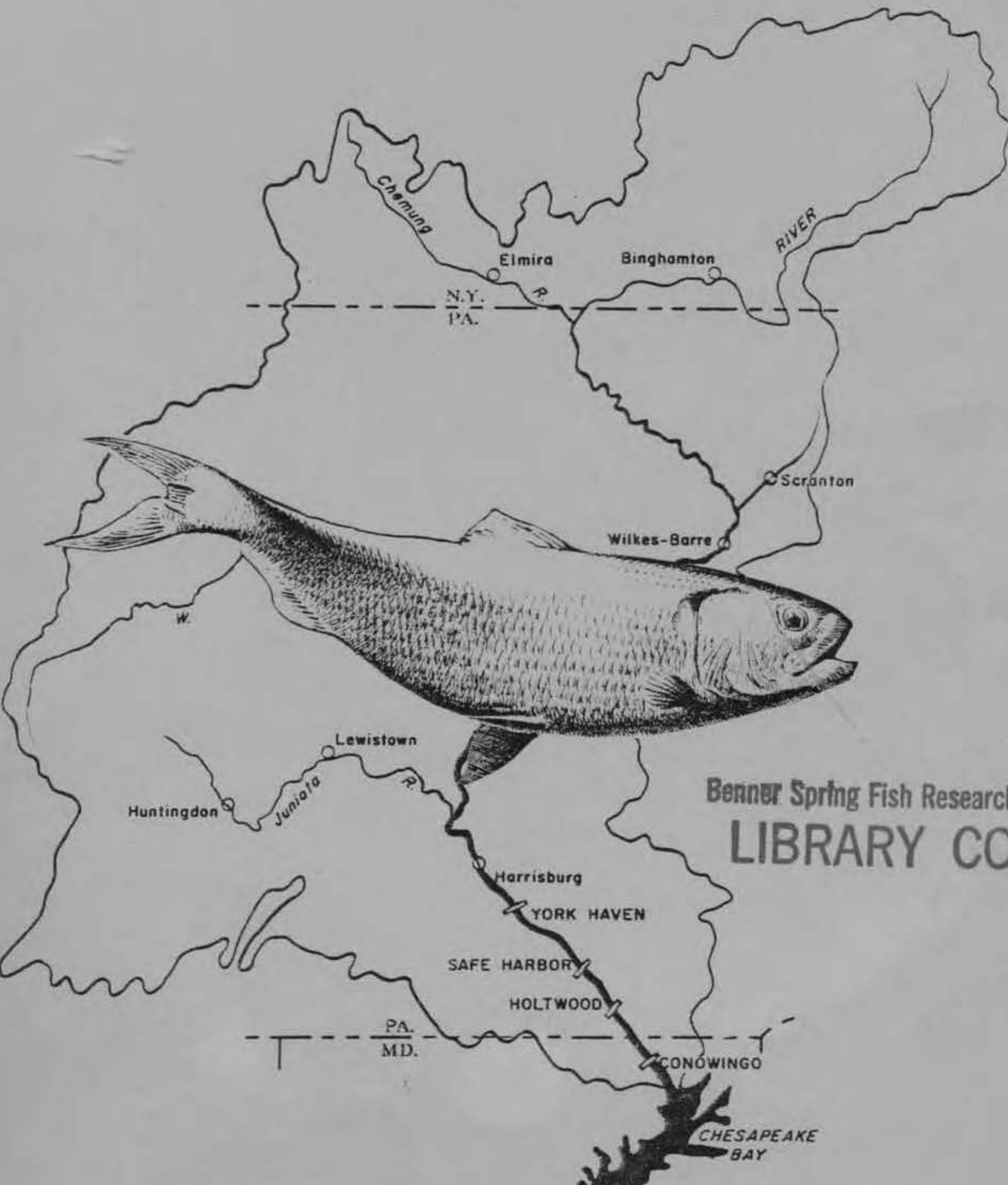
Restoration of American Shad to the Susquehanna River

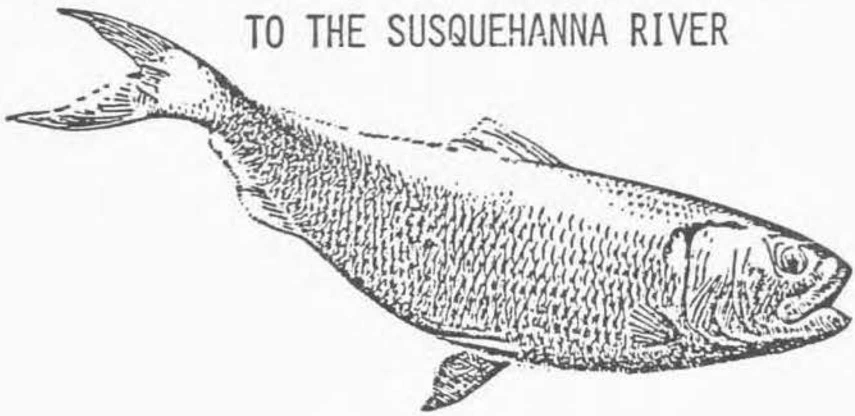
ANNUAL PROGRESS REPORT
— 1985 —



SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

JANUARY 1986

RESTORATION OF AMERICAN SHAD
TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1985

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

JANUARY 1986

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INTRODUCTION

This Annual Report discusses the numerous activities undertaken by the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) during 1985. These efforts represent a continued commitment on the part of interested state and federal agencies and private utility companies to rebuild stocks of American shad and other diadromous fishes in the Susquehanna River system. The program is based on the premise that a population of shad can be developed through natural reproduction of stocked adults and production of hatchery reared fry and fingerlings. Young shad resulting from these stockings should be imprinted to return to the Susquehanna River above dams as spawning adults in future years. Hydroelectric dam development in the lower Susquehanna precludes natural migration to historic spawning grounds.

Following an evidentiary hearing and over 3 years of negotiation, licensees of the three upstream hydroelectric stations on the Susquehanna River (PA Power & Light Co., Safe Harbor Water Power Corp., York Haven Power Co.) reached settlement with intervenors in the FERC relicensing proceeding relating to anadromous fish restoration. The Agreement, signed by all parties on December 7, 1984 and approved by FERC on April 10, 1985, provides among other things $3.7 million for shad restoration activities during 1985 through 1994. A separate settlement is currently being pursued with Philadelphia Electric Company (PECO) whose subsidiaries, Philadelphia Electric Power Company and Susquehanna Power Company, operate the Conowingo project in the lower river.

A total of about $370,000 was spent from the Settlement Agreement in 1985. Activities funded included collection and transport of prespawn adult American shad from the Hudson River to the Susquehanna; shad egg collection from east and west coast rivers, hatchery operations, fry and fingerling marking and stocking and cultural research; juvenile shad recovery including netting and impingement surveys and mark detection analysis; radiotelemetry investigation of adult shad movements following river release; hydroacoustic techniques assessment to better understand juvenile shad distribution and abundance; and shad stock discrimination based on elemental ratios in otoliths. PECO continued to support the program through operation of the fish trap and lift at Conowingo Dam, and juvenile shad collection at several lower river power plants. The Maryland Department of Natural Resources (Tidal Fisheries) conducted tag and recapture shad population assessment and age analysis of the stock in the upper Chesapeake Bay and lower Susquehanna River and assisted with juvenile recovery below Conowingo.

During 1985, the SRAFRC Technical Committee met three times and the Policy Committee once. A special subcommittee developed "A Plan to Assess and Improve Downstream Migration of Juvenile American Shad in the Susquehanna River". The Plan, approved for implementation in September, provides long-term direction to SRAFRC for measuring and enhancing juvenile shad outmigration from the river.

SUMMARY OF ACCOMPLISHMENTS

During the period April 28 through May 24, 1985, a total of 4,134 prespawn adult shad and 2,000 blueback herring were seined from the Hudson River near Hudson, NY and transported to the Susquehanna Basin. Survival to stocking was 76% for shad and 99% for herring. Three truckloads (380 shad) were assessed for delayed mortality in flow through ponds at PFC's Pleasant Mount hatchery, one load (100 fish) was stocked into an "artificial stream" pond at Benner Spring for controlled spawning, and the remaining shad and herring were delivered to Tunkhannock, PA on the North Branch Susquehanna. Only one load of 64 shad was hauled from the Holyoke lift on the Connecticut River in 1985.

In a first time effort to determine movements of adult shad following release in the river, 27 fish were fitted with radiotransmitters and tracked from boat, air, and shore. Four groups of shad were tagged including 20 fish from the Hudson and 7 from the Connecticut. Post-stocking mortality was low (4 fish) and the 23 survivors moved rapidly downstream reaching York Haven Dam within 3-22 days following release. No spawning congregations were noted upstream, though samples of adult shad taken in the York Haven and Safe Harbor forebays were ripe and partially spent. A few fertile eggs were collected below York Haven. Passage mortality at York Haven and Safe Harbor projects was calculated to be 18% at each dam.

The Conowingo Dam fish lift operated for 55 days between April 1 and June 14, 1985. A total of 2.3 million fish were caught including 1,546 American shad, 6,763 blueback herring, 377 alewives, and 9 hickory shad. Gizzard shad comprised 94% of all fish taken at Conowingo and other abundant species included white perch and channel catfish. Of 326 lift caught American shad tagged and released to the tailrace, 47 were recaptured in the lift. Additionally, 33 shad tagged by the Maryland DNR in 1985 were captured at least once in the lift. Shad were transported from the lift to the PFC West Fairview Access area across the river from Harrisburg on 15 dates (17 loads). A total of 967 fish were hauled and observed mortality was only 1.7% (16 fish).

Sex ratio of tagged American shad at the Conowingo lift was 3.35 : 1.0 favoring males. A total of 421 shad were aged from scales with males ranging from age III to VI and females III-VII. Most males were age IV with 7% repeat spawning indicated whereas mean age of females was V with 8% showing spawning checks on scales. Modified trap operations and favorable flow conditions in 1985 produced the second best year of shad collection at the lift. Number of shad transported upstream was the greatest of any year since trap operations began in 1972.

The Maryland Department of Natural Resources continued their tag and recapture population assessment for shad in the upper Bay and lower river in 1985. A total of 320 shad were tagged, mostly from gill nets and hook and line angling. Forty-two fish were recaptured (some more than once) after being at-large for 2-34 days. Peterson and Schaefer population estimates for the stock were 11,093 and 12,903, respectively. Age analysis of shad taken by hook and line in the Conowingo tailrace was similar to that found in lift collections. Gill nets apparently selected for larger fish indicating a slightly older population with increased repeat spawning.

A major element of the shad stock rebuilding program in the Susquehanna is hatchery production of fry and fingerlings at the PFC Van Dyke facility on the Juniata River. Shad egg collections began on the Pamunkey River in Virginia where 5.28 million eggs were taken during April. The James River produced 2.05 million and the Delaware 6.1 million shad eggs during late April through mid-May. A total of 12.06 million eggs were collected from the Columbia River (Oregon) during June. The 25,568,500 eggs delivered to Van Dyke in 38 shipments in 1985 was considerably reduced from 1983 and 1984 due to adverse fishing conditions on the Columbia River. The Delaware egg take was however the highest on record for that river. Egg viability ranged from 41% for Columbia shipments to 62% for those from the Pamunkey.

Total fry production in 1985 was 7.9 million (76% survival from viable eggs) and most fish were held for 18 days. Of the fry produced, 5.4 million were stocked into the Juniata River at Thompsontown, 812,000 were stocked into Conowingo Pond, 600,000 were delivered to the Lehigh River and 252,000 to the Schuylkill. The remaining 886,000 fry were used for fingerling production and research at Van Dyke, Thompsontown, Benner Spring, and Wellsboro (USFWS lab). A total of 115,200 fingerling shad were produced in 1985 with 61,200 stocked into the Juniata and 53,300 delivered to Conowingo Pond and the Susquehanna below Conowingo Dam.

Research conducted at Van Dyke in 1985 focused on oxytetracycline (OTC) tagging and improvement of feeding regimes. All fry produced from Virginia eggs and some from the Delaware were treated in 12-hour baths for 4 consecutive days with 25 ppm OTC concentration. Later Delaware and all Columbia fry were treated at 50 ppm OTC concentration prior to release. Analysis of otoliths under ultraviolet light indicated that marking efficiency at 25 ppm OTC averaged 5.9% compared to 98.4% for those treated at 50 ppm. Marking fingerlings using OTC-laced feed was unsuccessful. Double marking shad at 50 ppm using two separate immersions at ages 5-8 days and 15-18 days produced 98% detectable double marks. Numerous other marking tests and feed research are discussed in Job III.

The juvenile shad assessment program began in mid-August on the North Branch Susquehanna and lower Juniata rivers. Sixty-three seine hauls at five locations over 4 weeks in the Susquehanna above Sunbury, PA failed to take any young shad (2 juvenile bluebacks were taken at Wilkes-Barre). This supports the radiotelemetry conclusion that most adult shad rapidly moved downstream following release. At Amity Hall on the Juniata shad were taken each collecting date from August 21 thru October 24 (212 fish total). Shad first appeared in cast net collections at York Haven on September 19 and most fish passed that point by late October. Seining at Wrightsville in September produced 29 shad, and cast netting in the Safe Harbor forebay was largely unproductive during the autumn (31 fish in 8 weekly collecting attempts). Shad first appeared at Holtwood on October 24 and by mid-

November were available in great abundance. Hundreds of shad were collected by cast net and thousands by experimental lift net (RMC) at Holtwood. Strainer and screen impingement collections at Safe Harbor, Conowingo, and Peach Bottom APS were minor (50 shad total), and one shad was collected below Conowingo Dam in the Maryland DNR trawl survey.

Sixty-two shad from Amity Hall were analyzed for the OTC mark placed on hatchery fish. The presumed mark retention rate for all fish passing this point was 53% based on test results of fish held at Benner Spring. The fact that 44 fish (71%) from Amity Hall retained the mark indicates early outmigration from the Juniata River of those fish marked at 25 ppm OTC. Where hatchery and wild fish comingle in the lower Susquehanna, it was presumed that any reduction from the predicted mark retention rate for hatchery fish (i.e. 53%) would be a reflection of relative abundance of naturally produced shad. Of almost 200 fish analyzed from collections taken at York Haven, Wrightsville, Safe Harbor, Holtwood, Peach Bottom and Conowingo, 50% were marked indicating that few outmigrant juveniles resulted from spawning of adults transplanted in the river.

SRAFRC funded a special study in 1985 to evaluate the usefulness of hydro-acoustic detection to monitor juvenile shad movements. During a 2-week demonstration at York Haven and Safe Harbor forebays, fixed and mobile acoustic surveys indicated that shad behavior (and perhaps abundance) can be assessed with this technology. Day/night distribution, effects of power plant operations, and usefulness of controlled spills in passing shad were preliminarily observed.

Under a special study grant from the Maryland DNR, the University of Maryland undertook x-ray microanalysis of juvenile shad otoliths to determine whether elemental ratios in these calcified structures differed for fish reared in different waters (i.e. "stream signatures"). A comparison of 15 shad from Amity Hall (Juniata nursery) and 15 fish reared in ponds at Benner Spring Research Station (both 1984 collections) indicated 100% separation of the stocks based on elemental ratios. In 1985, SRAFRC funded UMD to validate the technique by demonstrating that elemental ratios found in otoliths of juveniles taken from mid-Delaware River nursery waters were essentially the same as in a similar growth region in otoliths from adult shad from the same river reach (i.e. does the "signature" stay with the fish throughout it's life?). Preliminary results of this effort failed to validate the technique (only 3% agreement). Researchers believe that the two groups of shad examined did not represent a distinct sub-unit stock of the Delaware River population.

In response to SRAFRC concerns about "smoltification", imprinting, and adaptation to seawater for juvenile shad the National Fishery Research and Development Laboratory (USFWS) in Wellsboro, PA offers us an interim report on their work on pre-migratory physiology of American shad. This work is expected to continue in 1986 and SRAFRC will provide test fish.

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

Richard St. Pierre
Program Coordinator

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JOB I. TRANSFER ADULT AMERICAN SHAD TO THE SUSQUEHANNA RIVER FROM OUT OF BASIN

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1.1 INTRODUCTION

From 1981 through 1984, 15,450 adult shad have been transferred from out-of-basin sources and released to the Susquehanna River. The purpose of this activity is to establish a run of American shad to the Susquehanna River based upon fish which are spawned in the river.

The 1985 work plan is basically a continuation of activities conducted since 1982, with the following revisions suggested by the Technical Committee:

(a) The three existing transport trucks and tanks utilizing the Fresh-Flo aerators with oxygen injection were to be used in 1985 to haul 5,000 - 6,000 prespawned adult shad to the Susquehanna.

(b) All fish were to be collected from the Hudson River and stocked at Tunkhannock, PA. The Holyoke lift on the Connecticut River was to be used only as a backup source if sufficient numbers of shad were not available from the Hudson River.

(c) An alternate source of shad for future use was to be identified. SRAFRC was advised by the Connecticut River Atlantic Salmon Commission that transfer operations for shad at Holyoke would be limited to only two days per week and would be terminated after the 1985 season.

(d) Female mortality in transfer was to be examined. Efforts were to be undertaken in 1985 to assess female versus male short term survival at the Tunkhannock release site and delayed mortality utilizing the flow-through pond at Pleasant Mount Fish Culture Station. The Technicial Committee suggested that the failure to collect any juvenile shad during two of the past four Evaluation Programs (Job IV) may be indicative of excessive female mortality.

(e) One load of shad was to be transported to Benner Springs to determine if shad would spawn in a controlled environment.

(f) The SRAFRC recommended that blueback herring be taken if available, when equipment was standing by and not being used to haul shad.

The Hudson River out-of-basin transfer program, in its fourth year was to utilize methods developed in past years. This program was to be conducted by NES, using local commercial fisherman to harvest shad with trucking and mortality assessment support from the PA Fish Commission.

The Connecticut River operational procedures, if utilized, were to differ little from previous years (see 1981-1934 SRAFRC reports). This operation was to be conducted by the PFC, using Pleasant Mount Fish Cultural Station as a center for operations.

1.2 HUDSON RIVER SHAD TRANSFER PROGRAM

In 1982, 1983 and 1984, NES successfully captured prespawned adult shad from the Hudson River and transferred them to a release site on the upper Susquehanna River. A total of 7,707 fish were presumed alive at release, resulting in a survival rate of 83%. Past experience by NES on the Hudson River indicated that a substantial adult shad population was available for the transfer program. However, unlike the Connecticut River, there was no means for capture of adult shad other than netting. In 1982, NES began operations utilizing gill-nets as primary gear; however, shad capture was shifted to haul seine when low survival resulted. The success of the haul seine and the operation in general has led to its overall expansion.

1.2.1 Collection Site

Since 1981 American shad have been collected from the Hudson River in the vicinity of the Greendale Landing, Greenport, N.Y. In 1985 a second seine site located immediately north of the Rip Van Winkle Bridge, on the west shore of Rodgers Island was fully developed. Both sites can be effectively seined and are viable areas for shad collection.

1.2.2 Schedule and Collecting Methods

The Hudson River program was conducted from 28 April - 24 May on a seven day per week basis. Operational timetables were contingent on tidal conditions: i.e., when the tide was running full haul seines could not be used effectively. Generally fishing activities took place between 0600 and

2000 hours. Sampling days were utilized to the fullest in order to reach the proposed goal.

A 500 x 12 ft haul seine with 2 inch square mesh wings and 1 inch square mesh bag was utilized to collect shad. The seine operation was directed through mutual agreement with commercial fishermen and NES to ensure that the operation was carried out in the most effective manner. Crews ranging from 10-12 technicians worked cooperatively with commercial fishermen contracted to collect shad. The seine was hauled along the shoreline as soon as the tide changed from ebb to flood. This tidal condition was used to minimize manpower needs in hauling the seine. Two people were needed to lay out the net from a boat captained by a fishermen while an additional 5-6 individuals pulled the opposite end of the net along the shoreline. An entire area was encircled and the net ultimately pulled to the shore. The shad were concentrated in the bag section. Crews worked to capture shad, transport them to a shore-based site and load the tank truck.

Shad collected in the seine were immediately hand-brailed from the bag to one of three tanks mounted in 16 ft boats. One system consisted of a 400-gallon oval fiberglass tank, while the other boat supported two 245-gallon round galvinized stocktanks. Both systems were circulated by 3 HP trash pumps which drew water from the bottom center of the tank to an intake valve on the top inside tank wall. Oxygen levels were maintained by oxygen injection through Bioweave tubing at the base of each tank.

1.2.2 CONTINUED

The number of fish loaded in each tank was determined daily by several factors including water temperature, size of fish, river conditions and site location. The typical load for the 400-gallon oval tank was 70 fish and 40 fish for each of the 245-gallon round tanks. The shuttle boats, after loading, were driven by NES personnel to a shore-based loading site. The shuttle time for the up-river site was approximately 20 minutes and 5 minutes for the down-river site.

At the shoreline 3-5 shad were individually hand-brailed from the stock tank into a 15-gallon round galvanized metal wash tub filled with water. Two individuals carried each tub a distance of about 100 yards. The shad were lifted by hand to the opening of the transfer tank and deposited into the tank. The process was continued until all shad had been loaded.

The minimum load to be transferred to the Susquehanna was 50 shad. The optimum number for transport is 125-130 fish.

1.2.3 Description of Transfer Equipment

Each transport tank has a 1,100 gallon capacity and is about 4-ft high and 8-ft diameter. The top is removable and shad are loaded through a 2-ft square hatch on the top. Unloading is accomplished by removing the outside circular cap by a gate release located on the back of the tank. A portable shoot, fitted with a flexible discharge tube, is attached below the unloading

1.2.3 CONTINUED

hatch and directs both water and shad into the river.

Water circulation is created by two Fresh-Flo (model #TT, 12 VDC) aerators mounted through the lip of the tank. Power is supplied by the trucks' existing electrical system. Water current speed in the tank is adjusted by directing the aerator discharge against the tank wall or into the desired flow direction. A 12-inch section of Porex tubing is mounted under the aerators so that the oxygen flows directly into the aerators' intake screens. A flow meter as well as an oxygen injection cylinder are utilized in order that a constant amount of oxygen can be maintained. Two 3 HP gasoline-driven trash pumps are used for filling the tanks and are also available as a back up system in the event that there is a problem with the Fresh-Flo aerators.

1.2.4 Water Procurement and Conditioning

Water for each of the transport units was taken from the Hudson River at the Hudson Boat Launch site until river temperature exceeded 65°F. Once that occurred, water was procured by the PFC from the well at Pleasant Mount, and by NES at the ICC Quarry, Hudson, N.Y. Water from these sources was typically 5-10°F below that of the Hudson River.

Water was treated with 80 pounds of Agway Solar Salt (0.9% solution) and 100 ml of Argent Silicone Based Antifoam Solution (diluted to 500 ml with distilled water). This treatment was based on shad transport studies conducted by the PFC during the 1983 program. (See 1983 Annual Progress Report -

1.2.4 CONTINUED

Appendix I-A Adult American Shad Transportation Studies - 1983). The report suggests that the addition of salt to the transport tank seems to reduce mortalities in long-duration stocking trips. The antifoam is necessary to reduce foaming which results from the addition of salt.

1.2.5 Temperature/Oxygen Monitoring

Cooling of the transport tank was not necessary. Cooling is necessary when water temperature is more than 70°F, a situation which did not occur. Water temperature differential between the Hudson River and the Susquehanna River was measured and every effort was made to minimize increases in temperature during transport. Dissolved oxygen (DO) was maintained by an aeration system which is an integral part of the transport tank. Dissolved oxygen (DO) and temperature were monitored by the PFC with a YSI Model 57 oxygen meter. Readings were monitored throughout the course of the trip and recorded at two hour intervals. A final water temperature and dissolved oxygen reading was made in the tank prior to stocking.

1.2.6 Release of Fish

Tunkhannock, PA., was used as the primary release site. At the release site, the truck was backed down the access ramp to the shoreline and circulation systems shut down. The hatch cover was removed and the release shoot attached. Before the hatch was raised, visually dead shad were removed. Some mortality was unavoidable during transfer. After release, drivers dip-netted around the release site for approximately 15-30 minutes to retrieve any fish which died in transit or during release. It is probable that not all dead fish are recovered in this manner, though the use of a V-shaped net at the point of discharge served to concentrate dead fish. PFC Waterway Conservation Officers and deputies assisted in retrieval and disposal of mortalit

1.2.7 Herring Collection and Transport

On recommendation from the SRAFRC, blueback herring were to be transported when shuttle equipment was not being used for shad and herring were available. Herring were collected at the Greenport site, utilizing the 500 x 12 ft shad net. NES experimented with a 450 x 10 ft haul seine with 1 inch square mesh wings and bag, but abandoned this gear when large numbers of white perch were gilled.

Collection methods for herring were basically a continuation of those utilized during the shad operation. Transport procedures differed in that more than three times the number of herring could be transported than shad and the Fresh-Flo aerators used in the shad program were not effective in herring transport. NES discovered that herring scales lost during transport clogged the aerator intake screens preventing proper water circulation. As a result, the small engine circulation pumps with oxygen injection were used when herring were transported.

1.3 RESULTS

1.3.1 Release Sites

The primary release site on the Susquehanna River was at Tunkhannock, PA. This site was utilized for all transports, excluding three loads to Pleasant Mount Lagoon for delayed mortality assessment, and one load to Benner Spring for a controlled spawning attempt. Some 380 shad were delivered to a ½-acre earthen pond at Pleasant Mount Fish Cultural Station and 100 shad to Benner Spring Research Station.

Average time for loading the tank depended on the number of fish taken in the haul, the site utilized for hauling, and the number of trucks to be loaded. The entire operation took approximately 3-5 hours, and typical travel time from the Hudson River to Tunkhannock was less than 6 hours.

1.3.2 Number of Shad Transplanted and Survival

Shad were collected from the Hudson River between 28 April and 24 May. Low flow conditions and an atypically warm spring resulted in an early shad run and it is possible that a week of hauling opportunity in late April was missed. Some 3,654 prespawned adult shad were transferred by NES and the PFC from the Hudson and released at Tunkhannock. High mortalities were experienced during the first week, but survival improved dramatically thereafter. Of the 3,654 shad hauled, a total of 2,772 were released alive (Table 2). The average survival for Hudson fish was 76%.

Of the shad hauled to Pleasant Mount, 296 (78%) survived hauling and delayed mortality for several days in the pond was minimal. Survivors were restocked at Tunkhannock. Ninety of the 100 fish delivered to Benner Spring survived the haul from the Hudson River.

1.3.3 Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen (DO) were monitored from the two PFC transport units. The NES unit was not monitored, however the PFC data is considered representative since identical systems were utilized.

Hudson River water temperatures during the time of capture ranged from 55-69°F (Table 3). Transport tank temperature increase during the 4½-6 hour trip was limited to less than 2°F. This is significantly lower than the 5°F temperature increase which was typical of the small engine life support systems utilized in previous years. Water temperature in the Susquehanna River ranged from 58-64°F.

Dissolved oxygen at transport end averaged 7.2 ppm (range 4.0 - 9.0 ppm). DO is believed to be a limiting factor when temperatures exceeded 65°F. Therefore, when these conditions occurred, other water sources for the transport tanks were used. These sources were typically 5-10°F cooler than the Hudson River and consequently could support higher DO levels.

1.3.4 Rip Van Winkle Bridge Collection Site

In the 1982, 1983 and 1984 Hudson River transfer operations, shad were collected in the vicinity of Greendale Landing. During those seasons this site produced significant numbers of shad for the restoration effort. However, efforts have shown that shad were abundant in this location only from the change of ebb to flood tide. As a result, fishing operations were limited to up to six seine hauls before the flooding tide made seining impossible.

1.3.4 CONTINUED

To maximize the number of shad hauled for the program, it was apparent that an additional site located within two river miles from the transport area was needed. From information gathered during the 1983 study, NES located a seining site immediately north of the Rip Van Winkle Bridge on the west shore of Rodgers Island. This area was fully developed in 1985, and should be a major contributor to the program.

One significant benefit of the new site is that shad were found in large numbers during the ebb tide. Therefore, 2-3 hauls could be made up-river, fish shuttled to the transport site and the trucks loaded, before seining activities at the Greendale site (down-river) began. As a result, this location can expand the per day seining effort and should increase the number of shad available to the program.

1.3.5 Quality Control

To ensure optimum conditions between collection and loading sites and increase the number of fish per trip, improvements were made to the shuttle boat systems. These improvements were based on keeping shad alive and in good condition for up to one hour, and are as follows:

(a) A second 5-ft diameter 245-gallon round galvanized tank was mounted in-line with an identical tank used in 1984. The two tanks were mounted in an 18-ft Jon-Boat and utilized the existing 3 HP trash pump to fill, drain, and circulate water in each of the tanks. NES found that this system could adequately support 40 shad per tank (80 total).

1.3.5 CONTINUED

(b) An improved oxygen injection system was employed in each of the shuttle tanks. This system was installed to increase dissolved oxygen levels during transport, especially when river temperatures exceeded 60°F. Each unit consisted of a LK oxygen cylinder, Western regulator, high pressure ball valve and tubing, and a 3-ft section of Bioweave hose. Air flow was controlled by the regulator and the in-line ball valve with oxygen dispersion through the Bioweave. Biologists observed that the condition of fish was greatly improved with the addition of this system.

1.3.6 Results of Benner Spring Spawning Trial

The Benner Spring pond used for controlled spawning is shaped like a square donut with paddlewheels providing a constant current. The pond was stocked on 10 May with 55 male and 35 female adult shad. Between 14 May and 7 June, 22 dead fish were recovered from the pond including 13 females, 6 males, and 3 of unknown sex. Spawning activity was first reported on 7 June and between 8 June and 2 July another 25 mortalities were removed from the pond (8 females; 5 males; 12 unknown). On 21 June, juvenile shad were first seen, and by 18 July, many dead adults were sighted on the bottom. The pond bank ruptured on 9 August and was completely drained on the 13th. All remaining adults were dead but 50-100 fingerlings were recovered alive.

1.4 HERRING- NUMBER TRANSPORTED AND SURVIVAL

The herring run at the Catskill Region of the Hudson River typically starts in early April and continues through late May. Herring were abundant in the haul seine throughout the shad collection program, but were taken only when the availability and the condition of shad declined. Herring were collected at the Greendale Landing site on 17, 18, 19 and 24 May. Some 2,000 blueback herring were hauled by NES in four seperate shipments of 500 f per load. All fish were released at Tunkhannock, PA., with excellent survival. A total of only four herring were found dead at release.

1.5 CONNECTICUT RIVER SHAD TRANSFER PROGRAM

The adult shad transfer on the Connecticut River (Holyoke Lift) was first conducted on an experimental basis in 1980. Since its inclusion in the program the Connecticut River has supplied over 6,200 fish for the restoration effort. In 1985 SRAFRC was advised by the Connecticut River Basin Atlantic Salmon Commission that collection of shad at the lift would be limited to two days per week, and terminated thereafter. This year's work plan called for the Connecticut to be used exlusively as a backup source if sufficient numbers of shad were not taken from the Hudson.

1.5.1 Results

As a result of the Hudson River operation not meeting the 5,000 shad goal, the Holyoke Lift was utilized for transfer. However, low flow conditions on the Connecticut made the fish lifts inoperable until late in the season. A total of only one attempt was made by the PFC (24 May) with some 64 shad taken and transported to Tunkhannock. Sixty-two shad survived the 9-hour trip.

1.6 SUMMARY

1.6.1 Comparison with Efforts of 1980 through 1985

The number of shad transferred from out-of-basin sources to the Susquehanna River ranged from a low of 193 in 1980 to 5,637 in 1983. The 1985 program provided some 4,198 shad for a 6 year total 19,648 (Table 1). Survival to stocking during this period averaged 77% (range 59 to 84%), while the number released alive increased from 114 in 1980 to 4,310 in 1983. Transfer procedures throughout the years have also been modified and improved to best meet the SRAFRC goals.

1.6.2 Hudson River

In 1982 the Hudson River was added to the adult shad transfer program on an exprimental basis. A total of 1,176 prespawned American shad were collected by haul seine and transferred to the Susquehanna River with a survival rate of 84%. The success of that effort and the effectiveness of seining encouraged SRAFRC to expand the operation over the years. In 1985 a goal of some 5,000 - 6,000 prespawn adult shad were to be taken by haul seine and trucked to Tunkhannock, PA., with at least 75% survival.

This spring all three transport units utilized the Fresh-Flo aerators with oxygen injection. Dissolved oxygen for the units averaged 7.2 ppm and temperature increase was less than 2°F.

During the period of 28 April through 24 May a grand total of 4,134 shad were transferred, of which some 3,158 were presumed alive at release. The

1.6.2 CONTINUED

average survival rate during transfer was 77%. Tunkhannock was used as the only river release site, however one load was trucked to Benner Springs for a controlled spawning attempt and several loads to Pleasant Mount Lagoon for delayed mortality assessment.

A second seining site located in the vicinity of the Rip Van Winkle Bridge was fully developed this spring and made a significant contribution to the program. The abundance of shad at this site and the Greendale Landing site is encouraging for efforts in future years.

In late May when the availability of shad declined, NES hauled about 2,000 blueback herring to Tunkhannock. Fish were transferred in four loads of 500 herring per truck with excellent survival.

1.6.3 Connecticut River

In 1985 SRAFRC was advised by the Connecticut Basin Atlantic Salmon Commission that the fish lift would be available on a limited basis and be terminated thereafter. The Holyoke Lift was to be used as a backup source, if sufficient numbers of shad were not taken from the Hudson this spring, a situation that did occur.

On 24 May, a total of 64 shad of which 62 survived were trucked to Tunkahnnock, PA.

TABLE 1. Comparison of prespawned Adult American shad transferred from Connecticut River (1980-85) and Hudson River (1982-85) to Susquehanna River.

Year	Number Transported	Number Alive	Percent Survival
	CONNECTICUT RIVER		
1980	193	114	59%
1981	1,486	1,165	78%
1982	2,287	1,573	69%
1983	1,946	1,187	61%
1984	299	185	62%
1985	64	62	97%
TOTAL	6,275	4,286	68%
	HUDSON RIVER		
1982	1,176	992	84%
1983	3,691	3,123	84%
1984	4,372	3,592	82%
1985	4,134	3,158	76%
TOTAL	13,373	10,865	81%
GRAND TOTAL	19,648	15,151	77%

TABLE 2. Data on Prespawned Adult Shad Transferred from the Hudson River to the Susquehanna River at Tunkhannock, PA., by NES and the PFC, 1985.

Date	Trip # and Agency	Release Site	Number Transported	Number Dead	Number Alive	Total Tank Time (HRS:MIN)	Weather and Air Temperature
Apr. 28	1 - NES	Tunkhannock	125	56	69	4:15	60 - Overcast
29	2 - NES	"	130	63	67	3:45	65 - Clear
30	A1 - PFC	"	126	81	45	6:00	73 - Clear
30	B1 - PFC	"	120	75	45	5:20	73 - Clear
May 1	A2 - PFC	"	103	25	78	5:15	55 - Clear
1	B2 - PFC	"	100	6	94	5:00	55 - Clear
2	3 - NES	Pleasant Mt.	130	73	57	4:30	49 - Overcast
2	A3 - PFC	Tunkhannock	95	72	23	5:20	49 - Overcast
2	B3 - PFC	"	85	55	30	5:20	49 - Overcast
3	4 - NES	"	130	15	115	4:20	50 - Rain
4	5 - NES	"	130	20	110	4:00	70 - Clear
5	6 - NES	"	130	41	89	4:30	70 - Clear
6	7 - NES	Pleasant Mt.	130	3	127	4:30	63 - Rain
7	A4 - PFC	Tunkhannock	98 (Females)	6 (Females)	92	4:25	58 - Clear
7	B4 - PFC	"	124 (males)	3 (m)	121	4:40	58 - Clear
8	A5 - PFC	"	121	3	118	-	58 - Clear
8	8 - NES	"	125	4	121	4:00	58 - Clear
9	9 - NES	"	136	4	132	3:45	70 - Clear
10	10 - NES	"	130	23	107	4:15	78 - Clear
10	A6 - PFC	Pleasant Mt.	80-Males 40-Females	3 5	77-Males 35-Females	-- --	78 - Clear

CONTINUED

TABLE 2. CONTINUED

Date	Trip # and Agency	Release Site	Number Transported	Number Dead	Number Alive	Total Tank Time (HRS:MIN)	Weather and Air Temperature
May 10	B6 - PFC	Benner Spr.	100	10 (used for spawning experiments)	90	--	78 - Clear
11	11 - NES	Tunkhannock	130	45	85	4:15	85 - Clear
11	A7 - PFC	"	125	94	31	4:15	85 - Clear
11	B7 - PFC	"	124	33	91	4:05	85 - Clear
12	12 - NES	"	137	22	115	4:15	75 - Overcast
12	A8 - PFC	"	124	16	108	4:45	75 - Overcast
13	13 - NES	"	105	16	89	3:45	78 - Clear
13	A9 - PFC	"	125	18	107	4:40	78 - Clear
13	B9 - PFC	"	114	29	85	4:35	78 - Clear
14	A10 - PFC	"	127	42	85	---	85 - Clear
14	B10 - PFC	"	70	3	67	3:50	85 - Clear
17	14 - NES	"	20-shad 500-herring	0	20-shad 500-herring	6:00	70 - Rain
18	15 - NES	"	50-shad 500 herring	4-shad 4-herring	46-shad 496-herring	3:45	75 - Rain
19	16 - NES	"	29-shad 500-herring	4-shad 0-herring	25-shad 500-herring	3:45	65 - Clear
20	17 - NES		130	2	128	4:30	84 - Clear
21	18 - NES	"	140	2	138	4:00	70 - Clear
22	19 - NES	"	48	0	48	4:15	70 - Clear
23	20 - NES	"	48	0	48	4:00	70 - Clear
24	21 - NES	"	500-herring	0	500	4:00	70 - Clear
SHAD TOTALS		TUNKHANNOCK	3,654	882	2,772		
		PLEASANT MT.	380	84	296		
		BENNER SPRING	100	10	90		

TABLE 3. Record of Dissolved Oxygen and Temperature during Transport of Adult American Shad by the PFC from the Hudson River to the Susquehanna River, 1985.

			DISSOLVED OXYGEN (PPM)					TEMPERATURE (°C)					
Date	Trip #	Water Source	Hudson River	Start Tank	Two Hrs.	Four Hrs.	Finish	Hudson River	Start Tank	Two Hrs.	Four Hrs.	Finish	Susquehanna River
4-30	A1	Hudson	9	9	8	9	9	56	56	56	57	57	60
30	B1	"	9	9	9	9	9	56	56	56	57	57	60
5- 1	A2	"	9	10	7	6	6	55	55	56	56	56	61
1	B2	"	9	10	7	6	6	55	55	56	56	56	61
2	A3	"	9	9	9	8	9	56	56	57	59	60	61
2	B3	"	9	9	8	8	7	56	56	57	59	60	61
7	A4	"	-	-	-	-	-	55	55	56	56	57	58
7	B4	"	-	-	-	-	-	55	55	56	56	57	58
9	A5	"	9	9	7	6	6	54	54	54	56	56	-
10	A6	"	7	-	-	-	-	57	-	-	-	-	-
10	B6	"	7	6	6	8	7	57	57	58	62	64	-
11	A7	"	-	-	7	4	4	55	60	68	-	-	62
11	B7	"	-	-	-	-	-	-	54	-	-	-	-
12	A8	Pleasant Mt. Well	-	10	9	9	-	-	54	54	56	56	62
13	A9	"	-	8	7	7	8	62	59	61	62	64	62
13	B9	"	-	-	-	-	-	62	61	61	62	62	62
14	A10	"	-	8	5	-	-	69	53	-	-	-	-
14	B10	"	-	8	6	6	6	69	53	54	55	57	64
24	B11	"	-	9	9	9	9	-	55	55	56	55	-

JOB II AMERICAN SHAD EGG COLLECTION PROGRAM

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2.1 INTRODUCTION

Egg Collection in 1985 was to be conducted on the James and Pamunkey Rivers (Virginia), the Delaware River (Penna. - New Jersey), and the Columbia River (Oregon-Washington). Eggs were to be delivered to the Van Dyke Hatchery. The fish released from the hatchery will supplement the development of the shad population below the Conowingo Dam with the urge to migrate upstream past the dams to spawn.

The SRAFRC goal for 1985 was to obtain 30-50 million shad eggs over a three month period. Improvements to the Van Dyke Hatchery would expand its production capacity to over 10 million 18-day old fry and 120,000 fingerlings in 1985.

In 1984 East and West Coast egg collection activities resulted in the incubation of a record 41.1 million American shad eggs. Of these a total of 11.99 million fry and 30.5 thousand fingerlings were stocked.

2.2 METHODS

2.2.1 Egg Collection

Eggs were collected from shad in spawning condition taken in gill-nets by commercial fishermen. Eggs were artificially fertilized in essentially the same manner established by Kilcer (1973), with minor revision developed in 1983. These modifications were made as a result of consultation with the PFC and fish culture experts on the West Coast. 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 2-3 minutes to allow for optimum fertilization. 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. This rinsing process was repeated two times to remove dead sperm, unfertilized and broken eggs, and debris. Fertilized 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, clean water added and agitated to provide aeration. Once the eggs were hardened the water was drained and five liters each of eggs and clean water was placed in a plastic bag which had

2.2.1 CONTINUED

an outer plastic bag for protection in shipping.

Pure oxygen was put into the bag containing eggs and the bag securely tied with two castrator 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 ratio of females to males.

2.2.2 Collection Areas

2.2.2.1 Pamunkey River, Virginia

NES biologists began egg collection efforts on the Virginia Rivers on 4 April, upon confirming reports that shad had been taken by fishermen in spawning condition. Biologists worked with commercial fishermen at Thompson's Landing, New Kent, Virginia, located approximately 4-6 miles upstream of Lester Manor. Previous years' efforts have proven that this area is a viable location for catching adult spawning shad. Netting was usually conducted between 1530 and 2200 hours on a seven day per week schedule. NES biologists operated from the shoreline at Thompson's Landing. As fish were captured they were shuttled to the shoreline as quickly as possible. Fish in spawning condition were then processed.

2.2.2.2 James River, Virginia

Experience in past years has proven that shad migrate up the James River to spawn approximately two weeks later than on the Paumunkey River.

2.2.2.2 CONTINUED

Egg Collection efforts on the James River began on 24 April at Berkley Plantation Landing. Berkley Plantation is in the Charles City-Hopwell section of Virginia, directly below the Benjamin Harrison Bridge.

Commercial fishermen using gill-nets worked together with biologists out of small row boats during egg collection operations. Eggs were stripped from spawning females and fertilized on the boat, rather than on the shoreline, as was the case on the Pamunkey River. Gill-netting was conducted from 1530 to 2200 hours.

2.2.2.3 Columbia River, Oregon- Washington

The egg collection program on the Columbia River, Oregon-Washington was initiated on 5 June. This decision was determined only after NES had confirmed through commercial fishermen that spawning shad were available in sufficient numbers.

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. The nets utilized during the 1985 operation were 150 fathoms in length, tapered in depth, with sections of 5 and 5½ inch monofilament mesh. Typically, three 45-60 minute drifts were made nightly. Gill-netting was conducted from 1700 to 2200 hours.

2.2.2.4 Delaware River, Pennsylvania - New Jersey

The Delaware River was first utilized for American shad egg collection in 1983 by personnel of the U.S. Fish and Wildlife Service, PA Fish Commission and a group of local volunteers. The Delaware was known to have a significant shad population, however unlike the Pamunkey, James and Columbia rivers, no commercial fishery existed. Shad used by SRAFRC from the Virginia and Oregon rivers are part of the seasonal commercial harvest.

This years sampling program was conducted by PFC at Smithfield Beach, 8 miles upstream (NE) from East Stroudsburg, PA., from 30 April to 15 May. Shad were captured with anchored gill-nets (200-ft long x 6-ft deep, with 4 3/4 - 6-in mesh) set parallel to the current. Nets were set between dusk and midnight, and the catch was shuttled by boat to the shore for processing. Operations were terminated when the majority of shad taken were no longer in spawning condition. Shad used for egg collection were donated to the East Stroudsburg State College Raptor group as food for protected birds of prey.

2.3 TRANSPORTATION

2.3.1 Virginia Rivers

Shad eggs collected from the Pamunkey and James Rivers were transported by automobile, as was the case in 1983 and 1984. Eggs collected at the rivers were driven to Sandston, Virginia. Arrangements were made to deliver the shipments from Sandston to the Van Dyke Hatchery. NES personnel in Virginia notified the hatchery nightly to verify the estimated number of liters and the ETA of the shipment. The average delivery time from Virginia to Van Dyke was six hours.

2.3.2 Columbia River

After packaging the eggs from the Columbia River, the boxes were transported by van to the Eastern Airlines Terminal at the Portland International Airport. This year's operation utilized Eastern Airlines Sprint Service (Small package service), rather than United Airlines, the carrier contracted in previous operations, as a result of the strike on United Airlines.

Egg shipments were flown from Portland to Atlanta on Eastern Airlines Flight #453 and transferred to Eastern Airlines Flight #809 to Baltimore-Washington International Airport (BWI). Upon arrival of egg shipments into BWI, eggs were transported by van to the Hatchery. Approximate shipping time was 11-13 hours.

2.3.3 Delaware River

Egg shipments from the Delaware River were transported in the same manner as in Virginia. Eggs were delivered by automobile from the collection site to the Van Dyke Hatchery. The driving distance to the hatchery was approximately 3 hours.

2.4 COLLECTION SCHEDULE

The shad egg collection schedule was based on experience gained over a eleven 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 55-60°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 concluded spawning activities. The West Coast operation was based on the number of fishing days that the budget could support and/or the quality and quantity of eggs available.

2.5 QUALITY CONTROL

In 1983 a cooperative effort was made to improve procedures of collection, artificial fertilization and shipment of American shad eggs.

2.5 CONTINUED

This effort demonstrated that quality eggs could be successfully collected from various river systems.

Quality control of spawning techniques and transportation arrangements are essential for providing "quality" eggs to the program. In past years, male shad shortages occasionally necessitated the use of milt from dead males to fertilize eggs, and the use of milt from one male to fertilize the eggs collected from more than three females. The shortage of male shad is believed to have occurred because the fishing gear utilized by commercial fisherman was designed to catch fish that typically approach the size of larger female American shad.

In 1985 arrangements were made with commercial fisherman to construct nets of 5 and 5½ inch mesh, rather than the 5½ and 5 3/4 inch mesh used in previous years. This gear was designed to increase the number of males per catch and consequently improve the results of artificial fertilization.

2.6 RESULTS

2.6.1 Pamunkey River

Shad egg collection began on 4 April on the Pamunkey River, Virginia and continued throughout the duration of the annual adult spawning runs. Water temperature ranged from 57 to 76°F. Egg collection efforts were halted on 30 April when commercial fishermen no longer caught shad in gill-nets. A total of 5.28 million eggs, were collected from the Pamunkey River.

Low precipitation and high temperatures in late March and April resulted in an early shad run in Virginia. The majority of eggs on the Pamunkey River were taken between 5 and 16 April when water temperature ranged from 57 to 64°F.

2.6.2 James River

The James River provided some 2.05 million shad eggs from 24 April-10 May 1985. Water temperature during the period of collection ranged from 68-78°F.

Commercial fishermen at Berkley Plantation and Grants Crossing indicated that the 1985 up-river shad run on the James River was the worst that they could recall. They attributed the poor fishing to the unseasonably warm spring which raised water temperature above the 70°F mark as early as 20 April, resulting in increased down-river spawning.

2.6.3 Columbia River

Egg Collection on the Columbia River began on 5 June and continued through 26 June. Water temperatures ranged from 55-68°F. A total of 12.06 million eggs were sent to the Van Dyke Hatchery in 15 seperate shipments.

Egg production on the Columbia River was down significantly from previous years. This was in part the result of a dry/hot spring which

2.6.3 CONTINUED

lowered water levels 10-15 feet below normal, preventing fishermen from effectively fishing their gear. Egg production was also hampered by a less than average shad run.

However, though overall production was down in 1985, the addition of new gear greatly improved the male catch. A total of 287 males and 829 females were taken in 1985.

2.6.4 Delaware River

In 1985 the Delaware produced the higest total number of eggs in the history of the collection program. Spawning in the Delaware River started earlier than past years and the PFC crews working at Smithfield Beach took a total of 6.1 million eggs. Eggs were shipped to Van Dyke Hatchery from 30 April - 15 May in nine seperate shipments.

Of the 6.1 million eggs collected, some 32% were stocked in the Lehigh (1.28 million) and Schuylkill (0.67 million) rivers as part of the restortation of American shad to those river systems.

2.6.5 All Rivers Combined

The shad egg collection operation was conducted on three East Coast rivers and the Columbia River between 4 April and 26 June. Over the three month period a total of 25,568,500 eggs were collected from the various rivers. The James, Pamunkey and the Delaware produced 13.50 million

2.6.5 Continued

eggs, while some 12.06 million were obtained from the Columbia River. Although, the Virginia rivers and Columbia rivers were not as productive as in some years, the Delaware had its highest total since its inclusion in the program.

2.6.6 Summary

The 25.57 million eggs collected during East and West Coast river egg collection program was down approximately 37% from 1984. The Columbia River was off the most, producing only 12.06 million shad eggs this year, compared to 27.8 million in 1984. This was primarily due to a poor shad run at the Camas-Washington reef (Troutdale area) and low river flows which hampered gill-netting operations. The Virginia rivers were also less productive as a whole in 1985. Low flows and high temperatures apparently disrupted the normal pattern of shad migration to the upper Virginia river; shad were not present in large numbers on any predictable basis. Although the James, Pamunkey and Columbia rivers had off-years, the Delaware River produced some 6.1 million shad eggs.

TABLE 1. Sampling period for East and West Coast rivers for collection of American shad eggs, 1985.

RIVER	SAMPLING SCHEDULE DATES	TOTAL FISHING DAYS
Pamunkey	4 April - 30 April	26
James	24 April - 10 May	13
Columbia	5 June - 26 June	16
Delaware	30 April - 15 June	9

TABLE 2. Collection data of the total volume and number of American shad eggs on the Pamunkey, James, Columbia and Delaware rivers, 1985.

RIVER	VOLUME OF EGGS SHIPPED (L)	TOTAL NUMBER OF EGGS
Pamunkey	168.8	5,286,400
James	48.0	2,050,300
Columbia	438.9	12,068,500
Delaware	168.7	6,163,300
TOTALS	824.4	25,568,500

TABLE 3. Total number (millions) of American shad eggs collected from the Pamunkey, Mattaponi, James, Potomac, Susquehanna, Delaware, Connecticut, Hudson and Columbia Rivers, 1971-1985.

Year	Pamunkey	Mattaponi	James	Potomac	Susquehanna	Delaware	Connecticut	Columbia	Hudson	Totals
1971	--	--	--	--	8.42	--	--	--	--	8.42
1972	--	--	--	--	7.10	--	--	--	--	7.10
1973	8.45	6.48	--	34.64	4.74	--	4.30	--	--	58.61
1974	9.75	6.80	19.20	5.56	--	--	0.53	8.18	--	50.02
1975	1.88	--	7.15	5.70	--	--	--	18.42	--	33.15
1976	--	--	--	--	--	4.10	--	54.80	--	58.90
1977	4.40	0.57	3.42	--	--	--	0.35	8.90	--	17.64
1978	6.90	--	10.11	--	--	--	--	--	--	17.01
1979	3.17	--	4.99	--	--	--	--	--	--	8.16
1980	6.73	--	6.83	--	--	--	--	--	--	13.56
1981	4.58	--	1.26	--	--	--	--	5.78	--	11.62
1982	2.03	--	1.25	--	--	--	--	22.57	--	25.85
1983	5.49	--	5.91	--	--	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
TOTALS	68.49	13.85	62.91	45.90	20.26	15.30	5.18	178.10	1.17	411.16

TABLE 4. Collection data for American shad eggs taken on the Pamunkey River, 1985.

Collection Date	Water Temperature (°F)	Number of Adult Shad	Volume of Eggs Received at Hatchery (in liters)	Weather Condition Air Temperature (°F)	Number of Commercial Fishermen & Boats
April 4	60	0	No shipment	Clear/60°	2 - 1
5	61	58	13.7	Clear/80°	3 - 2
6	63	42	13.3	Clear/75°	3 - 2
8	59	70	18.1	Overcast/60°	3 - 2
9	57	0	No shipment	Overcast/50°	1 - 1
10	56	8	No shipment	Clear/55°	1 - 1
11	57	13	No shipment	Clear/69°	4 - 3
12	61	68	19.0	Clear/75°	4 - 3
13	61	85	22.9	Clear/80°	5 - 4
14	62	0	No shipment	Overcast/60°	1 - 1
15	62	107	32.4	Overcast/65°	5 - 4
16	64	74	25.5	Rain/75°	5 - 4
17	66	43	11.3	Clear/70°	4 - 3
18	65	0	No shipment	Clear/80°	1 - 1
19	68	40	9.0	Clear/93°	4 - 3
20	70	0	No shipment	Clear/93°	1 - 1
21	72	0	No shipment	Clear/94°	1 - 1
22	74	12	No shipment	Clear/94°	4 - 3
23	76	0	No shipment	Clear/90°	4 - 3
24	75	0	No shipment	Rain/75°	1 - 1
25	74	10	No shipment	Clear/70°	3 - 2
26	75	20	3	Clear/85°	3 - 2
27	76	0	No shipment	Clear/85°	1 - 1
28	76	0	No shipment	Clear/80°	1 - 1
29	76	10	No shipment	Clear/70°	2 - 1
30	76	0	No shipment	Clear/85°	No fishing

TABLE 5. Collection data from American shad eggs on the James River, 1985.

Collection Date	Water Temperature (°F)	Number of Adult Shad	Volume of Eggs Received at Hatchery (in liters)	Weather Condition Air Temperature (°F)	Number of Commercial Fishermen & Boats
April 24	75	0	No shipment	Rain/ 75°	1 - 1
25	76	0	No shipment	Clear/ 70°	1 - 1
26	76	66	14.0	Clear/ 85°	4 - 2
27	76	28	7.0	Clear/ 85°	4 - 2
29	76	0	No shipment	Clear/ 70°	High Winds
30	76	10	No shipment	Clear/ 85°	4 - 2
May 1	78	59	16.2	Clear / 80°	4 - 2
2	76	2	No shipment	Rain/ 65°	1 - 1
3	68	20	No shipment	Clear/ 55°	5 - 3
4	70	4	No shipment	Clear/ 60°	3 - 2
7	73	12	4.4	Clear/ 60°	2 - 1
8	73	17	6.4	Clear/ 60°	4 - 2
10	73	20	No shipment	Clear/ 75°	2 - 1

TABLE 6. Collection data for American shad eggs taken on the Columbia River, 1985.

Collection Date	Water Temperature (°F)	Number of Adult Shad Male	- Female	Volume of Eggs Received at Hatchery (in liters)	Weather Conditi Air Temperatur (°F)
June 5	60	20	60	25.3	Overcast/60°
6	59	Net Torn		No shipment	Heavy Rain/5
7	55	30	60	29.7	Overcast/60°
10	59	19	83	54.5	Clear/70°
11	62	12	90	45.7	Clear/72°
12	64	30	90	49.5	Clear/75°
13	64	20	50	30.2	Clear/77°
14	64	10	30	14.4	Clear/80°
17	65	20	20	10.2	Clear/79°
18	67	40	40	17.2	Clear/78°
19	68	20	60	31.7	Clear/75°
20	68	25	70	32.6	Clear/89°
21	68	25	76	34.6	Clear/85°
24	65	8	40	21.9	Overcast/72°
25	66	6	40	19.6	Clear/75°
26	67	2	20	11.7	Clear/77°

TABLE 7. Collection data for American shad eggs taken on the Delaware River, 1985.

Date Shipped	Date Received	Vol (l) Received	Eggs
April 30	May 1	18.6	605,600
May 1	2	23.8	722,300
6	7	9.8	278,700
7	8	21.6	671,300
8	9	8.5	258,400
12	13	35.5	1,269,500
13	14	19.2	900,100
14	15	18.4	781,700
15	16	13.3	675,700

JOB III. AMERICAN SHAD HATCHERY OPERATIONS

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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 provided from the settlement agreement between upstream hydroelectric project owners and intervenors in the FERC relicensing proceeding related to American shad restoration in the Susquehanna River (approved in April, 1985).

Production goals for 1985 included the stocking of 10^{+} million 18-day-old shad fry, and 50 thousand 50^{+} day old fingerlings. An effort was made to mark all hatchery-reared American shad fry by immersion in oxytetracycline (OTC) bath treatments in order to distinguish hatchery reared outmigrants from juveniles produced by natural spawning of transplanted adults. In addition, all fry were exposed to phenethyl alcohol, an imprinting agent to be used as a chemical attractant at the Conowingo Dam fish collection facility. Procedures were initiated in 1985 to disinfect all egg shipments received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Expansion/improvement of the Van Dyke facility approved by SRAFRC for 1985 will be undertaken in winter 1985-1986. The expansion/improvement plans include the following: development of the capability for using Juniata River water as a supplement to spring water, installation of 16 additional rearing tanks, construction of a brine shrimp incubation room, construction of a data processing room, construction of an egg disinfection area, remodeling of the egg incubation area, re-plumbing of the tank effluent network, and excavation in the abandoned railroad bay to permit quick-release of fry into a gooseneck trailer.

Research conducted at Van Dyke in 1985 focused on oxytetracycline tagging and improvement of feeding regimes. Oxytetracycline tagging research (Project 6b) included the following tests: 1) Treatment of 5-8 day old fry at 25 ppm oxytetracycline vs. an untreated control to determine treatment induced mortality and marking efficiency for very young fry; 2) Bath treatment of 15-18 day old fry at 25 ppm oxytetracycline followed by treatment with OTC laced feed at 115-128 days of age to attempt to produce a unique double mark for fingerlings; 3) Treatment of 15-18 day old fry by immersion in 50 ppm oxytetracycline for 12 hrs./day vs. 6 hrs./day for four consecutive days to determine if detectable tags could be administered in a single 8-hour shift; 4) Treatment of 5 to 8-day-old fry at 25 ppm OTC vs. 50 ppm OTC to assess treatment induced mortality and determine marking efficiency for very young fry at different concentrations; 5) Treatment of fry with bath treatments at 50 ppm OTC at 5-8 and 15-18 days of age to attempt to produce a unique double mark for fry.

Feeding research (Project 7) involved two tests: 1) Survival, growth, and incidence of feeding was compared for tanks fed *Artemia* nauplii plus AP100 larval diet (two tanks) vs. *Artemia* nauplii plus milled *Artemia* flakes (one tank) vs. *Artemia* only. 2) Survival, growth, and incidence of feeding was compared for tanks fed *Artemia* nauplii plus three sizes (150, 200, 250 micron) of AP100 larval diet. In addition, preliminary tests were conducted to assess the use of salt to reduce mortality during transportation.

