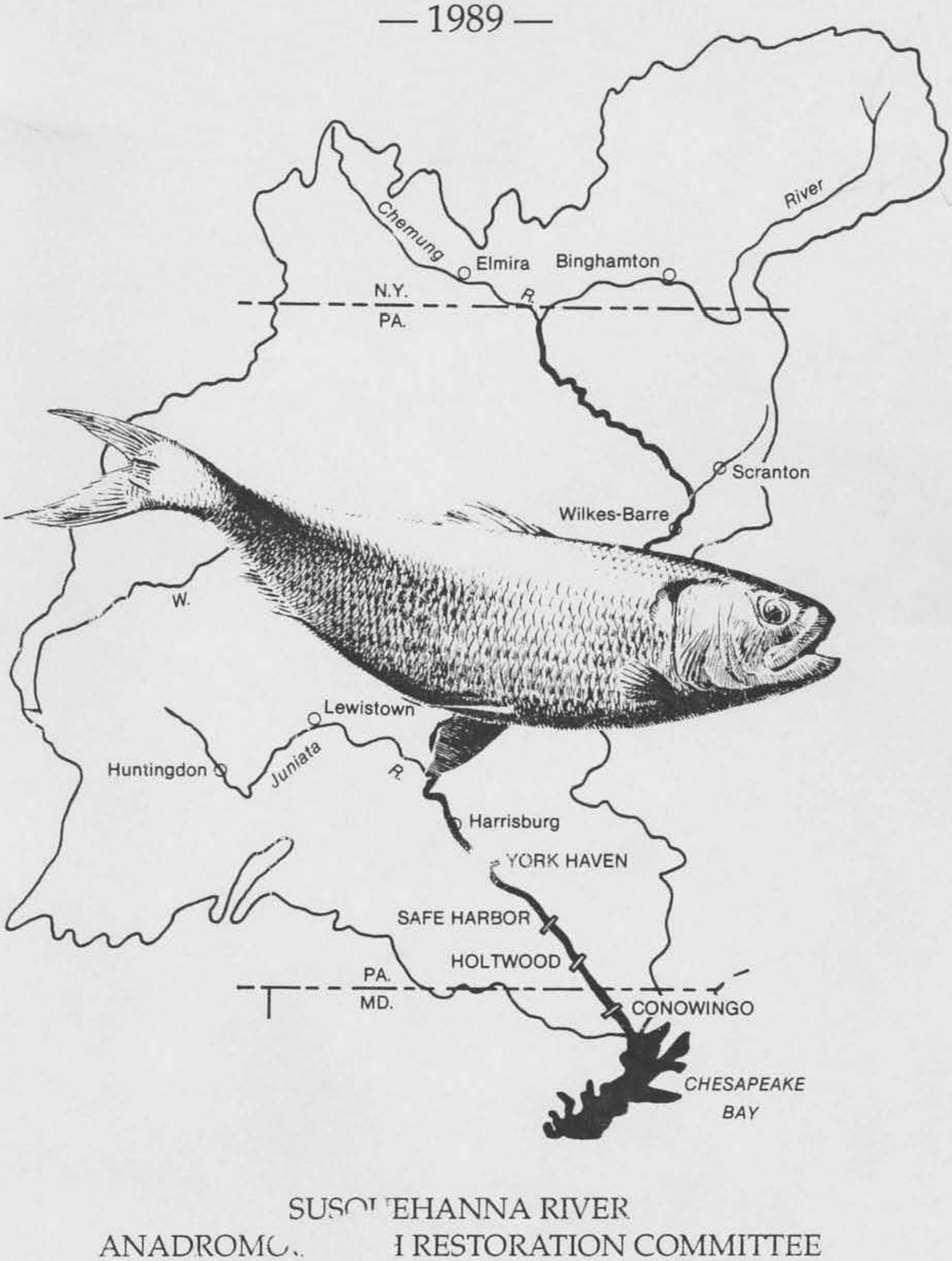
Restoration of American Shad to the Susquehanna River

ANNUAL PROGRESS REPORT

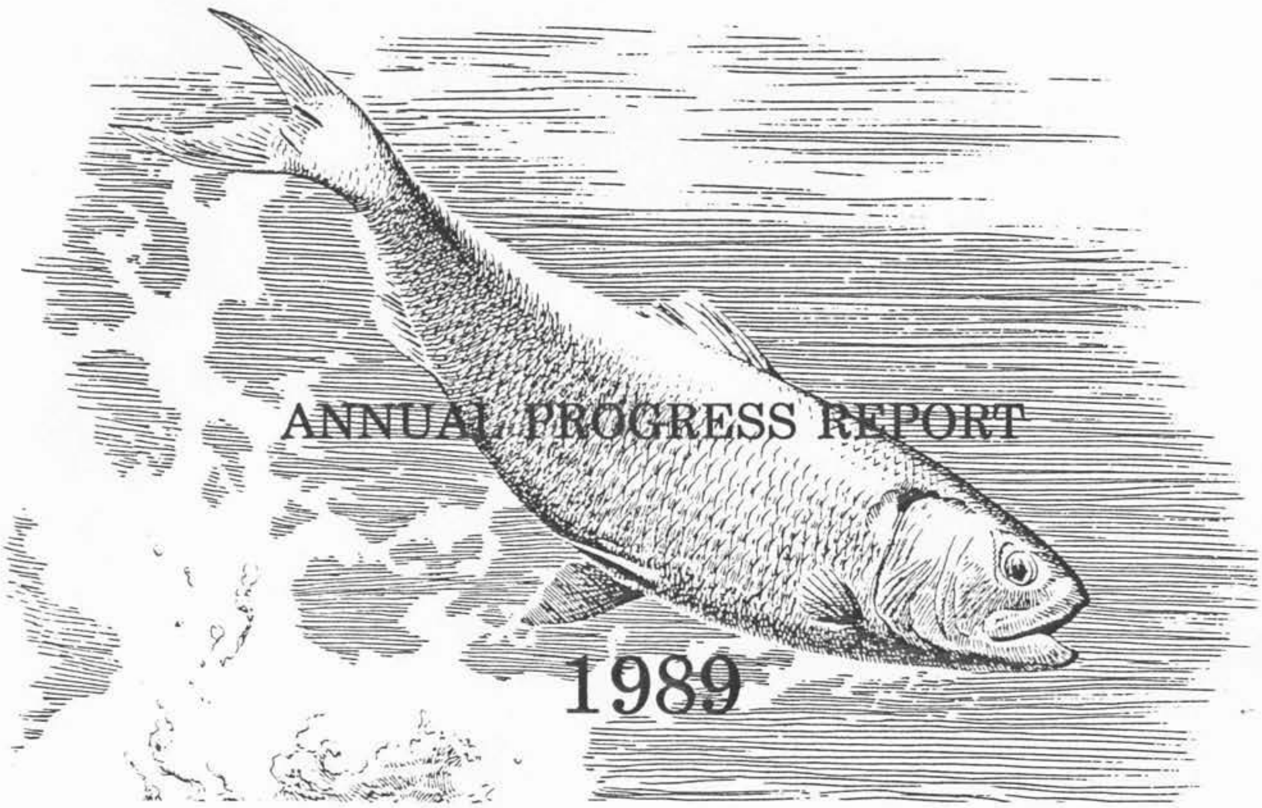
— 1989 —



SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

FEBRUARY 1990

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1989

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

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

FEBRUARY 1990

EXECUTIVE SUMMARY

The 1989 Annual Report of the Susquehanna River Anadromous Fish Restoration Committee presents results from numerous studies and activities aimed at demonstrating that American shad can be restored to the river. This is the fifth year of a 10-year program to rebuild stocks based on hatchery releases and natural reproduction of adult shad collected at the Conowingo fish lift and transferred upstream to spawn. Considerable efforts are also dedicated to evaluating and improving downstream migration of juvenile shad from the river. The restoration program represents a continuing commitment of state and federal fishery resource agencies and private utility companies to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1989 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 75,329 fish (Petersen Index). This was based on recapture of 61 shad from a tagged population of 559 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay (298 shad) and angling in the Conowingo tailrace (261 fish). Fifty-six of the recaptures came from the lift at Conowingo. Estimated stock size in 1989 was 55% larger than in 1988 and 20 times greater than that of 1984. The shad population in the Conowingo tailrace was estimated to be 42,516, also a 55% increase over that of 1988.

The trap and lift at Conowingo Dam (rm 10) operated for 53 days during the period 5 April through 18 June, 1989. A total of 1.07 million fish representing 45 taxa were handled. The great majority of the catch (93%) was comprised of gizzard shad, white perch and channel catfish. Alosa species included 3,611 blueback herring, 8,311 American shad, 1,902 alewives, and 28 hickory shad. American shad catch in 1989 was 3,142 more than in 1988 and represented a new record high for the Conowingo fish lift since it began operating in 1972.

Effectiveness of the trap is related to hydroproject operation and river flow conditions. The record shad catch in 1989 was accomplished in spite of a high flow event during 7-20 May which curtailed trap operations at a time generally considered to be the peak of the spawning run.

Catch of shad was equally split before and after the high flow interruption. Between 19 April and 5 May, 3,977 shad were collected (mean 234/day). From 21 May to 5 June, 3,629 shad were taken (mean 227/day). The largest one-day catch ever recorded at the trap (1,417) occurred on 4 June. Overall sex ratio of shad in Conowingo collections was 3.4 to 1 favoring males. Males ranged in age from II to VII (80% @ IV-V), and females were IV to VII (72% @ V-VI). Only 28 of 414 fish examined were repeat spawners.

A total of 6,469 shad was transported to potential upstream spawning areas with only 92 observed mortalities. Of that total, 6,064 shad were stocked at The PFC access at Falmouth and 405 were placed at Bainbridge, both below York Haven Dam. Additionally, 228 shad were stocked into Conowingo Pond at the Baltimore City water intake. Sixty of these shad were fitted with radiotags and released in three groups of 14, 22, and 24 between 25 April and 6 June. Forty-two tagged shad (70%) migrated upstream at least as far as Muddy Run (19.4 km); 38 fish (63%) reached the Norman Wood Bridge (21.7 km); and 28 (47%) entered the Holtwood tailrace. Eighteen of those fish were also found in the Holtwood spillway during spilling conditions.

A total of 262 adult shad from the Conowingo lift were transported to the Fish and Wildlife Service research laboratory at Wellsboro, PA in three shipments between 30 May and 12 June. These were used in a special study (with West Virginia University) to artificially induce spawning in shad using injections of human chorionic gonadotropin (HCG). Some amount of vitellogenesis and ovulation was induced by HCG treatment, but few eggs were taken and most adults died, presumably due to handling stress.

The Pennsylvania Fish Commission operated the intensive culture facility at Van Dyke and rearing ponds at Thompsontown, Benner Spring, and Upper Spring Creek. During the period 16 April to 20 June, almost 43 million shad eggs were delivered to Van Dyke from the Pamunkey and James River, Virginia (2.44 M), the Delaware River (5.96 M), the Hudson River (11.18 M), and the Columbia River, Oregon (23.1 M). Overall viability of eggs received was a record 60% resulting in production of 22.27 million fry and 70,000 fingerlings.

All fry produced at Van Dyke were distinctively marked with one to four separate 6-hour immersions in 200 ppm tetracycline (TC). About 9.56 million 16-20 day old fry were stocked in the Juniata River at Thompsontown; 3.91 million were stocked in the main stem Susquehanna at Montgomery Ferry, and 7.65 million were placed in the lower Susquehanna River at Lapidum, MD. Most fingerlings were stocked at Thompsontown. In addition to immersion tags put on fish at Van Dyke, pond reared fish were also marked with TC-laced feed.

Cultural research conducted by the PFC in 1989 included examination of egg survival as related to jar processing sequence; egg viability testing with Van Dyke and May-Sloan jars; temporal patterns of egg mortality; sedation of shad fingerlings to reduce handling stress; and improvements in fingerling harvest techniques from ponds. PFC also continued a special study to evaluate the use of otolith microstructure to distinguish between wild and hatchery-reared shad in the Susquehanna River. They confirmed that growth increments on otoliths are formed daily, that otolith growth is proportional to linear growth in length, and that Van Dyke fry grow more slowly than wild fish. Mean increment width is significantly smaller in hatchery fish than wild fish for those days held in culture conditions. Based on otolith microstructure, researchers correctly classified 90-95% of all hatchery and wild fish examined.

As in past years, a considerable effort was devoted to assessing relative abundance, growth, timing of migration and source of juvenile shad during autumn exodus from the river. Shad were sampled with cast nets in the York Haven forebay. At

Holtwood, both cast nets and lift nets were used in the forebay behind Unit 10. Cooling water intake strainers and screens were routinely examined for impinged shad at Safe Harbor, Conowingo and Peach Bottom, and netting and electrofishing were conducted in the lower river below Conowingo.

It appears that high flows in the river during June-July pushed hatchery fish downstream earlier than in past years. Almost 1,800 juvenile shad (25-95 mm) were collected with seines and other gear during mid-July through August below York Haven Dam. This effort occurred between Columbia/Wrightsville and Marietta, PA as part of the impact assessment associated with a gas pipeline crossing of the river near Marietta. Autumn shad collections at York Haven and Holtwood were very small compared to earlier years.

Shad from York Haven, Columbia, Wrightsville, Marietta, Holtwood, and Conowingo Pond were returned to Benner Spring for tetracycline mark analysis. A total of 252 otoliths were examined from these collections and only 7 (2.8%) were unmarked and displayed wild microstructure. Virginia river fish represented the highest relative survival based on numbers of fry stocked. Hudson fish constituted 25-47% of all juveniles analyzed but relative survival was only 23% of that for Virginia fish because of their high stocking rate. Delaware and Columbia River shad were poorly represented in the total catch, making up only 34.5% of the outmigrant population and 75% of the fry stocked. It is speculated that these two strains were adversely affected by high river flows in July which closely coincided with time of stocking.

Maryland DNR personnel collected 192 juvenile shad with various gear in the upper Chesapeake Bay during mid-July to the 1st of October. Of 111 fish analyzed for tags on otoliths, 69% were double-marked fish stocked at Lapidum; 10% were stocked above dams from several strains; 16% were unmarked but showed typical hatchery microstructure; and 4.5% were determined to be wild fish.

The Electric Power Research Institute (EPRI) and Metropolitan Edison Company co-funded a study at York Haven Dam to investigate the effectiveness of underwater strobe lights to repel juvenile shad away from turbines and through an open trash sluice. Unfortunately, very little information was gained due to lack of fish in autumn months and the unscheduled shutdown of Unit 1 which had been shown in 1988 to attract shad to the sluice gate area.

Two studies were attempted at the Holtwood project in 1989 aimed at identifying the migratory pathway for outmigrating juvenile shad as they approached and entered the forebay. Radio telemetry and hydroacoustics were employed, but only limited data were collected due to lack of fish (acoustics) and signal reception problems (telemetry).

American shad egg collection, hatchery culture, research and marking, juvenile recovery and mark analysis, adult and juvenile telemetry studies, artificially induced spawning trials and hydroacoustic assessment at Holtwood were funded from the 1985 settlement agreement with upstream utilities. EPRI and Met Ed funded the strobe light demonstration study at York Haven. Philadelphia Electric Company paid for operation of the trap and lift at Conowingo, transfer of adult shad upstream, and strainer checks at Conowingo Dam. Maryland DNR funded the adult shad population assessment and juvenile shad electrofishing survey in the lower river as part of a state-federal program.

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

Richard St. Pierre
Susquehanna River Coordinator

TABLE OF CONTENTS

JOB II (Continued)

JOB III. **AMERICAN SHAD HATCHERY OPERATIONS, 1989**

M. L. Hendricks, T. R. Bender, Jr., and V. A. Mudrak
Pennsylvania Fish Commission
Benner Spring Fish Research Station
State College, PA

JOB IV. **EVALUATION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER, 1989**

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

JOB IV (Continued)

JOB V. **SPECIAL STUDIES**

TASK 1. **MIGRATION OF RADIO TAGGED ADULT AMERICAN SHAD THROUGH CONOWINGO POND TO THE HOLTWOOD HYDRO STATION**

RMC Environmental Services, Inc.
Drumore, Pennsylvania

TASK 2. BIOLOGICAL FIELD EVALUATION OF STROBE LIGHTS AT THE YORK HAVEN HYDROELECTRIC PROJECT

Stone & Webster Engineering Corp., Boston MA
for
Metropolitan Edison Company, Reading, PA
and
The Electric Power Research Institute, Palo Alto, CA

TASK 3. USE OF HUMAN CHORIONIC GONADOTROPIN TO INDUCE SPAWNING IN AMERICAN SHAD

T. W. H. Backman
U. S. Fish and Wildlife Service - NFRDL
Wellsboro, Pennsylvania
and
Chung-fu Liu
West Virginia University
Morgantown, West Virginia

TASK 4. EMIGRATION ROUTES AND BEHAVIOR OF JUVENILE AMERICAN SHAD AT THE HOLTWOOD HYDROELECTRIC STATION - 1989

RMC Environmental Services, Inc.
Drumore, Pennsylvania

TASK 5. HOLTWOOD HYDROELECTRIC PROJECT AMERICAN SHAD OUTMIGRATION STUDY

Acres International Corporation
Amherst, New York

TASK 6. USE OF OTOLITH MICROSTRUCTURE TO DISTINGUISH BETWEEN WILD AND HATCHERY-REARED AMERICAN SHAD IN THE SUSQUEHANNA RIVER

M. L. Hendricks and D. L. Torsello
Pennsylvania Fish Commission
Benner Spring Fish Research Station
State College, PA

and

T. W. H. Backman
U. S. Fish and Wildlife Service
National Fishery Research and Development Lab
Wellsboro, Pennsylvania

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

D. Weinrich, J. Mowrer, A. Jarzynski, M. Howell and R. Hochberg
Fisheries Division
Maryland Department of Natural Resources
Annapolis, Maryland

JOB I. SUMMARY OF CONOWINGO DAM FISH PASSAGE FACILITY OPERATION IN SPRING 1989

RMC ENVIRONMENTAL SERVICES, INC.
Muddy Run Ecological Laboratory
1921 River Road, P. O. Box 10
Drumore, Pennsylvania 17518

ABSTRACT

The Lift was operated on 53 days from 5 April through 18 June 1989. A total of 1,065,820 million fish representing 45 taxa were collected. Gizzard shad dominated the daily catch and comprised over 89% of the total catch. Alosids comprised less than 1.3% of the total catch and included 8,311 American shad, 3,611 blueback herring, 1,902 alewife, and 28 hickory shad. The American shad catch was the largest observed since operation began in 1972 even though a high flow event prevented Lift operation from 6 to 20 May; normally a period of high shad abundance.

Lift efficiency is related to river flows and station operation. The 1989 settlement agreement resulted in modified station operation and contributed to the increased catch. Males dominated the catch throughout the season accounting for an overall male/female ratio of 3.4:1. Males ranged in age from II to VII (80% IV and V) and females from IV to VIII (72% V and VI). A total of 28 shad examined were repeat spawners. A total of 1,614 shad collected were used for study and/or released back to the tailrace due to post spawned condition. Some 6,697 shad were transported to upstream spawning areas.

INTRODUCTION

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

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

Objectives of the 1989 operation were to: (1) contribute to restoration efforts by the trap and transfer of prespawned American shad to pre-determined upstream localities, (2) monitor relative abundance of Alosa species, (3) obtain life history information from selected migratory and resident fishes, (4) monitor species composition, (5) assist the Maryland Tidewater Administration in assessing the American shad population in the upper Chesapeake Bay and (6) obtain sagital otoliths from American shad for stock identification.

METHODS

Prior to the operation of the Lift, surveys were initiated on 22 March 1989 to detect the arrival of alosids into the lower river system. Herring surveys were conducted at Stafford Bridge, at the mouth of Deer Creek, and in Octorara Creek. Herrings were first observed on 29 March. Water temperature during these surveys varied from 38.3 to 59 F.

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

High flows (>150,000 cfs) delayed the start of lift operation. Lift operation commenced on 5 April and occurred on an alternate half-day (0700-1300 hrs) basis through 19 April. With the collection of 54 American shad on 19 April the Lift was operated daily (0700 to approximately 1900 hr) until 6 May. Increasing river flows on 6 May resulted in discharges in excess of 120,000 cfs at Conowingo Dam and cancellation of operation at approximately 1000 hours. Lift operation resumed on 21 May and was operated daily through 13 June. Although the Lift was operated daily from 14 to 18 June, operation was reduced to a half-day basis due to the decline in the shad catch and the advanced sexual condition of those collected.

The mechanical aspect of Lift operation in 1989 was similar to that described in RMC (1983). Fishing time and/or Lift frequency was determined by fish abundance and the time required to process the catch. However, due to large numbers of gizzard shad in the tailrace, two modifications implemented in 1985 to maximize collection of American shad were utilized (RMC 1986). Operation "Fast Fish"* (RMC 1986) was employed on an as needed basis and resulted in increased fishing time during periods of heavy

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

fish activity by reducing mechanical delays associated with normal Lift operation. On several occasions, as a result of changes in water level and turbine discharge in the tailrace, large numbers of gizzard shad were attracted to the Lift. In an effort to maximize the collection of American shad, weir gate 1 (Figure 1.1) was closed and fish that had accumulated were lifted rapidly within minutes. Normal operation of the Lift was resumed after most fish had been removed.

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

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

Fishes were processed as reported earlier (RMC 1983). Fishes were either counted or estimated (when large numbers were present) and released back to the tailrace. Length, weight, sex, and scale samples were taken from blueback herring, hickory shad, alewife, striped bass, and striped bass x white bass hybrid. The use of scientific and common names of fishes collected (Table 6.2) followed Bailey et al. (1970). Life history information (i.e. length, weight, sex, spawning condition, scales and otoliths) were taken from American shad that were sacrificed or released back to the tailrace and those that died in handling and transport. Per the 1989 work plan every 50th shad collected was sacrificed so otoliths could be removed and utilized in a stock identification study by the Pennsylvania Fish Commission.

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

HOLDING AND TRANSPORT OF SHAD

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

RESULTS

The relative abundance of fishes has fluctuated since 1972 (Table 1.3). Fluctuations have resulted primarily from changes in species abundance and modification to Lift and turbine operation. Prior to 1980, alosids (primarily blueback herring) and white perch dominated the catch. Generally, from 1980 to 1989 the catch has been dominated by gizzard shad, white perch, and channel catfish.

In 53 days of Lift operation in 1989 (5 April through 18 June) 1,065,820 fish of 45 taxa were caught (Tables 1.3 and 1.4). Predominant species in order of numerical abundance were gizzard shad, comely shiners, channel catfish, and white perch. Alosids (blueback herring, alewife, hickory shad, and American shad) comprised less than 1.3% of the total catch. The catch of gizzard shad was the lowest recorded since 1984 (Table 1.3). Gizzard shad dominated the daily catch and comprised over 89% of the total catch. The daily catch ranged from 640 on 6 May to 69,400 on 25 April (Table 1.4).

Although large numbers of gizzard shad were observed in the tailrace and they dominated the catch daily it appeared that shutdown of Unit Nos. 1 and 2 when river flows were <65,000 cfs may have been the primary reason for the reduced catch of gizzard shad at the lift. Operation "Fast Fish" was not utilized as frequently in 1989. Also, modified weir gate openings, in combination with operation "Fast Fish" was utilized on 3 days in 1989 versus 17 days in 1987 and 1988 (Table 1.5).

American Shad

The 1989 catch of American shad (8,311) at the Lift was the highest ever recorded since Lift operation began in 1972 (Table 1.3). Over 83% (6,945) of the shad collected were transported. One thousand ninety shad were released back to the tailrace. The remainder of the fish consisted of RMC tag recaptures, Maryland DNR recaptures, handling and holding mortalities, and fish that were sacrificed.

A total of 73 shad (0.9%) died during daily operation of the Lift. Mortalities resulted from mechanical operation of the Lift, handling, and holding procedures. The mortality at the Lift was within the range of mortality (1-3%) normally observed at the Holyoke Fish Lift where handling is generally non-existent; shad swim through a flume to gain access to the area upstream of the dam.

American shad were first observed at the Lift on 7 April (Table 1.4 and Figure 1.2). Most shad (3,659) were collected from 24 April through 6 May prior to a high flow event which shutdown Lift operation for a two week period. This shutdown occurred during a period when historically a large number of shad are present in the tailrace. From 21 May through 4 June, 3,525 shad were collected. The largest daily catch (1,417 shad) ever recorded at the lift occurred on 4 June. This represented 17% of the 1989 shad catch.

As in the past, the catch per effort (CPE) of American shad varied by station generation and time of day (Table 1.6). The total catch of shad was much lower on weekends (2,796) than on weekdays (5,515). However, the CPE was over 47% higher on weekends. The CPE was 22.4 and 15.2 on weekends and weekdays, respectively. Generally during both periods catches were greatest between 1100 and 1900 hrs with the highest catches occurring from 1500 to 1900 hrs.

The CPE was greatest during periods of minimum flow and was 2.5 fold higher during periods of minimum flow at 1 unit generation (5,000 cfs) than at 2 unit generation (7,500 and 10,000 cfs) (Table 1.7).

American shad were collected at water temperatures of 48.0 to 77.2 F and at natural river flows of 18,200 to 123,000 cfs (Table 1.4 and Figure 1.2). Over 88% (7,375 shad) of the catch occurred at river flows less than 40,000 cfs. Some 3,937 shad were collected from 19 April to 4 May when flows were less than 35,000 cfs.

Over 54% of the shad were collected at water temperatures ≤65 F (Table 1.8). Water temperatures during the period of peak shad abundance (24 April to 6 May) ranged from 55.4 to 60.0 F. Water temperatures during the peak period (21 May to 4 June) of shad abundance following the high flow event ranged from 62.5 to 70.4 F.

TRANSPORT

Pre-spawned American shad were transported from 21 April through 17 June. Most American shad were transported to the Pennsylvania Fish Commission (PFC) access areas located between Safe Harbor and York Haven Dam. Three loads containing 228 shad were transported to the Baltimore Water Intake and released into a net pen for telemetry studies. Another 248 shad were transported to the USFWS Laboratory at Wellsboro for artificial spawning studies.

A total of 6,697 (81% of 1989 catch) American shad were transported to potential upstream spawning areas with an overall observed stocking survival of 98.4% (Table 1.9). A total of 6,064, and 405 American shad were stocked above

Safe Harbor Dam at PFC access areas at Falmouth, and Bainbridge, respectively.

Transportation of shad occurred on 29 days and was accomplished in 43 trips. Generally, individual trips to Falmouth and Bainbridge averaged approximately 2 hr. The number of trips per day ranged from one to four; load size varied between 33 to 323 fish per trip. Trip survival varied between 88.7 to 100%. Shad were transported at water temperatures between 54.2 to 74.7 F.

The transport of a large number of shad afforded the opportunity to estimate the potential contribution of these fish to the restoration program. The potential egg deposition of shad was calculated assuming an average fecundity of 200,000 eggs/female. Some 1,592 females collected were transported to upstream spawning areas. Estimated egg deposition of these 1,592 fish was 318 x 10^6 eggs.

Based on 1987 results, holding facilities were utilized to allow shad collected on a given day to be held overnight or for several days to maximize transport operations and release larger schools of fish. Some 2,551 shad were held over at the Lift. The number of shad held varied from 1 to 216. A total of 26 shad died in the holding tanks; 10 were males and 16 were females.

SEX RATIOS

Visual macroscopic inspection of shad was made to determine daily and seasonal sex ratios. Generally, when the daily catch exceeded 100 shad a minimum subsample of 100 fish was examined. Generally, when the daily catch was less than 100 shad all fish were sexed. Four thousand seventy-seven American shad were sexed in 1989. The daily sex ratio of shad collected at the Lift is given in Table 1.11. Males dominated the catch throughout the season accounting for an overall male/female ratio of 3.4:1. Males outnumbered females from 5 April to 12 June. The number of females contributing to the catch increased in late May and peaked from 12 June to 18 June. Generally, the distribution of males to females in relation to the catch in 1989 was similar to that observed in past years.

AGE COMPOSITION

Four hundred twenty-eight scale samples were collected in 1989. Scale samples were obtained from fish sacrificed for otoliths, transport and handling mortalities, and from fish released back to the tailrace. In contrast to previous years scale sample collection occurred on a systematic basis, every 50th fish was sampled. This sampling scheme is believed to provide a more accurate age composition of shad collected at the Lift.

Ninety-seven percent (414) of the scale samples collected were aged successfully in 1989. Males ranged from

II to VII years old while females aged were IV to VII years old (Table 1.11). Most males (80%) were IV and V year olds while most females (72%) were V and VI year olds. Nineteen males and nine females were repeat spawners.

The age composition of shad released back to the tailrace was similar to that of shad which were sacrificed or died from handling and transport (Table 1.12).

TAG - RECAPTURE

In order to maximize the trap and transport of pre-spawned American shad no American shad were floy tagged in 1989. Although over 1,000 American shad were released back to the tailrace they were not tagged due to their advanced sexual spawning condition. One American shad which was floy tagged by RMC in 1988 was recaptured twice in 1989. Two American shad which were radio tagged and released on 25 April 1989 above Conowingo Dam were recaptured at the lift on 3 June and 4 June.

The Maryland Department of Natural Resources (DNR) tagged a total of 559 American shad in 1989; 298 from pound nets in the upper bay and 261 from hook and line in the Conowingo Dam tailrace. RMC recaptured 63 of these fish at the Lift in 1989, seven were captured twice (Table 1.13). Of the 56 Maryland DNR recaptures 46 and 10 were tagged in the tailrace and in the upper bay, respectively. The ten tagged in the upper bay averaged 32.3 days free before capture at the Lift, while those tagged in the tailrace and recaptured at the Lift averaged 13.6 days free.

RIVER HERRING AND HICKORY SHAD

The combined catch of river herrings (blueback and alewife) and hickory shad decreased from that observed in 1988 (RMC 1988), but was much lower than historic levels (Table 1.3). A total of 1,902 alewife was collected, with the first capture on 13 April (Table 1.4). Over 94% of the catch occurred from 21 April to 3 May at water temperatures of 54.4 to 60.8 F.

A total of 3,611 blueback herring was collected (Table 1.3). The number collected was over 75% less than that observed in 1988. Blueback herring typically arrive later than alewife and were first collected on 25 April. Sixty percent of the blueback herring were collected from 23 May to 31 May at water temperatures of 64.4 to 66.8 F.

The hickory shad catch (28) continued to be low (Table 1.3). The first hickory shad was captured on 20 April. Sixty-eight percent of total catch was collected from 28 April to 3 May. Water temperatures during this period ranged from 58.1 to 60.8 F.

DISCUSSION

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

A combination of several factors resulted in the record catch of 8,311 shad at the Lift. However, it appeared that the primary reasons were an increased shad population and modification of station operation (Unit Nos. 1 and 2 off when river flows were less than 65,000 cfs).

The settlement agreement of 1989 required the shutdown of Unit Nos. 1 and 2 (adjacent to the Lift) when river flows were less than 65,000 cfs. This increases Lift efficiency since the attraction flow from the Lift is not competing with the discharge from the adjacent units. Seasonally (1 April-18 June) since 1985 river flows exceeded 65,000 cfs most frequently in 1989 (Figure 1.4). However, river flows when the Lift was operated in 1989 rarely exceeded 65,000 cfs, particularly from mid-April to early May (Figure 1.2). As a result, Unit Nos. 1 and 2 were off for a greater percentage of Lift operating time (Figure 1.5).

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

Catch rates in 1985 were much lower. In contrast, the estimated shad population in the upper Chesapeake Bay has been increasing since 1985 (Weinrich et al., 1989).

Catch rates in all years were highest at station discharge of 5,000 cfs (Table 1.14, and Figure 1.6). In 1989, 12.6% (1,050 shad) of the catch occurred at a discharge of 5,000 cfs. Catch rates when generation increased and/or varied generally declined in each year.

Generally, a similar trend in the CPE at various levels of generation was observed within months since 1985 (Figure 1.7 to 1.9). That is, catch rates decreased as generation increased. However, a greater amount of variation was observed within months than between years.

In 1989 some 19% (1,614) of the shad collected were either used for study and/or released back to the tailrace due to post spawned condition. Over 99% (6,697) of those available were transported to upstream spawning areas. Although usage and length of stay in upstream spawning areas by these fish is unknown four shad were observed during creel surveys at York Haven. Anglers caught 1 American shad on 21 May, 2 on 21 July, and 1 on 17 July in the tailrace of York Haven Hydroelectric Station.

LITERATURE CITED

Bailey, R. M., J. E. Fitch, E. S. Herald, B. A. Lachner, C. C. Lindsey, C. R. Robins, and W. S. Scott. 1978. A list of common and scientific names of fishes from United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 6. 150 pp.

Cating, J. P. 1953. Determining age of American shad from their scales. U. S. Fish Wildl. Service, Fish. Bull. 54(85):187-199.

RMC. 1983. Summary of the operation of the Conowingo Dam Lift in spring 1982. Prepared for Philadelphia Electric Company by RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, Pennsylvania. 32 pp.

RMC. 1986. Summary of the operation of the Conowingo Dam Lift in spring 1985. Prepared for Philadelphia Electric Company by RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, Pennsylvania. 44 pp.

Weinrich, D. W., J. P. Mowrer, M. H. Holvell, and A. Jarzynski. 1989. Investigations of American shad in the upper Chesapeake Bay 1988. Fed. Aid. Prog. F-37-R. Ann. Rept. U.S. Dept. Int., Fish Wildl. Serv. 83 pp.

TABLE 1.1

The status of steps taken prior to 31 March 1989 to make the Conowingo Dam Fish Lift reliable and operable at 120,000 cfs.

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

TABLE 1.2

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

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

TABLE 1.2

Continued.

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

Table I.2

Continued.

