, fixed-aspect transducer was pointed under the raft toward the side of the gate closest to the west bank of the river. This provided a fixed view of the region with the greatest densities of fish. The transducer was connected to a color monitor, and a computer was used to record the output in digitized form. A video camera and recorder were used to record the Koden screen image for additional qualitative behavioral review.

A third fixed-aspect hydroacoustic monitoring station was used to collect data from the area immediately in front of the gate. The transducer for this station was mounted in the forebay a few feet off the face of cableway, about ten feet from the sluice gate and was oriented across the gate. The equipment for this system was equivalent to that described above for the raft-mounted, fixed-aspect hyrdoacoustic monitoring system.

Strobe Light Equipment

The forebay in the region where the raft was located is about 15 to 20 feet deep. Four strobe lights were mounted in an array (nine foot lateral spacing by three foot vertical spacing) off the downstream side of the raft and pointing toward the gate. The top two lights were positioned about three feet from the water surface. The controllers and synchronizer were mounted on the cableway wall and the power cables hung from the rail supports to the raft.

One controller was used to flash all of the lights simultaneously. The controller had the capacity to adjust the strobe output (day, twilight, and night settings) and flash rate (40 to 500 flashes per minute). For this testing program, the lights were set at the brightest (daylight) setting and operated at 300 flashes per minute.

On the last night of testing, the strobe light array was disassembled and two lights were mounted on the raft and two on the trash racks. The raft-mounted strobes were positioned just below the water surface and pointed down toward the bottom of the forebay. The strobes on the trash rack were mounted about three feet below the water surface and were oriented perpendicularly away from the racks and toward the office building on the west bank of the forebay. Each of the two pairs of lights could be individually controlled.

Mercury Lights

Initially, two 1000-watt mercury lights were positioned on opposite sides of the sluice gate about two feet below the water surface. The fixtures were pointed across the gate to provide maximum illumination of the area immediately in front of the gate. Due to the ineffectiveness of this arrangement, only the mercury light on the west side of the gate was used during the second night of testing. During this second night of tests the mercury light was lowered to a depth of about five feet. For the third and all subsequent days of testing except the last, this one mercury light was used but was lowered to the bottom of the forebay (a depth of 14 feet at this point) since it appeared that fish were avoiding the light. By placing the light near the bottom, it was hoped that fish deeper in the forebay would move toward the surface and be more likely to pass through the gate. On the last day of testing, the mercury light was mounted on the downstream side of the raft about three feet below the water surface. The raft-mounted light was pointed back towards the gate.

Sound Systems

Two independently-developed sound systems were also tested as part of this test program. Both studies used underwater speakers and/or sound projectors to transmit sound energy to the water. These systems were developed using proprietary technology of the two independent study teams and therefore details of the equipment used is limited. For both test programs, the equipment was tested from the foam-ballasted raft.

SAMPLE METHODS

Hydroacoustics

The effectiveness of the test devices was monitored primarily by hydroacoustic techniques. During the first night of testing, the scanning hydroacoustic system was used to confirm that the position of the raft was the most appropriate location. Thereafter, the system was used to monitor behavioral response to the test devices. This system could monitor the movement of fish (usually away from the lights) and the refuges or locations where fish were no longer repelled.

The three, fixed-aspect hydroacoustic systems had an ensonification rate of 10 or 60 per minute. Each sample period was five minutes long; therefore, each sample integrated data from either about 50 or 300 pings. For each sample, the number of pings, the number of return signals above a fixed sound pressure threshold, and an index of the average value of the return signals were recorded.

The raft-mounted hydroacoustic system was programmed to collect data from three zones in the ensonified field. These three zones represent three, fifteen-foot sections between the downstream end of the raft and the cableway wall (see Figure 3). The office building mounted transducer was programmed to record data from three equally-spaced zones across the intake forebay.

Sound Devices

Tests with the sound devices were conducted independently of those with the mercury and strobe lights. The methods and results of the first set of tests will be reported in a separate document. During the second set of sound tests, the sound frequencies used were recreated and projected from plots of the sound spectra of various fish noises, as reported by a U.S. Navy hydroacoustic survey. Additional sound frequencies were systematically projected as both pure and pulsed tones to test for any behavioral responses. The period before, during and after the projection of these sounds was monitored from the raft-mounted, fixed-aspect transducer. Since fish were concentrated in great abundance in this area during the testing, a subjective real-time analysis of the effect of each sound was conducted.

Sound mapping of ambient conditions was conducted prior to each of the independent sound system evaluations. This measuring and mapping information was used to evaluate the sound pressure levels generated by the test devices.

Light Devices

Tests of lighting devices and ambient (control) conditions were generally each one hour in length. During this hour period, typically 12 hydroacoustic samples from Zones 1, 2 and 3 were collected. Each sample represented a 5-minute summary hydroacoustic observation in each zone.

A fourth type of test was described as a gate-strobe test. In these tests, the sluice gate was opened and fish behavior was evaluated over a one-hour period, as described below:

control condition (gate closed)	20 minutes
control with gate open	5 minutes
strobe light with gate open	5 minutes
control with gate open	5 minutes
strobe light with gate open	5 minutes
control with gate open	5 minutes
control condition (gate closed)	15 minutes

Testing was sequenced to provide as equal distribution of test types as possible across nights and across time periods within a night. The order of testing also provided an equal distribution of time paired sequences as possible (e.g., mercury followed by strobe, control followed by mercury, etc.). There were some constraints in the time required to open or close the gate which created some minor deviations in duration of gate strobe tests.

For the last night of testing, test durations were generally 10 minutes for all tests conducted with the gate closed. Two, 30-minute mercury light tests were conducted with the gate closed. All tests conducted with the gate open were of five minutes duration.

Light intensities were measured via photocell as described in Section 3.0 of the EPRI Interim Report where equipment used is described in greater detail. Light measurements were taken in a three-dimensional matrix of positions between the raft and the sluice gate. Light mapping was conducted under ambient conditions as well as separately with the strobes and mercury lights operating. Spot measurements were conducted daily to verify the performance of the equipment. Light measurements were also conducted from a fixed location during the early afternoon to obtain a relative measure of light transmission.

The timing and duration of any meaningful rainfall, wind or storm event was recorded along with daily monitoring of cloud cover conditions.

To summarize and statistically analyze the hydroacoustic data, the measure of target abundance used was percentage of the time one or more defined targets were in a zone of the ensonified field. A defined target was identified from a returned hydroacoustic signal whose sound pressure level exceeded the fixed threshold. The Statistical Analysis System (SAS, 1985) was used to plot percentage data over time and by test condition (i.e., control, mercury, strobe, gate-strobe). The SAS procedure GLM was used to test for statistical differences in hydroacoustic target abundance between test conditions. The GLM framework uses the method of least squares to conduct many different analyses including regression and analysis of variance for unbalanced data. The SAS procedure UNIVARIATE was used to provide additional summary information on the distribution of sample observations.

RESULTS

Light Testing

The hydroacoustic observations obtained from the raft-mounted transducer were judged in the field to more accurately represent fish abundance in the study zone than those from the cableway, wall-mounted transducer. The region ensonified by the cableway transducer has a low water velocity when the gate is closed. Shad were not consistently aggregating in this zone during typical operating conditions. Data from the raft-mounted transducer was used to summarize and statistically evaluate the effect of the test devices.

Figures 4 to 10 are plots of the relative target abundance for each date of sampling and by time and test condition. Each point on the plot represents the percentage of the five minute sample period in which one or more defined targets were in the sampling zone. As shown in Figure 3, zone 1 is the area closest to the raft, zone 3 is the zone closest to the gate, and zone 2 is the middle area.

Since American shad outmigration occurs mainly at night, daytime abundance was typically low. Daytime test results were highly variable. The low and variable abundance of fish overwhelmed the ability of the test program to measure the effectiveness of the devices in a quantitative way. As an example of the low daytime abundance, Figures 9 and 10 show afternoon sampling on the 26th and 27th was suspended (no sample period) because of lack of targets. The figures plotting target abundance over time often show target abundance increasing greatly about 6 PM. This closely corresponds to the time when visual observations of the forebay show surface dimpling behavior of outmigrating juvenile American shad. Figure 4 for October 15-16 shows an example of how target abundance rapidly increased during the period around dusk (6:15 PM). This pattern can also be seen in the plot on Figure 7 for October 24.

In general, Figures 4 to 10 show that hydroacoustic targets almost completely exited the ensonified zone when the strobe lights were illuminated. The figures also show that target abundance was not noticeably changed due to operation of the mercury lights.

Figure 4 for October 15-16 shows that the first strobe test had little effect in reducing target abundance in the first 15 minutes of testing in zone 3, furthest from the strobe light (6:30 to 6:45 PM). This pattern can also be seen on Figure 9 for October 26 (5:30 to 6:30 PM) and on Figure 10 for October 27 (5:30 to 6:30 PM). At this time of early evening, ambient light

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is still high compared to night conditions. To the human eye, the relative intensity of the strobe light was not as great as that later in the evening.

On October 24, the river water surface level rose in response to heavy rain upstream. The water was noticeably more turbid. Strobe and gate strobe tests conducted on this night (6:30 to 7:30 PM and about 10 PM in Figure 7) and on the following two nights (7:30 to 10:30 in Figures 8 and 9) showed a relative response to the strobe which was less dramatic than on previous or subsequent nights (especially in the zone furthest from the lights).

Figures 4 to 10 generally show that the effect of the mercury lights was not greatly different from that of the control condition. There were some unusual observations from the mercury light data. There was an unexplained sharp reduction in abundance shown in Figure 4 for October 15-16 at about 8:20 PM. There was also reduced abundance in zone 3 on October 15-16 (about 11 PM) (Figure 4), October 24 (7:45 PM) (Figure 7), October 25-26 (6:30 to 7:30 PM) (Figure 8), and October 27 (8 PM) (Figure 10) which may indicate an avoidance response in the vicinity of the mercury light.

Figure 11 is a plot of test results for the last day (October 28th) of light testing under modified testing conditions. These results were very similar to those obtained during the previous test conditions. The varied test conditions provided additional information on the range of effectiveness of the strobe lights. This information is described in more detail under the discussion of behavioral observations. Figure 11 shows that target abundance was high during control periods as it was under the previous test conditions. The plot also shows the raft-mounted strobe lights were very effective but only in zone 1. This is to be expected since the downward orientation of the raft-mounted strobes limited the surface light penetration only to zone 1.

During the modified testing on October 28th, the upstream-most trash rack mounted strobes were effective only in zones 2 and 3 when the upstream strobe did not operate. These tests show how the shad would move out of the penumbra of the downstream strobe and remain in the unlighted zone 1.

The plot in Figure 11 shows the effect of the mercury light was not consistent or sustained. Even with the mercury light mounted on the raft adjacent to the area of greatest target abundance, the response was not great. These tests confirmed that the location of the mercury light was not an influence in the effectiveness of the device.