EGG SHIPMENTS

A total of 25.6 million eggs (814.3 L) were received in 38 shipments at Van Dyke in 1985 (Tables 1 and 2). By comparison, in 1984, 41.1 million eggs were received in 39 shipments. Egg shipments from the Pamunkey and Columbia Rivers decreased from 1984 to 1985 (9.8 and 27.8 million eggs shipped in 1984 vs. 5.2 and 12.1 million eggs shipped in 1985, respectively). These declines in egg shipments are thought to be the result of climatic conditions (early springtime temperatures and low water conditions). Egg shipments from the James and Delaware Rivers increased from 1984 to 1985 (.7 and 2.6 million eggs shipped in 1984 vs. 2.0 and 6.1 million eggs shipped in 1985, respectively).

Overall egg viability (defined as the percentage which ultimately hatches) was 40.9%, down from 45.2% in 1984. Egg viability for the Pamunkey River was similar in both years (64.5% in 1984 vs. 62.5% in 1985). Egg viability for the James River decreased from 63.9% in 1984 to 52.6% in 1985. Egg viability for the Delaware River increased from 31.2% in 1984 to 50.5% in 1985. Egg viability for the Columbia River decreased from 39.2% in 1984 to 24.5% in 1985, and was responsible for the decrease in overall viability.

The low egg viability experienced in Columbia River shipments was the result of human error during the egg disinfection process, which was initiated in 1985. As a result of low pH during disinfection, shipments 27, 28, 29, and parts of shipment 26 experienced total mortality, while shipment 30 experienced partial mortality. These egg shipments were disinfected with an iodine product whose constituents were significantly more acidic than those used on other shipments. Egg viability for Columbia River shipments, excluding shipments 26 to 30, averaged 41.1%.

PRODUCTION

Survival, production, and stocking of American shad fry are presented in Tables 2, 3, and 4. Survival of all fry from viable eggs to stocking, was 76.2% (Table 3), up from 72.8% in 1984 (Wiggins et al., 1984a). This increase in survival is more significant than it appears since a large portion (46.9%) of the fry stocked in 1984 were less than 14 days of age, while in 1985 no fry were stocked at less than 14 days of age and only 7.6% were stocked at less than 18 days of age. Survival of Columbia River fry to 18 days increased from 57.4% in 1984 to 69.8% in 1985. The increase in survival from 1984 to 1985 is presumed to be a result of changes in feeding regimes, specifically the use of AP100 larval diet as a food supplement, fed by automatic feeders, on a production basis.

Total fry production in 1985 was 7.9 million (Table 3), down from 1984 (13.5 million) as a result of the decrease in numbers of eggs shipped. The majority of the fry produced were stocked in the Juniata River (5.4 million). Fry were also released into ponds at Van Dyke (252,000) and Benner Spring (584,000) for research and production of fingerlings. Wellsboro National Fishery Research and Development Center also received 51,000 fry for research purposes. For the first time, fry were also shipped to downstream release sites and out-of-basin sites. Conowingo Reservoir received 812,000 fry marked with a unique double mark from 5-8 and 15-18 days of age. In addition, fry from Delaware River sources were transported to the Lehigh River (600,000) and Schuylkill River (252,000).

Total fingerling production in 1985 was 115,000 (Tables 2 and 3), up from 30,500 in 1984. Fingerlings from the Benner Spring facility (Table 3) were stocked in the Susquehanna River below Conowingo Dam (53,000), while fingerlings from Van Dyke and Thompsontown were stocked in the Juniata River (62,000). A small number (665) of fingerlings were also provided to Radiation Management Corporation for use in radiotelemetry studies.

SURVIVAL

High mortalities were experienced in some tanks as a result of failure to re-establish flow in the tank after OTC treatment (1 tank), improper adjustment of flow in the tank after OTC treatment (2 tanks), low dissolved oxygen during OTC treatment (suspected in one tank), and below normal temperatures during hatch (one tank). Survival of all fry excluding these tanks was 81.2% and represents a realistic target for future efforts using current production techniques.

There is considerable variation in survival between tanks over and above that explained by known causes. Figure 1 and Table 5 provide a temporal analysis of that variation by comparing survival (computed from mean daily mortality) for four groups of American shad fry. Groupings were based on 19-day cumulative survival and tank location.

Low survival in outdoor tanks has been a problem in previous years (T. A. Wiggins, pers. comm.). Outdoor tanks which experienced 19-day survivals of less than 70% (n=3) began to experience high mortalities immediately after hatch (Figure 1). Mean cumulative survivals after 4 days of age were as follows:

	Group	Mean 4 day Survival
(Outdoor)	19 day S < 70% (n=3)	83.4%
(Indoor)	19 day S < 70% (n=2)	96.6%
	70% ≤ 19 day S ≤ 85% (n=29)	95.0%
	19 day S > 85% (n=21)	97.4%

These results were tested statistically with a one-way Anova (Ott, 1977) and found to be significantly different (F=71.8, d.f.=3, 51; a=.01). Duncan's New Multiple Range Test indicated that outdoor tanks with 19 day survival <70% were significantly different from the other groups and that tanks with 19 day survival >85% were significantly different from tanks with 19 day survival between 70 and 85%.

After 4 days of age, outdoor tanks experienced mortality trends similar to other groups. We postulate that these low survivals for outdoor tanks are related to high illumination levels present in the outdoor environment. Visual observation indicates that light levels are consistently higher than in indoor tanks despite the fact that an awning protects the outdoor tanks from direct sunlight. By experience, we know that American shad fry sometimes dive to the bottom of the tank and form dense schools. This behavior has been observed on many occasions and has been attributed to bright light in shipping bags and outdoor tanks, and to cold temperatures in indoor tanks. This behavior is often associated with high mortalities, presumably due to oxygen depletion within the dense school. The fact that survival in some outdoor tanks is good might be explained by favorable environmental conditions during the critical period immediately after hatch.

Indoor tanks with 19-day survival less than 70% (n=2) exhibited good survival until approximately 11 days of age, at which time mortalities increased and remained atypically high until stocking at 21 days of age (Figure 1, Table 5). Mean cumulative mortalities from 11 to 17 days of age were analyzed to minimize problems with unequal sample sizes.

	Group	Mean Cumulative Mortality (days 11-17)
(Outdoor)	19 day S <70% (n=3)	15.5%
(Indoor)	19 day S <70% (n=2)	38.0%
	70% ≤ 19 day S ≤ 85% (n=29)	12.4%
	19 day S >85% (n=21)	5.2%

These results were significantly different (F=220, d.f.=3, 51; a=.01). Duncan's New Multiple Range Test indicated that all four means were significantly different from each other.

Comparison of tanks with 19 day survival greater than 85% to those with 19 day survival between 70% and 85% (Figure 1, Table 5) indicated that significant differences in survival between these two groups existed in the first 4 days after hatch, and again from 11 to 17 days of age. This suggests that these shipments are encountering a minor genetic or environmental problem sometime between the spawning operation and the end of the hatching process, which manifests itself early in life and continues until at least day 17.

Increases in mortalities for all groups after 10 days of age correspond temporally with the transition from endogenous to exogenous feeding at 9 to 14 days of age. However, mortalities did not level off after 14 days as did those reported by Wiggins et al. (1985). These new mortality patterns may relate to changes in feeding regimes (use of dry diet as a food supplement) or OTC tagging.

High mortalities experienced with small lots of fish have been a nagging problem at Van Dyke (T. A. Wiggins, pers. comm.). In 1985, one such tank (initial density 44,800) had a 20 day survival of 32.7% and, as a result, was eliminated from the statistical analysis above. We postulate that mortalities in low density tanks are a consequence of failure to find feed and subsequent starvation, as a result of a feeding schedule which feeds according to number of fry without accounting for water volume. In the future, we will feed low density tanks based on 100,000 fry, regardless of the actual density.

OTC TAGGING

Based on research conducted in 1984, an effort was made in 1985 to tag all hatchery production fish with oxytetracycline (OTC) using bath treatments for fry and feed treatments for fingerlings. Hatchery produced outmigrants could then be distinguished from progeny which were naturally spawned from transplanted adults by evaluation of otoliths using fluorescent microscopy techniques.

Research conducted in 1984 concluded that a detectable tag could be produced by immersing 15 to 18 day old fry in a bath of 50 ppm OTC for 12 hours on each of four consecutive days, during which time feeding was suspended (Wiggins et al, 1984b). In order to tag all fry on a production basis, tags would have to be applied at an earlier age (5-8 days), and feeding would continue during tagging. Oxytetracycline toxicity has been reported in the literature (Weber and Ridgeway, 1962) and it was feared that younger fry (5-8 days) would not survive treatment at 50 ppm. As a result, it was agreed that all Virginia river fish would be treated at 25 ppm OTC and fed during treatment (Project 6a). Research was scheduled to determine survival of 5-8 day old fry treated at 25 ppm vs. an untreated control, and to determine survival of 5-8 day old fry treated at 25 vs. 50 ppm OTC (Project 6b). The results of this research would be used to determine the tagging methods used on subsequent shipments.

Table 6 summarizes OTC treatments by method and river stocked. Results of the initial test indicated that fry treated with 25 ppm OTC at 5-8 days of age survived better than an untreated control. As a result, Virginia river fish were treated with 25 ppm OTC as planned. On May 31, a decision was made to begin treating 15-18 day old fry at 50 ppm to ensure adequate dosage for marking. This resulted in some fry being treated at 25 ppm for 2 days and 50 ppm for 2 days (Table 6). Due to manpower shortages, the test comparing survival of 5-8 day old fry treated at 25 vs. 50 ppm OTC was not conducted until the first Columbia River shipment. The results of this test indicated that 5-8 day old fry survived better when treated at 50 ppm OTC than at 25 ppm. Subsequently, all treatments were at 50 ppm OTC.

OTC RESEARCH

All OTC research was conducted using methods developed in 1984 (Wiggins et al., 1984b). Bath treatments were administered for 4 consecutive days, 12 hours per day (unless otherwise specified). Fresh water flow was shut off during the bath treatments and oxygen levels maintained by the addition of pure bottled oxygen. Potassium phosphate and sodium phosphate buffers were used to maintain neutral pH. Dissolved oxygen and pH were checked periodically to ensure acceptable levels. Feeding was continued during treatments, however, it was sometimes necessary to reduce rations of dry diet to prevent clouding of the water with unused fish food.

Test 1 compared survival of fry treated with 25 ppm OTC at 5-8 days of age to an untreated control. Nineteen day survival of the treated fry (Figure 2, Table 7) was greater (89.8%) than fish in the control tank (78.8%). As a result, we were able to mark Virginia river fry at 25 ppm without sacrificing production. A portion of these fry were retained for grow-out in a raceway at Benner Spring Fish Research Station and sampled at 77 days of age. A total of 5.6% (5/90) had detectable tags (Table 7). These otoliths could be read without grinding.

Test 2 was an attempt to mark American shad fingerlings by feeding OTC laced feed at 115-128 days of age (Table 7). Four tanks of fish were involved in the test. Fish in all four tanks were transferred to ponds at Benner Spring Fish Research Station at 44-45 days of age. One tank (D1) was treated with 25 ppm OTC at 15-18 days of age and then fed OTC laced feed at 115-128 days of age. One tank (D2) was treated with 25 ppm OTC at 15-18 days of age but not fed OTC laced feed. For comparison, one tank of fish (C4) was treated with 25 ppm OTC at 5-8 days of age and one tank (D3) was held as an untreated control. Survival data for each of the four tanks is depicted in Figure 3.

Samples for otolith analysis were taken at 127-158 days of age (Table 7). Subsequent to sampling, all fish were fed OTC laced feed to ensure marking prior to release.

Analysis of otolith samples indicated that marking efficiency was similar for all three groups marked by immersion in 25 ppm OTC (5.7%, 7.0%, 5.3%, Table 7). This compares well with the 5.6% marking efficiency in Test 1, Tank A2, despite the fact that otoliths from Test 1 were sampled at 79 days of age and thus viewed without grinding while those from Test 2 were sampled at 158 days of age and required grinding on both sides. These mark detection rates are very poor in comparison to the 98.4 to 100% rates exhibited by fry treated at 50 ppm OTC (Table 7, Tests 3-6).

Test 2 samples involved fingerlings reared in outdoor ponds while Test 1 fingerlings were reared in an outdoor raceway. Combined marking efficiency (25 ppm OTC) for these tests was 5.9% (19/324). In contrast; Test 4, Tank B1, fish exhibited a 25 ppm OTC marking efficiency of 79.7% (Table 7). This group was reared entirely indoors. Exposure to sunlight in outdoor ponds has been shown to have a photolytic effect on tetracycline fluorophore in the scales of salmon (Weber and Ridgeway, 1967). Apparently, this phenomnon is also applicable (perhaps to a lesser extent) to otoliths, at least for American shad transferred to outdoor ponds at 44-45 days of age.

Marking fingerlings by feeding OTC laced feed at 3 g OTC per pound of feed was completely unsuccessful. None of the 71 fish examined displayed a detectable mark. Marking of salmonids with OTC laced feed has been quite successful (Weber and Ridgeway, 1967; Weber and Ridgeway, 1962; Choate, 1964; Trojnar, 1973). These studies all involved salmonids tagged in raceway situations where accurate censusing methods could be used and tetracycline doses determined as mg OTC per kg body weight. We were not able to determine biomass in our ponds, consequently, we fed OTC laced feed at dosages used for treatment of internal bacterial diseases (3 g OTC per pound of feed).

Test 3 was an attempt to mark fry with 50 ppm OTC by 6 hour bath treatment. Six hour bath treatments would benefit logistics and scheduling by allowing treatment within an 8 hour shift. Survival of fry tagged in 6 hour vs 12 hour baths is depicted in Figure 4. Lower survival for the 6 hour bath treatment resulted from mortalities prior to treatment.

Marking efficiency (Table 7) for fry treated for 6 hours (96.9%) was only slightly less than for fry treated for 12 hours (100%). Unfortunately, these lots were reared entirely indoors. In light of the photolytic effects of sunlight demonstrated earlier, further testing in an outdoor situation is necessary.

Test 4 compared survival and marking efficiency for fry marked at 25 vs 50 ppm OTC at 5-8 days of age. Survival of these lots was very similar (Figure 5), in fact, fry treated at 50 ppm survived slightly better than those treated at 25 ppm.

Marking efficiency (Table 7) was only slightly lower for fry marked with 25 ppm (79.7%) than for fry marked with 50 ppm (98.4%). However, both lots were reared entirely indoors, eliminating possible photolytic effects due to exposure to sunlight.

Test 5 (Table 7) was an attempt to produce a unique double mark for fry destined to be stocked at down-river sites. Fry were marked by immersion in 50 ppm OTC at 5-8 days of age and then again at 15-18 days of age. Samples were collected at 49 and 64 days of age and analysis indicated that a double mark was detectable on 100 of 102 samples (98.0%). One individual had no

5-8 day mark but a good 15-18 day mark. One individual had neither a 5-8 day nor a 15-18 day mark. Marks produced during this test were much more distinct than those produced by other tests. For example, 94.6% of the marks in this test were scored ++ or +++ while only 55.9%, 36.1%, and 62.7% of the 50 ppm marks in Tests 3, 4 and 6 (respectively) received similar scores.

Test 6 evaluated the marking efficiency of fry marked with 50 ppm OTC at 15-18 days of age and then reared in an outdoor pond. Fingerlings were sampled at 145 days of age and marking efficiency was 100%.

Nineteen-day survival (62.7%) was low, apparently as a result of low temperatures during hatch which caused the newly hatched fry to lay on the tank bottom in dense schools, presumably resulting in oxygen depletion. These mortalities had no bearing on the test.

Inspection of 19-day survival data (Table 7) from Tests 1, 3 and 4 indicates that in each case higher OTC concentrations or longer OTC treatment resulted in slightly better survival. In Test 3 (Figure 4) differences in survival between the two test tanks were well established prior to OTC treatment. In Tests 1 and 4 (Figures 2 and 5), however, survival between tanks was similar until after treatment, suggesting the possibility that OTC treatment may have a prophylactic effect.

FEED RESEARCH

Feed research was conducted using tanks with production densities of fry. Standard OTC treatments were administered during the test. Live *Artemia* nauplii (Sanders Brine Shrimp Company) were fed by automatic feeders developed by Theis and Howey (1981). Tanks which received live *Artemia* only were fed at the optimum rate of 18 *Artemia*/fish-day (Wiggins et al., 1984b). Tanks which received dry diet as a supplement to live *Artemia* were fed at a rate of 12 *Artemia*/fish-day. Live *Artemia* were enumerated volumetrically by determining the number present in a sub-sample and calculating the correct volume to be fed based on the sub-sample and the density of fry in the tank. Tank density was estimated using techniques developed by Wiggins et al. (1985).

Dry diet was pre-weighed on a triple beam balance, packaged in daily rations, and stored in a refrigerator until use. Daily dry diet ration was 64.5 g/250k fish (Wiggins et al., 1984b), based on the number of fry at hatch. Dry diet was fed by Sweeney model AF-6, vibrator type feeders. Both dry diet and live feeders were operated for 5 seconds every 5 minutes and adjusted to feed out in 8-10 hours. Twenty-five fish samples were extracted from each tank every other day for growth and feeding analysis.

Test 1 compared survival, growth, and incidence of feeding for American shad fry fed *Artemia* nauplii plus AP100 larval diet (12A + AP100, tanks C1, D3), vs. *Artemia* nauplii plus milled *Artemia* flakes (12A + AF, tank C2), vs. *Artemia* only (18A, tank D4).

Survival in the 4 test tanks was similar until 11 days of age when fish in tanks D3 and D4 began to die off (Figure 6). Percent daily mortalities from 11 to 19 days of age were averaged for each tank and a one way ANOVA (Ott, 1977) used to test for significant differences. Results indicated that there were significant differences in the mean daily mortality between tanks (F=18.8; d.f.=3, 30; a=.01). Duncan's New Multiple Range Test (Ott, 1977) indicated that the tank receiving 18A (D4) was significantly different from the others and tank D3 was also significantly different from the others. The two tanks with high fish survivals (C1 and C2) were not significantly different at the .05 level. The inconsistancy in the survival data of the two tanks receiving 12A + AP100 is a good example of unexplained variation in survival.

Growth for fry in these four tanks is depicted in Figure 6 and Table 8. Beginning on day 11 mean length appears to be consistently higher for tanks with better fish survival (C1, C2, Figure 6). This was tested using a two-way Anova (Ott, 1977) with four levels of factor A (tanks) and three levels of factor B (15, 17, 19 days of age). Significant differences (a=.01) were found between tanks (F=13.5) and between days of age (F=6.7). Interaction was not significant (F=1.3). Duncan's New Multiple Range Test indicated that there was no significant difference in mean length of fish between tanks C1 and C2, and no significant difference in mean length of fish between tanks D3 and D4. All other pairwise comparisons were significantly different. These results were consistent with survival data in that tanks with better survivals exhibited better growth.

As expected, significant differences in mean length were also found between days of age. Duncan's New Multiple Range Test indicated that mean length at 19 days of age was significantly greater than at 15 or 17 days of age, but that no significant difference existed between 15 and 17 days of age.

Incidence of feeding for American shad fry fed different diets is depicted in Figure 7 and Appendix 2. The low incidence of feeding on *Artemia* nauplii depicted for the tank fed *Artemia* plus milled *Artemia* flakes probably relates to our inability to distinguish live *Artemia* from milled *Artemia* in the gut. As a result, direct comparison of incidence of feeding for tanks fed 12A + AP100 vs 12A + AF is not possible, and the tank fed 12A + AF is not included in the following analysis.

One-way ANOVA was used to test the hypothesis that mean incidence of feeding on live *Artemia* was significantly different between tanks fed 12A + AP100 (C1, D3) than the tank receiving 18A only (D4). The test statistic was the number of fry in a 25 fry sample with live *Artemia* present in the gut. No significant differences were found, indicating that incidence of feeding on live *Artemia* was not shown to be influenced by the presence or absence of AP100 dry diet.

Mean incidence of feeding on dry diet was compared for tanks C1 and D3 (both fed 12A + AP100) using a t-test (Ott, 1977). No significant differences were found despite the fact that survival and mean length were significantly higher in tank C1 than in tank D3.

Temporal trends (or the lack thereof) in feeding on dry diet and live *Artemia* are apparent from Figure 7, and are left for the reader to interpret.

This test evaluated the use of milled *Artemia* flakes as a substitute for AP100 larval diet. Milled *Artemia* flakes are advantageous in that they are canned, and as such, do not require refrigeration. In addition, they are less expensive ($12.00/lb vs $15.35/lb for AP100, 1985 prices). Based on results of this test milled *Artemia* flakes may be an acceptable substitute and further testing with replication is warranted. The test also confirmed the utility of dry diets as a feed supplement to live *Artemia* and illustrated the nagging problem of unexplainably low survival in some tanks.

Test 4 compared survival, growth, and incidence of feeding for American shad fry fed *Artemia* nauplii plus three sizes of AP100 larval diet (150, 200, 250 micron). Fry utilized for this test were part of a group destined to be stocked in Conowingo Reservoir and, as such, were treated with 50 ppm OTC at 5-8 and 15-18 days of age. This test was terminated after 15 days as a result of high mortalities in two of the three tanks. These mortalities resulted from failure to restore proper fresh water flow to the tank after OTC treatment.

Survival of fry fed three different sizes of AP100 larval diet is presented in Appendix 3, Table 9, and Figure 8. Mean daily mortality from 2 to 4 days of age of fry fed 250 micron diet was consistently higher than the other two tanks (Figure 8) but this was not statistically significant (F=2.4; d.f.=2.6; a=.05). The reason for this is unknown, but is probably not related to diet.

After 2 days of age survival trends were similar for all three tanks until 9 days of age when mortalities began to increase for tanks fed the larger sizes of dry diet. Percent daily mortalities from 9 to 13 days of age were averaged for each tank and a one-way ANOVA used to test for significant differences. Results indicated that there were significant differences in the mean daily mortality between tanks (F=10.73; d.f.=2, 12; a=.01). Duncan's New Multiple Range Test indicated that the tank fed 150 micron diet had significantly lower mean daily mortality (9-13 days) than the other two tanks.

Growth of fry fed three different sizes of AP100 larval diet is presented in Table 9 and Figure 8. Growth was similar for all three tanks until 13 days of age when growth for fry fed 200 micron dry diet increased dramatically (Figure 8). A two-way ANOVA was used to test for significant differences in mean length between the three tanks over days 13 and 15. Significant differences in mean length existed between the tanks (F=18.7, a=.01) but not between days (F=.48, a=.01). Duncan's New Multiple Range Test indicated that fish from the tank receiving 200 micron diet had significantly greater mean length than the others but that no significant difference in mean length existed between the tanks receiving 150 and 250 micron diets.

Incidence of feeding is presented in Appendix 4 and Figure 9. One-way ANOVA was used to test the hypothesis that mean incidence of feeding on live *Artemia* was significantly different between the three tanks (150 micron, 200 micron, 250 micron). As before, the test statistic was the number of fry in a 25 fry sample with live *Artemia* present in the gut. Significant differences were found (a=.05, F=5.45) and Duncan's New Multiple Range Test indicated that mean incidence of feeding on live *Artemia* for the tank fed 200 micron diet was significantly lower than the other two, but the tanks fed 150 and 250 micron diets were not significantly different.

Mean incidence of feeding on dry diet was also tested with ANOVA and found to be significantly different between the three tanks (a=.01, F=24.4). Duncan's New Multiple Range Test indicated that mean incidence of feeding on dry diet for the tank fed 150 micron diet was significantly higher than the others, but there was no significant difference between the two tanks fed 200 and 250 micron diets.

Fry fed 200 and 250 micron dry diets had a consistently higher mean incidence of feeding on live *Artemia* than on dry diet. This was not apparent for fry fed 150 micron diet.

Temporal analysis of feeding patterns indicated that mean incidence of feeding on live *Artemia* increased with age for the tank fed 250 micron diet. Mean incidence of feeding on live *Artemia* for the group fed 150 micron diet appeared to peak from 9-13 days of age. No trend was apparent for the tank fed 200 micron diet.

Temporal patterns in mean incidence of feeding on dry diet were more obscure and are left to the reader to interpret.

This test was based on the premise that shad fry would prefer smaller prey items (Wiggins et al., 1984b) and would therefore exhibit greater survival, growth, and feeding when fed small sized dry diet. Trends in survival (Figure 8) are clearly consistent with this hypothesis. Analysis of growth patterns, however, are not. Fry fed 150 micron diet grew no better than did those fed 250 micron diet and fry fed 200 micron diet grew best. Incidence of feeding tended to support this hypothesis in some ways but not in others. For example, fry fed on 150 micron diet fed on live _Artemia_ and dry diet with similar frequencies, while fry fed 200 and 250 micron diets had a higher mean incidence of feeding on live _Artemia_ than on dry diet. In addition, incidence of feeding on dry diet was consistently higher for fry fed 150 micron diet than for the larger diets (Figure 9). Unexpectedly, incidence of feeding on live _Artemia_ was also highest for fry fed 150 micron diet. This might have been a result of better growth, but better growth was not demonstrated. It is possible that successful feeding on dry diet may have stimulated feeding on live _Artemia_ as well.

Statistical analysis of the results of the two feed tests indicate that statistically significant differences are present between the test tanks for certain parameters. A more important question is: Would statistically significant differences in these parameters be evident on a production basis (would one feeding regime be more beneficial than another)? Unfortunately, time did not permit replication of the tests, consequently no such claims can be made.

TRANSPORTATION STUDIES

A small scale test was conducted to assess the benefit of using a 0.25% solution of solar salt to mitigate stress during transport of American shad fry. Two groups of approximately 5,000 19-day-old fry were extracted from a production tank during drawdown. This estimate was derived by dividing the final tank density by the number of scoops of fry used to remove the crowded fry from the tank. Both groups were brailed (one scoop each) from the tank into polyethylene shipping bags. A measured quantity of solar salt was added to one bag to produce 0.25% solution. Pure oxygen was added to each bag and the bag sealed with a hog castrator. A second bag was used as insurance against breakage and the bags placed in styrofoam coolers. The coolers were leaned against the Van Dyke oil burner shed to simulate the vibrations encountered in hauling. After 4 hours the fish were stocked in outdoor tanks and mortalities were hand-counted daily for 5 days.

Initial density in the tanks (calculated by adding daily mortalities to the number of survivors) was very close to the estimated 5,000 (Table 10). Mortality after the first day was 30.6% for the tank transported with salt and 60.6% for the tank transported without salt. Cumulative mortalities were similar, however, from day 2 to day 5. Consistently high transport mortalities have been observed with small groups of fry (Wiggins et al., 1984b) and the high mortalities observed in both groups after day 1 may be related to starvation as discussed earlier. Transport mortalities for tanks at production densities were much lower (Wiggins et al., 1984b). Based on the first day's mortalities experienced in this test all subsequent shipments of American shad fry were transported in a 0.25% salt solution. Qualitative observations indicated that fry transported with salt were much more active and healthier looking at release than those transported without salt.

In a second test, several groups of American shad fingerlings were monitored during transport in the new gooseneck trailer hauling unit in an effort to determine the new unit's hauling capacity. Different numbers of fish were hauled in the various compartments (~130 gal./compartment). The number of fish per compartment was estimated by counting the fish in four or five buckets, averaging the counts and multiplying by the number of buckets used for each compartment.

All fish were hauled in 0.25% salt and antifoam (5 ml/100 gal), and D.O. and temperature were monitored. Results of the monitoring are presented in Tables 11 and 12.

Data indicates that approximately 3,500 fingerlings averaging 3.7 inches in length and 6.3 g in weight can be hauled in each 130 gallon compartment for 6 hours with no problem. Data presented in Table 11 appears to indicate that 5,000 fish/compartment is excessive; however, there may have been an equipment problem since the DO increased dramatically when a new Bio Weave diffuser was put in place. It appeared that in order to work efficiently (produce very fine bubbles), the Bio Weave Oxygen diffusers must lie perfectly flat on the bottom of the tank. Following this trip, the Bio Weave diffusers were re-connected using longer pieces of hose. After the modification, the diffusers worked very well.

The type of valves used for the oxygen diffusion system on each compartment (~130 gal./water) vibrated closed on a few occasions, and it was necessary to re-adjust them in order to maintain proper D.O. levels. The Fresh-Flow aerators, currently used as a back-up aeration system, were tried on several occasions and were found to be inadequate. Fish were sucked against the intakes and water flow was stopped. Further testing of the aerators should be done before they are eliminated as a back-up aeration system for transporting American shad fingerlings.

A third group of fish was hauled from Wellsboro to Benner Spring, but the water quality was so poor (mud, snails, vegetation and newts) that almost all the fish were lost. Different harvesting techniques will have to be used at Wellsboro in the future so that the fingerlings can be transported in clean water. Further monitoring of the gooseneck hauling unit will be conducted in 1986.

SUMMARY

A total of 38 shipments of eggs (25.6 million eggs) was received at Van Dyke in 1985. Total egg viability was 40.9%. Overall survival from hatching to stocking was a record 76.2%, resulting in the production of 7.9 million fry. The majority (5.4 million) of the fry produced were stocked in the Juniata River, but for the first time fry were also released in Conowingo Reservoir, and the Lehigh and Schuylkill Rivers. A record 115,000 fingerlings were produced for research and stocking in the Juniata River and the Susquehanna River below Conowingo Dam.

All fry produced (with the exception of a small number of research fish) were subjected to baths in 25 or 50 ppm OTC in order to distinguish hatchery produced out-migrants from naturally produced out-migrants.

Results of OTC research indicate that survival of fry treated with 25 ppm OTC at 5-8 days of age was greater than an untreated control. Survival of fry treated at 5-8 days of age was greater for fry treated at 50 ppm than at 25 ppm. Survival of fry treated by 12 hour baths (50 ppm OTC, 15-18 days of age) was greater than survival for 6 hour baths. These tests were not replicated and have not been subjected to statistical analysis. Marking efficiency for fry tagged with 25 ppm OTC and reared outdoors ranged from 5.3 to 7.0%. Marking efficiency for fry tagged with 25 ppm OTC and reared indoors was 79.7%. Marking efficiency for fry tagged with 50 ppm OTC ranged from 98.0 to 100%, and was independent of rearing locations. Marking

efficiency for fry tagged with 50 ppm OTC in 6 hour bath treatments and reared indoors was 96.9%. Marking efficiency for a double tag at 50 ppm OTC was 99.0%. No detectable marks were produced by feeding with OTC laced feed.

Results of the feed research indicated that survival of fry fed *Artemia* nauplii plus milled *Artemia* flakes was comparable to survival of fry fed the standard *Artemia* nauplii plus AP100 larval diet. In another test, survival of fry was inversely related to the size of the dry diet used as a supplement to live *Artemia* nauplii.

Survival of transported fry was increased (for at least the first day) by the the addition of 0.25% solar salt.

COMMENDATIONS FOR 1986

1. Continue to disinfect all incoming egg shipments. Monitor pH carefully to ensure survival.
2. Mark all production fry at 50 ppm OTC from 5 to 9 days of age (5 days) to ensure detectable marking.
3. Mark all fry destined for downriver sites at 50 ppm OTC from 5-9 and 15-19 days of age.
4. Initiate research on OTC tagging to assess the marking efficiency of marks in two and three above.
5. Continue research to develop an OTC tag for fingerlings using OTC laced feed, and to assess marks produced by 6 hour bath treatments.
6. Initiate research to develop quick-release capability for stocking American shad fry via a gooseneck trailer. This will enable us to transport large numbers of fry to downriver sites.
7. Time permitting, replicate portions of the 1985 feed test, specifically, test 12A + AP100 vs 12A + AF and 150 micron vs 200 micron AP100.
8. Time permitting, initiate research to improve enumeration methods for eggs and mortalities.

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Figure 1. Survival computed from mean daily percent mortality for four groups of American shad fry, Van Dyke, 1985. Tanks with massive mortalities of known cause are excluded.

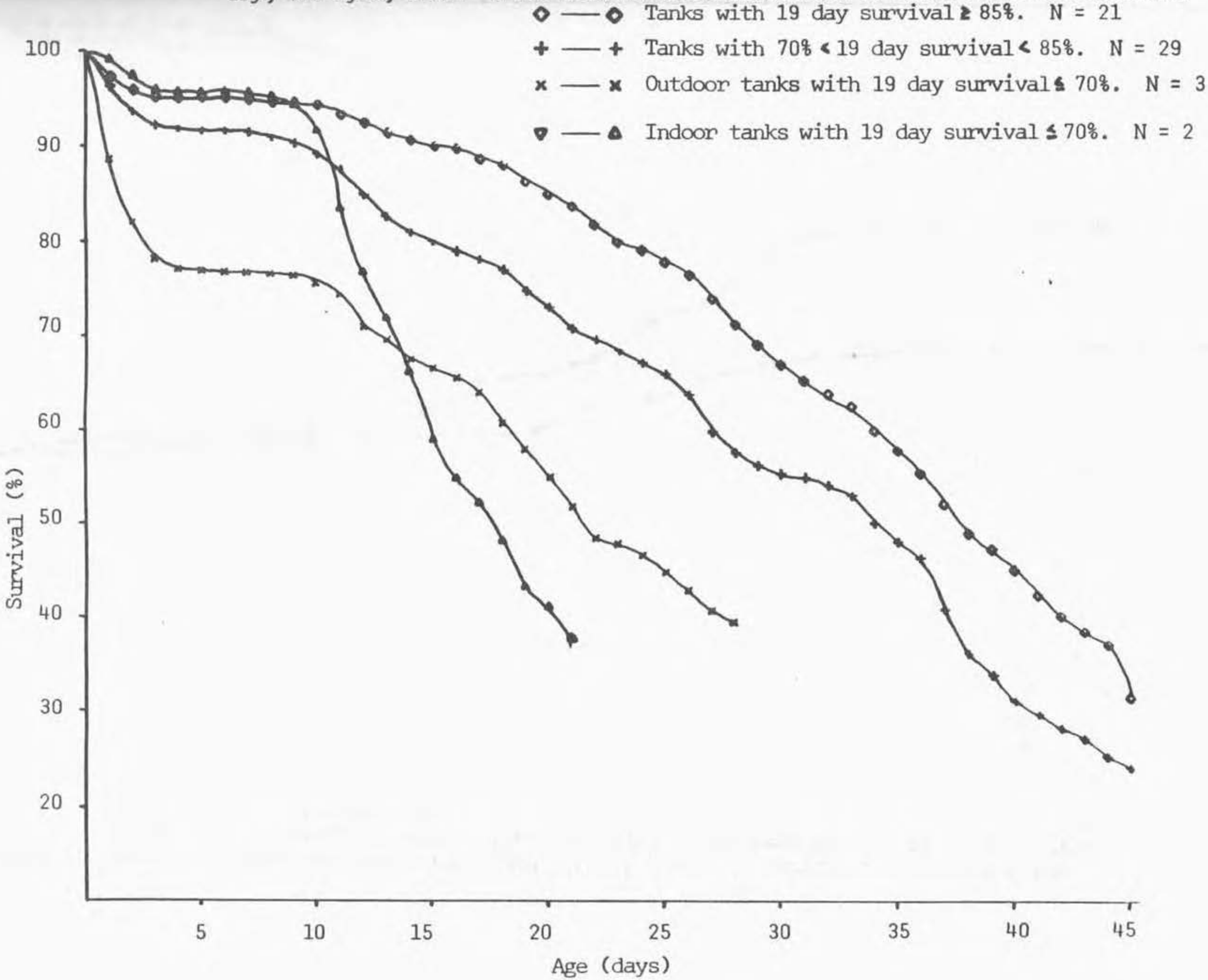

Figure 2. Survival of American shad fry tagged with 25 ppm oxytetracycline from 5 to 8 days of age vs. an untagged control, Van Dyke, 1985. Tags were applied by daily 12 hour bath treatments for four days.

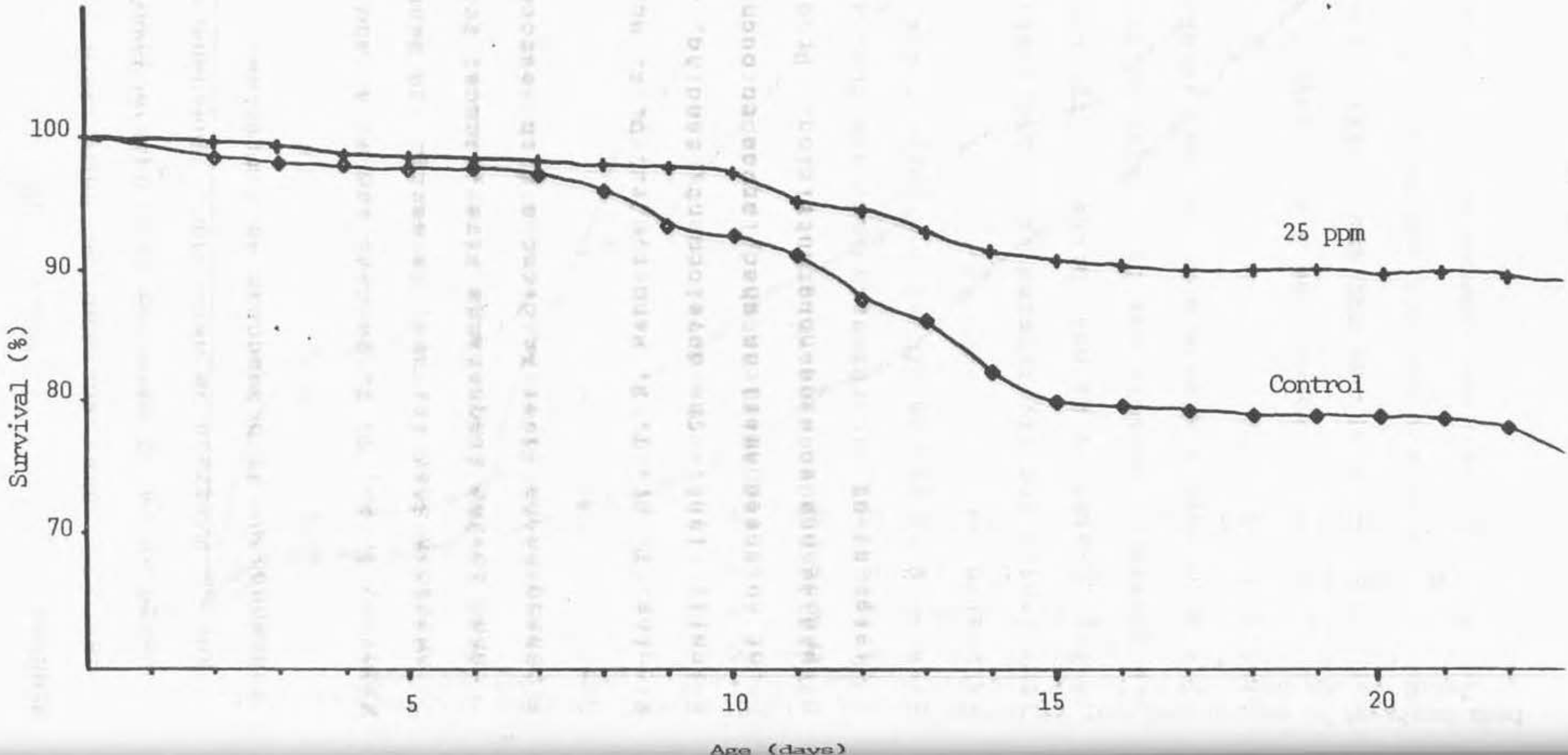

Figure 3. Survival of American shad fry tagged with 25 ppm oxytetracycline from 5-8 day of age vs 15-18 days of age (2 replicates) vs an untagged control, Van Dyke, 1985.

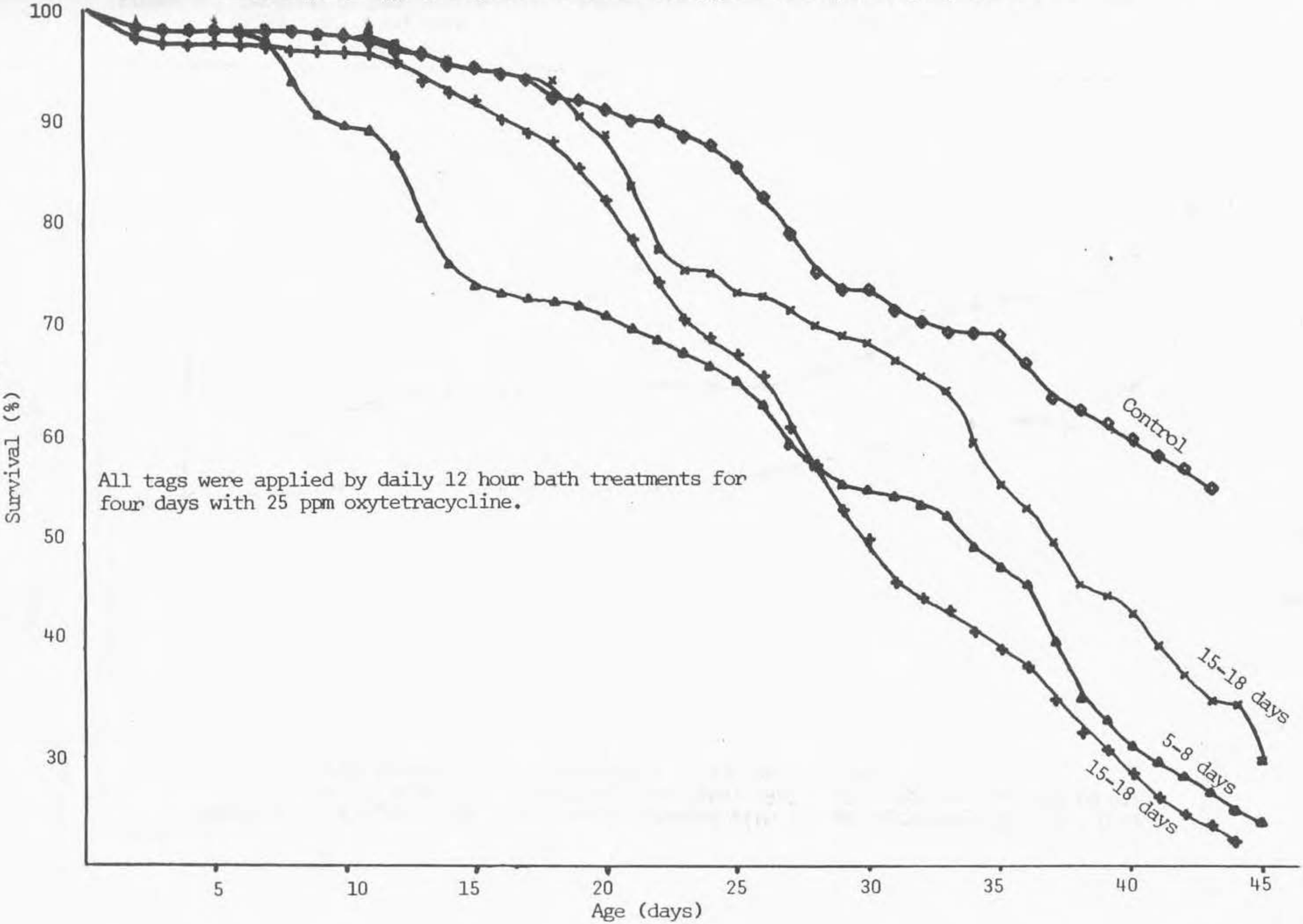

Figure 4. Survival of American shad fry tagged with 50 ppm oxytetracycline by 6 hour vs. 12 hour bath treatments, Van Dyke, 1985. All tags were applied by daily bath treatments for four days at 15-18 days of age.

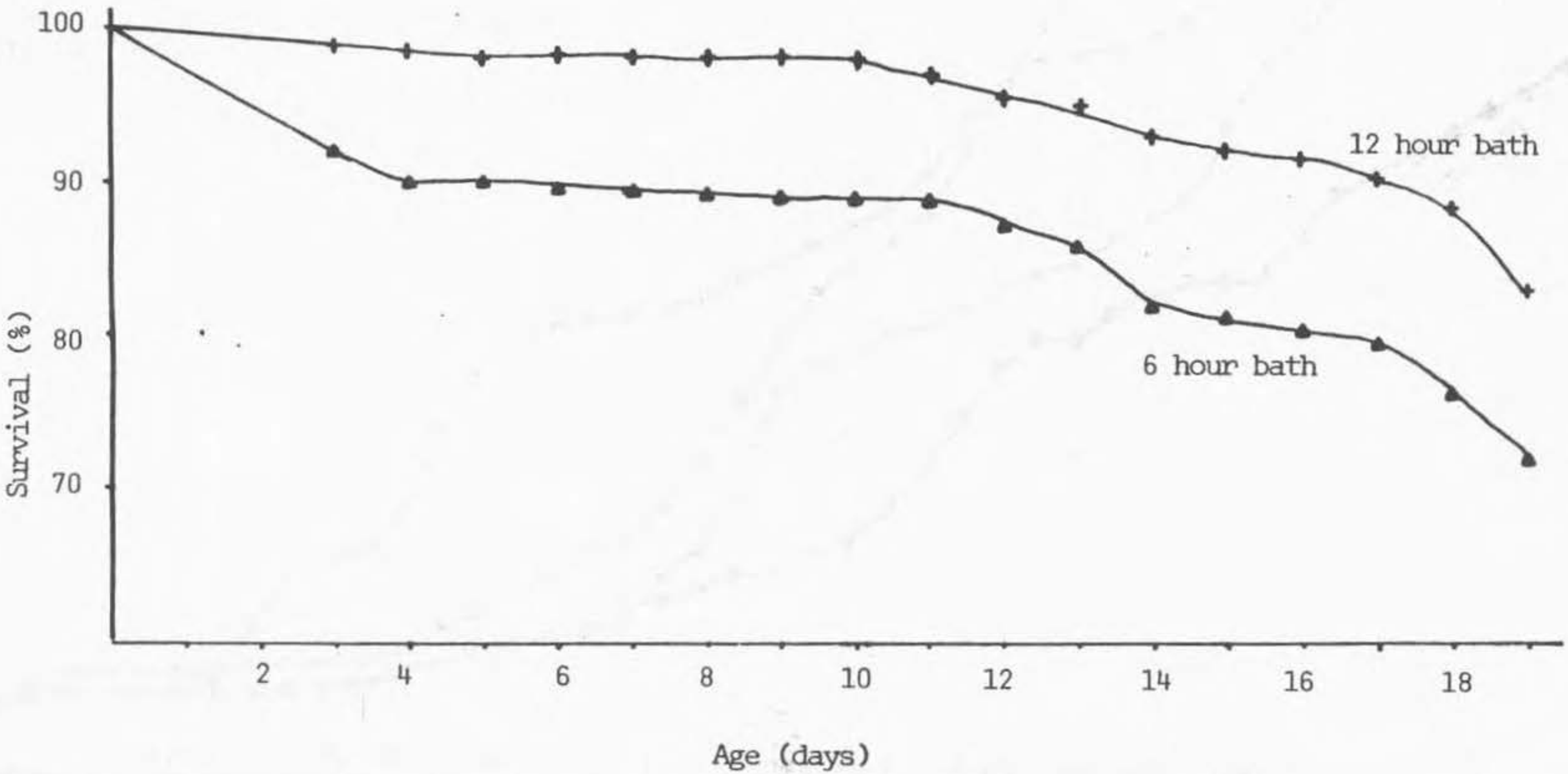

Figure 5. Survival of American shad fry tagged with 25 vs. 50 ppm oxytetracycline, Van Dyke, 1985. All tags were applied by daily 12 hour bath treatments for four days at 5-8 days of age.

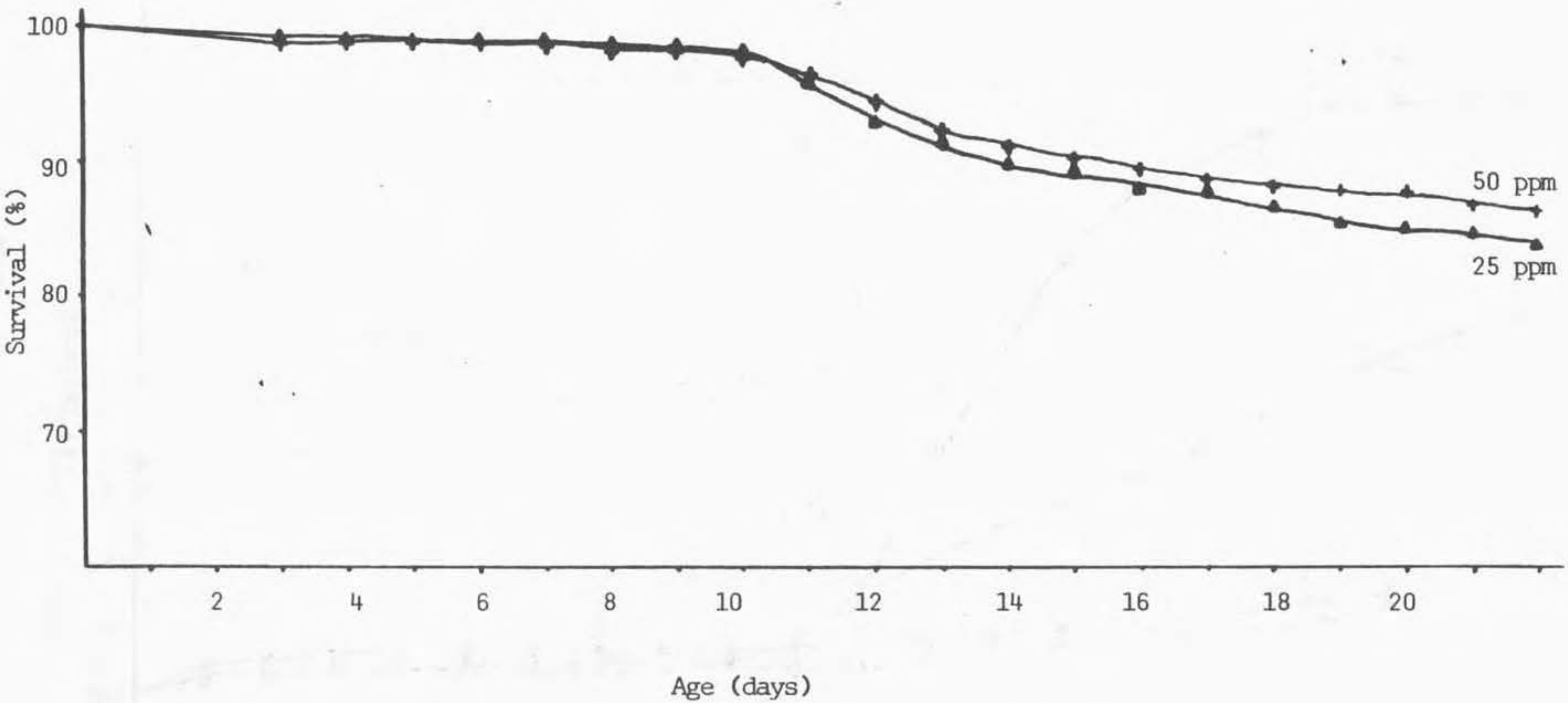

Figure 6. Survival and mean length of American shad fry fed *Artemia* nauplii plus AP100 larval diet, (2 replicates) *Artemia* nauplii plus milled *Artemia* flakes, and *Artemia* nauplii only.

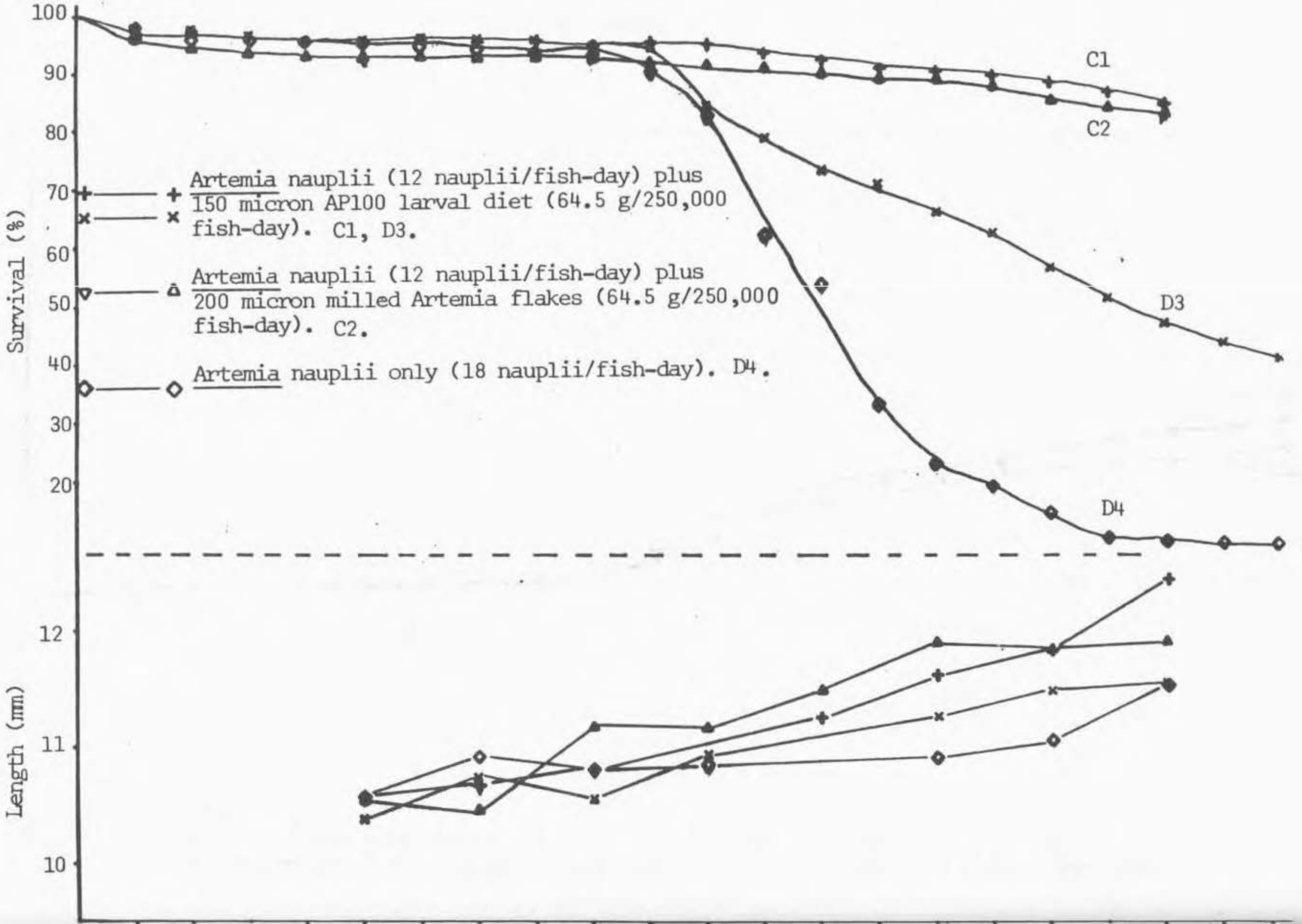

Figure 7. Mean incidence of feeding (%) for American shad fry fed three different diets.

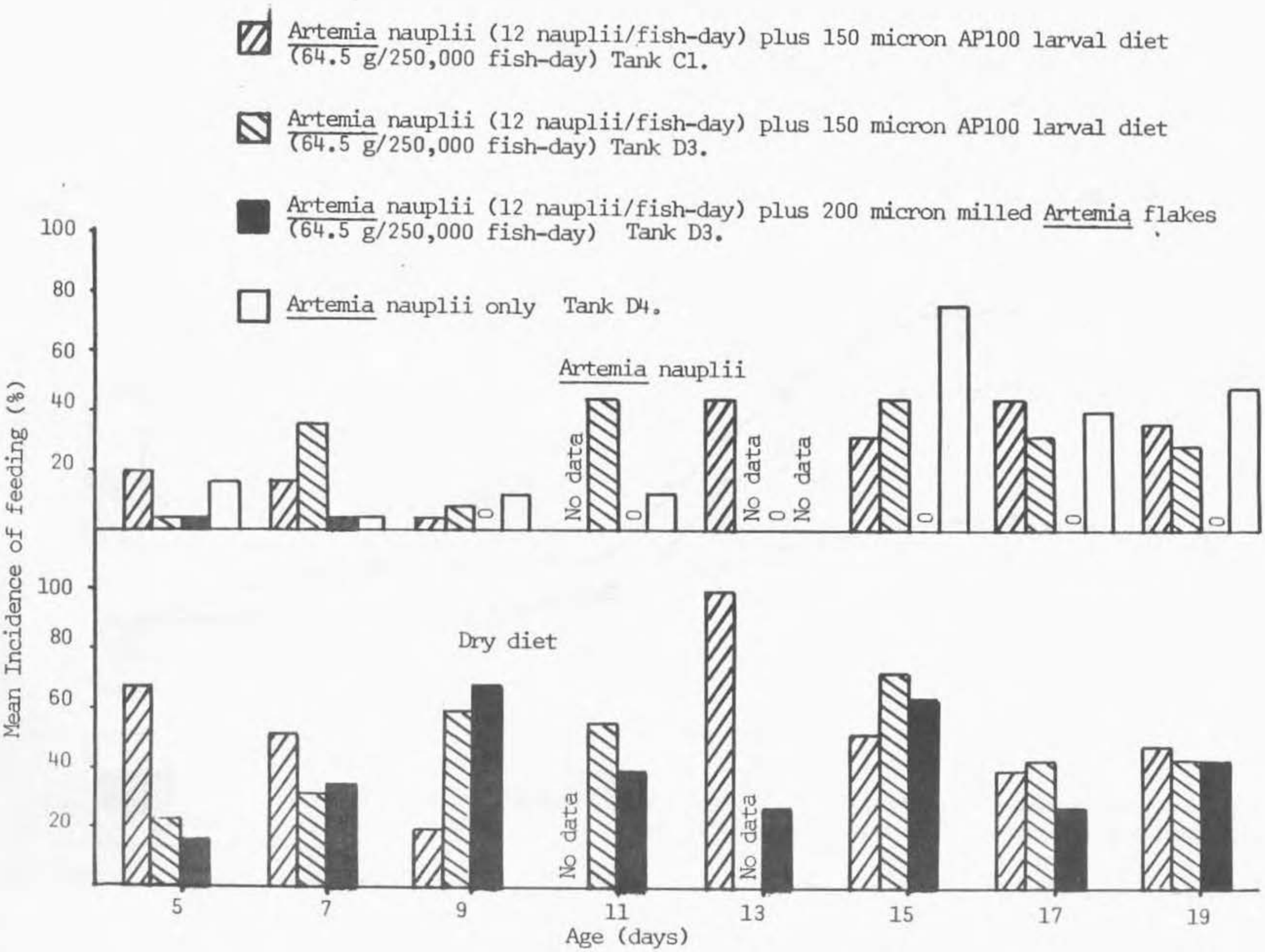

Figure 8. Survival and mean length of American shad fry fed Artemia nauplii (12 nauplii/fish-day) plus three sizes of AP100 larval diet (64.5 g/250,000 fish-day), Van Dyke, 1985.