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

TABLE 1.3

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1989.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
NO. DAYS	54	62	58	55	63	61	35	29	30	37
LIFTS	817	1,527	819	514	684	707	358	301	403	490
EST. OPER. TIME(HR.)	608	996	500	307	375	413	212	187	221	275
FISHING TIME(HR)	313	623	222	189	252	245	136	123	117	178
# SPECIES	40	43	42	41	38	40	44	37	42	48
AMERICAN EEL	805	2050	91937	64375	60409	14601	5878	1602	377	11329
BLUEBACK HERRING	58198	330341	340084	69916	35519	24395	13098	2282	502	618
HICKORY SHAD	429	739	219	20	-	1	-	-	1	1
ALEWIFE	10345	144727	16675	4311	235	188	5	9	9	129
AMERICAN SHAD	182	65	121	87	82	165	54	50	139	328
GIZZARD SHAD	24849	45668	119672	139222	382275	742056	55104	75553	275736	1156662
ATLANTIC MENHADEN	-	-	112	-	506	1596	-	-	16	42
TROUTS	1	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	34	67	20	24	54	291	70	15	23	219
BROWN TROUT	172	286	483	219	427	700	261	324	258	207
BROOK TROUT	1	3	4	1	-	2	23	-	4	3
TROUT	-	-	-	-	-	-	-	-	-	2
RAINBOW SMELT	-	-	-	-	-	-	-	-	-	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	1	10	-	-	1	-	-	-	1
NORTHERN PIKE	-	2	2	-	-	2	2	4	3	-
MUSKELLUNGE	20	104	9	7	12	48	14	5	27	1
REDFIN PICKEREL	-	-	-	-	-	-	-	-	-	-
MINNOWS	-	-	-	-	-	-	-	-	-	-
GOLDFISH	-	27	1	9	4	1	-	-	-	1
COMMON CARP	4370	16362	34383	15114	6755	16256	11842	14946	8879	18313
RIVER CHUB	-	-	-	-	-	-	-	-	1	-
GOLDEN SHINER	165	430	437	751	1622	652	221	304	35	155
COMELY SHINER	5	252	3870	2079	740	769	1152	1707	761	281
SPOTTAIL SHINER	34	137	2036	268	1743	8107	8506	1533	849	31
SWALLOWTAIL SHINER	-	-	-	-	-	-	-	-	-	3
ROSYFACE SHINER	1	-	-	1	-	-	-	-	-	-
SPOTFIN SHINER	103	40	3011	1231	45879	7960	3751	41	314	524
BLUNTNOSE MINNOW	-	-	-	-	-	-	4	-	-	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	1	-	-	-	4	-	-	-
CREEK CHUB	-	-	-	-	-	-	-	-	-	-
SHINERS	264	3	-	-	-	-	-	-	-	-
QUILLBACK	7119	27780	14565	8388	9882	6734	2361	5134	2929	3622
WHITE SUCKER	363	1034	286	152	444	282	189	906	1145	1394
CREEK CHUBSUCKER	3	3	1	-	-	-	-	-	-	4
NORTHERN HOG SUCKER	-	2	-	1	5	-	3	6	13	1
SHORTHEAD REDHORSE	1097	4420	434	445	1276	1724	697	2163	1394	6533
WHITE CATFISH	3070	6394	2200	6178	1451	3081	982	515	605	2199
YELLOW BULLHEAD	7	45	1	32	2	47	25	13	18	36
BROWN BULLHEAD	510	5328	1612	740	451	2416	125	284	675	531
CHANNEL CATFISH	61042	55084	75663	74042	41508	90442	48575	38251	38929	55528
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	-
MADTOMS	-	-	-	-	-	-	-	-	-	-
TADPOLE MADTOM	-	-	-	-	-	-	-	-	-	-
MUMMICHOG	-	-	-	-	1	-	-	-	-	-
WHITE PERCH	50991	647493	897113	511699	568018	224843	113164	43103	26971	83363
STRIPED BASS	3142	495	1150	174	13	1196	934	260	904	3277
ROCK BASS	66	32	31	46	227	128	50	46	88	381
REDBREAST SUNFISH	707	2056	1398	3040	3772	8377	4187	3466	1524	1007
GREEN SUNFISH	3	-	4	39	81	168	25	-	16	28
PUMPKINSEED	229	2578	2579	1000	878	1687	512	323	446	306
BLUEGILL	567	1423	927	3058	2712	5442	1361	813	942	1299
SMALLMOUTH BASS	182	298	119	153	327	701	262	374	455	881
LARGEMOUTH BASS	82	80	23	19	33	14	22	22	41	13
WHITE CRAPPIE	4457	664	4371	9290	2987	1003	673	384	100	231
BLACK CRAPPIE	8	4	25	45	86	199	103	53	15	20
TESSELLATED DARTER	-	1	4	1	-	-	1	-	-	2
YELLOW PERCH	5955	1090	682	494	2904	735	526	379	373	1007
LOGPERCH	-	-	-	-	-	-	27	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-	-	1
WALLEYE	1840	2734	1613	369	2267	2140	967	2491	4153	2645
BANDED DARTER	-	-	-	-	-	-	1	-	-	-
ATLANTIC NEEDLEFISH	1	-	-	1	-	-	-	-	-	2
LAMPREYS	-	-	-	-	-	-	-	-	-	-
SEA LAMPREY	-	2	-	2	29	11	1	2	1	55
LAKE HERRING	-	1	-	-	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	-	-	-	-	-	270	273	2674	39
TIGER MUSKIE	-	-	-	-	-	-	13	132	34	53
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-	-	-
	241419	1300345	1617888	917043	1175616	1169161	276045	197769	372379	1353308

TABLE 1.3

COMPARISON OF ANNUAL CATCH OF FISHES AT THE CONOWINGO DAM FISH LIFT, 1 APRIL THROUGH 15 JUNE, 1972-1989 (CONTINUED).

YEAR	1982	1983	1984	1985	1986	1987	1988	1989
NO. DAYS	44	29	34	55	59	60	63	51
LIFTS	725	648	519	1,118	831	1,414	1,339	1,117
EST. OPER. TIME(HR.)	502	299	251	542	546	639	637	539
FISHING TIME(HR)	336	224	192	421	449	532	513	457
# SPECIES	48	41	35	41	43	46	49	45
AMERICAN EEL	3961	1080	155	550	364	1662	103	157
BLUEBACK HERRING	25249	517	311	6763	6327	5861	14570	3598
HICKORY SHAD	15	5	6	9	45	35	64	28
ALEWIFE	3433	50	26	379	2822	357	674	1902
AMERICAN SHAD	2039	413	167	1546	5195	7667	5146	8218
GIZZARD SHAD	1226374	950252	912666	2182888	1714441	2488618	1402565	926213
ATLANTIC MENHADEN	-	1	-	1	-	-	-	-
TROUTS	-	-	-	-	-	-	-	-
RAINBOW TROUT	20	2	5	70	9	14	10	4
BROWN TROUT	219	225	141	175	65	83	85	110
BROOK TROUT	5	2	-	1	-	-	1	1
TROUT	-	-	-	-	-	-	-	-
RAINBOW SMELT	-	-	-	-	-	1	1	-
PALOMINO (RAINBOW TROUT)	-	-	-	-	-	1	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	1
NORTHERN PIKE	5	1	-	-	2	-	-	-
MUSKELLUNGE	4	-	-	15	-	-	1	-
REDFIN PICKEREL	-	-	-	-	-	1	-	-
MINNOWS	1	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	1	1
COMMON CARP	15362	16273	8012	6729	2930	4607	8535	875
RIVER CHUB	-	-	-	-	-	-	-	-
GOLDEN SHINER	92	216	8	292	23	40	28	5
COMELY SHINER	14214	3176	871	5141	582	21199	11734	35239
SPOTTAIL SHINER	315	2132	-	3525	6247	155	55	282
SWALLOWTAIL SHINER	-	-	-	-	1	-	-	-
ROSYFACE SHINEP	8	-	-	-	-	-	-	-
SPOTFIN SHINER	622	501	-	2695	695	796	65	5381
BLUNTNOSE MINNOW	-	-	-	-	-	-	65	-
BLACKNOSE DACE	2	-	-	-	-	-	-	-
LONGNOSE DACE	-	-	-	-	-	-	-	-
CREEK CHUB	-	-	-	-	-	-	1	-
SHINERS	6	-	-	-	-	-	-	-
QUILLBACK	1617	4679	1942	957	2327	1881	1578	170
WHITE SUCKER	582	412	109	776	853	263	540	410
CREEK CHUBSUCKER	2	-	-	-	-	5	1	-
NORTHERN HOG SUCKER	-	-	-	-	2	4	1	1
SHORTHEAD REDHORSE	6974	7558	3467	3362	2057	3583	4782	2735
WHITE CATFISH	565	224	77	1094	284	917	3849	1740
YELLOW BULLHEAD	61	10	7	21	35	41	80	445
BROWN BULLHEAD	338	179	69	461	134	163	345	402
CHANNEL CATFISH	40941	12559	20479	15200	18898	11699	36212	21692
MARGINED MADTOM	6	-	-	-	3	-	1	-
MADTOMS	1	-	-	-	-	-	-	-
TADPOLE MADTOM	1	-	-	-	-	-	-	1
MUMMICHOG	1	-	-	-	-	-	-	-
WHITE PERCH	53527	23151	6402	68344	56977	29995	90651	15713
* STRIPED BASS	60	23	181	213	194	1337	874	357
ROCK BASS	138	269	158	122	200	231	110	352
REDBREAST SUNFISH	1335	401	465	3366	1433	1471	730	443
GREEN SUNFISH	91	16	7	133	15	64	19	33
PUMPKINSEED	848	228	104	1013	402	490	135	115
BLUEGILL	1184	587	284	6048	1654	2436	1107	1561
SMALLMOUTH BASS	1095	1003	608	1081	666	536	548	491
LARGEMOUTH BASS	20	17	8	67	75	69	117	164
WHITE CRAPPIE	303	450	59	345	199	272	125	230
BLACK CRAPPIE	39	46	6	45	51	19	42	45
TESSELLATED DARTER	-	-	-	1	-	1	1	-
YELLOW PERCH	724	387	487	2145	2267	632	815	310
* LOGPERCH	-	-	-	1	1	1	2	-
SHIELD DARTER	-	-	-	-	-	-	-	-
WALLEYE	504	663	236	609	380	267	311	319
BANDED DARTER	-	-	-	-	-	1	-	-
ATLANTIC NEEDLEFISH	-	-	-	-	-	-	2	-
LAMPREYS	-	2	-	-	-	-	-	-
SEA LAMPREY	56	8	4	164	26	21	59	94
LAKE HERRING	-	1	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	160	355	282	1377	1713	5895	6203	5243
TIGER MUSKIE	56	16	10	73	35	30	20	33
BROOK TROUT X LAKE TROUT	-	-	2	-	2	5	-	1
STRIPED BASS X WHT PERCH	-	-	-	-	10	19	1	3
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	1
	1403175	1028090	957821	2317797	1830641	2593445	1592965	1035121

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.

DATE	05 APRIL	07 APRIL	09 APRIL	11 APRIL	13 APRIL	15 APRIL	17 APRIL	19 APRIL
# OF LIFTS	7	15	13	10	11	9	9	25
FIRST LIFT	615	610	610	608	612	608	610	610
LAST LIFT	1200	1200	1148	1200	1157	1131	1205	1800
OPERATING TIME (HR)	5.75	5.83	5.63	5.87	5.75	5.38	5.92	11.83
FISHING TIME (HR)	5.22	4.33	4.33	5.18	5.07	4.42	4.17	9.92
AVE RIVER FLOW	105000	91400	86700	64500	45700	40900	35500	29900
AVE WATER TEMP (F)	49.0	48.0	48.0	47.3	47.[illegible]	49.2	51.0	53.6
AMERICAN EEL	-	1	-	-	6	-	-	1
BLUEBACK HERRING	-	-	-	-	-	-	-	-
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	1	2	-	39
AMERICAN SHAD	-	1	-	-	-	1	-	54
GIZZARD SHAD	1974	10158	13470	6467	1678	3034	3489	9750
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	-	1			2	-	2	2
BROOK TROUT	-		-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
COMMON CARP	-	7	-	3	-	-	1	1
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	5	-
SPOTTAIL SHINER	-	-	-	-	-	1	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	1	-	-	-	-	-	-
WHITE SUCKER	1	1	-	-	1	2	8	68
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	-	-	-	-	-	4	4	168
WHITE CATFISH	-	-	-	-	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	3
CHANNEL CATFISH	4	212	35	14	181	48	48	186
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	-	-	-	-	-	-	-	2
STRIPED BASS	-	-	-	-	-	-	2	-
ROCK BASS	-	-	-	-	-	-	1	1
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	6	-	1	-
SMALLMOUTH BASS	-	-	-	-	1	2	1	3
LARGEMOUTH BASS	-	-	-	-	-	-	2	1
WHITE CRAPPIE	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	1	1
YELLOW PERCH	-	-	-	-	12	7	13	11
WALLEYE	-	1	2	-	-	-	-	1
SEA LAMPREY	1	2	1	1	-	2	-	1
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	58	8	9	4	12	14	304
TIGER MUSKIE	-	-	-	-	-	-	-	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-
	1980	10443	13516	6494	1892	3115	3592	10597

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.
(CONTINUED)

DATE	20 APRIL	21 APRIL	22 APRIL	23 APRIL	24 APRIL	25 APRIL	26 APRIL	27 APRIL
# OF LIFTS	29	26	26	32	29	36	39	34
FIRST LIFT	615	555	602	605	610	612	600	610
LAST LIFT	1625	1752	1747	1810	1745	1701	1747	1735
OPERATING TIME (HR)	10.17	11.95	11.75	12.08	11.58	10.82	11.78	11.42
FISHING TIME (HR)	8.95	8.85	8.75	9.40	9.30	8.85	9.77	9.13
AVE RIVER FLOW	31200	31100	27300	26400	25000	23800	19100	21900
AVE WATER TEMP (F)	54.4	54.2	54.4	55.4	55.4	57.0	57.6	58.0
AMERICAN EEL	5	-	7	5	1	1	3	4
BLUEBACK HERRING	-	-	-	-	-	10	9	21
HICKORY SHAD	1	2	-	1	-	4	-	-
ALEWIFE	21	443	115	107	45	48	43	71
AMERICAN SHAD	32	33	116	84	157	133	165	388
GIZZARD SHAD	31795	21439	20525	25669	28286	69400	46525	26816
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	1	1	2	1	-	2	2	2
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	1	-
GOLDFISH	-	-	-	-	-	-	-	-
COMMON CARP	1	-	-	-	-	-	-	2
GOLDEN SHINER	-	-	3	-	-	-	-	-
COMELY SHINER	1	55	16	-	-	-	-	-
SPOTTAIL SHINER	-	25	1	-	-	-	-	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	-	-	-	2	2	-
WHITE SUCKER	35	65	29	13	19	23	9	7
NORTHERN HOG SUCKER	-	-	-	-	-	1	-	-
SHORTHEAD REDHORSE	206	514	193	78	111	58	110	50
WHITE CATFISH	-	-	-	1	-	-	-	-
YELLOW BULLHEAD	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	1	1	-	-	-
CHANNEL CATFISH	56	12	161	57	42	28	35	68
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	3	-	-	1	9	38	189	550
STRIPED BASS	1	1	1	-	1	2	2	4
ROCK BASS	2	1	4	2	5	3	6	6
REDBREAST SUNFISH	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-
PUMPKINSEED	-	1	1	1	-	-	1	1
BLUEGILL	-	5	1	-	6	8	14	13
SMALLMOUTH BASS	4	6	15	11	15	15	30	12
LARGEMOUTH BASS	2	5	9	8	10	2	7	7
WHITE CRAPPIE	-	2	-	-	2	2	9	6
BLACK CRAPPIE	-	-	3	-	4	1	1	4
YELLOW PERCH	2	6	16	2	5	7	2	5
WALLEYE	2	6	9	4	10	6	5	8
SEA LAMPREY	3	-	1	-	6	9	5	3
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	760	814	409	153	392	419	742	233
TIGER MUSKIE	1	1	3	1	1	1	1	-
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	1	-	-	-	-	-	-
	32934	23438	21642	26200	29128	70223	47918	28281

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.
(CONTINUED)

DATE	28 APRIL	29 APRIL	30 APRIL	01 MAY	02 MAY	03 MAY	04 MAY	05 MAY
# OF LIFTS	32	20	29	25	38	36	39	16
FIRST LIFT	600	607	605	608	600	605	602	600
LAST LIFT	1800	1755	1746	1800	1754	1738	1748	1743
OPERATING TIME (HR)	12.00	11.80	11.68	11.87	11.90	11.55	11.77	11.72
FISHING TIME (HR)	10.75	9.70	9.95	9.87	10.80	10.15	10.83	10.75
AVE RIVER FLOW	18200	18500	19400	19400	22500	25000	25900	38900
AVE WATER TEMP (F)	58.1	59.0	58.9	59.4	60.8	60.8	59.0	58.9
AMERICAN EEL	4	6	6	7	4	2	6	9
BLUEBACK HERRING	13	45	21	27	79	288	12	18
HICKORY SHAD	4	1	4	1	3	6	-	-
ALEWIFE	109	111	88	147	379	92	9	6
AMERICAN SHAD	298	512	247	410	975	232	101	40
GIZZARD SHAD	19250	9550	27635	28660	50900	49850	45033	6573
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	1	3	-	2	-	2	-	3
BROOK TROUT	-	1	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	1	-	-	-	-
COMMON CARP	8	3	-	13	8	13	5	2
GOLDEN SHINER	-	-	-	1	-	-	-	-
COMELY SHINER	-	-	-	-	-	-	-	-
SPOTTAIL SHINER	-	-	-	-	1	4	1	-
SPOTFIN SHINER	-	-	-	-	-	-	-	-
QUILLBACK	-	-	2	-	1	-	1	1
WHITE SUCKER	5	2	4	3	11	13	6	4
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	47	29	134	58	133	178	147	45
WHITE CATFISH	-	-	-	3	11	-	1	6
YELLOW BULLHEAD	-	-	-	1	-	-	-	1
BROWN BULLHEAD	1	1	-	-	-	8	1	-
CHANNEL CATFISH	78	40	333	1084	1496	1199	52	670
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	808	732	1176	2065	2859	1595	530	1437
STRIPED BASS	1	2	2	3	5	6	2	2
ROCK BASS	17	6	3	21	17	21	22	14
REDBREAST SUNFISH	-	1	-	-	1	2	1	1
GREEN SUNFISH	1	-	-	-	-	-	-	-
PUMPKINSEED	1	-	-	-	5	-	1	3
BLUEGILL	24	6	6	10	26	49	18	23
SMALLMOUTH BASS	26	3	13	26	47	19	4	2
LARGEMOUTH BASS	2	1	5	2	12	1	2	-
WHITE CRAPPIE	12	3	9	6	12	12	1	3
BLACK CRAPPIE	3	-	2	4	3	3	-	-
YELLOW PERCH	18	1	5	11	16	5	8	18
WALLEYE	6	11	13	21	22	5	12	17
SEA LAMPREY	4	1	6	5	10	14	4	3
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	84	90	50	199	29	89	35	1
TIGER MUSKIE	1	2	1	2	-	-	-	1
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-
	20826	11163	29767	32794	57067	53708	46015	8903

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.
(CONTINUED)

DATE	06 MAY	21 MAY	22 MAY	23 MAY	24 MAY	25 MAY	26 MAY	27 MAY
# OF LIFTS	5	22	27	19	23	21	28	23
FIRST LIFT	559	615	610	604	610	600	605	607
LAST LIFT	1016	1800	1800	1745	1740	1800	1800	1800
OPERATING TIME (HR)	4.28	11.75	11.83	11.68	11.50	12.00	11.92	11.88
FISHING TIME (HR)	4.00	9.92	9.27	9.45	8.95	9.92	10.30	9.97
AVE RIVER FLOW	92400	105400	73600	67900	62800	55800	55300	53500
AVE WATER TEMP (F)	60.0	62.5	63.5	64.4	64.4	64.6	64.8	64.8
AMERICAN EEL	6	8	8	3	2	1	5	-
BLUEBACK HERRING	-	61	62	132	102	173	457	404
HICKORY SHAD	-	-	-	-	-	-	1	-
ALEWIFE	3	1	1	-	2	3	1	15
AMERICAN SHAD	1	86	88	68	41	27	161	95
GIZZARD SHAD	640	27500	31250	11160	16980	14475	32963	17970
RAINBOW TROUT	-	1	-	1	1	-	1	-
BROWN TROUT	-	7	10	7	3	10	10	5
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
COMMON CARP	-	7	52	38	40	2	3	14
GOLDEN SHINER	-	-	1	-	-	-	-	-
COMELY SHINER	-	195	88	120	155	1733	270	591
SPOTTAIL SHINER	-	-	-	-	-	8	-	-
SPOTFIN SHINER	6	-	30	-	10	-	-	100
QUILLBACK	-	-	-	1	1	1	-	-
WHITE SUCKER	2	1	9	4	5	3	4	7
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	11	80	62	67	56	41	11	7
WHITE CATFISH	33	6	11	-	31	45	12	28
YELLOW BULLHEAD	3	11	6	12	-	6	11	9
BROWN BULLHEAD	-	12	9	16	9	11	8	8
CHANNEL CATFISH	605	775	325	498	1285	2634	600	158
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	255	238	97	169	105	221	358	200
STRIPED BASS	3	2	1	3	5	3	3	4
ROCK BASS	4	22	5	43	14	10	27	9
REDBREAST SUNFISH	1	28	12	35	9	24	31	25
GREEN SUNFISH	-	1	2	-	1	1	2	4
PUMPKINSEED	4	1	7	15	6	10	5	15
BLUEGILL	16	64	57	77	60	78	103	125
SMALLMOUTH BASS	1	10	9	20	8	12	13	11
LARGEMOUTH BASS	-	2	2	8	7	3	4	1
WHITE CRAPPIE	2	-	7	16	9	8	6	3
BLACK CRAPPIE	-	1	1	-	-	-	1	-
YELLOW PERCH	10	1	9	24	19	15	6	3
WALLEYE	1	5	5	8	3	3	4	7
SEA LAMPREY	1	-	1	2	1	1	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	-	41	8	11	26	7	8	8
TIGER MUSKIE	-	-	-	-	-	-	1	1
BROOK TROUT X LAKE TROUT	-	-	-	1	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-
	1608	29167	32235	12559	18996	19569	35090	19827

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989. (CONTINUED)

DATE	28 MAY	29 MAY	30 MAY	31 MAY	01 JUNE	02 JUNE	03 JUNE	04 JUNE
# OF LIFTS	25	19	25	23	16	21	19	32
FIRST LIFT	600	615	606	615	605	610	601	557
LAST LIFT	1743	1800	1750	1807	1800	1740	1800	1900
OPERATING TIME (HR)	11.72	11.75	11.73	11.87	11.92	11.50	11.98	13.05
FISHING TIME (HR)	9.97	10.58	10.08	9.90	10.97	9.48	11.00	11.42
AVE RIVER FLOW	49000	45300	40700	35900	32600	32800	28900	31700
AVE WATER TEMP (F)	65.9	65.9	66.6	66.8	68.9	68.9	69.9	70.4
AMERICAN EEL	11	2	3	2	1	2	3	4
BLUEBACK HERRING	432	35	189	250	4	154	62	173
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	94	124	263	257	155	418	232	1417
GIZZARD SHAD	15625	13575	17070	8015	5465	20615	12405	11981
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	7	3	2	1	1	5	-	2
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
COMMON CARP	7	23	4	22	6	40	23	16
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	291	1400	630	666	1485	9720	4210	4050
SPOTTAIL SHINER	5	125	11	-	-	-	-	-
SPOTFIN SHINER	-	-	75	-	1100	130	605	635
QUILLBACK	3	-	-	2	-	-	-	-
WHITE SUCKER	8	3	1	1	3	1	1	2
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	34	27	21	7	-	6	-	3
WHITE CATFISH	26	8	46	11	14	50	35	26
YELLOW BULLHEAD	10	2	13	8	4	3	32	-
BROWN BULLHEAD	4	5	12	20	7	29	-	1
CHANNEL CATFISH	145	100	109	54	137	493	37	56
TADPOLE MADTOM	-	1	-	-	-	-	-	-
WHITE PERCH	139	236	233	272	587	131	74	54
STRIPED BASS	11	7	3	14	14	12	15	20
ROCK BASS	14	10	16	4	1	2	3	-
REDBREAST SUNFISH	35	34	28	10	26	10	24	15
GREEN SUNFISH	2	1	8	-	1	-	1	-
PUMPKINSEED	4	2	7	8	4	1	1	1
BLUEGILL	104	66	99	43	61	20	76	30
SMALLMOUTH BASS	16	32	11	11	8	9	11	6
LARGEMOUTH BASS	9	9	8	2	5	4	2	4
WHITE CRAPPIE	17	6	8	16	8	12	9	4
BLACK CRAPPIE	-	1	-	2	-	6	-	1
YELLOW PERCH	10	7	2	2	8	4	4	4
WALLEYE	11	7	13	11	6	11	2	11
SEA LAMPREY	1	-	2	-	-	1	-	-
STRIPED MULLET	-	-	-	1	-	-	-	-
STRIPED BASS X WHITE BASS	12	6	20	11	9	6	21	14
TIGER MUSKIE	1	3	1	1	1	-	1	1
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-
	17088	15860	18909	9724	9121	31893	17889	18531

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.
(CONTINUED)

DATE	05 JUNE	06 JUNE	07 JUNE	08 JUNE	09 JUNE	10 JUNE	11 JUNE	12 JUNE
# OF LIFTS	21	20	15	16	15	17	20	13
FIRST LIFT	605	613	611	607	600	601	558	605
LAST LIFT	1749	1800	1740	1756	1730	1753	1740	1800
OPERATING TIME (HR)	11.73	11.78	11.48	11.82	11.50	11.87	11.70	11.92
FISHING TIME (HR)	9.98	9.90	10.25	10.42	9.92	10.50	10.17	10.83
AVE RIVER FLOW	33500	34100	36300	38000	38400	41500	37300	31800
AVE WATER TEMP (F)	71.6	73.4	74.7	75.2	77.2	72.5	72.7	71.5
AMERICAN EEL	4	3	1	-	3	2	1	-
BLUEBACK HERRING	40	44	-	28	47	115	36	18
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	-	-	-	-	-	-
AMERICAN SHAD	103	29	7	21	36	67	63	96
GIZZARD SHAD	12350	14085	9790	11421	12180	10642	19508	5231
RAINBOW TROUT	-	-	-	-	-	-	-	-
BROWN TROUT	-	-	-	-	-	-	1	-
BROOK TROUT	-	-	-	-	-	-	-	-
CHAIN PICKEREL	-	-	-	-	-	-	-	-
GOLDFISH	-	-	-	-	-	-	-	-
COMMON CARP	98	37	20	249	68	16	4	8
GOLDEN SHINER	-	-	-	-	-	-	-	-
COMELY SHINER	6095	1245	10	215	6	-	1955	-
SPOTTAIL SHINER	100	-	-	-	-	-	-	-
SPOTFIN SHINER	2030	255	50	55	-	-	300	-
QUILLBACK	19	106	3	2	14	1	-	-
WHITE SUCKER	2	5	-	9	3	3	1	2
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-
SHORTHEAD REDHORSE	14	12	1	1	-	5	-	2
WHITE CATFISH	246	151	69	361	70	64	108	27
YELLOW BULLHEAD	10	33	18	22	11	10	-	5
BROWN BULLHEAD	54	37	17	40	21	10	5	6
CHANNEL CATFISH	568	1099	1685	1051	1311	945	63	194
TADPOLE MADTOM	-	-	-	-	-	-	-	-
WHITE PERCH	57	110	36	60	22	35	8	4
STRIPED BASS	15	51	18	21	11	22	11	8
ROCK BASS	7	3	2	-	1	-	-	-
REDBREAST SUNFISH	17	12	3	9	9	19	6	12
GREEN SUNFISH	-	-	-	5	1	-	-	1
PUMPKINSEED	2	4	-	-	3	-	-	-
BLUEGILL	45	63	18	30	3	45	20	28
SMALLMOUTH BASS	10	11	3	5	1	7	10	1
LARGEMOUTH BASS	6	1	-	1	1	4	2	1
WHITE CRAPPIE	5	7	3	5	-	-	-	-
BLACK CRAPPIE	-	-	-	2	-	-	-	-
YELLOW PERCH	2	-	-	-	-	6	2	2
WALLEYE	5	8	1	6	3	6	4	6
SEA LAMPREY	1	1	-	-	-	-	-	-
STRIPED MULLET	-	-	-	-	-	-	-	-
STRIPED BASS X WHITE BASS	25	29	5	8	7	18	11	4
TIGER MUSKIE	-	1	2	1	1	-	-	1
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	-	-
STRIPED BASS X WHT PERCH	-	-	-	-	-	-	-	-
BIGMOUTH BUFFALO	-	-	-	-	-	-	-	-
	21930	17442	11762	13628	13833	12042	22119	5657

TABLE 1.4

DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM FISH LIFT IN SPRING 1989.
(CONTINUED)

DATE	13 JUNE	14 JUNE	15 JUNE	16 JUNE	17 JUNE	18 JUNE	TOTALS
# OF LIFTS	21	12	14	20	12	13	1162
FIRST LIFT	607	605	609	600	600	615	
LAST LIFT	1745	1325	1205	1740	1410	1200	
OPERATING TIME (HR)	11.63	7.33	5.93	11.67	8.17	5.75	564.44
FISHING TIME (HR)	10.08	6.50	5.08	10.33	7.47	4.83	479.88
AVE RIVER FLOW	30500	29900	31400	51600	75200	123000	
AVE WATER TEMP (F)	71.6	71.6	71.3	71.3	72.4	71.5	
AMERICAN EEL	-	2	2	-	-	-	157
BLUEBACK HERRING	14	9	14	9	2	2	3,611
HICKORY SHAD	-	-	-	-	-	-	28
ALEWIFE	-	-	-	-	-	-	1,902
AMERICAN SHAD	256	16	18	65	20	8	8,311
GIZZARD SHAD	3755	6021	5615	14570	5860	4285	950,928
RAINBOW TROUT	-	-	-	-	-	-	4
BROWN TROUT	-	-	-	-	-	-	110
BROOK TROUT	-	-	-	-	-	-	1
CHAIN PICKEREL	-	-	-	-	-	-	1
GOLDFISH	-	-	-	-	-	-	1
COMMON CARP	1	1	9	4	10	2	891
GOLDEN SHINER	-	-	-	-	-	-	5
COMELY SHINER	-	12	20	-	155	-	35,394
SPOTTAIL SHINER	-	-	-	-	-	-	282
SPOTFIN SHINER	-	-	-	-	-	-	5,381
QUILLBACK	2	5	-	-	1	1	172
WHITE SUCKER	-	-	1	-	-	-	410
NORTHERN HOG SUCKER	-	-	-	-	-	-	1
SHORTHEAD REDHORSE	-	-	-	-	-	-	2,735
WHITE CATFISH	36	162	42	22	848	212	2,822
YELLOW BULLHEAD	1	203	-	6	40	-	491
BROWN BULLHEAD	4	14	27	7	35	115	559
CHANNEL CATFISH	84	448	94	361	1083	2780	25,916
TADPOLE MADTOM	-	-	-	-	-	-	1
WHITE PERCH	11	3	4	11	9	26	15,759
STRIPED BASS	7	27	9	18	18	15	408
ROCK BASS	3	-	-	-	-	-	352
REDBREAST SUNFISH	3	-	-	5	3	-	451
GREEN SUNFISH	-	-	1	-	-	-	33
PUMPKINSEED	-	-	-	-	-	-	115
BLUEGILL	7	3	4	34	9	8	1,612
SMALLMOUTH BASS	-	-	-	-	1	-	492
LARGEMOUTH BASS	-	-	-	1	-	-	165
WHITE CRAPPIE	-	-	-	1	1	1	233
BLACK CRAPPIE	-	-	-	-	-	-	45
YELLOW PERCH	-	-	-	-	3	-	313
WALLEYE	3	5	3	5	5	2	331
SEA LAMPREY	-	-	-	-	-	-	94
STRIPED MULLET	-	1	-	-	-	-	2
STRIPED BASS X WHITE BASS	4	1	15	10	9	-	5,262
TIGER MUSKIE	-	-	-	1	-	-	34
BROOK TROUT X LAKE TROUT	-	-	-	-	-	-	1
STRIPED BASS X WHT PERCH	1	2	-	-	-	-	3
BIGMOUTH BUFFALO	-	-	-	-	-	-	1
	4193	6935	5878	15130	8112	7457	1,065,820

TABLE 1.5

Total catch and catch per hr of American shad by date and weir gate setting during modified lift operation at Conowingo Dam Fish Lift, 1989.

Date		# Two Weir Gate Open	Both Weir Gates Open	Total Weir Gates Open
Apr 20	# shad	3	29	32
	Hrs fished	1.8	7.2	8.9
	Catch/hr fished	1.67	4.03	3.60
Apr 25	# shad	1	132	133
	Hrs fished	1.4	7.5	8.8
	Catch/hr fished	0.71	17.60	15.11
Apr 30	# shad	97	150	247
	Hrs fished	2.2	7.7	9.9
	Catch/hr fished	44.09	19.48	24.95
Total		101	311	412
Hrs Fished		5.4	22.4	27.6
Catch/hr		18.70	13.88	14.93

TABLE 1.6

Comparison of catch per effort (hr) of American shad on weekdays vs weekend days by generation (cfs) at the Conowingo Dam Fish Lift, 05 April 89 - 18 June 89.

	LIFT TIME	CHANGING CATCH/HOUR	5000 CFS CATCH/HOUR	6-10000 CATCH/HOUR	11-20000 CFS CATCH/HOUR	25-40000 CFS CATCH/HOUR	45000 CFS + CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	MORNING 5-9	14.7	2.4	0.0	2.9	7.6	10.0	10.3
	MID-AM 9-11	18.9	-	58.1	-	72.8	9.7	12.5
	MID-DAY 11-3	28.5	-	26.1	17.3	35.7	8.5	16.2
	LATE PM 3-12	12.7	-	56.3	23.8	35.1	9.5	21.0
	MEAN WEEKDAY	19.7	2.4	52.7	17.7	25.8	9.3	15.2
WEEKEND	MORNING 5-9	4.7	64.7	7.7	4.8	0.0	1.6	14.6
	MID-AM 9-11	15.0	76.0	22.5	-	14.7	4.0	9.6
	MID-DAY 11-3	26.4	302.3	35.3	66.0	14.5	8.5	26.4
	LATE PM 3-12	143.0	258.8	53.1	19.9	12.6	7.5	37.1
	MEAN WEEKEND	26.2	116.3	37.0	23.2	13.1	5.4	22.4

TABLE 1.7

Comparison of the American shad catch, catch per effort, and effort between discharges with one or two unit generation and high discharges (three or more unit generation) at the Conowingo Dam Fish Lift, 5 April to 18 June 1989.

Generation Status	No. Shad Caught	Total Minutes Fished	Number of Lifts	Shad Catch per Hour
One Unit	1050	566	33	111.31
Two Unit	1628	2210	136	44.20
High	5633	26016	993	12.99
Total	8311	28792	1162	17.32

TABLE 1.8

Catch of American shad in the Conowingo Fish Lift by water temperatures, 5 April to 18 June 1989.

Water Temp. (F)	Hours Fishing	CATCH		
		Number	Catch/ Effort	Percent
LE 65	269.70	4541	16.84	54.6
GT 65	210.17	3770	17.94	45.4
Total	479.87	8311	17.32	100.0

TABLE 1.9

Summary of transportation of American Shad from Conowingo Dam Fish Lift, 05 April to 18 June, 1989.