The statistical analysis used only night observations and did not include the data collected under modified test conditions on the final date of sampling. Because gate operation altered the orientation of fish relative to the transducer beam, changes in strength of the returned acoustical signal (and thus the defined target) become confounded with gate operating condition. Therefore, the tests with the gate open were also not included in the statistical analysis. The analysis was conducted separately for zones 1, 2, and 3 as well as for the average of the values in zones 1, 2, and 3.

Table 1 shows an ANOVA summary table for the statistical comparison using the data for zone 1. The table shows that there are statistically significant differences among the means for the three test conditions (control, mercury and strobe). A Duncan's multiple range test showed that the significant difference was attributed to the low target abundance observed during the strobe lights tests relative to the generally similar, and high mean target abundance for the control an mercury light tests. Table 2 shows the mean hydroacoustic target abundance (percent) in each zone by test condition. Information on the number of observations and the distribution quantities are also provided in the table. The 0 and 100 percent distribution quantiles represent the minimum and maximum values observed, while the 50 percent quantile is the median of the sample distribution. Likewise, the 25 and 75 percent quantiles represent the observations at the 1/4 and 3/4 points of the ranked observations.

Tables 3 through 8 show the same type of information for zones 2 and 3 and the average abundance values for zones 1, 2 and 3. For each of these three separate analyses, the results are similar. There are significant differences in mean abundance between test conditions. In all cases the difference is attributable to the low target abundance during strobe light testing. The tables of means show that the greatest differences among test conditions were observed in zone 1, as would be expected. The difference in mean target abundance between strobe and other test conditions decrease as distance from the strobes increases.

The qualitative observations obtained from the scanning and fixed-aspect hydroacoustic equipment confirm and further explain the results of the quantitative analysis and evaluation. The qualitative observations show precisely how far fish were repelled by the strobe lights and the behavior of the responses.

The observations from the scanning sonar system showed the fish moving out of the area between the raft and sluice gate during a strobe light test. Within seconds of initiation of a strobe light test, the fish would move to an area upstream of the raft (near unit 4) or to an area between the raft and the Met-Ed office on the west bank of the forebay. The scanning sonar also showed that targets did not congregate under the foam-ballasted raft.

The behavioral data from the fixed-aspect hydroacoustics system showed more detail of the response of targets to the strobes than the quantitative analysis revealed. The monitor showed that targets moved away from the strobe light even during full daylight. This response was restricted during daylight hours but as dusk approached, further observation showed a gradual and continuous increase in the effective repulsion range of the strobe light. The effect of greater water turbidity was shown in the qualitative review to result in a direct reduction in the range of repulsion of the fish.

The response of targets to the mercury light was a reduction of targets in the immediate vicinity of the light. However, the fish acclimated to the light and the effect was not as continuous or sustained as that for the strobe light. Another observation from the hydroacoustic monitor showed that avoidance to the mercury lamp increased during the 2 to 5-minute warm-up period for the lamp. As the light increased illuminescence fewer targets could be seen in the in the lighted zone. On the last night of testing the mercury and strobe lights were used together. The effect was to reduce the range of effectiveness of the strobe. This observed behavior is consistent with the previously observed behavior of the targets to gradually move away from the strobes as the ambient light levels decreased at dusk. Higher background light levels reduce the effectiveness of the strobes in repelling fish.

There was enough ambient light provided by distant plant lighting to permit some visual observation of many areas of the forebay. The visual observations confirmed the movement patterns of fish exposed to strobe or mercury light test conditions. The visual observations verified the rapid exit of fish from the strobe-lighted zone. They also confirmed the presence of fish just outside the penumbra of the strobe-lit area.

The most dramatic effect of the strobe lights which could not be fully observed with the hydroacoustic equipment occurred during the gate strobe testing. Typically when the gate was opened some fish in the immediate vicinity of the gate would move out through the gate. Fish would continue to move out the gate in low numbers while the gate was opened during the 5-mimute gate-open control. When the strobe lights on the raft were illuminated, large numbers of fish could be seen pouring out the gate in the first few seconds of the strobe test. Visual observations showed that these spilled fish accounted for most of the fish previously milling in front of Units 1 and 2. Some of the fish milling in this area would move alternately very rapidly for 5 to 10 seconds between the raft and the sluice gate before moving either outside the penumbra of the light or over the gate. While the gate was open and the strobes on the raft were illuminated, fish would continue to pass over the sluice gate in lower numbers but sometimes also in small schools. During the next 5-minute control period of a gate-strobe test (strobe lights off), the numbers of fish in front of the gate increased. When the second strobe illumination period began, large numbers of fish again passed out the gate in the same short period of time. The judgment of many observers was that the strobes were equally effective in moving the fish from the test zone over the gate during the second 5-minute gate strobe even though the short control period did not allow densities of fish to build to the previous level.

The visual observations confirmed the pattern of an increasing avoidance zone to the mercury light during the 2 to 5-minute warm-up period. The swimming speeds of the fish in the area illuminated by the mercury light did not appear to be as fast as those of fish startled by the illumination of the strobe lights. However, this observation has to be tempered by the general difficulty in observing fish illuminated by a strobe light.

Sound

Results of the first set of sound testing will be reported in a separate document. Results of the second sound testing program indicate that the aggregations of fish milling in front of Units 1 and 2 did exhibit a startle response and avoidance to some of the sounds projected. However, the

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avoidance responses were not strong (relative to those described for the response to the strobe light) and did not displace fish a great distance from the source. Furthermore, the displacements were not sustained; the fish rapidly acclimated to the condition and moved back into the area.

REFERENCES

Barnes-Williams. 1987. Hydroacoustic Evaluation of Juvenile Shad Movement and Passage at the York Haven Power Station, October-November 1986.

SAS. 1985. SAS User's Guide: Statistics, Version 5 Edition. Cary, NC:SAS Institute Inc. 956 p.

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Table 1

RESULTS OF GLM ANALYSIS OF VARIANCE
ZONE 1 DATA

Source of Variability	Degrees of Freedom	Mean Square	F-Value	Probability Level
Test Device	2	289090	1662.7	0.0
Residual	335	173		
Total	337			

Table 2

DISTRIBUTION OF FISH ABUNDANCE BY TEST DEVICE
ZONE 1 DATA

Device	Mean	Number of Observations	Quantiles(%) 0	25	50	75	84
Control	96.98	109	47.1	99.7	100	100	100
Mercury	98.00	96	25.4	100	100	100	100
Strobe	42.03	133	0	1.2	5.3	16.0	68.7

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Table 3

RESULTS OF GLM ANALYSIS OF VARIANCE
ZONE 2 DATA

Source of Variability	Degrees of Freedom	Mean Square	F-Value	Probability Level
Test Device	2	121422	187.2	0.0001
Residual	335	648		
Total	337			

Table 4

DISTRIBUTION OF FISH ABUNDANCE BY TEST DEVICE
ZONE 2 DATA

Device	Mean	Number of Observations	Quantiles(%) 0	25	50	75	84
Control	97.50	109	65.2	98.3	100	100	100
Mercury	96.20	96	15.5	97.7	100	100	100
Strobe	42.03	133	0	4.8	27.3	84.2	100

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Table 5

RESULTS OF GLM ANALYSIS OF VARIANCE
ZONE 3 DATA

Source of Variability	Degrees of Freedom	Mean Square	F-Value	Probability Level
Test Device	2	39248	43.12	0.0001
Residual	335	910		
Total	337			

Table 6

DISTRIBUTION OF FISH ABUNDANCE BY TEST DEVICE
ZONE 3 DATA

Device	Mean	Number of Observations	Quantiles(%) 0	25	50	75	84
Control	91.03	109	30.9	88.2	100	100	100
Mercury	83.10	96	3.4	70.8	93.6	100	100
Strobe	56.77	133	0	9.6	69.0	100	100

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Table 7

RESULTS OF GLM ANALYSIS OF VARIANCE
AVERAGE OF ZONES 1, 2 AND 3

Source of Variability	Degrees of Freedom	Mean Square	F-Value	Probability Level
Test Device	2	129807	321.4	0.0001
Residual	335	404		
Total	337			

Table 8

DISTRIBUTION OF FISH ABUNDANCE BY TEST DEVICE
AVERAGE OF ZONES 1, 2 AND 3

Device	Mean	Number of Observations	Quantiles(%) 0	25	50	75	84
Control	95.17	109	53.6	93.8	100	100	100
Mercury	92.44	96	17.8	87.9	97.7	100	100
Strobe	37.20	133	0	6.8	32.7	67.1	84.9

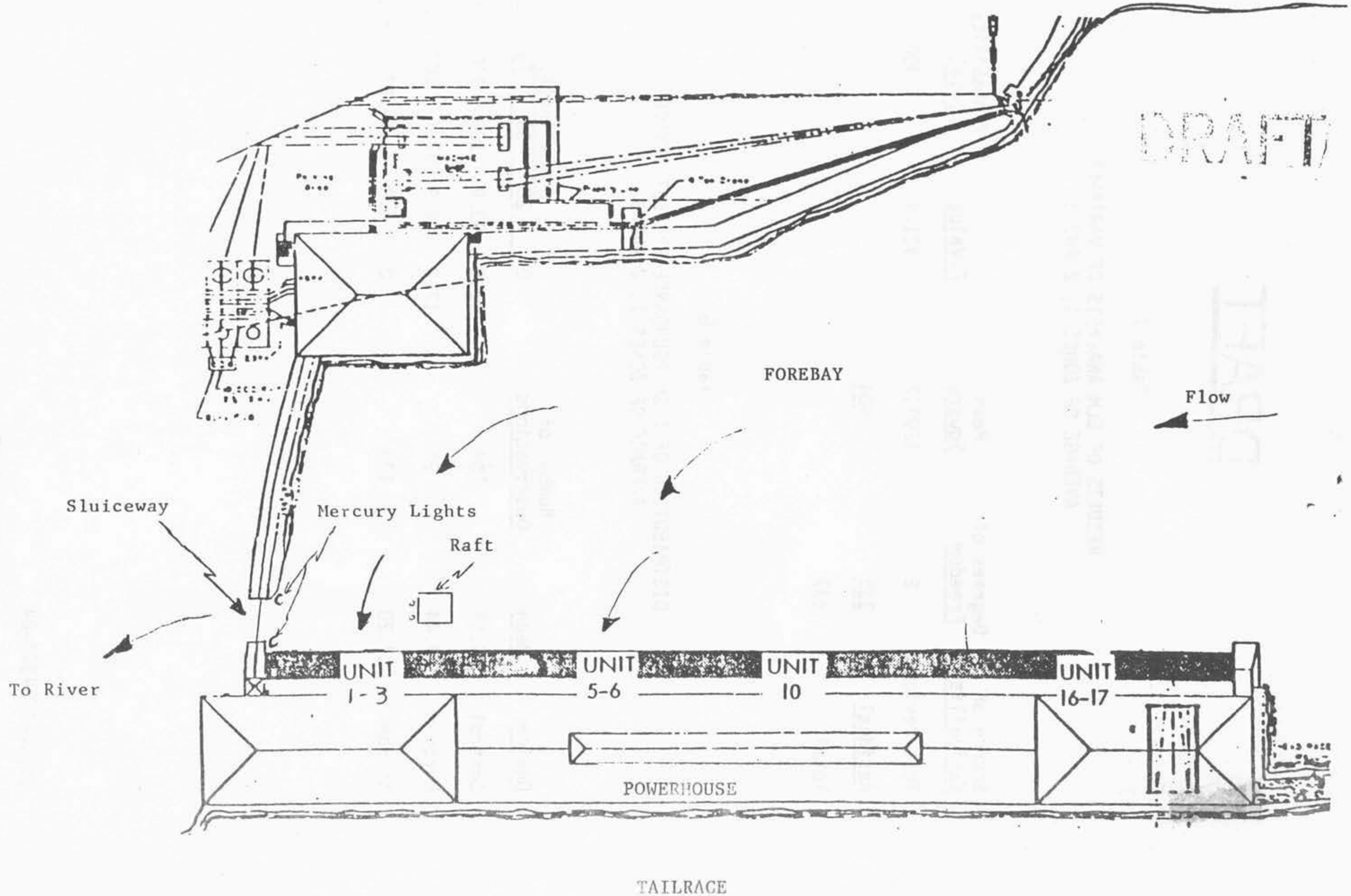

DRAFT
FOREBAY
Flow
Sluiceway
Mercury Lights
Raft
To River
UNIT 1-3
UNIT 5-6
UNIT 10
UNIT 16-17
POWERHOUSE
TAILRACE