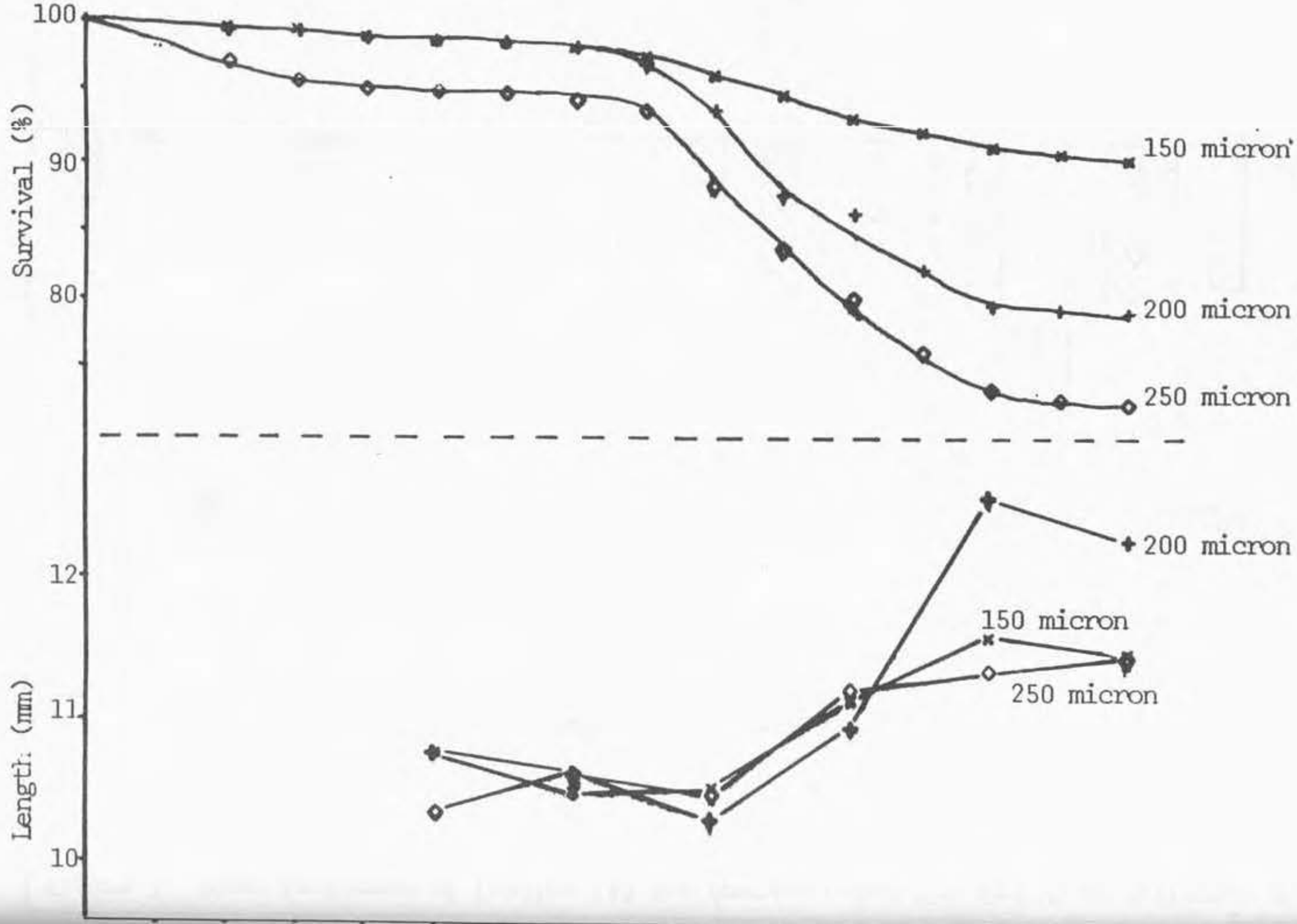

Figure 9. Mean incidence of feeding (%) for American shad fry fed *Artemia* nauplii (12 nauplii/fish-day) plus three sizes of AP100 larval diet (64.5 g/250,000 fish-day), Van Dyke, 1985.

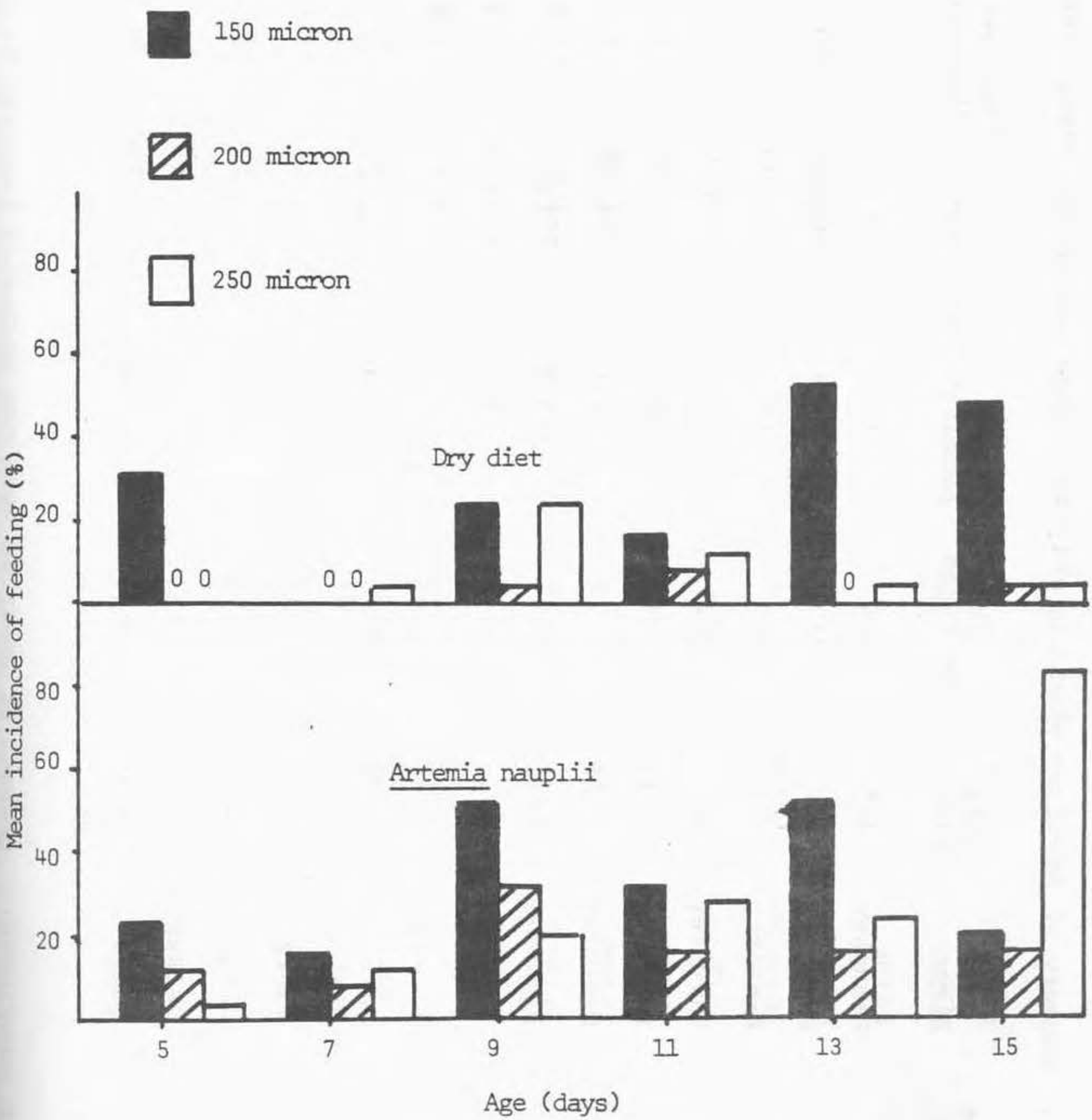

Table 1. Summary of American shad egg shipments received at Van Dyke, 1985.

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
1	Pamunkey	4/5	4/6	13.7	416,500	69.1	287,800	284,800
2	Pamunkey	4/6	4/7	13.3	347,400	58.5	203,300	201,500
3	Pamunkey	4/8	4/9	18.1	492,900	57.8	285,000	279,300
4	Pamunkey	4/12	4/13	19.0	464,900	57.3	266,500	259,700
5	Pamunkey	4/13	4/14	22.9	666,200	72.4	482,100	476,000
6	Pamunkey	4/15	4/16	32.4	954,300	62.0	594,600	582,800
7	Pamunkey	4/16	4/17	25.5	994,500	57.4	570,500	556,300
8	Pamunkey	4/17	4/18	11.3	403,400	63.4	255,900	242,000
9	Pamunkey	4/19	4/20	9.5	354,900	68.4	242,600	233,800
10	Pamunkey	4/26	4/27	3.1	191,400	60.3	115,400	114,400
	James	4/26	4/27	14.0	579,600	30.9	179,100	166,300
11	James	4/27	4/28	7.0	356,200	66.6	237,300	234,600
12	Delaware	4/30	5/1	18.6	605,600	60.1	364,000	321,300
13	Delaware	5/1	5/2	23.8	722,300	43.0	310,900	280,000
14	James	5/1	5/2	16.2	723,200	70.7	511,600	506,400

Table 1 (continued). Summary of American shad egg shipments received at Van Dyke, 1985.

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
15	Delaware	5/6	5/7	9.8	278,700	46.2	128,700	118,000
16	James	5/7	5/8	4.4	173,200	25.9	44,800	44,240
17	Delaware	5/7	5/8	21.6	671,300	54.0	362,600	335,400
18	Delaware	5/8	5/9	8.5	258,400	62.7	161,900	153,800
19	James	5/8	5/9	6.4	218,100	48.2	105,200	103,600
20	Delaware	5/12	5/13	35.5	1,269,500	48.9	621,400	605,000
21	Delaware	5/13	5/14	19.2	900,100	52.4	472,500	464,000
22	Delaware	5/14	5/15	18.4	781,700	50.9	398,000	390,700
23	Delaware	5/15	5/16	13.3	675,700	43.9	296,300	286,500
24	Columbia	6/5	6/6	25.3	769,700	47.7	366,900	349,800
25	Columbia	6/7	6/8	29.7	808,800	39.6	319,900	296,700
26	Columbia	6/10	6/11	54.5	1,579,200	11.6	183,500	181,600
27	Columbia	6/11	6/12	45.7	1,242,600	0	0	0
28	Columbia	6/12	6/13	49.5	1,448,400	0	0	0
29	Columbia	6/13	6/14	30.2	844,700	0	0	0
30	Columbia	6/14	6/15	14.4	401,400	19.7	79,100	76,100

Table 1 (continued). Summary of American shad egg shipments received at Van Dyke, 1985.

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
31	Columbia	6/17	6/18	10.2	295,700	41.7	123,200	118,600
32	Columbia	6/18	6/19	17.2	467,900	52.0	243,400	235,700
33	Columbia	6/19	6/20	31.7	862,300	48.2	416,000	407,300
34	Columbia	6/20	6/21	32.6	886,700	38.1	337,900	288,500
35	Columbia	6/21	6/22	34.6	846,500	22.7	192,200	177,000
36	Columbia	6/24	6/25	21.9	665,800	41.8	278,000	276,270
37	Columbia	6/25	6/26	19.6	609,600	44.3	269,900	264,860
38	Columbia	6/26	6/27	11.7	339,200	42.2	143,200	139,000
	Pamunkey River		TOTALS	168.8	5,286,400	62.5	3,303,700	
	James River			48.0	2,050,300	52.6	1,078,000	
	Delaware River			168.7	6,163,300	50.5	3,116,300	
	Columbia River			428.8	12,068,500	24.5	2,953,200	
			GRAND TOTAL	814.3	25,568,500	40.9	10,451,200	

TABLE 2. Annual summary of Van Dyke production from 1976-1985.

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Egg Vol. (ℓ)	120.3	145.8	381.2	164.8	347.6	286.0	624.3	938.6	1,157.3	814.3
Egg No. (x 6)	4.0	6.4	14.5	6.4	12.6	11.6	25.9	34.5	41.1	25.6
Egg Viability (%)	52.0	46.7	44.0	41.4	65.6	44.9	35.7	55.6	45.2	40.9
No. of Viable Eggs (x 6)	2.1	2.9	6.4	2.6	8.2	5.2	9.2	19.2	18.6	10.1
Shad Stocked										
Fry	518,000	968,901	2,124,000	629.500	3,526,275	2,029,650	5,018,800	4,047,610	11,995,690	6,959,990
Fingerlings	266,000	34,509	6,379	34,087	5,050	23,620	40,700	98,300	30,500	114,538
TOTAL	784,250	1,003,410	2,130,379	663,587	3,531,325	2,053,270	5,059,500	4,145,910	12,026,190	7,074,528
Fish Stocked/Eggs Received	19.4	15.9	14.0	10.4	28.3	17.7	19.6	12.0		27.9
Fish Stocked/Viable Eggs	37.3	34.2	33.0	25.1	43.1	39.3	54.8	21.6	72.8*	68.2*

Total Shad Stocked from 1976 to 1985 - 38,472,028

*Eggs and fish that were not used for stocking purposes were not included.

Table 3. Production and utilization of juvenile American shad at the Van Dyke Research Station, 1985.

Fry Released into the Juniata River	5,415,400
Fry Released into the Lehigh River	600,000
Fry Released into the Schuylkill River	251,980
Fry Released into Conowingo Reservoir	812,190
Fry Released into Ponds at Van Dyke and Ancillary Facilities	251,773
Fry Provided to Benner Spring Research Station	583,521
Fry Provided to Wellsboro National Fishery Research and Development Center	50,700
Total Fry Production	7,965,564
Total Number of Viable Eggs	10,451,200
Survival (%) of all Fry	76.2%
Survival (%) (Tanks with Massive Mortalities of Known Origin Excluded)	81.2%
Fingerlings Released into the Juniata River:	
From the Van Dyke Facility	16,891
From the Rearing Pond (Van Dyke)	1,390
From the Settling Pond (Van Dyke)	2,907
From the Canal Pond (Thompsontown)	40,000
Fingerlings Provided to Radiation Management Corp.	665
Fingerlings Released into the Susquehanna River:	
From Benner Spring Ponds (to Conowingo Reservoir)	30,150
From Benner Spring Ponds (to below Conowingo Dam)	23,200
TOTAL FINGERLING PRODUCTION	115,203

Table 4. Summary of juvenile American shad stockings and fish transfer activities, 1985. *Fish transferred to ponds, raceways, other facilities. **25 ppm (2 days)/50 ppm (2 days).

Date	Tank	Number	OTC Treatment	Stocking Location	River of Origin	Age (days)	Size
*5/1/85	A4, B1	*126,773	25 ppm	Canal Pond	Pamunkey	17	Fry
*5/1/85	A4	* 10,000	25 ppm	Rearing Pond	Pamunkey	17	Fry
5/5/85	B2, B3	209,910	25 ppm	Juniata	Pamunkey	18	Fry
5/6/85	A3	112,310	25 ppm	Juniata	Pamunkey	22	Fry
5/7/85	B4, C1	214,985	25 ppm	Juniata	Pamunkey	18	Fry
5/9/85	C2, C3	412,635	25 ppm	Juniata	Pamunkey	19	Fry
5/12/85	D4, E1	296,595	25 ppm	Juniata	Pamunkey	19	Fry
5/13/85	E2	204,095	25 ppm	Juniata	Pamunkey	19	Fry
5/15/85	E3	207,390	25 ppm	Juniata	Pamunkey	19	Fry
5/17/85	A2	96,100	25 ppm	Juniata	Pamunkey	34	Fry
5/19/85	E4	133,150	25 ppm	Juniata	Pamunkey	16	Fry
5/19/85	A1	110,080	25 ppm	Juniata	Pamunkey	15	Fry
5/19/85	A4	224,740	25 ppm	Juniata	Pamunkey	15	Fry
*5/23/85	A2	* 5,000	25 ppm	Raceway, B.S.	Pamunkey	40	Fry
*5/28/85	B1	* 10,000	25 ppm	Rearing Pond	James	20	Fry
5/28/85	B1, B2	442,860	25 ppm	Juniata	James	20	Fry
6/2/85	B4	14,660	25-50 ppm**	Juniata	James	19	Fry
6/3/85	F2	150,000	25 ppm	Lehigh	Delaware	27	Fry
6/3/85	F3	150,000	25 ppm	Lehigh	Delaware	26	Fry
6/4/85	C3, D4	226,310	25-50 ppm**	Juniata	Delaware	20	Fry
6/5/85	F4	180,000	25 ppm	Lehigh	Delaware	28	Fry
6/5/85	B3	120,000	25-50 ppm**	Lehigh	Delaware	23	Fry
*6/5/85	D1, D3	*154,521	37,980 25 ppm 116,541 Control	B.S. Pond	Pamunkey	44	Fry
*6/6/85	C4, D2	*424,000	25 ppm	B.S. Pond	Pamunkey	44	Fry
6/6/85	C1, C2	251,980	25-50 ppm**	Schuylkill	Delaware	23	Fry
6/7/85	E1, E2, E3	456,300	50 ppm	Juniata	Delaware	19	Fry
6/9/85	A2, A3	394,440	50 ppm	Juniata	Delawre	20	Fry
6/9/85	A1, A4	295,860	50 ppm	Juniata	Delaware	19	Fry

Table 4 (continued).

Date	Tank	Number	OTC Treatment	Stocking Location	River of Origin	Age (days)	Size
6/10/85	E4, F1	269,880	50 ppm	Juniata	Delaware	19	Fry
7/1/85	A1, A2	284,360	50 ppm	Juniata	Columbia	19	Fry
7/3/85	A3, A4	248,550	128,950 6 hrs,50 ppm 155,410 12 hrs,50 ppm	Juniata	Columbia	19	Fry
7/5/85	Rearing Pond	415	25 ppm	Juniata	Rearing Pond	81	Fingerling
7/10/85	B1, B2	141,520	50 ppm	Juniata	Columbia	22	Fry
7/11/85	B3	67,650	50 ppm	Juniata	Columbia	19	Fry
7/11/85	Canal Pond	20,000	25 ppm	Juniata	Pamunkey (Canal Pond)	86	Fingerling
7/14/85	B4, C1, C2	298,580	25 ppm	Juniata	Columbia	19	Fry
7/15/85	F3, F4	890	50 ppm	Juniata	Columbia	24	Fry
7/16/85	C3, C4	214,710	50 ppm	Conowingo R.	Columbia	19	Fry
*7/17/85	D1	* 50,700	50 ppm	Wellsboro	Columbia	20	Fry
7/17/85	D1	42,230	50 ppm	Juniata	Columbia	20	Fry
7/18/85	D2, E1	221,050	50 ppm	Conowingo R.	Columbia	21	Fry
*7/19/85	D3	* 15,000	50 ppm	Rearing Pond	Columbia	21	Fry
*7/19/85	D3	* 90,000	50 ppm	Canal Pond	Columbia	21	Fry
7/19/85	D4	9,320	50 ppm	Juniata	Columbia	21	Fry
7/22/85	E2, E3, E4	137,830	50 ppm	Conowingo R.	Columbia	19	Fry
7/23/85	F1, F2	238,600	50 ppm	Conowingo R.	Columbia	20	Fry
8/26/85	Settling Pond Head	642	Feed	Juniata	Unknown	?	Fingerling
8/27/85	A3, A4	4,096	50 ppm	Juniata	Columbia	74	Fingerling
8/27/85	A1	1,645	50 ppm	Juniata	Columbia	76	Fingerling
8/28/85	Settling Pond	935	Feed	Juniata	Unknown	?	Fingerling
8/29/85	A2	2,755	50 ppm	Juniata	Columbia	78	Fingerling
8/30/85	C4	980	50 ppm	Juniata	Columbia	64	Fingerling

Table 4 (continued).

Date	Tank	Number	OTC Treatment	Stocking Location	River of Origin	Age (days)	Size
8/30/85	C2	1,275	50 ppm	Juniata	Columbia	66	Fingerling
9/3/85	C1	890	50 ppm	Juniata	Columbia	70	Fingerling
9/3/85	D1	930	50 ppm	Juniata	Columbia	68	Fingerling
9/3/85	Settling Pond	1,330	Feed	Juniata	Columbia	?	Fingerling
9/4/85	B3	790	50 ppm	Juniata	Columbia	74	Fingerling
9/4/85	B4	930	50 ppm	Juniata	Columbia	71	Fingerling
9/5/85	B1, B2	2,600	50 ppm	Juniata	Columbia	79	Fingerling
9/9/85	Settling Pond	665	Feed	RMC	Columbia	?	Fingerling
9/11/85	Canal Pond	20,000	50 ppm	Juniata	Columbia	75	Fingerling
9.13.85	Rearing Pond	975	50 ppm	Juniata	Columbia	77	Fingerling

Table 5. Mean daily mortality (M_d) and cumulative survival (S) for four groups of American shad fry, Van Dyke, 1985. Tanks with massive mortalities of known cause are excluded.

	19 day S > 85%			70% < 19 day S < 85%			(Outdoor Tanks) 19 day S < 70%			(Indoor Tanks) 19 day S < 70%		
Day	M_d	n	S	M_d	N	S	M_d	N	S	M_d	N	S
1	2.7	5	97.3	3.7	10	96.3	11.0	1	89.0	0.6	1	99.4
2	1.2	19	96.1	2.4	24	94.0	7.3	3	82.5	2.0	2	97.4
3	0.5	21	95.7	1.6	29	92.5	4.9	3	78.5	1.4	2	96.1
4	0.2	21	95.5	0.3	29	92.2	1.3	3	77.4	0.2	2	95.9
5	0.1	21	95.4	0.1	29	92.1	0.3	3	77.2	0.1	2	95.8
6	0.1	21	95.3	0.2	29	91.9	0.3	3	77.0	0.0	2	95.8
7	0.2	21	95.1	0.2	29	91.7	0.2	3	76.8	0.2	2	95.6
8	0.2	21	94.9	0.4	29	91.3	0.2	3	76.7	0.2	2	95.4
9	0.1	21	94.8	0.8	29	90.6	0.3	3	76.4	1.0	2	94.5
10	0.4	21	94.4	1.2	29	89.6	0.8	3	75.8	2.5	2	92.1
11	0.8	21	93.7	1.8	29	87.9	1.7	3	74.5	9.4	2	83.5
12	1.0	21	92.7	3.3	29	85.0	4.6	3	71.1	7.7	2	77.0
13	1.1	21	91.7	2.5	29	82.9	2.0	3	69.7	6.4	2	72.1
14	0.9	21	90.9	2.0	29	81.3	2.8	3	67.7	8.1	2	66.3
15	0.5	21	90.4	1.2	29	80.3	1.6	3	66.7	10.8	2	59.1
16	0.6	20	89.9	1.3	29	79.2	1.1	3	65.9	7.0	2	55.0
17	0.6	19	89.3	1.1	28	78.4	2.7	3	64.1	5.3	2	52.1
18	1.1	19	88.4	1.6	27	77.1	4.7	3	61.1	7.1	1	48.4
19	1.7	19	86.9	2.9	23	74.9	4.8	3	58.2	10.1	1	43.5
20	1.5	10	85.6	2.2	7	73.2	4.9	3	55.3	5.5	1	41.1
21	2.0	6	83.8	3.2	6	70.9	6.2	3	51.9	7.4	1	38.0
22	2.4	6	81.8	1.5	5	69.8	3.0	3	48.8			
23	2.1	4	80.1	1.5	4	68.8	1.5	3	48.1			
24	1.1	4	79.2	2.0	1	67.4	1.9	3	47.1			
25	1.6	4	78.0	1.9	1	66.1	4.8	3	44.9			
26	1.6	4	76.7	3.6	1	63.7	4.3	2	43.0			
27	3.2	4	74.3	5.8	1	60.0	5.2	1	40.7			
28	3.7	4	71.5	3.5	1	57.9	2.6	1	39.7			
29	3.4	4	69.1	2.7	1	56.4						

Table 5 (continued). Mean daily mortality (M_d) and cumulative survival (S) for four groups of American shad fry, Van Dyke, 1985. Tanks with massive mortalities of known cause are excluded.

	19 day S > 85%			70% < 19 day S < 85%			(Outdoor Tanks) 19 day S < 70%			(Indoor Tanks) 19 day S < 70%		
Day	M_d	n	S	M_d	N	S	M_d	N	S	M_d	N	S
30	2.5	4	67.4	1.3	1	55.6						
31	2.9	4	65.4	1.0	1	55.1						
32	2.2	4	64.0	1.4	1	54.3						
33	1.8	4	62.8	2.0	1	53.2						
34	4.0	4	60.3	5.8	1	50.1						
35	3.8	3	58.0	4.0	1	48.1						
36	4.0	3	55.7	3.5	1	46.5						
37	6.2	3	52.2	11.8	1	41.0						
38	5.9	3	49.2	12.0	1	36.1						
39	3.2	3	47.6	5.4	1	34.1						
40	4.8	3	45.3	7.6	1	31.5						
41	5.6	3	42.8	4.8	1	30.0						
42	5.0	3	40.6	4.7	1	28.6						
43	4.3	3	38.9	4.9	1	27.2						
44	3.8	2	37.4	6.2	1	25.5						
45	15.2	1	31.7	4.7	1	24.3						

Table 6. Summary of oxytetracycline marking of juvenile American shad at Van Dyke Research Station and Benner Spring Research Station, 1985. *Double mark, bath treatments. **Double mark, bath/feed treatments.

RIVER STOCKED

Treatment		Juniata	Conowingo Reservoir	Lehigh R.	Schuylkill R.	Below Conowingo Reservoir
25 ppm bath	Fry	2,664,850		480,000		
	Fingerling	20,415		-		
50 ppm bath	Fry	2,380,630	812,190*			
	Fingerling	37,866	-			
25 ppm bath (2 days)/ 50 ppm bath (2 days)	Fry	240,970		120,000	251,980	
50 ppm bath (6 hrs)	Fry	128,950				
Feed Treatment Only	Fingerling	2,907 (VD)	12,850 (BS)			
25 ppm bath	Fingerling		17,300 (BS)**			23,200 (BS)**
TOTAL	Fry	5,415,400	812,190	600,000	251,980	
	Fingerling	61,188	30,150			23,200

TABLE 7. Summary of oxytetracycline tagging research with American shad fry, Van Dyke, 1985.

Test	Tank/pond	Shipment	Tag type	Bath Concentration (ppm)	Bath Duration (hrs.)	Feed Concentration (g OTC/lb. feed)	Feed Duration (days)	Age at Tagging (days)	19 day Survival (%)	Tag Efficiency % Initial	Tag Efficiency % Secondary	No. examined for tags	Age at Sampling (days)
1	A2	1	bath --	25	12	---	---	5-8/ --	89.8	5.6	--	90	79
	A3	1	control-- (none)	--	--	---	---	--- --	78.8	---	--		
2	C4/P1	6	bath --	25	12	---	---	5-8 --	72.6	5.7	0	88	158
	D1/P3	6	bath/feed	25	12	3	14	15-18/115-128	85.2	7.0	0	71	158
	D2/P2	6	bath --	25	12	---	---	15-18 --	89.9	5.3	0	75	158
	D3/P4	7	control - (none)	--	--	---	---	--- ---	92.0	0	0	109	127/148
3	A1	24	bath --	50	6	---	---	15-18 --	71.8	96.9	--	65	62
	A2	24	bath --	50	12	---	---	15-18 --	82.9	100.0	--	59	62
4	B1	26	bath --	25	12	---	---	5-8 --	85.5	79.7	--	59	57
	B2	26	bath --	50	12	---	---	5-8 --	87.9	98.4	--	61	57
5	C4	33	bath/bath	50/50	12/12	---	---	5-8/15-18	75.2	98.0	99.0	102	49/64
6	D1	34	bath --	50	12	---	---	15-18 --	62.7	100.0	--	67	145

Table 8. Summary of 19 day mean growth and survival of American shad fry fed three different diets: *Artemia* nauplii (12 nauplii/fish-day) plus 150 micron AP100 larval diet (64.5 g/250,000 fish day) (2 tanks) *Artemia* nauplii (12 nauplii/fish-day) plus 200 micron milled *Artemia* flakes (64.5 g/250,000 fish-day), *Artemia* nauplii only (18 nauplii/fish-day).

	DIET			
	Artemia plus AP 100 Tank C1	*Artemia* plus AP 100 Tank D3	*Artemia* plus milled *Artemia* Flakes (C2)	*Artemia* nauplii Only (D4)
Shipment	32	35	32	35
Initial Tank Density	126,700	83,100	116,700	85,800
Mean Length (mm) (n = 25)	12.5	11.6	11.9	11.6
Survival (%)	86.1	48.1	84.0	11.8

Table 9. Summary of 15 day mean growth and survival of American shad fry fed *Artemia* nauplii (12 nauplii/fish-day) plus three sizes of AP100 larval diet (64.5 g/250,000 fish-day), Van Dyke, 1985.

	Larval Diet Size		
	150 u	200 u	250 u
Shipment	36	36	37
Initial Tank Density	144,500	133,500	151,300
Mean length (mm) (n=25)	11.5	12.3	11.5
Survival (%)	90.3	79.2	72.6

Table 10. Mortalities of American shad fry transported in a 0.25% solution of solar salt vs an unsalted control, Van Dyke, 1985.

	F3 With Salt				F4 Without Salt			
Day	Density	Daily Mortality	% Daily Mortality	Cumulative Mortalities	Density	Daily Mortality	% Daily Mortality	Cumulative Mortalities
0								
	4,445				5,160			
1		1,359	30.6	30.6		3,127	60.6	60.6
	3,086				2,033			
2		2,018	65.4	76.0		978	48.1	79.6
	1,068				1,055			
3		306	28.7	82.9		481	45.6	88.9
	762				574			
4		83	10.9	84.7		108	18.8	91.0
	679				466			
5		144	21.2	88.0		109	23.3	93.1
TOTAL STOCKED	535				357			
TOTAL		3,910		88.0%		4,803		93.1%

TABLE 11. Transport of American shad fingerlings (Pond #2) to Lapidum Access Area, Maryland.

10-22-85 R. Witherite Gooseneck Trailer 361 miles
T. Bender Travel Time for Fish - 5.5 hours compartment #2, 14 hours compartment #1
Lv. BS 11:45 a.m. - Arrive Lapidum 5:20 p.m.
Lv. Lapidum 6:00 p.m. - Arrive BS 12:15 a.m.

Avg. Length of Fish 3.7 inches
Avg. Weight of Fish 6.3 grams Total Wt. Hauled - 149 lbs.

# Fish	5,000* Compt. 1	3,050 Compt. 2
Time	11:45 a.m.	11:45 a.m.
DO (ppm)	9.2	11.0 (turned O^2 down)
Temp. °C	12.5	12.5
Time	12:55 p.m.	12:55 p.m.
DO (ppm)	6.4 (turned O^2 up)	6.2
Temp. C	13.0 (fish don't look good, lots of scales)	12.5
Time	2:15 p.m.	2:15 p.m.
DO (ppm)	5.0 (turned O^2 up)	6.0 (turned O^2 up)
Temp. °C	13.0	13.0
Time	3:30 p.m.	3:30 p.m.
DO (ppm)	4.8 (turned O^2 up)	13.0
Temp. °C	13.0 (tried Fresh Flow - too powerful)	13.0
Time	5:25 p.m.	5:25 p.m.
DO (ppm)	6.4 (changed to new Bio Weave diffuser)	13.8
Temp. °C	13.0	13.0
River - 15.5°C DO 7.5		Fish Stocked - Look Good
Time	6:00 p.m.	Bio Weave Oxygen Diffusers must lie flat on the bottom to produce fine oxygen bubbles.
DO (ppm)	9.4	
Temp. °C	13.0	
Time	9:03 p.m.	
DO (ppm)	14.0	
Temp. °C	13.0	
Time	12:15 a.m.	
DO (ppm)	14.0	
Temp. °C	13.0	

*Compartment #1 returned to raceway <u>after 14 hours in tank</u>, immediate (1/2 hr) mortality 527. Six hour delayed mortality 1,274. An additional 1,023 at 30 hours. Total mortality after 54 hours in raceway 3,355 (67%).

TABLE 12. Transport of American shad fingerlings (Pond #1) to Lapidum Access Area, Maryland.

10-24-85	R. Witherite	Gooseneck Trailer	361 miles
	D. Truesdale	Travel Time for Fish	6 hours

Lv. BS 9:30 am - Arrive Lapidum 3:30 - Lv. Lapidum 4:00 pm Arrive BS 10:00 pm

Avg. Length of Fish 3.7 inches
Avg. Weight of Fish 6.3 grams Total Wt. Hauled - 176 lbs.

#Fish	3,600	2,300	2,000	1,750	3,000
	Compt. 1	Compt. 2	Compt. 3	Compt. 4	Compt.5
Time	9:23 am	9:23 am	9:23 am	9:23 am	9:23 am
DO (ppm)	14.7	11.4	16.8	16.0	13.8
Temp.°C	13.2°	13.2°	13.2°	13.2°	13.2°
Time	11:00 am	10:00 am	11:00 am	11:00 am	11:00 am
DO (ppm)	9.3	13.6	15.8	13.1	12.0
Temp.°C	13.2	13.0	13.0	13.0	13.0
	Change 0^2 Bottle at 11:50 am				
Time	1:00 pm	1:00 pm	1:00 pm	1:00 pm	1:00 pm
DO(ppm)	4.5 Adjusted	12.6	14.7	11.0	11.7
Temp.°C	13.5 0^2 Valve	13.5	13.5	13.5	13.5
Time	2:00 pm	2:00 pm	2:00 pm	2:00 pm	2:00 pm
DO (ppm)	8.4	10.3	12.7	9.8	9.0
Temp.°C	13.5	13.5	13.5	13.5	13.5
Time	3:15 pm	3:15 pm	3:15 pm	3:15 pm	3:15 pm
DO (ppm)	11.0	8.6	10.3	8.0	6.6
Temp.°C	13.5	13.5	13.5	13.5	13.5

River - 17.5°C D.O. 8.7 ppm All Fish Stocked in Excellent Condition

Note: 0.25% Salt and Antifoam (5 ml/100 gal) used in all compartments

Appendix 1. Larval survival to 19 days of age for American shad fry fed three different diets: *Artemia* nauplii (12 nauplii/fish-day) plu 150 micron AP100 larval diet (64.5 g/250,000 fish day) (2 tanks), *Artemia* nauplii (12 nauplii/fish day) plus 200 micron milled *Artemia* flakes (64.5 g/250,000 fish-day), *Artemia* nauplii only (18 nauplii/ fish-day).

	DIET			
Age (Days)	*Artemia* plus AP 100 Tank C1	*Artemia* plus AP 100 Tank D3	*Artemia* plus milled *Artemia* Flakes (C2)	*Artemia* nauplii Only (D4)
1	98.0		95.6	
2	97.7	98.2	94.3	96.6
3	97.0	97.0	93.4	96.4
4	96.9	96.9	93.3	96.2
5	96.8	96.8	93.3	96.1
6	96.8	96.7	93.3	96.0
7	96.8	96.6	93.3	95.6
8	96.8	96.5	93.2	94.8
9	96.6	95.9	93.1	94.0
10	96.4	95.2	92.5	91.6
11	95.8	84.9	91.8	83.8
12	94.8	80.3	91.3	63.8
13	93.2	74.3	90.6	55.2
14	92.0	72.2	90.0	34.7
15	91.8	67.4	89.9	24.3
16	90.8	64.1	88.1	20.8
17	89.8	57.6	86.3	16.3
18	88.1	53.5	85.0	12.6
19	86.1	48.1	84.0	11.8

Appendix 2. Mean incidence of feeding (%) for American shad fry fed three different diets: *Artemia* nauplii (12 nauplii/fish-day) plus 150 micron AP100 larval diet (64.5 g/250,000 fish-day) (2 tanks), *Artemia* nauplii (12 nauplii/fish day) plus 200 micron milled *Artemia* flakes (64.5 g/250,000 fish-day), *Artemia* nauplii only (18 nauplii/fish-day).

	DIET							
	Artemia plus AP 100 Tank C1		*Artemia* plus AP 100 Tank D3		*Artemia* plus milled *Artemia* Flakes (C2)		*Artemia* nauplii Only (D4)	
Age (days)	Dry Diet	*Artemia*	Dry Diet	*Artemia*	Dry Diet	*Artemia*	Dry Diet	*Artemia*
5	68	20	24	4	16	4	None	16
7	52	16	52	36	36	4	Fed	4
9	20	4	60	8	68	0		12
11	-	-	56	44	40	0		12
13	100	44	-	-	28	0		-
15	52	32	72	44	64	0		76
17	40	44	44	32	28	0		40
19	48	36	44	28	44	0		48
Mean	54.4	28	50.3	28	40.5	1	-	30

Appendix 3. Larval survival to 15 days of age for American shad fry
Artemia nauplii (12 nauplii/fish-day) plus three sizes of AP100 larva
diet (64.5 g/250,000 fish-day), Van Dyke, 1985.

	DRY DIET SIZE		
Age (days)	150 µ	200 µ	250 µ
2	99.5	99.3	97.0
3	99.1	99.1	95.6
4	98.9	98.9	95.1
5	98.8	98.8	95.0
6	98.7	98.7	95.0
7	98.3	98.2	94.6
8	97.7	97.3	94.0
9	96.2	94.0	88.9
10	94.6	88.1	84.0
11	93.1	86.5	80.2
12	91.9	82.5	76.2
13	91.2	80.0	73.5
14	90.7	79.5	72.9
15	90.3	79.2	72.6

Appendix 4. Mean incidence of feeding (%) for American shad fry fed *Artemia* nauplii (12 nauplii/fish-day) plus three sizes of AP100 larval diet (64.5 g/250,000 fish-day), Van Dyke, 1985.

	DRY DIET SIZE					
	150 u		200 u		250 u	
Age (days)	Dry Diet	*Artemia* Nauplii	Dry Diet	*Artemia* Nauplii	Dry Diet	*Artemia* Nauplii
5	32	24	0	12	0	4
7	0	16	0	8	4	12
9	24	52	4	32	24	20
11	16	32	8	16	12	28
13	52	52	0	16	4	24
15	48	20	4	16	4	84
Mean	28.7	32.7	2.7	16.7	8	28.7

JOB IV. JUVENILE AMERICAN SHAD OUTMIGRATION ASSESSMENT

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INTRODUCTION

This Job is particularly important to SRAFRC for several reasons. Late summer netting collections in the North Branch Susquehanna provide an indication of spawning success of American shad adults transferred to the basin from the Hudson River. Seining on the lower Juniata River may form the basis for future comparison of relative abundance of hatchery produced juveniles, and based on detection of the oxytetracycline mark on otoliths, provides a correction factor for calculating percentage of tagged fish which retain the mark to the point of emigration.

Weekly cast net samples from forebays at the York Haven, Safe Harbor, and Holtwood projects during September through December indicate the timing and duration of outmigration, allow for comparison of sizes of young shad as the season progresses, and from OTC analysis of otoliths, provides samples for computing the relative contribution of hatchery versus natural production of juveniles in the program. Cooling water intake strainers and screens at Safe Harbor, Conowingo, and Peach Bottom Atomic Power Station serve as passive collectors of outmigrant shad as these fish are entrained. These results may be useful for determining relative abundance.

Seining and trawling efforts below Conowingo Dam may be used to indicate whether or not shad are successfully escaping the river on their seaward journey. Collection success at the river mouth is density dependent, and due to the large expanse of the lower river and upper Chesapeake Bay being sampled, it is likely that significant numbers of shad will not be taken here until or unless a substantial outmigrant population is developed upstream and successfully passed at the hydroprojects.

Numerous individuals have contributed to juvenile collection and record-keeping in 1985. The author extends appreciation to Leroy Young and Larry Jackson (PFC), Joe Nack and Tom Koch (NES), Paul Heisey and Chris Frese (RMC), Ted Jacobsen (Ecology III), Tom Teitt (GPU-Nuclear), Dale Weinrich (MD DNR), and plant personnel at York Haven, Safe Harbor, Holtwood, and Conowingo for assistance provided. Penn State student intern Andrew Shiels did most of the processing and OTC analysis of otoliths under the direction of PFC researchers at Benner Spring.

EVALUATION OF SPAWNING SUCCESS FROM HUDSON RIVER TRANSFERS

Following considerable reconnaissance sampling in 1982-1984, four potential index seining sites were identified for future year comparison of relative abundance in the North Branch. These are located at Coxton Yards near Harding, Wilkes-Barre, Danville, and Sunbury. The 1985 sampling plan required that each site be sampled on four occasions biweekly from mid-August through September. Standardized effort involved at least 3 hauls of the 300-ft x 7-ft x 3/8-in seine at 30 minute intervals on each sample date. Wilkes-Barre and Sunbury were sampled during early morning hours and Coxton Yards and Danville were seined in the early evening.

North Branch Sampling Results

PFC and NES biologists cooperated in the North Branch survey. A total of 63 hauls were made on 10 dates between August 14 and September 25 (Table 4.1). A site at Falls, PA was sampled once and the Coxton Yards site was only sampled twice as a result of closure of the access ramp due to vandalism. No American shad juveniles were collected, though one adult was taken at Danville on August 29. Two blueback herring juveniles (57mm and 62mm FL) were collected at Wilkes-Barre on August 15, indicating that adults from the Hudson River reproduced in the North Branch. Twenty-four other species were taken in these collections (Table 4.2). River flows were slightly below normal all summer.

Staff from the Susquehanna SES Biological Laboratory (Ecology III) sampled the intake screens at PP&L's Susquehanna SES at Beach Haven each day between September 6 and October 11. No juvenile shad or herring were taken there. These investigators did however collect one small adult shad on May 7 while electrofishing in the river downstream from Beach Haven.

JUNIATA RIVER JUVENILE SHAD SURVEY

As noted in Job III several million shad fry and thousands of fingerlings were stocked into the Juniata River at Thompsontown from the Van Dyke hatchery. In past years it was determined that a single site at Amity Hall near the river mouth was an effective location for netting young shad. However, by restricting Juniata River collections to one location, it is doubtful that an accurate relative abundance relationship can be developed for year-to-year comparison.

As in the North Branch, PFC and NES worked together at Amity Hall. Gear used was a beach seine measuring 150-ft x 6-ft with ½-in mesh bag. Three hauls were made at 30-minute intervals between 6:30 and 9:10 am on each collection date. Amity Hall was sampled biweekly between August 21 and October 3, and weekly thereafter throughout October.

Results - Juniata River

A total of 24 seine hauls were made on eight dates. Juvenile shad were collected during each of the initial seven surveys when water temperatures ranged from 59-78°F. No shad were taken on October 31 and temperature had dropped to 50°F. Catch per unit effort ranged from 4 to 22 shad per haul (Table 4.3). A total of 212 juvenile American shad were collected and these fish measured from 55 to 119 mm (FL), with an average length of 93 mm. Ten fish(5%) displayed abnormalities such as deformed jaws and short gill covers. Shad were frozen and returned to Benner Spring for otolith analysis (OTC presence). Other fish in collections at Amity Hall included carp, spotfin, comely, and spottail shiners, smallmouth bass, redbreast and pumpkinseed sunfish, gizzard shad and walleye.

During a smallmouth bass survey of the Juniata River, the PFC Area Fisheries Manager collected several young shad while electrofishing. Two shad were shocked at Amity Hall on August 6, 1 was taken upstream from Thompsontown on August 13, and 17 fish were collected from Millerstown to a reach several miles below Newport on two sample dates in mid-August and mid-September. Fish shocked in August averaged 94 mm and in September 112 mm total length.

SHAD COLLECTIONS IN THE LOWER SUSQUEHANNA RIVER

Based on radiotelemetry results from Hudson River transplanted adult shad and the occurrence of ripe fish, it appeared that some reproduction happened in the vicinity of York Haven Dam and in Lake Clarke. Also, progeny from the 950 adult shad stocked near Harrisburg from the Conowingo trap, and normal exodus of outmigrant hatchery fish from the Juniata River would be expected to contribute to a sizable mixed stock of young shad in the lower Susquehanna during autumn months. Several agencies, consultants and power companies contributed effort to the downstream juvenile monitoring program in 1985.

Cast nets have been effective in collection of young shad at hydroproject forebays in past years. Because of the vagaries of sampling with such gear, these collections cannot be used as an indication of relative abundance. However, in 1985, 20-ft diameter cast nets were used to document occurrence of shad and timing of migration at York Haven, Safe Harbor, and Holtwood. Such collections were also necessary to provide fish for the OTC analysis for determining natural versus hatchery origin.

The cast net sampling was conducted by NES and PFC biologists during September through early December. A reconnaissance survey on August 20 indicated that shad had not yet reached York Haven. From September 5 through November 20, York Haven forebay was sampled weekly, usually near dawn. Safe Harbor forebay sampling started in late September following successful shad collection at York Haven. Netting continued weekly during late morning and afternoon through November 21. Similarly, Holtwood collections started one week after first occurrence of shad at Safe Harbor and continued weekly into December.

RMC biologists used boat-mounted electrofishing gear in the York Haven forebay on 3 dates in October and near Conowingo Dam on one occasion in December. They also used a lift net measuring 8-ft x 8-ft with 3/4-in mesh at Safe Harbor (October 29), Conowingo (November 13) and Holtwood (14 dates between October 16 and December 13). The purpose of these collections was to take large (5-7") fingerlings for a radiotelemetry feasibility study initiated by PECO.

In response to sightings of "dimpling" shad, NES and PFC personnel also attempted seining near Wrightsville, midway between York Haven and Safe Harbor, on two dates in September. The 300-ft net used in the North Branch was employed here.

As in past years, cooling water intake strainers at Safe Harbor were examined by SHWPC personnel for entrained shad on a daily basis between September 1 and December 5. Conowingo strainers were examined by RMC biologists once per week from October 9 through December 11, and Peach Bottom APS intake screens were sampled three times each week between October 16 and November 27.

Results at York Haven and Wrightsville

Following three unsuccessful attempts, juvenile shad were first collected at York Haven on September 19. Routine weekly collections from that date through October 17 produced 107 juveniles in 54 casts along the turbine intake gallery and near the trash sluice (Table 4.4). These fish ranged in size from 107-165 mm and averaged 125 mm fork length. An additional 12 shad were taken during a special attempt on October 15 as a verification of species composition during hydroacoustic studies. The last successful collection took 5 shad on November 14 when water temperature was 51°F.

RMC was very successful electroshocking juvenile shad at York Haven. On three dates between October 15-22, 397 juvenile and 1 adult American shad were taken during 4½ hours of fishing time in the forebay.

Using the 300-ft haul seine, PFC, NES and RMC biologists collected 29 young American shad at Wrightsville on September 10 and 19. These fish averaged 110 mm (range 82-125 mm) and were characterized by unusually high incidence of deformities (25%). Gizzard shad dominated other fish in the Wrightsville collections.

Safe Harbor Results

In 8 consecutive weekly attempts with cast nets at Safe Harbor between September 26 and November 21, juvenile shad were taken on only 2 dates, October 10th and 24th (Table 4.5). The 31 American shad were collected at the forebay trash gate and along the skimmer wall near the powerhouse. They ranged in size from 81 to 138 mm and averaged 125 mm fork length. Two bluebacks taken on October 10 measured 98 and 103 mm. Using the 8-ft by 8-ft lift net, RMC collected 59 juvenile shad in 128 lifts at Safe Harbor on October 29. Other fish in the lift net included 2 bluegills and 4 white crappie.

As indicated earlier SHWPC personnel inspected cooling water strainers from all operational turbines at Safe Harbor daily from September 1 through December 5. A total of only 15 shad were collected there, all between October 14 and November 17. Twelve of the fish came from old units (3-7) and 3 from new units 8 and 12. All but one of the shad were taken during the first 2 weeks of November. These fish ranged in size from 105 to 160 mm and averaged 129 mm. Hundreds of gizzard shad were taken from the Safe Harbor strainers during the sample period.

Holtwood Results

Young shad were first taken by cast net at Holtwood on October 24 and continued to be collected there on each sample date through December 4 (Table 4.6). Hundreds of American shad were cast netted on each attempt after November 14 along with many hundreds of young gizzard shad. Very little effort was used at Holtwood to collect fish. American shad ranged in size from 83 to 158 mm and averaged about 125 mm. Samples from all three hydroprojects were returned to Benner Spring for otolith analysis.

RMC's lift net was particularly effective at the Holtwood project where young shad appear to congregate during late November. In 102 lifts on eight dates between November 6 and December 4, an estimated 3,300 American shad were netted (mostly released alive) along with 4 adult shad, 3 adult herring, and several thousand gizzard shad. Earlier lift net collections during late October produced an additional 263 juvenile and

2 adult shad, and 2 adult and 1 juvenile blueback herring. In comparison to November catches, these were produced in 251 lifts. Finally by mid-December, with water temperatures falling to 34-37°F, shad numbers declined in lift net collections at Holtwood (Table 4.7).

Results from Conowingo and Peach Bottom Collections

Conowingo strainers (11 units) were examined once per week from October 9 through December 11. Four shad were collected on November 13 and 5 on November 20. One hundred to one thousand or more gizzard shad were taken from the strainers each week. RMC deployed their lift net in the Conowingo forebay on November 13 and collected 5 juvenile American shad, one gizzard shad and one white crappie in 85 lifts. On December 9, 2¼ hours of electrofishing in the Conowingo forebay produced only 14 gizzard shad.

Only one unit (#2) was operational at Peach Bottom APS during the autumn of 1985. Complete screen wash samples were examined every Monday, Wednesday, and Friday by RMC personnel during October 16 through November 27. A total of 26 juvenile American shad were collected at Unit 2 on various widely scattered dates when water temperatures ranged from 62 to 46°F. The 6 shad collected on October 18 were badly decomposed and are believed to have floated into the screen dead. Shad taken from strainers and screens at Safe Harbor, Conowingo and Peach Bottom were returned to Benner Spring for OTC analysis. Collecting dates and numbers of shad taken by impingement are shown in Table 4.8. Daily river flow and average water temperature as measured at Safe Harbor during September through mid-December is displayed in Figure 4.1.

SHAD COLLECTION BELOW CONOWINGO DAM

Maryland Department of Natural Resources continued their regular upper Bay juvenile sampling program during July through October, 1985 (Job VII). Prior to initiation of outmigrant sampling in the lower Susquehanna River in November, DNR personnel conducted midwater trawl trials in the York Haven forebay to test the effectiveness of this gear for collecting juvenile shad. Trawling was conducted at dawn and near dusk on October 16, 17, 22 and 23. No American shad were caught with the gear despite their presence as shown with cast nets, electroshocking, and hydroacoustic signals. Gear avoidance by shad juveniles is thought to be the reason for their absence in midwater trawl samples. In an attempt to increase net efficiency the ½-inch trawl belly mesh was replaced with 1¼-inch mesh net, thus allowing for increased speed during trawling. Subsequently, the midwater trawl did catch juvenile gizzard shad in the lower Susquehanna River which were absent from samples prior to modification, indicating increased efficiency.

Other gear used by the DNR in the 1985 outmigration survey included a 16-ft otter trawl and a haul seine measuring 200-ft x 10-ft with ½-inch stretch mesh. Single samples were taken at 14 sites each week utilizing gear at locations shown in Figure 4.2. Sampling began the first week of November and continued through the second week of December. A total of 30 seine hauls, 15 otter trawl runs, and 51 midwater trawl runs were conducted during this 6-week period (Tables 4-9 and 4-10). Catch was comprised mainly of gizzard shad, spottail shiners, yellow perch and white perch. Though no American shad were taken during this survey, one shad was collected during supplemental sampling in late October in the lower river (see Job VII).

OTC MARK DETECTION ANALYSIS

Juvenile shad from all collections at Amity Hall and lower river power stations were returned to Benner Spring for otolith processing. Otoliths were surgically removed from the fish, mounted on slides with Permount, ground and polished on both sides, and viewed under fluorescent light to detect the occurrence of the OTC ring (or rings). A faint mark was graded +, a moderate mark ++, and an intense mark +++.

As noted in Job III, approximately half the shad fry stocked into the Juniata River were marked with OTC at 25 ppm concentration and the remainder at 50 ppm. Results presented in Table 3.7 show that only 5.9% (19 of 324) of shad marked at the lower OTC concentration retained a visible mark up to age 158 days. Conversely, 100 of 101 (99%) of the fish marked at 50 ppm retained marks. If all downstream migrants in the Juniata were equally available for capture at Amity Hall during the 9-week collecting period (i.e no differential mortality between fish marked at different concentrations, and no early exodus from the river prior to mid-August sampling), then a predicted rate of positive marks at this location would be about 53%. As these hatchery produced fish moved downstream in the Susquehanna and joined naturally produced (unmarked) juvenile shad, mark detection rate should decline in relative proportion to the abundance of wild fish (assuming hatchery and wild fish have similar daily survival).

The 2.7 million fry marked at 25 ppm OTC were the earliest fish stocked from Van Dyke. Since the Juniata and mainstem Susquehanna River above dams may both be utilized by shad as summer nursery waters, it is likely that some early hatchery plants passed Amity Hall prior to later (50 ppm OTC mark) plants. Increasing mark detection rates over time from Amity Hall collections would confirm the occurrence of this movement pattern.

As shown in Table 4.3 the first collecting attempt at Amity Hall occurred on August 21 and the CPUE was the second highest recorded for the 8 sampling dates. Thus it is probable that shad moved past Amity Hall prior to mid-August. If the early outmigrants (those not sampled) largely represented early hatchery stockings (i.e. marked at 25 ppm OTC), then the mark detection rate for later samples would be expected to be higher than the predicted 53% due to a preponderance of later stocked fish (50 ppm OTC) in collections. Assuming this sequential movement continues in the lower Susquehanna, mark detection rates at and below York Haven should display a similar trend of fewer marks in earliest collections.

Minimum sample sizes for mark detection analysis were derived from tables provided in Simon and Schill (1984). Recognition of at least a 5% incidence of marked fish from a population at 95% confidence required a sample size of at least 60 fish from Amity Hall. A 90 fish sample from lower river collections permits a more critical look (99% confidence) where a mixed stock of shad (wild and hatchery) is expected.

RESULTS

In the first two collections of shad at Amity Hall (8/21 and 9/4), 9 of 20 fish analyzed (45%) displayed OTC marks. Five of the marks were graded ++ or better. In the next four collections at this site (9/18 through 10/18) 35 of 42 fish (83.3%) retained marks, 21 at grade ++ or better. Overall mark detection rate from Amity Hall collections was 70.9%. It appears that the sequential movement strategy in the lower Juniata River is confirmed and that earliest hatchery stockings passed Amity Hall prior to initiation of seining there.

Five York Haven shad collections had subsamples returned to BSRS for mark analysis. Of the 13 fish examined from samples taken on 9/19 and 9/26, only 1 (7.7%) displayed a mark. Of 43 shad analyzed from later collections (10/3 thru 10/17), 27 (62.8%) were marked. These results again appear to confirm the postulated sequential migration pattern, however, the outmigrant population at this point in the river is composed of a mixture of hatchery and wild fish. It may be expected that fish naturally produced in the York Haven/Harrisburg area emigrate sooner than hatchery produced fish due to their proximity in the river as water temperatures decline. If this is true and if wild fish make up a substantial portion of the mixed run, then earliest collections at downstream sites should show a dominance of unmarked fish.

Shad were collected at Wrightsville, about 14 miles below York Haven, on September 10 and 19. All 29 fish taken were analyzed for the OTC mark and the mark was detected from 12 fish (41.4%). These collections were made about the same time that shad first appeared at York Haven and a significant fraction of them were confirmed to be of hatchery origin. Therefore, if some portion of the juvenile stock in this reach of the river was of natural origin, it appears that their migration coincides with that of fish from the Juniata River.

Twenty-seven of the 31 shad collected with cast nets at Safe Harbor on 10/10 and 10/24 were analyzed and 16 fish (59.3%) displayed the OTC mark. Subsamples of shad taken from five collections at Holtwood during 10/24 through 11/21 were also processed. Of the 61 fish examined, 38 had detectable OTC marks (62.3%) and 20 of the marked individuals were graded ++ or better. The two October samples showed 54% and the three November samples had 68% marked fish.

A total of 35 shad were collected from strainers and screens at Peach Bottom APS and Conowingo during 10/18 thru 11/25. Only 5 of the 24 fish analyzed for the OTC mark were positive (20.8%). Although the sample size is small the results here contrast markedly from upriver mark detection rates. If all samples from York Haven, Wrightsville, Safe Harbor and Holtwood are pooled, 94 of 173 fish or 54.3% were marked (range 41-62%). A significantly reduced marked population below Holtwood could be caused by differential mortality of hatchery versus wild fish passing Holtwood, or more likely, the addition of large numbers of unmarked fish into Conowingo Pond.

Of the 30,150 fingerling shad stocked directly into Conowingo Reservoir (Table 3.6), 12,850 were unsuccessfully marked with OTC-laced feed and 17,300 were bathed in 25 ppm OTC concentration. At an average mark retention rate of less than 6% at 25 ppm only about 1,000 of the fingerlings would be expected to show the mark. The 800,000+ fry stocked into Conowingo Pond were double-marked in 50 ppm OTC. Only 1 of the 5 marked shad from Peach Bottom/Conowingo showed the double mark. Finally, we cannot rule out the possibility that natural reproduction occurred in the Holtwood vicinity or in Conowingo Pond, thus contributing to the unmarked population in this lower section of river. The single American shad juvenile collected below Conowingo Dam by Maryland DNR was preserved in formalin prior to freezing and displayed no mark. All results discussed above are summarized in Table 4.11.

DEFORMITIES IN JUVENILE SHAD

For the past several years a low incidence of physical deformity has been noted in juvenile shad collected in the Susquehanna River. Most frequently this is displayed as a deformed lower jaw, shortened gill covers, or irregular spinal curvature. Since these conditions are rarely noted in collections of wild shad juveniles in other East Coast rivers, we presume they result from hatchery culture (e.g., diet, crowding, handling, etc.).

All shad netted at Amity Hall are presumed to be of hatchery origin. Therefore incidence of abnormalities should be highest in these collections. As indicated earlier in this report, 10 of 212 shad (4.7%) taken at Amity Hall were deformed. Four of these fish were returned to BSRS and 3 (75%) carried the OTC mark. Also all three deformed shad from Safe Harbor collections were marked fish.

Other anomalies analyzed for OTC included 5 fish from Wrightsville, 2 from Holtwood and 1 from Peach Bottom. None of these fish displayed the OTC mark. We cannot positively identify these individuals as hatchery fish though they may be part of the production lot marked at 25 ppm OTC.

DISCUSSION

Failure to collect any juvenile American shad in the North Branch Susquehanna River tends to support the radiotelemetry results discussed in Job V. It appears that most of the 3,200 Hudson River adults planted at Tunkhannock left the North Branch prior to spawning. This may account for our inability to collect juveniles in 1982 and 1984 in the upper reaches. Rapid downstream migration of adults following hauling may be indicative of handling stress. This downrunning phenomenon is well documented in tagging programs on the Delaware and Connecticut Rivers. To avoid this problem in the future it may be desirable to hold transplanted adult shad for several days prior to direct release to the river in an effort to reduce stress. There are currently no such facilities in the North Branch for maintaining large numbers of shad.

Shad collecting effort at Amity Hall was of similar intensity this year as in 1984 with 24 hauls on 8 dates compared to 25 hauls on 7 dates. However, the 212 total catch of shad and 93 mm average length differed considerably from 1984 (1,295 fish averaging 75 mm). This was not unexpected since fry production at Van Dyke in 1985 was only about 45% of the record 1984 stocking. Larger average size of fish in 1985 may be partially explained by enhanced growth rate due to reduced competition for food, and the fact that most fry stocked this year were 4-10 days older than in 1984 giving them an early feeding advantage.