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
21 APR	33	54.2	107	FALMOUTH	1	99.1	9.0	9.0	53.6
22 APR	116	54.4	102	FALMOUTH	0	100.0	19.6	11.1	53.6
24 APR	157	55.4	68	B. W. INTAKE	0	100.0	-	-	-
			177	FALMOUTH	1	99.4	18.6	15.6	56.8
26 APR	165	57.6	134	FALMOUTH	0	100.0	20.0	12.1	53.6
27 APR	388	58.0	163	FALMOUTH	0	100.0	18.0	13.0	57.2
			257	FALMOUTH	3	98.8	15.8	15.0	-
28 APR	298	58.1	120	FALMOUTH	0	100.0	14.6	12.8	60.4
			261	FALMOUTH	0	100.0	18.6	14.8	60.8
29 APR	512	59.0	247	FALMOUTH	0	100.0	20.0	11.9	58.8
			261	FALMOUTH	1	99.6	16.8	15.8	59.0
30 APR	247	58.9	222	FALMOUTH	0	100.0	10.0	13.4	61.7
01 MAY	410	59.4	271	FALMOUTH	0	100.0	19.8	11.2	63.0
			140	FALMOUTH	0	100.0	14.2	19.0	-
02 MAY	975	60.8	305	FALMOUTH	0	100.0	14.2	14.2	60.8
			259	FALMOUTH	1	99.6	12.2	9.0	60.8
			323	FALMOUTH	0	100.0	14.8	9.2	60.8
03 MAY	232	60.8	229	FALMOUTH	0	100.0	12.9	12.8	59.4
04 MAY	101	59.0	158	FALMOUTH	0	100.0	16.7	9.7	59.5
22 MAY	88	63.5	5	B. W. INTAKE	0	100.0	-	-	61.7
23 MAY	68	64.4	94	B. W. INTAKE	0	100.0	16.8	16.8	-
24 MAY	41	64.4	175	FALMOUTH	0	100.0	13.0	9.0	60.8
27 MAY	95	64.8	162	FALMOUTH	0	100.0	14.2	12.4	66.2
30 MAY	263	66.6	185	WELLSBORO	22	88.1	13.2	14.6	64.4
			218	FALMOUTH	1	99.5	17.4	10.0	66.2
31 MAY	257	66.8	159	FALMOUTH	1	99.4	8.6	10.5	68.0
01 JUN	155	68.9	150	FALMOUTH	0	100.0	17.0	8.6	72.3
02 JUN	418	68.9	241	FALMOUTH	10	95.9	20.0	10.2	68.4
03 JUN	232	69.9	170	FALMOUTH	7	95.9	13.9	8.5	73.6
			91	FALMOUTH	1	98.9	9.5	9.5	75.2
04 JUN	1417	70.4	164	BAINBRIDGE	1	99.4	14.4	12.2	74.8
			217	FALMOUTH	10	95.4	14.2	13.5	76.1
			241	BAINBRIDGE	27	88.8	16.6	14.8	76.1
			264	FALMOUTH	25	90.5	15.2	8.9	73.9
05 JUN	103	71.6	61	B. W. INTAKE	0	100.0	-	-	-
06 JUN	29	73.4	46	WELLSBORO	0	100.0	-	-	-
07 JUN	7	74.7	64	FALMOUTH	0	100.0	16.8	10.0	68.2
10 JUN	67	72.5	75	FALMOUTH	0	100.0	12.6	15.2	68.4
12 JUN	96	71.5	17	WELLSBORO	0	100.0	13.7	13.7	-
			92	FALMOUTH	0	100.0	17.2	10.6	68.9
13 JUN	256	71.6	136	FALMOUTH	2	98.5	12.2	12.9	68.4
			33	FALMOUTH	0	100.0	13.9	13.4	68.0
18 JUN	8	71.5	81	FALMOUTH	0	100.0	18.0	9.2	69.4
SEASON TOTALS			6945		114	98.4			

TABLE 1.10

Daily sex ratio of American shad at the Conowingo Dam Fish Lift for 1989.

DATE	DAILY CATCH	NO. SEXED	NO. OF MALES	NO. OF FEMALES	RATIO (M/F)
05 APR	0	0			
07 APR	1	1	1		1:0
09 APR	0	0			
11 APR	0	0			
13 APR	0	0			
15 APR	1	1	1		1:0
17 APR	0	0			
19 APR	54	54	51	3	17.0:1
20 APR	32	32	28	4	7.0:1
21 APR	33	33	29	4	7.3:1
22 APR	116	116	95	21	4.5:1
23 APR	84	84	71	13	5.5:1
24 APR	157	93	78	15	5.2:1
25 APR	133	132	118	14	8.4:1
26 APR	165	110	89	21	4.2:1
27 APR	388	108	90	18	5.0:1
28 APR	298	107	85	22	3.9:1
29 APR	512	129	112	17	6.6:1
30 APR	247	197	160	37	4.3:1
01 MAY	410	130	110	20	5.5:1
02 MAY	975	121	96	25	3.8:1
03 MAY	232	158	133	25	5.3:1
04 MAY	101	100	87	13	6.7:1
05 MAY	40	40	34	6	5.7:1
06 MAY	1	1	1		1:0
21 MAY	86	86	71	15	4.7:1
22 MAY	88	86	74	12	6.2:1
23 MAY	68	68	60	8	7.5:1
24 MAY	41	41	37	4	9.3:1
25 MAY	27	26	21	5	4.2:1
26 MAY	161	108	89	19	4.7:1
27 MAY	95	94	78	16	4.9:1
28 MAY	94	92	77	15	5.1:1
29 MAY	124	113	104	9	11.6:1
30 MAY	263	206	165	41	4.0:1
31 MAY	257	254	203	51	4.0:1
01 JUN	155	124	99	25	4.0:1
02 JUN	418	128	80	48	1.7:1
03 JUN	232	105	70	35	2.0:1
04 JUN	1417	139	91	48	1.9:1
05 JUN	103	100	66	34	1.9:1
06 JUN	29	29	18	11	1.6:1
07 JUN	7	7	4	3	1.3:1
08 JUN	21	19	12	7	1.7:1
09 JUN	36	36	28	8	3.5:1
10 JUN	67	67	39	28	1.4:1
11 JUN	63	63	41	22	1.9:1
12 JUN	96	96	37	59	0.6:1
13 JUN	256	116	41	75	0.5:1
14 JUN	16	16	9	7	1.3:1
15 JUN	18	18	10	8	1.3:1
16 JUN	65	65	35	30	1.2:1
17 JUN	20	20	11	9	1.2:1
18 JUN	8	8	7	1	7.0:1
SEASON TOTALS	8311	4077	3146	931	3.4:1

TABLE 1.11

Age and spawning history of American shad collected at the Conowingo Dam Fish Lift in 1989; by sex, with mean, minimum and maximum fork length (mm).

Sex	Age	N	Spawning History			Fork Lengths		
				Repeats		mean	min	max
			Virgins	Once	Twice			
MALE	II	1	1			238	238	238
	III	23	23			306	242	352
	IV	112	108	4		368	309	449
	V	118	106	11	1	403	339	500
	VI	31	28	2	1	460	395	531
	VII	3	3			479	468	485
Subtotal		288	269	17	2	388	238	531
FEMALE	IV	13	13			411	380	440
	V	54	51	3		451	372	515
	VI	44	41	1	2	485	435	530
	VII	15	12	2	1	516	456	570
Subtotal		126	117	6	3	466	372	570
Total		414	386	23	5	412	238	570

Age and Spawning history of American shad collected at the Conowingo Dam Fish Lift in 1989; by sex, with mean, minimum and maximum fork length (mm).

Sex	Disposition	Age	N	Spawning History: Virgins	Repeats: Once	Repeats: Twice	Fork Lengths: mean	min	max
MALE	RELEASED	III	4	4			297	264	326
		IV	33	32	1		366	333	418
		V	31	26	5		404	339	463
		VI	11	11			454	395	482
		VII	1	1			468	468	468
	Totals		80	74	6	0	391	264	482
	HANDLING MORTALITY	III	3	3			304	295	315
		IV	23	21	2		370	334	436
		V	41	36	4	1	405	342	481
		VI	11	9	2		458	410	531
	Totals		78	69	8	1	398	295	531
	SACRIFICED	II	1	1			238	238	238
		III	16	16			309	242	352
		IV	56	55	1		369	309	449
		V	46	44	2		401	345	500
		VI	9	8		1	470	419	518
		VII	2	2			485	484	485
	Totals		130	126	3	1	380	238	518
Totals for Sex			288	269	17	2	388	238	531

Sex	Disposition	Age	N	Spawning History: Virgins	Repeats: Once	Repeats: Twice	Fork Lengths: mean	min	max
FEMALE	RELEASED	IV	3	3			412	396	420
		V	11	9	2		441	372	474
		VI	3	2	1		483	462	517
	Totals		17	14	3	0	444	372	517
	HANDLING MORTALITY	IV	5	5			407	388	430
		V	35	34	1		461	396	515
		VI	31	29		2	482	435	530
		VII	11	8	2	1	505	456	570
	Totals		82	76	3	3	472	388	570
	SACRIFICED	IV	5	5			415	380	440
		V	8	8			421	396	453
		VI	10	10			495	451	529
		VII	4	4			545	533	556
	Totals		27	27	0	0	466	380	556
Totals for Sex			126	117	6	3	466	372	570
Combined Totals			414	386	23	5	412	238	570

TABLE 1.13

Daily catch of American shad at the Conowingo Dam Fish Lift when Maryland DNR tagged shad were recaptured at the Lift in 1989.

Date	Daily Catch	No. of MD DNR Recaptures
28 Apr	298	1
30 Apr	247	1
1 May	410	2
2 May	975	5
3 May	232	2
22 May	88	2
25 May	27	2
26 May	161	1
27 May	95	2
28 May	94	1
29 May	124	1
30 May	263	4
31 May	257	1
2 Jun	418	2
3 Jun	232	2
4 Jun	1417	16
5 Jun	103	2
8 Jun	21	1
10 Jun	67	2
11 Jun	63	1
12 Jun	96	3
13 Jun	256	7
16 Jun	65	2
	6009	63

TABLE 1.14

Summary of American Shad catch by constant generation levels
(varying generation during a lift grouped separately)
1 April to 18 June, 1985 through 1989. Cleanout lifts excluded.

TOTAL DISCHARGE (X 1000 CFS)	UNIT 1	UNIT 2	1985				1986				1987				1988				1989			
			NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/HR	NO. LIFTS	TIME (MINS.)	TOTAL SHAD	SHAD/H
LE 5	OFF	OFF	229	4768	689	8.7	107	4394	3056	41.7	246	4842	2428	30.1	257	5984	2250	22.6	33	566	1050	111.
LE 5	OFF	ON	-	-	-	-	-	-	-	-	-	-	-	-	16	317	4	0.8	-	-	-	-
LE 5	ON	OFF	-	-	-	-	-	-	-	-	2	28	0	0.0	-	-	-	-	-	-	-	-
*TOTAL LE 5			229	4768	689	8.7	107	4394	3056	41.7	248	4870	2428	29.9	273	6301	2254	21.5	33	566	1050	111.
10-40	CHG	CHG	-	-	-	-	-	-	-	-	-	-	-	-	1	27	0	0.0	-	-	-	-
10-40	OFF	OFF	175	3660	116	1.9	154	4747	433	5.5	282	6488	2875	26.6	125	2648	642	14.5	377	6646	3103	28.
10-40	OFF	ON	-	-	-	-	3	77	1	0.8	-	-	-	-	19	298	132	26.6	2	60	75	75.
10-40	ON	OFF	26	477	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-40	ON	ON	11	22	0	0.0	3	43	0	0.0	2	30	0	0.0	25	441	66	9.0	-	-	-	-
*TOTAL 10-40			212	4159	116	1.7	160	4867	434	5.4	284	6518	2875	26.5	170	3414	840	14.8	379	6706	3178	28.
VARYING	CHG	CHG	3	47	0	0.0	21	857	44	3.1	32	801	50	3.7	46	1067	100	5.6	2	10	0	0.
VARYING	CHG	OFF	4	85	0	0.0	1	30	3	6.0	5	112	3	1.6	2	60	0	0.0	3	96	0	0.
VARYING	CHG	ON	-	-	-	-	1	30	23	46.0	4	105	8	4.6	16	432	18	2.5	-	-	-	-
VARYING	OFF	CHG	6	180	6	2.0	16	513	11	1.3	7	211	10	2.8	10	269	16	3.6	9	319	183	34.
VARYING	OFF	OFF	184	5050	341	4.1	132	4866	651	8.0	171	4932	920	11.2	98.	2547	638	15.0	150	4205	1466	20.
VARYING	OFF	ON	3	90	0	0.0	8	470	13	1.7	1	30	2	4.0	5	158	13	4.9	2	90	36	24.
VARYING	ON	CHG	1	25	0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VARYING	ON	OFF	12	293	1	0.2	-	-	-	-	-	-	-	-	1	8	0	0.0	-	-	-	-
VARYING	ON	ON	3	34	1	1.8	6	424	2	0.3	8	189	17	5.4	31	807	43	3.2	-	-	-	-
*TOTAL VARYING			216	5804	349	3.6	185	7190	747	6.2	228	6380	1010	9.5	209	5348	828	9.3	166	4720	1685	21.
+ 40	OFF	OFF	300	8222	379	2.8	166	5136	779	9.1	170	4955	852	10.3	125	3397	547	9.7	442	14313	2206	9.
+ 40	OFF	ON	17	481	4	0.5	79	2663	85	1.9	30	808	66	4.9	29	832	113	8.1	44	1364	152	6.
+ 40	ON	OFF	58	1352	1	0.0	7	175	0	0.0	29	629	73	7.0	3	49	0	0.0	-	-	-	-
+ 40	ON	ON	41	722	2	0.2	77	2760	39	0.8	365	7776	355	2.7	493	12057	574	2.9	44	1123	9	0.
*TOTAL + 40			416	10777	386	2.1	329	10734	903	5.0	594	14168	1346	5.7	650	16335	1234	4.5	530	16800	2367	8.
			1073	25508	1540	3.6	781	27185	5140	11.3	1354	31936	7659	14.4	1302	31398	5156	9.9	1108	28792	8280	17.3

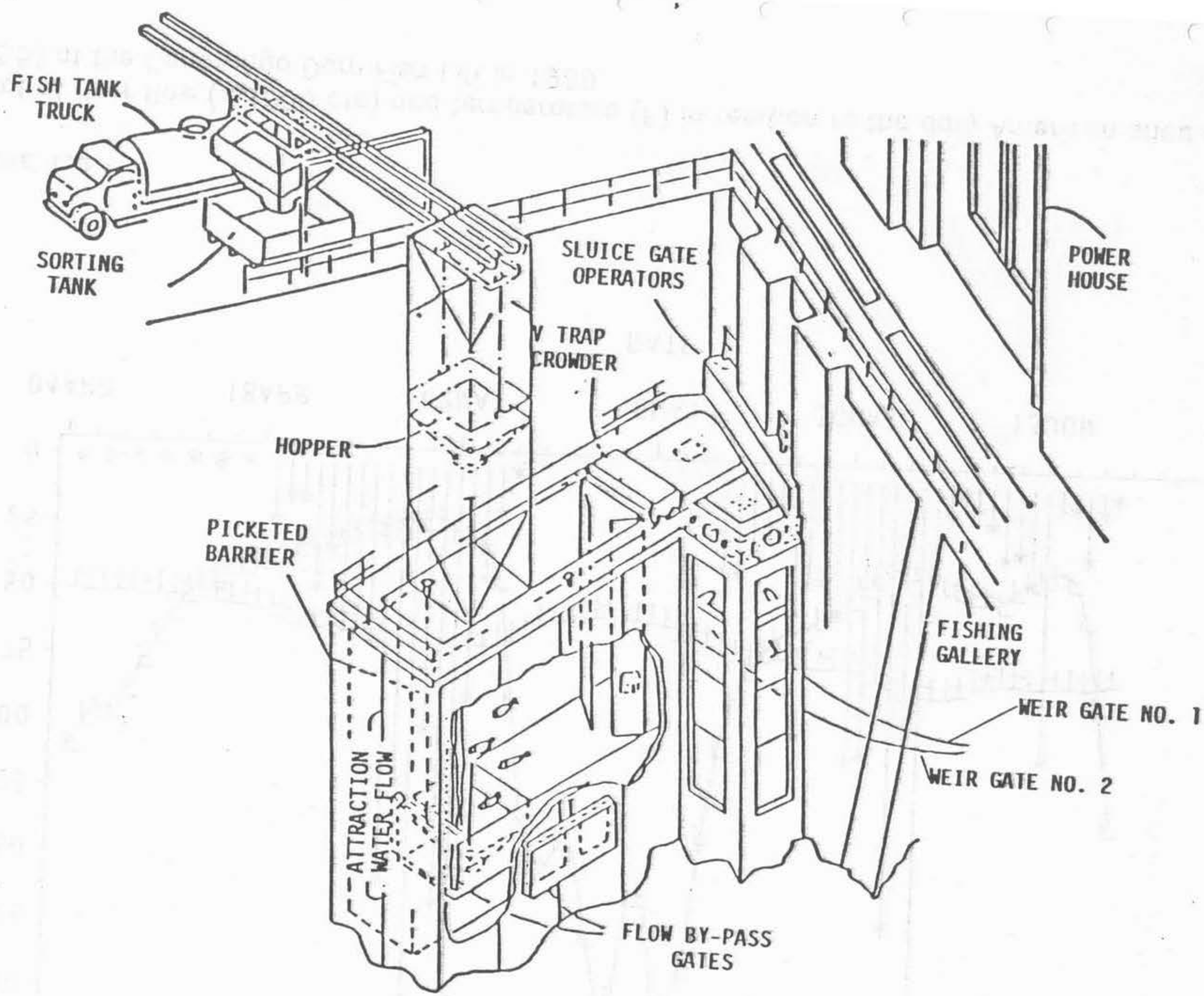


FIGURE 1.1

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

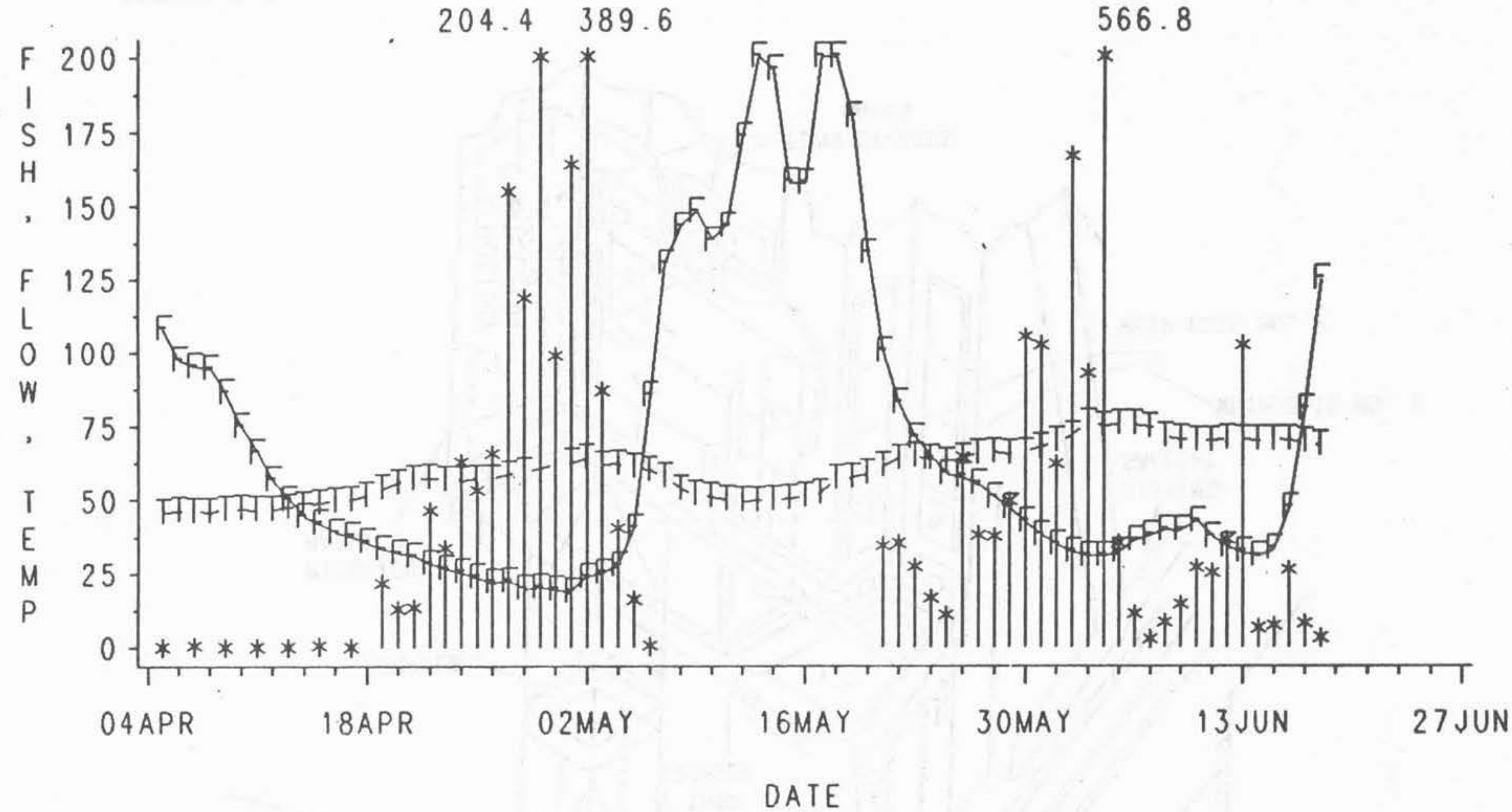


FIGURE 1.2

A plot of river flow (x 1000 cfs) and temperature (F) in relation to the daily American shad catch (x 2.5) at the Conowingo Dam Fish Lift in 1989.

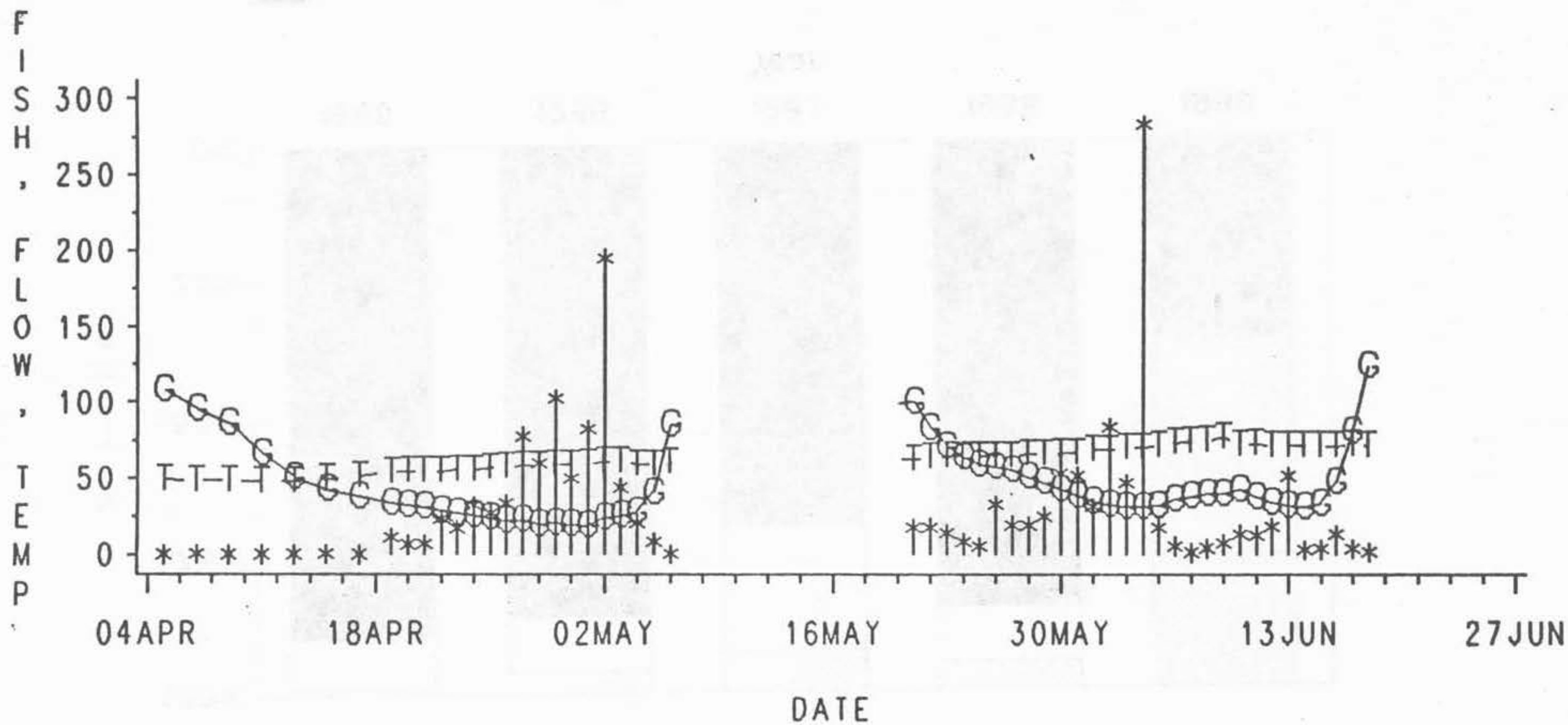
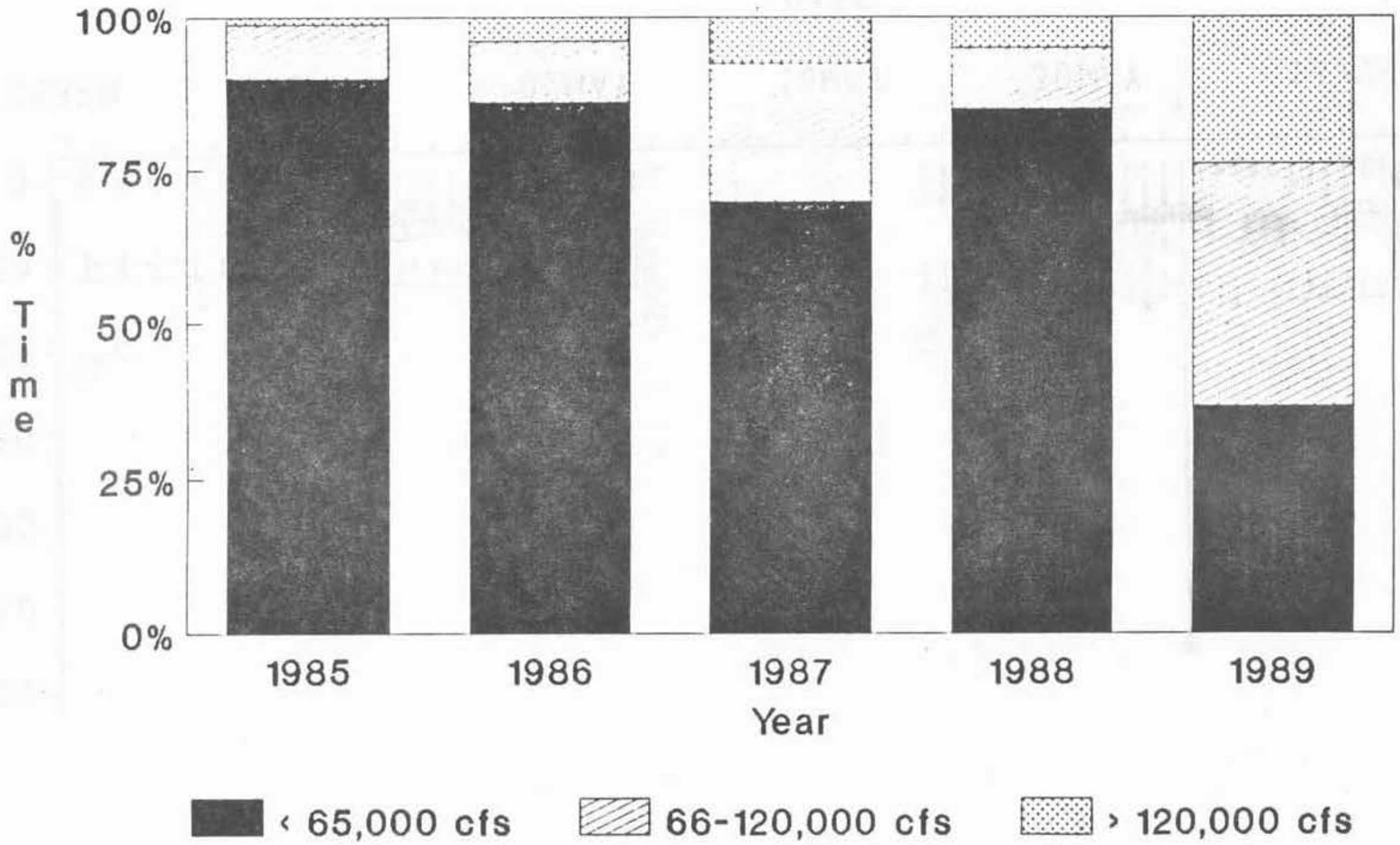


FIGURE 1.3

A plot of total draft (x 1000 cfs) and temperature (F) in relation to the daily American shad catch (x 5) at the Conowingo Dam Fish Lift in 1989. Total draft is the average during daily lift operation.

FIGURE 1.4.

Percentage of time river flows (cfs) were at various levels during Spring, 1985-89.



1.5

Percentage of time that the Conowingo Dam Fish Lift operated with Units 1 and 2 off, 1985-89.

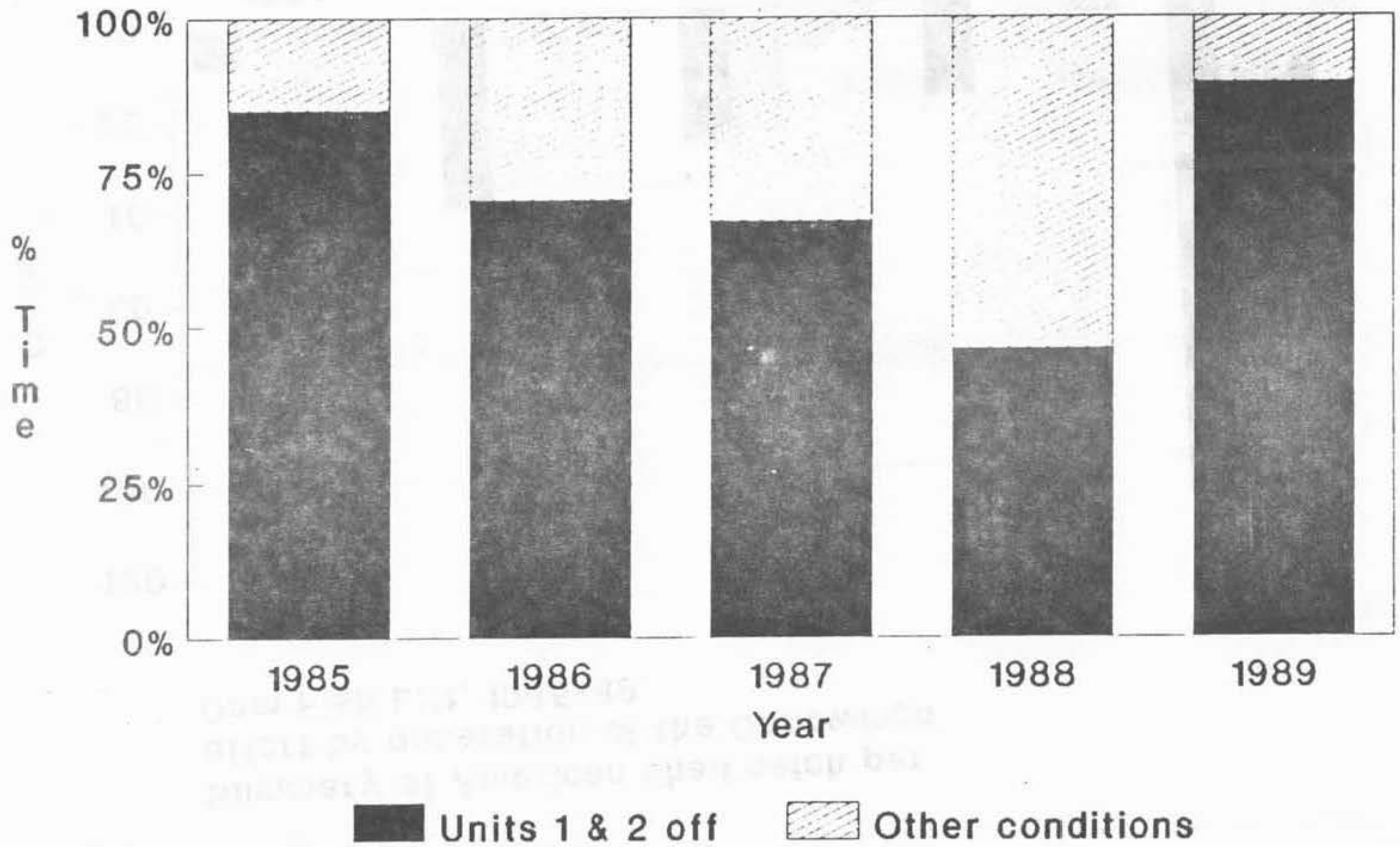


FIGURE 1.6.

Summary of American shad catch per effort by generation at the Conowingo Dam Fish Lift, 1985-89.

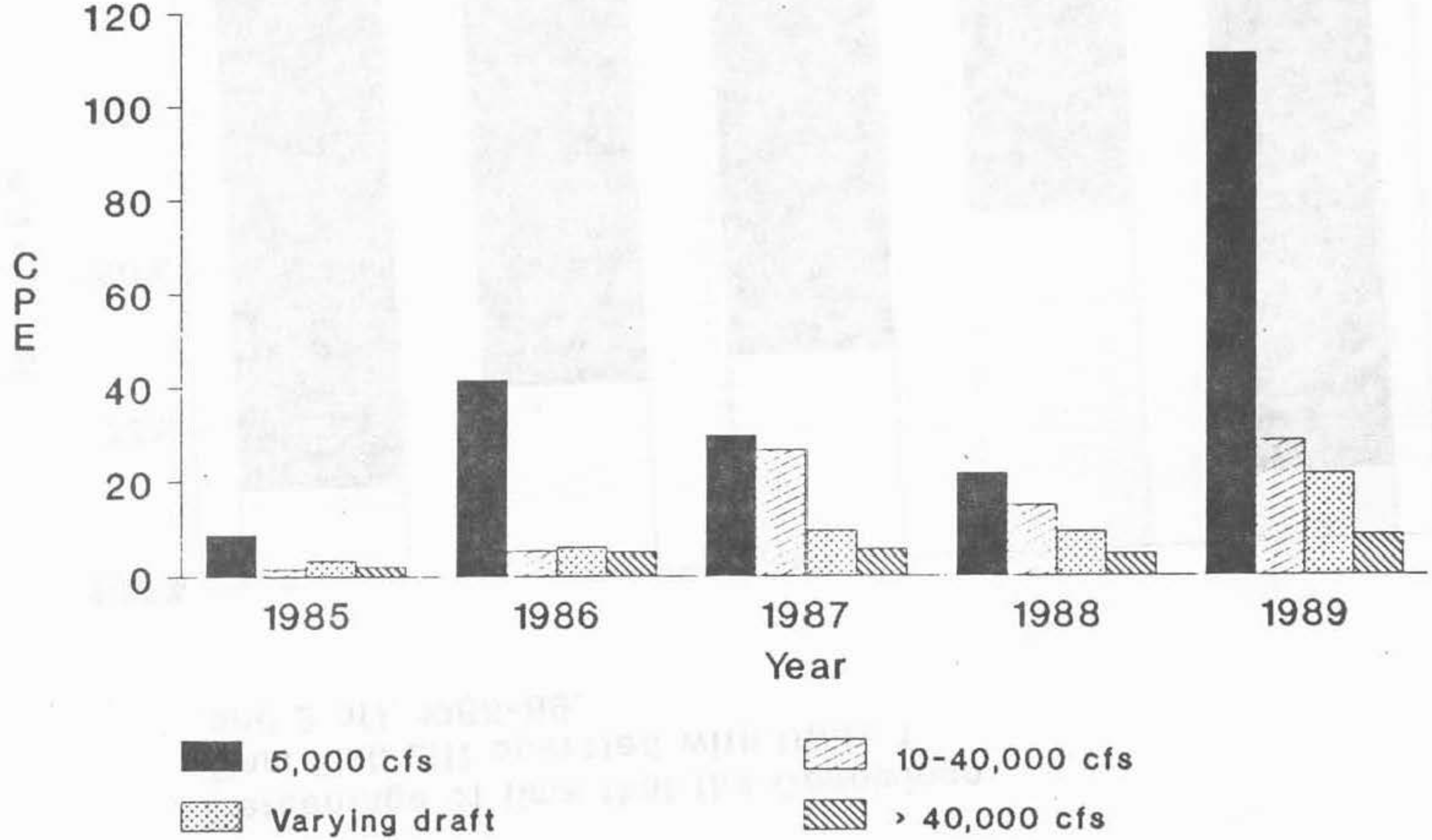


FIGURE 1.7

Summary of the American shad catch per effort by generation at the Conowingo Dam Fish Lift, April, 1985-89.