FIGURE 1

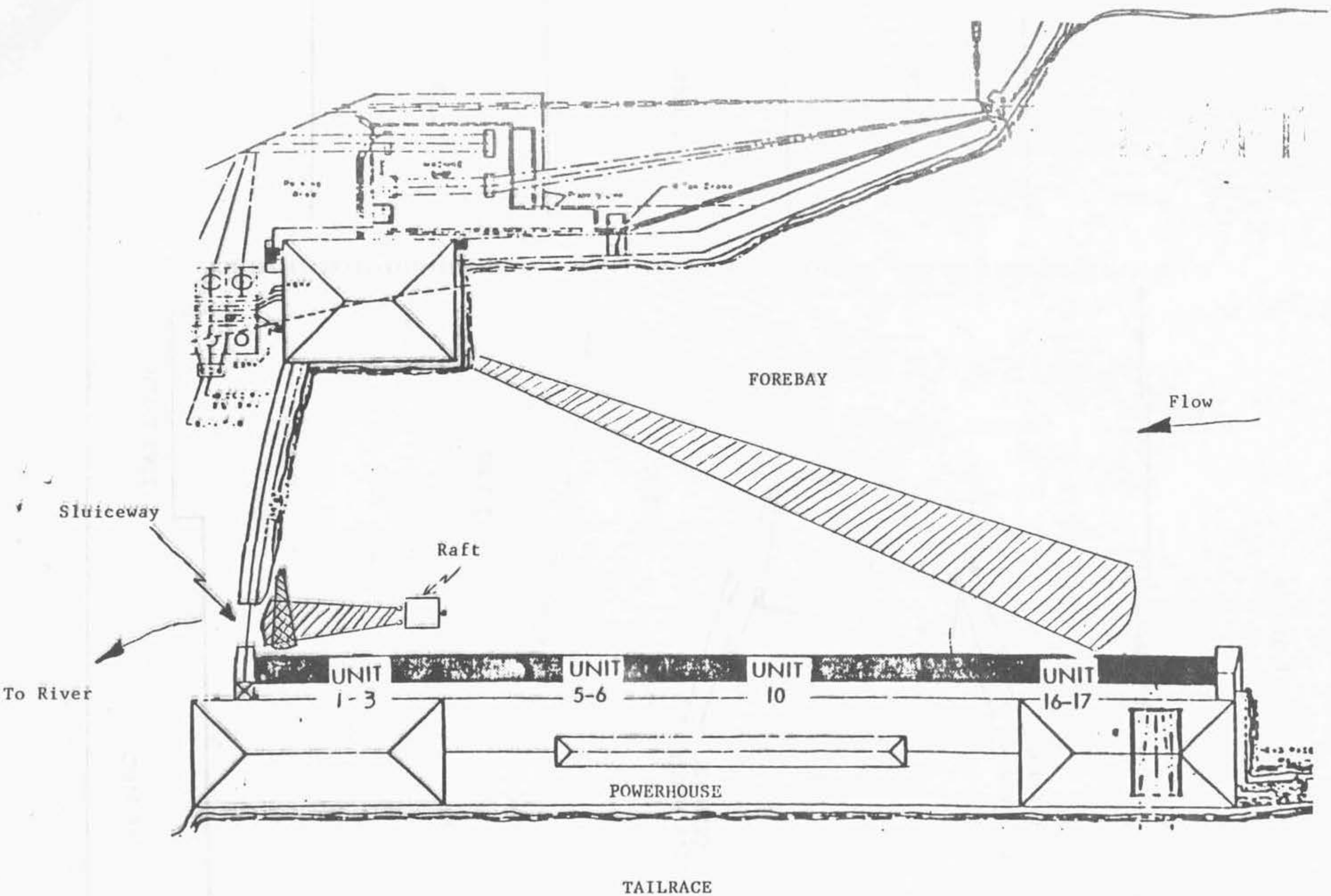

FOREBAY
Flow
Sluiceway
Raft
To River
UNIT 1-3
UNIT 5-6
UNIT 10
UNIT 16-17
POWERHOUSE
TAILRACE

FIGURE 2

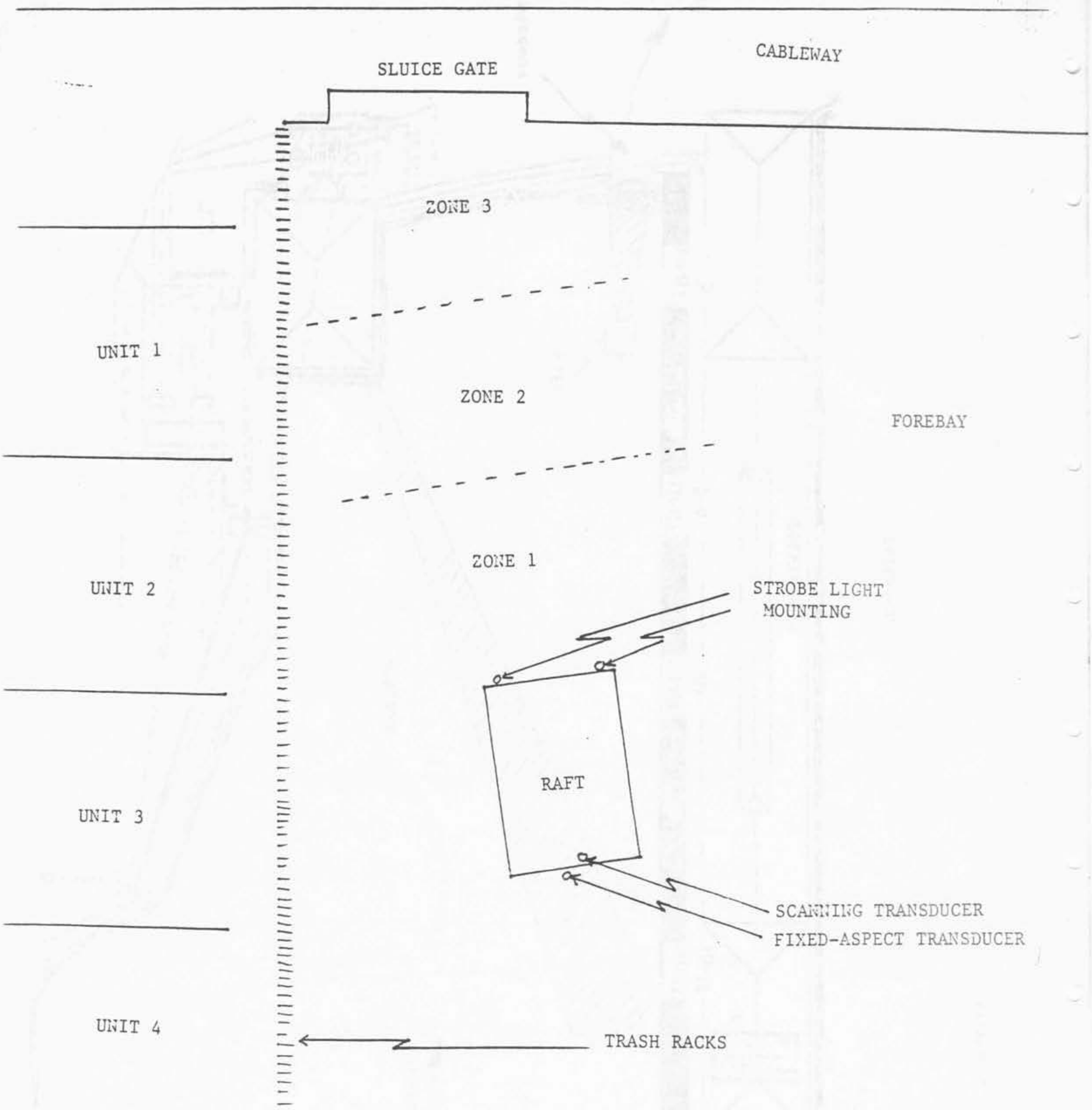
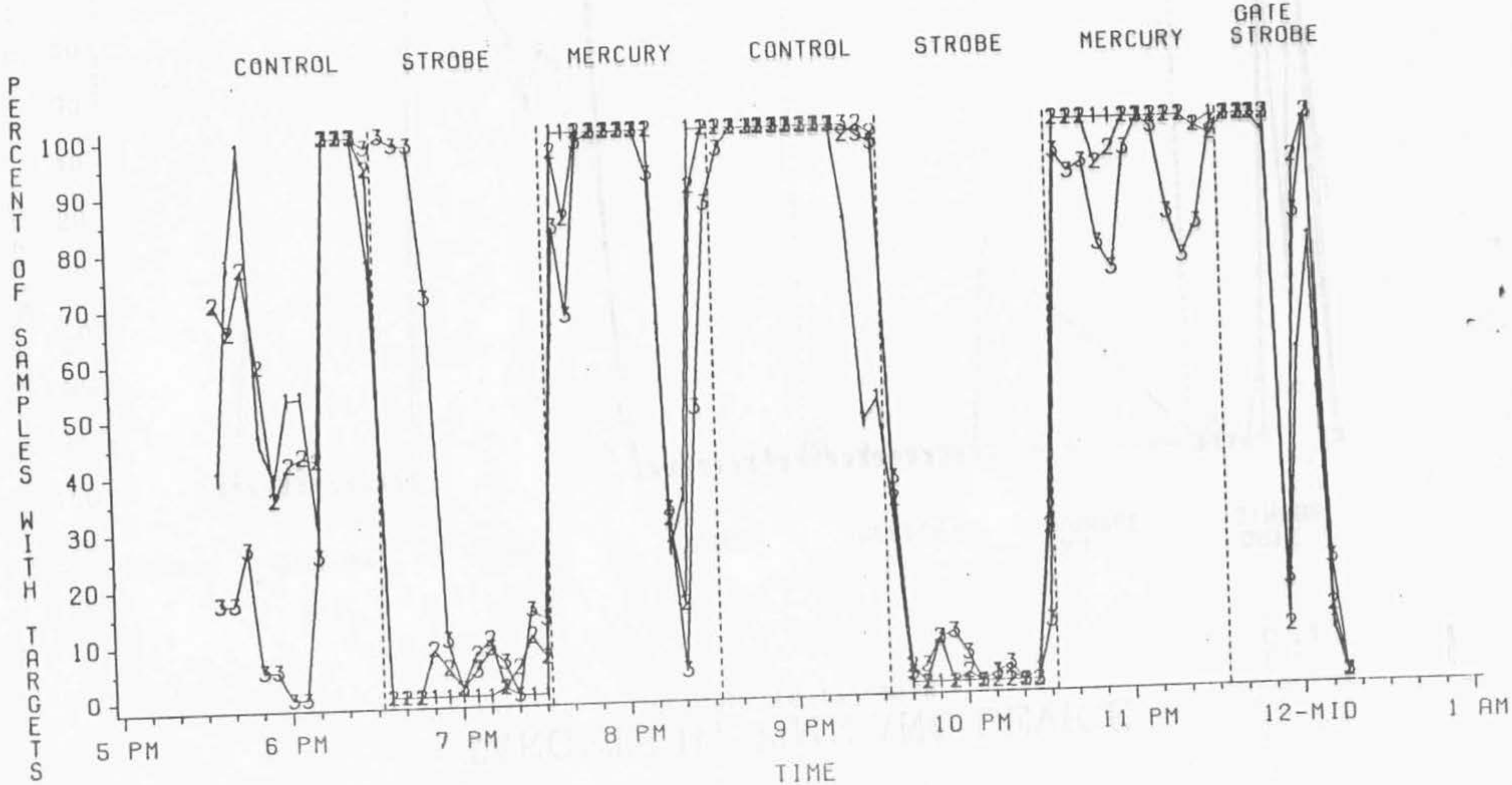