As pointed out in the 1984 Job IV accomplishment report, cast net sampling at hydroproject forebays cannot be used for determining relative abundance of juvenile shad. In 1985, juveniles first appeared at York Haven on 9/19 when water temperature was 71°F and most fish passed this project site by 10/31 (55°F). Shad were first collected at Holtwood on 10/24, peaked in abundance in late November, and apparently completed passage at that site by about the third week in December (37°F). These collections indicated that the peak of the run took about 5 weeks to migrate 32 miles through Lake Clarke and Lake Aldred. This period of migration is about 2 weeks longer than was observed in 1984. Since timing and rate of migration are largely related to falling water temperatures, it is interesting to note that during November, 1985 temperature declined at an average daily rate of 0.5°F compared to almost twice that rate in 1984.

Work conducted by RMC biologists using electrofishing at York Haven and a lift net at Holtwood offered an opportunity to evaluate the effectiveness of sampling gear not extensively used in the past. Both gears were very effective at capturing shad and the lift net was particularly useful for taking live fish for research purposes. With all other net, strainer and screen collections in the lower river producing fewer than 600 juvenile shad during autumn 1985, the thousands of shad taken in the lift net at Holtwood during peak weeks in November provided a gross indication of the magnitude of the run. In the 3 decades of upstream stocking and juvenile assessment in the Susquehanna (i.e. studies by Walburg, Whitney, Carlson, etc.), such numbers of shad have never before been recorded.

Catch of shad in cooling water strainers at Safe Harbor Dam in 1985 was considerably reduced compared to 1984 (15 fish versus 112). New Units 8 and 12 were frequently on-line but took only 3 of the entrained shad.

Perhaps the location and/or configuration of intakes and strainers at these new units makes them less effective than old units for collecting shad. The 9 shad collected from strainers at Conowingo exceeded numbers taken there in prior years (3 in 1984; 1 in 1983). With such small numbers little can be said about catch effectiveness or relative abundance. Peach Bottom entrainment sampling was similar to past years. The 26 shad collected from the Unit 2 intake screen compares with 38 and 31 shad collected in 1984 and 1983, respectively. Considering that 800,000+ double-marked fry were stocked into Conowingo Pond in 1985, it is somewhat surprising that shad catch at Peach Bottom was not greater. As mentioned, only one of the PBAPS shad evaluated showed the double OTC mark.

Maryland DNR's juvenile shad survey in the lower river and Flats area repeats past year results. Considering the size of the area being sampled, juvenile shad are apparently not in sufficient abundance below Conowingo to be detected with the intensity of the present survey. It may be useful to investigate shad collecting opportunities in the river immediately below Conowingo Dam where fish may be more concentrated. Such a survey should be scheduled 1 or 2 weeks following peak emigration at Holtwood.

Results of the OTC mark retention rates are somewhat speculative because of the large fraction of hatchery released fry which were not effectively tagged. However, with analysis of control shad held at BSRS indicating 99% tag retention at 50 ppm OTC concentration and 5.9% at 25 ppm, we could predict that the population at Amity Hall would show 50-55% positive marking. As unmarked naturally produced fingerlings come into collections downstream in the Susquehanna, this predicted mark rate should decrease in proportion to their abundance. For example, with a 50% mark rate in the Juniata and a 25% mark rate in the lower river, we might assume that half the outmigrants were of natural origin. The total subsample of collections between York Haven and Conowingo which were analyzed for OTC presence was 197 shad of which 50% (99 fish) were marked. From this assessment it appears that very few outmigrant juvenile shad in the Susquehanna River in 1985 resulted from natural reproduction of transplanted adults. In 1986 all hatchery produced shad will be marked at 50 ppm OTC, and the analysis of outmigrant production from spawning compared to hatchery releases will be better defined.

REFERENCES

Simon, R.C., and W.B. Schill. 1984. Tables of sample size requirements for detection of fish infected by pathogens: three confidence levels for different infection prevalence and various population sizes. Journal of Fish Diseases 7: 515-520.

Table 4.1. Juvenile American shad collections in the mainstem Susquehanna River above Clarks Ferry, August 14 - September 25, 1985.

Date	Location	# Am. Shad	Effort*	Time	Temp.
8/14	Coxton Yards	0	6	2010-2220	84°F
	Falls	0	3	1610-1710	83 F
8/15	Wilkes-Barre	0	7	0810-1205	82 F
	Danville	0	3	1945-2105	87 F
8/16	Sunbury	0	4	0755-0950	82 F
8/28	Coxton Yards	0	5	1930-2215	77 F
8/29	Wilkes-Barre	0	5	0710-1000	75 F
	Danville	0	3	1935-2115	77 F
8/30	Sunbury	0	3	0720-0910	75 F
9/12	Wilkes-Barre	0	7	0730-1015	72 F
	Danville	0	3	1915-2025	70 F
9/13	Sunbury	0	3	0745-0850	67 F
9/24	Wilkes-Barre	0	5	0735-0940	72 F
	Danville	0	3	1900-2010	72 F
9/25	Sunbury	0	3	0715-0920	68 F

*Each unit of effort is one haul with 300'x7'x3/8" seine.

Table 4.2. List of fish species taken in the North Branch Susquehanna River haul seine collections during August and September, 1985.

SPECIES	Falls	Coxton Yards	Wilkes-Barre	Danville	Sunbury
Smallmouth Bass	X	X	X	X	X
Largemouth Bass			X		X
Bluegill		X	X	X	X
Pumpkinseed Sunfish		X	X	X	X
Redbreast Sunfish				X	X
Black Crappie		X		X	X
White Crappie		X	X	X	X
Rock Bass		X		X	X
Walleye		X	X	X	X
Tessellated Darter				X	X
Common Carp	X	X			X
Spotfin Shiner	X	X	X	X	X
Spottail Shiner		X	X	X	X
Golden Shiner		X			
Common Shiner		X			
Rosyface Shiner		X	X		
Comely Shiner			X	X	X
<u>Notropis</u> spp.		X	X		X
Quillback	X	X		X	X
White Sucker			X		X
Blueback Herring			X		
Am. Shad (adult)				X	
Gizzard Shad		X	X	X	X
Muskellunge	X				
Tiger Musky					X
Channel Catfish	X				X
Brown Bullhead					X

Table 4.3. Juvenile American shad collections at Amity Hall on the Juniata River during August 21 through October 31, 1985 (fork lengths in millimeters).

Date	Shad catch	Mean length	Length range	Effort*	Catch/ effort	Water temp.
8/21	52	94	81-119	3	17.3	78°F
9/4	26	86	71-106	3	8.7	76
9/18	31	86	55-106	3	10.3	67
10/3	67	96	62-112	3	22.3	63
10/10	11	98	89-107	3	3.7	62
10/18	12	87	74-101	3	4.0	57
10/24	13	98	65-116	3	4.3	59
10/31	0	-	-	3	0.0	50
Totals	212	93	55-119	24	8.8	-

* each unit of effort is a haul with the 150' x 6' x ½" seine

Table 4.4. Summary of juvenile American shad collections at York Haven Dam forebay, August-November, 1985 (fork lengths in millimeters).

Date	Shad catch	Mean length	Length range	Effort*	Time of day	Water temp
8/20	0	-	-	15	0630-0710	80°F
9/5	0	-	-	10	0640-0720	80
9/10	0	-	-	11	0625-0710	81
9/19	10	150	135-161	20	0635-0755	71
9/26	6	157	154-160	17	0710-0800	70
10/3	28	127	108-149	2	1820-1835	63
10/10	19	121	107-133	6	1830-1915	64
10/15	12	136	121-155	28	1350-1800	64
10/17	44	129	111-165	9	0710-0830	63
10/31	0	-	-	1	0950	55
11/7	0	-	-	5	0710-0740	53
11/14	5	116	105-125	6	0725-0800	51
11/20	0	-	-	2	1615	48
Totals	124	125	105-165	132	-	-

* Each unit of effort is a single cast with the 20-ft diameter cast net.

Table 4.5. Summary of juvenile American shad collected with cast nets in Safe Harbor forebay, Sept.-Nov., 1985 (fork lengths in millimeters).

Date	Shad catch	Mean length	Length range	Effort (#casts)	Time of day	Water temp
9/26	0	-	-	14	1010-1120	72°F
10/3	0	-	-	9	1140-1240	65
10/10	7	116	81-132	9	1325-1415	63
10/16	0	-	-	8	1120-1200	63
10/24	24	127	114-138	2	1325-1335	61
11/7	0	-	-	8	1555-1630	53
11/14	0	-	-	6	1200-1230	54
11/21	0	-	-	5	1220-1240	50
Totals	31	125	81-138	61	-	-

Table 4.6. Summary of juvenile American shad collected with cast nets in Holtwood forebay, Oct. - Dec., 1985 (fork lengths in millimeters).

Date	Shad catch	Mean length	Length range	Effort (#casts)	Time of day	Water temp
10/16	0	-	-	10	0935-1025	63°F
10/24	22	122	90-150	3	1430-1455	61
10/31	10	127	83-149	4	1300-1320	51
11/7	20	115	90-143	1	1510	53
11/14	100+	125	86-158	3	1100-1115	54
11/21	100+	136	99-154	1	1030	50
12/4	100+	115	94-146	1	1200	38
Totals	350+	125	83-158	23	-	-

Table 4.7. Summary of lift net collections conducted by RMC at Holtwood forebay during October 16 - December 19, 1985.

DATE	10/16	10/21	10/25	10/28	11/1	11/6	11/8	11/11	11/13	11/15	11/21	11/27	12/4	12/13	12/19	TOTALS
No. LIFTS	15	15	78	83	60	19	12	4	19	10	14	15	9	10	15	
American shad (juveniles)	3	1	101	63	95	480*	229*	294*	604*	108	806*	227*	565*	43	7	3,625*
American shad (adults)	2	0	0	0	0	0	0	0	1	0	3	0	0	0	0	6
BB herring (juveniles)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
BB herring (adults)	0	0	0	2	0	2	0	0	0	0	1	0	0	0	0	5
Gizzard shad	100*	40	0	0	0	5	16	4	203*	1520*	2658*	109*	957*	1	33	5,646*
Bluegill	0	4	0	0	0	0	0	0	0	0	1	0	2	0	0	7
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
White crappie	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Blue tilapia	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
Channel catfish	0	0	0	0	0	0	1	1	4	0	0	0	0	0	0	6
Tiger musky	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	3

* Approximate numbers - estimates were made in most lift net collections containing more than 20 fish to minimize stress from prolonged confinement.

Table 4.8. Summary of juvenile American shad collections from strainers at Safe Harbor and Conowingo, and screens from Peach Bottom APS, October - December, 1985.

Date	Safe Harbor	Peach Bottom	Conowingo
9/1	0	-	-
	↓		
10/9	0	-	0
10/14	1	-	-
10/16	0	0	0
10/18	0	6*	-
10/21	0	0	-
10/23	0	0	0
10/25	0	0	-
10/28	0	1	-
10/30	0	1	0
11/1	0	0	-
11/3	1	-	-
11/4	0	0	-
11/6	1	6	0
11/7	1	-	-
11/8	0	0	-
11/9	3	-	-
11/10	2	-	-
11/11	2	3	-
11/13	0	1	4
11/14	2	-	-
11/15	0	3	-
11/16	1	-	-
11/17	1	-	-
11/18	0	1	-
11/20	0	-	5
11/22	0	3	-
11/25	0	1	-
11/27	0	0	0
12/4	0	-	0
12/5	0	-	-
12/11	-	-	0
Totals	15	26	9

*These fish appeared to be dead on arrival at the screen.

ble 9. Locations sampled and effort by gear during the 1985 Maryland DNR juvenile shad outmigration study.

Gear Type	Station No.	Effort	Station Name (see Figure 4.2)
Haul Seine	1	5	Wild Duck Cove
	5	5	Spoil Island
	6	5	Tydings Park
	7	5	Quarry
	LAP	5	Lapidum
	HVB	5	Happy Valley Br.
Otter Trawl	1	6	Wild Duck Cove
	5	6	Battery Island
	6	6	Tydings Park
Midwater trawl	1	5	Tydings Park
	2	4	Concord Lt-Perry Pt.
	3	4	Penn Central RR Bridge
	4	5	Garret Is.-Cecil West
	5	5	Garret Is.-Cecil East
	6	5	Garret Is.-Hartford East
	7	5	Garret Is.-Hartford West
	8	4	I-95 Bridge
	9	5	Port Deposit
	10	4	Port Deposit-Lapidum
	11	5	Lapidum

TABLE 4.10. Sample dates by gear type and water temperature during the 1985 Maryland DNR juvenile shad outmigration study.

Date	Seine	MW Trawl	Otter Trawl	Temperature Range (F)
November 5		x	x	56 - 57
November 6	x			56 - 57
November 12		x	x	56
November 13	x			56 - 57
November 19		x	x	48 - 49
November 20	x			51
November 25		x	x	47
November 26	x			45 - 47
December 4	x			38 - 41
December 6		x	x	38 - 39
December 10		x	x	38 - 39

Table 4.11. Oxytetracycline tagging analysis of outmigrating juvenile American shad in the Juniata and Susquehanna Rivers, 1985.

A. AMITY HALL

Mark Quality	collection dates 8/21	9/4	9/18	10/3	10/10	10/18	TOTALS
0	6	5	1	1	2	3	18
+	1	3	3	5	4	2	18
++	2	1	3	1	0	2	9
+++	1	1	3	3	5	4	17
% marked	4/10 (40%)	5/10 (50%)	9/10 (90%)	9/10 (90%)	9/11 (82%)	8/11 (73%)	44/62 (71%)

B. YORK HAVEN

Mark Quality	collection dates 9/19	9/26	10/3	10/15	10/17	TOTALS
0	8	4	6	4	6	28
+	0	0	8	1	6	15
++	1	0	1	0	4	6
+++	0	0	3	0	4	7
% marked	1/9 (11%)	0/4 (0)	12/18 (67%)	1/5 (20%)	14/20 (70%)	28/56 (50%)

C. WRIGHTSVILLE

Mark Quality	collection dates 9/10	9/18	TOTALS
0	3	14	17
+	1	3	4
++	2	3	5
+++	1	2	3
% marked	4/7 (57%)	8/22 (36%)	12/29 (41%)

- continued -

Table 4.11. Continued

D. SAFE HARBOR

Mark Quality	collection dates 10/10	10/24	TOTALS
0	2	9	11
+	4	6	10
++	1	1	2
+++	0	4	4
% marked	5/7 (71%)	11/20 (55%)	16/27 (59%)

E. HOLTWOOD

Mark Quality	collection dates 10/24	10/31	11/7	11/14	11/21	TOTALS
0	6	5	5	5	2	23
+	4	3	5	6	1	19
++	2	0	2	2	2	8
+++	3	1	2	3	2	11
% marked	9/15 (60%)	4/9 (44%)	9/14 (64%)	11/16 (69%)	5/7 (71%)	38/61 (62%)

F. PEACH BOTTOM/CONOWINGO

Mark Quality	collection dates 10/18	11/6	11/8	11/12	11/13	11/22	11/25	TOTALS
0	6	4	3	2	2	1	1	19
+	0	0	0	1	0	0	0	1
++	0	1	0	0	0	0	1	2
+++	0	1*	0	0	0	0	1	2
% marked	0/6 (0)	2/6 (33%)	0/3 (0)	1/3 (33%)	0/2 (0)	0/1 (0)	2/3 (67%)	5/24 (21%)

* double marked fish

JOB V. SPECIAL STUDY

RADIO TELEMETRY STUDIES ON

DISPERSAL, SPAWNING AND BEHAVIOR

OF AMERICAN SHAD TRANSPORTED TO

THE NORTH BRANCH OF THE

SUSQUEHANNA RIVER, 1985

PREPARED BY

RMC ENVIRONMENTAL SERVICES

Muddy Run Ecological Laboratory

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FOR

SUSQUEHANNA RIVER ANADROMOUS FISH

RESTORATION COMMITTEE

OCTOBER 1985

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INTRODUCTION

Adult American shad have been taken from the Hudson and/or Connecticut rivers and stocked in the North Branch of the Susquehanna River since 1981. Spawning success was documented in only two of the four years. Consequently, a radio tagging study was initiated in 1985 to provide insight into the post stocking behavior of the transported fish. The following aspects were studied:

1. The extent of post stocking mortality
2. The rate and nature of dispersal throughout the river
3. The extent and areas of fish congregation
4. Spawning areas

Although the original study plan did not include collection of data on behavioral responses of adult American shad at the four hydroelectric stations (York Haven, Safe Harbor, Holtwood and Conowingo) these data were gathered in a systematic manner. Most information was obtained from York Haven and Safe Harbor. Additionally, mortality estimates associated with downstream passage were determined for these two stations. Summarized movement data are given in the main report while movement and behavioral data on individual fish are given in Appendix I.

METHODS

Radio Tagging

A subsample of transported adult American shad was equipped with radio tags. These fish were from both the Hudson and Connecticut rivers and were released with other unmarked shad in the north branch of the Susquehanna River near Tunkhannock at river mile (RM) 217. Shad chosen for radio tagging (hereafter tagged) were captured and transported in the same manner as untagged fish. Shad were tagged at either the capture or release site by orally inserting a transmitter into the stomach. The tags were cylindrical, approximately 11 x 60 mm with a 210 mm whip antenna. Each tag weighed approximately 13 grams. Fish were carefully dip netted to a water filled container, tagged while partially submerged, and then released.

Only actively swimming fish were selected for tagging. Male and female fish were tagged in approximately the same proportion as the sex ratio in the transport tank. Fish were tagged on four different occasions during the transportation program. Most specimens were tagged at the release site. Only fish from the first transport run were tagged at the capture site.

Tracking

The dispersal and status of the tagged fish following their release near Tunkhannock was monitored by tracking shad from shore, truck, airplane and boat. Signals were received on an Advanced Telemetry programmable scanning receiver connected to either a base loaded whip antenna, 1/4 wave loop antenna, steel rod antenna, 2 or 5 element yagi antenna or no antenna at all. The loop and yagi antennas are directional and enable the tracker to determine the direction of the tagged fish; changes in signal strength is the primary factor used for location determination when using the other antennas. Most fix locations were generally accurate to 1/10 of a mile, however, many of the fixes assigned from boat and along shore in the forebay areas at hydroelectric stations were accurate to within several feet.

Tracking from Shore

Fish locations were determined from shore by scanning a portion of the river from several areas with a directional and/or nondirectional antenna. Shore scans were the most effective way to determine the presence of a tagged fish in the vicinity of York Haven, Safe Harbor, Holtwood and Conowingo hydroelectric stations (hereafter York Haven, Safe

Harbor, Holtwood and Conowingo). Shad were tracked by truck primarily in the upper portion of the Susquehanna River from the release site downstream to Berwick, PA. The fish were located by traveling roads that ran parallel to the river. Signals were received by a roof mounted whip antenna and/or a hand-held loop antenna.

Tracking from Air

Because many of the fish dispersed rapidly and traveled great distances downstream, an aircraft was used to cover large portions of the Susquehanna River in a relatively short period. Either a Cherokee low-wing or Cessna high wing plane was flown over the river. Most searches were conducted between 1,000 and 2,000 ft above mean sea level at air speeds around 85 mph in the Cherokee and 65 mph in the Cessna. A stainless steel rod antenna was mounted under the fuselage of the Cherokee, and two loop antennas were mounted on the wing struts of the Cessna. Fish location was determined primarily by variations in signal strength.

Tracking from Boat

A subsample of the tagged fish was located and followed by boat in portions of the river between York Haven and Conowingo. Some fish were tracked continuously for several hours in the vicinity of York Haven, Safe Harbor and Conowingo. Fish were located by guiding the boat in the direction of the signal that was received via a high gain, directional yagi antenna. As the boat neared the location of the fish, one of the trackers would periodically switch to a short-range antenna or no antenna. The signal was followed until the tracker was able to obtain the signal with an antenna/receiver combination having a limited range (less than 30 ft).

Monitoring Schedule

The dates, areas and methods used to monitor the tagged fish are shown in Table 1. The general monitoring schedule was as follows. Newly tagged fish were monitored at the release site for about an hour to ascertain immediate mortality and dispersal direction. These fish were located at least once more about 8 to 24 hours following stocking. This procedure was followed for each of four different stockings. After these initial trackings, an attempt was made to locate all tagged fish weekly, usually by airplane. Because most of the fish moved rapidly downstream and then held at the lower river hydroelectric stations, additional monitoring efforts were expended at York Haven, Safe Harbor, Holtwood and Conowingo. Monitoring was most intense at York

Haven and Safe Harbor. York Haven was checked almost daily from mid-May through mid-June and Safe Harbor almost daily in June. Some fish found at York Haven, Safe Harbor and Conowingo were also located hourly and sometimes every few minutes as they moved about the forebay and impounded waters. Safety concerns by PP&L at Holtwood prevented the collection of movement data within the forebay of this facility. Fish movements were also monitored during several periods when sluice gates were opened to spill trash at both York Haven and Safe Harbor.

Monitoring Spawning

The purpose of the American shad stocking program is to achieve successful spawning of the released fish. Prior to the study it was believed stocked shad would congregate and eventually spawn somewhere in the north branch of the river. The tagged fish were tracked to determine where and when they congregated so spawning could be documented by ichthyoplankton samples. Most tagged fish congregated at York Haven. Consequently, spawning activity was most intensely studied there. Ichthyoplankton samples were taken with a 1-meter plankton net fished just below the surface. The net was deployed from an anchored boat in the intake channel and tailrace area of York Haven (Figure 1). The contents of a 15 minute sample were preserved in 10% formalin. Fish eggs and larvae were sorted and identified.

Some tagged shad were also tracked at hourly or more frequent intervals in the forebay of York Haven and Safe Harbor from late afternoon to night. This additional surveillance was conducted to determine differences in diurnal spawning activity.

The spawning conditon of untagged fish was determined by collecting specimens in the forebays at both York Haven and Safe Harbor. At York Haven specimens were taken with a pitch fork gig as they swam along the trash bars; at Safe Harbor a 6 x 300 foot x 5.5 inch mesh nylon gill net was used (Figures 2 and 3).

RESULTS

Stocking Mortality

Twenty-seven tagged shad (20 from Hudson River and 7 from Connecticut River) were released alive at the Tunkhannock stocking site between 28 April and 25 May (Table 2). Five fish were tagged at the capture site on 28 April but two of these died prior to release. One of the dead fish was replaced by tagging an additional specimen at the release site. Thereafter, all tagging was done at the release site. All transported fish (tagged and untagged) were from the Hudson River except for the final load of 64 fish which came from the Connecticut River on 25 May.

Post stocking mortality of tagged shad was low. Only four fish were found dead in the Susquehanna River upstream of York Haven (RM 56). Tags of two fish (644B-Connecticut River, 764-Hudson River) were recovered from the north branch more than 36 miles downstream of Tunkhannock (Table 2 and Figure 4). One fish appeared to have died within three days of stocking while the other may have lived more than a week. The other two fish were in the mainstem of the Susquehanna River. Tag 709 was located below the dam at Sunbury (RM 122) and 563 was found at the mouth of the Juniata River (RM 86). The exact cause of death is not known, but their distances from the release site and dates of location indicated they did not die immediately after stocking. The presence of fish 709 in the tailwaters of a dam, suggests its death may have been associated with passage over that dam. It appears that fish which can swim away from the release site suffer low delayed mortality. Post stocking mortality does not appear to be a primary factor in the spawning success or failure of the transported fish.

Dispersal and Congregation

Tagged shad generally moved downstream from the Tunkhannock area shortly after tagging. Fourteen shad were found 7 to 51 miles downstream of the release site 8 to 24 hours after stocking (Table 2 and Figure 5). Only 10 shad were located near the release area during this time. The remaining three fish were not located at this time. Six of the 10 fish which did not rapidly leave the release site were among the seven fish tagged from the Connecticut River; these fish left the area within a few days. No tagged fish were ever located more than two miles upstream of the release site. Only one fish appeared to stay at the release area for more than a few days (723).

The first area where dispersed fish congregated was the forebay of York Haven (RM 56). The number of days which elapsed between stocking date and first known date when the fish reached York Haven was used to indicate the rate of the downstream dispersal (Table 2). A total of 23 fish reached York Haven. The number of days required for shad to reach York Haven ranged from 3 to 22 days (Table 2). More than half (13) were there in 9 days with four of these reaching York Haven within 6 days. The fastest fish, 803, was found below York Haven near Columbia (RM 40) in only three days. The remaining six fish (26%) displayed a more gradual downstream dispersal. More than two weeks elapsed until these fish reached York Haven. One of these fish (784) moved 9 miles upstream (RM 149 to 158) between 8 and 13 May. Other than minor upstream movements at the release site, this is the only fish which moved upstream while still in the north branch of the Susquehanna River (Figure 5). It arrived at York Haven on 20 May. This fish also had the longest lapse of time (22 days) to York Haven (Table 2).

The maximum hourly rate of movement recorded for each fish during the downstream dispersal ranged from 0.4 to 2.6 miles per hour (Table 2). Movement rates were 2.0 to 2.6 mph for the fish which reached York Haven within 5 days. The fastest rate observed during this study was 3.6 miles per hour for a fish (822) moving between York Haven and Safe Harbor, not during its initial downstream run.

There was no evidence that tagged shad congregated for extended periods in the north branch or mainstem of the Susquehanna River. Except for the first two days following stocking, only four tagged fish were located close to each other after leaving the release site and prior to arrival at York Haven. Fish 432 and 624 were 2.5 miles apart (RM 75.5 and 73.0) on 13 May and fish 504 and 543 were 2 miles from each other (RM 156 and 158) on 29 May. Three other fish, that delayed downstream emigration more than two weeks, were found within a 29 mile section of the river (between Nanticoke, RM 120, and just downstream of Berwick, RM 149) at least once between 8 and 20 May. There have been reports of a few shad being taken by rod and reel and seine from this portion of the river later in the year.

The rapid downstream dispersal of radio tagged shad appears typical for most transported shad. Large numbers of untagged and tagged shad were observed simultaneously in the forebay of York Haven indicating that many of the transported fish leave the north branch soon after stocking. Although no exact counts were made, hundreds of adult shad were observed on several occasions swimming just off the trash bars at York Haven. On 28 May shad large numbers of shad were observed along the entire 475 foot intake structure with about 15 fish every five feet. Some could have been shad taken at the Conowingo Fish Lift and transported to Harrisburg. However, most of the shad taken below Conowingo were considerably smaller than fish transported from the Hudson River or observed at York Haven.

Spawning

Five ichthyoplankton collections were taken at York Haven. One collection was taken upstream of the forebay in the intake channel just after midnight on 22 May and four collections were taken from the discharge in the tailrace between 9 and 11 PM on 30 May (Figure 1 and Table 3). The sample from the intake channel was taken in the immediate vicinity of a tagged female shad (662). Only one positively identified shad egg was taken in the intake channel collection. The egg appeared to be viable. Four eggs of appropriate size (2.5 to 3.1 mm diameter) for shad were taken in the discharge; however, the condition of the eggs did not permit a positive identification. Only 10 other eggs were taken. Numerous larvae (440) were taken but none of American shad (Table 3). Surface splashing, a typical spawning activity, was not observed for tagged or untagged shad in the York Haven forebay and in upstream areas the same night the ichthyoplankton collection was taken in the intake channel. Eight tagged shad were tracked intensively the same night. All fish continually moved about. Five moved upstream of the forebay into the intake channel area. Tagged fish behaved similarly in the forebay area of Safe Harbor. Shad were not observed splashing on the surface during late evening or night at Safe Harbor.

The eggs collected from the York Haven tailrace most likely came from fish spawning in the forebay or intake channel. The night (30 May) the tailrace was sampled, six tagged shad (3 male and 3 female) were present in the forebay and intake channel area. Additional observations of tagged shad at York Haven indicated that shad did not remain in the tailrace area upon passing the station, nor did they return to the area later.

Fish collected by gig and gill net at York Haven and Safe Harbor, respectively, were examined for spawning condition. A total of 17 fish was taken at York Haven from 21 to 28 May and four were collected at Safe Habor on 25 June (Table 4). The fish at York Haven consisted of 11 males and 6 females. Most taken on 21-23 May were running ripe while shad taken on 28 May were partially spent. The four fish captured at Safe Harbor were all spent females. The fish collected at both hydroelectric stations appeared healthy and most were free of scars or other external marks.

Body weights on a subsample indicated the fish were not emaciated.

The presence of ripe shad and eggs at York Haven indicate that spawning occurs in that area. There was no indication that spawning occurred in the vicinity of Safe Harbor; however, the peak spawning period was probably past when fish were intensively tracked and sampled at Safe Harbor.

Spawning success of stocked shad in the lower Susquehanna River may be partially dependent upon their concentration at York Haven. Green and ripe fish appear to stay for a sufficient time to permit spawning. Perhaps most stocked fish would exit the river prior to spawning if not contained.

BEHAVIOR AT HYDROELECTRIC STATIONS

The congregation of the tagged and untagged shad at the lower river hydroelectric stations provided an opportunity to gather data on their behavior and mortality at these facilities. Most information was gathered at York Haven and Safe Harbor. Less data were obtained at Holtwood and Conowingo due to time constraints and low numbers of tagged fish rather than technical feasibility.

Observations at York Haven Station

As mentioned previously, 23 tagged fish reached the York Haven Station. Shad were observed to congregate there. Fish were abundant from the week of 12 May through the week of 16 June (Table 5). Shad concentration in the York Haven forebay area was probably due to the design of the dam and powerhouse. Both structures are situated oblique to the river flow and direct the flow towards the west bank of the river (Figures 1 and 2). Flow in the forebay area is directed towards the furthermost downstream unit which is operating. Consequently, most of the flow is also oblique to the trash bars in front of the 475 foot powerhouse that contains 20 units. Water appears to enter directly through the trash bars in limited areas at the upstream and downstream end of the intake area.

Actual counts were not made, but hundreds of shad were observed swimming along the trash bars from mid-May through mid-June. Fish were observed swimming upstream against the current, just off the trash bars less than 2 feet below the surface. Turbidity may have obscured observation of fish at deeper depths. Generally the fish moved upstream along the length of the intake area. Groups of fish would turn away and move out into the forebay and then drop back downstream to repeat the upstream run along the trash bars. Although tagged fish were not visually identifiable, signals from these fish depicted the same type of movements when they were along the trash bars (Figure 6). Shad tracked during the evening and night of 21 May indicated that all shad in the York Haven forebay do not continually swim along the trash bars, some individuals move out of the forebay and into the intake channel. One specimen (844) moved more than a mile upstream.

The exodus of shad from the York Haven Station appeared to be primarily through spillage at a sluice gate. This gate is located off the downstream side of the intake area and is opened primarily to pass debris that collects in the forebay or is raked off the trash bars (Figure 2). Water passes through this sluice gate and enters the tailrace just downstream of discharge area from the powerhouse units. This sluice gate was opened 9 times from 13 May through 1 August (Table 6). The duration of each spill varied from a minimum of 0.2 to a maximum of 29.5 hours. A total of 14 tagged shad left during these spills (Table 6). The other tagged fish were not located at the proper time to determine their exit route or time.

The exit route and behavior of the tagged fish appeared to be typical of most of the shad concentrated behind York Haven. The water discharged through the sluice was clear enough to observe fish passage on at least five days (Table 6). Counts of shad passage lasted from 30 to 50 minutes on these days. Large numbers of shad were observed passing through the sluice during the period of observation and down the falls both head first and tail first. A total of 204 shad was observed leaving during 3.3 hours of spill (Table 6). On one occasion approximately 25 fish which appeared to be river herring passed through.

The number of days that tagged shad remained behind York Haven was partially dependent upon the frequency and duration of the sluice gate spills. Six of the 23 fish (26%) that reached York Haven did not stay more than one day, however, 57% were held for a week or more, 35% more than two weeks and one fish (603) remained almost 2 months (Table 2). More than 50% of the tagged fish present exited during two different spills that lasted for a day (Table 6). However, it is not known exactly at what time the fish left. Observations indicate that a large number of shad utilized the sluice immediately after the gate was opened.

Estimate of Passage Mortality

The additional monitoring of the fish at York Haven provided some data to estimate the mortality of tagged shad as they passed this facility. Twenty-two of the twenty-three fish which reached York Haven were located downstream of this facility (Table 2 and Figure 4). One fish (784) was present following a sluice gate opening but was never located again. As mentioned previously most fish passed during times the sluice gate was opened (Table 6). However, some may have come through the station or spilled over the dam. Four of the 23 fish which reached York Haven ceased activity after passing the station indicating 18% mortality due to passage (Table 2 and Figure 4).

Safe Harbor

A total of 18 tagged fish reached Safe Harbor (Table 7 and Figure 4). Three of these shad passed the station without detection and were located downriver. Fish were present at Safe Harbor from 9 May until 2 August. The arrival of most fish coincided with the sluice gate openings at York Haven. Movement rates between York Haven and Safe Harbor were 1 mile per hour (range from 0.2 to 3.6 mph) for most fish. The residency time of shad in the Safe Harbor area ranged from 1 to 61+ days, most stayed less than 25 days. The reasons for these variations in residency time are unknown at present.

Most fish (8 to 9) were present during the week of 2 and 16 June (Table 5). As at York Haven, the fish congregated in the forebay; however, they appeared to be less confined to the immediate forebay and frequently moved back upstream into Lake Clarke. After reaching Safe Harbor, four fish (322, 464, 523, and 723) moved back upstream about four miles on at least one occasion. On 25 June, three of these fish were found within a tenth of a mile of each other. However, this particular group of fish was probably not a spawning congregation because of the late date (25 June) and four untagged shad collected by gill net from the forebay on the same date were spent females (Table 4).

The sluice gate at the Safe Harbor Station was not utilized by the tagged shad. The area of the sluice gate was monitored regularly at the time debris and water were spilled from 4 June to 22 June to determine the route of exodus of shad. Twelve tagged shad were located in the forebay and in the immediate vicinity of the sluice gate during this period of monitoring (Table 7). None of these fish utilized sluice gate spills for passage.

The differences in utilization of the sluice gates by the shad at York Haven and Safe Harbor stations were most likely due to the design and operation of the sluice gates at the stations. Safe Harbor is situated perpendicular to the river and flow is primarily directly through the trash racks in front of the generating units, not oblique like

York Haven (Figures 2 and 3). Debris is passed primarily via a sluice gate(s) located outside the forebay. Gates at Safe Harbor are lowered rather than completely removed and only pass about the top foot of surface water. Water and debris were usually passed for about 5 minutes, every day near midnight at Safe Harbor compared to several hours about once a week at York Haven.

The passage of shad from the Safe Harbor Station was primarily through the turbines. All but one (322) of 18 tagged shad (94%) reaching Safe Harbor apparently passed through the turbines. This fish was still present in the forebay at the end of the study. Fixes on 12 fish were obtained downstream of the powerhouse; the other 5 were regularly located in the forebay or impoundment and then suddenly disappeared. No stationary signals were obtained on these fish downstream of the powerhouse suggesting safe passage. The failure to locate these shad later on may be due to less intensive monitoring at Holtwood and Conowingo and/or rapid transit past the three hydroelectric facilities. Only three fish (18%) were known to have died upon passing the Safe Harbor Station. However, it is not known whether this mortality was related to turbine passage and/or post-spawning.

One radio tag from a dead fish was recovered from a steep rocky bank 50 to 75 ft above the river. Bite marks on the transmitter and a few fish scales in the vicinity were evidence of mammalian predation.

Holtwood and Conowingo

Tagged shad were not monitored as intensively at Holtwood (RM 24) and Conowingo (RM 10), but some information on their behavior was obtained. At least nine shad reached Holtwood (Figure 4). The first fish (803) passed Holtwood around 9 May. The last fish was found during the week of 14 July. The most fish present in the Holtwood forebay at one time was two during the week of 26 May (Table 5).

The route of exodus at Holtwood is known for only two fish. One fish (744) passed through a turbine because it was located in the forebay and later in the tailrace. The other used a sluice gate because it was located outside the forebay above the dam and later below the dam off the west side of the Piney Island. This island separates the tailrace channel from the spillway area.

Three of the nine fish known to have reached Holtwood died in the vicinity of the station (Table 2 and Figure 4). The two fish discussed previously apparently died during passage and another fish (341) ceased movement while in the forebay.

Four fish were found in Conowingo Pond (Figure 4). Two of these were known to have reached Conowingo Dam. Fish 803 was the first fish to reach Conowingo; this fish moved downriver from the release site faster than any of the other fish. It reached Lake Clarke (RM 40) in 3 days and Conowingo (RM 10) in 5 days. This fish was tracked by boat in Conowingo pond when it made its initial run downstream to Conowingo Dam (Figure 7). It moved downstream along the west side of Conowingo Pond. It passed close to the intake area for Peach Bottom Atomic Power Station. When the fish arrived at Conowingo it made several approaches, went deep at least one time and then moved eastward along much of the dam. Finally, it turned back upriver and was last located 4.5 miles upstream. It was not found two days later when Conowingo Pond was monitored by airplane. The other shad (504) was found in the vicinity of Conowingo on three occasions from 6 June through 12 June (Figure 4). It was located near the powerhouse and also near the east side of the dam. The emigration route at Conowingo was through the turbines because sluice gates are rarely opened at this facility to pass debris. No dead or live shad were found from Conowingo to the mouth of the river (Figure 4).

Conclusions and Recommendations

The radio tracking study provided information on post-stocking mortality, dispersal, congregation, spawning, and turbine passage of stocked shad. Additionally, behavioral observations were made of stocked shad at the hydroelectric stations along the lower Susquehanna River, especially at York Haven and Safe Harbor. Estimates of mortality associated with downstream passage were made at York Haven and Safe Harbor.

1. Stocking Mortality

Post stocking mortality was minimal. Radio tagging did not affect the typical behavior of American shad and thus can be used as a valid means to obtain relevant data in future studies.

2. The Rate of Dispersal

Tagged fish dispersed rapidly from the release site in a downstream direction. The dispersal was continual for most fish. Tagged fish reached York Haven from 3 to 22 days after stocking, most arrived at York Haven (first significant barrier) in 9 days or less. Six fish (26%) took more than two weeks to reach York Haven. The simultaneous appearances of tagged and large numbers of untagged shad at

York Haven indicates that rapid downstream dispersal was typical behavior of most stocked shad.

3. Areas of Congregation

There was no evidence that tagged fish congregated in any specific areas prior to reaching the first barrier, York Haven. Nineteen of 23 tagged fish along with hundreds of other shad were located in the forebay of York Haven. Shad were abundant at York Haven forebay from the week of 12 May through the week of 16 June. Shad also congregated at Safe Harbor. Fifteen tagged shad that reached Safe Harbor were located in the forebay or immediate areas. Shad were abundant at Safe Harbor from the week of 19 May through 7 July. Fish did not appear to be as confined to the immediate forebay area at Safe Harbor as at York Haven, and some moved back upstream several miles.

The concentrating effect of the hydroelectric stations, especially York Haven, appeared to be a positive aspect because this facility slowed down the rapid emigration of fish from the Susquehanna River.

4. Spawning Areas

Spawning was documented at York Haven. One viable shad egg along with four "probable" shad eggs were taken.

Running ripe male and female shad were also collected at York Haven. Spawning was not documented in the north branch of the Susquehanna River; however, some may have occurred between Nanticoke and Berwick.

The concentration of shad at the York Haven facility appears to provide conditions that are conducive for spawning. Young shad captured in summer 13 miles downstream of York Haven may be progeny of adults which spawned near York Haven; however, they could also be of hatchery origin.

The adult stocking program provided few shad that would have spawned in the north branch of the Susquehanna River. This is primarily due to the rapid dispersal of most shad to downstream areas. However, shad may be encouraged to remain and spawn in the upper river by restricting their downstream movements and concentrating them prior to release. This may be accomplished by an instream or stream-side holding area; however, flood conditions must be considered. These fish then should be released in large schools so that there is a greater probability of both sexes finding each other for spawning.

Future sampling for young shad should be conducted near York Haven and downstream to determine relative abundance of naturally produced young shad. Young shad are most likely to be found in this area.

5. <u>Passage at Hydroelectric Facilities</u>

The York Haven facility concentrated most of the tagged and untagged shad as they moved downstream from the release site. Passage of shad at York Haven was primarily via a sluice gate at the downstream end of the forebay. Generally, this gate was opened several hours once a week to pass debris. Oblique flow across the trash bars in front of the generating units discouraged shad from passing through the turbines. Retention time of shad at York Haven was largely dependent upon the frequency of the sluice gate opening.

The appearance of shad at Safe Harbor corresponded closely to the sluice gate openings at York Haven. Most fish traveled from York Haven to Safe Harbor in a day. Shad passage at this facility was via the turbines. Little mortality occurred due to turbine passage. Shad appeared to be quite mobile at Safe Harbor and frequently moved out of the forebay and upstream into the impoundment.

Nine and four shad were known to have reached Holtwood Station and Conowingo Pond, respectively. Some of these fish were retained at both Holtwood and Conowingo stations. Shad exited Holtwood via the powerhouse and a sluice gate, which is outside the forebay. Passage at Conowingo was through the powerhouse.

Estimated mortality of adult shad associated with downstream passage was 18% at York Haven. Mortality was also 18% at Safe Harbor, but whether this was due solely to passage is not known. The tagged fish at both facilities could choose their time and route of exodus and did not experience forced passage.

TABLE 1

Monitoring schedule and methods of tracking to determine behavior of 27 adult radio tagged American shad released into the Susquehanna River near Tunkhannock, Pennsylvania, 28 April - 5 August 1985.

DATE	LOCATIONS MONITORED	METHOD
28-29 Apr	Rt. 87 Bridge to Pittston (RM 230-196)	Vehicle
29 Apr	Rt. 87 Bridge to Shickshinny (RM 230-171)	Airplane
4 May	Towanda to Holtwood Station (RM 275-24)	Airplane
5-6 May	Tunkhannock to Berwick (RM 220-162)	Vehicle
8 May	Rt. 87 Bridge to Columbia (RM 230-42)	Airplane
9 May	Columbia to Washington Boro (RM 43-40)	Vehicle
10 May	York Haven Station to Peach Bottom Station (RM 56-18)	Airplane
10-11 May	Fishing Creek to Conowingo Station (RM 20-10)	Boat
13 May	Rt. 87 Bridge to Conowingo Station (RM 230-10)	Airplane
14 May	York Haven Station to Conowingo Station (RM 56-10)	Airplane
15 May	Tunkhannock to Susquehanna Steam Station (RM 220-166)	Vehicle
16 May	Lake Clarke (RM 40)	Boat
	York Haven Station (RM 56)	Shore
20 May	York Haven Station (RM 56)	Shore
	Rt. 87 Bridge to Conowingo Station (RM 230-10)	Airplane
21 May	Goldsboro to York Haven Station (RM 60-56)	Boat
22 May	York Haven Station (RM 56)	Shore
23 May	York Haven Station (RM 56)	Shore
24 May	Washington Boro to Safe Harbor Station (RM 40-32)	Vehicle
	Holtwood Station (RM 24)	Shore
25 May	Tunkhannock to Pittston (RM 220-196)	Vehicle
26 May	York Haven Station (RM 56)	Shore
27 May	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore
28 May	York Haven Station (RM 56)	Shore
29 May	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
	Rt. 87 Bridge to Conowingo Station (RM 230-10)	Airplane
30 May	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
	York Haven Station tailrace (RM 56)	Boat
31 May	York Haven and Holtwood stations (RM 56 and 24)	Shore
1 Jun	Holtwood (RM 56)	Recorder *
3 Jun	Shickeshinny to Safe Harbor Station (RM 171-32)	Airplane
	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
4 Jun	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
5 Jun	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
6 Jun	York Haven and Safe Harbor stations (RM 56 and 32)	Shore
	York Haven Station to mouth of Susquehanna River (RM 56-0)	Airplane

continued

TABLE 1

Continued.

DATE	LOCATIONS MONITORED	METHOD
7 Jun	York Haven, Holtwood and Safe Harbor stations (RM 56, 32 and 24)	Shore
	Harrisburg to Conowingo Station (RM 72-10)	Airplane
8 Jun	Safe Harbor and Conowingo stations (RM 32 & 10)	Shore
9 Jun	York Haven and Safe Harbor stations (RM 56 & 32)	Shore
10 Jun	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
	Columbia to Safe Harbor Station (RM 42-32)	Boat
11 Jun	York Haven, Safe Harbor, Holtwood and Conowingo stations (RM 56, 32, 24 & 10)	Shore
12 Jun	Safe Harbor, Holtwood and Conowingo stations (RM 32, 24 and 10)	Shore
13 Jun	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
	Safe Harbor to Holtwood Station (RM 32-24)	Vehicle
14 Jun	Safe Harbor Station (RM 32)	Shore
15 Jun	York Haven Station (RM 56)	Shore
17 Jun	York Haven, Safe Harbor and Holtwood stations (RM 56, 32 and 24)	Shore
17-18 Jun	Columbia to Safe Harbor Station (RM 42-32)	Boat
18 Jun	York Haven Station (RM 56)	Shore
19 Jun	Safe Harbor Station (RM 32)	Shore
20 Jun	Safe Harbor Station (RM 32)	Shore
21 Jun	Berwick to Conowingo Station (RM 162-10)	Airplane
22 Jun	York Haven and Safe Harbor stations (RM 56 & 32)	Shore
25 Jun	York Haven Station (RM 56)	Shore
	Washington Boro to Safe Harbor Station (RM 40-32)	Boat
27 Jun	Safe Harbor Station (RM 32)	Shore
30 Jun	Safe Harbor Station (RM 32)	Shore
1 Jul	Safe Harbor Station (RM 32)	Shore
2 Jul	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore
3 Jul	Safe Harbor, Holtwood and Conowingo stations (RM 32, 24 & 10)	Shore
4 Jul	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore
5 Jul	Conowingo Station (RM 10)	Shore
6 Jul	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore
7 Jul	Holtwood Station (RM 24)	Shore
9 Jul	Columbia to Holtwood Station (RM 42-24)	Boat
10 Jul	York Haven Station (RM 56)	Shore
12 Jul	York Haven Station to Conowingo Station (RM 56-10)	Airplane
13 Jul	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore
15 Jul	Safe Harbor and Holtwood stations (RM 32 & 24)	Shore

continued

TABLE 1

Continued.

DATE	LOCATIONS MONITORED	METHOD
17 Jul	Holtwood Station (RM 24)	Shore
19 Jul	Holtwood Station to Conowingo Station (RM 24-10)	Boat
	Holtwood Station (RM 24)	Shore
20 Jul	Safe Harbor Station (RM 32)	Shore
23 Jul	Columbia to Holtwood Station (RM 42-24)	Boat
2 Aug	Columbia to mouth of Susquehanna River (RM 42-0)	Airplane
5 Aug	York Haven Station (RM 56)	Shore

* A chart recorder - radio receiver combination was used on a limited basis next to the forebay at the Holtwood Hydroelectric Station.

TABLE 2

Movement patterns of adult radio tagged American shad stocked in the north branch of the Susquehanna River near Tunkhannock, Pennsylvania (RM 217), April-May 1985.

Origin and Release Date	Fish Number	Sex	Farthest Distance Moved in First 8-24 hrs* (miles)	Days** to Reach York Haven	Days** at York Haven	Maximum Travel Rate Release Site to York Haven (mph)	Last Location	Last Date	Fate
HUDSON RIVER									
28 Apr	432	F	+2	19	7	0.6	Lake Clarke (RM 29)	21 Jun	Dead
	709	M	-32	-	-	1.8	Sunbury (RM 122)	8 May	Dead
	784	F	-	(22)	1	0.6	York Haven (RM 56)	20 May	Live
	844	F	- 1	(15)	23	0.8	York Haven (RM 55.5)	9 Jun	Dead
5 May	603	M	-8	(11)	(56)	1.5	York Haven (RM 55.8)	5 Aug	Dead
	624	M	-9	12	32	1.4	Safe Harbor (RM 32)	9 Jul	Live
	644	F	-35	(4)	(1)	2.2	Lake Clarke RM 40)	10 May	Dead
	662	F	-24	(11)	8	1.9	Holtwood (RM 24)	15 Jul	Live
	684	M	-20	(5)	(1)	2.1	Lake Aldred (RM 26.5)	13 May	Live
	723	F	- 1	(21)	23	0.9	Lake Clarke (RM 35.8)	25 Jun	Live
	744	M	+ 1	9	7	0.9	Holtwood (RM 23.8)	3 Jun	Dead
	764	M	-36	-	-	2.4	Nanticoke (RM 179.5)	8 May	Dead
	803	M	-51	(3)	(1)	2.6	Conowingo Pond (RM 14.5)	11 May	Live
	822	M	-22	(8)	8	1.3	Safe Harbor (RM 32)	12 Jul	Live
14 May	304	F	- 9	(5)	1	2.3	Holtwood (RM 23.9)	6 Jun	Dead
	322	M	-	(19)	(1)	0.9	Safe Harbor (RM 32)	2 Aug	Live
	341	M	-	7	3	1.0	Holtwood (RM 24)	4 Jun	Dead
	363	M	-16	7	15	1.7	Conowingo Pond (RM 20)	5 Jul	Live
	403	M	- 8	(11)	10	0.9	Safe Harbor (RM 32)	17 Jun	Live
	464	F	- 7	7	15	1.9	Conowingo Pond (RM 17.5)	12 Jul	Live
Average			-16	11	12	1.5			
CONNECTICUT RIVER									
25 May	482	M	+ 1	(9)	15	0.9	Lake Aldred (RM 26)	23 Jul	Dead
	504	M	0	(9)	2	1.1	Conowingo Dam (RM 10)	12 Jun	Live
	523	M	+ 1	9	2	1.1	Safe Harbor (RM 32)	25 Jun	Live
	543	M	+ 1	(9)	15	0.9	Brunner Island (RM 55.1)	21 Jun	Dead
	563	F	- 7	-	-	1.9	Mouth Juniata R. (RM 85.5)	21 Jun	Dead
	583	F	+ 1	(19)	5	1.0	Safe Harbor (RM 31.4)	23 Jul	Dead
	644B	F	0	-	-	0.4	Shickshinny (RM 173.5)	3 Jun	Dead
Average			0	14	8	1.0			

* Furthest distance moved from the release site, negative values indicate downstream movement
** Days are actual for some fish and approximate in parenthesis () for others depending upon the frequency of the monitoring schedule
Days are generally within ± 1 day.

TABLE 3

Eggs and larvae taken by a 1-meter plankton net fished near the surface in the intake channel and the tailrace of the York Haven Hydroelectric Station, May 1985.

Location	Intake Channel		Tailrace								Total	
Date	22 May		30 May									
Time	0029-0044		2106-2121		2139-2154		2207-2222		2248-2303			
Water Temp (F)	-		70		70		70		70			
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Species												
American shad	1	-	-	-	-	-	-	-	-	-	1	-
American shad*	-	-	1	-	2	-	1	-	-	-	4	-
Minnows	-	-	-	14	-	9	-	16	-	13	-	52
Carp	-	-	-	19	-	34	-	40	-	38	-	131
Suckers	-	-	-	1	-	1	-	1	-	2	-	5
Quillback	-	8	-	3	-	4	-	3	-	2	-	20
Sunfish Family	-	1	-	3	-	4	-	29	-	125	-	162
Rock Bass	-	-	-	-	-	1	-	1	-	4	-	6
Perches	-	1	-	-	-	1	-	-	-	-	-	2
Tessellated darter	-	-	-	-	-	1	-	5	-	6	-	12
Shield darter	-	1	-	-	-	-	-	2	-	-	-	3
Banded darter	-	2	-	4	-	6	-	2	-	5	-	19
Unidentified	2	16	1	1	3	-	4	7	-	4	10	28
TOTALS	3	29	2	45	5	61	5	106	0	199	15	440

* These could not be identified positively as American shad, but likely shad eggs based on size (2.5 - 3.1 mm diameter)

TABLE 4

Spawning condition of American shad collected from the forebay area of the York Haven and Safe Harbor Hydroelectric stations, May-June 1985.

Location	Date	Length FL (mm)	Weight(g)	Sex	Gonad Weight(g)	Spawning Condition
York Haven	21 May	477	1340	F	101	Running ripe
		483	1510	M	-	Running ripe
		-	-	M	-	Partially spent
		-	-	M	-	Partially spent
		-	-	F	-	Running ripe
		-	-	F	-	Spent
	22 May	-	-	M	-	Running ripe
		-	-	F	-	Running ripe
	23 May	-	-	M	-	Running ripe
	28 May	395	730	M	4	Spent
		509	1850	M	15	Spent
		431	900	M	9	Spent
		464	1340	F	76	Partially spent
		452	1050	M	24	Partially spent
		470	1280	M	39	Partially spent
		475	1350	F	59	Partially spent
		485	1590	M	27	Spent
Safe Harbor	25 Jun	496*	1446	F	53	Spent
		507*	1843	F	9	Spent
		545*	1673	F	37	Spent
		425*	1332	F	4	Spent

* Empty stomach

TABLE 5

Weekly minimum and maximum number of radio tagged American shad actually detected on each monitoring date in the forebay areas of the four hydroelectric stations in the lower Susquehanna River, April-August 1985.

	YORK HAVEN			SAFE HARBOR			HOLTWOOD			CONOWINGO		
Week Of	Days Monitored	Min	Max	Days Monitored	Min	Max	Days Monitored	Min	Max	Days Monitored	Min	Max
28 Apr	1	0	0	1	0	0	1	0	0	0	-	-
5 May	2	0	0	1	0	0	1	0	0	1	1	1
12 May	3	1	7	2	0	0	2	0	0	2	0	0
19 May	4	8	9	2	0	3	2	0	1	1	0	0
26 May	5	6	7	3	3	4	5	1	2	1	0	0
2 Jun	5	3	11	6	3	8	5	0	1	3	0	1
9 Jun	5	4	6	6	4	6	4	0	0	2	1	1
16 Jun	4	1	5	6	7	9	2	0	0	1	0	0
23 Jun	1	1	1	2	6	6	0	-	-	0	-	-
30 Jun	0	-	-	6	2	4	4	0	1	2	0	0
7 Jul	2	1	1	3	2	4	4	0	1	1	0	0
14 Jul	0	-	-	2	0	0	3	0	1	1	0	0
21 Jul	0	-	-	1	1	1	1	1	1	0	-	-
28 Jul	0	-	-	1	1	1	1	0	0	1	0	0
4 Aug	1	0	0	0	-	-	0	-	-	0	-	-
TOTALS	33			42			35			16		

TABLE 6

Number of radio tagged and untagged American shad that passed the York Haven Hydroelectric Station during spills of the sluice gate, May-August 1985. Dashes indicate duration of spills unknown.

Date	Total Time Sluice Gate Opened (hrs)	Number of Tagged Fish: Present Prior To Spill	Number of Tagged Fish: Passed during Spill	Time That Fish were Counted during The Spill (hrs)	Number of Fish Counted Leaving
13 May	-	1	0	-	-
20 May	3.5	9	1 (3)*	0.8	3
23 May	4	8	3	0.8	48
28 May	0.2	7	0	-	-
4-5 Jun	23.0	10	6	0.5	53
7 Jun	-	5	0	-	-
11 Jun	0.7	3	0	0.7	40 & (25)**
17-18 Jun	29.5	5	4 (1)*	0.5	60
1 Aug	-	-	(1)***	-	-
TOTALS				3.3	204

* Absent from York Haven Hydroelectric Station the day after the spill; however, exit via the sluice gate is uncertain

** Approximately 40 American shad and 25 herring

*** A single tagged shad remained at York Haven Hydroelectric Station after 18 June. It was found dead in the tailrace on 5 August; exit via the sluice gate is uncertain

TABLE 7

Residency time of radio tagged American shad that reached the Safe Harbor Hydroelectric Station in 1985. Numbers in parenthesis are approximations based on other location determinations and/or movement rate.

Assigned Fish No.	Dates: Last Located at York Haven	Dates: Arrival Safe Harbor	Maximum Movement Rate (mph) York Haven-Safe Harbor	Date Last Located at Safe Harbor	Days at Safe Harbor
432	23 May	27 May	0.4	7 Jun	12
624	17 Jun	18 Jun	0.9	9 Jul	22
662	23 May	27 May	0.8	27 May	1
684*	(11 May)	(12 May)	-	(12 May)	(1)
723	17 Jun	18 Jun	0.9	25 Jun	8
744**	20 May	(21 May)	-	(21 May)	(1)
803***	(8 May)	(9 May)	-	(9 May)	(1)
822	20 May	(21 May)	3.6	12 Jul	50
304	20 May	24 May	0.2	3 Jun	11
322****	-	3 Jun	-	2 Aug	61+
341	23 May	24 May	0.9	24 May	1
363	4 Jun	5 Jun	1.1	27 Jun	23
403	4 Jun	5 Jun	0.8	17 Jun	13
464	4 Jun	5 Jun	0.8	27 Jun	23
482	17 Jun	18 Jun	0.9	13 Jul	26
504	4 Jun	5 Jun	1.1	5 Jun	1
523	4 Jun	5 Jun	1.1	25 Jun	21
583	17 Jun	18 Jun	1.8	11 Jul	25

* Located at RM 112 on 8 May, next located at RM 26.5 on 13 May
** Located at RM 56 on 20 May, next located at RM 24 on 24 May
*** Located at RM 42 on 8 May, next located at RM 20 on 10 May
**** Fish suddenly appeared at Safe Harbor Hydroelectric Station, it was previously located on 15 May at RM 215. This fish was still active at Safe Harbor Hydroelectric Station when study was terminated

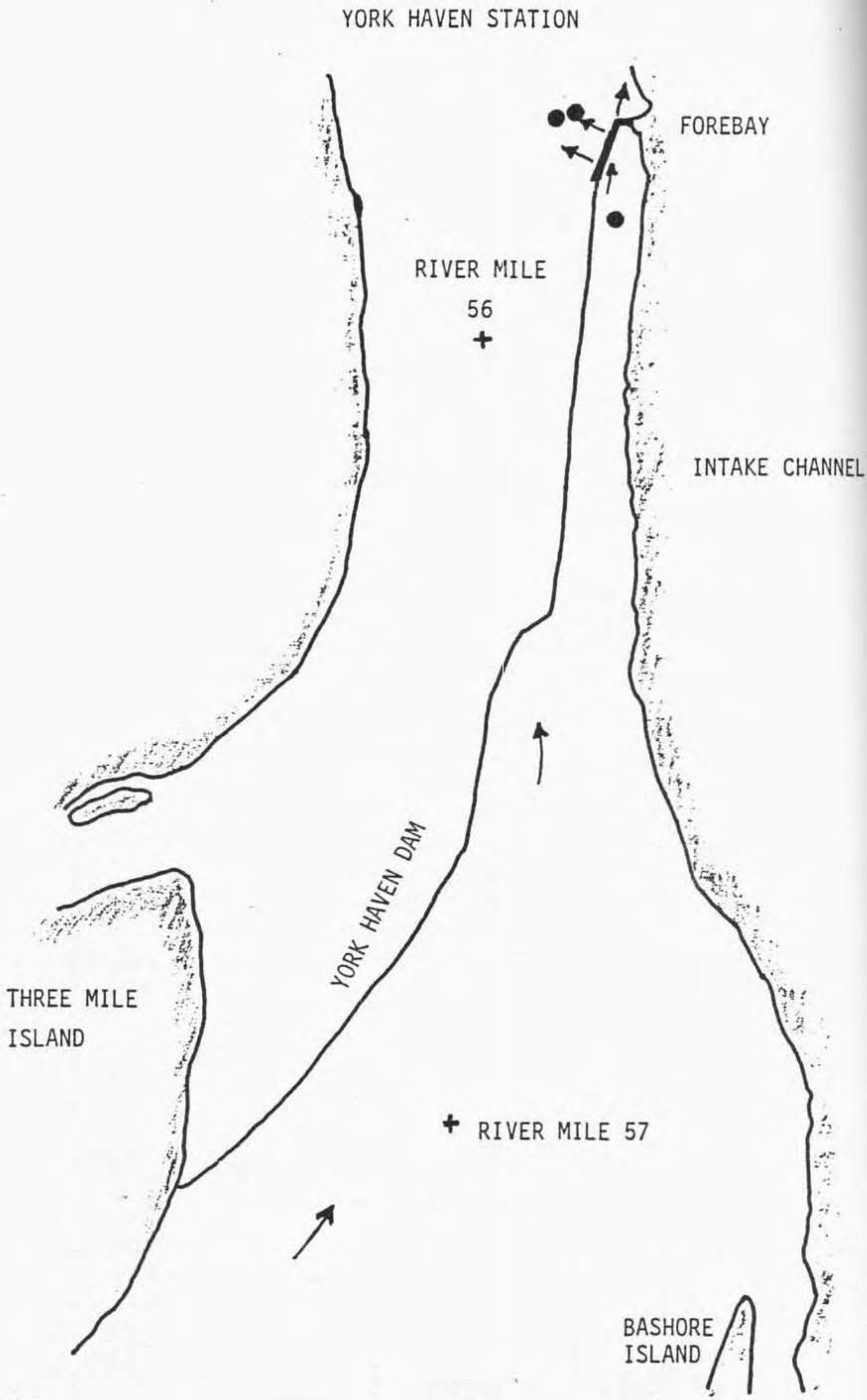


FIGURE 1

Sampling locations for meter net (●) in the vicinity of the York Haven Hydroelectric Station with main flow patterns (arrows).