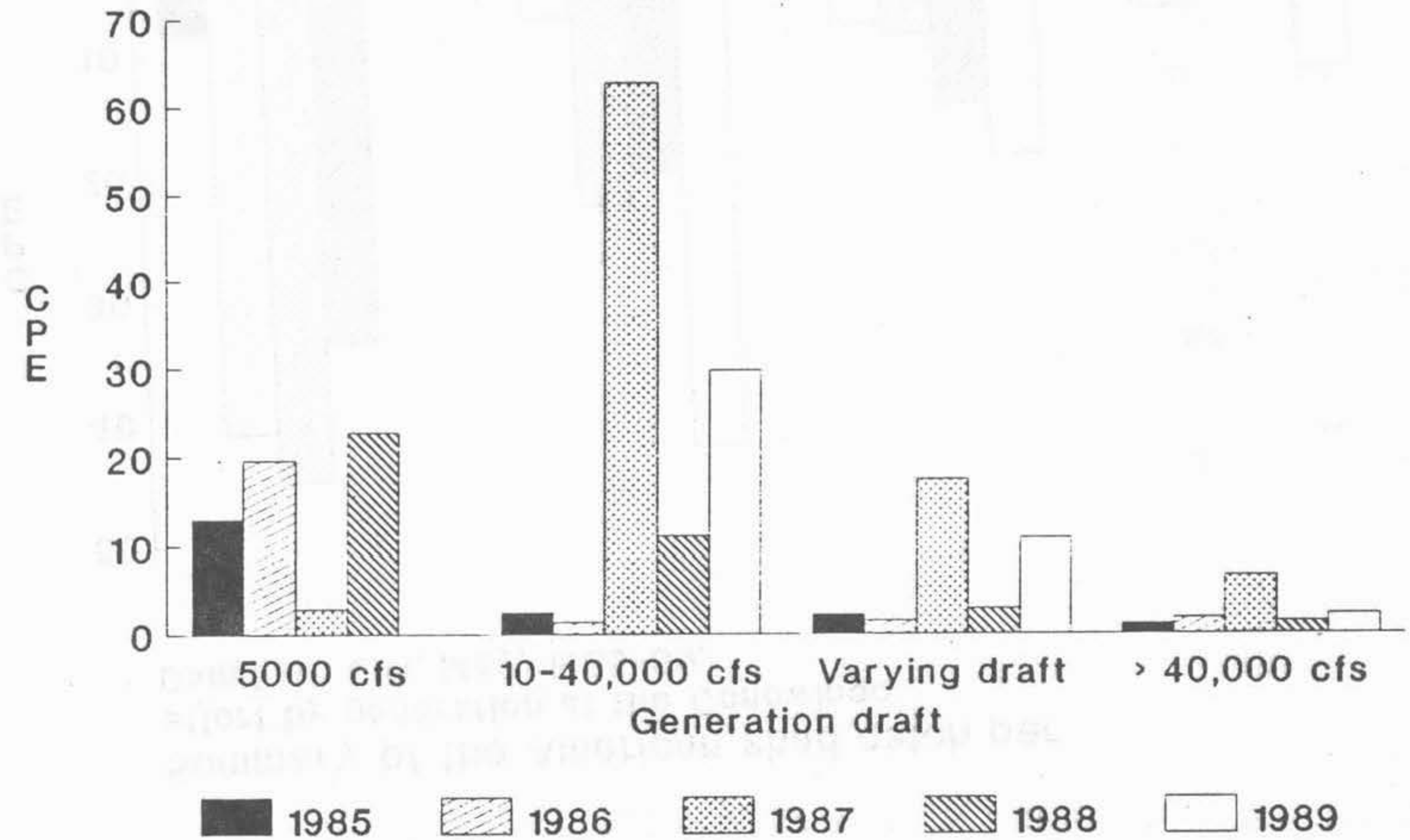


FIGURE 1.8

Summary of the American shad catch per effort by generation at the Conowingo Dam Fish Lift, May, 1985-89.

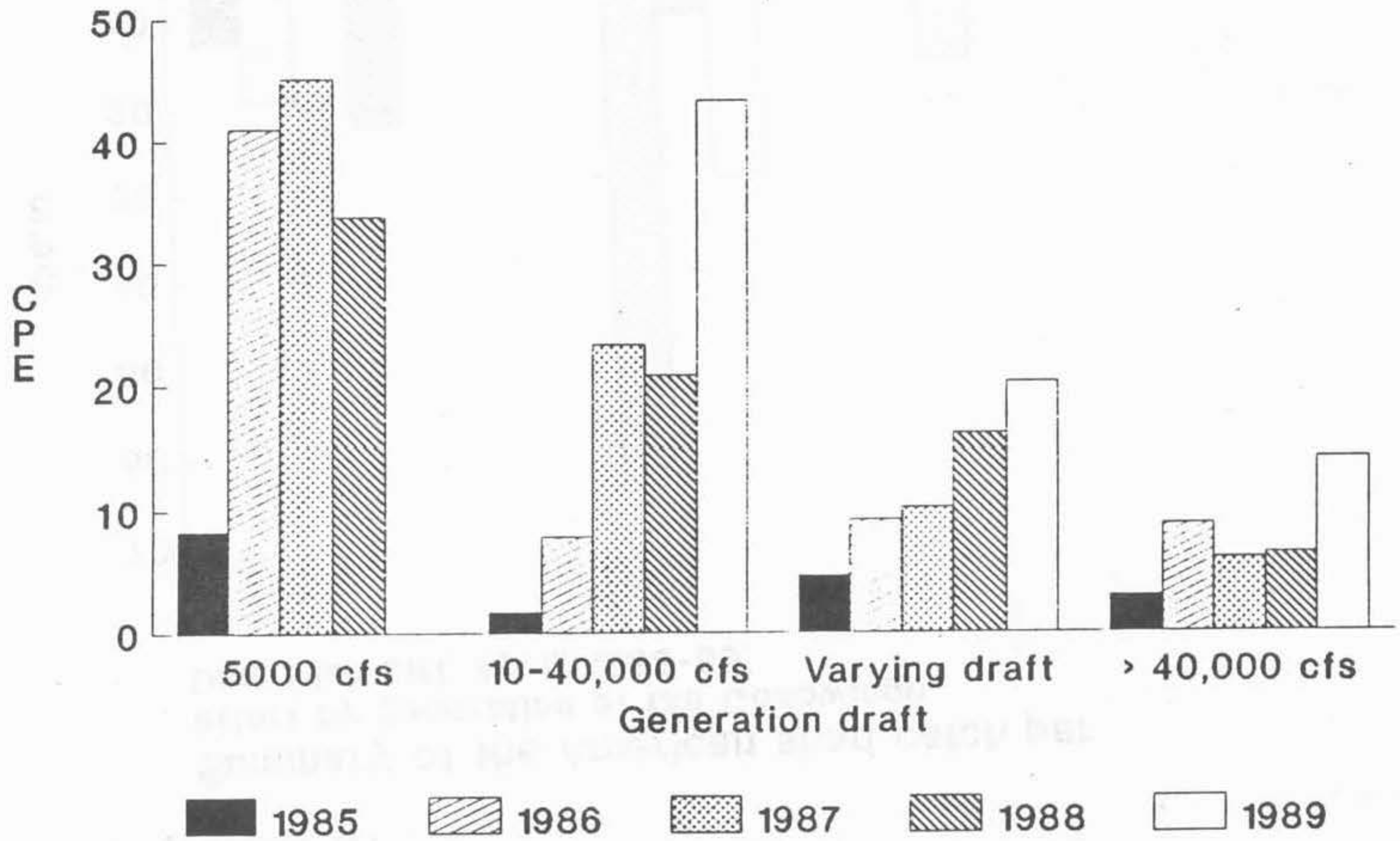
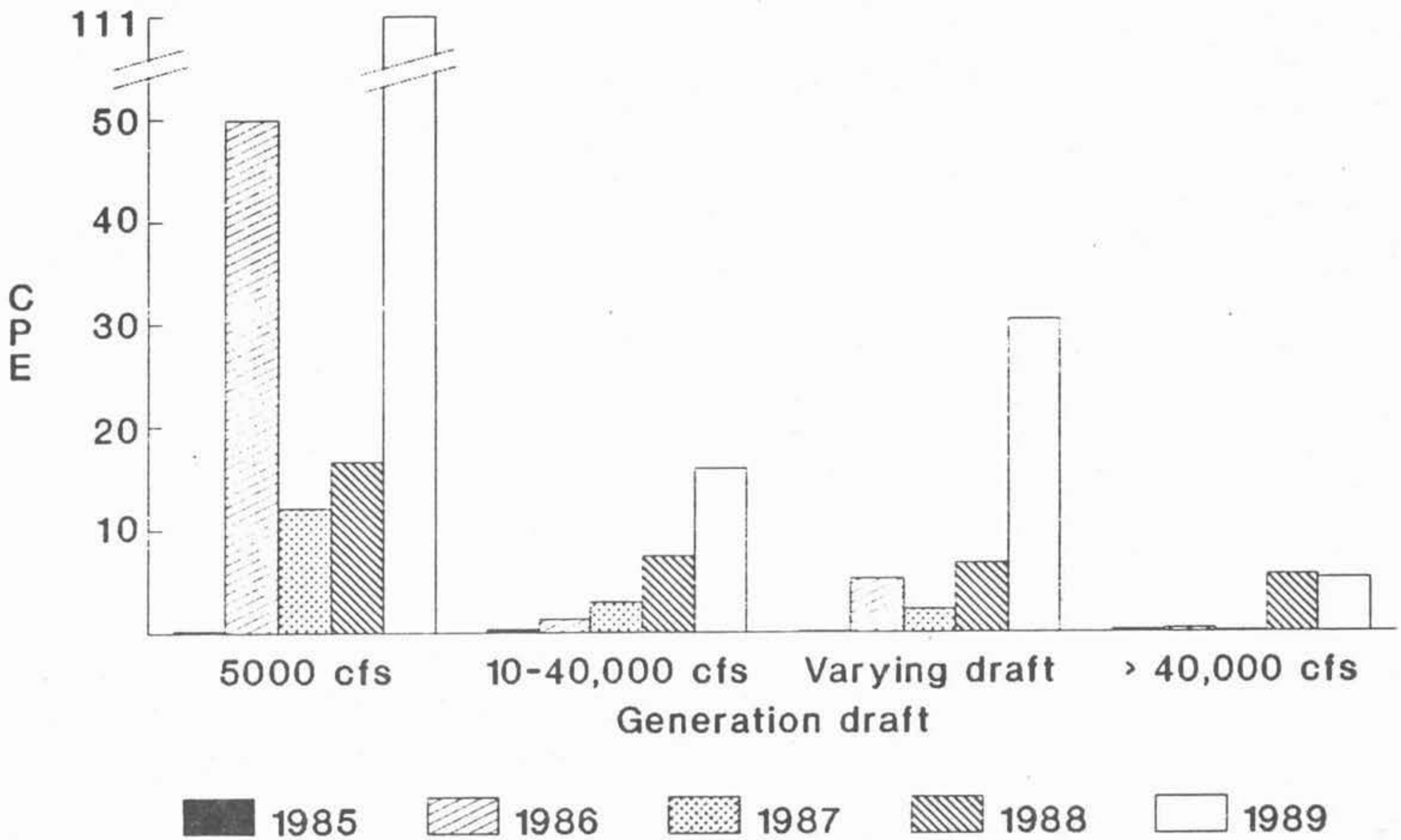


FIGURE 1.9

Summary of the American shad catch per effort by generation at the Conowingo Dam Fish Lift, June, 1985-89.



JOB II

AMERICAN SHAD EGG COLLECTION PROGRAM

J.A. NACK

National Environmental Services, Inc.

Lancaster, PA

2.1 INTRODUCTION

In September 1970, an agreement was signed between various utilities (Philadelphia Electric Power Company, Susquehanna Electric Company, Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, Metropolitan Edison Company, the States (Maryland, Pennsylvania and New York), and the U.S. Department of Interior for the implementation of a program for restoration of the American shad to the Susquehanna River. Part of the agreement called for a program to annually obtain 50 million or more artificially fertilized American shad eggs for transplantation to areas above existing dams on the Susquehanna River. The objective was to artificially develop a population of American shad which, as adults, would return to the river with the urge to migrate upriver above Conowingo and the other hydroelectric dams. The program began in the spring of 1971 and has continued annually to date. The 1989 results are included in this report.

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

2.1.1 Hatchery Program

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

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

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

2.2 OBJECTIVE OF PROGRAM

The SRAFRC goal for 1989 was to obtain sufficient number of shad eggs (35-45 million) over a three month period (April-June) to support the shad hatchery cultural program (Job III). From 1973 to 1988 over 400 million eggs were collected for the program (Table 1). A record 52.5 million eggs (5,535.7L) were sent to the Van Dyke Hatchery in 40 shipments in 1986. In 1989, eggs were to be collected from five rivers -- Pamunkey and James (Virginia), Delaware (New Jersey-Pennsylvania) Hudson (New York) and the Columbia (Oregon-Washington). The Cape Fear River, North Carolina, where experimental efforts were made in 1988, was deleted from the program in 1989 due to not being able to obtain enough spawning shad from local fishermen or through NES netting efforts.

2.3 METHODS

2.3.1 Egg Collection

Eggs were artificially fertilized using essentially the same method established by Kilcer (1973). A brief description of the procedure follows: Eggs were stripped from four to six spawning females into a dry collecting pan and fertilized with sperm from up to six live males. After dry mixing eggs and sperm for several minutes, a small amount of water was then added to the mixing pan to activate sperm and the gametes to ensure fertilization. The eggs were then allowed to set from 1 to 4 minutes. After the eggs settled, the water was drained and clean water added to the mixing pan. The eggs were rinsed to remove dead sperm, unfertilized and broken eggs, and debris. This rinsing process was repeated until all eggs were clean, which took four or more rinses. Eggs were then poured into large plastic buckets filled with clean river water and allowed to soak for a minimum of one hour to become hardened. During this period, water was periodically drained and clean water added.

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

On the Columbia River, although it represents a substantial source of eggs because of the large shad population, certain logistic difficulties have potentially negative impact on the shad egg collection program. The prime problem has been a relationship between time available to fish and the airline schedule for shipment of eggs back to the East Coast. It was no exception in 1989. In order to get eggs to the airport in time for the flight, the shipment had to be at the airport by 11:00 P.M. Thus, all fishing and operations to fertilize and harden the eggs needed to be completed by 10:30 P.M. Depending on the success of fishing, this meant that there might not be sufficient time to process all of the eggs collected.

2.3.2 Collection Areas (Table 2)

2.3.2.1 Pamunkey River

Egg collection efforts on the Pamunkey River commenced on 6 April 1989, after reports from commercial fishermen indicated that water temperature was approaching 55°F, and that spawning fish were appearing in gill net catches. Operations ceased on 27 April 1989 when spawning fish were no longer being caught.

NES biologists worked with up to five commercial fishermen at Thompson's Landing, New Kent, Virginia, located approximately 4-6 miles upstream of Lester Manor. Up to 21 gill nets, 4.75-6.00 inch mesh, were set out at any one time and drifted over a two mile stretch of river to catch adult shad. Netting operations were normally conducted between 1530 and 2200 hours, seven days a week. As fish were captured, they were shuttled to the shoreline where fish in spawning condition were processed.

2.3.2.2 James River, Virginia

Egg collections on the James River were initiated on 16 April, after commercial fishermen reported to NES biologists that they had caught a few ripe shad.

Only one commercial fisherman consistently fished the James River. Fishermen who had fished in previous years had either died or were no longer fishing. On a few nights, however, a second fisherman did fish. A total of five nets were used when both fishermen fished. Nets were of a similar mesh to those used on the Pamunkey.

An NES technician worked on the boat, with the fishermen, and stripped the roe and milt from the fish as they were caught. When two boats were fishing, efforts were co-ordinated to recover the eggs as expeditiously as possible.

2.3.2.3 Delaware River

In 1989, SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative to collect some 10 million shad eggs from the Delaware River. PFC biologists and biologists from Ecology III, Inc. conducted the collection program at Smithfield Beach, 8 miles upstream from East Stroudsburg, PA., from 21 May to 1 June. Shad were captured with 200 foot long x 6 feet deep anchored gill nets, with sections of 4.75-6.00 inch mesh, set parallel to the current. Up to 10 net sets were made in an evening. Nets were set between dusk and midnight. Spawning shad were shuttled to the shore for processing.

2.3.2.4 **Hudson River**

Information acquired through egg collection efforts on the Hudson River in 1988 led to an expanded effort in 1989. Although large numbers of eggs had not been collected from the Hudson River in past years, NES biologists found several spawning locations and caught ripe shad near the finish of the 1988 season. This research led to the goal of 10 million or more eggs set by SRAFRC for 1989. Eggs were to be collected by three methods: (1) gill netting, (2) NES haul seine operations, and (3) surveys of the NYSDEC haul seine efforts related to research on the Hudson River.

Sporadic efforts were made in the past to collect eggs from the Hudson River, primarily from haul seine operations designed to capture shad for the adult transfer program (terminated after 1987). Although the Hudson River has one of the largest populations of shad, efforts by commercial fishermen had not demonstrated where spawning shad might be taken. In 1989, NES undertook a gill-netting program to seek areas where spawning shad might be captured based on 1988 gill netting research. NES also expanded the haul seine operation to collect spawning shad at specific locations where it was known that ripe shad had been collected in the past.

In 1987 and 1988 NES biologists captured some spawning shad by gill nets while researching potential spawning areas between Hudson and Kingston, N.Y. The goal has always been to capture enough spawners to consistently ship large numbers of eggs to the PFC hatchery as has been done for other rivers. Information from the NYDEC New Platz office showed that shad spawned from Poughkeepsie north to the Troy Dam near Albany. The largest concentrations of eggs were noted to be found in the Catskill region when eggs were collected by bottom trawls and sleds during the power plant studies in the 1970's.

With this information available NES biologists began field operations in mid-April in hopes of achieving the SRAFRC goal of collecting 10 million or more eggs.

NES Gill Netting

Biologists began gill net operations early enough to develop the methodology needed for successful egg shipments as well as monitoring spawning behavior should spawning shad be collected. Up to five, 600 x 6 ft. and 600 x 8 ft. deep monofilament gill nets were set in areas along the east shore begining at 1600 hrs. The optimal condition for gill netting is at a period of "slack" tide or a slow moving flood tide. During this time and between 1700 and 2100 hours shad moved out of the channel and into the sand flats in shallow water depths where spawning takes place. While gill nets were anchored in known spawning areas, biologists drifted floating gill nets along the channel bank and adjacent to the set nets in an effort to capture all spawners from within an area.

Specifically there were three East shore areas from which gill netting was conducted: (1) Cheviot, N.Y., (2) between the Roe Jan Creek and Livingston's dock, (3) and on the west shore of Rodgers Island north of the Rip Van Winkle bridge. There was also one area across from Rodgers Island on the West shore south of the power line crossing where gill netting was practiced. Spawning shad were taken at all four locations.

Commercial Fishermen Haul Seine

Most eggs collected in 1989 were acquired from spawning shad captured with a 500-foot haul or beach seine. Haul seine operations have been conducted on the west shore of Rodgers Island (begining in 1984) at an area immediately north of the Rip Van Winkle bridge. Although thousands of shad are captured from this area each year by commercial fishermen, attempts to collect eggs have been fruitless due to lack of spawning females. As river temperature increased it was apparent that shad had to spawn somewhere near the seine site.

NES biologists and the commercial fishermen moved the seining operation north along the channel bank to an area where spawning females were previously caught with gill nets. With the ebb tide, fishermen and biologists began seining late in the afternoon at a time when the tide permitted a landing site, an area from where the net and catch could effectively be pulled in. After the net was pulled in and the shad were contained in the bag of the net the commercial fishermen sorted through the fish and loaded tubs full of spawning females. Biologists immediately processed the fish and eggs in a boat along side the seine. Live male shad were placed in a tank with cold water in an attempt to keep these fish alive and to ensure active sperm needed for fertilization.

New York Department of Environmental Conservation (NYDEC) Haul Seine

NES biologists made arrangements with NYDEC field personnel from the New Platz, N.Y. office to monitor their haul seine catches for spawning shad. Haul seine catches were conducted on 11 May in selected areas along the west shore of Rodgers Island. Few shad were captured and after careful inspection it was apparent no spawners would have been caught at the times and locations of the NYDEC seining program. Their primary objective was to catch striped bass for a tagging program. Haul seining during high tide was ideal for capture of striped bass but was not conducive for capturing spawning shad and therefore no further efforts to monitor the NYDEC field program was made. Phone communications were made during the NYDEC's program as a means for monitoring for spawners as they moved their seining operations downriver. NES biologists concentrated their efforts on the commercial fishermen's seining program.

2.3.2.5 Columbia River

The egg collection program on the Columbia River, Oregon-Washington was initiated on 5 June. Netting for shad was conducted on the north shoreline approximately two miles upstream at the Camas-Washougal Reef (Troutdale area). Shad were captured by gill nets, as in previous years. Net dimensions were 150 fathoms in length, tapered in depth, with sections of 4.75-5.75 inch monofilament mesh. Typically, three 45-60 minute drifts were made nightly. Gill-netting was conducted from 1700 to 2400 hours.

2.4 TRANSPORTATION

2.4.1 Pamunkey, James, Delaware and Hudson Rivers

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

Personnel at the rivers arranged transportation and the drivers notified the hatchery nightly as to the number of liters shipped and the ETA of the shipment. The average delivery time from Delaware and Virginia-Hudson rivers was approximately 3 and 6 hours, respectively.

2.4.2 Columbia River

After packaging the eggs from the Columbia River, the boxes were transported by van to the Portland International Airport. Eggs were flown from Portland on United Airlines to Harrisburg International Airport (Harrisburg, PA.). Shipments were required at the airport by 2300 hrs (Pacific Time). Upon arrival of the shipments to the East Coast, eggs were transported by van to the hatchery. Approximate shipping time for eggs which departed Portland at 2300 hrs (Pacific Time) was 11-13 hours. Eggs arrived at the hatchery between 1200 and 1500 hours EST.

2.5 COLLECTION SCHEDULE

The shad egg collection schedule was based on experience gained over a 13 year period. Initiation of collection activities on any river was determined through communications with commercial fisherman and/or participation in fishing activities which documented that spawning shad were available in sufficient numbers. Collection activities usually began when water temperature was 58-

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.

On the Columbia River the minimum of 5 liters of eggs is not the usual basis for terminating the operation. It has been extremely rare that on any night of fishing on the Columbia River that less than 5 liters of eggs are obtained. Impacting factors on the Columbia River include the close of the commercial shad fishing season. The season usually closes in the third week of June.

2.6 RESULTS AND DISCUSSION

2.6.1 Pamunkey River

Collection efforts began on 6 April on the Pamunkey River, Virginia and continued until 26 April. Water temperatures ranged from 53 to 65 °F (Table 3). Egg collection efforts were halted on 26 April when commercial fishermen no longer caught shad. A total of 1.86 million eggs were collected in 1989.

Several factors influenced the catch and number of eggs shipped to the hatchery. Large scale netting operations at the mouth of the Chesapeake Bay may have reduced the number of shad reaching the spawning grounds at Thompson's Landing. Consequently, the total catch was poor. Also, fishermen who began working at 7:00 AM, were unwilling to continue fishing in the evening - when most of the spawning fish are caught - when total catch in the morning was 20-30 shad. Since the best fishing occured during slack tide, the desire not to fish was especially limiting when slack tides occurred from 7:30 PM and later in the evening.

Extremes in weather also had an adverse affect on the catch. On 6 April 1989, water temperature was 56 °F. On 7 April a cold front brought rain and snow. As a result, water temperature decreased rapidly to 48 °F on 9 April. It did not return to 55 °F until 17 April. A few spawning shad were caught in this interim period but it was not until 15 April that a sufficient number of fish were caught to produce a shipment of eggs.

2.6.2 James River

The normal procedure when working in Virginia is to check the progress of the run on the James River, on a daily basis, once efforts have started on the Pamunkey River. Thus, begining on 6 April daily contact was made with the commercial fisherman on the James River. The catch of shad was low and did not contain spawning fish until 16 April. Collection of eggs on the James River occurred from 16 to 26 April at water temperatures of 60 to 66 °F.

From 1974 through 1983 the James River was a consistant source of shad eggs for the program, some 64 million eggs were collected over that period (Table 1). However, production from the James River has dropped off significantly since 1983. In 1989 0.53 million shad eggs (Table 4) were collected. This did represent an increase over 1988.

As on the Pamunkey, poor catches and a late slack tide limited collection. Another serious problem was the presence of striped bass in relatively high numbers. As many as 80 fish would be caught in an evening. Their tendency to tear and tangle nets limited the number of drifts the fishermen were willing to make.

2.6.3 Delaware River

Pennsylvania Fish Commission biologists and Ecology III biologists conducted shad egg collection efforts on the Delaware River on nine days, begining on 21 May and ending on 1 June. Approximately 6 million eggs (Table 5) were shipped to the Van Dyke Hatchery on five dates.

2.6.4 Hudson River

Egg collection on the Hudson River began on 26 April when NES biologists set anchored gill nets. River temperature was 50 °F and commercial haul seine operations had been netting green shad since 15 April. As river temperature increased to 52 °F some spawning shad were caught by gill nets. NES biologists continued to monitor the commercial haul seine harvest daily and gill net at night. On 10 May the first shipment of 8.1 liters of eggs collected by gill net were sent to the PFC hatchery (Table 6).

On 15 May, the first eggs from the haul seine catch of shad was shipped to the hatchery (Table 6). Eggs from this source were shipped on the next seven consecutive days. The total number of eggs from fish caught by gill net was 1.6 million. The total number of eggs from fish caught by haul seine was 9.6 million.

Both gill net caught fish and haul seine caught fish represent potential sources of eggs. The larger number, grand total and highest daily total were taken by haul seine but as many as 0.6 million were taken in one evening by gill net. Therefore, although future efforts should optimize the use of the haul seine, the gill net should not be ignored as a sampling tool.

2.6.5 Columbia River

Egg collection on the Columbia River began 5 June and continued through 19 June. Water temperatures ranged from 55 to 64 °F. Some 23.1 million shad eggs (Table 7) were sent to the Van Dyke Hatchery in 10 shipments.

2.7 ALL RIVERS COMBINED

The Columbia River continued to be the most productive river for shad eggs (Table 8). Some 23.1 million eggs were collected in 1989. The number of eggs obtained on the East Coast was 19.58 million, the highest total since 1974. This success was due to the contribution from the Hudson River.

2.8 REFERENCES

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

Table 1. Total number (millions) of American shad eggs collected from the Pamunkey, James, Delaware, Hudson and Columbia rivers, 1973 - 1989.

YEAR	PAMUNKEY	JAMES	DELAWARE	COLUMBIA	HUDSON	TOTAL
1973	8.45	-	-	-	-	8.45
1974	9.75	19.20	-	8.18	-	37.13
1975	1.88	7.15	-	18.42	-	27.45
1976	-	-	4.10	54.80	-	56.90
1977	4.40	3.42	-	8.90	-	16.72
1978	6.90	10.11	-	-	-	17.01
1979	3.17	4.99	-	-	-	8.16
1980	6.73	6.83	-	-	-	13.56
1981	4.58	1.26	-	5.78	-	11.62
1982	2.03	1.25	-	22.57	-	25.85
1983	5.49	5.91	2.40	19.51	1.17	34.48
1984	9.83	0.74	2.64	27.88	-	41.09
1985	5.28	2.05	6.16	12.06	-	25.55
1986	5.62	1.07	5.86	39.97	-	52.52
1987	4.35	0.11	5.01	23.53	-	33.00
1988	1.92	0.05	2.91	26.92	0.00	31.80
1989	1.91	0.53	5.96	23.11	11.18	42.69
TOTALS	82.29	64.68	35.04	291.63	12.35	485.99

TABLE 2. Sampling period for East and West Coast Rivers for collection of American shad eggs, 1989.

RIVER	DATES	TOTAL DAYS
Pamunkey	6 April - 27 April	22
James	16 April - 26 April	11
Delaware	21 May - 1 June	5
Hudson	24 April - 25 May	30
Columbia	5 June - 19 June	10

TABLE 3. Collection data for American shad eggs taken from the Pamunkey River, Virginia, 1989.

Date	Water Temp. (°F)	Number of Adult Shad Male	Female	Volume of Eggs (Liters)	Number of Eggs	Shipment Number
April 15	53	9	19	8.9	254,500	1
16	54	6	16	4.7	268,900	2
17	58	5	18	11.4	282,400	3
19	58	10	24	6.5	229,100	4
24	61	13	33	15.3	501,300	5
25	63	6	18	6.0	227,800	6
26	65	4	8	3.0	96,000	7
TOTALS	Avg=58.9	58	136	55.8	1,860,000	7

TABLE 4. Collection data for American shad eggs taken on the James River, Virginia, 1989.

Date	Water Temp. (°F)	Number of Adult Shad Male	Female	Volume Eggs (liters)	Number of Eggs	Shipment Number
April 16	60	1	2	1.0	26,900	1
17	61	2	6	2.6	74,400	2
24	63	3	8	5.6	157,200	3
26	66	6	13	8.5	267,900	4
TOTALS	Avg=62.5	12	29	17.7	526,400	4

TABLE 5. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1989.

Date	Water Temp. (°F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume Eggs (liters)	Number of Eggs	Shipment Number
May 22	64	-	-	7.0	212,800	1
29	63	-	-	28.7	1,050,500	2
30	63	-	-	49.7	2,254,400	3
31	64	-	-	31.0	1,305,800	4
June 1	68	-	-	24.3	1,140,100	5
TOTALS	Ave=64.4			140.7	5,963,600	5

TABLE 6. Collection data for American shad eggs taken on the Hudson River, New York, 1989.

Date	Water Temp. (°F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume Eggs (Liters)	Number of Eggs	Shipment Number	Gear
May 10	53	6	8	8.1	213,900	1	Gill
12	52	8	12	18.1	470,800	2	"
13	53	6	7	6.8	226,600	3	"
15	55	28	61	33.7	1,360,400	4	Seine
16	54	35	100	69.7	2,202,300	5	"
17	57	24	66	36.2	1,107,900	6	"
18	59	36	104	56.5	1,606,000	7	"
19	60	24	66	47.7	1,459,000	8	"
20	61	25	74	46.2	1,361,200	9	"
21	62	8	15	11.9	393,100	10	"
22	63	4	8	4.1	116,600	11	"
25	63	12	24	19.4	661,400	12	Gill
TOTALS	Ave=57.7			358.4	11,179,200	12	
			Gill-net	52.4	1,572,700	4	
			Seine	306.0	9,606,500	8	

Table 7. Collection data for American shad eggs taken on the Columbia River, Oregon 1989.

Date	Water Temp. (°F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume Eggs (Liters)	Number of Eggs	Shipment Number
June 5	55			79.9	2,706,000	1
6	56			86.5	2,857,400	2
7	55			97.2	3,185,500	3
8	57			83.8	3,090,500	4
9	58			68.7	2,473,400	5
12	60			46.5	1,657,800	6
13	60			48.5	1,787,500	7
14	61			52.6	2,002,600	8
15	64			37.1	1,326,100	9
19	62			47.4	2,011,400	10
TOTALS	Avg=58.8			648.2	23,098,200	10

TABLE 8. Total volume and number of American shad eggs collected on the Pamunkey, James, Delaware, Hudson, and Columbia rivers, 1989.

RIVER	VOLUME OF EGGS SHIPPED (L)	TOTAL NUMBER EGGS
Pamunkey	55.75	1,909,800
James	17.70	526,400
Delaware	140.65	5,963,600
Hudson	358.37	11,179,200
Columbia	648.20	23,098,200
TOTALS	1,220.67	42,677,200

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1989

M. L. Hendricks, T. R. Bender, Jr., and V. A. Mudrak

Pennsylvania Fish Commission

Benner Spring Fish Research Station

State College, PA

INTRODUCTION

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

Production goals for 1989 included the stocking of 10-15 million 18-day-old shad fry, and 50-100 thousand fingerlings. All hatchery-reared American shad fry were marked by immersion in oxytetracycline bath treatments in order to distinguish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in 1989 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

Research conducted in 1989 focused on describing temporal patterns of egg mortality, continued evaluation of new larger egg jars, and attempts at producing sedation in fingerlings using feed laced with Valium and Acepromazine.

EGG SHIPMENTS

Almost 43 million eggs (1,221 L) were received in 38 shipments in 1989 (Table 1), representing the second largest total since the program began in 1976 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 60.1% compared to 40.9%, 40.7%, 47.9%, and 38.7% in 1985 through 1988, respectively. The high egg viability was due to unusually high viability for Columbia River eggs. Egg viability for the Pamunkey River was 55.7% as compared to 64.5%, 62.5%, 55.3%, 51.1%, and 55.4% for 1984 through 1988, respectively. Egg viability for the James River was 49.9% (4 shipments). Egg viability for the Delaware River was 61.6% as compared to 31.2%, 50.5%, 57.9%, 55.4% and 61.6% for 1984 through 1988, respectively. Egg viability for our new egg source, the Hudson River, was 57.6%. Egg viability for the Columbia River was 61.6% as compared to 39.2%, 24.5%, 35.5%, 45.7% and 34.8% in 1984 through 1988, respectively.

Four egg shipments exhibited complete mortality. Fertilization of Shipment 3 (James River) was delayed due to a high by-catch of striped bass and the shad had probably been dead too long (Tim Robbins, pers. comm.). Shipment 12 (Hudson R.) was the first shipment from that river. The eggs were taken at low water temperatures (53°F) and were probably not quite ripe. Shipment 16(b) from the Hudson River was the latter half of a large shipment. The first half of the shipment (16a) exhibited 73% viability but after processing 16(a) no live males remained to fertilize 16(b). Shipment 23 (Hudson R.) constituted the first experimentation with the large egg holding tank constructed at Van Dyke. Inexperience in adjusting flows caused the eggs to silt over resulting in complete mortality.

PRODUCTION

Survival, production and stocking of American shad fry are presented in Tables 2, 3, and 4. Total fry production was a record 22.7 million compared to 13.5 million, 7.9 million, 16.6 million, 11.1 million, and 11.1 million in 1984 through 1988, respectively. Of the total fry production, 9.6 million were released in the Juniata River, 3.9 million in the Susquehanna River at Montgomery Ferry, and 7.6 million in the Susquehanna River below Conowingo Dam. Approximately 413 thousand fry were stocked into ponds for fingerling production at various sites (Table 4), 833 thousand fry were released into the Lehigh River, and 317 thousand were released into the Schuylkill River.

Total fingerling production for 1989 was an estimated 69,850 (Table 4) compared to 30,500, 115,000, 73,000, 81,500 and 74,000 in 1984 through 1988, respectively. All fingerlings were released in the Juniata River at Thompsontown, with the exception of three groups transferred to other facilities for research purposes. Approximately 3,500 fingerlings from Benner Spring raceways E1 and F1 were transferred to I,S&T for use in turbine mortality studies at Safe Harbor Dam. Another 5,000 fingerlings from Benner Spring Pond 4 were transferred to Crane Aquaculture for use in turbine mortality studies in 1990. An estimated 1,000 fingerlings from Upper Spring Creek Pond 1 were transferred to RMC for additional research and development work.