CABLEWAY
SLUICE GATE
ZONE 3
UNIT 1
ZONE 2
FOREBAY
ZONE 1
UNIT 2
STROBE LIGHT MOUNTING
RAFT
UNIT 3
SCANNING TRANSDUCER
FIXED-ASPECT TRANSDUCER
UNIT 4
TRASH RACKS

FIGURE 3

TARGETS BY TIME AND DEVICE

OCTOBER 15-16, 1988

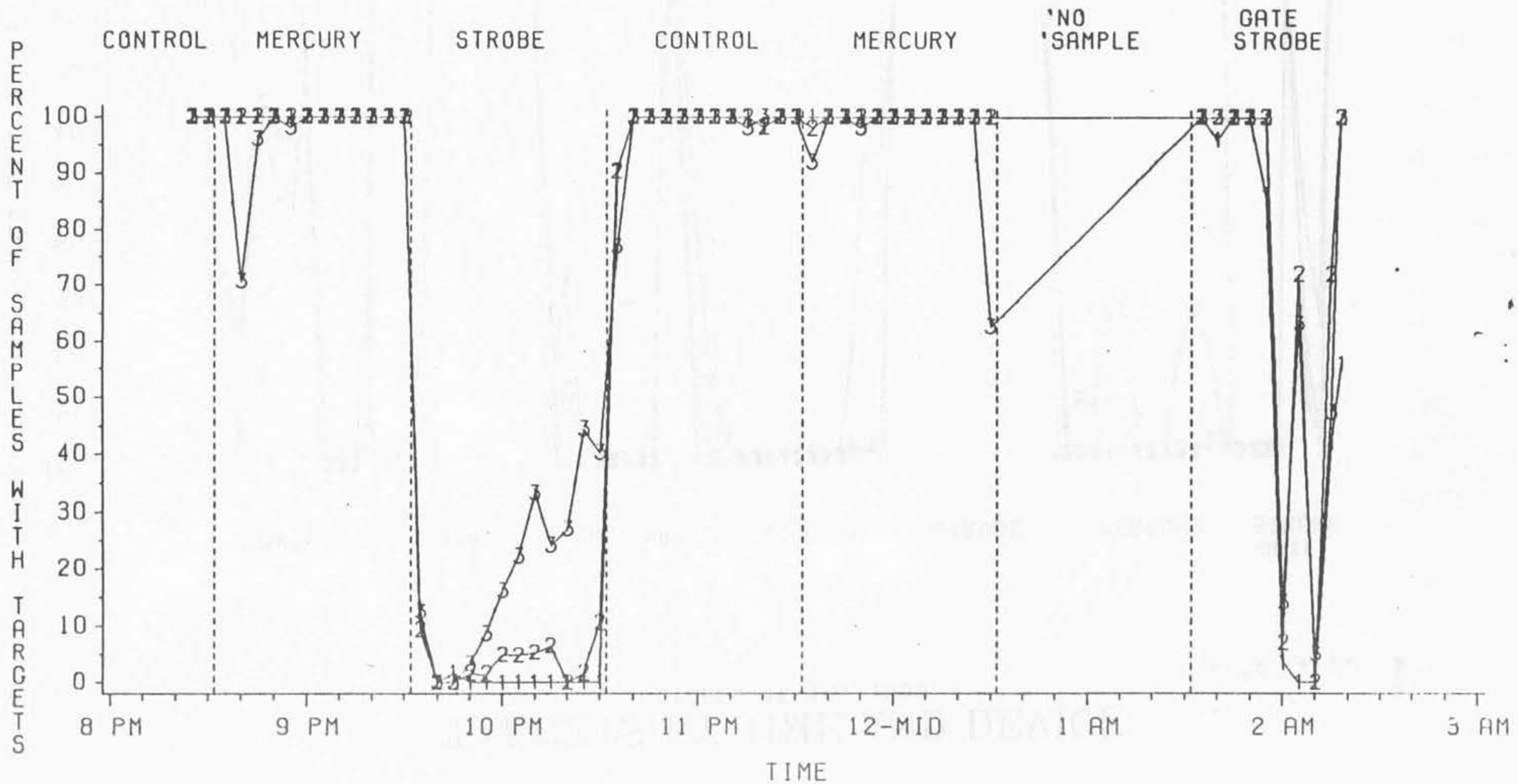


1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

FIGURE 4

TARGETS BY TIME AND DEVICE

OCTOBER 16-17, 1988

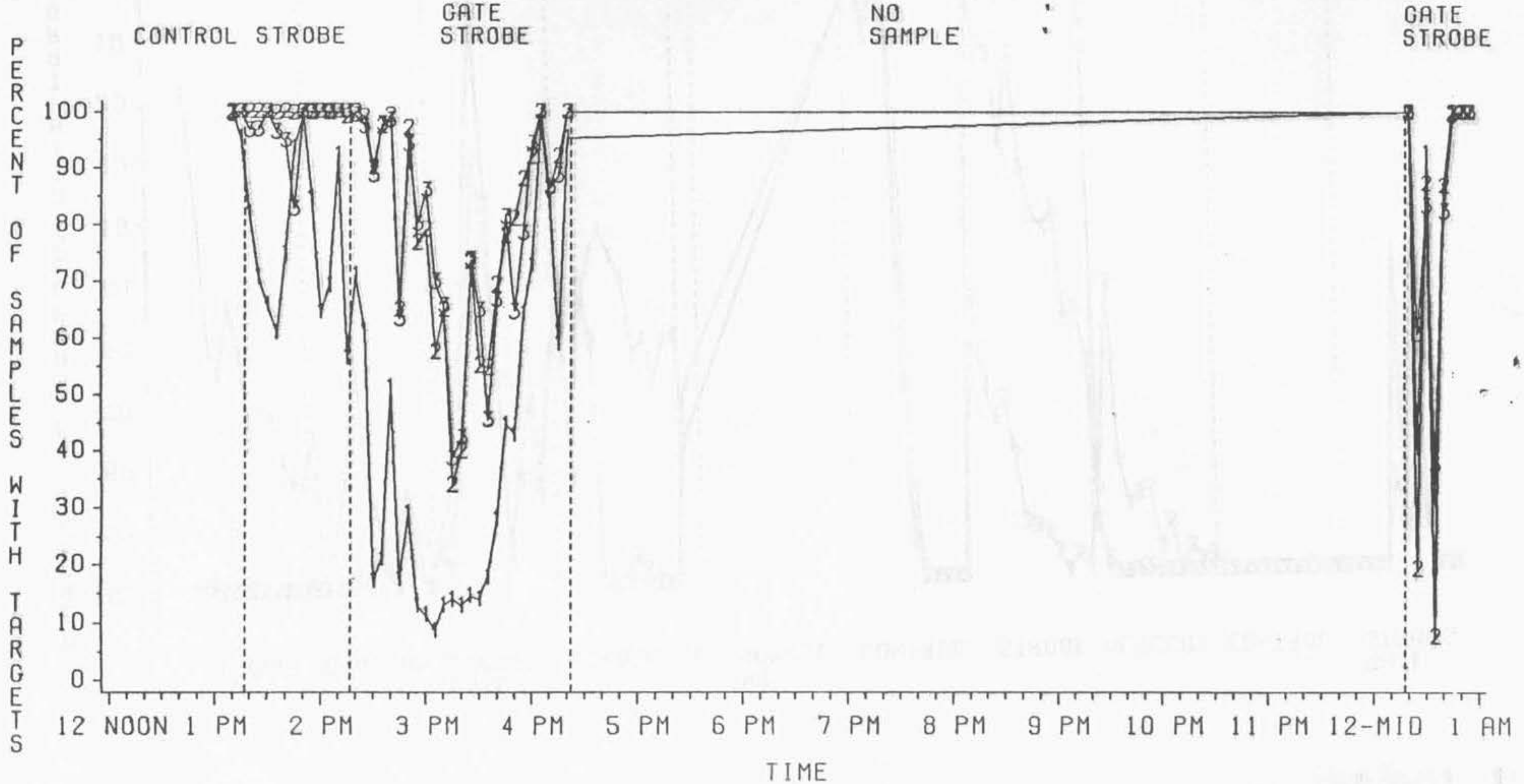