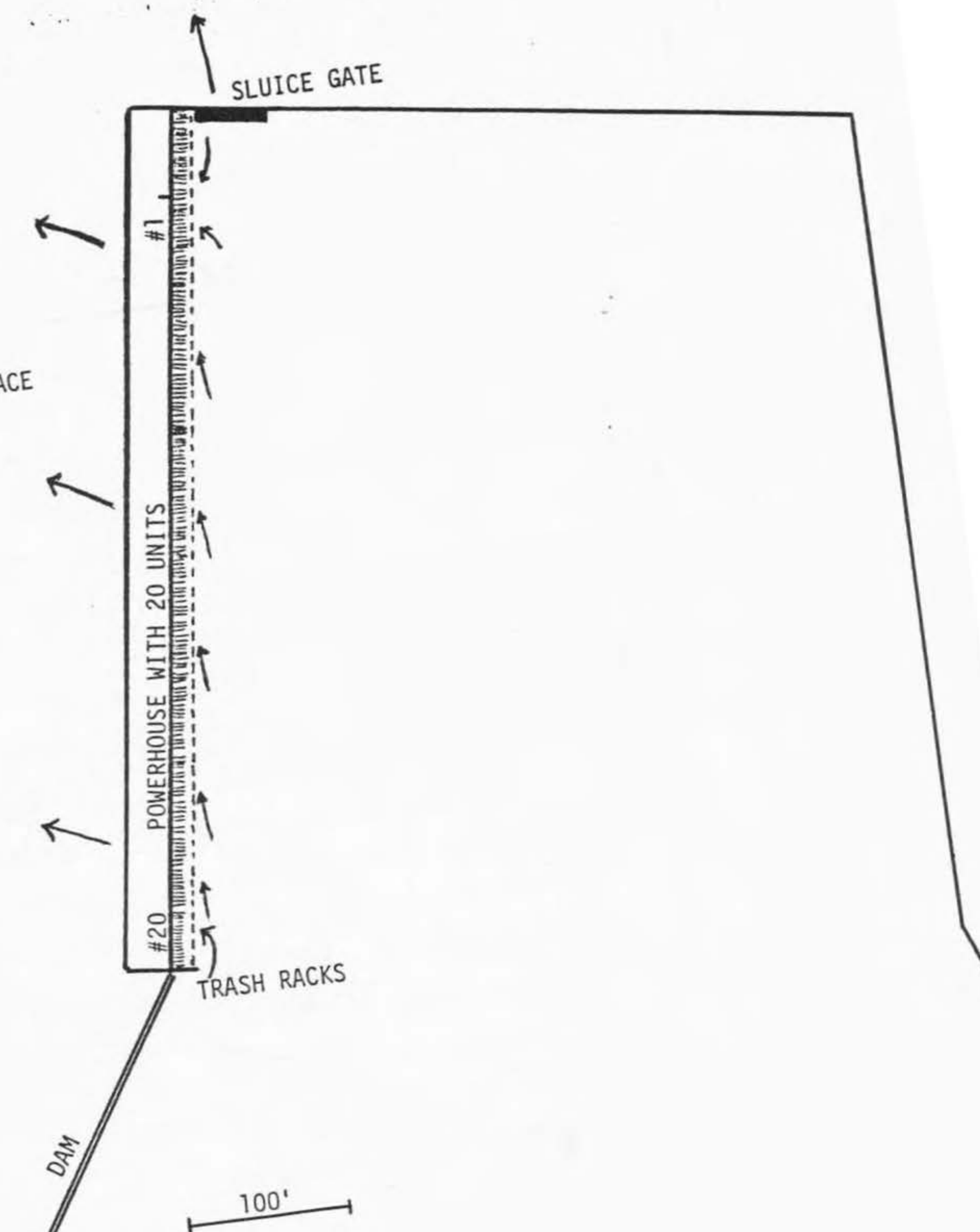


FIGURE 2
Main flow patterns (arrows) in the vicinity of the York Haven Hydroelectr
Station and forebay.

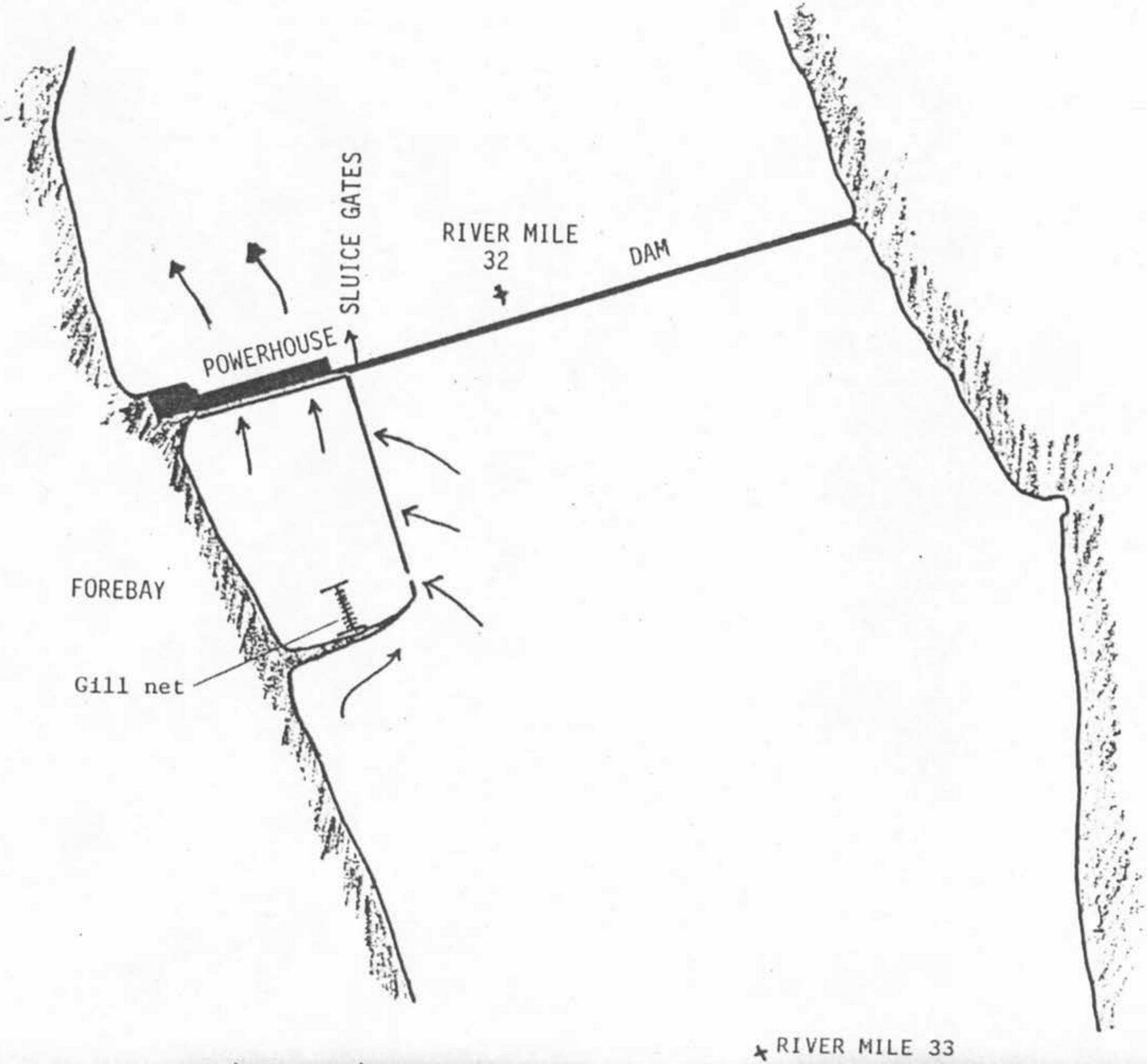


FIGURE 3
MAIN FLOW PATTERNS (ARROWS) AND GILL NET SAMPLING LOCATION IN THE VICINITY OF THE SAFE HARBOR HYDROELECTRIC STATION.

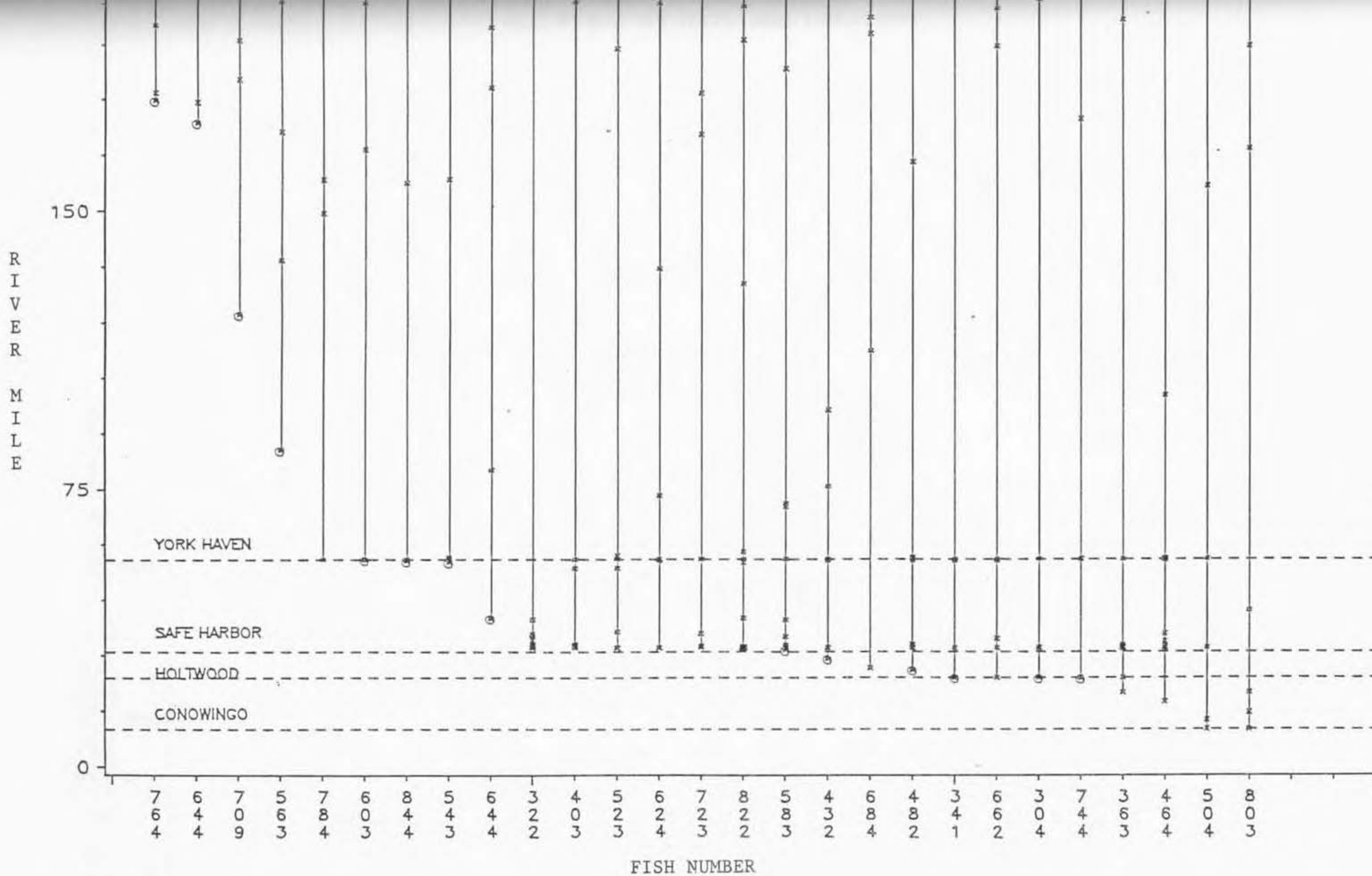


FIGURE 4

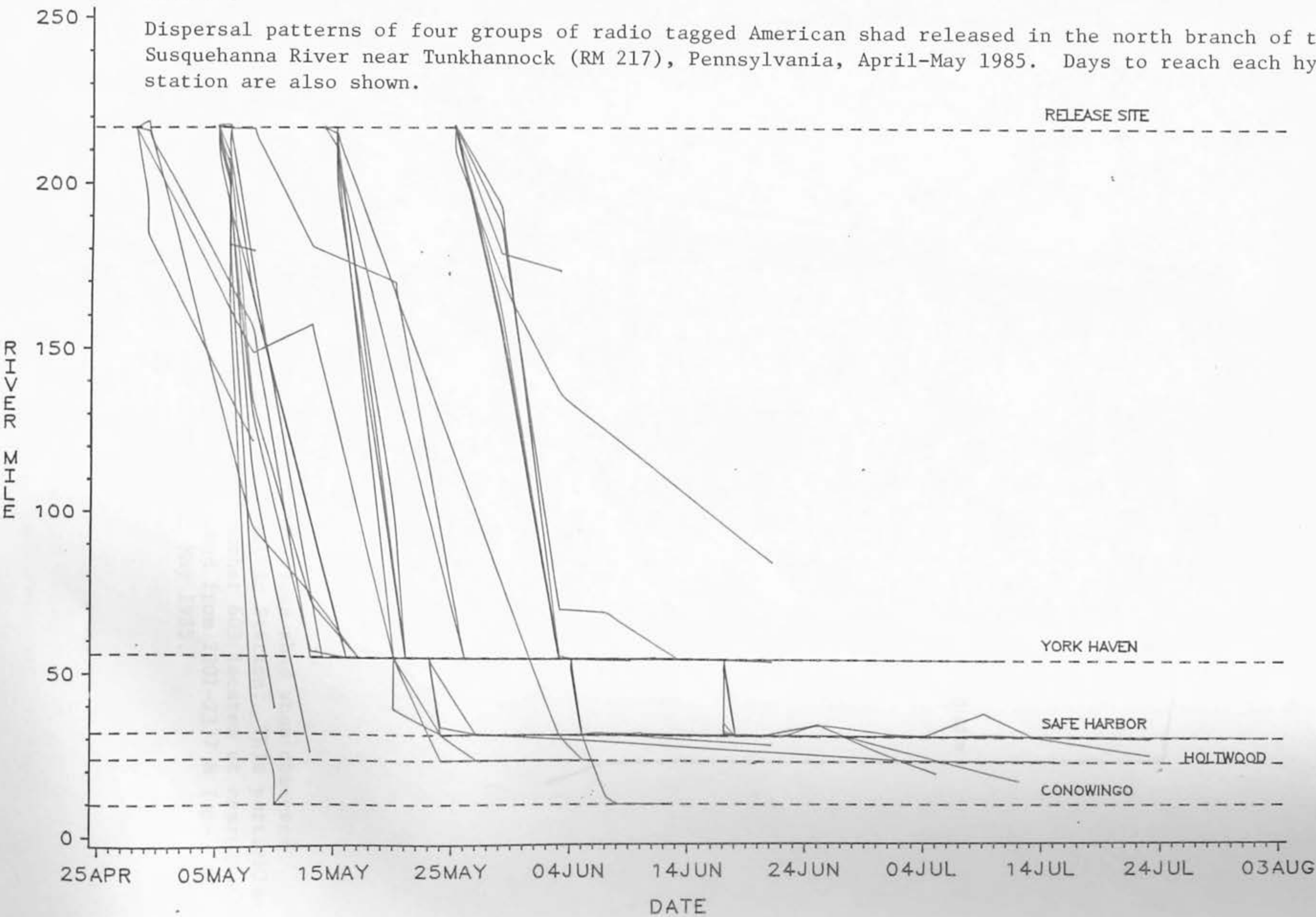
Locations of 27 radio tagged American shad (X) following stocking in the Susquehanna River near Tunkhannock, PA (RM 217), April and May 1985. Cessation of fish activity = O.

SRAFRC SHAD TELEMETRY — 1985

ALL FISH: BY DATE AND LOCATION

FIGURE 5

Dispersal patterns of four groups of radio tagged American shad released in the north branch of the Susquehanna River near Tunkhannock (RM 217), Pennsylvania, April-May 1985. Days to reach each hydro-station are also shown.



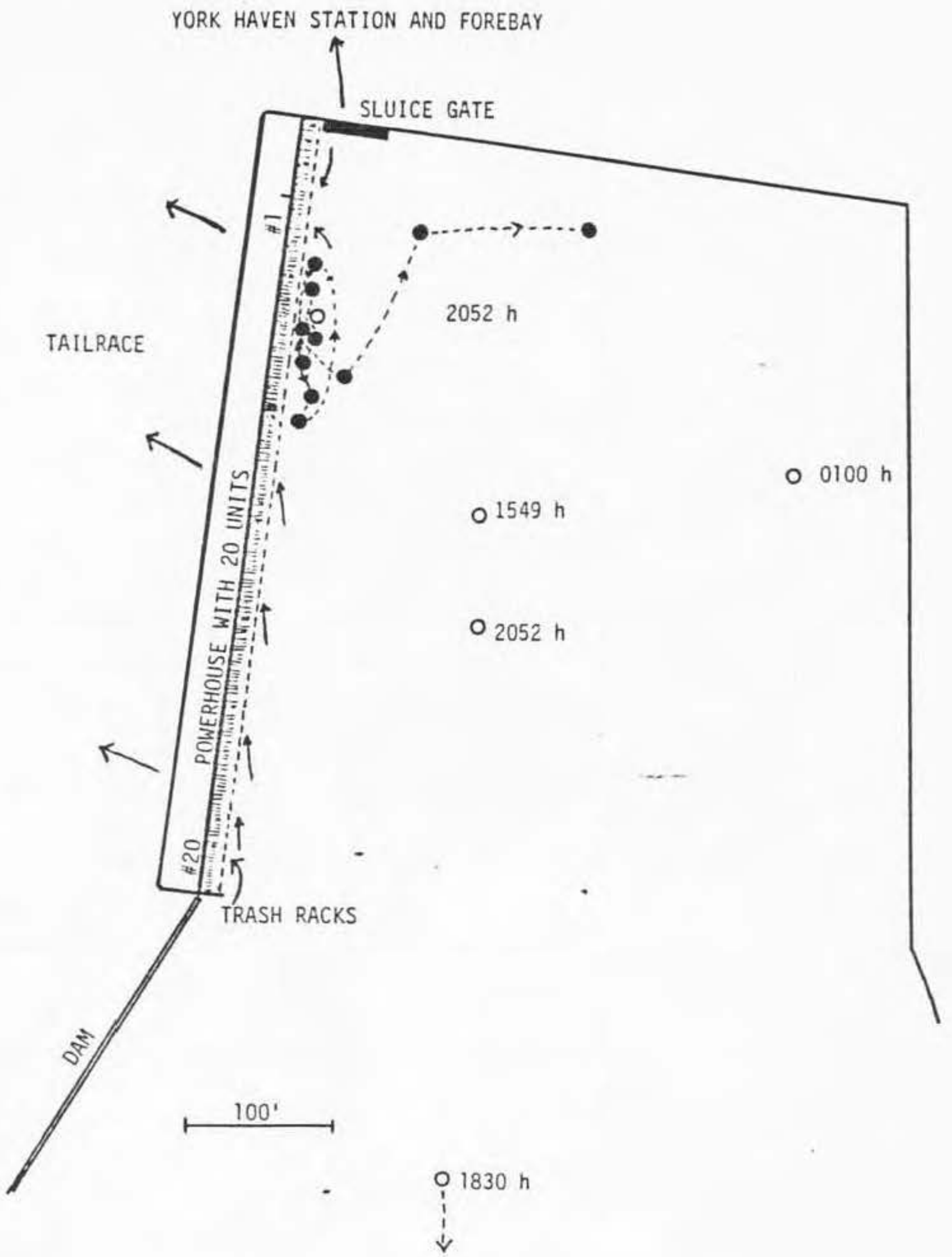


FIGURE 6

Example of dominant movement pattern of American shad when observed in the forebay of the York Haven Hydroelectric Station. This particular track is for radio tagged American shad number 603 located at approximately 2 hr intervals (○) and intensively followed from 2301-2337 h (●---●) during the late afternoon and night of 21 May 1985.

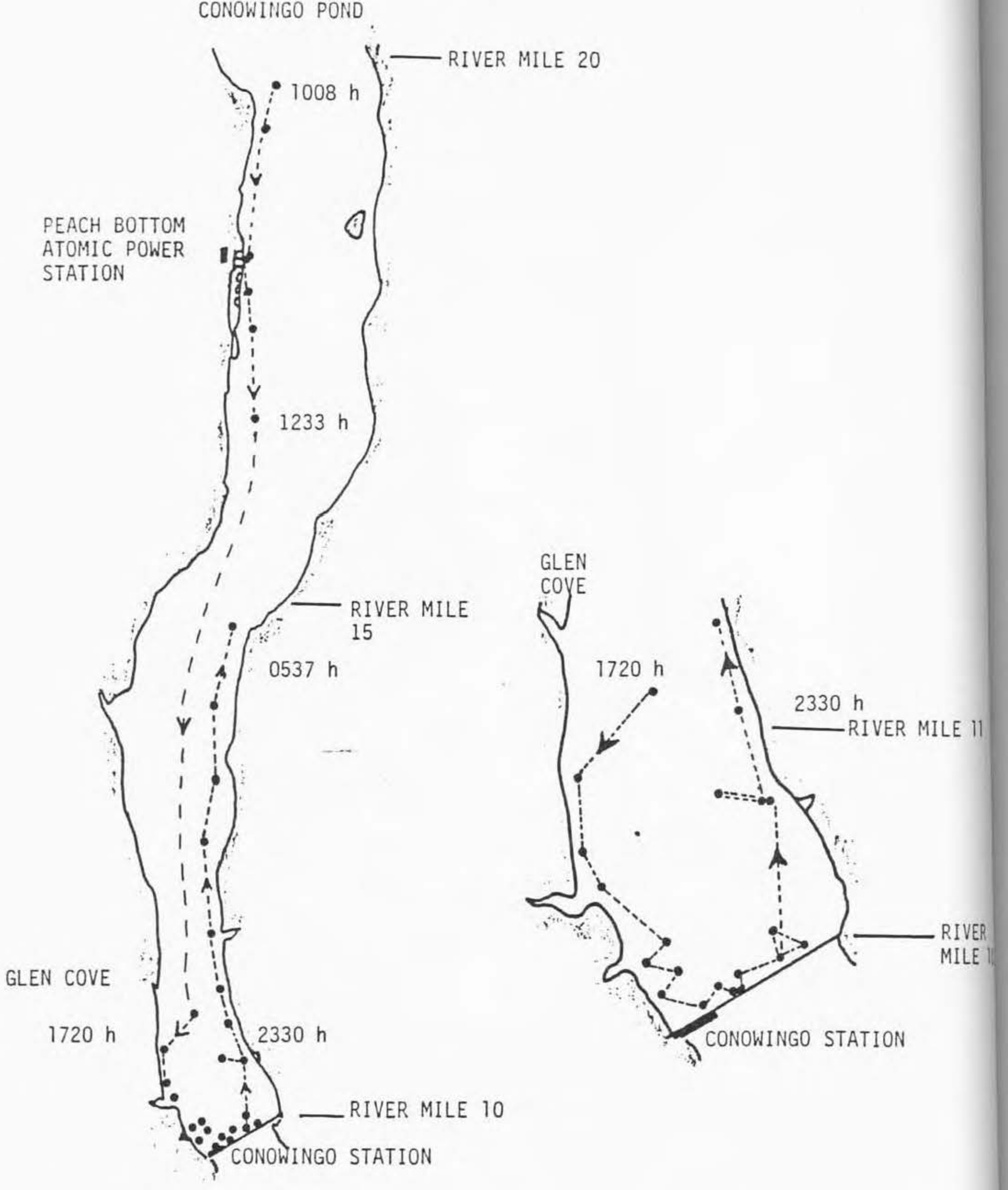


FIGURE 7

Movement pattern of radio tagged American shad number 803 tracked in Conowingo Pond and as it approached Conowingo Hydroelectric Station from mid-morning on 10 May until early morning on 11 May 1985.

JOB V. SPECIAL STUDY

HYDROACOUSTIC EVALUATION AND STUDIES AT THE YORK HAVEN POWER STATION AND THE SAFE HARBOR POWER STATION SUSQUEHANNA RIVER, PENNSYLVANIA

OCTOBER - NOVEMBER 1985

Barnes-Williams Environmental Consultants
132 Washington Street
Binghamton, New York 13901
(607) 723-3113

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. Fixed aspect and mobile hydroacoustic monitoring demonstrated the ability to monitor shad movement continuously over long periods of time.
2. Real-time data were generated on site during the study.
3. The display screen allowed for visual on site observation of fish behavior and immediate modification of procedures.
4. The direction of fish movement and location in the water column can be seen on the display screen.
5. Mobile surveys at York Haven found no concentration of fish throughout the entire head race and forebays. Fish were only seen near the corner of the forebay by Unit 1.
6. Shad move into the York Haven forebay area during the evening hours as shown by overnight and 24 hour hydroacoustic surveys.
7. American shad juveniles moved downstream in pulses as shown by the hydroacoustic real-time surveys.
8. At Safe Harbor shad (American and gizzard) concentrated along the outer wall above the openings into the forebay.
9. The on-site capability of the hydroacoustic equipment used by Barnes-Williams would allow an investigator to design and <u>modify</u> a testing procedure to evaluate shad movement at York Haven. The real-time data and visual display are essential for this purpose.

INTRODUCTION

Barnes-Williams Environmental Consultants was retained to design and conduct a hydroacoustic survey and assessment regarding the downstream migration of juvenile American shad at York Haven Dam, York Haven, Pennsylvania and Safe Harbor Dam, Safe Harbor, Pennsylvania. Specifically, the primary objectives of this study were two fold: first to accomplish all field work necessary to permit the subsequent evaluation of hydroacoustic analysis for studying downstream outmigration of juvenile American shad. Secondarily, within the scope and time frame of the hydroacoustic evaluation program, determination of the vertical and horizontal distribution of American shad as they approach the York Haven Dam and Safe Harbor Dam in order to identify behavior and causes for particular distribution of shad was also an objective of the field study.

In this report we briefly describe the sensor/processor components, its theory of operation, the methods and objectives of the study, and demonstrate the results along with some preliminary analyses.

BRIEF DESCRIPTION OF EQUIPMENT AND OPERATION

Figure 1 and 1a are simplified block schematic diagram of the sensor/processor and data processing systems.

The technique of hydroacoustics involves propagating sound energy "... and then processing the received echo signals to estimate fish density".

The acoustic equipment produces an electrical signal of a specific carrier frequency, amplitude, and duration at the terminals of a transducer, which converts the electrical signal into a dynamic pressure wave of a corresponding frequency, amplitude, and duration. This acoustic signal, or pulse, is radiated from the transducer and spreads spherically in water. The radiated energy is greatest along the transducer acoustic axis (the axis of maximum transducer sensitivity), and varies off axis as a function of the transducer's directional properties (directivity). Also, the physical properties of water cause absorption of the radiated pulse energy; thus, the sound intensity is attenuated exponentially as the pulse spreads away from its source.

When the pulse encounters an object or target whose acoustic properties are different from those of water, a portion of the acoustic energy is reflected or scattered back toward the source. This reflected, or backscattered, energy also spreads spherically, is subject to attenuation, and varies in strength with the orientation of the target and as a function of the target's directivity. When the backscattered energy or echo impinges on the transducer, an electrical signal is produced which is handled by various methods to indicate the presence of the target.

The scattering characteristics of a single fish are of primary concern, particularly the scattering cross section of the fish as viewed above (dorsal view). The fish's scattering characteristics or cross section are a function of its orientation. When normalized to a standard reference, the scattering cross section is called the target strength.

Information in the electrical signal received at the transducer may be contained in phase variations, amplitude, frequency, duration, and the time delay between signal transmission and reception. Because the physics of sound propagation in water and the limited practical knowledge of hydroacoustic scattering from fish targets inhibit phase processing (except under special circumstances), the information concerning the number of targets that produce an echo must be derived from the remaining characteristics. For example, if a single fish target were insonified, the echo signal would have (in addition to a particular amplitude) a time duration on the order of the transmitted pulse duration. If several targets were packed tightly together, the echo-signal envelope (the curve which bounds the peak amplitudes of the echo signal) would have a larger amplitude than a single target, but would still have a time duration on the order of the transmitted pulse. Conversely, if the targets were uniformly distributed within an insonified volume, the echo-signal envelope could have a time duration considerably longer than the transmitted pulse, as the target echoes would be arriving in a random sequence.

The fundamental requirement for echo counting is the combined ability of the hydroacoustic apparatus and the received-echo signal processor to resolve or distinguish between the objects to be counted, and then to perform the counting function.

The resolution of targets refers to two coordinates: range (depth) and angle. Range resolution refers to the separation of targets at the same angle (referenced to a coordinate origin), and is expressed in terms of the distance between them. Angle resolution refers to the angular separation of targets at the same range, and is expressed in terms of the angle between them.

In addition to the basic consideration of target resolution, there are other vital practical factors that must be recognized, especially when fish are the targets of interest. Consider the situation depicted in Figure 1, which schematically shows two fundamental interacting elements in an underwater acoustic environment: the transducer and a single fish target. The directivity of the transducer determines the acoustic energy projected and received as a function of the angle between the target fish and acoustic axis of the transducer. The maximum energy is on the acoustic axis and diminishes off axis. If there is little or no knowledge of the backscattering properties of the fish target (except perhaps that a single large fish returns a larger echo signal than a single small fish), then it is possible that a single large fish target off axis may produce an echo signal smaller that or equal to the signal produced by a small fish directly on axis. Indeed, the differences in the echo signals are related to the size and position of the fish target.

Transducer directivity characteristics are conveniently measured under controlled condition. The beamwidth angle of the directivity function is the angular width between the acoustic axis of the transducer and the points at which a reference acoustic intensity is reduced to 0.5, 0.1, or some other arbitrary number.

Differences in the echo signals are also related to the body composition of the fish, i.e., its density. If the target fish has a swimbladder, complications in interpreting the echo signal may arise because the state of the fish's swimbladder and its attitude to the insonifying wave affect the fish's target strength.

In theory, the acoustic echo signal is the product of the average target density and the average of the individual backscattering characteristics of the insonified targets. Serial estimations of target density should therefore be proportional to the number of the insonified targets. However, data obtained from an echo integrator represents energy scattered not only from fish targets, but from other scatterers in the insonified volume (e.g., plankters, air bubbles, debris) as well as from other sources of extraneous noise.

The acoustic/sensor processor described in the Materials section is capable of producing useful indices of target flux density for either single (resolved) or multiple (unresolved) targets. The correlation between actual target enumeration and the processor derived estimation is a function of fish target species and size and velocity in the detection zone of the acoustic sensor. The last two parameters can be easily changed in the processor at the option of the observer in near real-time.

The statistical calculations combined with the histogram plot provides a powerful method to assess the applicability of the current processes, methods and assumptions used to calculate the number or weight of insonified fish targets.

METHODS - OPERATIONS - OBJECTIVES

The areas chosen for the study were the forebay areas of the York Haven Power Station and the Safe Harbor Power Stations (Figures 2 and 3). The weather in the area was mild with frequent light rain. Current patterns in both the York Haven Station and the Safe Harbor Station were dependent on operation of the generating units. No study of current velocity and pattern changes has been done, but some obvious changes in the direction and velocity of water movement in the forebay occurred as generating units were brought on-line and taken off-line.

Mobile surveys were done at both locations from a covered outboard pontoon boat. Surveys were successfully done in calm water at estimated speeds of 3 to 5 knots (Figure 3 and 4). Electric power (115 VAC) was supplied from a portable gasoline generator.

Fixed aspect surveys were conducted at both locations. At York Haven bottom to surface (Transducer mounted at the bottom of the trash racks directed upward) surveys were conducted at several locations along the intake trash racks (Figure 2). In addition, one survey was conducted scanning horizontally from a location along the catwalk.

At Safe Harbor overnight surveys were done in two locations (Figure 3). Because of the intake configuration surface to bottom hydroacoustic surveys were done.

Pre-survey set-up and calibration was conducted with the equipment during the week of October 7 to 11, 1985 in the Barnes-Williams Environmental Consultants Binghamton, New York, office. The following week set-up, field calibration and data collection was initiated at the York Haven Power Station. Approximately 12 daytime hours hydroacoustic samples were taken at Units 1, 3, 4, 16-17. In addition, 24 hour collections were taken at Unit 3. Hydroacoustic monitoring of the trash sluice during a spill and mobile surveys were done. The mobile surveys were done on two consecutive days, in the afternoon to early evening and in early morning.

During the week of October 28 to November 1, 1985 hydroacoustic surveys were conducted at Safe Harbor. Among the specific objectives was the examination of fish behavior at the training wall that borders the intake forebay.

Cast net samples were taken throughout the hydroacoustic study period to verify the presence of American shad in the York Haven and Safe Harbor forebay areas. American shad were found at York Haven throughout the study period. American shad and gizzard shad were found at Safe Harbor.

This report is divided into two sections: Evaluation of hydroacoustics as an applicable technique for the American shad restoration program. The discussion in this section will be limited to hydroacoustics, and its use at York Haven and Safe Harbor. The second part will examine the information collected at the two sites. The secondary objective of examining behavioral and distributional characteristics will be addressed to extent possible.

Applicability and usefulness of hydroacoustic analysis for studying downstream outmigration of juvenile American shad

This was the primary objective of the 1985 hydroacoustic program at Safe Harbor. The fixed aspect testing demonstrated the capacity of the technique to monitor the movement of juvenile shad over long periods of time at a particular location. Hydroacoustics has the advantage of being able to "look" at a segment of the aquatic habitat continuously whereas typical evaluation techniques are not capable of having this continuity. For example, with hydroacoustics observations over hours, days or weeks are possible. Real time data is generated throughout the selected survey period. Position and movement of fish can be observed directly on the display screen immediately, allowing the trained observer to see where the fish are and how they are behaving during all conditions that occur at the site during the survey period. This capability, where deemed appropriate, allows the modifications in the program to obtain additional data. In addition, magnetic tapes of the field surveys can be made for review at a later time. Real time data printouts that describe the various aspects of the hydroacoustic survey are provided for the predetermined survey periods. The following sample data sheet shows the information supplied and the resultant data that is generated.

YORK HAVEN 24 UNIT 3

Acoustic Sensor (KODEN CVS-8800)	Acoustic Signal Processor (85/275-2)	
Transmitter Carrier Frequency (KHz)	200	
Attenuation Constant (Nepers/Meter)	9.78E-03	
Source Level (micropascals at 1 Meter)	1.00E21	
Receiving Voltage Response (Volts/Micropascal)	7.08E-10	
Output Power	B3	
Sensitivity	4	
Range Select	10 Meters	
Maximum Sampling Range	5.9 Meters	
Minimum Sampling Range	1 Meter	
Sampled Depth Interval	4.9 Meters	
Transmit Pulse Time Interval	0.3 Ms.	
Seconds/Insonification	.16	
Analog Data Tape ID/Analog Recorder Counter #	0 -AR/0	
Volume Backscatter Threshold (/Cubic Meter)	1.23E-06	
Data (Julian Day)	0	

ACOUSTIC DATA SET NO. 0 / 10

	6	19.7
Estimated Target Velocity	M/Sec	Ft/Sec
Transducer Detection Zone Beamwidth(Degrees)	60.2	(-20Db)
Integrated Transudcer Directivity (/4π SR)	9.95E-03	
Sampled Time Interval (Seconds)	.6	
Sampled Volume per Insonification(Cubic Meters)	16.87	
Sampled Area per Insonification(Square Meters)	10.32	
Start Time Hr.:Min.:Sec.	19:34:00	

VOLUME BACKSCATTER(/CUBIC METERS)

Sample Number	Running Mean	Running CV	Running CIS	Internal Mean	Internal CV	Internal CIS
50	3.64E-06	.15	.04	3.64E-06	.15	.04
100	3.61E-06	.13	.03	3.58E-06	.11	.03
150	3.56E-06	.12	.02	3.47E-06	.09	.02
200	3.55E-06	.11	.02	3.49E-06	.07	.02
250	3.55E-06	.11	.01	3.57E-06	.11	.03
300	3.54E-06	.11	.01	3.52E-06	.11	.03
350	3.56E-06	.13	.01	3.63E-06	.21	.06
400	3.56E-06	.14	.01	3.58E-06	..15	.04
450	3.55E-06	.13	.01	3.44E-06	.09	.03
500	3.54E-06	.13	.01	3.49E-06	.07	.02
500	3.54E-06	.13	.01	3.49E-06	.07	.02

Time Hr.:Min.:Sec.	19:52:13
Number of Acoustic Samples	500
Sampled Volume (Meters ↑3)	8435
Sampled Area (Meters ↑2)	5160

DISTRIBUTION OF VOLUME BACKSCATTER

Interval of Volume Backscatter (/Cubic Meter)	Relative Frequency (Percent)
1.23E-06 – 2.47E-06	0
2.47E-06 – 4.95E-06	99
4.95E-06 – 9.91E-06	1
9.91E-06 – 1.98E-05	0
1.98E-05 – 3.96E-05	0
3.96E-05 – 7.92E-05	0
7.92E-05 – 1.58E-04	0
1.58E-04 – 3.17E-04	0
3.17E-04 – 6.34E-04	0
6.34E-04 – 1.26E-03	0
1.26E-03 – 2.53E-03	0
2.53E-03 – 5.07E-03	0

DATA SET ANALYSIS

1. Mean volume backscatter was 3.54E-06 ± 1.1% (0.95 Confidence).
2. Values of volume backscatter within a factor of 4.0 of the mean occured in 100% of the acoustic samples.
3. Values of volume backscatter within a factor of 2.0 of the mean occured in 99.6% of the acoustic samples.
4. Values of volume backscatter within a factor of 1.5 of the mean occured in 99% of the acoustic samples.
5. The total number of acoustic samples was 500.
6. Signals at or above the volume backscatter threshold of 1.23E-06/M↑3 occured in 500 or 100% of the acoustic samples
7. No signal was detected in 0 or 0% of the acoustic samples.
8. Signals below the volume backscatter threshold of 1.23E-06/M↑3 ocurred in 0 or 0% of the acoustic samples.
9. The total sampled volume between 1 and 5.9M is estimated to be approximately 8435 M↑3.
10. The total samples area at 3.45M is estimated to be approximately 5160 M 2.
11. The mean density of targets with a mean scattering cross section of 6.8 CM↑2 (15CM long clupeidae) ± 12% (0.95 Confidence) is estimated to be .027/M↑3 ± 12.1% (0.95 Confidence).
12. The total number of targets in the sampled volume is estimated to be 34 ± 12.1% (0.95 Confidence).

The data set analysis examines the hydroacoustic data (volume backscatter) and analyzes it for several statistical parameters. On the sample datasheet the targets (fish) were all of comparable size giving a very consistent, uniform volume backscatter signal. This information can then be converted to a useful index of the number of fish in a given area, or volume.

Photographs were taken of the display screen throughout the study period for the purpose of illustrating the capabilities of hydroacoustics in the shad restoration program. Photograph 1 illustrates directional movement of the fish. Note the diagonal signals on the display screen. These signals were caused by fish moving toward the surface as they crossed through the hydroacoustic beam. It is easy to see how fish moving toward or away from the transducer produce images like this. A transducer correctly placed would supply directional movement information at any power plant site.

Photograph 2 taken at York Haven depicts a typical screen with no target at all. The water depth is approximately 6 meters. The broad line between 0 and 1.7 meters is at the bottom of the trash racks and represents the face of the transducer. The line at 6 is the surface of the water. The area between these two lines, the water column covered by the hydroacoustic beam, is clear and devoid of targets.

Photograph 3 shows a split screen with fish targets in view. The lower half of the screen is just an expansion of the upper half expanding the image for closer observation. This mode might be used for closer examination of a particular layer in the water.

Photograph 4 depicts a situation in which many fish were observed. All of the signals between the surface and bottom lines represent fish (American shad juveniles). Fish were observed visually, as well as hydroacoustically, throughout the forebay area when this photograph was taken.

Mobile surveys were done at both York Haven and Safe Harbor. Photograph 5 shows a segment of the mobile survey at Safe Harbor. Note the high density of the targets (fish) in the 2 to 6 meter depth range and the lack of targets below 6 meters. This survey was done along the outside of the training wall that surrounds the intake forebay. It can easily be seen how effective this equipment is for locating fish concentrations in these areas. It would be difficult, if not impossible, to obtain this type of information by the use of conventional means.

Behavioral and Distributional Characteristics

Mobile surveys were done at York Haven on two successive days (October 22 and 23, 1985). The first survey was done in the late afternoon and early evening. Transects were run throughout the intake forebay area (Figure 4), out to the junction of the forebay with the main pool, Lake Frederic. No concentrations of fish targets were seen during the surveys except in the corner of the intake forebay near Unit 1 (Figure 5). Early the next day, October 23, 1985, another mobile survey was run of the same area, with the same results. Other sampling programs were going on at the time of the late afternoon-early evening mobile survey. Trawling, with experimental equipment, was being done by biologists from the State of Maryland in an effort to test their gear and electroshocking was being done by personnel from RMC to collect fish for their tag development program. Neither of these groups were very successful in collecting juvenile American shad. The trawling effort yielded no fish and the electroshocking collected fish in the area that the hydroacoustic survey had identified as having them. Very few juvenile shad were in the forebay area on this occasion.

In an effort to gain more information about the movements and behavior of the outmigrating shad, an overnight hydroacoustic survey was done on the night of October 22, 1985. A transducer was set from the catwalk along the cable passageway at the end of the intake forebay aimed horizontally toward the trash racks. Photograph 6 shows groups of targets that came in later, around dusk. The red band on the screen represents the transducer face. The photograph has been oriented in the same direction as the transducer placement. An apparent increase in the number of fish in the forebay occurred during the evening. However, it can be seen that the fish targets are located within the first 10-12 meters from the dam at this time. The mobile survey the next morning showed that there were very few targets in the forebay. In addition, a very small amount of dimpling was seen on the surface of the forebay waters. Dimpling by American shad juveniles is indicative of their presence.

The hydroacoustic surveys done at the intake trash rack show some locational characteristics about the outmigrating shad at York Haven. For most of the study period at York Haven the juvenile American shad were not available in large numbers. However, on October 24, 1985, the evening following the mobile surveys, large numbers of juvenile American shad began to move into the forebay area. Fish could be seen dimpling all over the surface of the forebay, and with the use of a large flashlight juvenile shad could be seen below the surface of the water in substantial numbers. Hydroacoustic surveys were done at Unit 3 during this period. On Thursday night, the following evening the fish (target) concentration was much less than the previous night.

York Haven data gathering was directed primarily at the demonstration of the applicability of hydroacoustics as a tool for use in the American shad restoration program. However, a substantial amount of useful information about shad concentrations, location and movement during the study period was gathered.

The first such surveys were done during the first week of the study (October 14 - 18). First it must be understood that all numbers presented in this report must be considered as representation of the fish numbers and not absolute. The duration and nature of the surveys dictates this approach, although the statistical analysis of the hydroacoustic data (volume backscatter) shows that the data is for the most part very good.

Hydroacoustic surveys were done for 24 hour periods in front of Unit 1, 3, and 16 - 17.

On October 17, no fish were detected in the vicinity of unit 17 - 18 at York Haven. The information represented by the flux density shows the number of targets passing through a "window" per unit time.

$$\text{Flux Density} = \frac{\text{Total No. of Targets}}{\text{Sampled Cross Section X Total Observation Time}}$$

The "window" (sampled cross section) is the area seen by the transducer.

At Unit 1, during the same week (October 16) a very small number of fish were seen (.014 targets per square meter per hour). On October 18, 1985 a controlled spill was run at the trash sluice to examine its potential as a means of passing shad around the power station without having them go through the generating units. During this test the flux density was equal to 2.68 targets per square meter per hour. The number taken as an index of the number of fish that passed through the sluice during the test means that approximately 11 fish per hour passed through the open sluice.

Overnight (24 hours) samples were done at Unit 3 on two (2) consecutive days the following week (October 23, 24). The first day, October 23, 1985, using the flux density as representative of the number of fish index, fish were observed at Unit 3 passing through the ensonified area at a rate of .11 fish per square meter per hour at 11:00 o'clock a.m. This continued at a relatively constant rate until the middle of the afternoon. Between 3:00 p.m. and 4:00 p.m. the flux density had increased to 4.6 targets (fish) per square meter per hour, many times any number previously encountered during the surveys at York Haven. By 7:30 p.m. the rate had increased to 6.9 fish/m2/hr. Visual observations of the forebay area were done throughout this period. Fish were seen in large numbers along the face of the trash racks with the aid of a powerful flashlight. In addition, dimpling was taking place over the entire surface of the forebay. The flux density in the area remained high for the next couple of hours and then dropped off during the night, by 8:30 a.m. the next morning the flux density was down to .06 targets/m2/hr. Then another increase occurred over the next hour at the Unit 3 location to a high of 8.2 fish/m2/hr. For the rest of the day the flux density remained between .25 and 1.2 fish/m2/hr., still several times that recorded during any previous survey.

Observation of fish behavior at the York Haven Power Station demonstrated that fish are not uniformly distributed over time at the York Haven forebay. The number of fish in the area was low throughout most of the study period.

The large number of fish that passed through the forebay on the 23rd and 24th of October showed that the juvenile American shad <u>may</u> move downstream through this area in pulses. Other observations based on the use of hydroacoustics are that the juvenile shad occupy a position approximately midway in the water column between 1.5 to 4 meters. Even though dimpling occurs at the surface most of the fish are in the center of the water column (Photo 4). During periods of lower fish concentrations (versus the one period when there were large numbers of fish in the area) the outmigrating shad were found to concentrate along the dam at the end of the forebay (cable passageway) (Photo 6).

At Safe Harbor the mobile surveys clearly showed that fish concentrate along the outside of the wall that defines the forebay. The wall has arched openings about 15± feet below the surface to allow water to pass through to the generating units. The fish (juvenile American shad and juvenile gizzard shad) concentrated in the 2 meter to the 6 meter depth, above the openings. Mobile surveys along the upstream face of the dam, across the river, did not show any areas of high fish concentration. Mobile surveys along the face of the training wall in front of the trash racks found fish concentrated in the upper part of the water column, above the lower edge of the training wall.

Overnight hydroacoustic surveys done near Unit 1 (by construction trailer) and in front of Unit 10 did not show simular indices. Concentration of .05 targets per square meter per hour were found at the construction trailer location while concentration of .50 to .70 were found in front of Unit 10. It must be stated that these numbers, although they are indicative of the conditions that occurred during the study, cannot be considered as anything more than that. The data collected suggest that the spatial and temporal distribution of shad are such that a study of short duration (3 days at Safe Harbor) is not long enough to accurately predict fish concentration locations.

TABLE 1. UNIT 3, YORK HAVEN
24 HOUR HYDROACOUSTIC SAMPLE
FLUX DENSITY (FISH/m^2/hr)

DATE	TIME	FISH DENSITY
October 23, 1985	11:00 - 11:52	.11
	11:55 - 12:46	.11
	12:50 - 13:26	.16
	13:30 - 14:46	.35
	14:50 - 15:40	.54
	15:44 - 16:50	4.60
	16:54 - 17:54	5.08
	17:54 - 18:43	5.56
	18:47 - 19:30	5.82
	19:34 - 19:52	6.90
	19:52 - 20:12	6.33
October 23-24	21:08 - 08:34	.06
October 24, 1985	08:36 - 08:52	8.20
	08:56 - 09:30	4.60
	09:33 - 11:20	.25
	11:24 - 12:47	.43
	12:51 - 14:15	.20
	14:19 - 14:55	1.20
	14:59 - 15:42	.99
	15:46 - 16:28	.95
	16:51 - 18:54	.67
	18:58 - 20:31	1.01

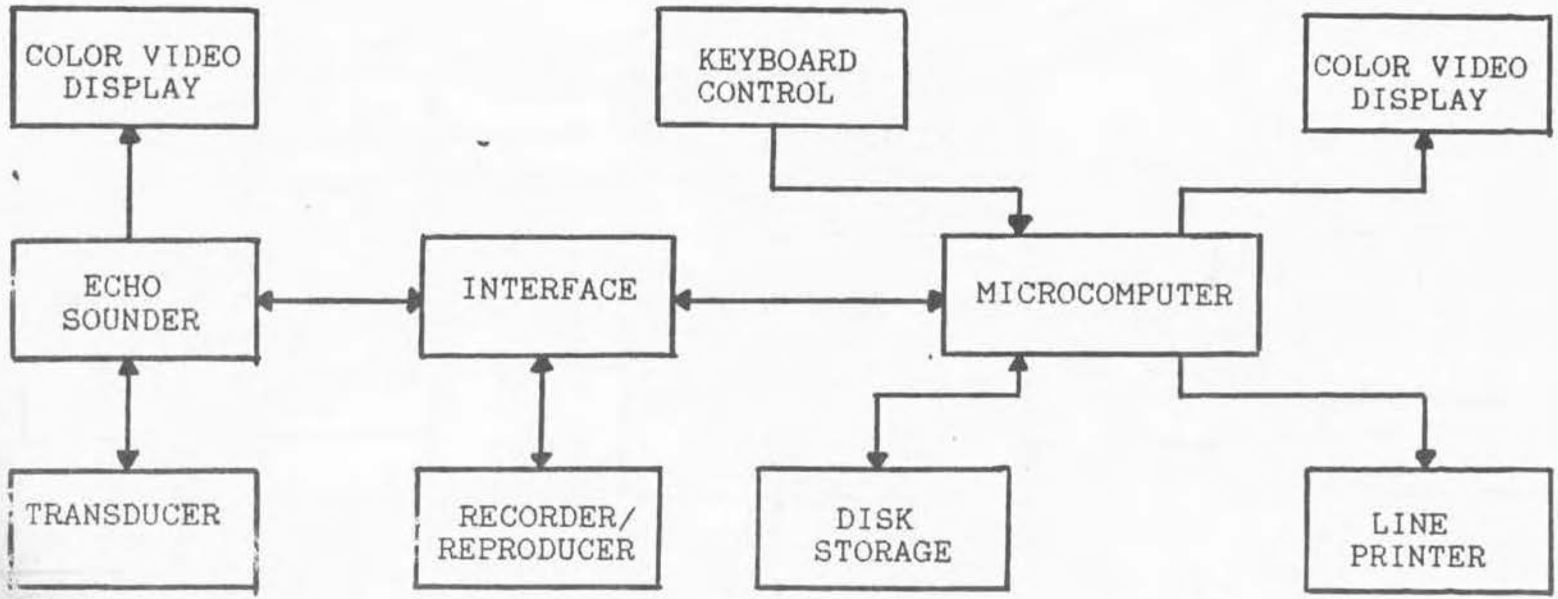


FIGURE 1.
BLOCK SCHEMATIC DIAGRAM
ACOUSTIC EQUIPMENT

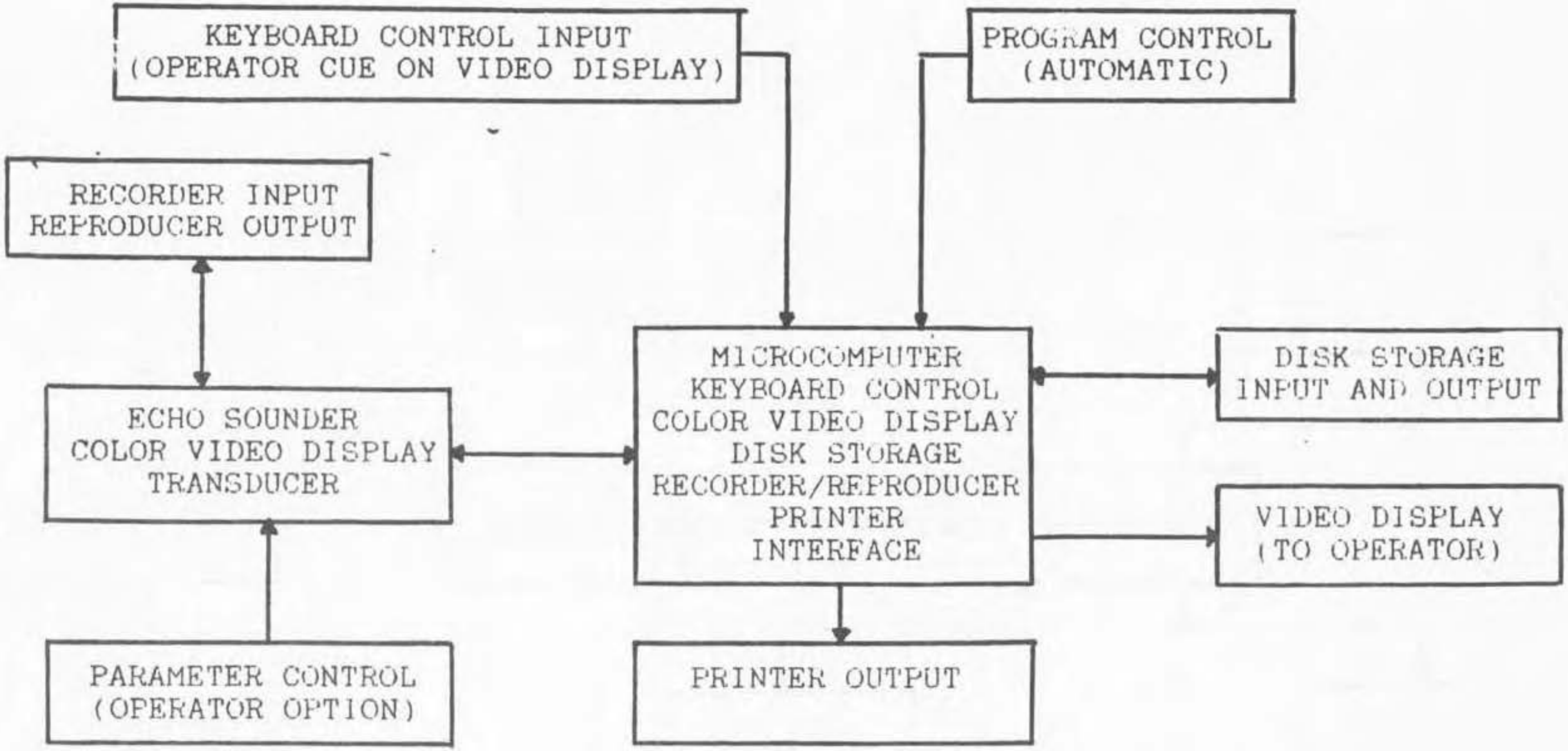


FIGURE 1A
SIMPLIFIED DATA HANDLING DIAGRAM
ACOUSTIC EQUIPMENT

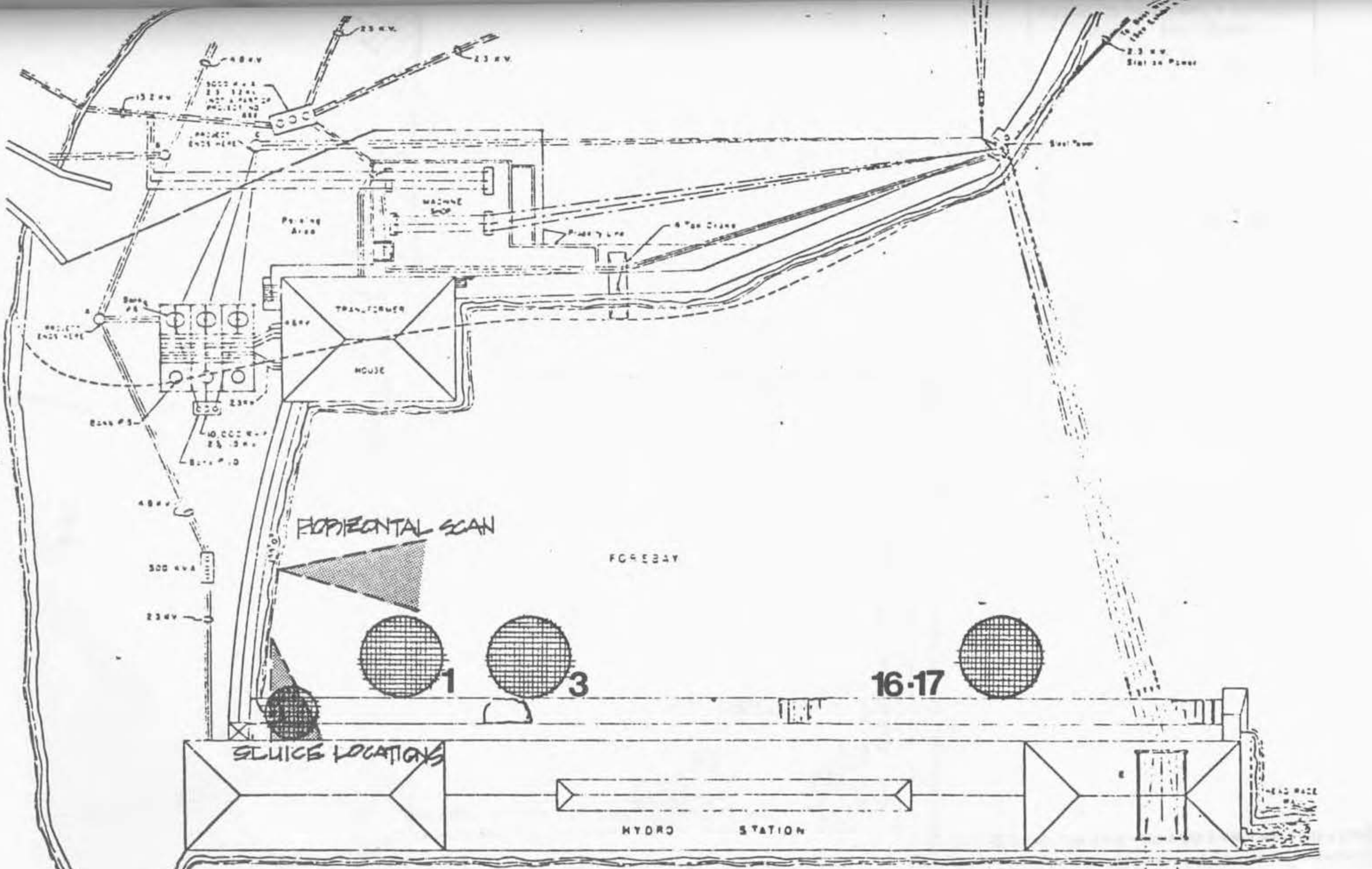


FIGURE 2
YORK HAVEN
HYDROACOUSTIC SURVEY LOC.