SURVIVAL

Survival of all fry was 88.4% compared to 72.8%, 76.2%, 75.6%, 70.1% and 89.8% in 1984 through 1988, respectively. The increase in reported survival over pre-1988 levels is, in part, due to modifications in daily mortality estimation instituted in 1988. Egg viability and survival of fry are combined and plotted as overall survival in Figure 1. Note that the increased survival in 1989 over 1988 is due to higher egg viability. For the second consecutive year we had no major mortality episodes due to human error.

EGG SURVIVAL AS RELATED TO JAR PROCESSING SEQUENCE

In 1988, we documented an apparent reduction in egg survival uring egg processing which resulted in the highest survivals in he first jars processed and the lowest in the last jars processed (Hendricks et al., 1989). Ten shipments, incubated in May-Sloan jars, were analyzed. All ten shipments exhibited this trend and 4 of the 7 which could be statistically tested exhibited significant decreases in survival during the processing sequence. A similar analysis was performed in applicable shipments received in 1989 (Tables 5, 6, Figures 2, 3). For May-Sloan jars (Figure 2), 12 of the 19 shipments analyzed exhibited a decrease in survival during jar processing sequence. Of these 12, eleven could be tested for significance by regressing egg survival vs jar processing sequence. T-tests (Ott, 1977) were used to test the slopes for significant difference from zero. Five of the 11 shipments tested exhibited significant decreases in survival during jar processing (a = .05). Seven shipments exhibited positive slopes (increases in survival) during processing. Four of these could be tested for statistical significance and none were significant.

Van Dyke jars were also subjected to this analysis (Figure 3). Twelve of the 17 shipments analyzed exhibited decreases in survival (negative slopes) during the processing sequence. Six of these 12 were tested for statistical significance and only c was significant. Five shipments exhibited positive slopes and one of these was significant.

It is clear from these data that the trend toward decreasing survival during the processing sequence is less apparent than in 1988 but appears to persist in some of the shipments despite improvements in egg handling procedures. Careful scrutiny of dead egg enumeration has revealed a possible explanation for this phenomena. Dead eggs from each jar are siphoned into one of four screen bottom graduated cylinders. When all four cylinders have been used the volumes are read, the dead eggs discarded, and the process repeated. Dead eggs from the first egg jar siphoned remain in the graduated cylinder longer and are subject to more draining and compaction. When read, this translates into fewer dead eggs and thus more live eggs and higher apparent survival. In a typical shipment, a 10% difference in dead egg enumeration can account for a 4% difference in overall survival. This could explain much of the observed phenomenon. It is interesting to note that Shipment 33 (Figure 2) appears to have a four jar periodicity in egg survival. Procedural changes and/or research will be conducted in 1990 to further explore this phenomenon.

Egg handling improvements made for 1989 included the use of 3 liter graduated pitchers instead of 2 liter graduated cylinders and installation of an egg misting system to keep eggs moist during processing. These improvements expedited egg handling, and reduced compaction and dessication. The relationship between these procedural changes and the record overall egg survival is not known. Since the record egg survival was almost exclusively a result of increased survival of Columbia River eggs, we speculate that the cause was more likely related to egg take operations or natural phenomena in Oregon.

VAN DYKE JAR TESTING

Use and testing of the larger Van Dyke jars was continued during 1989. Previous years testing (Hendricks et al., 1988, 1989) demonstrated consistently higher egg viability for the Van Dyke jars over the standard May-Sloan jars. Comparison of egg viability between the two types of jars was replicated five times in 1989 (Table 7). Egg viability for eggs incubated in Van Dyke jars exceeded viability in May-Sloan jars in four of the five replicates. Viability in the fifth replicate was identical for the two jar types.

Previous experience with the Van Dyke jars indicated a possible problem involving "dead spots" in the jar where insufficient flow caused egg mortality. This resulted in dead fry remaining in the jar after hatch (Hendricks et al., 1989). Both procedural and mechanical approaches at rectifying this problem were attempted. In the past, incubation jars were put on the tank for hatch on the sixth day of incubation. The eggs were sunned on days VII and VIII (Figure 4). Typically, some eggs would hatch on day VI, most on day VII and some on day VIII. Deviations from this schedule were rare and occurred only when low incubation temperatures delayed hatch. In 1989, we did not follow this schedule. Instead, we waited until fry began hatching in the jars while still on the egg battery. At that point we sunned the eggs and put the jar on the tank for hatch. As a result, we lost the first few fry (up to several hundred) which hatched from each jar into the hatchery effluent. In most cases, however, all the fry hatched within 20 minutes after moving the jar. This did not allow time for "dead spots" to develop. Although dead fry were occasionally found in the jar, this procedural change effectively eliminated the "dead fry" problem. This procedure was especially useful this year due to the extremely wet, cold spring. Cold weather patterns, coupled with high water usage due to record May egg shipments, severely over-taxed the Van Dyke heating system. Typical fry rearing temperatures averaged 58-60^{o}F compared to 64^{o}F for a typical year. As a result, egg hatching was delayed 1 to 2 days for most shipments. These delays would surely have resulted in "dead fry" problems if the jars had been incubating on the tanks rather than on the egg battery. In addition to these procedural changes, a second attempt was made to combat "dead fry" problems using mechanical means.

An alternate bottom screen, designed to create back-pressure and more uniform flow, was tested. The screen was constructed of 3 mm thick aluminum plates with 3 mm holes, 5 mm apart. Hot glue was used to selectively fill holes to create uniform flows from the edge to the center of the jar. From the periphery of the screen toward the center for a distance of 45 mm, 3/4 of the holes were filled. For the remainder of the screen, 1/2 of the holes were filled. Unfilled holes constituted roughly 15% of the surface area of the plate. The resultant flows produced uniformly rolling eggs from the periphery of the jar to the center. However, in testing, (Table 7, Shipment 29) viability was not substantially higher for the Van Dyke jar than for the May-Sloan jars. Additional tests with this and other bottom screens will be conducted in 1990 to further improve egg survival.

TEMPORAL PATTERNS OF EGG MORTALITY

Production of fry at Van Dyke is limited by egg availability and viability. Relatively small increases in egg viability can result in large increases in fry production. Nothing has demonstrated that better than this year's effort, in which a 55% increase in egg viability, coupled with a 34% increase in egg deliveries, resulted in a 113% increase in fry production over 1988.

Methods for improvement in overall egg viability might be suggested by a better understanding of egg development and of the critical developmental stages during which mortality occurs. Toward that end, we undertook a study involving daily sampling and classification of eggs during incubation.

Random samples of at least 300 eggs were taken during egg disinfection (Day I according to our arbitrary system of incubation day numbering) and each day thereafter (Figure 4). Samples taken on Day II through V were taken after dead eggs were siphoned off on day II and thus reflect only the live eggs left, plus any dead which did not layer. Samples were not taken after day V, since mixing the eggs to ensure a random sample resulted in premature hatch. All samples were preserved in 10% buffered formalin and dyed with rose bengal. A dissecting microscope was later used to classify the eggs according to stage of development and live or dead. Classification of developmental stage was according to Mansueti and Hardy (1967). However, we did not distinguish between the blastula and gastrula stages. In addition, unfertilized but water hardened American shad eggs were provided by NES. These eggs did not properly water harden and were all small. We therefore classified all small eggs as unfertilized. Some eggs appeared to be water hardened but had not developed into a centralized chorion surrounded by an obvious perivitelline space. These were arbitrarily classified "no development." Unfortunately, in some shipments, there seemed to be no clear distinction between unfertilized and "no development" eggs and many eggs were difficult to classify.

At the time of their arrival at Van Dyke, live eggs were generally in the gastrula stage with a large, clear perivitelline space. Obvious gastrula stage eggs occasionally exhibited thread-like material in the pervitelline space, which was assumed to be fungal mycelia. These eggs were assumed to be dead. Granular material which appeared to have broken off or burst out of the yolk, was sometimes present in the pervitelline space. These eggs were also assumed to be dead. In some cases, eggs had developed a centralized sphere and an obvious perivitelline space but the egg could not be classified based on developmental stage. We were unable to determine if no development had occurred or if development had occurred and was obscured by fungus or decay. These eggs were classified as dead and arbitrarily assigned to the gastrula stage.

At 16-17°C the blastula stage occurs at 6 hours, while late gastrula occurs at 20 1/2 hours (Mansueti and Hardy, 1967). Day I samples were taken approximately 10, 11, 8, and 17 hours after fertilization for shipments 10, 13, 25 and 30, respectively. Classification of the day I samples was problematic (Table 8). For example, most, if not all, of the eggs collected on day I for shipment 13 appeared to be dead with burst yolks. In contrast, viability for shipment 13 was 33%. We can only speculate that improper preservation in formalin may have caused the yolks to rupture. The day I samples for shipments 25 and 30 also exhibited large numbers of dead eggs in the gastrula stage. Live eggs in these shipments (Day I) constituted 35 and 33% of the samples, yet overall viability was 63 and 56%, respectively. It is likely that we misclassified live eggs as dead because yolks burst during handling or preservation. Gates et al. (1987) noted that improper egg preservation (particularly using buffered formalin) resulted in rupturing of the chorion and expulsion of the yolk contents into the perivitelline space.

Results of the study also indicated that very few eggs died after the gastrula stage except for shipment 13. For shipment 13, 84 (17%) of the 484 eggs sampled on day II had reached the early embryo stage prior to death. We have no explanation for this phenomenon at this time.

Overall, the results of the study were disappointing. Classification of the eggs at the laboratory was much more time consuming than expected and we were able to classify only a fraction of the samples collected. In addition, background information on the appearance of live and dead eggs was lacking, and improper preservation of eggs apparently caused misclassification of live eggs as dead. Also, classification of samples of siphoned off dead eggs would have been useful.

SEDATION OF AMERICAN SHAD FINGERLINGS

Harvest of American shad fingerlings from grow-out ponds has been hampered by high mortalities associated with stress and scale loss. During crowding, the shad become extremely skittish and exhibit pronounced fright reactions. The problem is exacerbated by their strong schooling instinct. Once the fish have reached the point where they are overcrowded, any stimulus, even an overflight by a dragon fly, will cause hundreds of shad to jump out of the water. Many land in the pond mud and suffer immediate mortality. Others impact the sides of the kettle, suffering scale loss and delayed mortality.

Murai et al. (1979) reported a significant beneficial effect on survival of American shad when fed 2 mg Valium/kg feed, prior to water transfer (water brailing). Ninety-six hour mortality was 1% for the group fed Valium vs 15% for a control. Shad treated with MS222 and MS222 with Valium experienced 55 and 47% mortality in the same experiment. Valium was ineffective at reducing mortality during air transfer (netting).

We attempted to produce sedation in raceway-reared American shad fingerling by feeding Valium and Acepromazine, a Phenothiozine type sedative (Table 9). Except for the first two trials we installed a screen in the center of each raceway, dividing the raceway and the shad into two groups of 500 to 1500 fish each. After allowing the shad to acclimate for approximately one hour, we began hand feeding the feed (Abernathy starter) mixed with the appropriate amount of sedative. The sedatives were pulverized in a mortar and pestel, mixed with a small amount of vegetable oil, and thoroughly mixed into the feed. The shad fed actively at first, but feeding generally declined over a period of approximately 30 to 40 minutes. Feeding was discontinued when the fish showed little interest in the food. After feeding, the fish were observed for several hours to determine the effect of the sedative on schooling behavior and fright response. We were hoping to produce a deep sedation which would eliminate the fright response and schooling behavior. Valium was fed at rates of 4, 8, 16, 32, 64, 128 and 132 mg/kg food (Table 9). These values are 2 to 66 times the concentrations fed by Murai et al. (1979). Acepromazine was fed at a rate of 60, 150, 300, 600, 2400, and 3080 mg/kg food. In order to determine mg of drug fed per kg body weight, we sampled 5 fish from trial 5 (Table 9), dissected their stomachs and weighed the contents. Wet weight of the fish ranged from 2.2 to 4.2 g. Wet weight of stomach contents ranged from .3 to 1.55% of body weight with a mean of .78%. Dry weight of stomach contents was not determined. Based on wet weight, Valium was fed at rates of .03 to 1.030 mg/kg body weight and Acepromazine was fed at .47 to 24.02 mg/kg body weight (Table 9). Adequate dosages of Valium for warm-blooded animals are approximately .22 mg/kg body weight while those for Acepromazine are 0.5 to 2.2 mg/kg (Dr. Michael Moss, VMD; pers. comm.). Thus, based on wet weight, Valium was fed at up to 5 times the dosage recommended for warm-blooded animals while Acepromazine was fed at nearly 12 times the recommended dosage. Dosages based on dry weight cannot be determined but are thought to be higher than those recommended for warm-blooded animals. Despite these high dosages, no effect on fright reaction was noted and only a very slight reduction in schooling was observed for Valium fed at 1 mg/kg body weight (Table 9). We were not able to produce the deep sedation we felt was necessary to counteract the stress associated with harvest and overcrowding.

Despite the lack of behavioral modification, sedatives might still prove beneficial to survival during harvest. In order to test this, we harvested raceways Flb (32 mg Valium/kg feed, trial4) and Fla (control) approximately 1 1/2 hours after feeding. The shad were crowded, water brailed to the transport unit, held for 2 hours and quick released back into the same raceway. Each raceway section contained approximately 300 to 500 shad. After 48 hours, 5 shad had suffered mortality in the test treatment while 6 controls had died. Ten of the eleven dead exhibited obvious damage from the crowding screens. The low mortality experienced in the control group made it impossible to detect any beneficial effect of the Valium. Low mortalities during raceway harvest of shad are typical and no further trials were conducted.

OTC TAGGING

All American shad fry and fingerlings stocked in the Susquehanna River Basin received marks produced by immersion in or feeding of oxytetracycline (Table 10). Immersion tags were administered to all fry by bath treatments at 200 ppm oxytetracycline for 6 hours duration. Fry stocked below Conowingo Dam received a double tag at 5 and 9 days of age. Fry stocked in the Juniata and Susquehanna Rivers above dams were uniquely marked, according to egg source river, to determine relative survival of fry from the various egg sources. Fry originating from Columbia River eggs received a single tag on day

5. Hudson River fry received a triple tag on days 5, 9 and 13. Delaware River fry received a triple tag on days 3, 13 and 17. Virginia River fry received a quadruple tag on days 5, 9, 13 and 17.

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

In addition to the five types of immersion tags used for fry, eight unique combinations of immersion/feed tags were also produced and the fish released or transferred to other facilities for research (Table 10).

Verification of tag retention was accomplished by stocking groups of tagged fry in raceways or ponds and examining otolith samples collected during harvest. Retention of immersion tags was lower than in 1988, when retention was 100%. Single tag retention in the Rearing Pond was 73% (Table 11) with eight individuals (26%) exhibiting double or triple tags. It is likely that these were hatchery escapees since the Van Dyke hatchery effluent is the influent for the Rearing Pond. Immersion tag retention for the remaining groups of fish ranged from 83% to 100% (Table 11). Four groups (CP, BSRF1, USCP3 and BSP4) exhibited 100% immersion tag retention. The three remaining groups (BSRE1, USPP1, and USCP2) exhibited 93%, 97% and 83% immersion tag retention, respectively.

Feed tag retention varied from group to group. No rearing pond fish retained the feed tag (Table 11), presumably because there were few fish in the pond and they were subsisting on natural prey. Conversely, Canal Pond fish exhibited 100% tag retention. Retention of the appropriate feed tag was good in Upper Spring Creek Ponds 1 and 3, and Benner Spring Pond 4 (88%, 84%, and 81% respectively), but very poor in Upper Spring Creek Pond 2 (15%). Despite the high retention, these tags were subdued and much more difficult to detect than previous years feed tags.

The overall poor quality of the tetracycline tags produced in 1989 is thought to be related to loss in tetracycline activity. In 1987, Elliott Lieberman (Argent Laboratories, pers. comm.) reported a 5% loss in OTC activity per year. Since we had difficulty in obtaining OTC in 1986, a large quantity was purchased in 1987 to ensure an adequate supply for 2 years. Treatment concentrations were adjusted to compensate for the anticipated loss of 5% activity per year. More recent information indicates that OTC should remain stable indefinitely when stored below 70°F (Greg Galloway, Argent Laboratories; Dr. Gramm, Pfizer Laboratory, pers. comm.). During the off-season, the OTC is stored in an air conditioned room at Benner Spring.

During the season, pre-weighed packets are stored at Van Dyke in a freezer. Prior to and during weighing, the OTC in question was stored for a time in the Van Dyke loft. Our recollections indicate that this lasted only a month or so, during the early part of the season, but temperatures in the loft could have exceeded 70°F.

In the future, contracts for the purchase of tetracycline will be written to ensure timely deliveries and eliminate the need for long-term storage.

FINGERLING HARVEST

Approximately 400 fingerling American shad were harvested from the Rearing Pond at Van Dyke on September 5, 1989. The primary purpose of the pond was tag verification for single tagged (Columbia River origin) fish. Fifty fish were retained for tag verification and the remaining 350 were released at Thompsontown. The low number of fish in the pond reduced crowding and expedited harvest, resulting in very few mortalities at the release site. The fish averaged 47 mm in length and .87 g (n = 50).

An estimated 20,000 fingerlings were released from the Canal Pond at Thompsontown on September 21, 1989. This was the most successful harvest of the Canal Pond to date. Anticipated problems with algae were minimized by draining the pond down excrutiatingly slowly. This prevented both attached and suspended algae from drifting into the catch basin. The drawdown was timed so that the critical crowding period occurred after dark. As in 1988, the fish became more calm and ceased schooling after dark. Drawdown and release went extremely well; few fish were stranded in the pond and very few were observed in poor condition after release to Delaware Creek. The fish averaged 71 mm in length and 2.2 g (n = 30).

The three Upper Spring Creek ponds were stocked with 50,000 fry each on May 22, 1989. Two of the ponds were harvested during October; approximately 10,000 fingerlings were harvested from Pond #2, and 15,000 from Pond #3. Approximately 16,000 fingerlings were harvested from Pond #1 on November 8th (Table 3). Overall, the Upper Spring Creek Ponds yielded 41,000 fingerlings (27% survival), 40,000 of which were released into the Juniata River at Thompsontown. The fish averaged 106 mm in length and weighed 9.2 g (n = 22). Harvesting techniques worked to perfection this year. Thorough cleaning of the catch basin with a 3" trash pump, prior to bringing fish into the basin, was the key to success. In addition, the electric chain hoist helped reduce the time for movement of fish to the truck. No difficulties with drawdown, harvest, loading, transport or stocking were encountered this year. Only 125 fish were lost during all phases of the operation, for all three pond this year; a dramatic improvement over last year's effort.

In addition to the fingerlings mentioned above, three groups of juvenile shad were transferred to other agencies for experimental purposes. Approximately 3,500 fish (Benner Spring Raceways E1 and F1) were transferred to Dr. John Mudre (IS&T) at Safe Harbor and approximately 5,000 from Benner Spring Pond #4 were delivered to BG&E's Crane Aquaculture Facility in Baltimore. Only 10,000 fry were initially stocked in BS Pond #4 in the hopes of rearing the fingerlings to a large size (185 mm) for use in tagging experiments. Although survival was good (50%), anticipated growth was not achieved. In addition, 1,000 fingerlings from USC Pond #1 were transferred to Mr. Paul Heisey (RMC) Muddy Run on November 16, 1989, for use in tagging experiments. It is anticipated that this year's success will be repeated in 1990.

In a repeat of last year's study, triploid grass carp, averaging 257 mm (10.1 inches) in length and 174 g (.38 lb) in weight, were released into two of the Upper Spring Creek shad ponds to determine their effectiveness as a biological control for filamentous algae. Pond #1 received 50 grass carp and 20 were released into Pond #2. The grass carp were stocked earlier this year (as soon as the ponds were filled) than in 1988 so they would be able to begin foraging on the filamentous algae as soon as it began to grow. Results were again disappointing; the fish grew well but survival was poor. Four fish survived in Pond #2 (20%) and 13 in Pond #1 (26%). At harvest, the fish averaged 465 mm (18.3 inches) in length and 1,458 g (3.2 lb) in weight but there was no obvious control of the filamentous algae. A similar study is tentatively planned for 1990.

SUMMARY

A total of 38 shipments (43 million eggs) was received at Van Dyke in 1989. Total egg viability was 60.1% and survival to stocking was 88.4%, resulting in production of a record 22.7 million fry. The majority of the fry were stocked in the Juniata River (9.6 million), with lesser numbers stocked in the Susquehanna River at Montgomery Ferry (3.9 million), the Susquehanna River below Conowingo Dam (7.6 million), the Lehigh River (833 thousand), and the Schuylkill River (317 thousand). A total of 60,350 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River. Approximately 3,500 fingerlings from Benner Spring raceways were transferred to I,S&T for turbine mortality studies at Safe Harbor Dam. Another 5,000 fingerlings from Benner Spring Pond 4 were transferred to Crane Aquaculture for use in turbine mortality studies in 1990. Approximately 1,000 fingerlings from Upper Spring Creek Pond 1 were transferred to RMC for use in research.

All American shad fry were tagged by immersion in 200 ppm oxytetracycline antibiotic for 6 hours. Fry released in the Susquehanna River below Conowingo Dam received a double tag on days 5 and 9. Fry released in the Juniata River and the Susquehanna River above dams received unique tags based on egg source river. Columbia River fry received a single tag on day 5;

Delaware River fry received a triple tag on days 3, 13 and 17; Hudson River fry received a triple tag on days 5, 9 and 13, and Virginia River fry received a quadruple tag on days 5, 19, 13 and 17.

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

Additional investigations of the relationship between egg jar processing sequence and egg survival were conducted in 1989. The phenomenon of decreasing egg survival during the processing sequence was apparent in 1989 but to a much lesser degree then in 1988. This phenomenon may be an artifact of the dead egg enumerating procedure.

Improvements in egg handling procedures for 1989 resulted in expedited processing, and reduced compaction and dessication; however, record survival of Columbia River eggs is thought to be related to egg take operations or natural phenomena in Oregon. Van Dyke jars continued to exhibit higher egg survival than did May-Sloan jars. Problems involving "dead spots" in the jars where flow is restricted and dead fry accumulate were largely resolved by changes in egg hatching procedures. Egg jars were left in the egg battery until fry began hatching. Egg jars were then sunned and moved to the tanks where hatching generally occurred within 20 minutes, before "dead spots" could develop. An alternative bottom screen for the Van Dyke jars was tested with inconclusive results.

A difficult and time-consuming study was undertaken to investigate American shad egg mortality over time, during incubation at Van Dyke. Results of the study were disappointing due to potential problems in handling and preservation of the samples, and lack of background information on appearance of live and dead eggs.

Attempts at producing sedation in fingerling American shad by feeding feed laced with Valium or Acepromazine were unsuccessful.

Retention of tetracycline tags were lower than in previous years, presumably due to losses of OTC activity. Immersion tag retention ranged from 83 to 100%, while feed tag retention ranged from 0 to 100%.

Harvest of American shad fingerlings was extremely successful. The new kettles at Upper Spring Creek were large enough to act as a raceway and permit schooling of the shad while the pond mud was flushed out. Subsequent crowding and harvest was expedited, the shad remained calm and mortality was minimal.

RECOMMENDATIONS FOR 1990

1. Continue to disinfect all egg shipments at 80 ppm free iodine.
2. Continue to stock one-half of production fry below Conowingo Dam (up to 5 million fry).
3. Tag all production fish according to the schedule approved by SRAFRC for 1989.
4. Feed all ponded fingerlings by hand in addition to automatic feeder to ensure complete TC tag retention.
5. Alter purchasing contracts to ensure tagging with fresh lots of tetracycline.
6. Change dead egg enumeration procedures to standardize draining time and eliminate bias due to jar processing sequence.
7. Continue to use Van Dyke jars for incubation of large egg shipments.
8. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
9. Continue testing an alternate bottom screen for the Van Dyke jars.

LITERATURE CITED

Gates, D. W., J. S. Bulak, and J. S. Crane. 1987. Preservation of striped bass eggs collected from a low-hardness, freshwater system in South Carolina. Prog. Fish. Cult. 49(3): 230-232.

Hendricks, M. L., T. R. Bender, Jr., and V. A. Mudrak. 1986. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr., and V. A. Mudrak. 1987. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr., V. A. Mudrak. 1988. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1987. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr., V. A. Mudrak. 1989. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1988. Susquehanna River Anadromous Fish Restoration Committee.

Mansueti, A. J., and J. D. Hardy, Jr. 1967. Development of Fishes of the Chesapeake Bay Region. University of Maryland. 202 p.

Murai, T., J. W. Andrews, and J. W. Muller. 1979. Fingerling American shad: Effect of Valium, MS-222, and sodium chloride on handling mortality. Prog. Fish. Cult. 41(1): 27-29.

Figure 1. Mean survival(%) of all American shad eggs and fry incubated and reared at Van Dyke, 1988 and 1989.

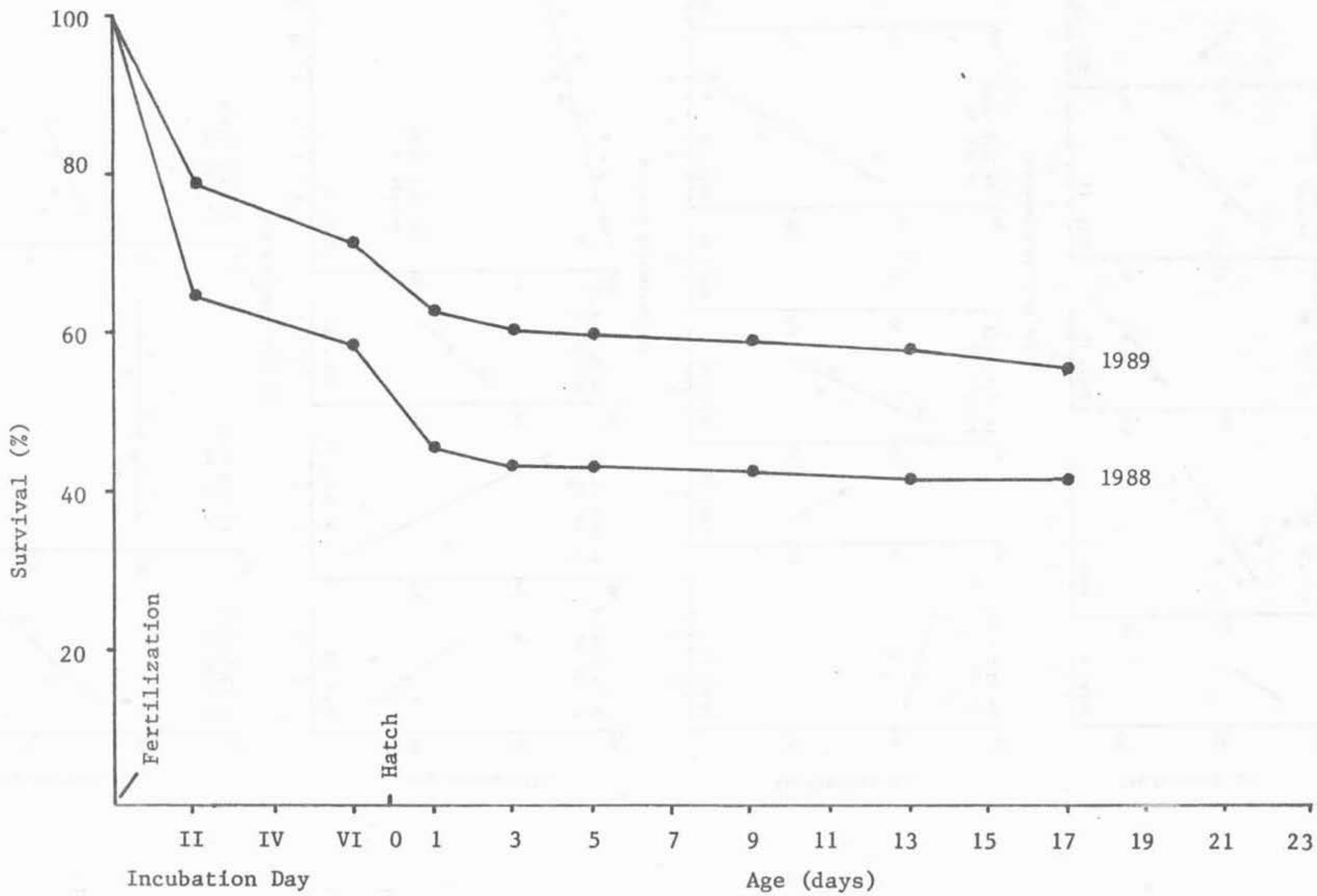


Figure 2. Regressions of Percent Egg Survival vs. Jar Processing Sequence for American shad eggs incubated in May-Sloan jars, Van Dyke, 1989.

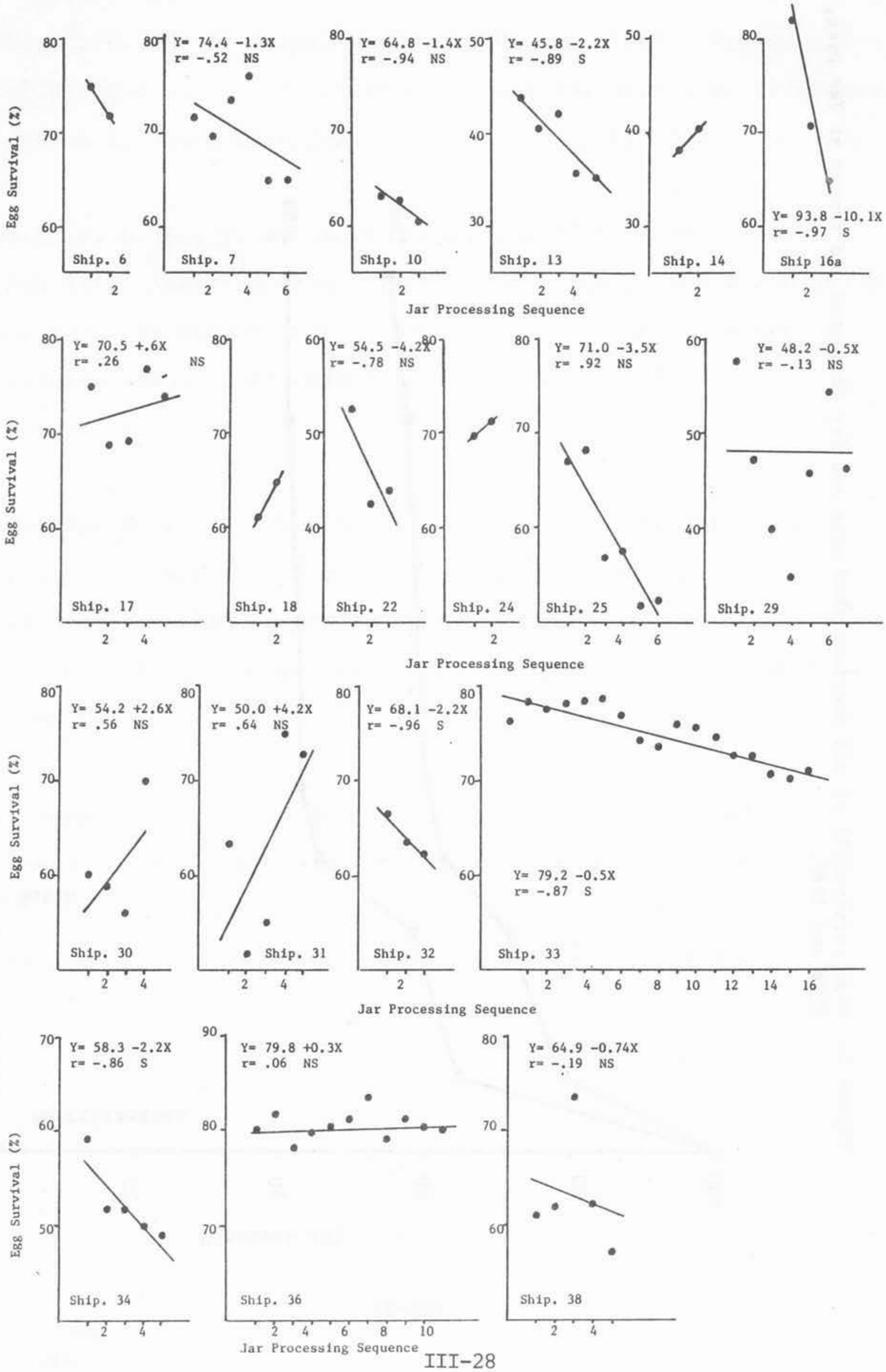


Figure 3. Regressions of Percent Egg Survival vs. Jar Processing Sequence for American shad eggs incubated in Van Dyke jars, Van Dyke, 1989.

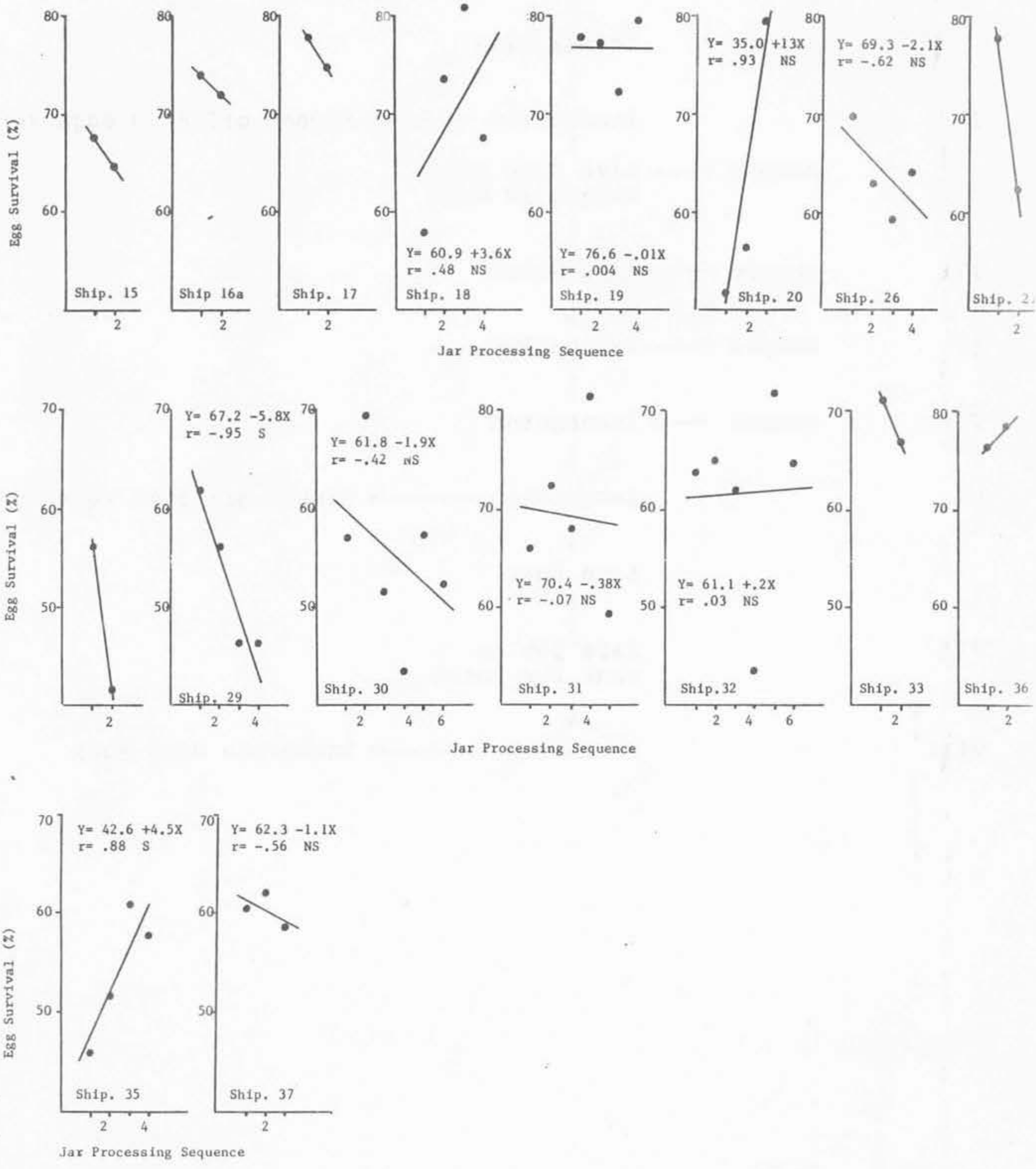


Figure 4. Schematic of American shad egg enumeration, incubation and sampling procedures, at Van Dyke, 1989.