1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

FIGURE 5

TARGETS BY TIME AND DEVICE

OCTOBER 23-24, 1988



1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

FIGURE 6

TARGETS BY TIME AND DEVICE

OCTOBER 24, 1988

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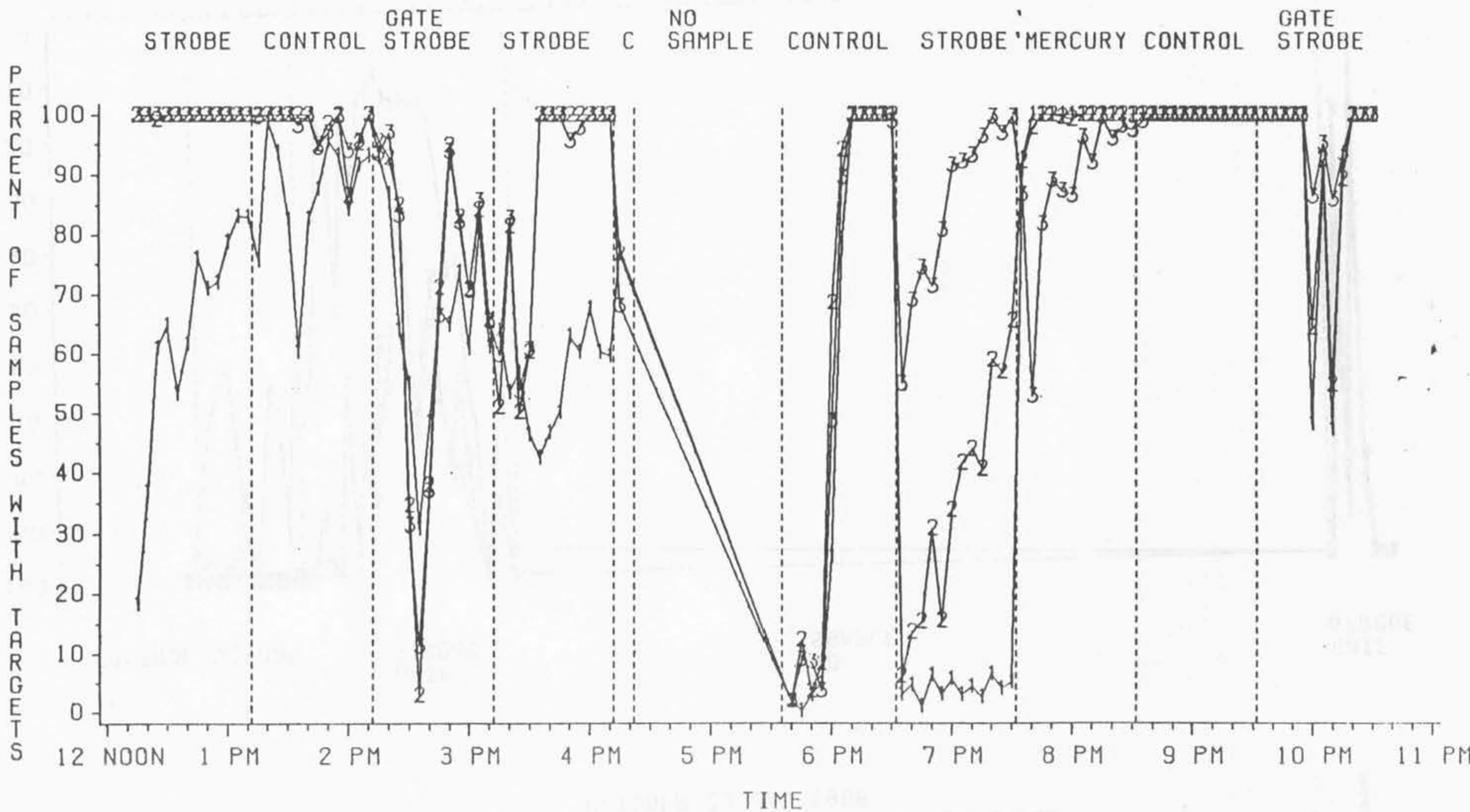
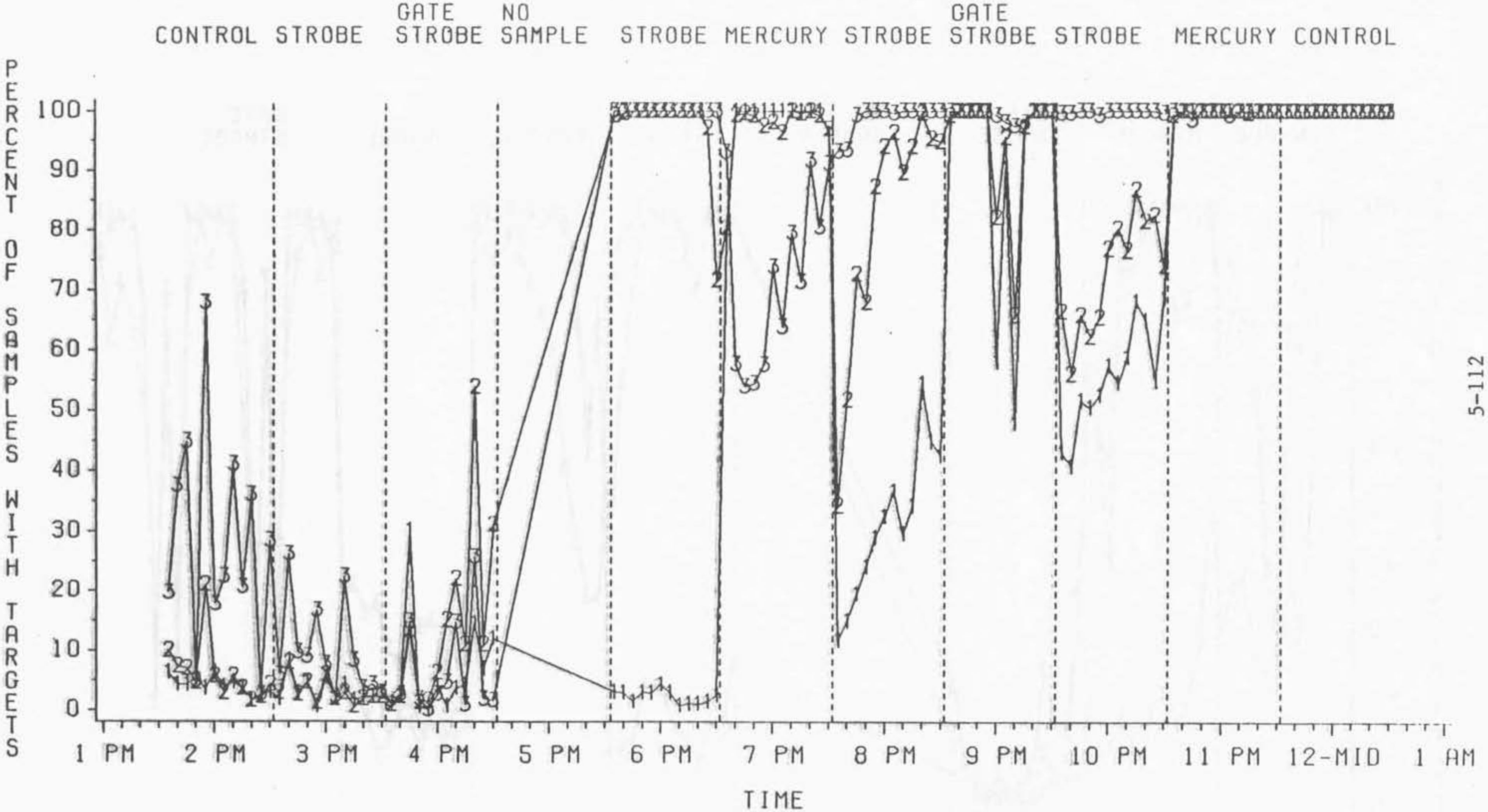


1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE
C = CONTROL TESTING PERIOD