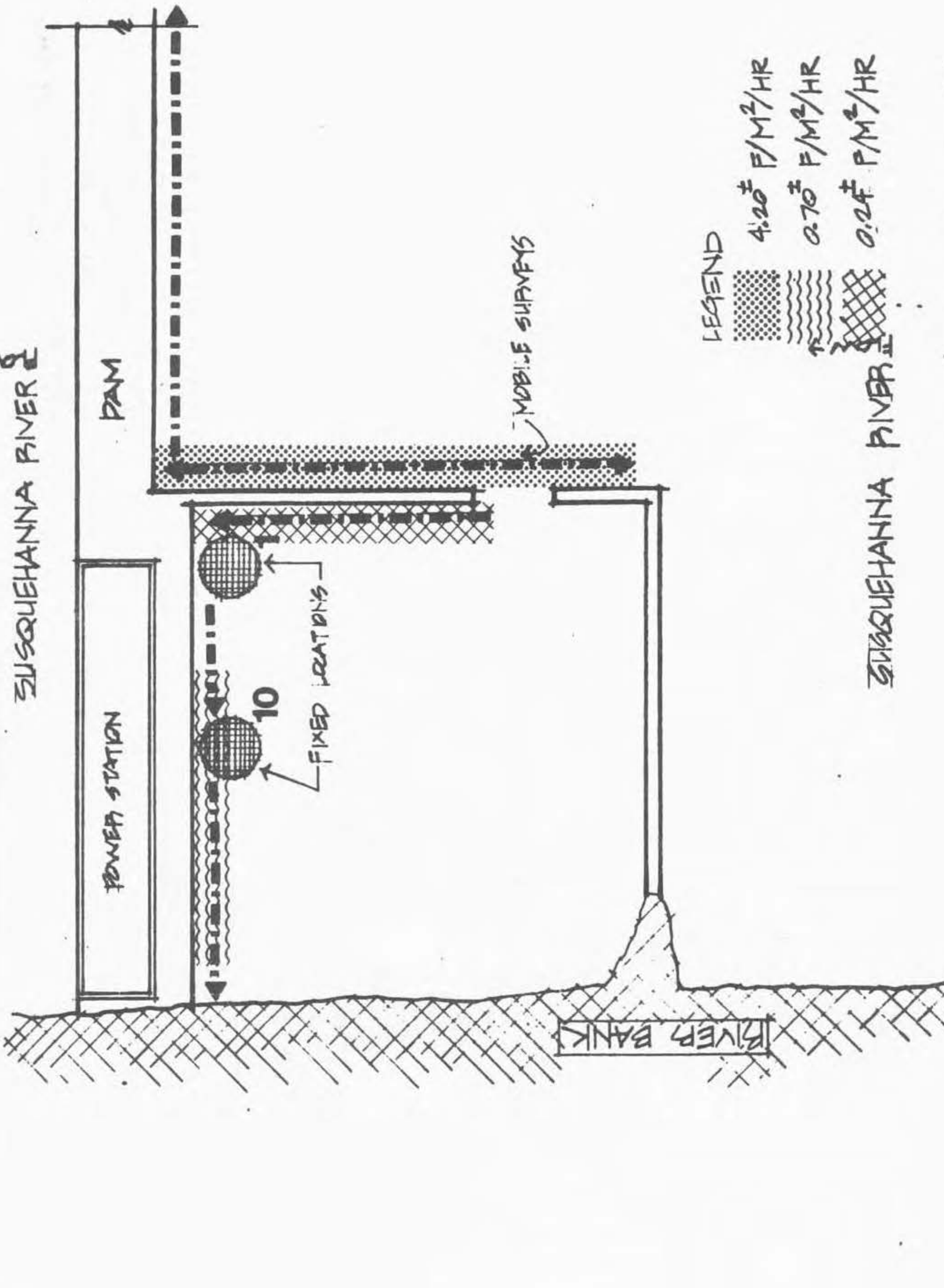


FIGURE 3
SAFE HARBOR
MOBILE SURVEY + FIXED SURVEY LOCATIONS

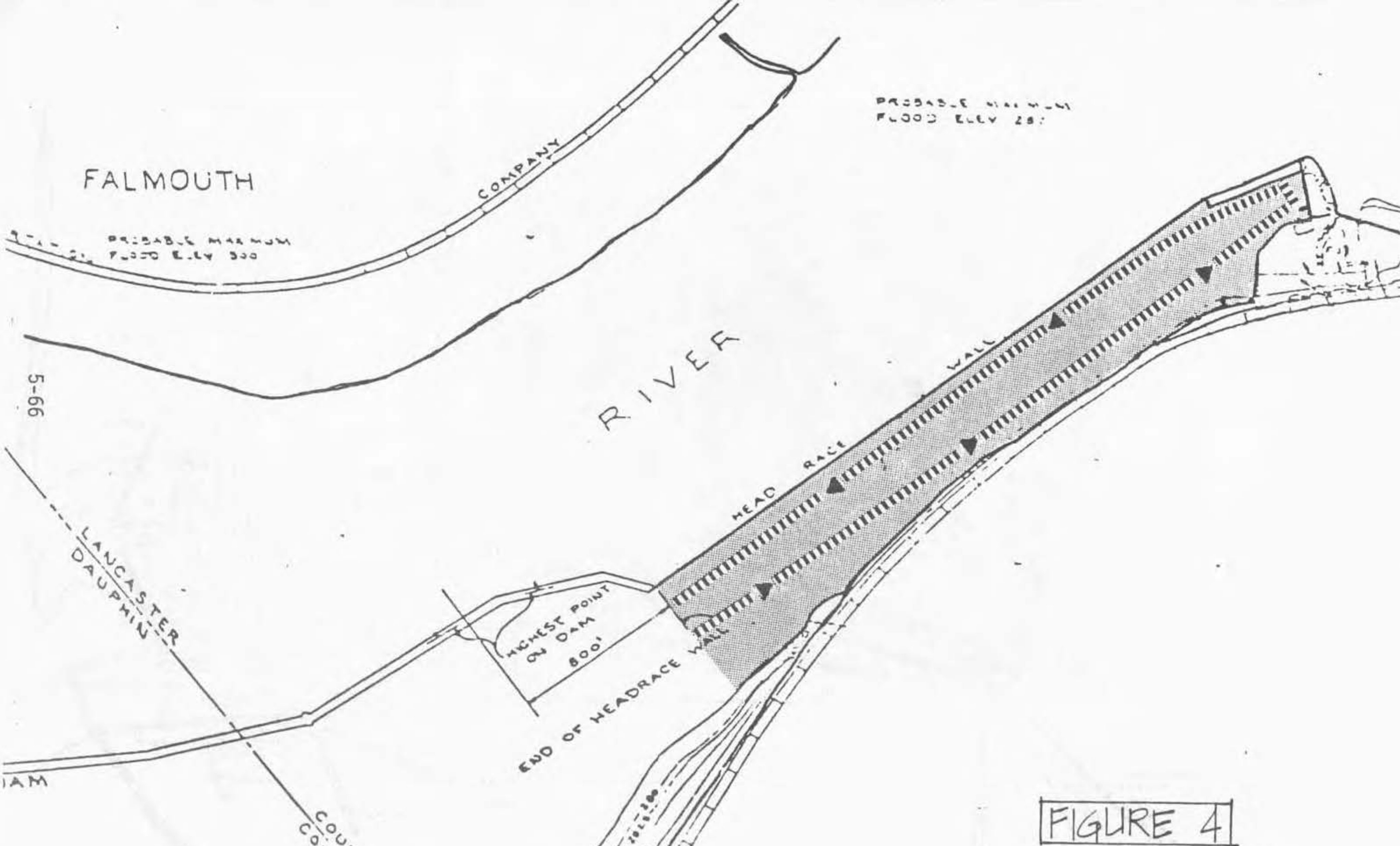


FIGURE 4
MOBILE SURVEYS
YORK HAVEN

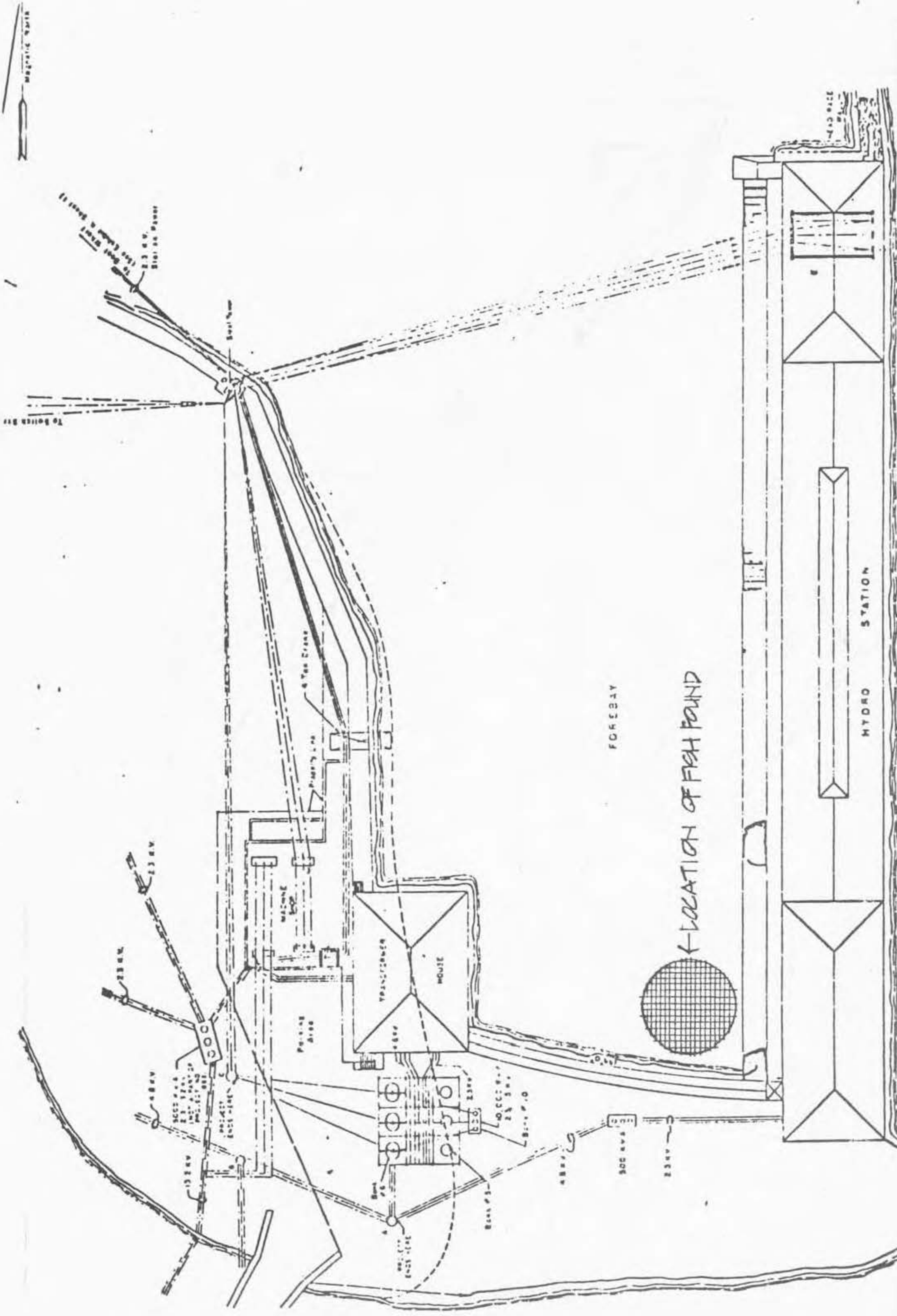
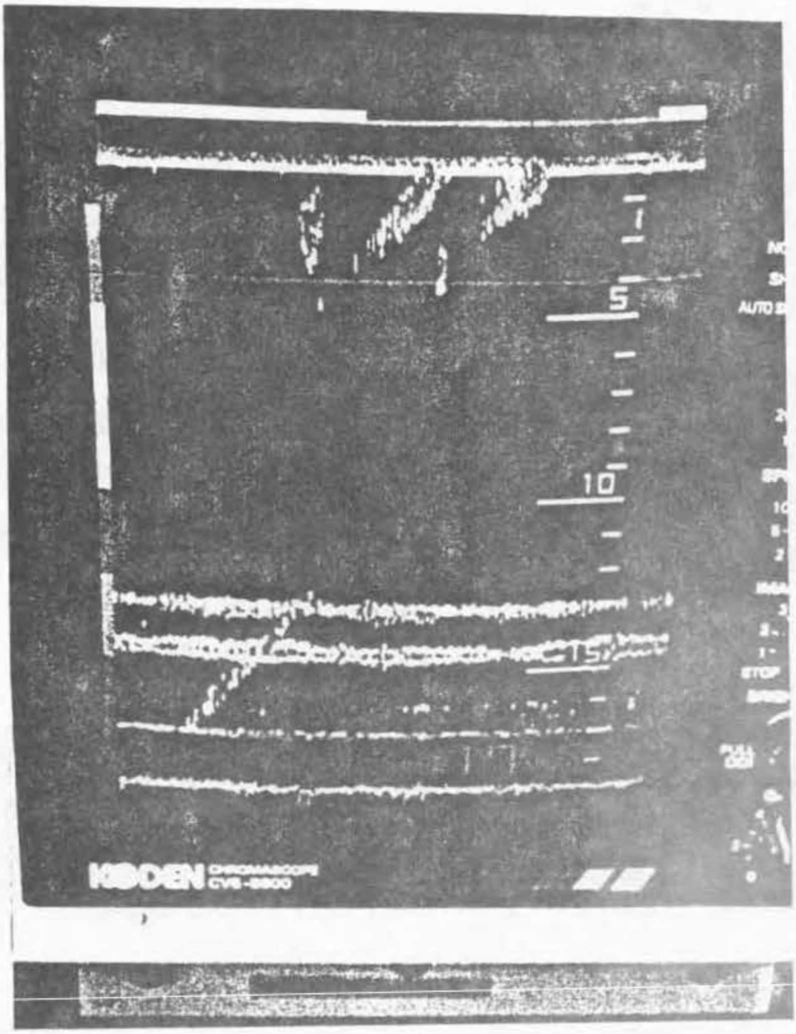
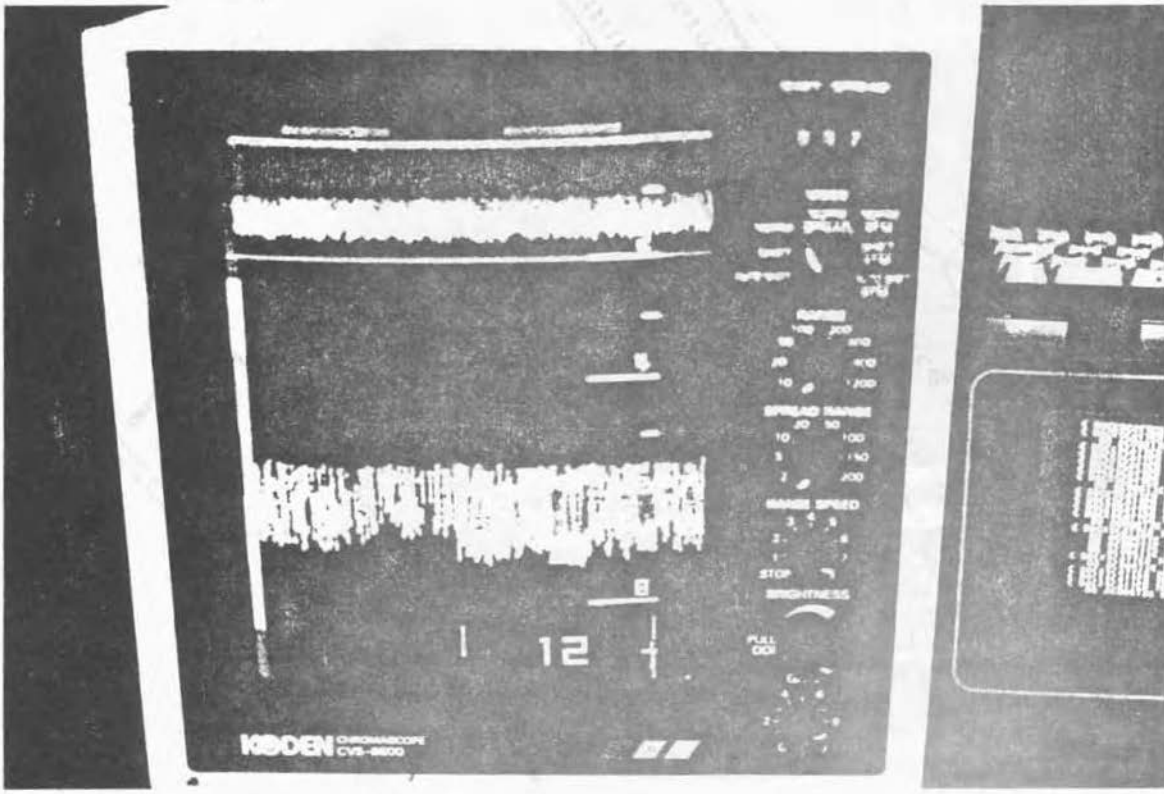

← LOCATION OF FISH POND
FOREBAY
HYDRO STATION
TRANSFORMER HOUSE

FIGURE 5



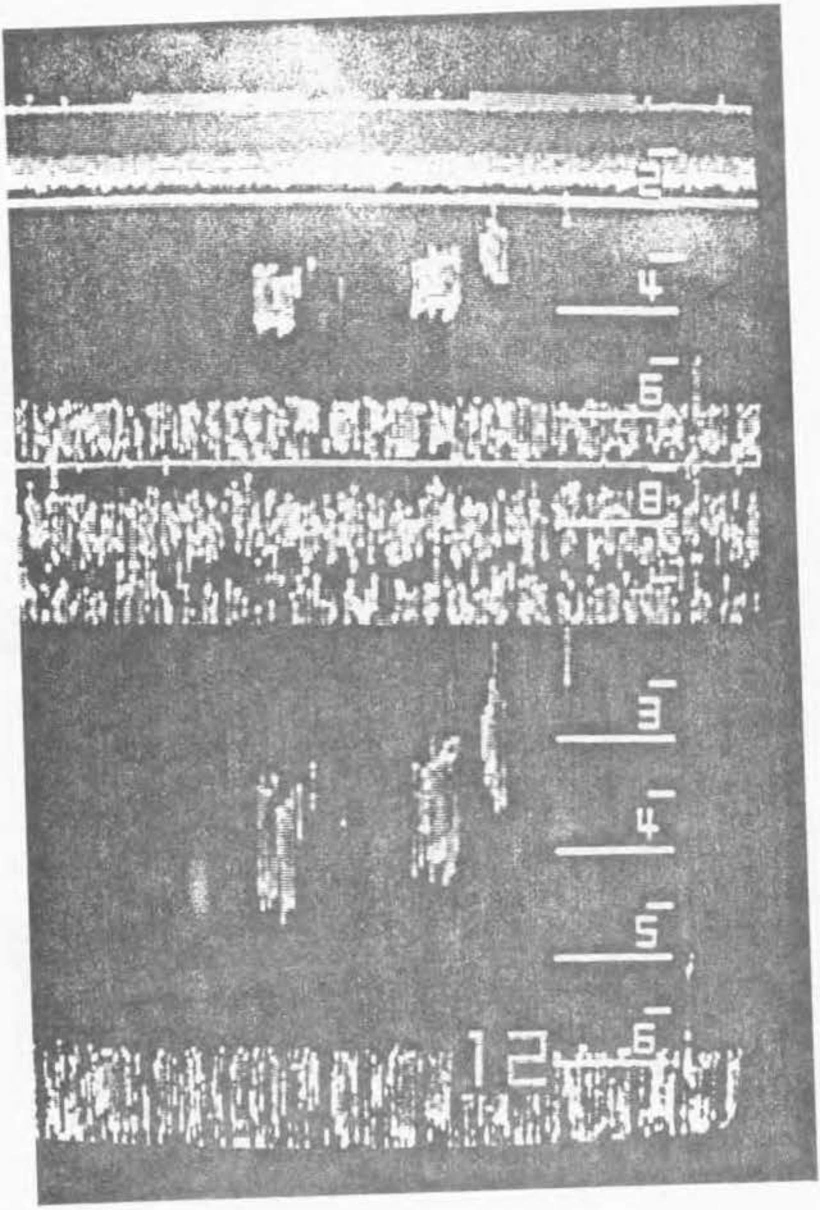
PHOTOGRAPH 1

Directional movement can be seen on the display screen as diagonal images. These represent targets that are moving toward the face of the transducer.



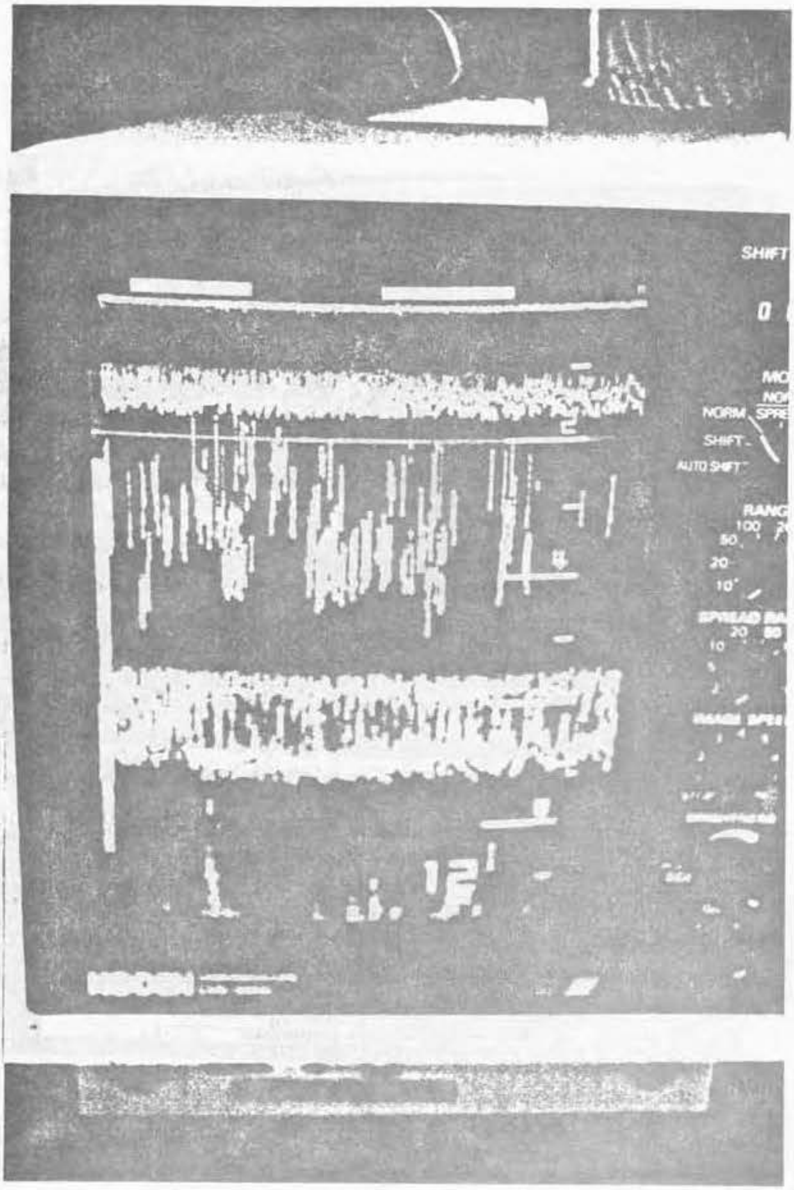
PHOTOGRAPH 2

Transducer face is represented by red-orange-yellow band (top of screen). Surface of water is broken colored line at 6. No targets in this field of view.



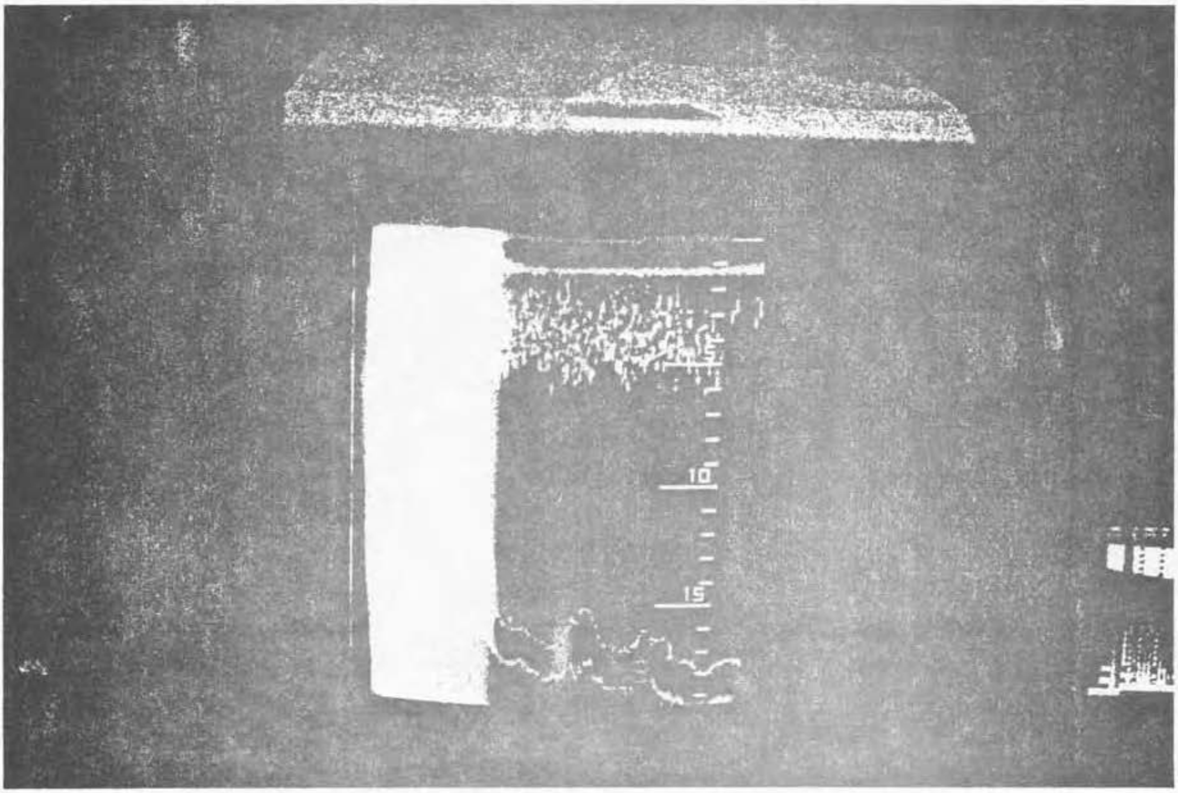
PHOTOGRAPH 3

Split screen mode useful for examining a specific layer. Bottom half is expanded view of top half.



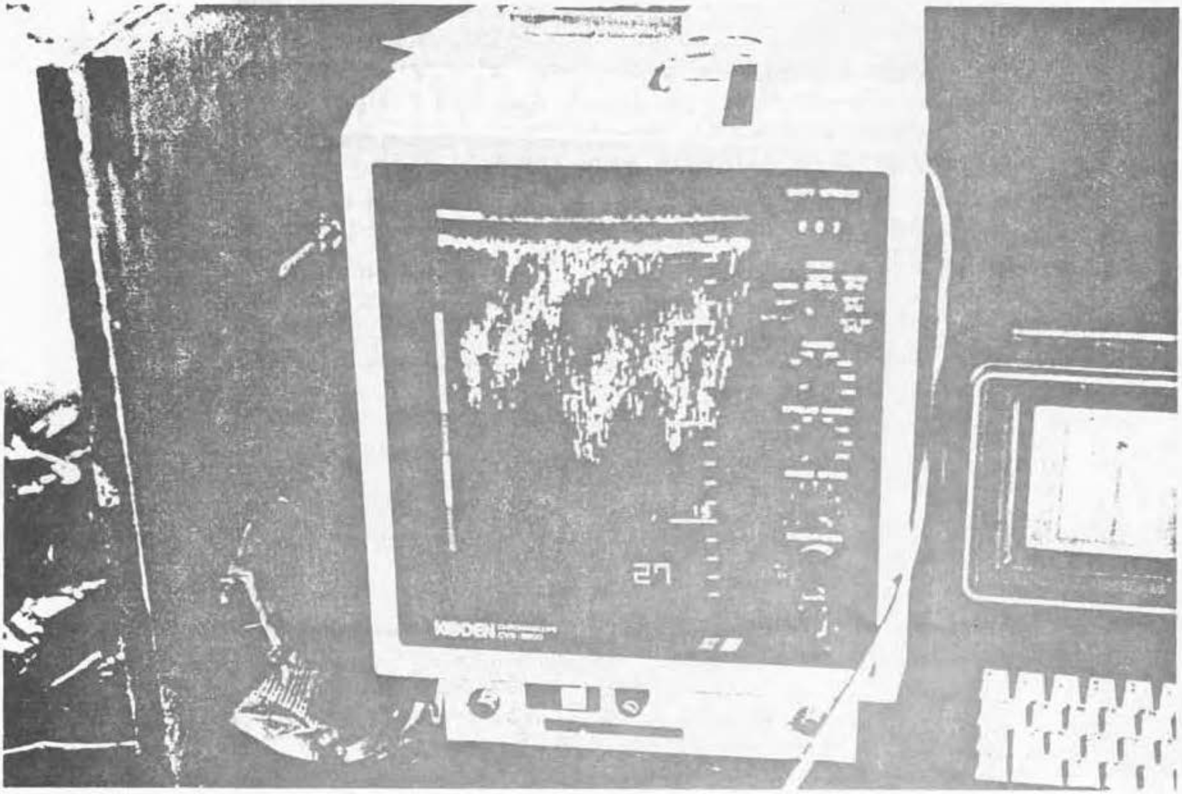
PHOTOGRAPH 4

Many targets in view between
2 and 4 meters.
Compare to Photograph 2.



PHOTOGRAPH 5

Mobile survey at Safe Harbor.
Note large number of targets in
the upper 6 meters.



PHOTOGRAPH 6

Targets (fish) near the end dam
of York Haven forebay.
Transducer mounted horizontally.
Photograph oriented in direction
of transducer.

[UMCEES]CBL 85-112

JOB V. SPECIAL STUDY

DISCRIMINATION OF NATURAL AND HATCHERY STOCKS OF AMERICAN SHAD, ALOSA SAPIDISSIMA

FINAL REPORT

DNR CONTRACT F36-85-008
University of Maryland, CEES No.: 07-4-30021

by

Richard A. Smucker R.A. Smucker 12-4-85

and

David A. Wright D.A. Wright 12/6/85

Abstract

Otoliths excised from hatchery-reared and river-reared American shad, *Alosa sapidissima*, were analyzed by energy dispersive X-ray microanalysis. Elements occurring in each otolith were ratioed against the calcium content of that otolith to determine relative concentrations. These data were analyzed by stepwise discriminant function analysis (BMDP 7M). This program selected a subset of elements (Na, Si, S, Ni, Cu, Br, Sr, Nb, Tc, Tb, Ho, Re, Po, At, and U) which best discriminated between hatchery and river-reared populations of American shad. Using these parameters, 100% discrimination between the two groups was achieved. This method shows great promise as a tool assisting management of unit stocks.

Objectives

The purpose of this research was to discriminate natural from hatchery-reared shad fingerlings. This was accomplished by performing elemental analysis of shad otoliths from growth rings indicative of the indvidual fish's early life history.

Methods and Materials

Samples were received frozen (-20°)by this laboratory on 18 October, 1984, through the office of George Krantz, Maryland Department of Natural Resources. Three sets of American shad (*Alosa sapidissima*) fingerlings were obtained from the following sites of the Juniata River; a Susquehanna River feeder stream:

Amity Hall Access Area, 28 August, 1984 (27 samples/15 analyzed)

Penn Hatcheries Pond-Reared, 11 October, 1984 (21 samples/15 analyzed).

Juniata at Amity Hall, 17 August, 1984 (15 samples/0 analyzed)

Only two sets were analyzed, as agreed upon in contract.
Fish samples were thawed to room temperature in 95% ethanol and measured for total length. Saccular otoliths (2 per fish) were surgically removed (Panella, 1980) from 15 shad collected at Amity Hall Access Area and 15 shad collected at Penn Hatcheries (pond-reared). The dorsal skin pigments of the former group were dull and greenish compared to the latter group which were black and glossy.

All otoliths were washed in several changes of 95% ethanol for debridement of adhering tissue and then air-dried. One otolith from each fish was embedded in L.R. white resin (London Resin Co., Basingstoke, Hampshire, England); the other otolith was archived for future reference. Embedded otoliths were ground sagitally with 200 grit, then 400 grit carbon tetraboride lapstones. Boron-tetraboride is a non-contaminating, fused abrasive (Titan Tool Co., Buffalo, NY). At the nucleus (or central core), the otoliths were polished with 0.25µm grit diamond paste on polishing felt to insure a smooth surface. Otoliths were subsequently etched with 25% acetic acid for 30 seconds to expose daily growth rings, rinsed with distilled water and oven dried (60°C).

All otoliths were analyzed with a Tracor Northern TN-2000 energy dispersive X-ray spectrometer interfaced with a JEOL JSM-U3 scanning electron microscope. A 25 KeV electron beam was scanned across an otolith surface of 40,000μm^2, an area which included daily growth rings three through twenty-five to thirty (Fig. 1 and 2). Each otolith was analyzed in this fashion for 1000 seconds to generate an elemental X-ray profile over a 0-20 KeV spectrum (See Figure 3). A microprocessor and associated software were used to identify elements and integrate peak areas. The X-ray spectrometer was calibrated daily with elemental standards to insure the accuracy of the analyses.

Data from each sample were normalized to the calcium signal for respective samples. Statistical evaluation of the normalized data was performed using stepwise discriminant function analysis (Biomedical Data Programs, Section 7M) (Dixon, et al, 1981).

Results and Discussion

The series of elements observed in this study is listed in Table 1. Lanthanide series elements appeared in otoliths from both sample sites in the same frequency as elements occurring in greater abundance in the environment. Lanthanum (La^{3+}) is known to compete with calcium (Ca^{2+}) in muscle and nerve tissues (Weiss, 1974). Other lanthanides may behave similarly. Terbium, one of the lanthanides which is important as a component of the discriminant elemental signature for this study, shares the same valence characteristics as calcium. Metals, in general, are incorporated into carbonate matrixes (Jensen and Cummings, 1967; Livingston and Thompson, 1971).

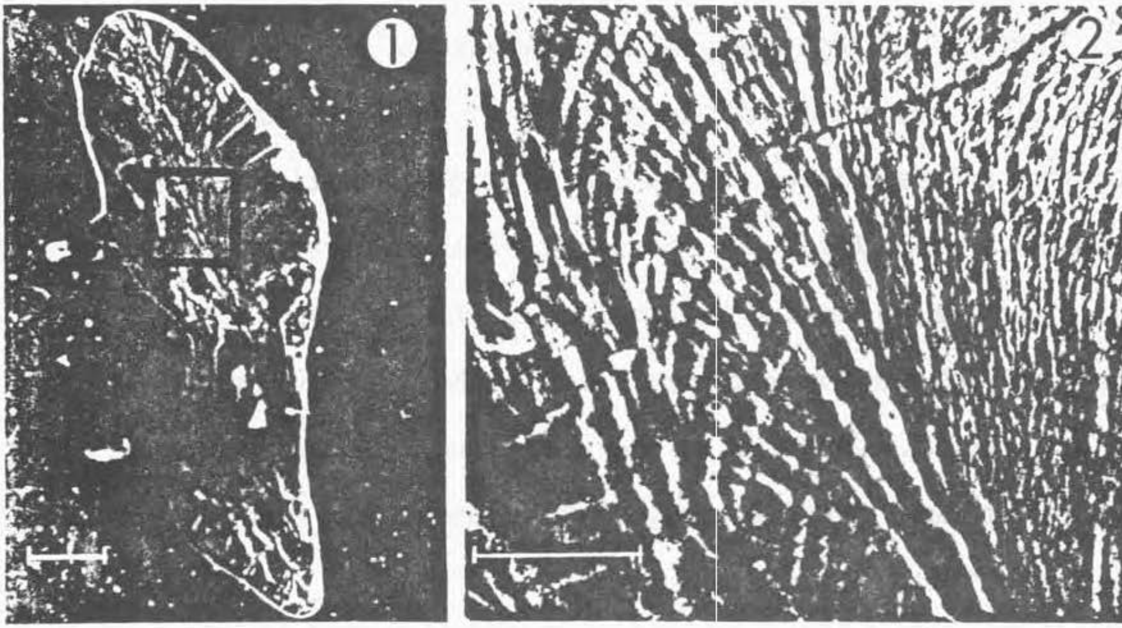


Fig. 1 & 2. Scanning electron micrographs of juvenile shad otolith embedded in LR White medium. (1). Secondary electron image of otolith ground to expose the nuclear region. (2). Enlargement of the boxed-in region (▭) shown in Fig. 1. Examples of daily growth rings are clearly visible and the nucleus center is just below the right hand corner of Fig. 2. Size bars indicate 200 μm (Fig.1) and 50 μm (Fig.2).

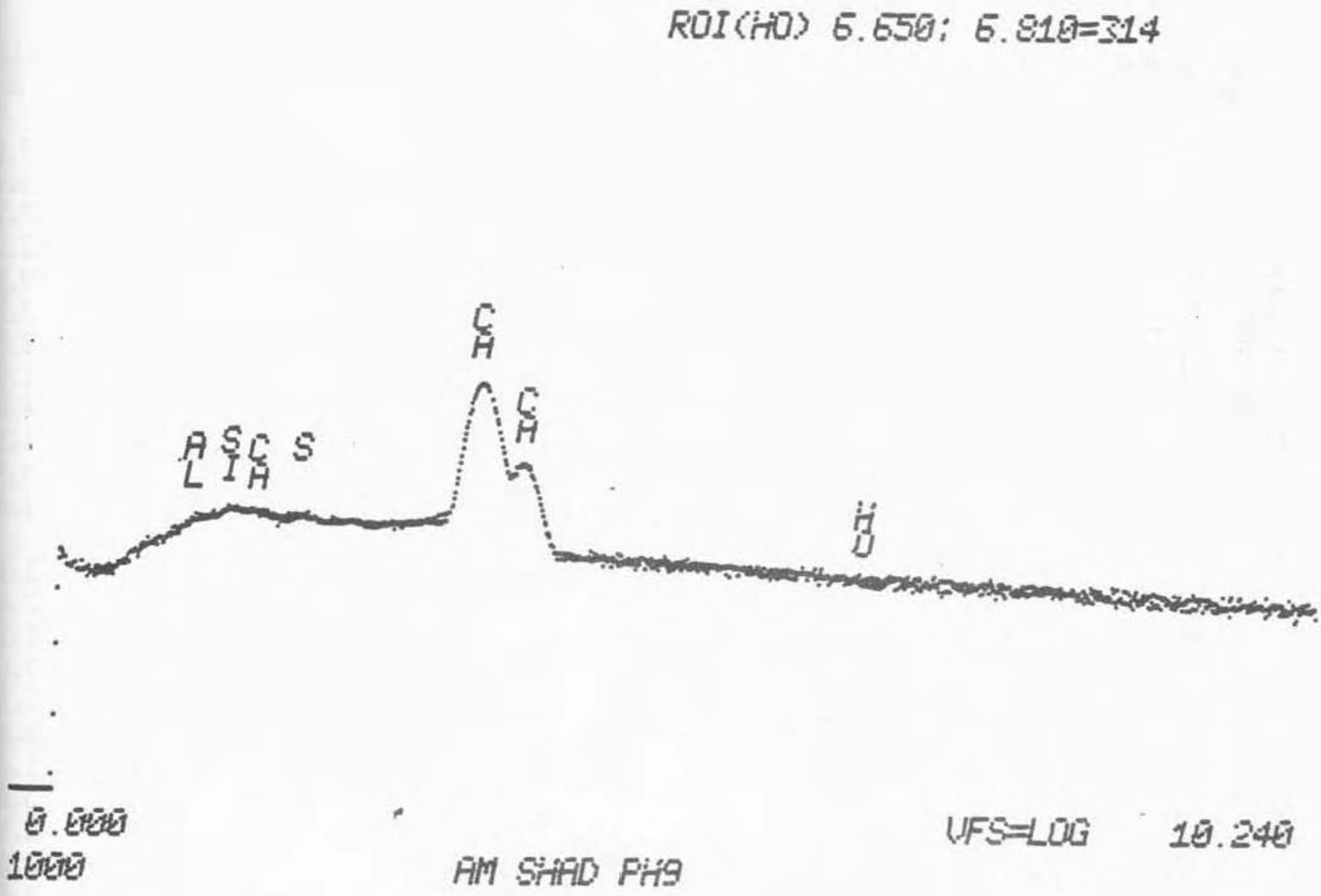


Fig. 3 Energy dispersive X-ray spectrum typical of those used in otolith characterization. Spectra were accumulated over a "real time" of 1000s. For clarity of presentation, only the 0-10.24 KeV region of the spectrum is presented in this figure.

Table I. Elements and the concentration* in which they occur in the otoliths of *Alosa sapidissima* from two sample sites.

PENN HATCHERIES POND REARED

	Elements in Otoliths	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	P 13	P 14	P 15	$\bar{x}$	σ
Representative Elements	Na**											8				21	1.933	5.663
	Al	13				11	8	6			5		21	9	35	73	12.067	19.470
	Si**	7	10		7					15	14	59	21	4	81	70	19.200	27.371
	S**	3	7		17	16	12	4	18	9	10	19	31	15	29	49	16.600	12.200
	Cl																0.000	0.000
	Se					2				13						9	1.600	3.924
	Br**		2		2			2		2	1			2	6	6	1.533	2.031
	Rb					2		1	3			6					0.800	1.699
	Sr**	3		1				1					9			14	1.868	4.103
	Bi		1	3						4				3			0.733	1.387
	Po**	2		1									2				0.333	0.724
	At**			1						3				1	3		0.533	1.060
Transition Elements	V			5					2								0.467	1.356
	Mn								7				8				1.000	2.646
	Fe			3				3	3								0.600	1.243
	Co					9				4			5				1.200	2.678
	Ni**						3					6			6		1.000	2.171
	Cu**		3			3				11		8	4	8	21	15	4.867	6.512
	Nb**		3	2	4												0.600	1.298
	Tc**				7		1		3	4					6	13	2.267	3.807
	Hf	7	8		6												1.400	2.923
	Re**	5	4		9	2	2		2	4		4	7				2.600	2.849
	Pt		5		4						1		6	3	6		1.667	2.410
Lanta-nides	Nd						6					4	5				1.000	2.104
	Tb**							9									0.600	2.324
	Ho**						3		2	11							1.067	2.890
	Tm			8					3				4		9		1.600	3.066
Acti-nides	U**						2							1		6	0.600±	1.595

* Concentration is expressed as a ratio to calcium content of the otolith surface area analysed x1000.

** Elements selected by discriminant function analysis for the classification in Table II.

Table I (continued)

AMITY HALL ACCESS AREA

Elements in Otoliths	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A 10	A 14	A 15	A 16	A 18	A 19	x̄	σ
Na**				2		17						2				1.400	4.372
Al	9	7	4	5	21	49		7	15	7	14	4		3	6	10.067	12.168
Si**		13	4			34		5	21	5	66					9.867	18.376
S**	12			18	40	72		9	11	13	46		14	6	8	16.600	20.532
Cl						49					21	8				5.200	13.364
Se								3								0.200	0.775
Br**	6			2	5	6	5			3					2	1.933	2.434
Rb				1			5		4	3					3	1.067	1.751
Sr**	3					7		6		3	12	5		7		2.867	3.758
Bi	2									2	4					0.533	1.187
Po**	7			2					7				13			1.933	3.918
At**													2			0.133	0.516
V											14	7			4	1.667	3.958
Mn			8	5		7	4							4		1.867	2.900
Fe				2					8		13	3				1.733	3.788
Co				2							19					1.400	4.896
Ni**										3	15					1.200	3.895
Cu**	5	3							4	6		3	3	5	2	2.067	2.219
Nb**		6	3		3		2	6								1.333	2.193
Tc**			3				2						5	4		0.933	1.710
Hf						15		4				5	6			2.267	4.148
Re**			1								9			3		0.867	2.386
Pt						7				3			6			1.067	2.344
Nd					7	9	5				9			2		2.133	3.502
Tb**								11				2		5	3	1.667	3.080
Ho**	4						3	3		2						0.800	1.424
Tm					5	11	3			4			3			2.467	3.871
U**	2						2			2						0.400	0.828

All data was digitized and normalized as a ratio to calcium in each sample. Statisical evaluation of the normalized data was by stepwise discriminant function analysis (BMDP 7M) (Dixon, et al, 1981).

Discriminant function analysis of these data determined the best subset of these data for discriminating between the two sites evaluated. Table 2 indicates the percentage of shad from each site which were correctly identified, based on the elements listed, as originating from that site. It is important to note that while all the juvenile shad analyzed ultimately originated from the Penn Hatcheries, growth rings examined included rings laid down by the animal after transfer or release (8-20 days following hatch) to the collection site . It is not surprising, then, that no misidentifications occurred for these two sites. Table III is a summary of discriminant function "canonical variables" determined for each fingerling. The data from Table III is plotted as a histogram in Figure 4. As can be seen from the histogram, there is no overlap of the canonical variables between pond-reared and river-reared stocks.

Applicability

Data and analyses, in this report, define procedures and results which enable discrimination between stocks of American shad. The fundamental technique relies on the biogeochemical record of fish otoliths and therefore the variability of natural water geochemistry. Elemental data , normalized to the calcium matrix, can be statistically evaluated to provide qualitative and quantitative discrimination between the fish 's river-of-origin.

Acknowledgements

We thank Linda G. Morin for technical assistance in otolith retrieval and X-ray analysis, and in preparation of this report; Timothy J. Mulligan, for his assistance in computer analysis; and Billie Little, for typing the report.

Table II. Classification of American shad (*Alosa sapidissima*) according to site of origin by Discriminant Function Analysis N=30

	Percent Correct	Number of cases classified into group Amity Hall	Penn Hatcheries
Amity Hall	100.0	15	0
Penn Hatcheries	100.0	0	15
Total	100.0	15	15

Elements Used: Na, Si, S, Ni, Cu, Br, Sr, Nb, Tc, Tb, Ho, Re, Po, At, U.

Table III. Discriminate Function Canonical Variables for Individual Shad Otoliths

AMITY HALL GROUP		PENN HATCHERY GROUP	
Individual	Canon Var.[a]	Individual	Canon Var.[a]
AH 1	3.31	PH 1	-3.20
2	4.67	2	-1.69
3	0.66	3	-2.02
4	1.98	4	-3.22
5	2.85	5	-2.07
6	2.80	6	-3.14
7	2.14	7	-1.07
8	1.77	8	-0.44
9	1.42	9	-2.96
10	3.19	10	-1.91
11	2.94	11	-3.25
12	3.23	12	-3.17
13	2.84	13	-3.90
14	2.81	14	-2.69
15	0.73	15	-2.62

[a] *The canonical variable is a statistical composite based upon the qualitative and quantitative elemental composition.*

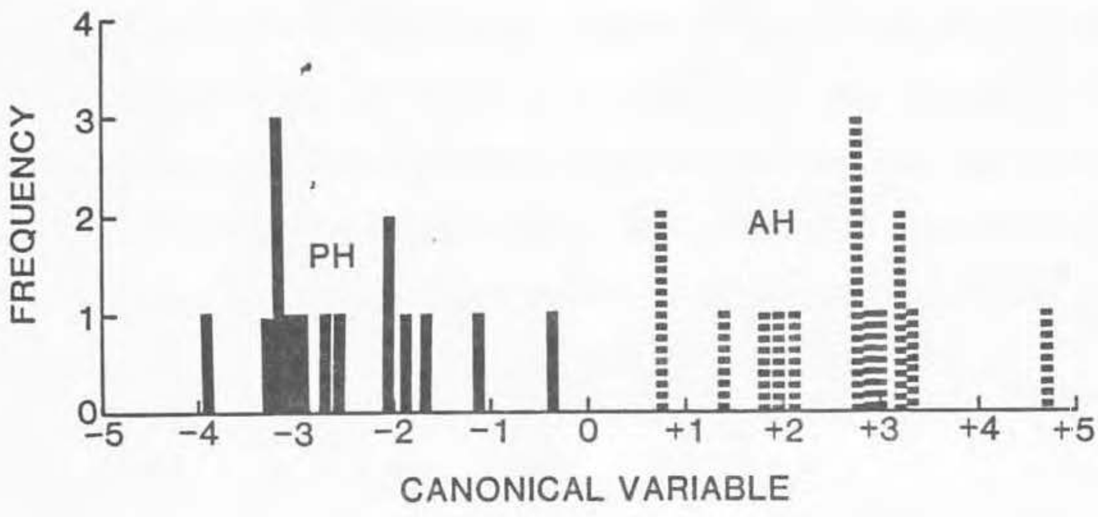


Fig. 4. Histogram of statistically determined canonical varibles. Data taken from Table III. There is no overlap in the canonical variables; that is, between the two groups of shad: Penn Hatchery (PH) and Amity Hall (AH).

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JOB V. SPECIAL STUDY
(continued)

DEVELOPMENT OF STREAM SIGNATURES FOR SUSQUEHANNA RIVER SHAD

1: Validation of Otolith-Based Strategy Using the Delaware River Shad Fishery

PROGRESS REPORT

c/o Dr. Richard A. St. Pierre
Susquehanna River Anadromous
Fish Restoration Committee
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University of Maryland, CEES No. 07-4-35050

by

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This report identifies the status of year-to-year shad otolith stream signature validation. Previously, we have established the clear cut efficacy of using otolith chemical signatures for the discrimination of stream-to-stream and stream-to-hatchery fish populations. (Full citations and discussions will appear in the final report.)

Requisite to the evaluation of shad populations for discriminating "prospective" Susquehanna stocks and Chesapeake Bay spawning stocks has been the need to validate the technique of X-ray microanalysis and subsequent discriminant function analysis of the detected elements. A known shad fishery spawning area, the Delaware River, was chosen to establish the otolith signature for a discrete spawning unit of shad.

The analytical and statistical techniques used to obtain the results reported herein will be described in full in the final report. Analyses for adult shad (Bushkill sampling site) and 1985 shad fingerlings (taken between Dingman's Ferry and Bushkill Falls) are summarized in Table I. Surprisingly the two groups were essentially discriminated on the basis of their respective elemental otolith signatures.

Two major explanations for this discrepancy are offered:

1. There are significant Delaware River geologic microscale differences reflected in the adult shad otoliths. In other words, the adult shad collected at the Bushkill sample site may have originated (and spawned) downriver from that site or, more likely, a site further upstream.
2. The other explanation, "otoliths are not stable records", has no support in the literature. In fact, quite the opposite is true. "There is no evidence for any resorption of otoliths although other calcareous deposits ... may be resorbed in other vertebrates." *

* Simkiss,K. (1974). Calcium metabolism of fish in relation to ageing. In: T.B. Bagenal (editor), Proceedings of an International Symposium on The Ageing Of Fish, p.1-12. Unwin Brothers, Ltd., Surrey.

It should appear that the former explanation offers the most viable rationale for the currently obtained discrimination between the Delaware River adult and fingerling shad. There are at least two distinct micro-scale geologic subsystems within the Delaware River system. First, the Eastern and Western Branch region of the Delaware River have significant carbonate buffering due to exposed carbonate deposits. Second, the Lackawaxen watershed of the central west drainage region of the Delaware River system lacks carbonate deposits and therefore is significantly more acidic (reflected in the humic acid content). The increased acidity may result in a concurrent shift in ionic composition of the Lackawaxen River water. It is conceivable that adults sampled for this study do not represent a single spawning stock, but a mixture of two or more discrete spawning stocks inadvertently captured while enroute to their natal streams.

Future Directions:

Our recommendation for the continuation of this study is to analyze and establish signatures for adult shad and fingerlings only from the successful East Branch Delaware River spawning grounds. In this way, there will be the highest probability of obtaining shad spawning stock which reflect their actual nursery grounds and the commensurate valid comparison with same site fingerlings.

Table I. Classification of shad adults and fingerlings from the same river site by Discriminant Function Analysis. N=60

Group	Percent Correct	Number of cases classified into group Adult	Juvenile
Adult	96.7	29	1
Juvenile	96.7	1	29
Total	96.7	30	30

Elements Used: Na, Al, Si, Cl,V, Ni, Se, Rb, Tc, Nd, Re, U, Bi, Tb, Gd, Rn, Os, Pr, Ru, Er, Eu, Rh, Pa.

JOB VI. SUMMARY OF OPERATION OF THE CONOWINGO DAM FISH PASSAGE FACILITY IN SPRING 1985

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INTRODUCTION

The Conowingo Dam Fish Passage Facility (hereafter Fish 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 Fish Lift has been to monitor fish populations below Conowingo Dam and transport as many migratory fishes (American eel, herrings, hickory shad, American shad, and striped bass) upriver as possible. Support for the operation of the Fish Lift is provided by the Philadelphia Electric Power Company (PECO) and Susquehanna Power Company.

The Conowingo Hydroelectric Station is operated as a run of the river peaking power station. The maximum rated peak discharge from its eleven units is 85,000 cfs. Natural river flow in excess of 85,000 cfs is released over the spillway. Generally, under efficient operating 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 1985 operation were to (1) monitor relative abundance of Alosa species, (2) monitor species composition, (3) obtain life history information from selected migratory and resident fishes, (4) contribute to restoration efforts by the trap and transfer of prespawned American shad and other migratory fishes to upstream localities, and (5) assist Maryland Tidewater Administration in assessing the American shad population in the upper Chesapeake Bay.

METHODS

Prior to the operation of the Fish Lift several surveys were conducted to detect the arrival of alosids into the lower river area. Alternate day herring checks at Deer Creek and Rock Run were initiated on 18 March. About 12 herrings were first observed in Deer Creek at Stafford Bridge on 25 March at a water temperature of 45 F. These were later confirmed to be alewife by checking an angler's creel. As the water temperature in Deer Creek increased so did the herring abundance. When the water temperature reached 60.0 F on 14 April up to 100 river herring were commonly observed at Stafford Bridge. Conversations with anglers indicated that alewife, blueback herring, and hickory shad were present at this time, however, most were blueback herring.

Preparations for the operation of the Fish Lift began during the week of 25 March following the observation of herring in the lower river and decreasing river flow. Weir gate and crowder motors were installed on 26 March. Adjustments to limit switches, calibration of weir gates, and all necessary maintenance were completed on 29 March; a test run of the facility was successfully completed that afternoon.

Fish Lift operation commenced on 1 April on an alternate half-day basis, as agreed to by PECO and outlined in the 1985 Susquehanna River Fish Restoration Committee (SRAFRC) work plan (SRAFRC 1985). However, operation on 3 April was cancelled due to high river flow (>120,000 cfs). Operation resumed on 5 April and continued on an alternate half-day basis until 15 April, when problems with the hopper closing mechanism prevented operation. Upon completion of the repairs, the Fish Lift operated daily (almost uninterrupted) from 17 April through 29 May between 0600 or 0700 h to 1800 or 1900 h. Because few American shad were collected on 28 and 29 May and their advanced sexual condition, the Fish Lift was operated on an alternate half-day schedule from 31 May through 14 June.

Beginning 23 April PECO modified the normal pattern of station generation at Conowingo Dam to enhance Fish Lift effectiveness. Modification was a result of an increased catch of American shad on 21 and 22 April. PECO implemented a policy that kept turbines No. 1 and 2 off from 0600 to 1800 h as river flow and other conditions permitted (i.e. electrical production needs). This modified generation scheme was maintained through 2 June and terminated when few American shad in a post spawned condition were collected.

The mechanical aspect of Fish Lift operation in 1985 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 extremely large numbers of gizzard shad and on occasion carp, two modifications to lift operation were employed to maximize collection of American shad. The first modification consisted of leaving the crowder in the normal fishing position and raising the hopper every 5 to 10 minutes. Generally, after 30 to 60 minutes all remaining fish were crowded and removed from the holding channel. The removal of fish from the holding channel by this method increased fishing time. This modification was termed (for this report) "fast fish".

Occasionally, as a result of changes in water levels in the tailrace, large numbers of fish would be attracted to the lift. In an effort to maintain the increased collection of shad either weir gate 1 or 2 was closed and the fish that had accumulated were lifted rapidly utilizing operation "fast fish". After a large number of fish had been removed the operation of the Fish Lift was changed back to the normal operational mode.

Attraction velocity and flow during periods of normal and "fast fish" operation at the Fish Lift in 1985 were similar to those maintained in 1982 (RMC 1983). Based on the 1982 experience, hydraulic conditions were maintained in the area of the Fish 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 after a weir gate was closed. Generally, during periods of lower flow (≤ 3 small units) both house service units were set at 35% gate (discharge of $\approx$ 150 cfs) and the weir gate that remained open was lowered to its maximum depth. During periods of higher flow (>3 small units) house units were set at 35% and 75% gate (discharge of $\approx$ 265 cfs) and the weir gate that remained open was set about 10 ft below tailrace elevation. These modifications generally resulted in a attraction velocity of 6 to 8 ft/sec from the open weir gate and a flow in the holding channel of 1 to 2 ft/sec.

Since 1972 a continuous minimum flow of 5,000 cfs through Conowingo Dam has been maintained from 15 April through 15 June. Unit No. 5 was used in 1985 to release the continuous minimum flow from 15 April through 10 May and from 19 May through 14 June. Unit No. 6 was used from 11 through 18 May when station discharge did not exceed 5,000 cfs. The minimum release of 5,000 cfs from either Unit Nos. 5 or 6 was based on results of 1982 and experience at other fish passage facilities which showed that passage effectiveness increases when competition between the attraction flow from the fish passage and the flow releases from other sources is reduced.

Release of the chemical attractant, phenethyl alcohol, was scheduled to follow the SRAFRC 1985 Work Plan (SRAFRC 1985). The attractant was to be released on every other scheduled day of Fish Lift operation from 15 April until water temperature reached 68 F. However, as in the past, equipment malfunction prevented release of the attractant per program specifications.

Fishes were processed as reported in 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 scientific and common names of fishes taken (Table 6.1) followed Bailey et al. (1970).