Day	Sample	Procedure	Other
0		Fertilization	
I	sample ←	Disinfection	
		Enumeration	
II		Incubation	→ Siphon off dead eggs (enumerate)
	sample ←	Live Eggs plus Unlayered Dead	
III	sample ←	Incubation	
IV	sample ←	Incubation	
V	sample ←	Incubation	
VI		Incubation	→ Siphon off dead eggs (enumerate)
		Live Eggs	
VII		Jars put on tank for hatch	
VIII		Hatch End	→ Enumerate dead eggs

Table 1. American shad egg shipments received at Van Dyke, 1989.

Shipment Number	River	Date Shipped	Date Received	Vol. (L) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
1	Pamunkey	4/15	4/16	8.9	254,500	53.7	136,700	135,700
2	Pamunkey	4/16	4/17	4.7	268,900	5.5	14,800	14,860
3	James	4/16	4/17	1.0	26,900	0	0	0
4	Pamunkey	4/17	4/18	11.4	282,400	48.7	137,600	137,160
5	James	4/17	4/18	2.6	74,400	33.5	24,900	24,820
6	Pamunkey	4/19	4/20	6.5	229,100	71.9	164,600	163,200
7	Pamunkey	4/24	4/25	15.3	501,300	69.9	350,500	323,100
8	James	4/24	4/25	5.6	157,200	54.5	85,700	82,300
9	Pamunkey	4/25	4/26	6.0	277,800	70.1	194,700	189,700
10	James	4/26	4/27	8.5	267,900	55.9	149,700	146,000
11	Pamunkey	4/26	4/27	2.95	96,000	66.7	64,000	62,700
12	Hudson	5/10	5/11	8.10	213,900	0	0	0
13	Hudson	5/12	5/13	18.10	470,800	40.3	189,500	173,400
14	Hudson	5/13	5/14	6.80	226,600	37.4	84,800	82,400
15	Hudson	5/15	5/16	33.7	1,360,400	66.5	904,000	861,300
16(a)	Hudson	5/16	5/17	32.0	898,100	73.0	655,700	632,300
16(b)	Hudson	5/16	5/17	37.7	1,304,200	0	0	0

Table 1 (continued).

Shipment Number	River	Date Shipped	Date Received	Vol. (L) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
17	Hudson	5/17	5/18	36.2	1,107,900	75.0	830,800	808,0
18	Hudson	5/18	5/19	56.5	1,606,000	68.9	1,106,600	1,047,9
19	Hudson	5/19	5/20	47.67	1,459,000	76.5	1,115,400	1,080,4
20	Hudson	5/20	5/21	46.2	1,361,200	64.7	880,600	876,3
21	Hudson	5/21	5/22	11.9	393,100	57.1	224,300	209,0
22	Delaware	5/22	5/23	7.0	212,800	46.2	98,400	7,4
23	Hudson	5/22	5/24	4.1	116,600	0	0	0
24	Hudson	5/25	5/26	19.4	661,400	68.2	450,800	305,1
25	Delaware	5/29	5/30	28.7	1,050,500	63.0	661,400	412,8
26	Delaware	5/30	5/31	49.7	2,254,400	64.0	1,443,600	1,410,2
27	Delaware	5/31	6/1	31.0	1,305,800	69.9	913,000	857,1
28	Delaware	6/1	6/2	24.25	1,140,100	41.0	559,200	551,4
29	Columbia	6/5	6/6	79.9	2,706,000	51.6	1,396,200	1,220,9
30	Columbia	6/6	6/7	86.5	2,857,400	56.0	1,600,300	1,590,7
31	Columbia	6/7	6/8	97.2	3,185,500	63.9	2,037,000	2,031,8
32	Columbia	6/8	6/9	83.8	3,090,500	64.0	1,977,100	1,966,7
33	Columbia	6/9	6/10	68.7	2,473,400	72.4	1,791,800	1,786,2

Table 1 (continued).

Shipment Number	River	Date Shipped	Date Received	Vol. (L) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
34	Columbia	6/12	6/13	46.5	1,657,800	51.1	847,900	782,900
35	Columbia	6/13	6/14	48.5	1,787,500	53.7	960,000	956,300
36	Columbia	6/14	6/15	52.6	2,002,600	78.7	1,576,900	1,564,500
37	Columbia	6/15	6/16	37.1	1,326,100	60.3	799,100	766,100
38	Columbia	6/19	6/20	47.4	2,011,400	61.7	1,240,100	1,151,400
	Pamunkey River		Totals	55.75	1,909,800	55.7	1,062,900	
	James River			17.70	526,400	49.4	260,300	
	Delaware River			140.65	5,963,600	61.6	3,675,600	
	Hudson River			358.37	11,179,200	57.6	6,442,500	
	Columbia River			648.20	23,098,200	61.6	14,226,400	
		Grand Total		1,220.67	42,677,200	60.1	25,667,700	

Table 2. Annual Summary of Van Dyke production from 1976-1989.

Year	Egg Vol. (L)	Egg No. (exp.6)	Egg Viability (%)	Viable Eggs (Exp. 6)	No. of Shad Stocked (All Rivers) Fry (Exp. 3)	Fingerling (Exp. 3)	Total (Exp. 3)	Fish Stocked/ Eggs Rec'd.	Fish Stocked/ Viable Eggs
1976	120.3	4.0	52.0	2.1	518	266	784	0.194	0.373
1977	145.8	6.4	46.7	2.9	969	35	1,003	0.159	0.342
1978	381.2	14.5	44.0	6.4	2,124	6	2,130	0.104	0.330
1979	164.8	6.4	41.4	2.6	629	34	664	0.104	0.251
1980	347.6	12.6	65.6	8.2	3,526	5	3,531	0.283	0.431
1981	286.0	11.6	44.9	5.2	2,030	24	2,053	0.177	0.393
1982	624.3	25.9	35.7	9.2	5,019	41	5,060	0.196	0.548
1983	938.6	34.5	55.6	19.2	4,048	98	4,146	0.120	0.216
1984	1,157.3	41.1	45.2	18.6	11,996	30	12,026	-	0.728*
1985	814.3	25.6	40.9	10.1	6,960	115	7,075	0.279	0.682*
1986	1,535.7	52.7	40.7	21.4	15,867	61	15,928	0.302	0.744
1987	974.2	33.0	47.9	15.8	10,274	81	10,355	0.314	0.655
1988	885.2	31.8	38.7	12.3	10,441	74	10,515	0.331	0.855
1989	1,220.7	42.7	60.1	25.7	22,267	60	22,327	0.523	0.869

Total Shad Stcked from 1976 to 1989 = 98,210,108
*Eggs and fish that were not used for stocking purposes were not included.

Table 3. American shad stocking and fish transfer activities, Van Dyke, 1989.

*All tetracycline tags administered by 6 hour immersion in 200 ppm oxytetracycline except feed tag administered by feeding 40g oxytetracycline per pound of food.

Date	Tank(s)	Number	Tagging days*	Location	Origin	Age (Days)	Size
5/12/89	A1	800	5,9,13,17	BG & E	Pamunkey	20	Fry
5/18/89	A4	5,000	5,9	BS Race.El	Pamunkey	18	Fry
5/22/89	A3	49,990	5,9,13,17	USC Pond 1	Pamunkey	26	Fry
5/22/89	A3	49,990	5,9,13,17	USC Pond 2	Pamunkey	26	Fry
5/22/89	A3	49,980	5,9,13,17	USC Pond 3	Pamunkey	26	Fry
5/24/89	A1	10,000	5,9,13,17	BS Pond 4	Pamunkey	32	Fry
5/25/89	A4,B2	496,470	5,9	Lapidum	Pamunkey	24,25	Fry
5/30/89	A1	15,000	5,9,13,17	BG & E	Pamunkey	38	Fry
5/30/89	A1	94,730-	5,9,13,17	Thompsontown	Pamunkey	38	Fry
6/1/89	A2,B1	220,030-	5,9,13,17	Thompsontown	James	31,37	Fry
6/1/89	B3	162,560-	5,9,13,17	Thompsontown	James/ Pamunkey	30	Fry
6/5/89	B4	5,000	5,9,13	BS Race.Fl	Hudson	17	Fry
6/5/89	C4	5,000	4,8	BS Race.El	Hudson	13	Fry
6/5/89	B4	162,330-	5,9,13	Thompsontown	Hudson	17	Fry
6/6/89	C1	78,540-	5,9,13	Thompsontown	Hudson	17	Fry
6/8/89	C4,D1, D2,D3	1,376,800	4,8	Lapidum	Hudson	14,15	Fry
6/9/89	C2,C3	844,350-	5,9,13	Thompsontown	Hudson	18	Fry
6/12/89	F3,F4,G1	1,418,990	5,9	Lapidum	Hudson	15,17	Fry
6/13/89	F1,F2	531,210-	4,8,12	Thompsontown	Hudson	19	Fry
6/14/89	G3	10,000	5,9,13	Wellsboro	Hudson	17	Fry
6/14/89	D4	446,370-	5,9,13	Thompsontown	Hudson	20	Fry
6/15/89	G2,G3	527,980-	5,9,13	Thompsontown	Hudson	19	Fry
6/16/89	G4	82,500-	3,13,17	Thompsontown	Delaware	18	Fry
6/24/89	H4	200,000	3,13,17	Canal Pond	Delaware	18	Fry
6/28/89	H1	273,940-	5,9,13	Thompsontown	Hudson	27	Fry
6/28/89	H2	394,290-	3,13,17	Thompsontown	Delaware	24	Fry
6/29/89	A2	316,810	3,13,17	Schuylkill R.	Delaware	21	Fry
6/30/89	A1,I1	611,390-	3,13,17	Thompsontown	Delaware	23,24	Fry
6/30/89	B1,B2, B3,B4	1,170,130-	5	Thompsontown	Columbia	17	Fry
7/1/89	C1	505,620-	5	Thompsontown	Columbia	16	Fry
7/1/89	C2,C3	819,240-	5	Thompsontown	Columbia	16	Fry

Table 3 (continued).

Date	Tank(s)	Number	Tagging days*	Location	Origin	Age (Days)	Size
7/2/89	C4,D1	711,820	5	Thompsontown	Columbia	16,17	Fry
7/2/89	D2	505,990	5	Thompsontown	Columbia	17	Fry
7/2/89	D3	581,610	5	Thompsontown	Columbia	17	Fry
7/3/89	D4	415,080	5	Thompsontown	Columbia	17	Fry
7/3/89	I3,I4	507,940	3,13,17	Lehigh R.	Delaware	26	Fry
7/3/89	I2	325,230	3,13,17	Lehigh R.	Delaware	27	Fry
7/4/89	F1	416,880	5	Thompsontown	Columbia	17	Fry
7/5/89	A3	10,000	3,13,17	Wellsboro	Delaware	27	Fry
7/6/89	E1,E2, E3,E4	1,733,790	5,9	Lapidum	Columbia	19	Fry
7/7/89	H3,A3	556,450	3,13,17	Montgomery F.	Delaware	29,31	Fry
7/7/89	F2	412,990	5	Montgomery F.	Columbia	19	Fry
7/8/89	F3,F4	739,530	5	Montgomery F.	Columbia	20	Fry
7/9/89	G1,G2	665,690	5	Montgomery F.	Columbia	19	Fry
7/10/89	J1,J2,J3	1,520,440	5,9	Lapidum	Columbia	18	Fry
7/11/89	A4	2,000	5	Rearing Pond	Columbia	18	Fry
7/11/89	A4,J4	716,910	5	Montgomery F.	Columbia	18	Fry
7/11/89	G3,G4	816,490	5	Montgomery F.	Columbia	20	Fry
7/17/89	H4,K1,K2	1,106,010	5,9	Lapidum	Columbia	20	Fry
9/5/89	Rearing Pond	350	5+ Single Feed	Thompsontown	Columbia	74	Fingerlin
9/21/89	Canal Pond	20,000	3,13,17+ Single Feed	Thompsontown	Delaware	107	Fingerlin
10/4/89	BS Race-way E1	2,500	4,8 or 5,9	I,S&T (Safe Harbor)	Pamunkey/ Hudson	157,134	Fingerlin
10/4/89	BS Race-way F1	1,000	5,9,13	" "	Hudson	138	Fingerlin
10/13/89	USC Pond 2	10,000	5,9,13,17 + Triple Feed	Thompsontown	Pamunkey	170	Fingerlin
10/25/89	USC Pond 3	15,000	5,9,13,17+ Quad. Feed	Thompsontown	Pamunkey	182	Fingerlin
10/30/89	BS Pond 4	5,000	5,9,13,17+ Single Feed	B,G & E	Pamunkey	191	Fingerlin
11/8/89	USC Pond 1	15,000	5,9,13,17+ Double Feed	Thompsontown	Pamunkey	186	Fingerlin
11/16/89	USC Pond 1	1,000	5,9,13,17 + Double Feed	RMC	Pamunkey	204	Fingerlin

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1989.

	Site	Fry	Fingerling
Releases	Juniata River	9,556,590	60,350
	Susquehanna R. (Montgomery Ferry)	3,908,060	-
	Susquehanna R. (below Conowingo Dam)	7,652,500	-
	Lehigh River	833,170	-
	Schuylkill River	316,810	-
	Sub Total	22,267,130	60,350
Transfers	Van Dyke Ponds	202,000	
	Benner Spring Ponds/ Raceways	25,000	
	Upper Spring Creek Ponds	149,960	
	Baltimore Gas and Electric	15,800	5,000
	Wellsboro	20,000	
	I,S&T (Safe Harbor)	-	3,500
	RMC	-	1,000
	Sub Total	412,760	9,500
	Total Production	22,679,890	69,850
	Total Number of Viable Eggs	25,667,700	
	Survival of all Fry	88.4	

Table 5. Survival of American shad eggs incubated in May-Sloan jars as a function of jar processing sequence, 1989. Jars with less than 2.0 or more than 2.6 liters of eggs were eliminated.

Shipment	Jar	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
6	5	1	2.5	88,100	74.8
	6	2	2.5	88,100	71.6
7	8	1	2.5	81,900	71.4
	9	2	2.5	81.900	69.5
	10	3	2.5	81,900	73.5
	11	4	2.5	81,900	76.0
	12	5	2.5	81,900	64.8
10	18	1	2.5	78,800	63.1
	19	2	2.5	78,800	62.6
	20	3	2.5	78,800	60.3
13	4	1	2.5	64,700	43.7
	5	2	2.5	64,700	40.2
	6	3	2.5	64,700	42.0
	7	4	2.5	64,700	35.4
	8	5	2.5	64,700	35.2
14	12	1	2.5	83,300	38.1
	13	2	2.5	83,300	40.2
16a	15	1	2.5	70,200	82.1
	16	2	2.5	70,200	70.8
	17	3	2.0	56,100	64.9
17	23	1	2.5	76,500	74.5
	24	2	2.5	76,500	68.4
	25	3	2.5	76,500	68.8
	26	4	2.5	76,500	76.3
	27	5	2.5	76,500	73.5
18	28	1	2.5	71,100	60.8
	29	2	2.5	71,100	64.6
22	31	1	2.5	76,000	52.2
	32	2	2.5	76,000	42.2
	33	3	2.0	60,800	43.8

Table 5 (continued).

Shipment	Jar	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
24	36	1	2.5	85,200	69.4
	37	2	2.5	85,200	71.0
25	1	1	2.5	91,500	66.9
	2	2	2.5	91,500	68.0
	3	3	2.5	91,500	56.4
	4	4	2.5	91,500	57.1
	5	5	2.5	91,500	51.5
	6	6	2.5	91,500	52.0
29	10	1	2.5	84,700	57.3
	11	2	2.5	84,700	47.0
	12	3	2.5	84,700	39.7
	13	4	2.5	84,700	34.5
	14	5	2.5	84,700	45.6
	15	6	2.5	84,700	54.2
	16	7	2.5	81,300	46.1
30	17	1	2.5	82,600	59.6
	18	2	2.5	82,600	58.4
	19	3	2.5	82,600	55.6
	21	4	2.5	82,600	69.3
31	23	1	2.5	81,900	62.9
	24	2	2.5	81,900	51.2
	25	3	2.5	81,900	54.5
	26	4	2.5	81,900	74.5
	27	5	2.5	81,900	72.3
32	32	1	2.5	92,200	66.3
	33	2	2.5	92,200	63.1
	34	3	2.5	92,200	62.0

Table 5 (continued).

Shipment	Jar	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
33	36	1	2.5	90,000	75.8
	37	2	2.5	90,000	78.0
	38	3	2.5	90,000	77.3
	39	4	2.5	90,000	77.9
	40	5	2.5	90,000	78.2
	41	6	2.5	90,000	78.3
	42	7	2.5	90,000	76.8
	43	8	2.5	90,000	74.0
	44	9	2.5	90,000	73.2
	45	10	2.5	90,000	75.8
	46	11	2.5	90,000	75.4
	47	12	2.5	90,000	74.2
	48	13	2.5	90,000	72.3
	49	14	2.5	90,000	72.4
	50	15	2.5	90,000	70.3
	51	16	2.5	90,000	70.0
	52	17	2.5	90,000	70.6
34	54	1	2.5	90,900	58.6
	3	2	2.5	90,900	51.2
	4	3	2.5	90,900	51.2
	5	4	2.5	90,900	49.5
	6	5	2.5	90,900	48.6
36	10	1	2.5	95,200	79.7
	12	2	2.5	95,200	81.2
	13	3	2.5	95,200	77.7
	14	4	2.5	95,200	79.3
	15	5	2.5	95,200	79.9
	16	6	2.5	95,200	80.7
	17	7	2.5	95,200	83.0
	18	8	2.5	95,200	78.6
	19	9	2.5	95,200	80.6
	20	10	2.5	95,200	79.7
	21	11	2.6	99,000	79.4
38	23	1	2.5	106,100	60.5
	24	2	2.5	106,100	61.4
	25	3	2.5	106,100	73.0
	26	4	2.5	106,100	61.6
	27	5	2.5	106,100	56.7

Table 6. Survival of American shad eggs incubated in Van Dyke jars as a function of jar processing sequence, 1989. Jars with less than 10 liters of eggs were eliminated

Shipment	Jar	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
15	201	1	12.5	504,600	67.7
	202	2	12.5	504,600	64.7
16a	204	1	12.5	350,800	74.0
	205	2	12.5	350,800	72.0
17	215	1	12.5	382,600	77.8
	209	2	11.2	342,800	74.8
18	210	1	12.5	355,300	57.9
	211	2	12.5	355,300	73.5
	212	3	12.5	355,300	80.7
	213	4	12.5	355,300	67.5
19	214	1	12.5	382,600	77.7
	217	2	12.5	382,600	77.1
	216	3	12.5	382,600	72.2
	218	4	10.2	311,200	79.3
20	219	1	12.5	368,300	51.9
	220	2	12.5	368,300	56.3
	221	3	12.5	368,300	79.5
26	227	1	12.5	567,000	69.8
	228	2	12.5	567,000	63.0
	201	3	12.5	567,000	59.2
	202	4	12.2	553,400	64.0
27	203	1	12.5	526,500	78.0
	204	2	12.5	526,500	62.2
28	205	1	12.5	587,700	56.1
	206	2	11.8	552,400	41.6
29	212	1	12.5	423,300	62.2
	209	2	12.5	423,300	56.3
	210	3	12.5	423,300	46.2
	211	4	12.5	423,300	46.3
30	213	1	12.5	412,900	56.9
	214	2	12.5	412,900	69.3
	215	3	12.5	412,900	51.3
	216	4	12.5	412,900	43.3
	217	5	12.5	412,900	57.3
	218	6	12.5	412,900	52.2

Table 6. (Continued)

Shipment	Jar	Jar Processing Sequence	Dry Vol. (L)	No. of Eggs	% Survival
31	220	1	12.5	409,700	65.6
	225	2	12.5	409,700	72.3
	222	3	12.5	409,700	67.9
	223	4	12.5	409,700	81.3
	224	5	12.5	409,700	59.2
32	226	1	12.5	461,000	63.6
	227	2	12.5	461,000	64.9
	228	3	12.5	461,000	62.0
	201	4	12.5	461,000	43.4
	202	5	12.5	461,000	71.6
	204	6	12.5	461,000	64.4
33	208	1	12.5	450,100	71.0
	203	2	12.5	450,100	66.8
35	205	1	12.5	465,500	45.7
	206	2	12.5	465,500	51.5
	207	3	12.5	465,500	60.5
	212	4	10.5	391,000	57.7
36	209	1	12.5	475,800	76.4
	210	2	12.5	475,900	78.4
37	215	1	12.5	446,800	60.4
	216	2	12.5	446,800	62.0
	217	3	12.1	432,500	58.3

Table 7. Survival of American shad eggs incubated in Van Dyke jars vs controls incubated in May-Sloan jars, Van Dyke, 1989.

Shipment	Jar	Jar Type	Bottom Screen	Dry Vol. (L)	No. of Eggs	No. of Viable Eggs	% Survival
17	23	MS	Window	2.5	76,500	57,000	74.5
	24	MS	Window	2.5	76,500	52,300	68.4
	25	MS	Window	2.5	76,500	52,600	68.8
	26	MS	Window	2.5	76,500	58,400	76.3
	27	MS	Window	2.5	76,500	56,200	73.5
			Subtotal	12.5	382,500	276,500	72.3
	215	VD	Window	12.5	382,600	297,800	77.8
25	1	MS	Window	2.5	91,500	61,200	66.9
	2	MS	Window	2.5	91,500	62,200	68.0
	3	MS	Window	2.5	91,500	51,600	56.4
	4	MS	Window	2.5	91,500	52,200	57.1
	5	MS	Window	2.5	91,500	47,100	51.5
			Subtotal	12.5	457,500	274,300	60.0
	226	VD	Window	12.5	457,600	323,500	70.7
29	10	MS	Window	2.5	84,700	48,500	57.3
	11	MS	Window	2.5	84,700	39,800	47.0
	12	MS	Window	2.5	84,700	33,600	39.7
	13	MS	Window	2.5	84,700	29,200	34.5
	14	MS	Window	2.5	84,700	38,600	45.6
			Subtotal	12.5	423,500	189,700	44.8
	211	VD	Plate	12.5	423,300	196,100	46.3
34	54	MS	Window	2.5	90,900	53,300	58.6
	3	MS	Window	2.5	90,900	46,500	51.2
	4	MS	Window	2.5	90,900	46,500	51.2
	5	MS	Window	2.5	90,900	45,000	49.5
	6	MS	Window	2.5	90,900	44,200	48.6
			Subtotal	12.5	454,500	235,500	51.8
	211	VD	Window	12.5	454,400	251,900	55.4

Table 7. (Continued)

Shipment	Jar	Jar Type	Bottom Screen	Dry Vol. (L)	No. of Eggs	No. of Viable Eggs	% Survival
38	23	MS	Window	2.5	106,100	64,200	60.5
	24	MS	Window	2.5	106,100	65,200	61.4
	25	MS	Window	2.5	106,100	77,400	73.0
	26	MS	Window	2.5	106,100	65,400	61.6
	27	MS	Window	2.5	106,100	60,200	56.7
			Subtotal	12.5	530,500	332,400	62.7
	222	VD	Window	12.5	530,400	332,700	62.7

Table 8. Developmental stages of live and dead American shad eggs collected daily during incubation Van Dyke, 1989. See Figure 4 for definition of incubation day and sampling schedule. Note that dead eggs were siphoned off prior to sampling on Day II.

Shipment	River	Incubation Day	Live Eggs No.	Live Eggs %	Live Eggs Stage	Number of Dead Eggs: Unfertilized	No Development	Gastrula	Early Embyro	Tail Free	Tail Free+	To De
10	P	I	166	55	gastrula	3	4	134	-	-	-	14
		II	343	93	tail free	-	-	21	-	5	-	2
		III	312	92	tail free+	1	5	22	-	-	-	2
		IV	498	95	tail free++	1	1	23	-	-	1	2
		V	-	-	-	-	-	-	-	-	-	-
13	H	Most eggs appear dead with burst yolks										
		II	330	68	early embryo	25	41	4	84	-	-	15
		III	295	81	tail free	11	6	48	-	6	-	7
		IV	387	79	tail free+	18	5	73	-	-	8	10
		V	177	76	tail free++	12	2	39	-	-	3	5
25	D	I	241	35	gastrula	39	51	356	-	-	-	44
		II	231	84	early embryo	8	13	22	1	-	-	4
		III	223	77	tail free+	34	14	19	-	-	-	6
		IV	271	84	tail free++	31	7	12	-	-	-	5
		V	250	85	tail free++	6	14	28	-	-	-	4
30	C	I	98	33	gastrula	3	68	126	-	-	-	19
		II	324	92	early embryo	4	23	2	-	-	-	2
		III	279	93	tail free	4	16	-	-	-	-	2
		IV	257	93	tail free+	3	15	-	-	-	-	1
		V	231	94	tail free++	2	13	-	-	-	-	1

Table 9. Effect of feeding Valium and Acepromazine sedatives to fingerling American shad, Benner Spr 1989.

Trial	Date	Raceway	Sedative	Concentration		Effect on schooling behavior	Effect on fright reaction
				mg/kg feed	mg/kg body wt.*		
1	8/16	Fl	Valium	4	.03	None	None
2	8/17	Fl	Valium	8	.06	None	None
3	8/21	Elb	Valium	16	.12	None	None
4	8/21	Fld	Valium	32	.25	None	None
5	8/23	Elb	Acepromazine	60	.47	None	None
6	8/23	Ela	Acepromazine	150	1.17	None	None
7	8/24	Flb	Acepromazine	300	2.34	None	None
8	8/24	Fla	Acepromazine	600	4.68	None	None
9	8/25	Elb	Valium	64	.50	None	None
10	8/25	Ela	Valium	128	1.00	Very slight reduction in schooling	None
11	9/20	Elb	Acepromazine	2400	18.72	None	None
12	9/20	Ela	Valium	132	1.03	None	None
13	9/20	Fla	Control	-	-	None	None
14	9/20	Flb	Acepromazine	3080	24.02	None	None

*Assumes fish eat .78% of their body weight.

Table 10. Tetracycline tagging regime for American shad stocked in the Susquehanna River Basin, 1989. Immersion tag/feed tag.

Size at Stocking	Pond/ Raceway	Stocking Location	Egg Source River: Virginia	Delaware	Hudson	Columbia
Fry	-	Thompsontown (Juniata R.)	Quadruple/0	Triple (3,13,17)/0	Triple (5,9,13)/0	Single/0
Fry	-	Montgomery Ferry (Susquehanna R.)	-	Triple (3,13,17)/0	-	Single/0
Fry	-	Lapidum (below Conowingo)	Double/0	Double/0	Double/0	Double/0
Fingerling	Rearing Pond (VD)	Thompsontown	-	-	-	Single/ single
Fingerling	Canal Pond	Thompsontown	-	Triple (3,13,17)/ Single	-	-
Fingerling	Benner Sp. Pond 4	BG&E (Crane Aquaculture)	Quadruple/ Single	-	-	-
Fingerling	Benner Sp. Raceways E1,F1	I,S&T (Safe Harbor)	Double/0	-	Triple (5,9,13)/0	-
Fingerling	Upper Spring Creek Pond 1	Thompsontown/RMC	Quadruple/ Double	-	-	-
Fingerling	Upper Spring Creek Pond 2	Thompsontown	Quadruple/ Triple	-	-	-
Fingerling	Upper Spring Creek Pond 3	Thompsontown	Quadruple/ Quadruple	-	-	-

Table 11. Tetracyline tag retention for American shad reared in 1989.

Pond/ Raceway	Tag Immersion/Feed	# Exhibiting Tag	Projected # Stocked	Disposition
Rearing Pond	Single/single*	0		
	Single/0	22/30 (73%)	260	
	Double/0**	7/30 (23%)	80	
	Triple/0**	1/30 (3%)	10	Stocked
			350	T-town
BSRE1	Double/0*	27/29 (93%)	2,330	
	Single/0	2/29 (7%)	170	I,S&T
			2,500	Safe Harbor Studies
CP	Triple/single* (days 3,13,17)	31/31 (100%)	20,000	Stocked T-town
BSRF1	Triple/0* (days 5,9,13)	21/21 (100%)	1,000	I,S&T Safe Harbor Studies
USCP1	Quadruple/double*	29/33 (88%)	13,180	
	Quadruple/single	1/33 (3%)	460	
	Quadruple/0	2/33 (6%)	910	
	Quadruple/various	32/33 (97%)	14,550	
	Single/double	1/33 (3%)	450	Stocked
			15,000	T-town
			1,000	RMC Studies

Table 11 (continued)

Pond/ Raceway	Tag Immersion/Feed	# Exhibiting Tag	Projected # Stocked	Disposition
USCP2	Quadruple/triple*	4/29 (15%)	1,380	
	Quadruple/double	2/29 (7%)	690	
	Quadruple/single	5/29 (17%)	1,720	
	Quadruple/0	13/29 (45%)	4,480	
	Quadruple/various	24/29 (83%)	8,270	
	Triple/0	1/29 (3%)	350	
	Double/0	3/29 (10%)	1,030	
	Single/0	1/29 (3%)	350	Stocked
			10,000	T-town
USCP3	Quadruple/quadruple*	27/32 (84%)	12,660	
	Quadruple/triple	4/32 (12%)	1,880	
	Quadruple/0	1/32 (3%)	460	Stocked
	Quadruple/various	32/32 (100%)	15,000	T-town
BSP4	Quadruple/single*	25/31 (81%)	4,030	
	Quadruple/0	6/31 (19%)	970	B,G&E
	Quadruple/various	31/31 (100%)	5,000	Studies

* attempted tag combination
** thought to be hatchery escapees

JOB IV.

EVALUATION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER

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

INTRODUCTION

Juvenile American shad were collected at numerous locations in the lower Susquehanna River in 1989 in an effort to document timing of the migration, growth rates and abundance. Analysis of tetracycline marks on otoliths of subsampled shad was used to indicate what proportion of the collection is of hatchery origin. Also, because the various shad egg sources and pond culture sites were distinctively marked (see Job III), the relative contribution of each stocked strain and culture situation to the outmigrant population could be differentiated.

Many individuals were involved in collection and analysis of juvenile shad in 1989. For their contributions to this report, appreciation is extended to Joseph Nack and Tim Robbins (NES), Paul Heisey and Chris Frese (RMC), Ted Rineer (SHWPC), Dale Weinrich (DNR), and Mike Hendricks and Don Torsello (PFC).

HATCHERY AND ADULT SHAD STOCKING SUMMARY

Juvenile American shad in the Susquehanna River above Conowingo Dam are derived from two sources - natural reproduction of adult spawners transferred upstream from the fish lift at Conowingo and hatchery stocking of fry and fingerlings from PA Fish Commission facilities in Pennsylvania. Juveniles occurring below Conowingo may result from natural spawning below or above dams, hatchery fry stocking at Lapidum, MD, or fry or fingerlings released above dams from Pennsylvania hatcheries.

A total of 6,469 adult American shad were hauled from the Conowingo fish lift during mid-April through mid-June and stocked below York Haven Dam (see Job I). Overall sex ratio in these transfers was 3.4 : 1.0 favoring males and there were 114 observed mortalities associated with transporting fish. This stocking level compares with 4,645 live shad above Safe Harbor in 1988 and 6,567 in 1987.

During the 1989 shad production season, PA Fish Commission biologists reared and released a record 21.1 million shad fry (15-37 days old) and 70,000 fingerlings (107-204 days old) in the Susquehanna watershed. Fry were stocked between May 30 and July 4 in the Juniata River at Thompsontown (9.557 million), between May 25 and July 17 at Lapidum, MD (7.653 million), and at Montgomery Ferry on the main stem above the confluence of the Juniata River between July 7-11 (3.908 million). Most fingerlings were stocked at Thompsontown with minor numbers at Safe Harbor and Holtwood.

The 13.465 million shad fry stocked above dams in the Susquehanna in 1989 compares to 6.45 M, 5.18 M, and 9.90 M in 1988, 1987, and 1986, respectively. Shad stocking at Lapidum below Conowingo Dam in 1989 substantially exceeded the 3-year average of 4.41 million during 1986-1988. Fingerling production this year was very similar to recent plants (61,000 to 81,000 in 1986-88).

JUVENILE SHAD COLLECTIONS - 1989

American shad outmigration from the river was assessed during September - November with nets at York Haven and Holtwood forebays, from cooling water strainer collections at Safe Harbor and Conowingo hydroelectric projects, and from travelling screens at the Peach Bottom Atomic Power Station intake.

Middle to late summer occurrence of young shad was monitored at and near the vicinity of the Texas Eastern pipeline crossing project (Marietta, PA) during July and August, and in the lower Susquehanna River and Flats by Maryland DNR during annual juvenile finfish and striped bass surveys (Job VI). Samples of shad from the various netting and electrofishing collections were returned to Benner Spring Research Station (PFC) for tetracycline mark analysis. All collecting sites for 1989 are shown in Figures 4-1, 6-2 and 6-3.

MID-SUMMER SHAD COLLECTIONS

York Haven to Holtwood

National Environmental Services was contracted by the Texas Eastern Gas Pipeline Company to assess the impact of laying two 36-in. gas pipelines across the Susquehanna River near Marietta, PA. All drilling and bedrock blasting for the crossing occurred between July 15 and August 28 in an area 7 miles below York Haven Dam and 5.5 miles upstream from Columbia/Wrightsville, PA. Periodic collections were made between Holtwood and Three Mile Island with most assessment concentrated near the pipeline crossing (Erb's Landing) and at Columbia and Wrightsville. Collecting gear included 300 and 400-ft. seines, 20-ft. diameter cast nets, one-meter and 1/2 meter hoop (bongo) nets, a fixed trawl with 100-ft guide wings, and electrofishing (Robbins and Lathrop, 1990).

During July and August, the York Haven forebay was sampled on three occasions and produced only 3 American shad in 43 throws of the cast net. Seining in the TMI East Channel near Red Hill Dam produced an additional 7 shad in five trips. Another seine site near Brunner Island, immediately below York Haven Dam, was sampled twice in July and produced 10 shad. The Holtwood forebay was netted on five occasions between July 23 and August 28 and 3 American shad were collected in 35 cast net throws.

Seine sites at Columbia and Wrightsville produced a total of 1,161 juvenile American shad in five collecting dates between July 22 and August 30. Of these, 1,048 shad were taken on July 22 which coincided with several days of high river flow (60,000+ cfs) and water temperature depression to the mid-60's (°F). Fish ranged in size from 25-85 mm and averaged 61 mm in late July and early August (n=94). By mid to late August, shad averaged 78 mm and ranged between 35-110 mm (n=21).