FIGURE 7

TARGETS BY TIME AND DEVICE

OCTOBER 25-26, 1988



1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

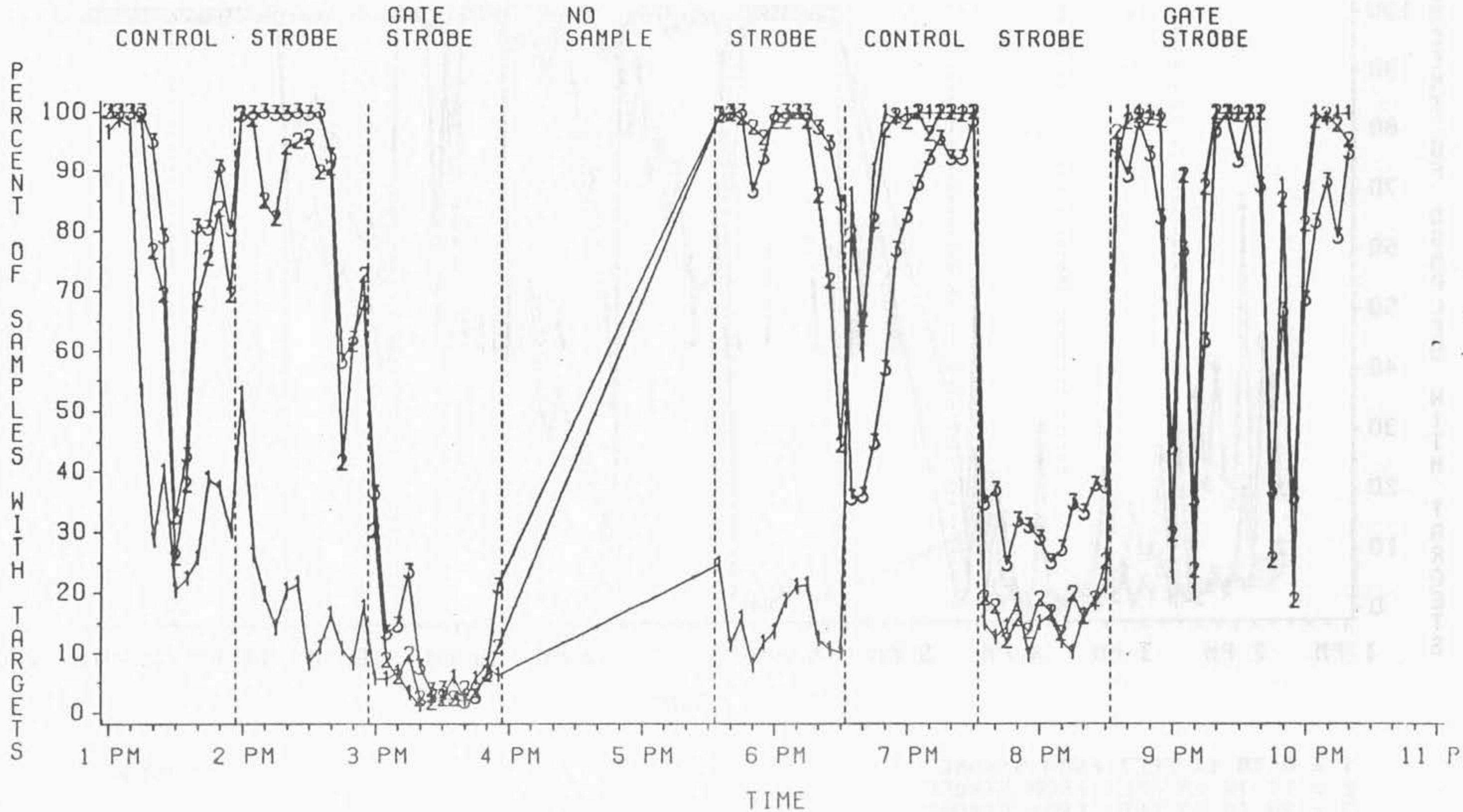
FIGURE 8

5-112

DRAFT

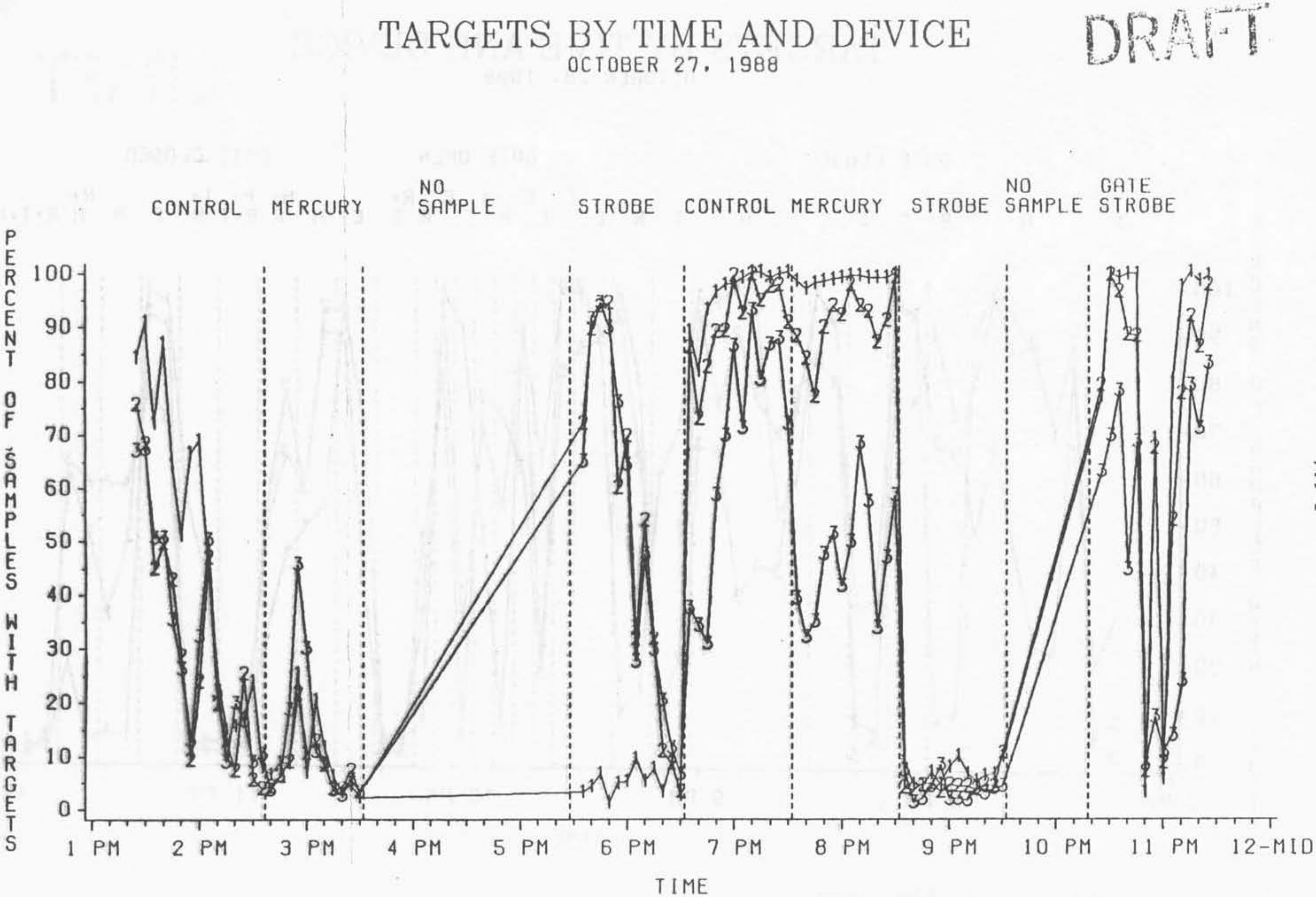
TARGETS BY TIME AND DEVICE

OCTOBER 26, 1988



1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

FIGURE 9



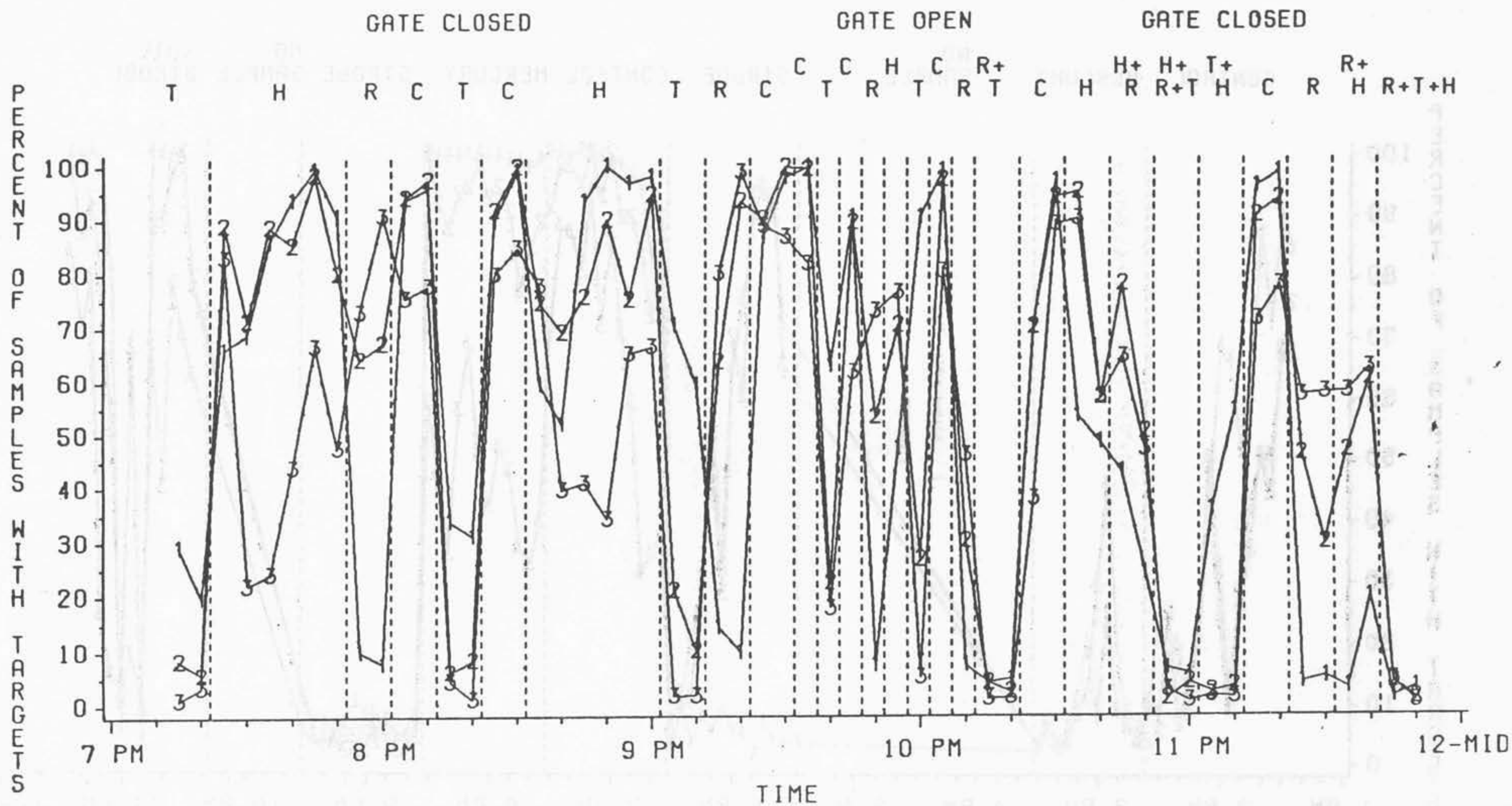
1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE

FIGURE 10

TARGETS BY TIME AND DEVICE

OCTOBER 28, 1988

DRAFT



1 = 0 TO 14 FEET FROM STROBE
2 = 14 TO 28 FEET FROM STROBE
3 = 28 TO 42 FEET FROM STROBE
C = CONTROL TESTING PERIOD
H = RAFT MOUNTED MERCURY LIGHT TESTING PERIOD
R = RAFT MOUNTED STROBE LIGHT TESTING PERIOD
T = TRASH RACK MOUNTED STROBE LIGHT TESTING PERIOD

FIGURE 11

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

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INTRODUCTION

The American shad fishery in Maryland waters of the Chesapeake Bay has been closed to sport and commercial fishing since 1980. Since that time the Maryland Department of Natural Resources (MDNR) has monitored the number of adults present at the head of the Bay during the spring spawning season. Our yearly mark-recapture effort provides an estimate of the population of American shad in the upper Bay. The Petersen Index and Schaefer Method for calculating abundance have been used for all population estimates since 1980. Mark-recapture data also provides length, weight, age, sex, and spawning history data for our adult population characterization. The adult work is followed by a juvenile recruitment survey to assess reproductive success. The information obtained through these activities is provided SRAFRC to aid in restoration of American shad runs to the Susquehanna River.

METHODS AND MATERIALS

Tagging procedures for 1988 differed from previous years. Greater emphasis was placed on pound nets as shad captured from three commercially operated pound nets were utilized for marking and data collection purposes (Figure I). While hook and line sampling in Conowingo tailrace continued virtually unchanged, no anchor gill net fishing was done in 1988. Tagging procedures and data collection for pound net and hook and line sampling followed the methodology established in past years and is described in previous SRAFRC reports.

RESULTS

Pound net tagging effort was initiated on April 4 and continued through May 14. Hook and line sampling was begun on April 27 and ended on June 3. A total of 484 adult American shad were captured by these two gears and 75% (364) were subsequently tagged (Table 1). Recaptures of 1988 marked fish numbered 38 and one fish previously tagged in 1986 was also collected. Recapture data for the 1988 season is summarized as follows:

a) 34 fish recaptured by the Conowingo Fish Lift (does not include three double recaptures)

three fish recaptured from the Delaware River one fish recaptured by hook and line

b) 34 fish recaptured were initially caught by hook and line

seven fish recaptured were initially caught by pound net

c) 35 fish were recaptured in the same area as initially tagged

three fish were recaptured upstream of their initial tagging location

d) shortest period at large: two days

longest period at large (1988 fish only): 43 days

mean number days at large: 20.8

e) number of double recaptures: 3

f) 1986 fish: at large 746 days

The 1988 population estimates for adult American shad in the upper Chesapeake Bay using the Petersen Index and Schaefer Method were 48,546 and 52,843, respectively (Tables 2 & 3). Yearly comparisons of adult population estimates in the upper Bay from 1980 through 1988 with associated 95% confidence intervals are presented in Figure II. Recapture rates for both pound net and hook and line captured fish decreased in 1988 (Table 4) indicative of a possible increase in overall run size. However, the high flow event of May 20 through May 27 certainly affected the recapture of tagged adults in the tailrace. Comparison of pound net and hook and line catch per unit of effort (Table 5) indicates a substantial increase in hook and line success but little change in pound net success.