American shad were sorted and held for transport in circular tanks continually supplied with river water. Transport occurred whenever 50 or more green or gravid shad were collected in a day, and/or at operator's discretion. All healthy, active shad not transported were tagged with floy anchor tags and released back to the tailrace. Prior to release length, weight, sex, and spawning condition were determined as conditions permitted. Scale samples were taken when possible.

Transportation of American shad was accomplished utilizing a 800 gallon circular transfer unit. The air supply system on the transfer unit was modified in 1985 to include both bottled oxygen and compressed air. The holding and handling procedures employed during transport were similar to those used in previous years.

American shad scales were cleaned, mounted, and aged according to Cating (1953). Age determinations and spawning history of blueback herring and alewife followed similar procedures. The procedures employed to determine age structure and spawning history of clupeids are 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.

RESULTS

In 55 days of Fish Lift operation (1 April through 14 June) 2,317,797 fish of 41 taxa were caught (Table 6.2). Predominate species in order of numerical abundance were gizzard shad, white perch, and channel catfish. Alosids (blueback herring, hickory shad, alewife, and American shad) comprised less than 0.4% of the total catch.

The relative abundance of fishes has fluctuated since 1972. The 1985 catches were similar to those between 1980 and 1984 (Table 6.2). In this period the catch was dominated by gizzard shad, carp, channel catfish, and white perch. Between 1972 and 1979 alosids (primarily blueback herring) and white perch dominated the catch.

The catch of gizzard shad (2,182,888) in 1985 was the highest recorded for any species since 1972, and comprised over 94% of the total catch (Tables 6.2 and 6.3). The daily catch was also dominated by gizzard shad and ranged from 2,971 (5 April) to 118,250 (28 April).

The catch of alosids (excluding American shad) increased in 1985 from the lowest reported in 1984 but was much lower than the recorded historic levels (Table 6.2). A total of 6,763 blueback herring, 377 alewife, and 9 hickory shad was collected. Most alewife were collected prior to 29 April at water temperatures of 49.1 F to 67.5 F (Table 6.3). Blueback herring were first collected on 23 April. However, peak catches of blueback herring occurred at water temperatures >65 F (after 26 April).

Some 44 of 57 alewives and 156 of 166 blueback herring were aged (Tables 6.4 and 6.5). Alewives ranged in age from III to VI years; IV year olds dominated. Blueback herring ranged in age from IV to VII years; V year olds dominated. Comparison of males and females of both species within a specific age group indicated that females grew faster than males.

Most alewives were virgins; over 58% of the blueback herring were repeat spawners (Tables 6.4 and 6.5). Alewives were found to have spawned a maximum of two times while bluebacks spawned three times. Generally, the incidence of repeat spawning of bluebacks was greatest once the fish attained V years of age. All three time spawners were at least VI years old.

American Shad Catch

A total of 1,546 American shad was collected in 1985 (Table 6.2). The first shad was collected on 9 April at a water temperature of 50.9 F (Table 6.3). Increased numbers of American shad were not observed in the catch until 21 April when 19 were collected.

The 1985 catch of American shad at the Fish Lift was the second highest to date (Table 6.2). Disposition of shad collected varied according to numbers collected, sexual condition, and other factors. Over 80% of the shad collected were either transported or tagged. The remainder were comprised of Maryland tagged fish, RMC tag recaptures, and mortalities that resulted from the trap and transfer operation.

A total of 87 American shad died at the Fish Lift in 1985 with over 93% of the mortalities incurred from 28 April through 2 May. The increased mortality was markedly reduced by monitoring and maintaining increased DO levels in the holding tanks.

American shad were collected daily from 21 April through 29 May (Table 6.3 and Figure 6.2); the largest number (144) was collected on 1 May at 67.7 F. Examination of the daily catch indicated that shad abundance varied daily but reflected three peaks of abundance. The largest number of shad (523) was collected from 27 April through 2 May. Other periods of increased abundance occurred from 17 through 19 May and 25 through 27 May when 194 and 157 shad were taken, respectively.

As in the past, the catch per effort (CPE) of American shad varied by time of day and station generation (Tables 6.6 and 6.7). The CPE was three fold higher when one unit was in operation (Table 6.6). The CPE was about twice as high during weekend operation (Table 6.7). Also, the catch per effort was greatest during the mid-day (1101-1500 h) and afternoon (1501-1900 h) periods on weekdays and greatest during early morning (0600-0900 h) operation on weekends.

American shad were collected at water temperatures of 50.9 to 73.4 F and at natural river flows of 12,700 to 68,400 cfs (Table 6.3 and Figure 6.2). However, over 75% of the shad were collected at water temperatures >65 F (Table 6.8). Water temperature from 21 April to 27 May varied with increased or decreased river flow and ranged from 59.0 to 68.9 F.

Lift operation was modified in 1985 to reduce trapping delays that resulted from mechanical operation and/or overcrowding due to high densities of fish competing for space. Operation "Fast Fish" was a primary reason that over 2.3 million fish were taken in 1985. This mode of operation increased daily fishing time by reducing mechanical delays associated with normal lift operation. By modifying weir gate openings in combination with operation "Fast Fish" an increased catch rate of American shad resulted on 9 of 17 days (Table 6.9).

Tag and Recapture

A total of 326 American shad was tagged in 1985 (Table 6.10); 56 shad were recaptured. Forty-seven were recaptured at the Fish Lift (Table 6.11). Seven shad were collected by the Maryland DNR, four were collected in the tailrace by angling, and the others were collected by gill net off Spencer Island. One shad was caught by a sport angler in the lower tailrace off Snake Island. A commercial netter caught a shad in the lower Chesapeake Bay at Picketts Harbor, Virginia.

Of the 56 recaptures seven were multiple recaptures, and two were tagged in 1984. The average days free for first time recaptures was 14 days and ranged from 5 to 27 days. The average days free for the multiple recaptures was 10 days and ranged from 1 to 21 days. The two 1984 recaptures were free a total of 360 and 348 days, respectively.

A total of 42 American shad floy tagged by the Maryland DNR was captured at the Fish Lift. Thirty-four shad tagged in the tailrace were captured at the Lift once. Average days free for first time recaptures was 11.7 and ranged from 3 to 30 days. Two recaptures in the tailrace were multiple recaptures; one fish was collected twice and the other three times. One shad collected at the lift was tagged at the Maryland DNR pound net sampling location. Three shad collected were tagged in the tailrace in 1984.

Age Composition

A total of 446 shad was scaled and 421 were successfully aged (Table 6.12). Males were III to VI years old; IV year olds dominated. Females were III to VII years old; VI year olds dominated. Twenty-two males (7%) and nine females (8%) were repeat spawners.

The sex ratio of tagged American shad was 3.35 males to a female (Table 6.10). The sex ratio varied daily but males generally dominated.

Adult Transportation

Prespawned American shad were transported between 24 April and 26 May. All shad were released at one of two release sites above York Haven Dam. Release sites used were the public boat launch at City Island, Harrisburg and the Pennsylvania Fish Commission (PFC) access at Fairview. The

City Island release site was only used for the first stocking trip due to low river level. All other stocking trips utilized the PFC Fairview access due to the improved water condition it afforded. The water depth at this site was approximately 5 ft.

A total of 967 American shad was transported with an overall survival of 98.3% (Table 6.13). Transportation of shad was accomplished in 17 trips. Generally, individual trips averaged two hours. Load size varied from 25 to 109 fish per trip. Trip survival varied from 80 to 100%. Transport water temperature varied from 61.8 to 68.0 F. Based on a sex ratio of 3.35:1 (male to female) it was calculated that 284 prespawned female shad were transported upstream.

The 1985 SRAFRC work plan outlined provisions for transport of river herring. However, no attempt was made to transport blueback herring because it would have interferred with American shad transport and secondly when sufficient numbers were available for transport, they were either ripe and/or spent.

DISCUSSION

Fish Lift operations indicate that the shad population has not increased over the last four years. When the catch of American shad was standardized for effort and station generation during years of modified lift operation (1982-1985) and compared the peak abundance was noted in 1982

(Table 6.14). The total CPE from 1982 through 1985 was 8.1, 2.8, 2.4, and 4.6, respectively. The CPE in 1982 was nearly double that observed in 1985; catch rates in 1982 and 1984 were similar and about half the 1985 rate. The catch per effort of shad at various generation levels was generally similar in all years with the highest CPE occurring during periods of lowest generation.

The relatively higher catch rates of American shad at the lift in 1982 and 1985 resulted primarily from modified operations rather than from an increase in the size of shad population. Modified operations included flow modifications within the facility, to the attraction flow and from the powerhouse. These modifications were made as a result of a better understanding of the behavior of American shad with respect to flow. In addition, other factors that influenced the catch in 1985 were low river flow, reduced competition between the attraction flow and station generation, and operator experience.

The hydrologic and mechanical conditions in 1985 were ideal for capturing shad. Natural river flow during the shad run, particularly in April, was the lowest historically observed. The cooperative efforts of Conowingo Dam personnel and PECO were instrumental in eliminating competing flows from station Units 1 and 2 during the peak period of shad abundance, which has been shown to influence the shad catch. Operation "fast fish" and manipulation of weir gates in concert with "fast fish" also resulted in the increased collection of shad.

From the tag-recapture of shad it appears that the Fish Lift may have captured a relatively large portion of the upper bay shad population that migrated to the base of the Conowingo Dam. Maryland DNR tagged a total of 150 shad on the east side of the tailrace. Thirty-four were recaptured at the Fish Lift which yielded a 22.7% recovery rate. However, this represents a conservative rate because of the tendency of shad to move downstream from the tagging site. Because of this behavior it is likely that a larger number of tagged shad might not have been available in the tailrace for capture by the lift.

In conclusion, the collection of American shad at the Fish Lift has been enhanced due to flexible operation which allows the operators to modify operation to maximize lift effectiveness relative to the changing conditions.

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TABLE 6.1.

List of scientific and common names of fishes collected at the Conowingo Dam Fish Lift, Spring 1972 through 1985 (according to Bailey et al. 1970).

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

TABLE 6.1. Continued.

Scientific Name	Common Name
Family - Cyprinidae	
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 gyrinus	Tadpole madtom
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 6.1. Continued.

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

TABLE 6.2.

Comparison of annual catch of fishes at the Conowingo Fish Lift, 1 April through 15 June, 1972 to 1985.

Year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
No. Days	54	62	58	55	63	61	35	29	30	37	44	29	34	55
Lifts	817	1527	819	514	684	707	358	301	403	490	725	648	519	1118
Est. Oper. Time (Hr.)	607	996	500	307	375	413	212	187	221	275	502	299	251	542
Fishing Time (Hr)	313	623	222	189	252	245	136	123	117	178	336	224	192	421
No. Species	40	43	42	41	38	40	44	37	42	48	48	41	35	41
American eel	805	2050	91937	64375	60409	14601	5878	1602	377	11329	3961	1080	155	550
Blueback herring	58198	330341	340084	69916	35519	24395	13098	2282	502	618	25249	517	311	6763
Hickory shad	429	739	219	20	-	1	-	-	1	1	15	5	6	9
Alewife	10345	144727	16675	4311	235	188	5	9	9	129	3433	50	26	379
American shad	182	65	121	87	82	165	54	50	139	328	2039	413	167	1546
Gizzard shad	24849	45668	119672	139222	382275	742056	55104	75553	275736	1156662	1226374	950252	912666	2182888
Atlantic menhaden	-	-	112	-	506	1596	-	-	16	42	-	1	-	1
Trouts	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow trout	34	67	20	24	54	291	70	15	23	219	20	2	5	70
Brown trout	172	286	483	219	427	700	261	324	258	207	219	225	141	175
Brook trout	1	3	4	1	-	2	23	-	4	3	5	2	-	1
Trout	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Chain pickerel	-	1	10	-	-	1	-	-	-	1	-	-	-	-
Northern pike	-	2	2	-	-	2	2	4	3	-	5	1	-	-
Muskellunge	20	104	9	7	12	48	14	5	27	1	4	-	-	15
Minnows	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Goldfish	-	27	1	9	4	1	-	-	-	1	-	-	-	-
Carp	4370	16362	34383	15114	6755	16256	11842	14946	8879	18313	15362	16273	8012	6729
River chub	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Golden shiner	165	430	437	751	1622	652	221	304	35	155	92	216	8	292
Comely shiner	5	252	3870	2079	740	769	1152	1707	761	281	14214	3176	871	5141
Spottail shiner	34	137	2036	268	1743	8107	8506	1533	849	31	315	2132	-	3525
Swallowtail shiner	-	-	-	-	-	-	-	-	-	3	-	-	-	-
Rosyface shiner	1	-	-	1	-	-	-	-	-	-	8	-	-	-
Spotfin shiner	103	40	3011	1231	45879	7960	3751	41	314	524	622	501	-	2695
Bluntnose minnow	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Blacknose dace	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Longnose dace	-	-	1	-	-	-	4	-	-	-	-	-	-	-
Minnows	264	3	-	-	-	-	-	-	-	-	6	-	-	-
Quillback	7119	27780	14565	8388	9882	6734	2361	5134	2929	3622	1617	4679	1942	957
White sucker	363	1034	286	152	444	282	189	906	1145	1394	582	412	109	776
Creek chubsucker	3	3	1	-	-	-	-	-	-	4	2	-	-	-
Northern hog sucker	-	2	-	1	5	-	3	6	13	1	-	-	-	-
Shorthead redhorse	1097	4420	434	445	1276	1724	697	2163	1394	6533	6974	7558	3467	3362
White catfish	3070	6394	2200	6178	1451	3081	982	515	605	2199	565	224	77	1094
Yellow bullhead	7	45	1	32	2	47	25	13	18	36	61	10	7	21
Brown bullhead	510	5328	1612	740	451	2416	125	284	675	531	338	179	69	461
Channel catfish	61042	55084	75663	74042	41508	90442	48575	38251	38929	55528	40941	12559	20479	15200
Margined madtom	-	-	-	-	-	-	-	-	-	-	6	-	-	-
Madtoms	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Tadpole madtom	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Mummichog	-	-	-	-	1	-	-	-	-	-	1	-	-	-
White perch	50991	647493	897113	511699	568018	224843	113164	43103	26971	83363	53527	23151	6402	68344
* Striped bass	3142	495	1150	174	13	1196	934	260	904	3277	60	23	181	213
Rock bass	66	32	31	46	227	128	50	46	88	381	138	269	158	122
Redbreast sunfish	707	2056	1398	3040	3772	8377	4187	3466	1524	1007	1335	401	465	3366

continued

TABLE 6.2. Continued.

Year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
No. Days	54	62	58	55	63	61	35	29	30	37	44	29	34	55
Lifts	817	1527	819	514	684	707	358	301	403	490	725	648	519	1118
Est. Oper. Time (Hr.)	607	996	500	307	375	413	212	187	221	275	502	299	251	542
Fishing Time (Hr.)	313	623	222	189	252	245	136	123	117	178	336	224	192	421
No. Species	40	43	42	41	38	40	44	37	42	48	48	41	35	41
Green sunfish	3	-	4	39	81	168	25	-	16	28	91	16	7	133
Pumpkinseed	229	2578	2579	1000	878	1687	512	323	446	306	848	228	104	1013
Bluegill	567	1423	927	3058	2712	5442	1361	813	942	1299	1184	587	284	6048
Smallmouth bass	182	298	119	153	327	701	262	374	455	881	1095	1003	608	1081
Largemouth bass	82	80	23	19	33	14	22	22	41	13	20	17	8	67
White crappie	4457	664	4371	9290	2987	1003	673	384	100	231	303	450	59	345
Black crappie	8	4	25	45	86	199	103	53	15	20	39	46	6	45
Tessellated darter	-	1	4	1	-	-	1	-	-	2	-	-	-	1
Yellow perch	5955	1090	682	494	2904	735	526	379	373	1007	724	387	487	2145
Logperch	-	-	-	-	-	-	27	-	-	-	-	-	-	1
Shield darter	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Walleye	1840	2734	1613	369	2267	2140	967	2491	4153	2645	504	663	236	609
Banded darter	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Atlantic needlefish	1	-	-	1	-	-	-	-	-	2	-	-	-	-
Lampreys	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Sea lamprey	-	2	-	2	29	11	1	3	1	55	56	8	4	164
Lake herring	-	1	-	-	-	-	-	-	-	-	-	1	-	-
Striped bass x white bass	-	-	-	-	-	-	270	273	2674	39	160	355	282	1377
Tiger muskie	-	-	-	-	-	-	13	132	34	53	56	16	10	73
Splake	-	-	-	-	-	-	-	-	-	-	-	-	2	-
	241419	1300345	1617888	917043	1175616	1169161	276045	197769	372379	1353308	1403175	1028090	957821	2317797

TABLE 6.3.

Daily summary of fishes collected at the Conowingo Fish Lift in spring, 1985.

Date	1 Apr	5 Apr	7 Apr	9 Apr	11 Apr	13 Apr	17 Apr	19 Apr
No. Lifts	9	11	13	11	12	10	15	13
First Lift	715	615	605	605	620	600	600	605
Last Lift	1300	1200	1155	1220	1155	1206	1340	1210
Operating Time	5.75	5.75	5.83	6.25	5.58	6.10	7.67	6.08
Fishing Time (Hr)	3.75	4.58	4.67	5.00	4.50	4.17	6.25	4.38
Ave River Flow	90300	88200	69500	56200	47900	42200	32200	30100
Ave Water Temp	51.8	46.4	48.2	50.9	49.1	52.7	54.5	56.3
Attractant Used?	NO	NO	NO	NO	NO	NO	NO	NO
American eel	2	3	-	-	-	-	2	-
Blueback herring	-	-	-	-	-	-	-	-
Hickory shad	-	-	-	-	-	-	-	-
Alewife	4	-	1	11	1	-	1	3
American shad	-	-	-	1	-	-	-	-
Gizzard shad	10960	2971	24500	4700	21350	4083	3162	9950
Atlantic menhaden	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	-	-	-	-	-
Brown trout	1	1	1	3	-	1	-	1
Brook trout	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Carp	2	-	-	-	-	-	2	1
Golden shiner	-	-	-	-	-	-	-	5
Comely shiner	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	40	201
Spotfin shiner	-	-	-	-	-	-	-	-
Quillback	-	-	-	-	-	-	1	-
White sucker	87	1	10	10	2	11	54	19
Shorthead redhorse	5	-	1	2	1	-	107	5
White catfish	-	-	-	-	-	-	-	-
Yellow bullhead	1	-	-	-	-	-	-	-
Brown bullhead	1	-	-	-	-	-	-	-
Channel catfish	269	-	-	1	1	-	14	84
White perch	-	-	-	-	-	-	-	20
Striped bass	-	-	-	-	-	-	-	1
Rock bass	-	-	-	-	-	-	-	-
Redbreast sunfish	-	-	-	-	-	-	-	-
Green sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	5
Bluegill	-	-	-	-	-	8	35	25
Smallmouth bass	-	-	-	-	-	-	8	8
Largemouth bass	-	-	-	-	-	-	3	2
White crappie	-	-	-	-	-	-	-	-
Black crappie	-	-	-	-	-	1	-	-
Tessellated darter	-	-	-	-	-	-	-	-
Yellow perch	20	-	-	2	2	4	76	299
Logperch	-	-	-	-	-	-	-	-
Walleye	-	-	2	1	-	-	6	3
Sea lamprey	-	1	-	-	-	1	-	1
Striped bass x white bass	15	2	71	18	22	26	111	170
Tiger muskie	-	1	-	-	-	-	5	-
TOTAL	11367	2980	24586	4749	21379	4135	3627	10803

Date	21 Apr	22 Apr	23 Apr	24 Apr	25 Apr	26 Apr	27 Apr	28 Apr
No. Lifts	33	44	25	21	28	26	31	26
First Lift	605	600	635	700	600	600	600	505
Last Lift	1704	1809	1814	1805	1805	1725	1850	1655
Operating Time	10.98	12.15	11.65	11.08	12.08	11.42	12.83	11.83
Fishing Time (Hr)	5.68	5.65	9.07	8.42	9.40	7.23	8.95	8.60
Ave River Flow	26500	26200	24400	25900	22100	22600	22600	21900
Ave Water Temp	59.0	59.7	61.0	61.8	65.3	66.2	67.4	67.5
Attractant Used?	No	No	No	No	No	Yes	No	Yes
American eel	1	2	1	15	6	9	16	4
Blueback herring	-	-	10	11	52	61	428	386
Hickory shad	-	-	-	1	-	-	2	1
Alewife	45	34	25	33	12	1	4	72
American shad	19	6	36	45	22	21	62	108
Gizzard shad	82000	114785	45705	40715	41065	72075	101670	118250
Atlantic menhaden	-	-	-	-	-	-	-	-
Rainbow trout	1	-	-	-	-	-	-	-
Brown trout	2	1	-	1	-	3	2	3
Brook trout	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	2	-
Carp	2	44	28	11	82	285	159	138
Golden shiner	9	3	11	41	20	25	46	17
Comely shiner	-	-	-	-	10	6	-	200
Spottail shiner	120	152	158	469	678	125	245	36
Spotfin shiner	-	-	-	-	-	-	-	-
Quillback	-	4	-	-	5	31	2	19
White sucker	88	92	16	54	30	42	34	6
Shorthead redhorse	57	298	178	54	79	64	109	21
White catfish	-	1	-	-	-	-	-	1
Yellow bullhead	-	-	-	-	1	-	2	2
Brown bullhead	-	-	-	8	3	1	2	4
Channel catfish	53	82	54	318	183	85	90	24
White perch	301	488	1005	365	629	476	530	335
Striped bass	1	2	-	-	-	-	-	-
Rock bass	3	2	2	8	10	3	3	7
Redbreast sunfish	3	8	6	30	47	26	42	23
Green sunfish	1	-	-	1	5	2	1	1
Pumpkinseed	2	11	5	20	15	19	8	2
Bluegill	142	76	96	47	140	111	159	55
Smallmouth bass	42	27	52	30	74	129	285	105
Largemouth bass	6	1	5	1	6	-	9	4
White crappie	11	3	3	4	13	4	13	12
Black crappie	1	-	1	-	6	2	1	1
Tessellated darter	-	-	-	-	-	-	-	-
Yellow perch	155	178	120	98	149	86	114	52
Logperch	-	-	-	-	-	-	-	-
Walleye	14	20	12	20	9	9	31	10
Sea lamprey	4	3	1	-	1	2	7	20
Striped bass x white bass	115	81	24	7	9	3	3	5
Tiger muskie	4	4	2	7	4	3	4	3
	83202	116408	47556	42414	43365	73709	104085	119927

TABLE 6.3 . Continued.

Date	29 Apr	30 Apr	1 May	2 May	3 May	4 May	5 May	6 May
No. Lifts	22	35	31	28	28	24	22	21
Fist Lift	510	506	502	515	519	605	607	600
Last Lift	1702	1904	1845	1755	1805	1800	1800	1730
Operating Time	11.87	13.97	13.72	12.67	12.77	11.92	11.88	11.50
Fishing Time (Hr)	9.75	10.32	10.07	9.93	9.78	9.95	9.82	9.83
Ave River Flow	19500	17700	19600	17800	26700	40400	45300	41900
Ave Water Temp	67.7	67.7	67.7	66.2	67.1	65.3	65.3	64.5
Attractant Used?	No	No	No	Yes	No	Yes	No	Yes
American eel	6	14	7	7	30	4	5	6
Blueback herring	1	164	135	113	105	922	214	86
Hickory shad	-	-	3	-	-	-	-	-
Alewife	-	-	3	1	6	12	2	3
American shad	9	66	144	134	9	68	74	41
Gizzard shad	49095	86725	54320	48565	39650	45195	14210	24247
Atlantic menhaden	-	-	-	-	-	-	-	-
Rainbow trout	-	-	50	-	-	1	-	-
Brown trout	-	1	3	1	12	4	4	4
Brook trout	-	1	-	-	-	-	-	-
Muskellunge	1	1	7	-	-	-	-	-
Carp	596	247	30	53	205	3	6	6
Golden shiner	5	10	8	3	5	11	7	2
Comely shiner	-	-	-	26	-	16	23	7
Spottail shiner	15	731	37	75	12	21	2	-
Spotfin shiner	-	3	-	-	-	-	1	-
Quillback	2	3	-	-	7	1	1	2
White sucker	4	6	8	7	13	29	4	8
Shorthead redhorse	27	106	19	107	203	87	62	109
White catfish	14	7	7	8	7	11	10	10
Yellow bullhead	-	-	-	1	-	1	-	-
Brown bullhead	1	14	-	1	5	7	8	4
Channel catfish	351	172	304	239	590	89	214	358
White perch	630	355	1124	970	1792	1355	380	1087
Striped bass	-	-	-	-	-	1	2	-
Rock bass	2	9	4	4	1	5	5	4
Redbreast sunfish	65	91	20	23	23	39	34	29
Green sunfish	-	2	1	2	1	4	1	2
Pumpkinseed	21	49	9	12	3	11	3	1
Bluegill	143	146	44	22	45	117	47	23
Smallmouth bass	48	17	20	17	21	24	11	3
Largemouth bass	-	1	-	-	1	1	-	-
White crappie	2	14	6	2	-	10	1	-
Black crappie	-	2	1	-	1	12	-	-
Tessellated darter	-	-	-	1	-	-	-	-
Yellow perch	86	127	72	42	20	22	14	1
Logperch	-	-	-	-	-	-	-	-
Walleye	11	15	14	17	9	11	2	8
Sea lamprey	8	25	18	15	7	4	10	4
Striped bass x white bass	2	1	1	2	15	4	2	3
Tiger muskie	2	-	1	2	1	-	1	2
	51147	89125	56420	50472	42799	48102	15360	26060

Date	7 May	8 May	9 May	10 May	11 May	12 May	13 May	14 May
No. Lifts	22	21	22	13	17	28	23	21
First Lift	558	558	600	1105	600	604	555	555
Last Lift	1730	1700	1820	1800	1555	1712	1820	1600
Operating Time	11.53	111.03	12.33	6.92	9.92	11.13	12.42	10.08
Fishing Time (Hr)	9.38	8.87	10.43	5.63	8.35	7.92	10.33	8.30
Ave River Flow	68400	32100	27700	26200	19100	23600	21200	22000
Ave Water Temp	62.6	62.6	62.6	64.4	63.5	63.5	63.5	65.3
Attractant Used?	No	Yes	No	Yes	No	Yes	No	Yes
American eel	3	3	2	-	-	3	3	9
Blueback herring	321	109	124	16	95	335	49	141
Hickory shad	-	-	-	2	-	-	-	-
Alewife	8	13	3	9	3	15	5	1
American shad	35	21	46	18	5	30	61	22
Gizzard shad	77710	86450	31700	33275	96150	85175	25350	33925
Atlantic menhaden	-	-	-	-	-	-	-	-
Rainbow trout	-	-	-	1	-	1	-	-
Brown trout	6	2	3	1	1	3	5	5
Brook trout	-	-	-	-	-	-	-	-
Muskellunge	1	-	-	-	1	-	-	-
Carp	47	64	22	26	3	3	67	106
Golden shiner	-	3	4	2	7	6	5	10
Comely shiner	30	-	-	111	30	-	175	451
Spottail shiner	-	-	2	100	30	60	-	-
Spotfin shiner	-	-	-	-	-	-	-	25
Quillback	-	3	1	-	-	-	2	53
White sucker	5	9	11	6	6	3	9	35
Shorthead redhorse	75	80	222	55	128	55	256	220
White catfish	4	6	5	-	-	1	17	6
Yellow bullhead	1	6	-	-	-	-	-	-
Brown bullhead	6	2	10	5	2	1	17	8
Channel catfish	283	142	126	65	85	9	79	248
White perch	1133	521	1583	208	1426	825	1305	1286
Striped bass	1	-	1	1	-	-	-	-
Rock bass	1	-	5	5	3	2	4	1
Redbreast sunfish	53	10	35	88	88	115	112	93
Green sunfish	1	1	2	22	1	11	4	1
Pumpkinseed	16	12	2	19	23	40	65	32
Bluegill	56	32	75	88	156	166	222	136
Smallmouth bass	12	7	7	10	20	20	2	8
Largemouth bass	1	2	1	1	2	-	-	-
White crappie	2	-	-	2	11	15	4	1
Black crappie	-	-	-	-	1	-	-	-
Tessellated darter	-	-	-	-	-	-	-	-
Yellow perch	17	-	4	6	6	24	22	7
Logperch	-	-	-	-	-	-	-	-
Walleye	5	6	8	8	13	15	8	9
Sea lamprey	4	7	3	-	6	4	-	-
Striped bass x white bass	1	2	4	2	3	3	6	6
Tiger muskie	1	-	1	1	2	3	1	1
	79839	87513	34012	34153	98307	86943	27855	36846

TABLE 6.3. Continued.

Date	15 May	16 May	17 May	18 May	19 May	20 May	21 May	22 May
No. Lifts	24	22	19	25	17	21	19	19
First Lift	557	605	605	605	605	609	600	600
Last Lift	1715	1656	1710	1730	1600	1729	1750	1700
Operating Time	11.30	10.85	11.08	11.42	9.92	11.33	11.83	11.00
Fishing Time (Hr)	8.90	8.75	9.42	9.37	8.55	8.98	10.25	9.23
Ave River Flow	20900	18800	18700	21100	24200	22600	23500	21500
Ave Water Temp	66.6	68.9	68.9	68.0	68.0	68.0	68.9	68.9
Atrractant Used?	No	No	No	No	No	No	No	No
American eel	28	22	9	9	4	15	31	13
Blueback herring	122	66	10	76	83	16	15	60
Hickory shad	-	-	-	-	-	-	-	-
Alewife	-	2	-	-	-	4	3	7
American shad	20	18	23	100	71	5	3	11
Gizzard shad	60390	57960	60450	39240	50160	7150	13155	20700
Atlantic menhaden	-	-	-	-	-	-	-	-
Rainbow trout	-	4	-	-	1	-	-	-
Brown trout	14	6	3	14	7	1	2	4
Brook trout	-	-	-	-	-	-	-	-
Muskellunge	1	-	-	-	-	-	-	-
Carp	232	30	108	46	1037	156	36	54
Golden shiner	1	1	-	1	6	-	2	-
Comely shiner	25	725	335	-	175	25	25	50
Spottail shiner	6	-	125	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	145	40	75
Quillback	4	-	3	-	100	33	154	8
White sucker	7	10	6	5	1	6	5	3
Shorthead redhorse	137	148	41	19	8	45	54	26
White catfish	14	9	3	2	-	20	48	40
Yellow bullhead	-	-	-	-	-	-	4	-
Brown bullhead	9	10	4	6	3	9	34	22
Channel catfish	413	371	209	89	88	371	653	453
White perch	3777	3075	2165	3977	2235	2675	1175	3835
Striped bass	-	-	2	1	1	1	-	1
Rock bass	2	2	1	3	1	-	2	3
Rebreast sunfish	170	183	142	173	139	78	74	82
Green sunfish	7	-	7	-	2	3	1	7
Pumpkinseed	41	52	29	53	25	22	17	22
Bluegill	256	235	200	213	159	75	111	123
Smallmouth bass	9	8	8	14	10	2	3	3
Largemouth bass	-	1	5	2	5	1	-	1
White crappie	8	19	5	14	7	-	-	2
Black crappie	1	1	-	1	3	-	-	-
Tessellated darter	-	-	-	-	-	-	-	-
Yellow perch	19	24	11	11	22	11	13	14
Logperch	1	-	-	-	-	-	-	-
Walleye	23	25	5	19	16	10	12	14
Sea lamprey	-	1	-	-	-	-	1	-
Striped bass x white bass	15	13	16	34	9	9	16	12
Tiger muskie	1	2	2	-	-	-	1	1

Date	23 May	24 May	25 May	26 May	27 May	28 May	29 May	31 May
No. Lifts	21	21	22	18	23	19	17	12
First Lift	600	605	600	600	613	600	600	600
Last Lift	1728	1745	1700	1700	1755	1625	1700	1200
Operating Time	11.47	11.67	11.00	11.00	11.70	10.42	11.00	6.00
Fishing Time (Hr)	9.20	9.93	8.92	9.42	8.88	8.58	8.67	4.42
Ave River Flow	19400	19400	16000	17100	15900	11500	12700	17400
Ave Water Temp	68.0	68.0	67.1	68.0	68.0	68.00	68.9	71.6
Attractant Used?	No	No	No	No	No	No	No	No
American eel	5	8	22	4	4	12	30	26
Blueback herring	10	43	233	548	1505	43	11	16
Hickory shad	-	-	-	-	-	-	-	-
Alewife	3	4	8	3	7	4	-	2
American shad	5	16	23	102	32	2	3	3
Gizzard shad	30099	12995	28101	49800	60250	6800	9180	22850
Atlantic menhaden	-	-	-	-	-	-	-	1
Rainbow trout	-	-	1	-	-	-	2	1
Brown trout	2	4	7	5	8	2	1	3
Brook trout	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Carp	7	9	3	3	306	432	696	8
Golden shiner	1	2	1	2	2	1	-	5
Comely shiner	50	50	1801	535	85	30	50	-
Spottail shiner	-	-	-	-	85	-	-	-
Spotfin shiner	-	82	1152	565	237	65	175	-
Quillback	3	-	1	1	2	21	259	1
White sucker	-	2	-	-	2	1	2	-
Shorthead redhorse	4	17	3	4	1	28	34	-
White catfish	125	54	13	4	7	112	23	6
Yellow bullhead	-	1	-	-	-	-	-	-
Brown bullhead	35	27	7	1	2	20	4	20
Channel catfish	530	838	82	82	21	243	263	925
White perch	4065	3477	2207	3100	4100	2645	3030	2015
Striped bass	2	-	3	9	9	2	-	2
Rock bass	4	4	1	1	1	-	1	-
Redbreast sunfish	93	99	58	213	82	93	96	73
Green sunfish	-	2	1	2	3	3	8	-
Pumpkinseed	10	24	11	50	22	31	35	6
Bluegill	68	162	303	335	179	124	157	84
Smallmouth bass	-	-	3	3	1	-	3	-
Largemouth bass	-	-	1	1	-	-	1	-
White crappie	8	6	29	9	23	7	12	11
Black crappie	-	-	2	1	1	1	-	-
Tessellated darter	-	-	-	-	-	-	-	-
Yellow perch	6	26	1	4	11	7	4	16
Logperch	-	-	-	-	-	-	-	-
Walleye	8	21	22	17	8	13	16	8
Sea lamprey	-	1	-	1	2	1	-	-
Striped bass x white bass	40	28	69	39	67	18	29	10
Tiger muskie	-	2	-	2	1	-	1	-
	35183	18004	34169	55446	67066	10761	14127	26092

TABLE 6.3. Continued.

Date	2 Jun	4 Jun	6 Jun	8 Jun	10 Jun	12 Jun	14 Jun	Totals
No. Lifts	11	14	12	14	17	12	13	11
First Lift	555	600	600	605	610	600	600	
Last Lift	1200	1132	1150	1200	1136	1140	1143	
Operating Time	6.08	5.53	5.83	5.92	5.43	5.67	5.72	541.86
Fishing Time (Hr)	4.72	3.42	5.00	4.47	3.57	4.67	4.45	420.73
Ave River Flow	19400	32300	23100	22900	16300	14800	12200	
Ave Water Temp	72.5	73.4	73.4	72.5	74.3	75.2	72.5	
Attractant Used?	No	No	No	No	No	No	No	
American eel	16	2	18	38	6	22	43	550
Blueback herring	19	-	8	-	1	-	-	6,763
Hickory shad	-	-	-	-	-	-	-	9
Alewife	-	-	-	-	-	-	-	379
American shad	4	-	1	1	-	-	-	1,546
Gizzard shad	24875	28050	5270	20900	28620	3350	12860	2,182,888
Atlantic menhaden	-	-	-	-	-	-	-	1
Rainbow trout	-	4	1	-	-	2	-	70
Brown trout	3	3	2	4	3	1	1	175
Brook trout	-	-	-	-	-	-	-	1
Muskellunge	-	-	1	-	-	-	-	15
Carp	135	457	35	255	365	14	67	6,729
Golden shiner	1	-	-	1	-	-	-	292
Comely shiner	75	-	-	-	20	-	-	5,141
Spottail shiner	-	-	-	-	-	-	-	3,525
Spotfin shiner	125	5	-	-	-	-	-	2,695
Quillback	24	42	21	77	28	4	34	957
White sucker	-	2	3	-	1	1	-	776
Shorthead redhorse	1	-	-	-	-	-	-	3,362
White catfish	1	85	47	69	215	36	46	1,094
Yellow bullhead	-	-	-	-	1	-	-	21
Brown bullhead	-	30	19	29	38	17	5	461
Channel catfish	110	2245	270	590	785	441	515	15,200
White perch	335	130	40	45	75	42	5	68,344
Striped bass	19	3	9	4	9	123	3	213
Rock bass	-	1	-	1	1	-	-	122
Redbreast sunfish	73	45	97	61	37	58	44	3,366
Green sunfish	2	6	8	3	-	1	-	133
Pumpkinseed	42	8	23	26	37	15	7	1,013
Bluegill	112	32	290	121	151	94	52	6,048
Smallmouth bass	2	1	1	-	1	1	1	1,081
Largemouth bass	2	-	-	-	-	-	-	67
White crappie	11	1	8	10	7	10	5	345
Black crappie	2	1	-	-	-	1	-	45
Tessellated darter	-	-	-	-	-	-	-	1
Yellow perch	27	7	13	29	26	8	10	2,145
Logperch	-	-	-	-	-	-	-	1
Walleye	12	4	6	15	11	20	7	609
Sea lamprey	-	-	-	-	1	-	-	164
Striped bass x white bass	89	2	17	9	12	82	3	1,377
Tiger muskie	2	-	1	-	-	-	1	73
	26119	31166	6209	2278	30451	4344	13709	2,317,797

TABLE 6.4.

Mean, minimum, and maximum fork length (mm); age; and spawning history of alewife collected at the Conowingo Dam Fish Lift in 1985.

Sex	Age	N	Spawning History: No. Virgins	No. Repeats (Single)	Mean (FL)	Min. (FL)	Max. (FL)
Male	3	10	10		231	208	238
	4	10	9	1	238	227	249
	5	5	4	1	260	247	269
	6	2	1	1	269	264	274
TOTAL		27	24	3	242	208	274
Female	3	1	1		231	231	
	4	8	7	1	252	240	266
	5	3	3		267	256	288
	6	4	1	3	275	269	284
TOTAL		16	12	4	259	231	284

TABLE 6.5.

Mean, minimum, and maximum fork length (mm); age; and spawning history of blueback herring collected at the Conowingo Dam Fish Lift in 1985.

Sex	Age	N	Spawning History: No. Virgins	No. Repeats: Single	No. Repeats: Double	Mean (FL)	Min (FL)	Max (FL)
Male	4	10	9	1	1	237	218	260
	5	63	30	33		248	229	277
	6	20	4	16	1	258	234	270
	7	3			3	266	250	279
TOTAL		96	43	50	4	252	218	279
Female	4	3	3			243	238	250
	5	34	17	17		256	234	284
	6	17	2	12	3	266	247	290
	7	3		1	2	280	277	284
TOTAL		57	22	30	5	255	238	284

TABLE 6.6.

Comparison of the American shad catch, catch per effort (hr), and effort between low (one unit generation) and high discharges (two or more unit generation) at the Conowingo Dam Fish Lift, 21 April through 27 May 1985.

Generation Status	No. Caught	Total Time Fished (min)	Number Of Lifts	Catch Per Hr
Low	686	4228	206	9.74
High	845	15660	714	3.24
TOTAL	1531	19888	920	4.62

TABLE 6.7.

Comparison of catch per effort (hr) of American shad on weekdays vs. weekend days and generation (cfs) at the Conowingo Dam Fish Lift, 21 April through 27 May 1985.

	Lift Time	5000 cfs Catch/Hr	10-20000 (cfs) Catch/Hr	25-40000 (cfs) Catch/Hr	45000 cfs (cfs) Catch/Hr	Total Catch/Hr
Weekdays	0600-0900	2.3	2.2	1.1	1.5	1.7
	0901-1100	2.4	-	-	3.2	3.2
	1101-1500	8.2	6.3	6.2	2.6	3.3
	1501-1900	13.7	3.5	1.6	1.1	7.2
Mean Weekday		9.7	4.3	2.4	2.5	3.8
Weekend	0600-0900	13.5	6.5	1.1	2.4	11.6
	0901-1100	6.1	1.3	0.0	3.0	3.2
	1101-1500	8.6	1.5	0.3	8.5	5.5
	1501-1900	9.2	0.2	0.0	6.7	6.4
Mean Weekend		10.2	1.5	0.3	5.8	6.6
Grand Mean		10.0	2.7	1.6	2.9	4.7

TABLE 6.8.

Catch/hour and percent of American shad in the Conowingo Dam Fish Lift by water temperature, 21 April through 14 June 1985.

Water Temp (F)	Hours Fishing	Catch		
		No.	C/E	%
≤ 65	100.40	360	3.59	23.5
> 65	231.07	1171	5.07	76.5
TOTAL	331.47	1531	4.62	100.0

TABLE 6.9.

Total and catch/hour of American shad by date and weir gate setting during modified lift operation at Conowingo Dam, 1985.

Date		#One Weir Gate Open	#Two Weir Gate Open	Both Weir Gates Open	Daily Total
22 Apr	#American shad		1	4	5
	Fishing Time(hr)	0.0	0.6	5.0	5.6
	Catch/Hr		1.67	0.80	0.89
26 Apr	#American shad	2		19	21
	Fishing Time(hr)	0.3	0.0	7.0	7.2
	Catch/Hr	6.67		2.71	2.92
27 Apr	#American shad		4	58	62
	Fishing Time(hr)	0.0	0.3	8.6	8.9
	Catch/Hr		13.33	6.74	6.97
28 Apr	#American shad		69	39	108
	Fishing Time(hr)	0.0	3.2	5.4	8.6
	Catch/Hr		21.56	7.22	12.56
29 Apr	#American shad		4	5	9
	Fishing Time(hr)	0.0	3.3	6.5	9.8
	Catch/Hr		1.21	0.77	0.92
30 Apr	#American shad		58	8	66
	Fishing Time(hr)	0.0	2.3	8.0	10.3
	Catch/Hr		25.22	1.00	6.41
1 May	#American shad		68	76	144
	Fishing Time(hr)	0.0	3.6	6.5	10.1
	Catch/Hr		18.89	11.69	14.26
2 May	#American shad		104	30	134
	Fishing Time(hr)	0.0	2.8	7.2	9.9
	Catch/Hr		37.14	4.17	13.54
3 May	#American shad		0	9	9
	Fishing Time(hr)	0.0	1.2	8.5	9.7
	Catch/Hr		0.00	1.06	0.93

Continued

TABLE 6.9. Continued.

Date		#One Weir Gate Open	#Two Weir Gate Open	Both Weir Gates Open	Daily Total
8 May	#American shad		3	18	21
	Fishing Time(hr)	0.0	3.7	5.2	8.9
	Catch/Hr		0.81	3.46	2.36
11 May	#American shad	1	4	0	5
	Fishing Time(hr)	0.5	2.8	5.1	8.3
	Catch/Hr	2.00	1.43	0.00	0.60
15 May	#American shad		11	9	20
	Fishing Time(hr)	0.0	2.6	6.3	8.9
	Catch/Hr		4.23	1.43	2.25
16 May	#American shad		5	13	18
	Fishing Time(hr)	0.0	2.8	6.0	8.8
	Catch/Hr		1.79	2.17	2.05
18 May	#American shad	5	3	92	100
	Fishing Time(hr)	0.5	1.2	7.7	9.4
	Catch/Hr	10.00	2.50	11.95	10.64
24 May	#American shad	0		16	16
	Fishing Time(hr)	0.5	0.00	9.4	9.9
	Catch/Hr	0.00		1.70	1.62
26 May	#American shad		17	84	101
	Fishing Time(hr)	0.0	3.6	5.6	9.2
	Catch/Hr		4.72	15.00	10.98
27 May	#American shad		8	24	32
	Fishing Time(hr)	0.0	3.3	5.6	8.9
	Catch/Hr		2.42	42.9	3.60
Total # shad		8	359	504	871
Total Fishing Time(hr)		1.8	37.3	113.6	152.7
Catch/Hr		4.44	9.62	4.44	5.70

TABLE 6.10.

Daily number by sex of American shad Floy tagged at the Conowingo Dam Fish Lift, 1985.

Date	Female	Male	Total
9 Apr	1		1
21 Apr	3	16	19
22 Apr		6	6
23 Apr	12	21	33
25 Apr	4	12	16
26 Apr	2	15	17
29 Apr	1	7	8
30 Apr	2		2
2 May	1	2	3
3 May	1	6	7
8 May	6	12	18
10 May	4	11	15
11 May	2	3	5
12 May	6	18	24
14 May	5	17	22
15 May	5	11	16
16 May	2	13	15
17 May	4	14	18
20 May		5	5
21 May		2	2
22 May	2	6	8
23 May		4	4
24 May	2	13	15
25 May	3	17	20
27 May	7	17	24
28 May		2	2
29 May		1	1
TOTAL	75	251	326

TABLE 6.11.

Data for tagged American shad recaptured at the Conowingo Dam Fish Lift, 1985.

Recapture Date	Tag Date	Days Free
28 Apr	3 May 1984	360
28 Apr	21 Apr	7
9 May		10
28 Apr	22 Apr	6
28 Apr	21 Apr	7
29 Apr	23 Apr	6
30 Apr	23 Apr	7
10 May		10
30 Apr	23 Apr	7
1 May	23 Apr	8
8 May		7
1 May	21 Apr	10
1 May	25 Apr	6
1 May	23 Apr	8
1 May	23 Apr	8
2 May	21 Apr	11
2 May	23 Apr	9
23 May		21
2 May	21 Apr	11
2 May	25 Apr	8
5 May	21 Apr	13
5 May	23 Apr	11
7 May	23 Apr	13
9 May	23 Apr	17
26 May		17
12 May	22 Apr	20
13 May	23 Apr	20
13 May	26 Apr	17
15 May	10 May	5
15 May	10 May	5

TABLE 6.11. Continued.

Recapture Date	Tag Date	Free Days
16 May	27 Apr	19
18 May	12 May	6
18 May	10 May	8
18 May	26 Apr	22
18 May	21 Apr	27
18 May	12 May	6
18 May	10 May	8
19 May	23 Apr	26
19 May	3 May	16
24 May	14 May	10
25 May	14 May	11
26 May		1
25 May	12 May	13
29 May		4
25 May	14 May	11
26 May	16 May	10
26 May	17 May	9
26 May	8 May	18
26 May	21 Apr	35
26 May	12 Jun 1984	348
26 May	14 May	12
27 May	14 May	13
27 May	12 May	15
27 May	8 May	19
27 May	14 May	13
29 May	24 May	5

TABLE 6.12.

Mean, minimum, and maximum fork length (mm), age, and spawning history of American shad collected at the Conowingo Dam Fish Lift in 1985.

Sex	Age	N	Spawning History: No. Virgins	Spawning History: No. Repeats (Single)	Mean (FL)	Min. (FL)	Max. (FL)
Male	3	42	42		339	247	389
	4	179	5	14	387	337	455
	5	79	73	6	446	386	490
	6	6	4	2	484	460	540
TOTAL		306	124	22	398	247	540
Female	3	2	2		405	392	418
	4	35	33	2	419	350	471
	5	48	47	1	464	421	512
	6	23	18	5	509	465	565
	7	7	6	1	542	502	574
TOTAL		115	106	9	463	350	574

TABLE 6.13.

Summary of Transportation of American shad from the Conowingo Dam Fish Lift, 24 April through 26 May 1985.

Date	# Collected	Water Temp(F)	No. Transported	Location	Observed Mortality
24 Apr	45	61.8	40	City Is,PA	8
27 Apr	62	67.4	50	PFC Fairview Access,PA	3
28 Apr	108	67.5	74	PFC Fairview Access,PA	0
30 Apr	66	67.7	50	PFC Fairview Access,PA	0
1 May	144	67.7	33 65	PFC Fairview Access,PA	0 3
2 May	134	66.2	109	PFC Fairview Access,PA	0
4 May	68	65.3	67	PFC Fairview Access,PA	0
5 May	74	65.3	68	PFC Fairview Access,PA	0
6 May	41	64.5	39	PFC Fairview Access,PA	0
7 May	35	62.6	34	PFC Fairview Access,PA	0
9 May	46	62.6	45	PFC Fairview Access,PA	2
13 May	61	63.5	53	PFC Fairview Access,PA	0
18 May	100	68.0	65 25	PFC Fairview Access,PA	0 0
19 May	71	68.0	66	PFC Fairview Access,PA	0
26 May	102	68.0	84	PFC Fairview Access,PA	0
TOTAL	1157		967		16

NA - Not available

TABLE 6.13. Continued.

Date	% Survival	DO Start	DO Finish	Water Temp (F) at Stocking Location
24 Apr	80	6.2	5.2	63.0
27 Apr	94	13.0	10.0	68.0
28 Apr	100	13.2	10.2	68.8
30 Apr	100	13.4	9.8	69.9
1 May	100	8.2	9.5	69.9
	95	12.4	10.5	69.9
2 May	100	9.7	7.6	64.4
4 May	100	9.4	NA	61.7
5 May	100	14.2	10.5	63.5
6 May	100	10.2	12.4	63.5
7 May	100	9.2	10.0	63.5
9 May	96	9.2	7.5	68.0
13 May	100	9.3	11.0	68.9
18 May	100	13.0	12.2	68.0
	100	8.9	12.8	66.2
19 May	100	10.6	10.6	66.2
26 May	100	13.8	12.6	72.5
	98.3			

TABLE 6.14.

Summary of American shad catch by generation during periods of peak abundance at the Conowingo Dam Fish Lift, 1 through 31 May 1982, 19 May through 6 June 1983, 23 through 29 May 1984, and 21 April through 27 May 1985.

Total Discharge (x 1,000 cfs)	Unit 1	Unit 2	1982 No. Lifts	1982 Time (min)	1982 Total Shad	1982 Shad/ Hr	1983 No. Lifts	1983 Time (min)	1983 Total Shad	1983 Shad/ Hr	1984 No. Lifts	1984 Time (min)	1984 Total Shad	1984 Shad/ Hr
≤ 5	On	Off	1	15	1	4.0	-	-	-	-	-	-	-	-
≤ 5	Off	On	23	575	19	2.0	-	-	-	-	-	-	-	-
≤ 5	Off	Off	157	4571	1179	15.5	19	495	125	15.2	1	15	0	0.0
			181	5161	1199	13.9	19	495	125	15.2	1	15	0	0.0
10-40	On	On	5	171	1	0.4	4	120	4	2.0	16	155	6	2.3
10-40	On	Off	1	30	0	0.0	-	-	-	-	-	-	-	-
10-40	Off	On	46	1253	202	9.7	-	-	-	-	-	-	-	-
10-40	Off	Off	61	1937	138	4.3	33	930	70	4.5	8	165	54	19.6
			113	3391	341	6.0	37	1050	74	4.2	24	320	60	11.3
Change	On	On	7	190	4	1.3	2	45	0	0.0	6	90	1	0.7
Change	On	Off	4	120	19	9.5	-	-	-	-	-	-	-	-
Change	Off	On	15	405	35	5.2	-	-	-	-	-	-	-	-
Change	Off	Off	38	1194	204	10.3	24	690	68	5.9	2	50	7	8.4
			64	1909	262	8.2	26	735	68	5.6	8	140	8	3.4
>40	On	On	36	1181	3	0.2	225	5135	88	1.0	120	2729	58	1.3
>40	On	Off	12	350	12	2.1	-	-	-	-	-	-	-	-
>40	Off	On	30	898	21	1.4	1	30	1	2.0	5	150	8	3.2
>40	Off	Off	28	1006	46	2.7	21	600	19	1.9	-	-	-	-
			106	3435	82	1.4	247	5765	108	1.1	125	2879	66	1.4
TOTAL			464	13896	1884	8.1	329	8045	375	2.8	158	3354	134	2.4

TABLE 6.14. Continued.

Total Discharge (x 1,000 cfs)	Unit 1	Unit 2	1985 No. Lifts	1985 Time (min)	1985 Total Shad	1985 Shad/ Hr	1982-1985 No. Lifts	1982-1985 Time (min)	1982-1985 Total Shad	1982-1985 Shad/ Hr
≤ 5	On	Off	-	-	--	-	1	15	1	4.0
≤ 5	Off	On	-	-	-	-	23	575	19	2.0
≤ 5	Off	Off	205	4213	685	9.8	382	9294	1989	12.8
			205	4213	685	9.8	406	9884	2009	12.2
10-40	On	On	11	22	0	0.0	36	468	11	1.4
10-40	On	Off	-	-	-	-	1	30	0	0.0
10-40	Off	On	-	-	-	-	46	1253	202	9.7
10-40	Off	Off	150	2905	110	2.3	252	5937	372	3.8
			161	2927	110	2.3	335	7688	585	4.6
Change	On	On	2	4	1	15.0	17	329	6	1.1
Change	On	Off	-	-	-	-	4	120	19	9.5
Change	Off	On	1	30	0	0.0	16	435	35	4.8
Change	Off	Off	164	4509	340	4.5	228	6443	619	5.8
			167	4543	341	4.5	265	7327	679	5.6
>40	On	On	15	45	1	1.3	396	9090	150	1.0
>40	On	Off	-	-	-	-	12	350	12	2.1
>40	Off	On	8	241	4	1.0	44	1319	34	1.5
>40	Off	Off	283	7747	377	2.9	332	9353	441	2.8
			306	8033	382	2.9	784	20112	638	1.9
TOTAL			839	19716	1518	4.6	1790	45011	3911	5.2

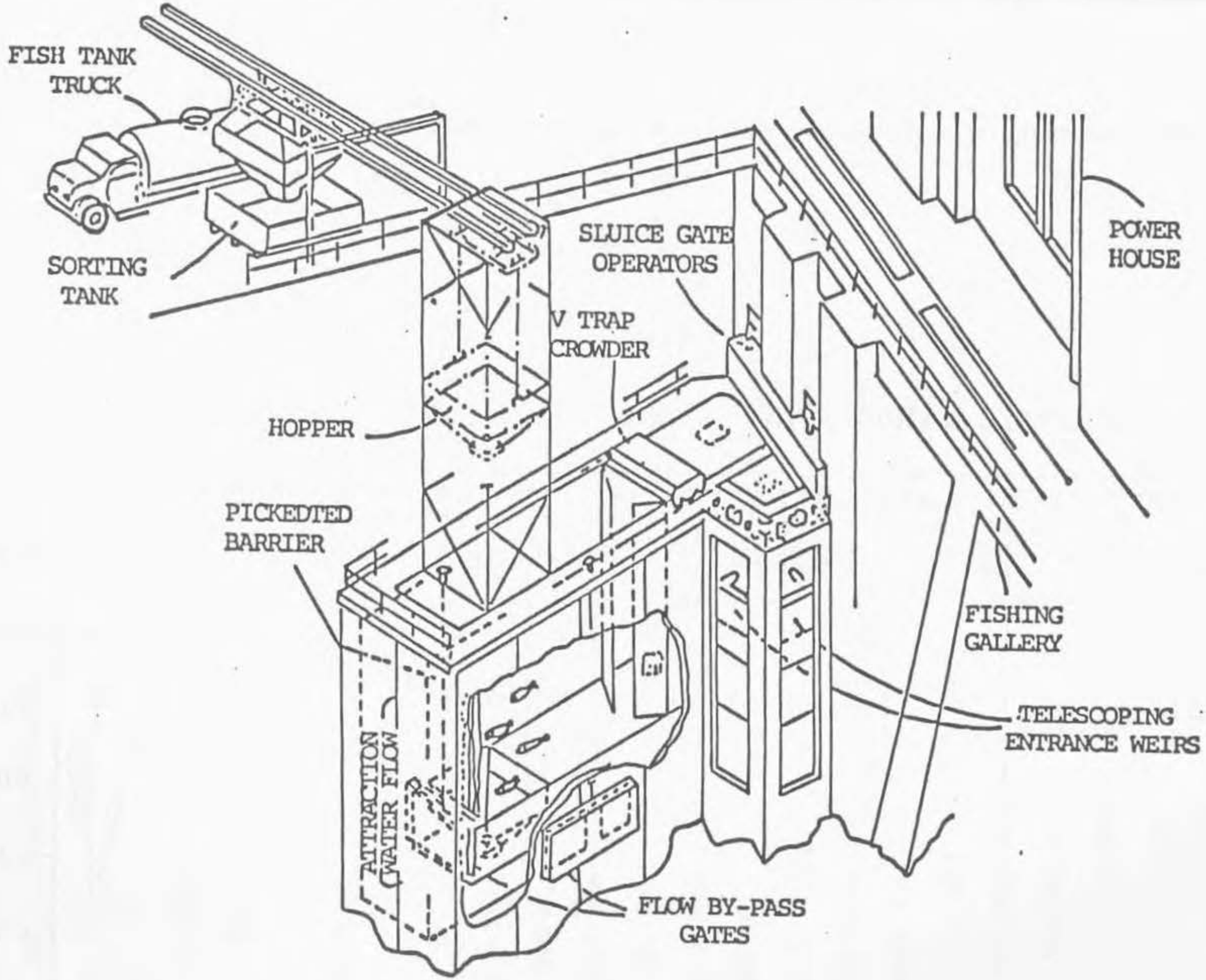

FIGURE 6.1.

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

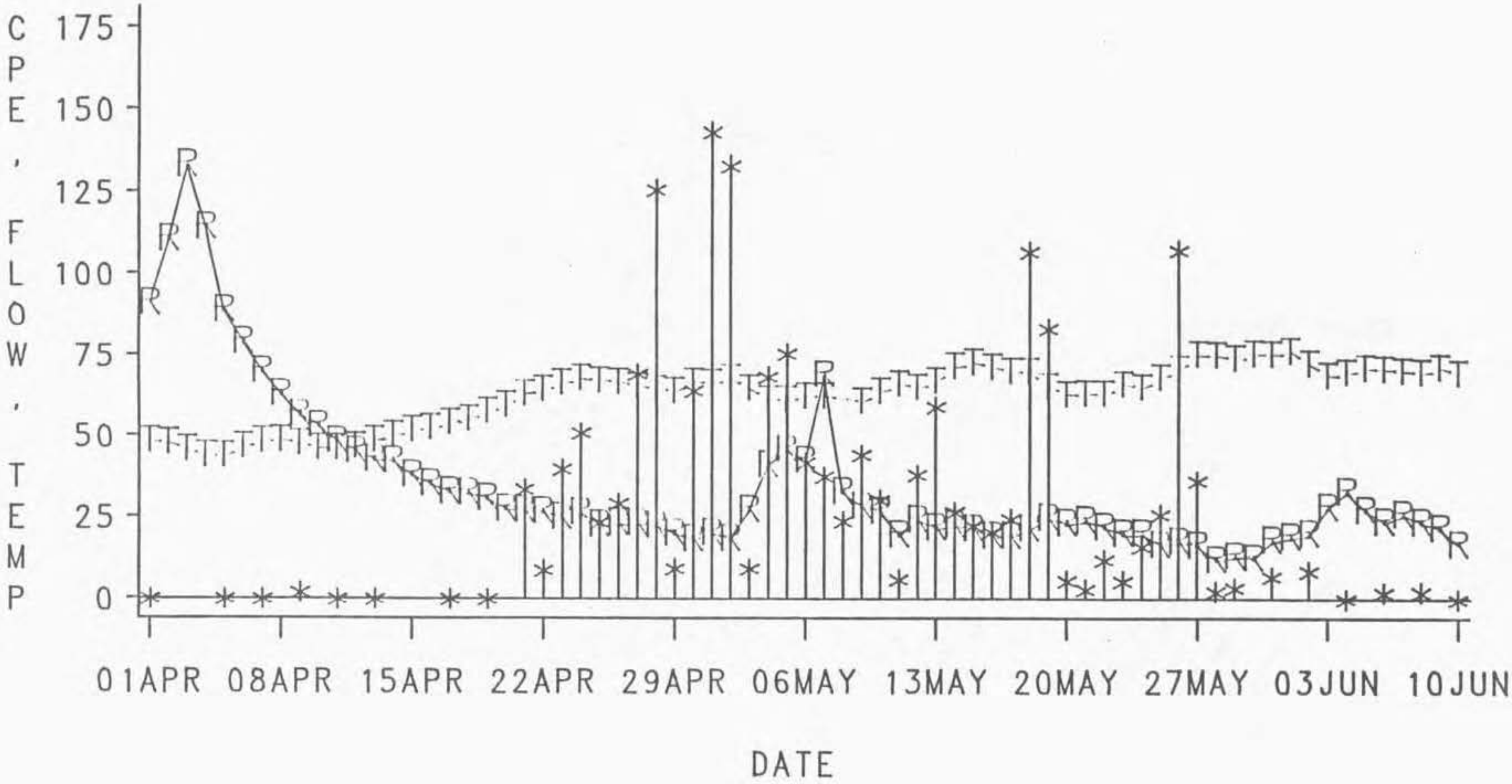

FIGURE 6.2.