The collecting sites around Erb's Landing and the pipeline crossing vicinity produced 600 American shad on 21 sample dates between July 17 and August 30. Shad were taken on all but three occasions and collections varied from one to 91 fish per date (mean = 29). Table 1 shows length frequency distribution of 368 shad measured at the pipeline crossing collection sites. For all dates in July and August, 72% (265 fish) were less than 50 mm and 29% (107) were less than 35 mm. All July and August shad collections associated with monitoring of the pipeline crossing project are shown in Table 2.

Bubble screens, a barrier net and pre-detonation shots were used to reduce the number of resident and migratory fishes in the blast zone. A total of only 13 juvenile American shad were included in near-field mortality collections at the pipeline crossing site. Channel catfish comprised over 44% of fish killed with lesser numbers of quillback, white sucker, shorthead redhorse, smallmouth bass, walleye, gizzard shad and other residents (Robbins and Lathrop, 1990).

__Susquehanna River Mouth and Flats__

Juvenile American shad were collected with a 100-ft. haul seine (79 fish); otter trawl (16 fish); and electrofishing (97 fish) in the upper Chesapeake Bay during July through early October at numerous sites in conjunction with Maryland DNR's annual juvenile finfish and striped bass relative abundance surveys. Specific results by gear, collecting location and date are provided in Job VI and otolith analysis for these fish are given in this report.

AUTUMN SHAD COLLECTIONS

York Haven Dam

Evening collections with the 20-ft. diameter cast net (3/8-in. mesh) were attempted at York Haven once each week from the first of September through November 9. Shad were not observed or collected here until October 12 when 68 fish were taken in four casts. Only 6 and 7 shad were collected on October 20 and 26, respectively, and none were taken thereafter (Table 3). Successful October collections at York Haven were made at water temperatures of 54-58 °F and shad ranged in size from 122-148 mm (mean 135 mm).

Safe Harbor Dam

Safe Harbor personnel began examining cooling water intake strainers at the hydroelectric project in early September. No shad appeared in these clean-outs until October 2. Between October 2-25, a total of 30 American shad were taken on 13 dates. Ten (33%) of the shad appeared on October 21 and no more than 4 shad were observed in any other collection (Table 4). Daily inspections continued from October 26 through November 15, but no additional shad were taken.

Holtwood Dam

The forebay at Holtwood (inner forebay near Unit 10) was sampled with cast net weekly from September 5 through November 28. Table 5 shows that very few shad were taken on any dates, but that 38 of 42 fish in autumn collections at Holtwood were netted between September 26 and October 17 in 40 throws. Water temperature during these four collecting dates was between 61-68 °F and fish ranged in size from 98 - 147 mm (mean 122 mm).

RMC used their 8-ft. x 8-ft. lift net in the Holtwood inner forebay to collect live juvenile shad for special studies at Holtwood, Safe Harbor and Conowingo. Standard effort was ten lifts per day or night and collections were made on 19 dates between September 22 and November 15 (Table 6). A total of 556 American shad and fewer than 200 gizzard shad were collected in 286 lifts of the net. Of that number, 457 American shad (82%) were taken on one day, October 21, in 56 lifts. Other collections included 23 shad on September 23; 63 shad taken in five days between October 4-15; 8 shad in five days between October 16-20; and, 5 shad in all subsequent collections between October 26 and November 15 (7 dates).

<u>Peach Bottom</u>

Cooling water intake screens at Peach Bottom Atomic Power Station in Conowingo Pond were checked once per week during August 22 through October 17 with no American shad observed. Sampling switched to three times per week beginning October 23 and 3 shad were collected on October 24. Observations continued until November 22 with a break during October 30 - November 6, but no additional shad were taken.

<u>Conowingo Dam</u>

All cooling water intake strainers at Conowingo project were examined for shad each Wednesday from October 18 through November

29. A total of 6 American shad and about 265 gizzard shad appeared in the seven weekly collections. Five of these American shad appeared between November 8-22.

RESULTS OF OTOLITH MARK ANALYSIS

Hundreds of American shad taken in collections by NES, RMC, and Maryland DNR were frozen and returned to Benner Spring for mark assessment on otoliths. Fish were subsampled from these collections to provide a representation of the entire collecting season at select sites. Otoliths were surgically removed from the fish, cleaned and mounted on slides with Permount, ground and polished to the focus on both sides, and viewed under ultraviolet light to detect the presence of fluorescent rings indicative of tetracycline immersion or feed treatments. The technique is explained in further detail by Lorson and Mudrak (1987).

York Haven Collections

Fifty-two of the 90 shad collected by NES at York Haven forebay and the East Channel of Three Mile Island were processed. Although no adult spawners were stocked above York Haven in 1989, 3 juvenile shad examined from a collection on July 21 were unmarked. Extremely high river flows in mid-May (210,000 cfs) may have allowed some adult shad to migrate above the East Channel dam at TMI and spawn. It is also possible that anglers may have caught shad below York Haven and transplanted them above the dam.

All other York Haven shad processed for tetracycline marks were confirmed to be of hatchery origin. Forty-nine fish from collections made during the weeks of July 30, October 1, 8, 15, and 22 were examined (Table 7). Of these, 22 (45%) were of Virginia River origin (quadruple mark), 16 (33%) showed the Hudson River tag (days 5, 9, 13), 7 (14%) were Columbia River fish (single immersion), and the remaining 4 (8%) were from Delaware River stockings (marked on days 3, 13, 17). None of the fish displayed the feed tag placed on fingerlings released from ponds.

__Columbia, Wrightsville and Marietta Collections__

More than 100 shad from net collections made during monitoring of the Texas Eastern pipeline crossing were returned to Benner Spring for mark analysis. A total of 66 fish, taken between July 21 and August 11, were examined from Columbia, Wrightsville, Washington Boro, and Marietta (river miles 42-48).

Of the 23 shad examined from mid-July collections, 14 (61%) were from the Virginia egg sources, 7 (30%) were Hudson, and only 1 fish (4%) was Columbia River stock. The remaining otolith showed typical hatchery microstructure but no discernable tag due to auto-fluorescence (see Job V, Task 6). Otoliths from shad taken in early to mid-August showed a completely different stock make-up with Columbia River fish representing 22 of 43 (51%) of those examined. Hudson, Virginia and Delaware fish constituted 21%, 16%, and 9%, respectively of the remainder with another single fish showing hatchery structure but no tag on the otolith (Table 7).

Holtwood Collections

Shad collected in the Holtwood inner forebay by NES and RMC were provided to the PFC for mark analysis. Of the three earliest fish examined (July 23 cast net sample), two were wild and one was a Hudson fish. An additional 126 shad were processed from collections made between September 11 and October 21. Of these, 54 (43%) were Hudson River fish, 46 (37%) Columbia, 21 (17%) Virginia, and 2 (1.6%) Delaware source (Table 7). Additionally, 2 wild fish and one unmarked hatchery fish were noted. As was the case at York Haven and Columbia/Wrightsville, no feed-tagged shad (i.e. fingerling releases) were detected.

Conowingo Dam

Five of the nine shad taken in the cooling water strainers and screens at Conowingo and Peach Bottom (October 24 - November 22), were examined for hatchery marks (Table 7). Three of these were quadruple marked Virginia fish, one was a Columbia and the remainder was a wild yearling.

River Mouth and Flats

Mounted otoliths from young shad collected by Maryland DNR biologists during their abundance index surveys for juvenile finfish and striped bass were provided to PFC for assessment. A total of 111 otoliths from 1989 year-class shad were viewed from collections made between late July and early October at various sites with electrofishing gear, seines and trawls.

Eighty-eight of 111 fish (79%) were marked and 77 of these (87%) showed the double immersion tag indicating they were cultured at Van Dyke from various egg sources and stocked at Lapidum, MD (Table 7). Also, 7 shad (6.3% overall) were triple-marked Hudson fish, 3 (2.7%) were single-marked Columbia, and one fish showed the Delaware River tag. Thus, 11 shad in the 111 fish sample (10%) came from fry stockings in the Juniata River or main-stem above dams. No fingerling feed tags were observed.

Twenty-three shad otoliths from this collection were unmarked. Of these, 18 showed microstructure characteristic of hatchery fish and 5 showed wild microstructure. Maryland DNR researchers are correlating individual otolith analysis data with collecting location, date and gear to determine if there is any pattern to the stock assessment observed here.

DISCUSSION

Run Timing

In all prior years of juvenile shad outmigration assessment in the Susquehanna the run from the river was well defined. Fish usually first appeared at York Haven in mid-September to mid-October when water temperature dipped below 70° F. Abundance typically built rapidly to peak levels by mid-October to early November with temperatures ranging 55-60° F, and tapered off as water temperature dropped below about 50° F. Shad stocked in the Juniata River as fry from Van Dyke rarely appeared at York Haven or points further downstream before mid-September.

By contrast, tetracycline marked shad from Juniata River stockings appeared in abundance this summer during mid-July through August in the Columbia-Wrightsville-Marietta collection areas below York Haven. Hatchery fry stocked above all dams also appeared in the earliest Holtwood and upper Chesapeake Bay collections in late July. Mid-summer river temperatures fluctuated with flows and ranged between 64° F on July 17-18 and 83° F on August 6 (Figure 4-2). Average daily water temperatures during July and August were 72° F and 77° F, respectively, as measured at Safe Harbor Dam.

In past years we have speculated that river flow during summer and fall months was an important factor in triggering juvenile shad migration from upstream nursery areas (St. Pierre, 1989; Young, 1988). Precipitation and river discharges were unusually high in

1989 which likely accounted for early appearance of juvenile shad 50-100 miles downstream from the Thompsontown release site on the Juniata River.

As pointed out earlier, a record 9.557 million shad fry were released at Thompsontown between May 25 and July 4, and 3.908 million fish were placed at Montgomery Ferry during July 7-11. This latter stocking was necessitated by flooding in the Juniata River. As measured by the USGS gauge at Newport, PA, 10 miles downstream from Thompsontown, mean river flow in the Juniata in May and June, 1989 was about twice the long-term average (Figure 4-3). July flows were worse, amounting to an almost six-fold increase (12,000 cfs versus 2,100 cfs). Average rainfall in the Juniata Basin was 9.26 inches in July and caused small stream flooding and extremely high and turbid conditions in the main river. The precipitation surplus in the Juniata watershed (amount above normal) for the January-July, 1989 period was the highest in the Susquehanna Basin reaching 10 to 14-inches in the area around Lewistown to Thompsontown (SRBC, 1989).

Naturally, heavy rainfall was not limited to the Juniata watershed. The Harrisburg gauge showed similar flow elevations for May through July (Figure 4-3). Based on daily records from the Safe Harbor project, June flows averaged 66,000 cfs this year compared to the 55-year average of 28,600 cfs; and July flows averaged 41,700 cfs versus the long-term average of 15,100 cfs. Peak days of 127,000 to 155,000 cfs were recorded during June 19-23. Flows exceeded 60,000 cfs on two occasions in July.

High river flows associated with summer rainstorms held water temperatures below 70° F for most of June and 12 days in July (Safe Harbor data). Thus, much of the stocking of very young shad occurred, by necessity, during periods when the nursery waters were high, turbid and cool. Early appearance of large numbers of these shad below York Haven in July-August indicates that they either chose to migrate early due to temperature-flow conditions more typical of autumn, or more likely, that they were swept downstream with flood waters until they reached the relatively quiescent headwaters of Lake Clarke.

Almost 8 million Columbia River shad were stocked at Thompsontown or Montgomery Ferry between June 30 - July 11 as 16-20 day old fry. A large percentage of shad collected near Marietta, PA during July 17-20 were less than 40 mm (TL). Most shad in the 25-50 mm size range which were assessed for tetracycline marks on otoliths were of Columbia River origin. Thus, Columbia River fry moved downstream a distance of 35-50 miles in a period of 6-18 days, a situation most indicative of larval drift in fast high water.

Abundance

In past year reports we discussed relative abundance of juvenile shad during autumn outmigration at York Haven based on weekly cast net samples and hydroacoustic assessment; at Holtwood based on cast net and lift net collections; and at Conowingo, Safe Harbor and/or Peach Bottom based on daily or weekly strainer and screen impingement samples (St. Pierre, 1989; Young, 1988). The fixed-aspect acoustic monitor across the York Haven headrace was not employed in 1989. Also, with upstream stocked fry reaching the river mouth as early as mid-July, none of the forebay netting or late-start strainer checks were useful for comparison against prior year data. The 1989 outmigration in the river was not measurable by any standards used in past years.

In 1988, juvenile gizzard shad were very abundant at Holtwood and Conowingo with tens of thousands taken in nets and from strainers (St. Pierre, 1989). By contrast, only a few hundred were noted at these sites in 1989 with comparable effort. This dramatic change from one year to the next is probably a result of the same environmental conditions in the river which affected American shad movements and abundance.

In the upper Chesapeake Bay, juvenile American shad were much more abundant to all DNR collecting gear than in any prior year since 1980 when survey information was first included in SRAFRC reports. Catch per unit effort (CPUE) for haul seine and trawl was three to five times higher in 1989 than in any other year. Electrofishing in the upper bay during August 15 through October 31, 1989 produced 97 juvenile shad in 9.24 hours of shock time. In 1988, the first year this gear was used, only 2 shad were taken in 11.3 hours during late September through mid-November.

Otolith mark analysis indicated that 69% of all fish examined from upper bay collections were hatchery fry stocked at Lapidum, 10% were from hatchery fry stocked above dams, and an additional 16% were unmarked but displayed otolith microstructure typical of hatchery fish. This indicates that shad abundance in terms of successful outmigration from the river appears to be higher in 1989 than in any past year. The abundance is related to record stocking of hatchery fry at Lapidum and upstream, and high river flow conditions which pushed fish to the bay early and probably reduced turbine mortality on the upstream stock due to spillage at hydro projects.

Growth

Shad collected during mid-July through August near the Texas Eastern pipeline crossing (Marietta) averaged 32 mm to 57 mm and ranged from 25 mm to 95 mm total length (Figure 4-4). Fish less than 60 mm have rarely been collected in the Susquehanna River in past assessments. Crecco and Savoy (1985) determined that juvenile shad in the 35-60 mm (TL) range are 40-60 days old in the Connecticut River. However, shad fry cultured in high densities at Van Dyke grow more slowly that wild fish, at least until they are stocked (Wiggins, et al, 1984). Based on time of collection, make-up of the mixed stock and size of fish, it appears that growth was normal in the Susquehanna River in 1989 despite the high river flows experienced.

Juvenile American shad measured at York Haven during collections made on October 12-26 averaged 135 mm. Holtwood fish taken on September 26 - October 17 averaged 122 mm. This compares to 1988 average sizes of 122 mm and 113 mm at York Haven and Holtwood, respectively, for collections taken one to four weeks later.

Forty-one of 47 shad (87%) from late season York Haven cast net samples were earliest stocked fry from Virginia, Hudson and Delaware River egg sources. A much higher proportion of Holtwood fish (33%) were later stocked Columbia River shad. The smaller average size of shad at Holtwood, compared to York Haven was also noted in 1988 cast net collections. St. Pierre (1989) theorized that this disparity may relate to smaller fish congregation in quiet heated waters of Holtwood's inner forebay.

<u>Stock Composition and Mark Analysis</u>

Of the 13,464,650 shad fry stocked above dams in the Juniata and Susquehanna River in 1989, Virginia fish amounted to only 477,320 (3.5%), placed at Thompsontown on May 30 and June 1. Based on tetracycline mark analysis, however, quadruple tagged (Virginia) shad constituted 26.6% (67 of 252) of all fish examined from lower river and upper bay collections which carried distinctive river-of-origin marks from the hatchery (Table 4-8). This is similar to 1988 results when Virginia fish made up 40% of the recoveries and less than 11% of fry stocked.

Hudson River shad comprised 37.3% of all shad examined with upstream marks, but with a stocking of 2,864,720 fry during June 5-28, their performance (i.e. relative survival) was only about one-fourth that of Virginia fish. This was the first year for Hudson River shad culture at Van Dyke.

As usual, Columbia River shad fry made up the largest share of fish stocked upstream. A total of 8,477,650 Columbia fry (63% of total stockings) were placed at Thompsontown and Montgomery Ferry during June 30 - July 11. Mark analysis showed that this source constituted 31.7% of downstream recoveries (80 of 252 fish), and relative survival was only 7% of that for Virginia fish (Table 4-8). Similarly, in 1988 Columbia River fish amounted to almost 82% of those stocked and only 35.5% of the downstream recoveries (St. Pierre, 1989).

Delaware River shad showed disappointing results. This source provided 1,644,630 shad fry (12.2% of total) stocked above dams between June 16 and July 7. Yet mark analysis indicated that only 11 of 252 fish (4.4%) in downstream collections were of Delaware River origin. Relative survival of this shad source was only 5% of that for Virginia fish, and about 25% of Hudson fish. Whereas Virginia and Columbia River fish performed similarly in 1988 and 1989, Delaware shad showed a 20-fold reduction in relative survival this year.

Mark analysis data were separated between nursery collections (July-August) and outmigration collections (September-October) to determine if the relative lack of late stocked Columbia and Delaware fish in early samples might be an indication that these fish simply held position in upstream refuge/nursery areas. If this was the case, later sampling at downstream hydro projects should have shown a noticeable increase in relative abundance for these strains. Columbia River fish comprised 34.7% of summer collections and 30.6% of autumn collections and Delaware contributions were 5.6% and 3.3%

Most Delaware fish were stocked 4 weeks after Virginia fish and 2 weeks after Hudson River fish at the same time that Columbia shad stocking began (Job III). These two strains where therefore both exposed to high river conditions associated with early July rainfall. Delaware and Columbia River shad survival (relative to Virginia fish) was similar at 5% and 7%, respectively.

It can be speculated that environmental conditions during the first several weeks post-stocking adversely affected survival of these two strains. Crecco and Savoy (1984) have shown close correlation between year-class strength (a function of larval survival) and June river flows in the Connecticut River (i.e. high flows generate weak year-classes). This phenomenon, related to July flow in the Susquehanna, may account for the observed poor survival of Delaware and Columbia strain shad.

Over 69% of shad examined from upper Chesapeake Bay collections had double-marked otoliths indicating that they were stocked as fry at Lapidum, MD. These stockings occurred between May 25 and July 17 and included 6.5% Virginia river fish, 36.5% Hudson and 57% Columbia. All strains were marked the same (days 5 and 9) and cannot be further segregated in these collections. Approximately 10% of upper bay shad examined were of upstream hatchery origin (mostly Hudson River fish), and 16.2% were unmarked but showed typical hatchery microstructure on otoliths.

In 1986, 10 of 21 (47.6%) juveniles from Upper bay collections displayed the double mark indicating that they came from the 5.2 million shad fry stocked at Lapidum. Only one fish (4.8%) that year was of upstream origin with the remainder presumed to be wild. A total of only 7 specimens were examined from 1987 and 1988 upper bay collections.

Juvenile shad resulting from natural reproduction above dams in the Susquehanna River comprised only 2.8% (7 of 252) of fish examined for hatchery marks and microstructure. This compares with 5.5% and 9% of collections in 1988 and 1987, respectively. High river flows experienced in mid-May could have pushed spawners back downstream as noted in the Conowingo Pond telemetry study (Job V, task 1). Similarly, eggs and larvae produced from later spawning adults would have been exposed to abnormally high flows in June and July which could result in poor survival or displacement of fish from upstream sampling areas.

In collections of shad below Conowingo Dam, wild juveniles made up 4.5% (5 of 111) of fishes examined for hatchery marks. During the prior 3 years, wild fish constituted 55% (15 of 27) of the juvenile shad examined. Again, high spring and summer river flows may have contributed to the abundance of hatchery fish in the upper Chesapeake in 1989.

No feed tagged fingerlings reared in ponds in Pennsylvania were collected in the lower river or upper bay in 1989. However, only the first 20,000 fish released from the Thompsontown canal pond on September 21 (107-day old Delaware fish) were placed into the river early enough to expect any recovery. With only 182 fish examined from all collections made after October 1, likelihood of detecting any fish from this stock was slight.

REFERENCES

Crecco, V. A., and T. F. Savoy. 1985. Effects of biotic and abiotic factors on growth and relative survival of young American shad, *Alosa sapidissima*, in the Connecticut River. Can. J. Fish. and Aquat. Sci. 42(10): 1640-1648.

Crecco, V. A., and T. F. Savoy. 1984. Effects of fluctuations in hydrographic conditions on year-class strength of American shad (*Alosa sapidissima*) in the Connecticut River. Can. J. Fish. and Aquat. Sci. 41(8): 1216-1223.

Lorson, R. D., and V. A. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. No. Amer. J. Fish Mgmt. 7: 453-455.

Robbins, T. W., and B. Lathrop. 1990. Report on the impact of construction on young American shad and resident fishes of the Susquehanna River associated with the Texas Eastern Gas Pipeline Company crossing at Marietta, PA. Env. Div. The Wyatt Group, Lancaster, PA

SRBC. 1989. Staff Report of the Susquehanna River Basin Commission for September, 21, 1989 - Harrisburg, PA.

St. Pierre, R. A. 1989. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River. 1988 Ann. Prog. Rep. to SRAFRC, Harrisburg, PA.

Wiggins, T. A., T. R. Bender, D. D. Truesdale, K. R. Stark and V. A. Mudrak. 1984. American shad hatchery operations and cultural research. In Restoration of American shad to the Susquehanna River. 1983 Ann. Prog. Rept. to SRAFRC, Harrisburg, PA.

Young, L. M. 1988. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River. 1987 Ann. Prog. Rept. to SRAFRC, Harrisburg, PA.

Table 4-1 Length frequency data (5mm groups) for young American shad taken in the vicinity of the Texas Eastern pipeline crossing, Susquehanna River, Marietta, PA, July - August 1989. Totals indicate measured fish only; unmeasured released fish are not entered.

DATE	17-Jul	18-Jul	20-Jul	21-Jul	24-Jul	25-Jul	27-Jul	29-Jul	01-Aug	03-Aug	05-Aug	09-Aug	11-Aug	15-Aug	16-Aug	17-Aug	19-Aug	28-Aug
LENGTH (mm)																		
20.1-25.0	2	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-
25.1-30.0	14	2	-	-	-	-	-	7	10	10	-	1	1	-	-	-	-	-
30.1-35.0	18	8	2	-	1	-	-	3	4	7	1	3	6	1	1	-	1	-
35.1-40.0	8	11	9	-	-	1	-	1	2	3	6	1	11	-	1	-	-	-
40.1-45.0	8	11	11	2	5	-	1	-	1	-	2	-	5	-	5	-	-	-
45.1-50.0	6	8	18	3	2	1	3	-	-	-	1	-	7	-	2	1	-	-
50.1-55.0	3	8	6	-	4	1	-	1	1	-	1	-	1	-	1	-	-	1
55.1-60.0	-	7	13	-	5	-	-	1	-	-	-	-	1	-	-	-	-	2
60.1-65.0	-	1	5	1	6	-	2	-	-	-	1	-	-	-	1	-	-	-
65.1-70.0	1	1	4	-	3	-	2	-	-	3	-	-	-	-	-	-	-	-
70.1-75.0	-	-	-	-	4	-	-	-	-	1	-	-	1	-	-	-	-	-
75.1-80.0	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	-	-	-
80.1-85.0	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-
85.1-90.0	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
90.1-95.0	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
TOTAL	60	57	68	6	31	3	8	15	21	24	17	5	35	1	11	1	1	3
MEAN (x)	36.4	44.6	49.9	49.0	58.4	48.3	56.0	32.4	32.7	37.3	54.3	33.8	44.3	31.0	44.9	50.0	31.0	57.0
STANDARD DEVIATION (s)	8.7	9.4	8.9	7.6	11.5	9.1	10.1	10.1	13.6	14.8	20.2	2.9	13.3	-	8.3	-	-	5.2

From Robbins and Lathrop, 1990

Table 4-2 Numbers and location of American shad taken in the vicinity of the Texas Eastern pipeline crossing, Susquehanna River, Marietta, PA, 17 July - 30 August, 1989. (Blast days are indicated with an asterisk (*). Dash (-) indicates area not sampled on that date. Zero (0) indicates sampling in the area, but no shad taken).

Sampling Date	Above York Haven Dam	Below York Haven Dam Brunner Island	Erb's Landing and Blast Vicinity	Columbia & Wrightsville	Holtwood Dam	Safe Harbor Dam	TOTAL
7-17	-	-	60	-	-	-	60
7-18*	-	-	57	-	-	-	57
7-19	-	10	-	-	-	-	10
7-20*	-	-	68	-	-	-	68
7-21	3	-	15	-	-	-	18
7-22	-	-	-	1048	-	-	1048
7-23	2	-	-	-	2	0	4
7-24	-	-	75	-	-	-	75
7-25*	-	-	3	-	-	-	3
7-27*	-	-	20	-	-	-	20
7-28	-	0	0	-	-	-	0
7-29*	-	-	15	-	-	-	15
8-1	-	-	24	-	-	-	24
8-2	3	-	-	35	-	-	38
8-3*	2	-	24	10	-	-	36
8-4*	-	-	0	-	-	-	0
8-5*	-	-	17	-	-	-	17
8-6	0	-	-	-	0	-	0
8-9*	-	-	91	-	-	-	91
8-11*	-	-	35	-	-	-	35
8-13	0	-	-	61	0	-	61
8-15	-	-	1	-	-	-	1
8-16*	-	-	90	-	-	-	90
8-17*	-	-	1	-	-	-	1
8-18	0	-	-	-	-	-	0
8-19*	-	-	1	-	-	-	1
8-20	-	-	-	-			0
8-21	0	-	-	-	-	-	0
8-24*	-	-	0	-	-	-	0
8-28*	-	-	3	-	-	-	3
8-30	-	-	-	7	-	-	7
TOTAL	10	10	600	1161	2	0	1783

From Robbins and Lathrop, 1990

Table 4-3. Juvenile American shad collected in cast nets at the York Haven project forebay, July - November, 1989.

Date	Shad Catch	Effort (# casts)	Catch/ Effort	Mean FL (mm)	Length Range	Water Temp.-F
7/21	3	25	0.33	40	30-52	80
8/06	0	10	0.0	-	-	72
8/13	0	8	0.0	-	-	70
9/03	0	10	0.0	-	-	72
9/07	0	12	0.0	-	-	74
9/15	0	12	0.0	-	-	78
9/21	0	10	0.0	-	-	71
9/28	0	10	0.0	-	-	70
10/6	0	10	0.0	-	-	58
10/12	68	4	17.0	135	122-148	56
10/20	6	10	0.7	128	123-138	54
10/26	7	10	0.6	141	135-148	55
11/01	0	10	0.0	-	-	60
11/09	0	8	0.0	-	-	53
Totals	84	24*	3.37*	135	30-148	-

*peak weeks only (10/12-10/26)

Table 4-4. Collection of juvenile American shad from cooling water strainers at Safe Harbor project, September - November, 1989.

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

Table 4-5. Juvenile American shad collected with cast nets at Holtwood project forebay, July-November, 1989.

Date	Shad Catch	Effort (# casts)	Catch/ Effort	Mean FL (mm)	Length Range	Water Temp.-F
7/23	3	5	0.6	not measured		80
8/06	0	6	0.0	-	-	72
8/13	0	6	0.0	-	-	70
8/20	0	8	0.0	-	-	74
8/28	0	10	0.0	-	-	85
9/05	1	10	0.1	not measured		85
9/11	3	12	0.25	127	125-130	74
9/19	0	12	0.0	-	-	78
9/26	8	10	0.8	122	104-132	68
10/4	15	10	1.5	115	98-130	61
10/10	5	10	0.5	131	116-146	64
10/17	7	10	0.7	129	117-147	64
10/24	0	10	0.0	-	-	56
10/31	0	10	0.0	-	-	60
11/07	0	10	0.0	-	-	54
11/28	0	6	0.0	-	-	42
Totals	42	40*	0.9*	125	98-147	-

(*peak weeks only)

Table 4-6. Catch of juvenile American shad with 8-ft. x 8-ft. lift net at Holtwood project forebay, September-November, 1989 (RMC data).

Date		Number of Lifts	Number of Shad
09/22		10	23
10/04		10	0
10/05		10	4
10/06		10	33
10/13	(AM)	10	25
	(PM)	10	0
10/15		10	1
10/16		10	0
10/17	(AM)	10	0
	(PM)	10	0
10/18		10	0
10/19	(AM)	10	0
	(PM)	10	0
10/20	(AM)	10	0
	(PM)	10	8
10/21	(AM)	10	31
	(PM)	46	426
10/26		10	5
10/30	(AM)	10	0
	(PM)	10	0
11/03		10	0
11/06		10	0
11/09		10	0
11/13		10	0
11/15		10	0
TOTALS		286	556

Table 4-7. Tetracycline marking of juvenile American shad collected in the Susquehanna River and Flats, 1989. Key: Immersion tag(days)/feed tag.

[LEGEND: 0/0 - no marks; 5/0 - Columbia fry; 5,9/0 - Lapidum fry; 5,9,13/0 - Hudson fry; 3,13,17/0 - Delaware fry; 5,9,13,17/0 - Virginia fry]

	YORK HAVEN FOREBAY		COLUMBIA/MARIETTA		HOLTWOOD FOREBAY		CONOWINGO POND		UPPER CHESAPEAKE BAY	
Week of	Tag	# Fish	Tag	# Fish	Tag	# Fish	Tag	# Fish	Tag	# Fish
07/16	0/0	3	5/0	1	-	-	-	-	-	-
			5,9,13/0	5						
			5,9,13,17/0	12						
				18						
07/23	-	-	0/0**	1	0/0	2	-	-	0/0**	1
			5,9,13/0	2	5,9,13/0	1			5,9/0	4
			5,9,13,17/0	2					5,9,13/0	1
				5		3				6
07/30	5/0	1	5/0	14	-	-	-	-	0/0	1
	5,9,13,17/0	1	3,13,17/0	4					5,9/0	2
		2	5,9,13/0	9						3
			5,9,13,17/0	7						
				34						
08/06	-	-	5/0	5	-	-	-	-	5,9/0	1
08/13	-	-	0/0**	1	-	-	-	-	5,9/0	1
			5/0	3						
				4						
08/20	-	-	-	-	-	-	-	-	5,9/0	3
									3,13,17/0	1
									5,9,13/0	2
										6

Table 4-7. (Continued)

[LEGEND: 0/0 - no marks; 5/0 - Columbia fry; 5,9/0 - Lapidum fry; 5,9,13/0 - Hudson fry; 3,13,17/0 - Delaware fry; 5,9,13,17/0 - Virginia fry]

Week of	YORK HAVEN FOREBAY Tag	# Fish	COLUMBIA/MARIETTA* Tag	# Fish	HOLTWOOD FOREBAY Tag	# Fish	CONOWINGO POND Tag	# Fish	UPPER CHESAPEAKE BAY Tag	# Fish
08/27	-	-	-	-	-	-	-	-	0/0	1
									0/0**	5
									5/0	1
									5,9/0	4
									5,9,13/0	1
										12
09/03	-	-	-	-	5,9,13/0	1	-	-	-	-
09/10	-	-	-	-	5/0	1	-	-	0/0	3
					5,9,13/0	3			0/0**	10
						4			5,9/0	47
									5,9,13/0	3
										63
09/17	-	-	-	-	-	-	-	-	5/0	1
									5,9/0	1
										2
09/24	-	-	-	-	5/0	1	-	-	0/0**	1
					5,9,13/0	7				
						8				
10/01	5/0	3	-	-	5/0	7	-	-	0/0**	1
	5,9,13/0	4			5,9,13/0	6			5/0	1
	5,9,13,17/0	1			3,13,17/0	1			5,9/0	14
		8			5,9,13,17/0	1				16
						15				

Table 4-7. (Continued)

[LEGEND: 0/0 - no marks; 5/0 - Columbia fry; 5,9/0 - Lapidum fry; 5,9,13/0 - Hudson fry; 3,13,17/0 - Delaware fry; 5,9,13,17/0 - Virginia fry]

	YORK HAVEN FOREBAY		COLUMBIA/MARIETTA*		HOLTWOOD FOREBAY		CONOWINGO POND		UPPER CHESAPEAKE BAY	
Week of	Tag	# Fish	Tag	# Fish	Tag	# Fish	Tag	# Fish	Tag	# Fish
10/08	5/0	2	-	-	5/0	9	-	-	-	-
	5,9,13/0	11			5,9,13/0	17				
	5,9,13,17/0	11			5,9,13,17/0	4				
		24				30				
10/15	5/0	1	-	-	0/0	2	-	-	-	-
	3,13,17/0	4			0/0**	1				
	5,9,13/0	1			5/0	28				
	5,9,13,17/0	2			3,13,17/0	1				
		8			5,9,13/0	21				
					5,9,13,17/0	16				
						69				
10/22	5,9,13,17/0	7	-	-	-	-	0/0	1***	-	-
							5/0	1		
							5,9,13,17/0	2		
								4		
11/05	-	-	-	-	-	-	5,9,13,17/0	1	-	-
TOTALS	0/0	3	0/0**	2	0/0	4	0/0	1***	0/0	5
	5/0	7	5/0	23	0/0**	1	5/0	1	0/0**	18
	3,13,17/0	4	3,13,17/0	4	5/0	46	5,9,13,17/0	3	5/0	3
	5,9,13/0	16	5,9,13/0	16	3,13,17/0	2		5	5,9/0	77
	5,9,13,17/0	22	5,9,13,17/0	21	5,9,13/0	55			3,13,17/0	1
		52		66	5,9,13,17/0	21			5,9,13/0	7
						129				111

**hatchery microstructure, tag not visible due to autofluorescence
*** yearling

Table 4-8. Numbers of American shad fry released and juveniles recovered, by egg source river, Juniata and Susquehanna Rivers, 1989. Recoveries of wild fish and fish released as fingerlings are excluded.