A total of 413 American shad (252 hook and line and 161 pound net) were examined for physical characteristics in 1988. Age groups III, IV, and V constituted the majority of males collected by both gears with age group IV predominating (Table 6). The percentage of pound net captured five year old males was substantially greater than for hook and line while the converse was true for three year old males. Comparison of pound net captured females to those collected via hook and line indicates a larger percentage of older fish (age groups V and VI) being captured from the commercial nets (Table 6). The incidence of repeat spawners in 1988 remained quite similar to levels recorded during 1987 and for other years (Table 7).

Juvenile alosid sampling in the upper Chesapeake Bay during 1988 was limited to midwater trawl runs in the Susquehanna River, Susquehanna Flats, and the Northeast River (Figure III). Sampling began during the first week of June and continued bi-weekly through the first week of September. No young-of-the-year American shad were captured from any of the 17 stations sampled. Total catch and catch per unit of effort information for alewife and blueback herring from the upper Bay in 1988 are presented in Table 8.

FIGURE I. Gear and locations utilized in capturing adult American shad from the upper Chesapeake Bay during 1988

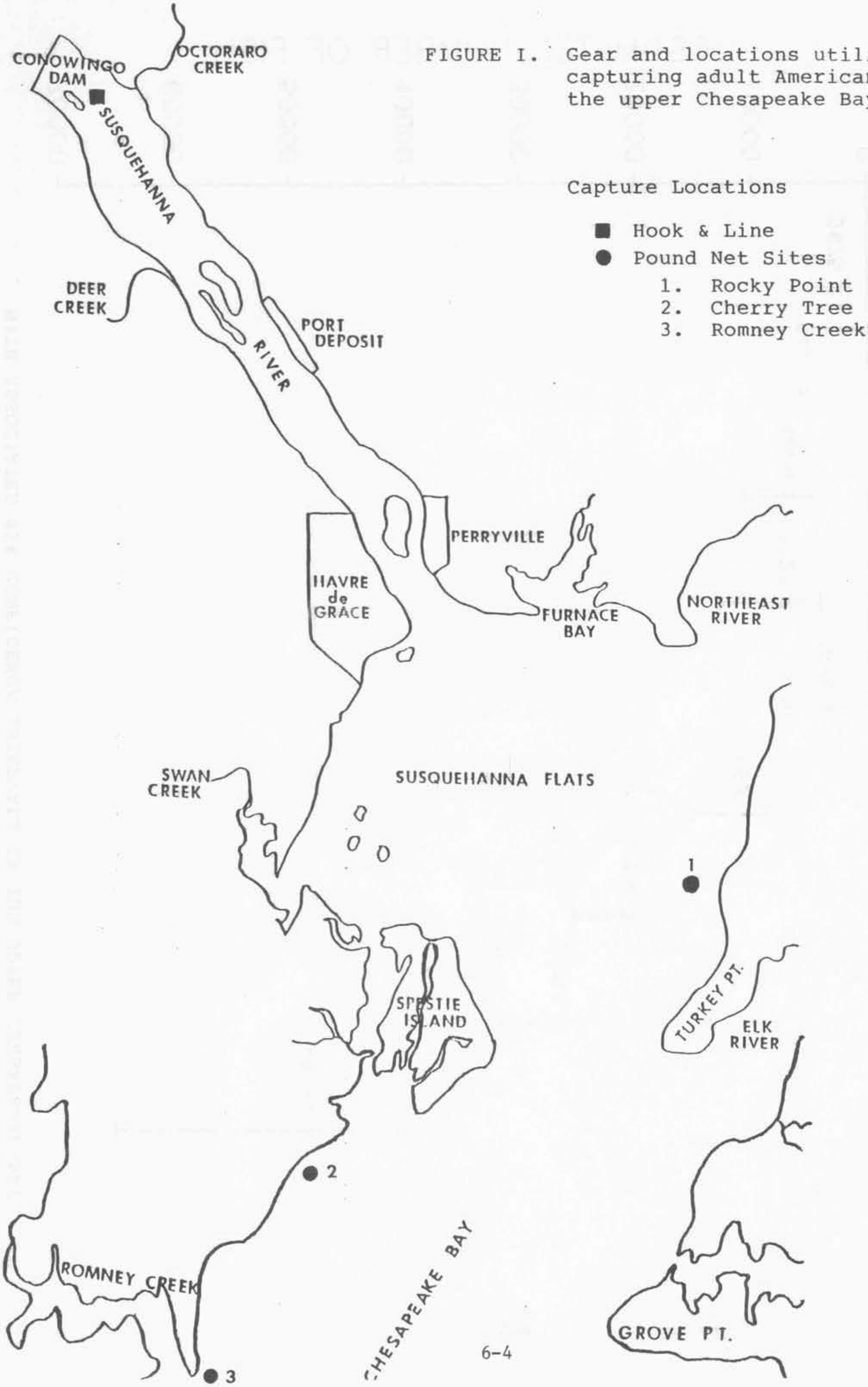
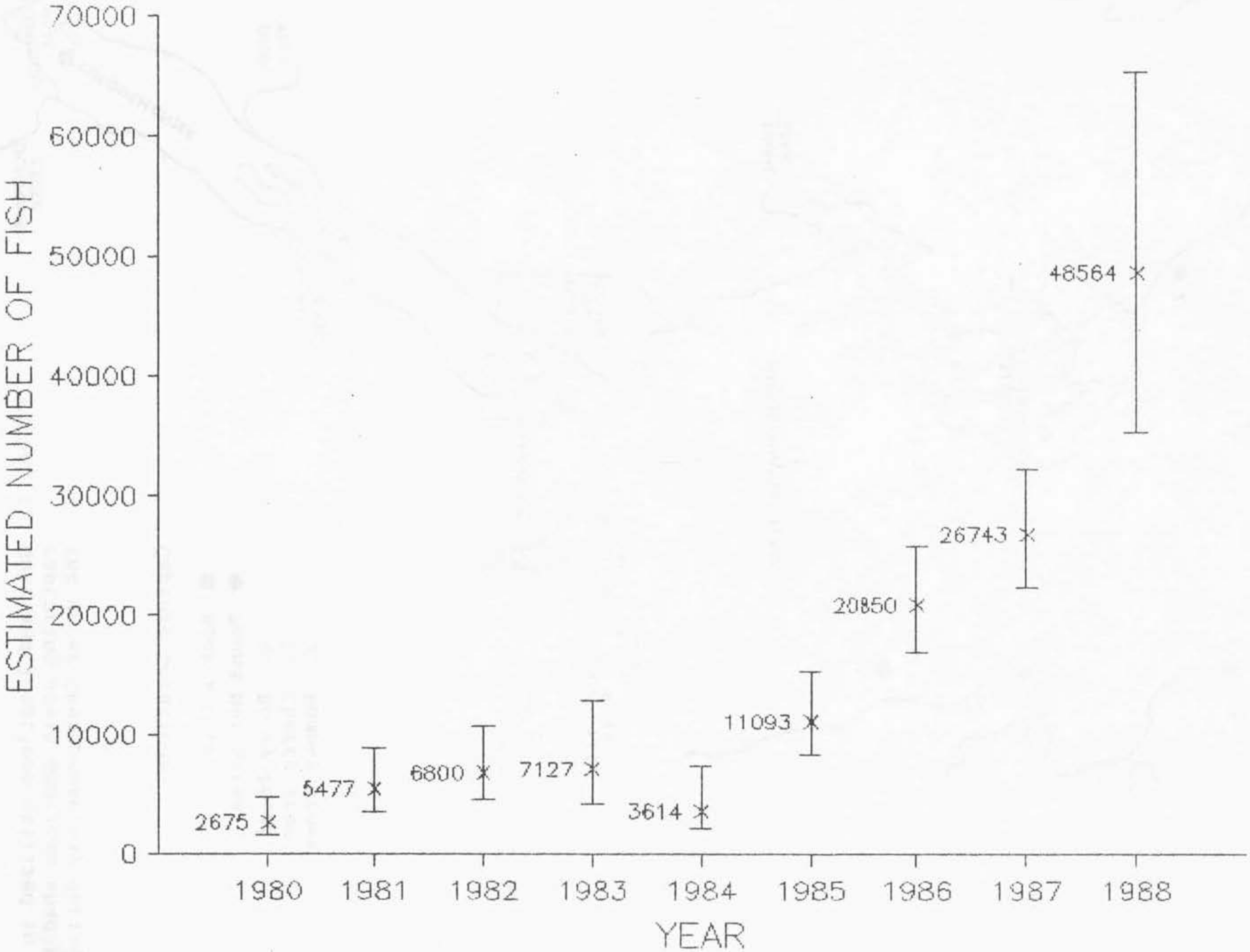


FIGURE II. YEARLY COMPARISONS OF THE ADULT AMERICAN SHAD POPULATION ESTIMATES WITH ASSOCIATED 95% CONFIDENCE INTERVALS IN THE UPPER CHESAPEAKE BAY.



6-5

FIGURE III. Upper Chesapeake Bay mid-water trawl stations sampled during the 1988 juvenile alosid survey.