A plot of river flow (cfs) and water temperature (F) in relation to the daily American shad catch at the Conowingo Dam Fish Lift in 1985.

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

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INTRODUCTION

Prior to the late 1970's, American shad were an important part of Maryland's commercial and sport fisheries. From colonial times to the late 1960's, annual shad harvests ranked high in both pounds landed and dock-side value relative to other exploited fishery resources (Mansueti and Kolb 1953, Walburg and Nichols 1967). Sport angling for shad, a relatively recent activity as compared to the commercial exploitation, generated many hours of recreation throughout the State.

Historically, the principal river for shad production in Maryland has been the Susquehanna. Until 1980, a commercial shad fishery had been pursued on the Susquehanna for more than 200 years while a successful sport fishery in this region had been ongoing since the 1930's. Total annual commercial landings of American shad in the upper Chesapeake Bay (NOAA Code 089, 090, 064) averaged 204,000 pounds from 1962 through 1973. Forste (MTA in-file data) estimated the value of sport angling for shad on the Susquehanna River in 1970 to be 3.9 million dollars.

Because of a sharp, continuous decline in the reported harvest of American shad since the mid 1970's, Maryland closed its waters to shad fishing on April 4, 1980. The most precipitous decline occurred in the Susquehanna drainage which saw commercial landings drop from a reported 180,000 pounds in 1970 to only 2,300 for 1979.

Concerned by the seriousness of this situation, the Tidewater Administration of Maryland's Department of Natural Resources proposed a long term investigation of American shad in the upper Chesapeake Bay. The primary objective of this study was to assess the status of head-of-the-Bay shad stocks, specifically those utilizing the Susquehanna River drainage. The information obtained would be used to formulate management policies designed to restore American shad to stable, harvestable levels. To meet this objective, five separate jobs were initiated: estimation of the adult spawning population, characterization of brood stock, sport angling survey, juvenile recruitment assessment, and literature review and survey.

METHODS AND MATERIALS

Capture, holding, and tagging procedures for 1985 differed little from previous years and are described in the SRAFRC 1982 and 1983 annual reports. Collecting gears for adult capture included a 500' x 8' x 5 1/4" stretch mesh anchor gill net set off Port Deposit, Maryland, a pound net located on the western side of the Susquehanna Flats, and rod and reel fished from a boat anchored in the tailrace of the Conowingo Dam.

RESULTS

The 1985 tagging effort comprised five days of pound netting, 3 of gill netting and 18 of hook and line tagging. Thirty fish were tagged by pound net, 134 by gill net, and 156 by hook and line (Table 1). Of the 320 fish tagged 42 were subsequently recaptured (Table 2). Recapture data is summarized below:

a) 35 were recaptured by the Conowingo fish lift(3 double recaptures)
4 were recaptured by rod and reel
6 were recaptured by gill net

b) 1 fish was tagged from the pound net
34 were tagged from rod and reel captures
7 were tagged from the gill net

c) 2 fish were recaptured upstream of the tagging location
40 were recaptured in the same area

d) The shortest period at large = 2 days
The longest period at large = 34 days
The average period at large = 10.6 days
There were also 2 recaptures of fish tagged the spring of 1984.

The upper Bay population estimates by Peterson Index (11,093) and Shaefer

Method (12,903) are contained in Tables 3 and 4.

DISCUSSION

Low river flow during the spring of 1985 and the generation schedule at the Conowingo Dam caused trap efficiency to increase over previous years. This is indicated by the increased percentage of trap recaptures of DNR tailrace tagged fish (23.7%) and for all DNR tagged fish (14.1%). The trap recapture rate has ranged from 0.7 to 7 percent in recent years. Gill net efficiency (Table 5) was similar to that observed during 1984. Hook and line effort and tagging success was the greatest to date.

SUMMARY OF POPULATION ASSSESSMENT

The estimated number of spawning American shad in the upper Bay for 1985 was 11,093 and 12,903 by Peterson Index and Shaefer Model respectively. This is a small increase from previous years.

ADULT POPULATION CHARACTERIZATION

Data collected from adult American shad included sex, age, spawning history, and length information (Tables 6 + 7). Sex ratios were biased toward males (1:0.38 to 1:0.52) by all collection methods except anchor gill net (1:1.24), which is highly selective for the larger older females. For all methods combined, the 1985 sex ratio was 1:0.5 males to females. All fish collected were from 3 to 7 years of age. Repeat spawning ratio varied from 5.3 to 33.3 percent for males and 7.8 to 36.3 for female American shad. Overall, repeat spawners for 1985 comprised 13.4 percent of all fish sampled.

SPORT ANGLING SURVEY

The 1985 DNR lower Susquehanna River creel survey began on April 6 and continued through June 26. The following information was collected during this period.

A. Effort/Catch Data:
   - -estimated # anglers = 50,683
   - -estimated hours fished = 148,849
   - -estimated catch = 129,031

B. Estimated Sport Catch of American shad, 1980-1985

American shad

1980 = 8
1981 = 118
1982 = 266
1983 = 132
1984 = 358
1985 = 135

C. Catch Per Angler Hour and Hours to Catch One Fish 1984-1985

	1984		1985	
Species	CPAH	HTC	CPAH	HTC
White Perch	0.774	1.3	0.862	1.2
Striped Bass	0.298	3.4	0.097	10.3
Chan. Catfish	0.208	4.8	0.336	2.9
Herring	0.013	75.7	0.003	369.6
American Shad	0.006	172.4	0.003	369.6
Hickory Shad	0.0048	208.3	0.0014	677.7

D. The estimated sport catch of hickory shad in 1985 decreased from the 1984 estimate, but was significantly higher than the estimates from 1980 to 1983. Catch and catch/effort data for this species are presented as follows:

Year	Est. catch	CPAH	HTC
1980	27	0.0002	5,000
1981	39	0.0002	5,000
1982	10	0.0001	10,000
1983	0	0.0	-
1984	292	0.0048	208
1985	160	0.0014	677

JUVENILE RECRUITMENT SURVEY

Collection techniques for the 1985 juvenile recruitment survey were identical to that of previous years. Sampling with a 200' x 10' x 1/4" haul seine and modified otter trawl (16' headrope) was conducted on a bi-weekly basis at 8 seine and 6 trawl stations. As in previous years, replicate hauls were taken at each site every other week. This year however, supplemental sampling was conducted during the off weeks. Supplemental sampling consisted of single seine hauls and trawl runs at each of the respective sites. Combined juvenile sampling comprised 213 seine hauls and 153 otter trawls during 1985. One young-of-the-year American shad, 150 mm in length was collected during the supplemental survey. This was given to Pennsylvania Fish Commission personnel for otolith examination. Catch compositions for 5 important finfish species are presented in Table 8.

Comparison of 1984 vs 1985 replicate sampling noted increased catches of alewife and blueback herring. Catches of white perch and striped bass were considerably reduced. Numbers of young alosids remains low, especially American shad. Reproduction of shad species is still below detectable levels, indicating either reduced egg production by the remnant brood stock, adverse environmental conditions causing high egg and larval mortality, or a combination of these factors.

TABLE 1 Comparison of the total catch and number tagged by location and gear type for adult American shad captured during the 1985 upper Chesapeake Bay tagging program

Gear Type	Location	Catch	Number Tagged
Pound Net	Susq. Flats	33	29
Anchor Gill	Susq. River	141	138
Hook & Line	Susq. River	173	156*
Fish Lift	Susq. River	1,448**	-
TOTALS		1,795	320

* 17 Fish not tagged via hook & line capture below 350 mm length minimum
** Fish lift catch minus RMC recaptures of their tagged shad

TABLE 2 Capture and recapture dates, locations, and gear types for 42 American shad recaptured during the 1985 tagging program.

Tag Date	Recapture Date	Tagging Location	Gear	Recapture Location	Gear	Days at large
4/21	5/6	Susq. F.	PD	Susq. R.	HL	15
4/22	5/4	Susq. R.	HL	Susq. R.	FL	12
4/23	4/25	Susq. R.	GN	Susq. R.	GN	2
4/23	4/25	Susq. R.	GN	Susq. R.	GN	2
4/23	4/25	Susq. R.	GN	Susq. R.	GN	2
4/24	4/28	Susq. R.	HL	Susq. R.	FL	4
4/24	5/2	Susq. R.	HL	Susq. R.	FL	8
4/24	5/18	Susq. R.	HL	Susq. R.	FL	14
4/24	5/1	Susq. R.	HL	Susq. R.	FL	7
4/25	4/30	Susq. R.	GN	Susq. R.	GN	5
4/25	4/30	Susq. R.	GN	Susq. R.	GN	5
4/25	4/30	Susq. R.	GN	Susq. R.	GN	5
4/25	5/29	Susq. R.	GN	Susq. R.	HL	34
4/26	4/30	Susq. R.	HL	Susq. R.	FL	4
4/25	5/2	Susq. R.	HL	Susq. R.	FL	6
4/25	5/2	Susq. R.	HL	Susq. R.	FL	6
4/25	5/2	Susq. R.	HL	Susq. R.	FL	7
4/25	5/1	Susq. R.	HL	Susq. R.	HL	6
4/25	5/6	Susq. R.	HL	Susq. R.	FL	11
4/25	5/1	Susq. R.	HL	Susq. R.	FL	6
4/26	5/26	Susq. R.	HL	Susq. R.	FL	30
4/26	5/5	Susq. R.	HL	Susq. R.	FL	9
4/29	5/12	Susq. R.	HL	Susq. R.	FL	13
4/29	5/22	Susq. R.	HL	Susq. R.	FL	23
5/1	5/5	Susq. R.	HL	Susq. R.	FL	4
5/6	5/26	Susq. R.	HL	Susq. R.	FL	20
5/6	5/21	Susq. R.	HL	Susq. R.	FL	15
5/6	5/19	Susq. R.	HL	Susq. R.	FL	13
5/6	5/31	Susq. R.	HL	Susq. R.	FL	25
5/8	5/18	Susq. R.	HL	Susq. R.	FL	10
5/8	5/26	Susq. R.	HL	Susq. R.	FL	18
5/8	5/26	Susq. R.	HL	Susq. R.	FL	18
5/8	5/13	Susq. R.	HL	Susq. R.	FL	5
5/9	5/18	Susq. R.	HL	Susq. R.	FL	9
5/9	5/26	Susq. R.	HL	Susq. R.	FL	17
5/10	5/13	Susq. R.	HL	Susq. R.	FL	3
5/10	5/19	Susq. R.	HL	Susq. R.	FL	9
5/10	5/14	Susq. R.	HL	Susq. R.	HL	4
5/13	5/26	Susq. R.	HL	Susq. R.	FL	13
5/14	5/18	Susq. R.	HL	Susq. R.	FL	4
5/15	5/26	Susq. R.	HL	Susq. R.	FL	11
5/15	5/27	Susq. R.	HL	Susq. R.	FL	12

PD=pound net; GN=gill net; HL=hook & line; FL=fish lift

TABLE 3 Population estimate of adult American shad utilizing the Susquehanna River, Susquehanna Flats, and the Northeast River for 1985 by 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 1985 Survey -

C = 1485
R = 42
M = 320

Therefore -

$$N = \frac{(320 + 1)(1485 + 1)}{42 + 1}$$

$$= 11,093$$

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)

$$\text{Upper } N^* = \frac{(320 + 1)(1485 + 1)}{30.3 + 1} = 15240$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(320 + 1)(1485 + 1)}{56.8 + 1} = 8253$$ @ .95 confidence limits

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TABLE 4 Population estimate of adult American shad using the Susquehanna River, Susquehanna Flats, and Northeast River during 1985 by 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 Recovery	Week of Tagging 1	2	3	4	5	6	7	Tagged Fish Recovery (Ri)	Total Fish Recovery (Ci)	Ci/Ri
1								0	124	0.00
2	3	12						15	738	49.20
3	2	4						6	388	64.67
4		1	7	1				9	366	40.67
5		3	5	3				11	181	16.45
6			1					1	6	6.00
7								0	1	0.00
Tagged Fish Recovered (Ri)	5	20	13	4	0	0	0	42		
Total Fish Tagged (Mi)	59	147	71	31	13	0	0	321		
Mi/Ri	11.80	7.35	5.46	7.75	0.0	0	0			

B. Computed totals of American shad in the Susquehanna River and Susquehanna Flats and Northeast River during 1985.

Week of Recovery (j)	Week of Tagging (i) 1	2	3	4	5	6	7	Total
1								
2	1742	4339						6081
3	1526	1901						3427
4		299	1554	315				2168
5		363	449	382				1194
6			33					33
7								
Totals	3268	6902	2036	697				12,903

TABLE 5 Catch, effort and catch per unit effort (CPUE) for adult American shad by anchor gill nets during the 1980-1985 upper Chesapeake American shad tagging program.

Anchor Gill Nets	Year	Total Catch	SQ. Yd Hrs of Net Fished	Sq. Yd Hrs needed to catch one shad
	1980	115	31,600	275
	1981	228	59,591	261
	1982	277	93,200	336
	1983	213	8,311	39
	1984	125	7,822	63
	1985	134	10,667	67

TABLE 6 Age frequency, number, and percent repeat spawners by gear type and sex for adult American shad collected from the Susquehanna and Northeast Rivers during 1985.

Gear Type	Sex	Sex Ratio	III	IV	V	VI	VII	%Repeat Spawners	Totals
Pound Net	M		5	11	6				22
	Rpts				2			9.0	2
		1:0.50							
	F		1	1	4	4	1		11
	Rpts				1	2	1	36.3	4
Anchor Gill Net	M		2	10	47	4			63
	Rpts			2	15	4		33.3	21
		1:1.24							
	F			5	42	28	3		78
	Rpts.				5	16	3	30.8	24
Hook & Line	M		22	70	21				113
	Rpts.			4	2			5.3	6
		1:0.53							
	F			13	27	18	2		60
	Rpts.				2	10	2	23.3	14
Trap	M		42	179	79	6			306
	Rpts.			14	6	2		7.3	22
		1:0.38							
	F		2	35	48	23	7		115
	Rpts.			2	1	5	1	7.8	9
Totals	M -		73	270	157	10			510
	Rpts.			19	28	6		10.4	53
		1:0.52							
	F		3	56	122	73	13		267
				2	9	33	7	19.1	51

TABLE 7 Mean fork lengths (mm) and length ranges by sex and age groups for adult American shad collected by gear type during the 1985 Upper Chesapeake Bay tagging operation

Age Group	Sex	N	Mean	Range Min.	Range Max.
A. Anchor Gill Net					
III	M	2	348	335	360
IV		10	416	385	450
V		47	423	380	460
VI		4	450	425	465
IV	F	5	434	415	445
V		42	461	425	515
VI		28	492	445	520
VII		3	508	480	525
B. Hook & Line					
III	M	22	362	330	385
IV		70	381	320	435
V		21	436	390	465
IV	F	13	420	360	470
V		27	451	425	480
VI		18	497	460	525
VII		2	515	505	525
C. Pound					
III	M	5	353	332	364
IV		11	399	345	445
V		6	419	400	440
III	F	1	349	-	-
IV		1	430	-	-
V		4	454	427	480
VI		4	519	494	533
VII		1	508	-	-
D. Trap					
III	M	42	339	247	389
IV		179	387	337	455
V		79	446	386	490
VI		6	484	460	540
III	F	2	405	392	418
IV		35	419	350	471
V		48	464	421	512
VI		23	509	465	565
VII		7	542	502	574

TABLE 8 Juvenile catch composition of five species taken during the 1984 and 1985 Juvenile Recruitment Surveys.

Species	Gear	1984 Regular Total	1984 Regular CPUE	1985 Regular Total	1985 Regular CPUE	1985 Supplemental Total	1985 Supplemental CPUE
American	HS	0	0.0	0	0	0	0
Shad	OT	0	0.0	0	0	1	0.019
Blueback	HS	40	0.315	96	0.667	54	0.783
Herring	OT	17	0.210	16	0.160	2	0.038
Alewife	HS	11	0.087	99	0.688	41	0.594
Herring	OT	49	0.721	171	1.710	68	1.283
White	HS	914	7.197	228	1.583	159	2.304
Perch	OT	2410	35.44	1014	10.140	519	9.792
Striped	HS	22	0.173	8	0.056	5	0.072
Bass	OT	10	0.147	1	0.010	3	0.057

INTERIM REPORT

NFRDL Research on the pre-migratory physiology of American shad

by

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Introduction

Reestablishment of American shad Alosa sapidissima (AMS) populations in rivers along the East coast of the United States will require hatchery progagation of large numbers for release over time. When to release artificially propagated AMS in enhancement programs for maximum survival and return is not known. Part of the problem rests in our inability to decide when this species is ready to migrate. The question, "do AMS undergo physiological changes during freshwater (FW) life in advance of their downstream migration?" needs to be answered. If the answer is yes, can these changes be used as valid predictors of migration. Because of our inability to decide exactly when to release these fish, many may be stocked at the wrong time to be imprinted to a "home" stream and to migrate as physiological changes dictate.

The chronology and magnitude of physiological events during the FW life of AMS and the relation between these events and downstream migration and survival are not known. Biologists have generally observed, however, that survival of AMS decreases the longer they remain in FW in the fall (personal communication). Our study, consists of looking for pre-migratory physiological changes during the FW phase that are indications of adaptation to seawater (SW) and impending migration. We are assuming that AMS undergo the same physiological changes observed in Pacific and Atlantic salmon parr and smolts (Wedemeyer et al. 1980. and Saunders 1979). The changes they observed are listed in the following table.

Physiological characteristics	Level in smolts compared with parr
Body silvering, fin margin blackening	Increases
Hypoosmotic regulatory capability	Increases
Salinity tolerance and preference	Increases
Weight per unit length (condition factor)	Decreases
Growth rate	Increases
Body total lipid content	Decreases
Oxygen consumption	Increases
Ammonia production	Increases
Liver glycogen	Increases
Blood glucose	Increases
Endocrine activity	Increases
Thyroid (T_4)	
Interrenal	
Pituitary growth hormone	
Gill microsome, Na^+, K^+-ATPase enzyme activity	Increases
Ability to grow well in full-strength (35 ^{o}/oo) seawater	Increases
Buoyancy (swim bladder, Atlantic salmon)	Increases
Migratory behavior	Increases

We measured, at monthly intervals changes in appearance, behavior, sea water tolerance and ion composition of AMS. Establishing correlative relations between physiological and behavioral changes in AMS is important to the development of a release method.

Background and Justification

The American shad, a popular sport and food fish, once was one of the most abundant and valuable anadromous species along the Atlantic coast of Eastern North America. Domestic and industrial pollution, ineffective or non-existent flood plan management, construction of dams without adequate fish passages, and expanded and indiscriminate inshore and offshore fishing efforts have reduced populations to a fraction of their former abundance (St. Pierre, 1976). When all impediments to restoration are considered, dams appear to be the most important factor limiting recovery today. Sidell (1979) states that although overfishing probably would have been a significant factor in the decline of AMS populations if the rivers had remained unobstructed, historical evidence indicates that barriers to passage of anadromous species to their spawning grounds has been the primary cause of fishery declines in the Susquehanna River. Reestablishment of AMS above dams in the Susquehanna, for example, should now be possible because technology for building functional fish passageways is available. More importantly, water quality conditions, have improved in many rivers. Carlson (1968) reported that about 74% of the 466 miles of the Susquehanna River and its tributaries used by AMS in the 1800's appear suitable for restoration of viable runs. Moreover, successful introduction of AMS to the Pacific coast is good evidence that restoration of this species through artificial propagation, adequate fish passage, and transportation is possible.

Because mature AMS home to natal rivers to spawn, restoration of perpetuating populations can only be attained from larvae which have been imprinted with the rivers chemical characteristics (Sidell, 1979). Reestablishing breeding populations of AMS in rivers historically important as spawning and nursery areas will therefore require producing and stocking great numbers of underyearling AMS. The key to AMS restoration is then the development of a method for producing and releasing at the proper time large numbers of these fish to suitable spawning and nursery areas without significant mortality.

AMS are susceptible to handling stress (Chittenden 1971) but appear quite tolerant to a wide range of environmental conditions in estuaries. Chittenden (1973) noted that AMS tolerate abrupt changes from 0 to 30 $^{o}/oo$ salinity but complete mortality occurred when the change was from 30 to 0 ^{o}/oo salinity. Tagatz (1961), however, found that juvenile AMS could tolerate abrupt change from SW to FW but were intolerant to abrupt changes from FW to SW between 7 to 21°C. Chittenden (1973) attributed the differences in reponse of AMS to salinity observed by Tagatz and himself to handling stress. Dodson et al. (1972) observed the meandering time for AMS in the leading edge of the SW lasted for up to 70 hrs during their upstream movement from SW to FW. They concluded that meandering behavior provides a transition period for the fish to osmoadapt to FW. (They also note that there is no available data on the behavior consequences of movement of AMS from FW to SW and vice versa.) Even though AMS appear to adjust slowly to FW it is possible that they are either never completely in equilibrium in FW and under a constant low level of stress or their osmoregulating system is less well developed to handle ionic shift during the FW phase of their life. Additional stress through handling, added to a constant low level of stress, could overtax the physiological system resulting in delayed mortalities, particularly in soft water. Leggett and O'Boyle (1976) observed that adult AMS transferred quickly (2.5 hrs) from FW to FW, had decreased sodium and chloride levels, increased calcium, glucose and lactic acid levels and stable potassium and magnesium levels. High delayed mortalities (75 h) were a result of physiological stress. This supports Dodson et al. (1972) observation that the slow, meandering transition from SW to FW by migrating AMS permits them to adapt to FW and is essential to their survival. The effects of rapid movement from FW to SW by downstream migrants has not been carefully studied.

Downstream migration of juvenile AMS is apparently triggered by temperature (Leggett and Whitney, 1972). Juvenile AMS normally spend their first summer in the river in which they were spawned and begin to move downstream when the temperature drops below 15.5°C for several days (Smith, 1899; Sykes and Kehman, 1957; Walburg and Nichols, 1967; and Chittenden, 1969). In laboratory studies, Chittenden (1972) observed that AMS did not avoid low temperatures when changes were rapid but weakly avoided 8°C and strongly avoided 5°C when temperatures were lowered slowly. Although 2.2°C was the median lower lethal temperature observed, 4-6°C may also be lethal after prolonged exposures in the fall or winter without acclimation. Moss (1970) in another laboratory study, concluded that young AMS are capable of avoiding potentially lethal, rapid temperatures increases of about 4°C. The relation between temperature and physiological change in juvenile AMS and its role as a controlling factor in their fall migration is not understood.

Katz (1978) has shown that AMS have an exogenous rhythm with respect to daylength. He observed that AMS form schools and increase their swimming speed with the onset of light, however, the schools break up and swimming speed decreases in the dark. AMS behave the same in light even if the lighted period is shifted to another time of the day. AMS held under continuous light have no daily rhythm. Katz (1978) indicates that since there appears to be a lack of endogenous rhythm in AMS that some other mechanism is operating to synchronize migration. We suggest that the singular and combined effects of decreasing temperature and daylength in the fall are responsible for the timing of migration of juvenile AMS. AMS may respond to exogenous cues by undergoing pre-migratory physiological changes. Correlations between the physiological and environmental changes may provide useful indicators and predictors of migration.

Because clupeids are generally stressed by confinement and handling, various methods to mitigate stress during transport have been tried. Anderson (1968) transported gizzard shad successfully in 0.5% salt and MS-222; Guest and Prentice (1982) had varying success handling blueback herring in various media containing anesthetics; and Standley and Colby (1971) hauled alewives in 0.2% NaCl with a 50% delayed mortality, that they attributed to a sudden exposure to SW. To alleviate the handling stress in AMS, Murai et al. (1979) attempted to use valium, MS-222, and sodium chloride to reduce handling mortality. They found MS-222 to be toxic at 10 mg/L but AMS given an oral dose of valium could be transported successfully in 1% sodium chloride provided there was a minimal scale loss.

Several methods of measuring stress and recovery time in fish are available and include measurements of catecholamines, cortisol, blood glucose, liver glycogen, and blood electrolytes (Wedemeyer and McLeay, 1981). Ultimately, however, stress becomes biologically significant when it decreases the ability of the fish to tolerate additional stress after release. Survive and grow to maturity and a return of AMS to their former level of abundance in East Coast rivers is the major goal of our work. We intend to use physiological tests, and stress challenges to determine when AMS are ready to migrate and when they must be released.

OBJECTIVES

Goal: To discover pre-migratory physiological and behavioral indicators of physiological transformation that can be used to determine the release time for hatchery produced AMS leading to a maximum adult return.

Objective 1: Identify physiological and behavioral changes that either precede or accompany migration and adaption of AMS to SW.

Objective 2: To determine if there are observable or measurable differences in behavior and physiology of AMS exposed to SW.

Materials and Methods

Source and care of AMS

On 17 July 1985, about 51,000 18 to 20-day-old Columbia River AMS from the Pennsylvania Fish Commission's VanDyke Hatchery were placed in two hypalon-lined ponds at the NFRDL (20-21°C). The ponds were filled with water two weeks before the fry arrived. When the AMS arrived, the ponds were teeming with live food organisms. We began adding starter feed (SD-9) to the ponds on 18 July, 1985. Significant numbers of AMS were observed in the ponds on 22 July 1985. We began adding _ad libitum_ amounts feed 4 and 5 times per day on 5 and 13 August 1985 respectively. On 26 August we began to feed AMS the Atlantic salmon diet (ASD2-30). We began transferring large numbers of AMS from ponds to circular holding tanks in the laboratory, on 17 October and completed transfer on 14 November. Excess fish, except 2500 that were left to overwinter in ponds, were provided to the Pennsylvania Fish Commission (approximately 15,000).

Seawater challenge

The seawater challenge procedure used is described in detail by Klock and Rottiers (MS in preparation) and is similar to that developed by Clarke and Blackburn (1977). Briefly, in the seawater challenge, AMS were suddenly introduced to 30-33 $^{o}/oo$ SW (Jungle Synthetic Sea Salt, Table 1) of the same temperature as their holding water and held there for 24, h before samples were removed for analysis. In this study we held some fish longer and also sampled at 48, 72, 120, and 168 h. A control group of AMS, was given the same treatment except the sea salt was omitted from the water. In two other simultaneous tests AMS were suddenly introduced to 10 and 40 $^{o}/oo$ SW to determine salinity tolerance and osmoregulatory ability at low and high SW concentrations. AMS removed after various exposure times from all test groups were analyzed for total body concentrations of several ions.

At monthly intervals, beginning in September, AMS were evaluated after 24, 48, 72, 120, and 168 h exposures to FW and, 10, 33, and 40 $^{o}/oo$ SW. The test system was composed of four 4-ft circular tanks containing aeration water. Weight of salt added was estimated on the basis of volume of water in the tank and the final concentration was adjusted after hydrometer readings. The test system was set up 1 or 2 days before the fish were introduced to the SW to allow the salt to dissolve and the water temperature to stabilize.

On the test day, 100 fish from a holding tank were randomly counted into each of the 4 circular tanks. A sub-sample of 100 AMS from the population in the holding tank was anesthetized, weighed and measured to obtain beginning estimates of mean weight and length. Starting time, salinity, dissolved oxygen, and temperature were recorded. Dissolved oxygen readings and observations on fish condition were made at least daily during a test. Mortalities and time of death were recorded. All dead fish were weighed and measured.

After 24 h, 10 AMS from each test group were killed and later analyzed for whole body concentrations of calcium, magnesium, potassium, and sodium. After 48, 72, 120, and 168 h, 5 AMS from each test group were similarly removed and processed.

AMS were prepared for analysis of total body ions following the method of Shearer (1984). Calcium, magnesium, potassium and sodium ions were analyzed on an Instrumentation Laboratory 457 atomic absorption spectrophotometer, following the method of Paschen (1970).

Temperature and salinity tests

In 96 h bioassays every two weeks, AMS were introduced to four different salinities at four temperatures. At the end of each 24 h, all dead fish were removed, weighed, and measured.

At monthly intervals beginning in November, AMS were evaluated after 24, 48, 72, and 96 h in FW and 10, 20, and 30 $^{o}/oo$ SW and at 3, 5, 10, and 15° C. Bioassays were replicated each month. Four 5-gal plastic containers lined with black plastic (one for each salinity concentration) were placed in each of four 4-ft circular tanks (one for each temperature level). A portable water chiller in the center of the circular tanks regulated water temperature; oxygen level in each of the test containers were maintained by air bubblers in the test water. Salinity was determined by using a hydrometer. The test system was set up 1 or 2 days before the fish were introduced to the containers to allow the salt to dissolve and the water temperature in all tanks to stabilize at 10° C.

On the test day, 15 AMS from a holding tank (10° C) were randomly counted into each of the 4 containers in each of the 4 tanks. Beginning temperature in all tanks was 10° C, and fish were allowed to adjust to the test system environment for 2 h. At the end of 2 h, starting time, salinity, dissolved oxygen, and temperature were recorded. The chiller in the 15° C tank was turned off, and water temperature was allowed to adjust to room temperature (about 15° C). Water temperature in the 3 and 5° C tests was dropped 1° C/h until the test temperatures were reached. Water temperature in the 10° C test was left unchanged. After 24, 48, 72, and 96 h, all dead fish were removed, weighed, and measured. Temperature and dissolved oxygen in all test containers were recorded.

Growth experiments

Growth was measured for AMS reared in identical 300 gal, closed FW and SW systems (Fig. 1). Each closed system was composed of two 3-ft rearing tanks, one 4-ft reservoir/aeration tank and a recirculation pump. Return flows were by gravity from the elevated 3-ft tanks. Tanks were filled with water 1 or 2 days before AMS introduced to each 3-ft tank. Because AMS cannot survive the routine handling procedures used for other fishes, a subsample from the population from which the test fish were drawn, was weighed and measured to get beginning estimates of mean weight and length. Jungle brand sea salt (Table 1) was added at a rate of 13 kgs (1 box) per day for 3 days until the $33^{o}/oo$ SW concentration was reached. To minimize water loss, the tanks were quickly cleaned twice per week. Daily records of pH, temperature, oxygen content, and mortality were kept. All dead fish were weighed and measured. AMS were fed a ration of ASD2-30 equal to 3% BW/day 4 times/day. At the end of a test, length and weight of each AMS were measured and the system drained. Samples of AMS were frozen for ion and proximate analysis.

Results and discussion

Growth in ponds

AMS grew an average of 0.04 g/day between 7 July and 25 October (Fig. 2). Growth for the remainder of the calendar year was 0.019 g/day. This was a period of declining temperatures. The average weight of AMS on 18 December was about 5 g.

Survival of AMS in our ponds probably exceeded 60%, representing about 36,000 AMS. Of these fish, 15,000 were given to the Pennsylvania Fish Commission.

About 2500 AMS remain in the pond under the ice. With an inflow water temperature of about 8° C and pond water temperature of about 4° C it is unlikely that any AMS will overwinter, however, as of early January live AMS were still observed in the ponds.

Growth in FW and SW

High mortalities observed in two groups of AMS in FW (48 and 59%) and one group in SW (90%) made it difficult to evaluate the seasonal effects on growth (Table 2). From the data we collected on growth in both FW and SW it appears that AMS grow faster in SW when ration and temperature are equal. Overall mortality was highest in FW. AMS in FW often appeared stressed and were more easily disturbed.

Tolerance to gas supersaturation (Bill Krise)

Twenty juvenile AMS (average length and weight 8.4 cm and 3.7 g) placed in each of six replicate groups at each of seven different gas supersaturation levels (11-166 mm Hg above ambient) were exposed for 192 h (8 days) in 100-liter aquaria. The objective was to determine the 192 h ET-25 for AMS.

Gas level (Δ P-mmHg)	Mean % Mortality
11	4.2
68	3.4
72	5.8
80	4.2
118	13.4
123	25.0
166	27.5

Gas bubbles were observed on the heads of AMS exposed to gas saturations equal to a ΔP of 123 and 166 mm Hg. These bubbles were around the eyes and on the gill cover. Bubbles seen in the nares were larger than those observed externally. Because mortality to AMS exposed to a gas saturation less than or equal to a ΔP of 80 mm Hg did not change with increasing gas level over this range we attributed them to handling stress. AMS tolerated gas levels of 116.4% (ΔP = 120) for at least 192 h (8 days). Because it required 8 days at gas saturations in excess of 116.4% to attain an ET-25, it appears that AMS are about as sensitive to gas saturation as salmonids and likely to survive below dams in areas of high gas saturation, as well as salmonids.

Tolerance to temperature and salinity change

During the first 24 h of exposure mortality was highest in FW and in 40 ^{o}/oo SW. AMS were most tolerant (highest survival) when held in 10 ^{o}/oo SW (Table 3 and Fig. 3) at any temperature on any date. In FW, survival was highest at 15° C. Some AMS held at 3° C appeared to be dead or narcotized, apparently due to their reduced metabolism rate at the low temperatures. This type of behavior was not observed at higher temperatures. Tolerance to 40 ^{o}/oo SW decreased in November and further decreased in December below 30 ^{o}/oo SW (Table 3 and Fig. 3). Because temperatures were essentially the same during the tests in all months reduced SW tolerance of AMS in November and December appears due to a seasonal effect. These data suggests that delayed entry into SW may result in high mortality, suggesting that AMS should be stocked in time to reach SW by November.

Sea water tolerance 1984

A cooperative study was designed to determine if AMS undergo premigratory physiological changes in the fall. In August, gas supersaturation killed all the AMS being reared in ponds by the Pennsylvania Fish Commission. Preliminary data were collected, however, from a group of 350 fish tested at the Pennsylvania Fish Commission's Van Dyke Hatchery. Mortality of AMS given a sudden exposure to SW was 46% and for fish given a stepwise exposure over the same 24-48- h period was 8%. There was no mortality fish in FW. Mean hematocrits were 52 and 43% and blood chlorides 106 and 164 mM/L for fish in FW and SW respectively. These data indicate that in late September when the tests were performed AMS were unable to regulate their blood ions in SW. Because of the difficulty of collecting sufficient blood for ion analysis from young-of-the-year shad (mean weight of 1.8 g and length of 6.1 cm) we measured whole body ion concentrations. Sodium, potassium, magnesium, and calcium ion concentrations were highest in fish given a sudden exposure to SW. In fish given a stepwise exposure to SW the whole body ion concentration was similar to that of FW fish (controls). The higher body ion concentration for fish given a sudden exposure to SW may be due to a greater water loss during the 24 h exposure.

Sea water challenge 1985

In contrast to results of tests performed in 1984, AMS tested in 1985 were most tolerant to SW in September (Table 3 and Fig. 3). Except for fish tested in 10 ^{o}/oo SW, there was a decreased tolerance to SW with time of year. Mortality of AMS in holding tanks increased with time of year, increasing markedly in December (Fig. 4). Survival of AMS was always highest in 10 ^{o}/oo SW regardless of month or temperature. In tests at the Van Dyke hatchery in 1984, AMS were not moved immediately before testing as in 1985 tests at the NFRDL. Survival of AMS was always reduced after a FW to FW transfer. In 1984, AMS were less tolerant to sudden exposures to SW. Because chemical analyses of AMS are incomplete we can not say anything yet about seasonal changes in their ability to regulate ion concentration. SW tests will continue into January, however, at the present rate of mortality few fish will be left by the end of this month.

Behavior

AMS feed well on man-made diets in tanks and ponds. Generally, AMS swim in tight, fast schools that become tighter and faster when excited. Noises easily excite these fish. When a tank is bumped some AMS jump out of the water and others roll over as if dead, however, they recover in 5-10 min and resume swimming. The possible effects of these disturbances on delayed mortality is unknown. AMS school normally in FW and in 10 and 30 ^{o}/oo SW but not in 40 ^{o}/oo SW. In most tanks AMS swim into the stream of inflow water.

Disease

Samples of AMS examined at the Lamar (Northeast FTC) revealed no evidence of disease.

Conclusions

1. AMS were successfully reared in ponds. Survival from fry to fingerling exceeded 60%.
2. FW to FW transfer of AMS usually resulted in high mortalities at any temperature or time of the year (20-100%).
3. There was a seasonal increase in mortalities of AMS in holding tanks from about 10 to 75/day, that increased to about 75 to 225/day in December.
4. There is a seasonal decrease in tolerance of AMS to SW from 40 ^{o}/oo in September to 10 ^{o}/oo in December.
5. Survival was highest (about 100%) when AMS were held in 10 ^{o}/oo SW.
6. Disturbance and the resulting excitablity to AMS may result in delayed mortality.
7. AMS did not school when held in 40 ^{o}/oo SW.
8. In the 1985 tests, unlike those in 1984, AMS tolerated sudden exposures to SW for 24+ h but did poorly in FW.

9. Growth and survival of AMS were highest in SW.

10. There was no evidence of disease in AMS.

11. There appears to be a "best" time for migration of AMS because tolerance to SW decreases in late fall.

12. AMS were about as tolerant to gas supersaturation as salmonids.

Recommendations

1. We suggest that the optimum condition for survival of AMS appears to be in 10 ^{o}/oo SW. We suggest further tests to precisely define the optimum SW concentration.

2. We continue tests of seasonal tolerance of AMS to temperature and salinity next year to determine the limits of FW life and to determine what and when physiological abilities to osmoregulate in SW are lost.

3. We develop a sound or disturbance bioassay to evaluate the effects of handling and holding techniques on the survival and delayed mortality of AMS. And we evaluate the possible effects of SW (10 ^{o}/oo) on stress and survival.

4. We follow the dietary transition of AMS from live to dry feeds in ponds and measure seasonal changes energy stores during FW life.

5. We compare the performance of AMS from Delaware and Columbia River stocks in these experiments.

6. We evaluate the role of light on behavior and survival (continuous natural).

7. We begin our experiments earlier next year.

8. We develop a less stressful way of getting the AMS from ponds and from tank to tank.

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TABLE 1. COMPOSITION OF SYNTHETIC SEA SALT USED IN SEA WATER CHALLENGES

OCEAN 50 SEAMIX

SYNTHETIC SEA SALTS

OCEAN 50 SEAMIX — 50 essential elements blended into one single fast dissolving powder. Based on new Naval analysis of real sea water that is much more accurate than older formulas. We find this excellent for algaes, anemones, starfish and lower forms of marine life, as well as reef fish and other higher marine life.

DIRECTIONS FOR USE: Mix contents of this container with 100 gals. of tap water and adjust to 1.022 specific gravity at 24°C. (75°F.). If a smaller quantity of water is needed, use 3 lbs. 3 oz. with each 10 gals. of tap water. Our laboratory tests show that best results with all sea life is obtained at 1.022 specific gravity.

CONCENTRATION OF ELEMENTS IN **OCEAN 50 SEAMIX** WHEN MIXED AS DIRECTED

ELEMENTS	CONCENTRATION MG/LITRE	ELEMENTS	CONCENTRATION MG/LITRE
Chlorine	19000	Arsenic	0.003
Sodium	10500	Uranium	0.003
Magnesium	1350	Nickel	0.002
Sulfur	885	Vanadium	0.002
Calcium	400	Manganese	0.002
Potassium	380	Titanium	0.001
Bromine	65	Antimony	0.0005
Carbon	28	Cobalt	0.0005
Strontium	8	Cesium	0.0005
Boron	4.6	Cerium	0.0004
Silicon	3.	Yttrium	0.0003
Fluorine	1.3	Silver	0.0003
Nitrogen	0.5	Lanthanum	0.0003
Lithium	0.17	Cadmium	0.0001
Phosphorus	0.07	Tungsten	0.0001
Iodine	0.06	Germanium	0.00007
Barium	0.03	Chromium	0.00005
Indium	0.02	Thorium	0.00005
Zinc	0.01	Scandium	0.00004
Iron	0.01	Lead	0.00003
Aluminum	0.01	Mercury	0.00003
Molybdenum	0.01	Gallium	0.00003
Selenium	0.004	Bismuth	0.00002
Tin	0.003	Niobium	0.00001
Copper	0.003	Thallium	0.00001
		Gold	0.000004

Jungle

LABORATORIES CORPORATION

BOX 630 CIBOLO, TEXAS 78108

Table 2. Growth of American shad in closed fresh and sea water systems.

				FRESH WATER					SEA WATER				
Test [1/] No.	(No. of Days)	Date	Temp. Mean (range)	No. Fish	Mean wt (g)	Mean Length (cm)	Mortality (%)	Growth [2/] g/day	No. Fish	Mean wt (g)	Mean Length (cm)	Mortality (%)	Growth g/day
1	30												
Beginning		09/23/85	15.0 (12.6-17.8)	200	2.5	6.7	---	---	200	2.5	6.7	---	---
End		10/22/85		83	2.4	7.0	59	-.003	189	3.0	7.4	5.5	.017
2	5												
Beginning		10/28/85	13.2 (10.0-16.0)	200	4.4	8.4	---	---	200	4.4	8.4	---	---
End		11/01/85		199	---	---	.5	---	20	---	---	90	---
3	29												
Beginning		11/15/85	15.4 (14.0-18.0)	200	4.4	8.4	---	---	200	4.4	8.4	---	---
End		12/13/85		104	4.1	8.6	48	-.010	168	5.3	9.0	16	.031

[1/] Salt was added to the water in tests 1 and 3 one day at a time over a three day period. Salt was gradually added over a 1 day period in test 2.

[2/] Water and lipid content of fish were 72.8 and 10.5 % respectively for AMS in FW and 73.6 and 10.4% for AMS in SW.

Table 3. Percent cumulative mortality of American shad exposed to various temperatures and salt concentrations at monthly intervals at NFRDL, 1985.

		TEMPERATURE															
		3° C				5° C				10° C				15° C			
		Time (Hrs.)				Time (Hrs.)				Time (Hrs.)				Time (Hrs.)			
Month & Salinity	°/oo	24	48	72	96	24	48	72	96	24	48	72	96	24	48	72	96
Nov	0	53	67	67	83	33	47	80	80	20	60	77	90	33	43	43	43
	10	0	7	7	23	0	0	0	0	0	0	0	0	0	3	3	3
	20	13	20	23	27	0	0	13	13	0	0	0	0	7	7	10	10
	30	53	63	73	77	67	73	73	80	20	23	27	33	30	33	40	40
Dec	0	33	50	77	80	20	60	90	100	30	43	53	57	20	40	57	60
	10	0	17	37	67	3	13	13	13	7	7	7	7	0	7	7	7
	20	7	50	67	90	3	10	10	20	0	0	3	3	7	7	7	7
	30	50	80	87	93	27	33	33	37	40	40	43	43	50	53	57	57

FIGURE 1. IDENTICAL CLOSED SYSTEMS FOR GROWING AMERICAN SHAD IN FRESH AND SALT WATER (Each system contains 300 gal. of water that is held at ambient air temperature).

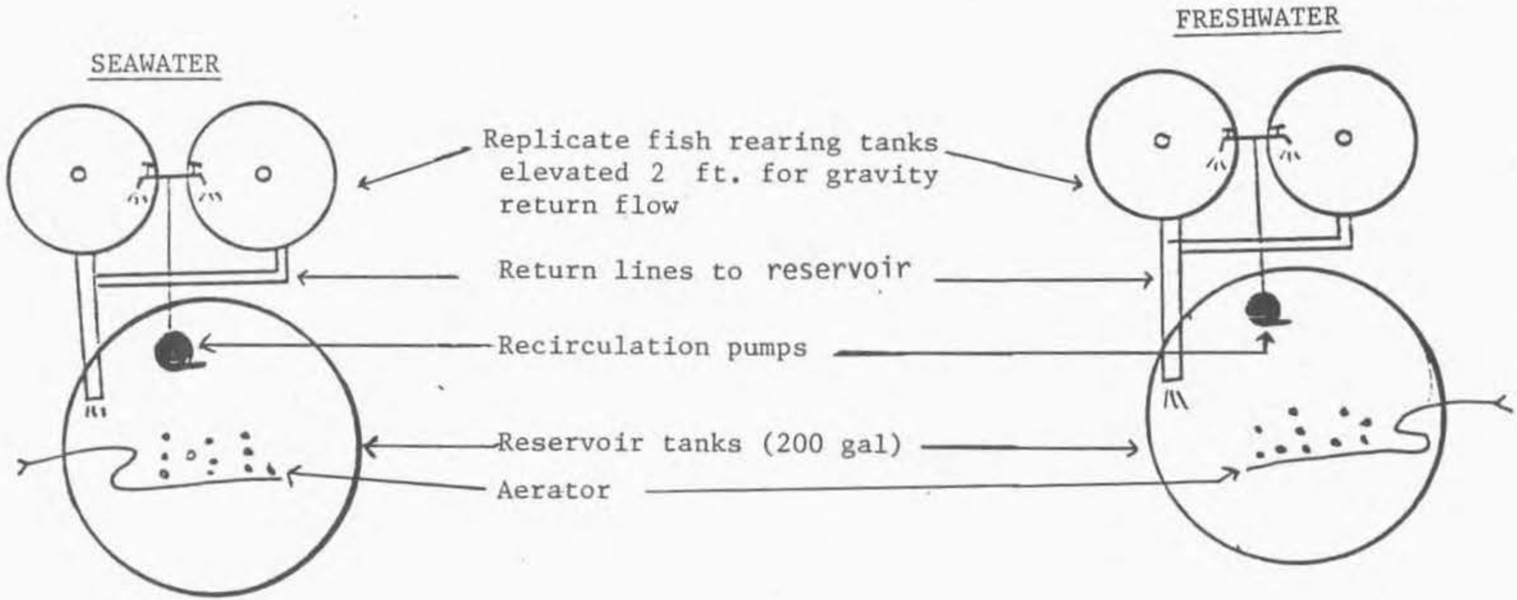
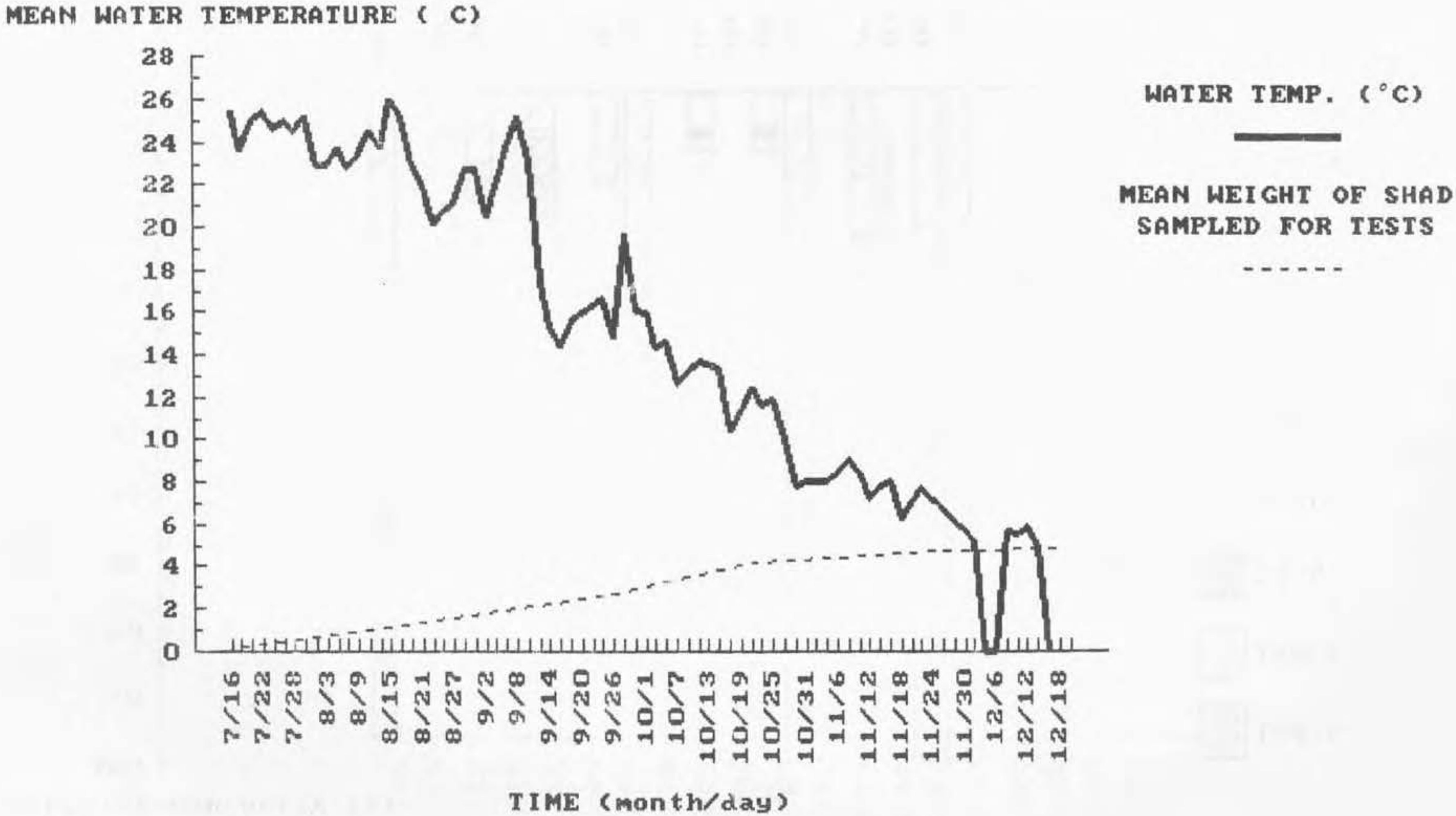


FIGURE 2. **MEAN WATER TEMPERATURE IN REARING PONDS AND GROWTH RATE OF AMERICAN SHAD AT NFRDL (1985)**



SHAD WERE REMOVED FROM PONDS ON 10/17 AND 11/14
GROWTH RATE LINE IS THE SAME SCALE AS THE Y-AXIS
GROWTH RATE IS MEAN WEIGHT IN GRAMS

FIGURE 3. PERCENT CUMULATIVE MORTALITY OF AMERICAN SHAD EXPOSED TO DIFFERENT CONCENTRATIONS OF SEA SALT AT THE NFRDL, 1985.

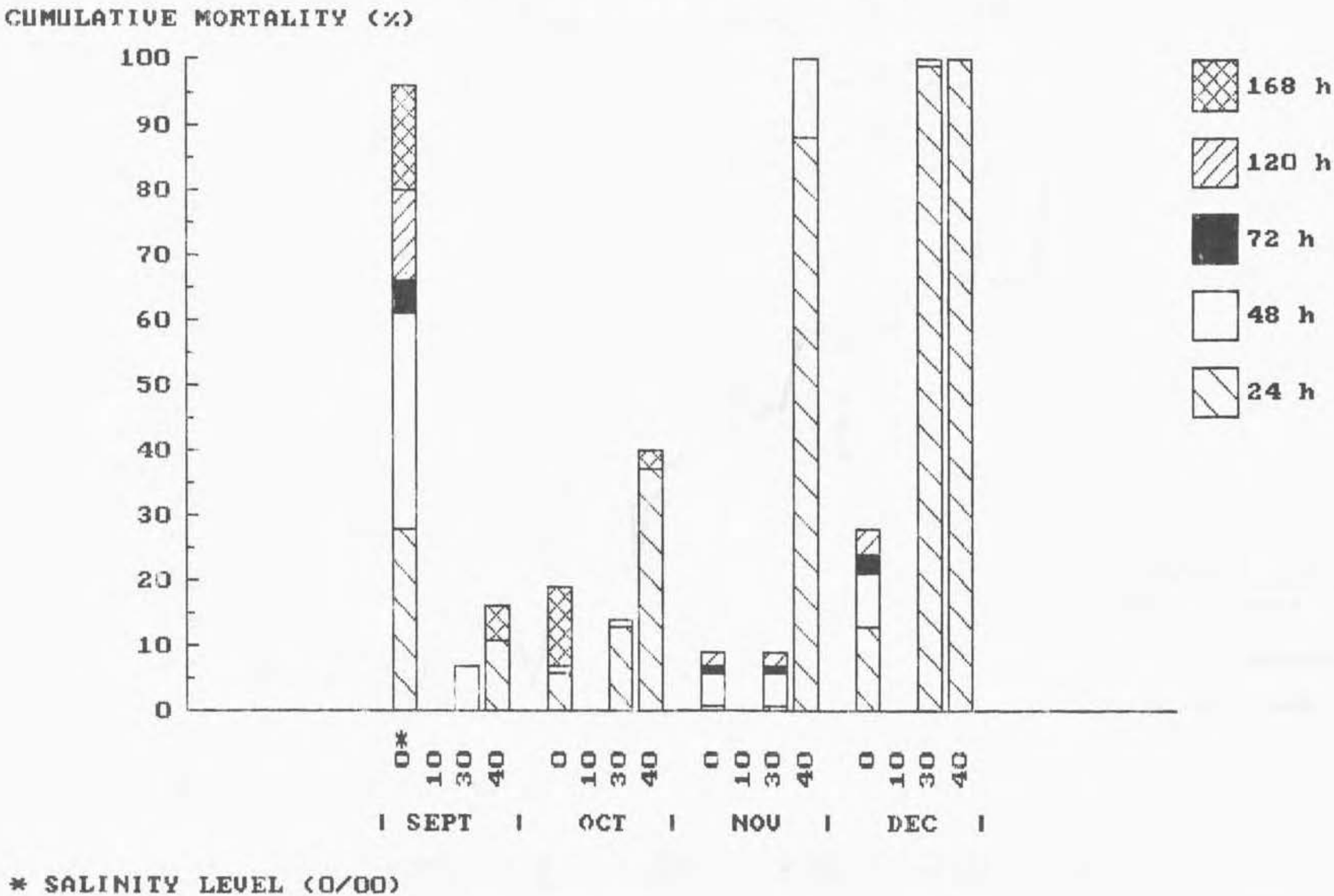
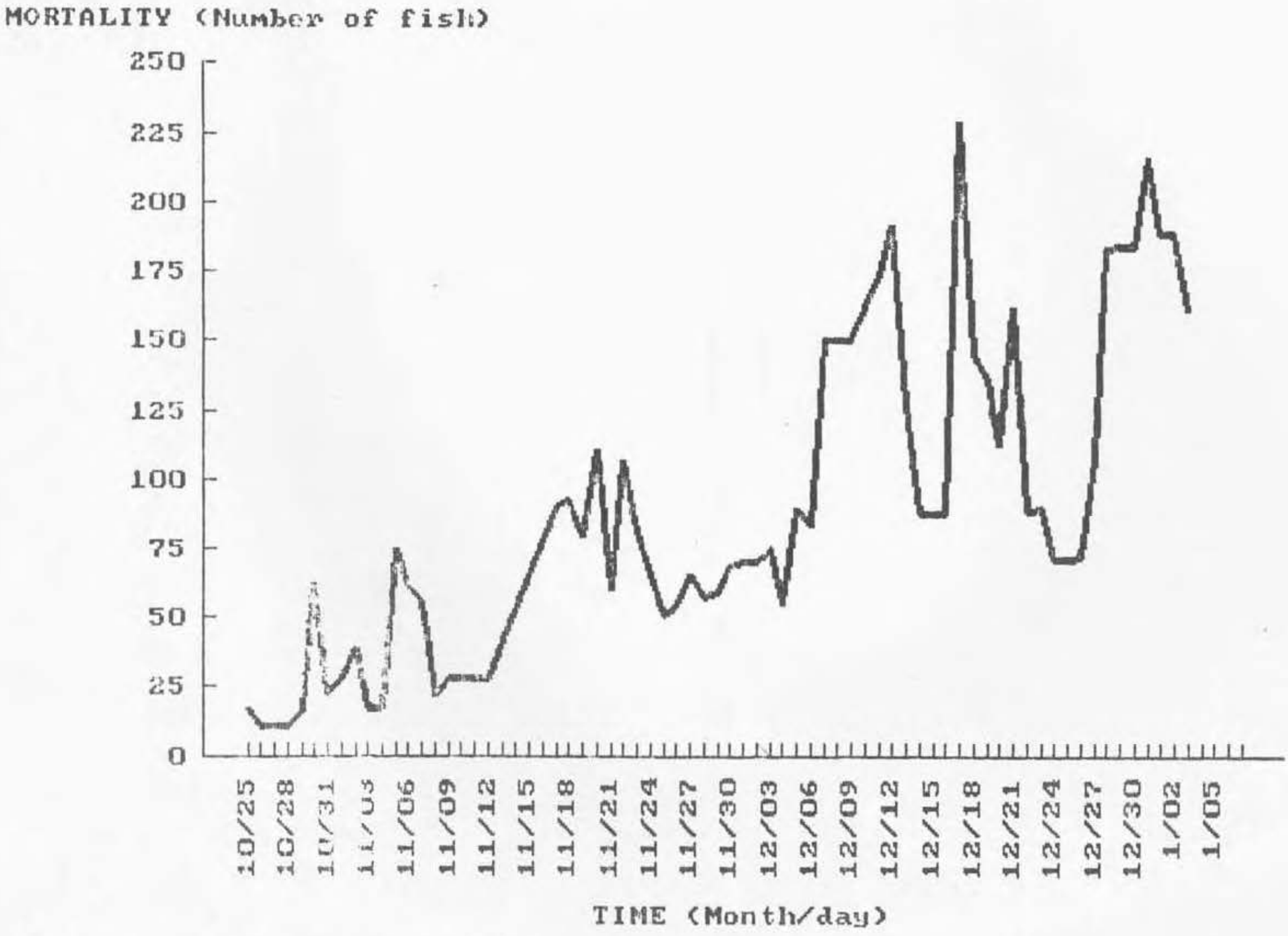


FIGURE 4. SEASONAL MORTALITY OF AMERICAN SHAD IN HOLDING TANKS AT NFRDL, 1985-6.



SHAD WERE REMOVED FROM PONDS ON 10/17 AND 11/14

LAST
PAGE