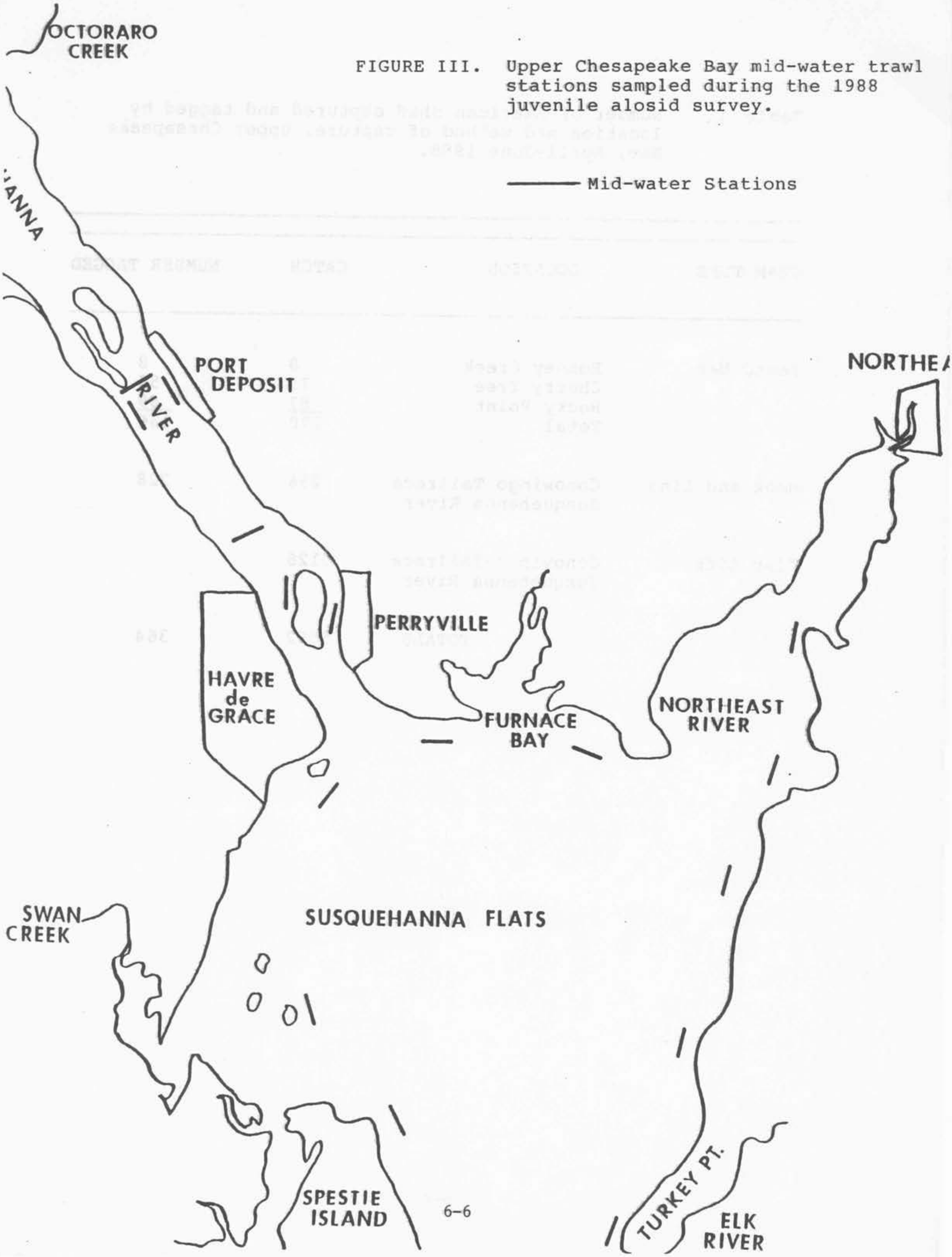


Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, April-June 1988.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Romney Creek	8	8
	Cherry Tree	75	59
	Rocky Point	87	69
	Total	170	136
Hook and Line	Conowingo Tailrace Susquehanna River	256	228
Fish Lift	Conowingo Tailrace Susquehanna River	5126	
	TOTALS	5552	364

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1988 using the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1988 survey-

C = 5188
R = 38
M = 364

Therefore-

$$N = \frac{(364 + 1)\ (5188 + 1)}{(38 + 1)}$$

$$= 48{,}564$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(364 + 1)\ (5188 + 1)}{27.67 + 1} = 66{,}062$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(364 + 1)\ (5188 + 1)}{52.17 + 1} = 35{,}621$$ @ .95 confidence limits

Table 3. Population estimate of adult American shad in the Susquehanna River during 1988 using the Schaefer method.

A. Recoveries of American shad tagged in successive weeks listed according to week of recovery, total tagged each week and fish recovered.

	Week of Tagging									Tagged Fish Recovery (Ri)	Total Fish Recovery (Ci)	Ci/Ri
	1	2	3	4	5	6	7	8	9			
Week of Recovery												
1										0	23	
2										0	29	
3										0	559	
4										0	597	
5				1						1	637	637
6			1							1	1242	1242
7				1		5				6	858	143
8										0	4	
9					2	6	1			9	387	43
10			1	1	1	7	4		1	15	986	65
11					1	2	1		2	6	261	43
Tagged Fish Recovered (Ri)			2	3	4	20	6	0	3	38		
Total Fish Tagged (Mi)	3	14	29	62	57	118	67	0	14			
Mi/Ri	-	-	15	21	14	6	11	0	5			

Table 3 , (continued)

B. Computed totals of adult American shad in the upper Chesapeake Bay during 1988 using the Schaefer Method.

Week of Recovery (j)	Week of Tagging (i) 1	2	3	4	5	6	7	8	9	Total
1										0
2										0
3										0
4										0
5				13186						13186
6			17995							17995
7				2960		4219				7179
8										0
9					1230	1522	482			3234
10			953	1360	940	2713	2943		309	9218
11					622	513	487		409	2031
Totals			18948	17506	2792	8967	3912		718	52843

Table 4. Number of American shad marked by method, number recaptured and recapture rate, upper Chesapeake Bay, 1980-1988.

Year	Number Tagged	Number Recaptured (all methods, including trap)	Recapture Rate
POUND NET			
1980	89	9	10.11
1981	58	4	6.90
1982	76	5	6.58
1983	0	0	-
1984	0	0	-
1985	30	1	3.33
1986	0	0	-
1987	7	2	28.57
1988	136	4	2.94
GILL NET			
1980	65	4	6.15
1981	186	13	7.00
1982	182	11	6.04
1983	207	12	5.80
1984	122	3	2.46
1985	134	7	5.22
1986	69	6	8.70
1987	54	5	9.26
1988	-	-	-
HOOK AND LINE			
1980	0	0	-
1981	1	0	0
1982	81	5	6.17
1983	10	0	0
1984	99	7	7.07
1985	156	34	21.79
1986	267	79	29.59
1987	329	104	31.61
1988	228	34	14.91

TOTAL FOR ALL GEAR TYPES, 1980-1988

Year	Percent Recapture Rate (# recaptured/# marked)
1980	8.44
1981	6.94
1982	6.19
1983	5.52
1984	4.52
1985	13.13
1986	25.00
1987	28.24
1988	10.44

Table 5. Catch, effort and catch per unit effort (CPUE) for adult American shad by hook and line and pound net during the 1980-1988 tagging program in the upper Chesapeake Bay.

A. Hook & Line

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPAH*	CPUE HTC**	POP. EST.
1982	***	88	-	-	6800
1983	***	11	-	-	7127
1984	52.0	126	2.42	0.41	3614
1985	85.0	182	2.14	0.47	11083
1986	147.5	437	2.96	0.34	20850
1987	108.8	399	3.67	0.27	26743
1988	43.0	256	5.95	0.17	48564

B. Pound Net****

YEAR	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POP. EST.
1980	26	50	1.92	2675
1981	38	50	0.86	5477
1982	27	62	2.29	6800
1985	10	30	3.00	11083
1988	33	87	2.64	48564

* Catch per angler hour
** Hours to catch 1 shad
***Hours fished not recorded
****Pound net CPUE from Rocky Pt. pound net only

Table 6. **Catch and age composition by sex and gear type for American shad collected during the 1988 tagging program in the upper Chesapeake Bay.**

Sex / Gear	II	III	IV	V	VI	VII
			AGE GROUPS			
Male						
Hook and Line						
Number caught	3	59	86	26	1	-
Percent age comp.	1.7	33.7	49.1	14.9	0.6	
Pound net						
Number caught	1	14	40	29	1	-
Percent age comp.	1.2	16.5	47.1	34.1	1.2	
Trap						
Number caught	1	13	37	46	20	
Percent age comp.	0.9	11.1	31.6	39.3	17.1	-
Female						
Hook and Line						
Number caught	-	5	37	28	7	-
Percent age comp.		6.5	48.1	36.4	9.1	
Pound net						
Number caught	-	2	17	40	17	-
Percent age comp.		2.6	22.4	52.6	22.4	
Trap						
Number caught	-	-	22	60	68	11
Percent age comp.	-	-	13.7	37.3	42.2	6.8

Table 7. Age frequency, number and repeat spawners by gear type and sex for adult American shad collected during the 1988 upper Chesapeake Bay tagging program.

GEAR TYPE	SEX	SEX RATIO	AGE GROUPS II	III	IV	V	VI	VII	% REPEAT SPAWNERS	TOTALS
Hook	M		3	59	86	26	1	0		175
&	Rpts.		0	1	8	2	0		6.3	11
Line		1 : 0.44								
	F		0	5	37	28	7	0		77
	Rpts.			0	1	0	1		2.6	2
Pound	M		1	14	40	29	1	0		85
Net	Rpts.		0	0	5	0	0		5.9	5
		1 : 0.89								
	F		0	2	17	40	17	0		76
	Rpts.			0	4	2	1		9.2	7
Trap	M		1	13	37	46	20	0		117
	Rpts.		0	0	1	3	1		4.5	
		0.73 : 1								
	F		0	0	22	60	68	11		161
	Rpts.				1	1	0	1	1.9	
Totals	M		5	86	163	101	22	0		377
	Rpts.		0	1	14	5	1		5.8	22
		1 : 0.83								
	F		0	7	76	128	92	11		314
	Rpts.		0	5	3	3	0	1	3.8	12
							TOTALS		4.9	691
										25

Table 8. Effort, catch, and catch-per-unit-of-effort (CPUE) by sampling station with corresponding salinity ranges for juvenile alewife herring, blueback herring and American shad from the upper Bay drainage areas during 1988*.

SITE	RIVER MILE	SALINITY RANGE(PPT)	SPECIES	CATCH BY MONTH JUN.	JUL.	AUG.	SEP.	TOTAL CATCH	CPUE
Susquehanna Flats									
1	186	0.2-0.8	none	0	0	0	**	0	0
2	188.6	0.1-0.2	none	0	**	**	**	0	0
3	189.0	0.1-0.3	none	0	0	0	0	0	0
4	190.2	0.1-0.8	none	0	0	0	0	0	0
5	191.9	0.1-0.2	none	0	0	0	0	0	0
6	192.5	0.1-0.2	blueback	10	0	0	0	10	1.4
7	192.7	0.1-0.2	alewife	1	0	0	0	1	0.1
			blueback	65	4	0	0	69	9.9
	alewife monthly subtotal			1	0	0	0	1	
	monthly CPUE			0.1	0	0	0		0.02
	blueback monthly subtotal			75	4	0	0	79	
	monthly CPUE			5.4	0.3	0	0		1.9
Northeast River									
1	0.5	0.1-0.8	blueback	107	50	0	0	157	22.4
2	1.8	0.1-0.2	alewife	9	0	0	0	9	1.3
			blueback	1	4	0	0	5	0.7
3	2.4	0.1-0.2	alewife	2	0	0	0	2	0.3
			blueback	3	22	11	2	38	5.4
4	5.2	0.1-0.1	alewife	23	0	0	0	23	3.9
			blueback	0	3	0	0	3	0.4
	alewife monthly subtotal			34	0	0	0	34	
	monthly CPUE			4.3	0	0	0		0.5
	blueback monthly subtotal			111	79	11	2	203	
	monthly CPUE			13.9	9.9	1.8	0.7		3.0
Monthly totals for all areas:									
	alewife monthly totals			35	0	0	0	35	
	monthly CPUE			1.0	0	0	0		0.3
	blueback monthly totals			186	83	11	2	282	
	monthly CPUE			5.5	2.6	0.4	0.2		2.6

*There were no catches from the Susquehanna River proper in 1988
**Area not sampled during this month

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