Egg Source	Fry Released		JUVENILES RECOVERED York Haven		Columbia/ Wrightsville*		Holtwood Forebay		Cono. Pond/ Upper Bay		Total (all sites)		Relative Survival
river	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
VIRGINIA	477,320	(3.5)	22	(44.9)	21	(32.8)	21	(16.9)	3	(20.0)	67	(26.6)	1.00
HUDSON	2,864,720	(21.3)	16	(32.6)	16	(25.0)	55	(44.4)	7	(46.6)	94	(37.3)	0.23
DELAWARE	1,644,630	(12.2)	4	(8.2)	4	(6.3)	2	(1.6)	1	(6.7)	11	(4.4)	0.05
COLUMBIA	8,477,980	(63.0)	7	(14.3)	23	(35.9)	46	(37.1)	4	(26.7)	80	(31.7)	0.07
TOTALS	13,464,650		49		64		124		15		252		

*includes Marietta and Washington Boro

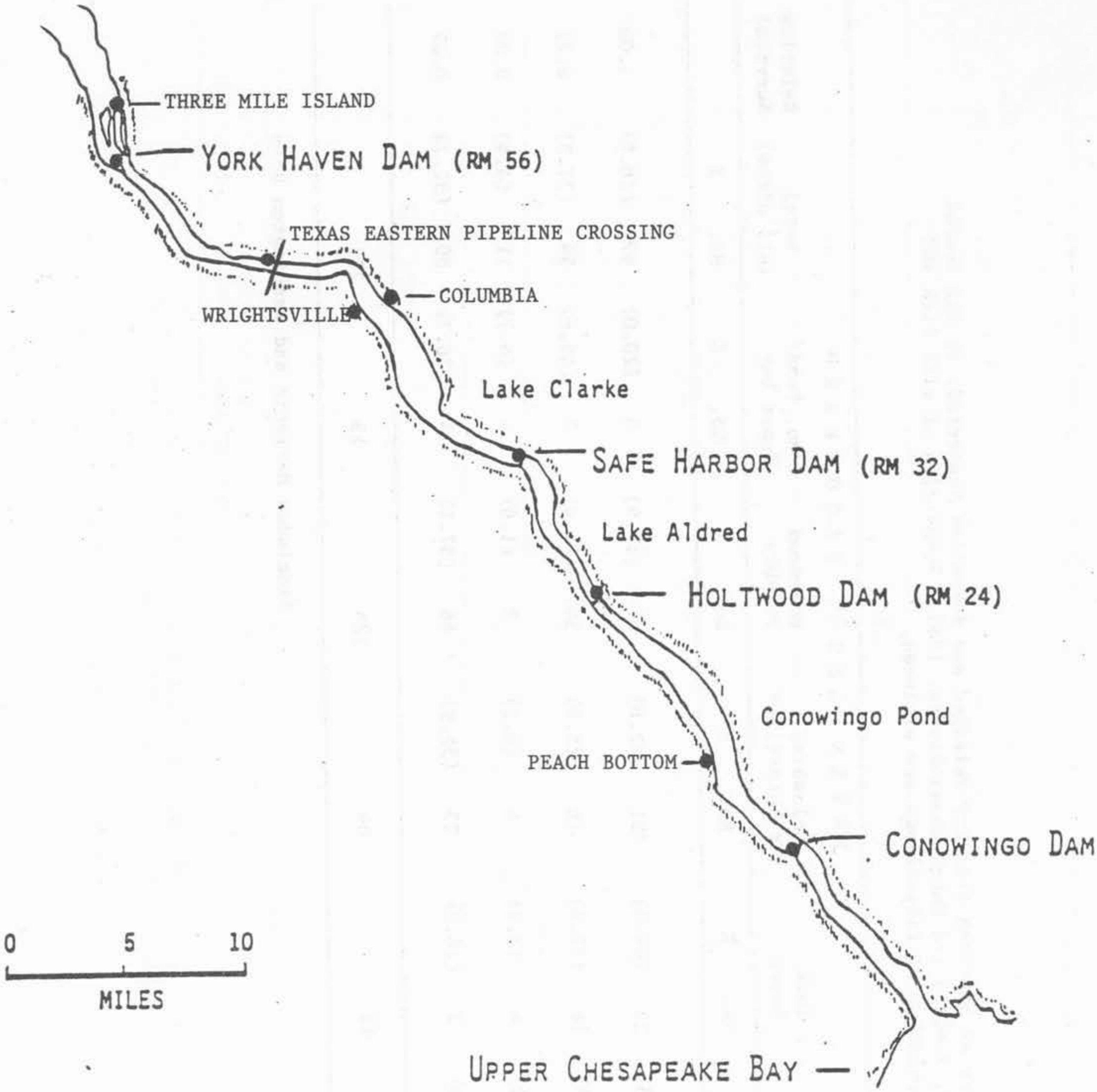


Figure 4.1. Juvenile American shad sampling locations in the Lower Susquehanna River, 1989.

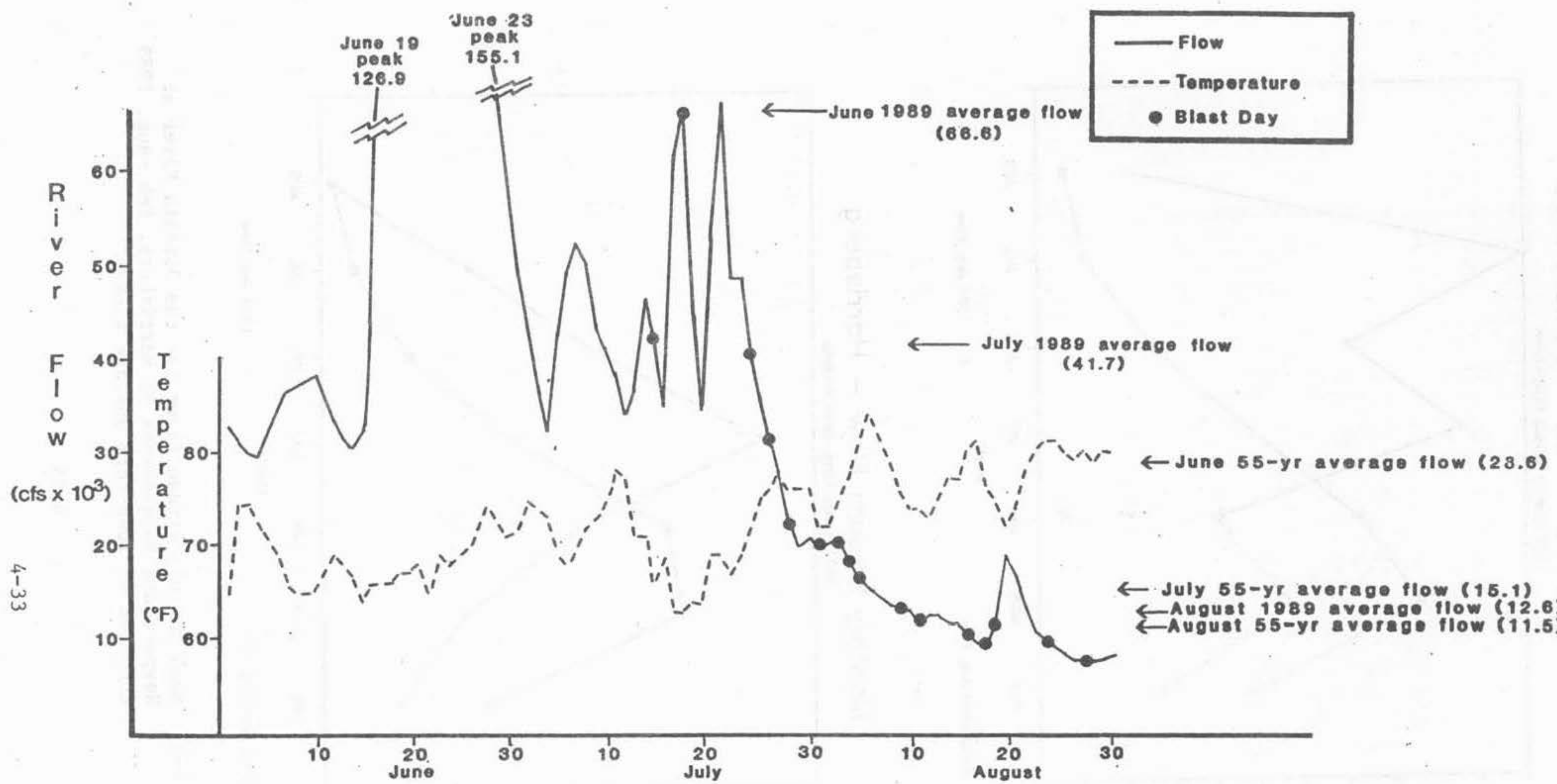
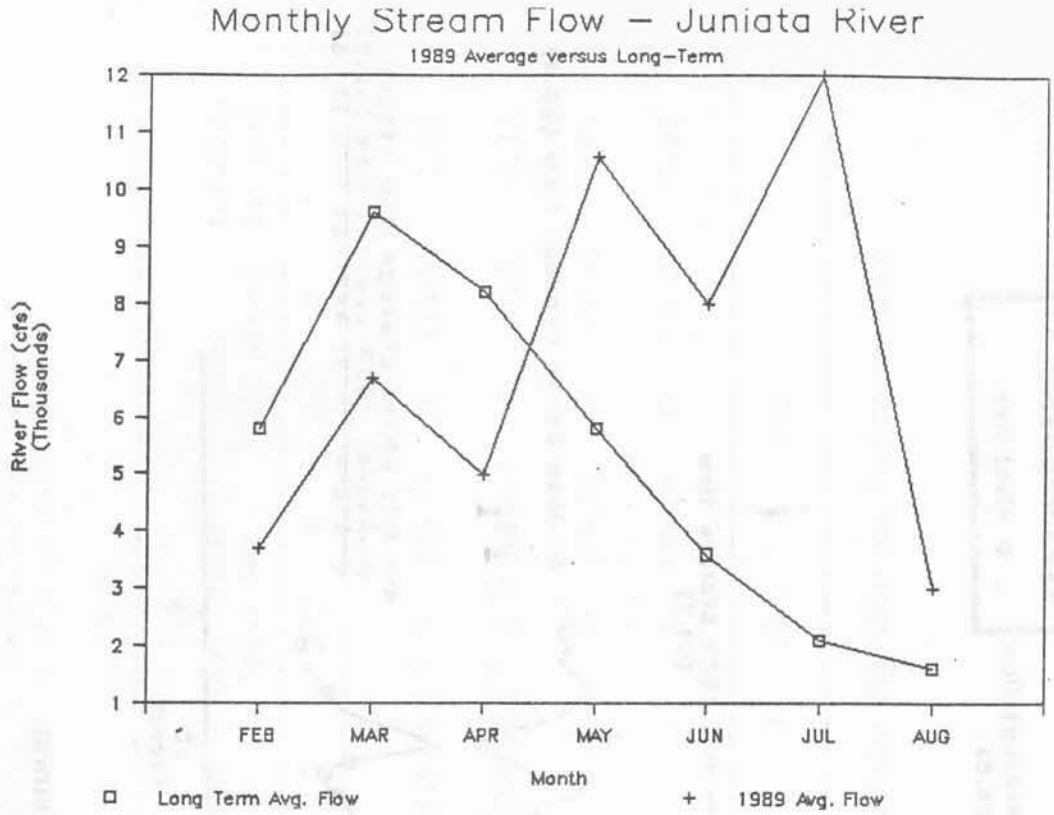


Figure 4-2. River flow (in cfs x 10^3) and water temperature (°F) Susquehanna River, near Marietta, PA, June through August, 1989.



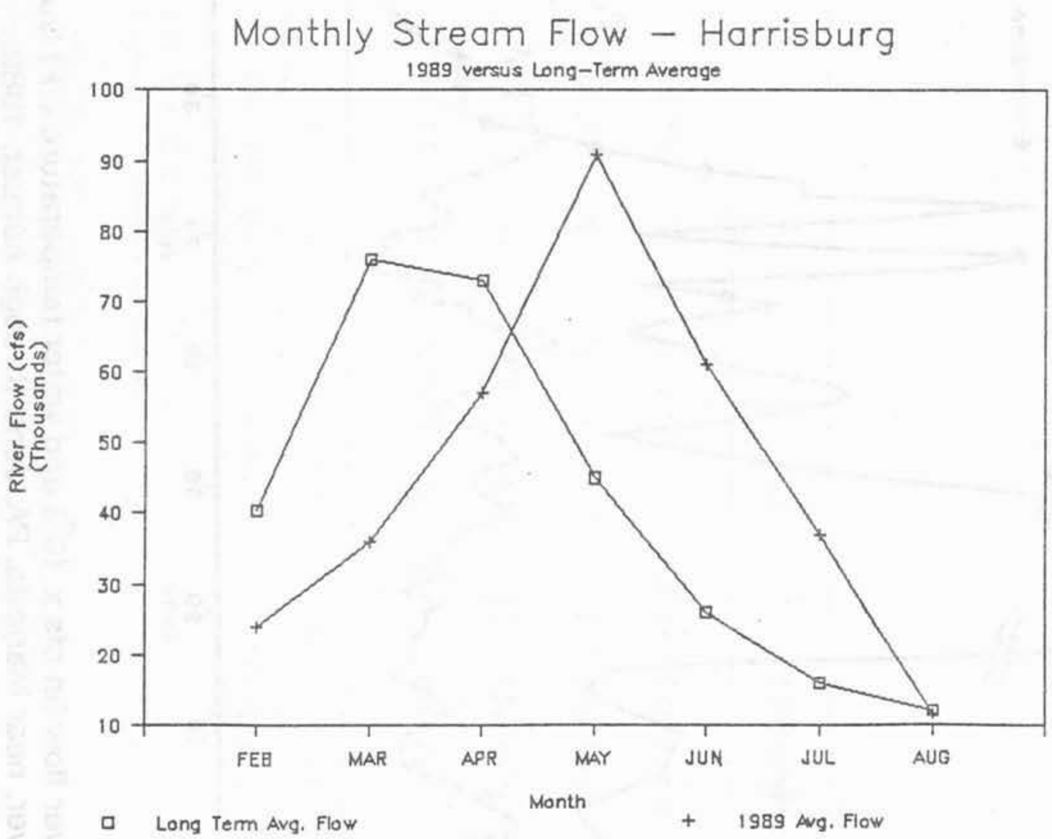


Figure 4-3. Mean monthly stream flows for the Juniata River at Newport and Susquehanna at Harrisburg, Feb.-Aug. 1989 compared to long-term average flows.

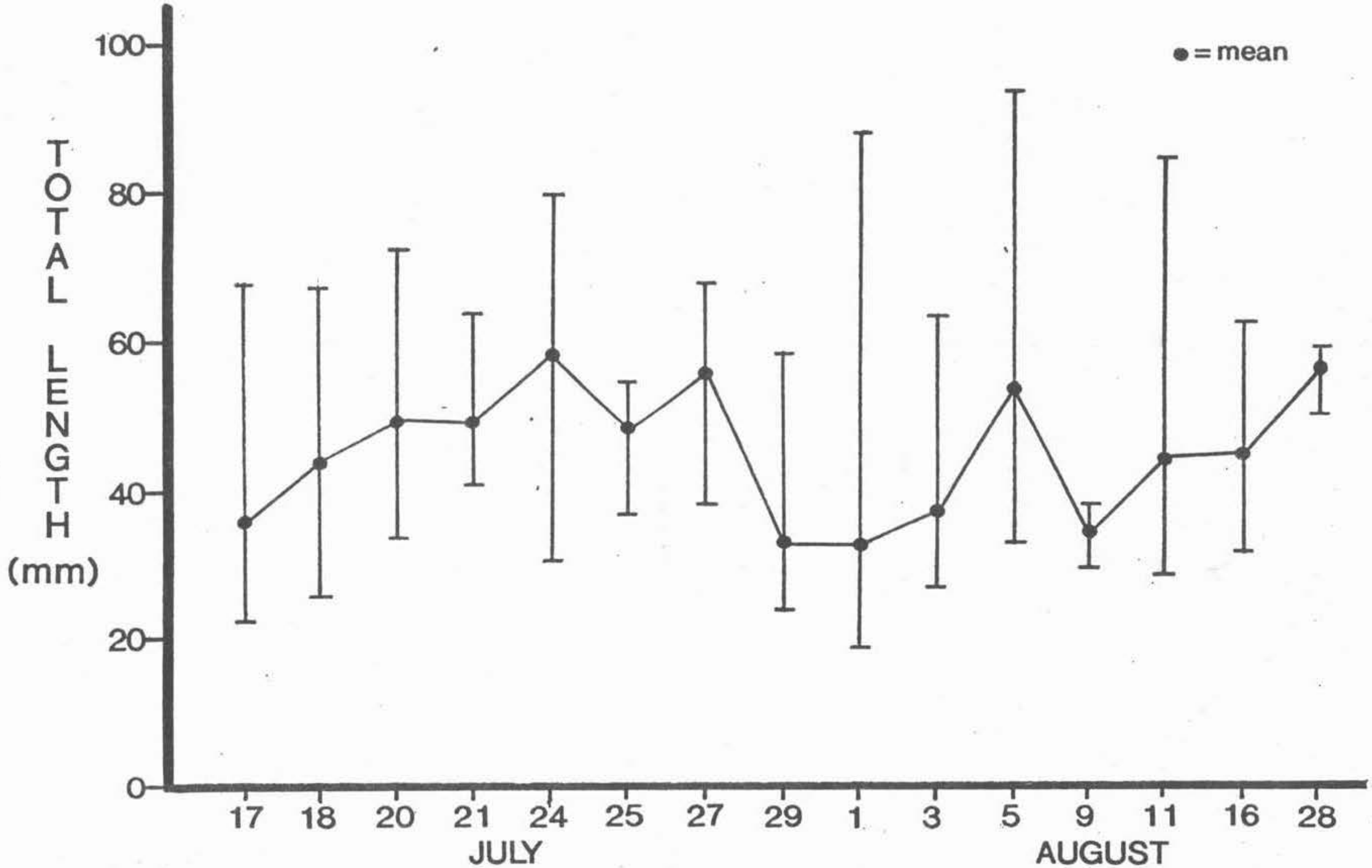


Figure 4-4 Mean length (mmTL) and size range of American Shad taken in the vicinity of the Texas Eastern pipeline crossing, Susquehanna River, Marietta, PA. July–August, 1989

JOB V(1) MIGRATION OF RADIO TAGGED ADULT AMERICAN SHAD THROUGH CONOWINGO POND TO THE HOLTWOOD HYDROELECTRIC STATION

BY

RMC ENVIRONMENTAL SERVICES, INC.
Muddy Run Ecological Laboratory
1921 River Road, P. O. Box 10
Drumore, Pennsylvania 17518

ABSTRACT

Sixty adult American shad, *Alosa sapidissima*, were radio tagged and released into Conowingo Pond to determine: what percentage of fish migrate to Holtwood Hydrolectric Station, routes used to reach Holtwood, movement near the Station, and the effects of water spills on shad distribution at Holtwood Dam. Twenty-eight shad migrated to the Station. An additional three shad only entered the spillway area. No distinct passage routes of shad were observed, however, shad favored the eastern side of the pond when reaching the island complex downstream of Holtwood. Shad moved extensively into and out of the Holtwood tailrace, and between the tailrace and spillway area. Shad were located in the spillway area during periods of moderate spillage. However, few shad were there when spillage flows exceeded 25,000 cfs.

INTRODUCTION

Individual hydroelectric facilities on the lower Susquehanna present unique environmental conditions for migrating American shad (Alosa sapidissima) due to tailrace configuration and hydraulic variations. Shad movements through Conowingo Pond may be influenced by several variables including operation of a pumped storage project and hydroelectric generation schedules. This report summarizes data on the movements of American shad trapped and radio tagged at the Conowingo Fish Lift (Fish Lift), then transported to and released into Conowingo Pond. Radio tagged shad were monitored to determine: (1) what percentage of fish released into Conowingo Pond continue migrating to Holtwood Hydroelectric Station (Holtwood); (2) routes use to reach the Holtwood; (3) movements in the Holtwood tailrace and spillway area; and (4) effects of water spills over Holtwood Dam on fish distribution.

METHODS

Adult American shad were collected at the Fish Lift and radio tagged on 4 occasions. Methods to capture, handle, tag, and transport shad are described in RMC (1989). Transmitters averaged 10 mm in diameter, 55 mm in length, and weighed 10.5 g. Unique frequencies between 48 and 49 MHz were transmitted by 240 mm whip antennas. To facilitate remote monitoring, all transmitters were manufactured to operate at one of three pulse rates.

Tagged specimens were sexed and placed in a transport vehicle with other untagged shad. They were then transported above the Dam and released into a net pen at Baltimore Water Intake approximately 300 m upstream of the Conowingo powerhouse. Three specimens were released directly into the pond on one occasion. The 6.1 x 6.1 x 1.6 m net pen was constructed of 40 mm rigid plastic netting on a PVC pipe framework. Most shad were retained in the pen for 24 h to facilitate recovery from potential stress of handling and tagging. Fish were then allowed to exit the pen through a 1.6 x 3.1 m door.

Shad were logged by continuous monitoring devices (CMDs) and manually located by boat two times per week. CMDs were deployed at Muddy Run Pumped Storage Station (Muddy Run), Norman Wood Bridge (Norman Wood), Holtwood, and Conowingo stations (Figure 1). Each CMD consisted of a data collection computer (DCC) interfaced with an ATS programmable scanning receiver coupled to a single antenna or an antenna array. The CMDs were programmed to scan each frequency for three seconds. When a signal was received, the DCC compared times between five pulses. The DCC logged day, time, frequency, pulse rate and variance in its random access memory, if the variance was <5,000 milliseconds. Data were discarded if the variance was >5,000 milliseconds. Data were offloaded using a Tandy 600 portable computer and stored on 3.5 in diskettes.

CMDs at Muddy Run, Norman Wood, Holtwood, and Conowingo stations were coupled to a 5 element yagi, a dipole, and underwater antennas, respectively. The CMD at Holtwood was calibrated to log only fish near Unit 10. An attempt was made to locate all shad in Conowingo Pond at least one time on each manual tracking day. Additionally, Holtwood tailrace was usually monitored three times. To evaluate shad distribution patterns in the tailrace, a single fix was randomly chosen on each fish located manually in the tailrace on monitoring days.

One shad was intensively tracked in the tailrace for two hours by boat. Locations were plotted on field maps.

RESULTS

Tagging and Release

Sixty tagged shad were released into Conowingo Pond in lots of 14, (Group 1), 3 and 19 (Group 2), and 24 (Group 3) on 25 April, 22 and 24 May, and 6 June, respectively (Table 1). The male/female ratio for tagged fish was 2.33:1.

Shad from Groups 1, 2, and 3 left the net pen within 5 to 50 min (X=13 min, N=8), 1 to 62 min (X=26 min, N=19) and 10 min to 2 h 25 min (X=61 min, N=23), respectively, after the gate was opened.

Upstream Dispersal

Fifty-one (85%) of 60 tagged shad moved some distance upstream after release. Forty-three (72%) of these migrated ≥16 km (10 mi) upriver. Forty-two (70%) shad continued upriver as far as Muddy Run (19.4 km), 39 (65%) migrated to

Deepwater Island (20.7 km), 38 (63%) reached Norman Wood Bridge (21.7 km) and 28 (47%) moved into the Holtwood tailrace (21.8 km) (Table 1). Eighteen (64%) of the 28 shad reaching the tailrace were also found in the Holtwood spillpool, west of Piney Island, during spill conditions. Three others (5%) were located only in the spillpool (Figure 2).

The percentage of shad migrating upriver differed between groups. All the shad from Group 1 and 20 (83%) from Group 3 moved upstream >16 km compared with only nine (41%) from Group 2. Similarly, the percentage of shad that moved upstream to Muddy Run, Norman Wood, and Holtwood tailrace differed between groups (Table 2).

Effects of Holtwood Spillage

The amount of water discharged over Holtwood Dam appears to determine the extent of which shad move into and/or remain in the spillway area. Holtwood Hydroelectric Station, operating at full generating capacity, spills water when incoming flows exceed approximately 30,000 cfs. During moderate spillage (<55,000 cfs average river flow) over Holtwood Dam, radio tagged shad frequented the spillway side (west) of Piney Island (Figure 3). However, shad left the area when spillage increased. Few tagged shad were located there at spills >25,000 cfs (average river flow >55,000 cfs). Most shad also moved or remained downstream of the tailrace in calm water areas at higher river flows (Figure 4). Only one (3%) of the 28 shad that reached the tailrace was present when river flows were greater than 55,000 cfs.

Upstream Migration Rates

Twenty-seven shad with known net pen exit times migrated to the Holtwood tailrace (21.8 km) within 12 h to 8 d ($\overline{X}$=2 d 11 h 41 min). The mean times to reach tailrace differed between groups. Groups 1, 2, and 3 averaged 4 d 17 h 36 min (N=7), 2 d 6 h 7 min (N=6), and 1 d 9 h 46 min (N=14), respectively (Table 2).

Upstream Migration Routes

Periodic manual monitoring indicated migrating shad generally moved randomly through Conowingo Pond (Figure 5). Upon reaching the upper portion of the Pond, shad generally favored the east side in the main channel (Figure 6). Shad were also located on the west side of the upper Pond in the island complex, however, these locations were recorded during periods of extremely high river flows.

CMD Data Evaluation

The CMDs positioned at Muddy Run, Norman Wood, and primarily the Holtwood tailrace provided valuable data during periods when manual tracking was not conducted. The Muddy Run CMD logged a total of 35 shad. Of these, 15 (43%) were logged only one time. The remaining 20 (57%) passed through the area on 2 to 26 occasions (Figure 7A). Conversely, lower numbers of single occurrences and higher numbers of multiple occurrences were recorded by the Norman Wood and Holtwood tailrace CMDs. Only 3 (8%) of 38 shad and 2 (10%) of 20 shad entering the monitoring areas of Norman

Wood and Holtwood tailrace, respectively, were logged one time. However, 35 (85%) shad logged at Norman Wood were recorded on 2 to 122 occasions (Figure 7B). Additionally, 18 (90%) of 20 shad were present near the Holtwood tailrace from 2 to 64 times (Figure 7C).

Shad Behavior in Holtwood Tailrace

Manual monitoring of 17 (61%) of the 28 shad located in the tailrace provided some insight into their behavior and movement patterns. Shad congregated primarily in three areas in the tailrace; along a rock shelf on the upper west side, an eddy just downstream of Unit 10 on the east side, and near the reflection wall (Figure 8). Shad were predominantly located along the rock shelf. Thirteen were located there at least one time. In comparison, 10 shad each were located near the eddy and reflection wall, respectively.

One shad, tracked intensively in the tailrace on 3 May moved through much of the peripheral zone of the upper tailrace passing along the reflection wall several times. It only moved in the eddy below Unit 10 on two occasions (Figure 9).

Although several shad moved into the tailrace area, their mean residency times (defined as the time shad spent within the CMD monitoring area per foray) were short. The mean residency times for 20 shad, logged by the Holtwood CMD, only ranged from 1 min to 1 h 39 min (Table 3).

DISCUSSION

Effects of Net Penning Shad

Use of an in-river net pen for holding shad after transport appears effective in improving upstream migration. Seventy-two percent of the radio tagged shad migrated ≥16 km upstream after release this year compared to 60% when released directly into Conowingo Pond in 1988. When comparing previous studies, this is the highest proportion of radio tagged shad which moved upstream. The percentage of upstream migrants may have been higher if a high flow event had not occurred prior to release of Group 2. Additionally, only 42% of radio tagged shad released prior to 1988 moved ≥16 km after release. However, caution must be exercised when comparing data prior to 1988 with that collected in 1989 since transport time and river conditions at the various release sites are not similar.

There was no apparent relationship between exit times from the net pen, and dispersal rates and maximum upstream distances travelled between the three groups. The mean exit times of tagged shad from the net pen nearly doubled between Groups 1 ($\overline{X}$-13 min), 2 ($\overline{X}$=26 min), and 3 ($\overline{X}$=61 min). This phenomenon can not readily be explained since Group 3, which on average remained in the pen longer, moved upstream and travelled similar distances as Group 1.

Upstream Dispersal

The rate of upstream dispersal varied considerably between the three groups of shad released. Of the shad released 100%, 41%, and 83% of Groups 1, 2, and 3, respectively, migrated ≥16 km upstream after release. The reason for the low percentage of the second group is unknown, however, average river flow was substantially higher for five days following their release. The average five day flow was 57,000 cfs and was declining after a high flow period when shad were released. In contrast, river flows were lower and steady during the first and final releases (Figure 10). The average five day river flow following release of the first and final groups were 22,000 and 39,000 cfs, respectively.

Water temperature did not appear to influence migration behavior. The average five day temperatures following release of the three groups were 14.8, 18.1, and 22.5 C, respectively. These temperatures remained steady throughout the five day period.

Effects of Holtwood Spillage

Conservatively, 35% of the tagged shad moved into the spillway area. Additionally, 30% of the shad moved freely from the spillway area into the tailrace also. All but three of the fish found in the spillway moved into the Holtwood tailrace on at least one occasion. Additional fish may have gone into this area on days when there was not manual tracking. The spillway area was monitored manually at the same frequency as the tailrace. The continuous monitors at Norman Wood and in the tailrace detected additional fish that moved past Norman Wood when no manual tracking was being conducted.

Although few exact location fixes were obtained for fish in the spillway area due to unsafe boating conditions during spills, general direction fixes indicated shad favored the large pool area on the eastern side of the spillway. Additionally, all fish did not immediately leave the spillway area when spillage ceased and this location was the only deep water area for shad to utilize.

CMD Data Evaluation

Information provided by the CMDs at Muddy Run, Norman Wood, and the Holtwood tailrace indicate shad primarily moved past Muddy Run without delay and moved extensively in the areas of Norman Wood and the tailrace. Tagged fish were logged more frequently at Norman Wood and the tailrace and less frequently at Muddy Run from just before sunrise until sunset. This suggests that some shad move upstream into the tailrace during daylight hours and drop downstream after dark, though not necessarily on a daily basis. Manual and CMD monitoring indicated shad would tend to drop downstream out of the heavy current to a pool located near Deepwater Island during the evening and night. In this area the flow pattern changes dramatically from that in the tailrace. The flow of water exiting the tailrace is fast and turbulent. As the water enters the Deepwater Island area, the flow is greatly reduced, creating an eddy for shad to hold. Near sunrise they would move upstream (Figure 11).

Shad Behavior In Holtwood Tailrace

A single shad continuously monitored in the tailrace on 3 May showed extensive movement throughout the area. Although data are extremely limited it appears shad generally prefer the western side of the tailrace.

Residency times of shad observed from CMD data in the tailrace were probably minimal. It is likely that shad were present for longer periods of time since the tailrace CMD was calibrated only to receive signals in a limited range.

RECOMMENDATIONS

A more thorough study on behavior and movement of American shad in the tailrace is needed. Repair and construction work along the face of the lower gallery at the Holtwood Station prohibited a study of this nature this year. Little detailed information could be gathered on shad movement patterns and utilization (preferences) once they entered the tailrace; only presence and absence could be ascertained. Due to the small area of the tailrace, definitive conclusions of movement and behavior could be adequately assessed with strategically positioned CMDs and minimal manual monitoring. CMDs have proven to be an effective tool for monitoring adult American shad.

REFERENCES

RMC. 1989. Progress Report V - Study for determination of flow needs for downstream migrant American shad at the Conowingo Hydroelectric Station, 1988. RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, Pennsylvania. 67 pp.

TABLE 1

Summary Table For Adult American Shad Released At Baltimore Water Intake, 1989.

Fish Num	Sex	Release Date	Release Time	Pen Exit Time	First Loc. At MRPSS	First Loc. At Deepwater Island	First Loc. At Normanwood Bridge	First Loc. In Holtwood Tailrace	Last Loc. In Holtwood Tailrace
+ 530.1	F	25 April	1445 h	1450 h	-------------	26 Apr 1110 h	-------------	HWT-30 Apr 0151 h	30 May 0330 h
550.1	M	25 April	1445 h	------	-------------	-------------	01 May 0444 h	-------------	-------------
+ 530.2	F	25 April	1445 h	------	26 Apr 1755 h	-------------	27 Apr 0604 h	HWT-30 Apr 0925 h	12 Jun 1501 h
+ 570.1	F	25 April	1445 h	1450 h	26 Apr 1929 h	28 Apr 0935 h	28 Apr 1631 h	HWT-01 May 1915 h	04 May 1556 h
**590.1	M	25 April	1445 h	1450 h	-------------	-------------	01 May 0757 h	HWT-03 May 1315 h	04 May 1229 h
610.1	F	25 April	1445 h	------	-------------	-------------	30 Apr 1634 h	HWT-03 May 1610 h	03 May 1749 h
+ 630.1	F	25 April	1445 h	1535 h	-------------	-------------	26 Apr 0050 h	HWT-26 Apr 0307 h	26 Apr 1842 h
+ 650.1	M	25 April	1445 h	------	-------------	-------------	30 Apr 1523 h	-------------	-------------
690.1	M	25 April	1445 h	------	28 Apr 1235 h	-------------	-------------	-------------	-------------
+ 710.1	M	25 April	1445 h	1450 h	-------------	-------------	-------------	HWT-26 Apr 0253 h	02 May 1734 h
550.2	M	25 April	1445 h	1450 h	-------------	-------------	29 Apr 0334 h	HWT-30 Apr 0734 h	29 May 1548 h
+ 570.2	M	25 April	1445 h	1510 h	-------------	26 Apr 1120 h	26 Apr 1144 h	HWT-01 May 0423 h	31 May 1538 h
590.2	M	25 April	1445 h	1450 h	01 May 1310 h	05 May 0835 h	-------------	-------------	-------------
610.2	M	25 April	1445 h	------	-------------	-------------	01 May 1208 h	-------------	-------------
730.1	F	22 May	1600 h	------	-------------	-------------	24 May 0319 h	-------------	-------------
750.1	F	22 May	1600 h	------	23 May 0648 h	-------------	-------------	HWS-26 May 1205 h	31 May 1538 h
770.1	M	22 May	1600 h	------	-------------	-------------	-------------	-------------	-------------
790.1	M	24 May	1150 h	1223 h	-------------	-------------	-------------	-------------	-------------
810.1	M	24 May	1150 h	1153 h	-------------	-------------	-------------	-------------	-------------
830.1	M	24 May	1150 h	1248 h	-------------	-------------	-------------	-------------	-------------
850.1	M	24 May	1150 h	1234 h	-------------	-------------	-------------	-------------	-------------
870.1	F	24 May	1150 h	1151 h	24 May 2305 h	-------------	25 May 0119 h	-------------	-------------
890.1	M	24 May	1150 h	1152 h	25 May 0141 h	-------------	25 May 0404 h	HWS-26 May 1205 h	30 May 0359 h
910.1	M	24 May	1150 h	1151 h	26 May 0549 h	-------------	26 May 0836 h	HWT-28 May 0607 h	28 May 1821 h
530.3	M*	24 May	1150 h	1151 h	-------------	-------------	-------------	-------------	-------------
550.3	M	24 May	1150 h	1225 h	-------------	-------------	-------------	-------------	-------------
570.3	M	24 May	1150 h	1207 h	-------------	-------------	-------------	-------------	-------------
590.3	F	24 May	1150 h	1158 h	-------------	-------------	-------------	-------------	-------------
630.2	M	24 May	1150 h	1252 h	-------------	-------------	-------------	-------------	-------------
650.2	M	24 May	1150 h	1151 h	24 May 2013 h	-------------	24 May 2343 h	HWT-25 May 1148 h	26 May 1155 h
670.1	M	24 May	1150 h	1246 h	-------------	-------------	-------------	-------------	-------------
670.2	M	24 May	1150 h	1249 h	-------------	-------------	-------------	-------------	-------------
690.2	M	24 May	1150 h	1216 h	26 May 0559 h	-------------	26 May 0833 h	HWS-31 May 1539 h	31 May 1539 h
710.2	F	24 May	1150 h	1250 h	26 May 2344 h	-------------	27 May 0616 h	-------------	-------------
730.2	M	24 May	1150 h	1209 h	25 May 0749 h	-------------	25 May 1928 h	HWS-26 May 1205 h	26 May 1205 h
750.2	M	24 May	1150 h	1157 h	-------------	-------------	-------------	-------------	-------------
610.3	F	6 June	1430 h	1500 h	-------------	-------------	-------------	-------------	-------------
630.3	M	6 June	1430 h	1551 h	-------------	-------------	12 Jun 0452 h	HWT-12 Jun 0615 h	21 Jun 1056 h
650.3	M	6 June	1430 h	1500 h	07 Jun 0600 h	-------------	07 Jun 0659 h	HWT-07 Jun 1410 h	16 Jun 1515 h
670.3	M	6 June	1430 h	1511 h	07 Jun 0219 h	-------------	07 Jun 0306 h	HWT-07 Jun 0948 h	08 Jun 1100 h
690.3	M	6 June	1430 h	1555 h	-------------	-------------	07 Jun 1425 h	HWS-07 Jun 1700 h	16 Jun 1520 h
710.3	F	6 June	1430 h	1628 h	-------------	-------------	-------------	-------------	-------------
730.3	M	6 June	1430 h	1440 h	07 Jun 0139 h	-------------	07 Jun 0225 h	HWT-07 Jun 0950 h	21 Jun 1055 h
750.3	M	6 June	1430 h	1547 h	06 Jun 2325 h	-------------	07 Jun 0045 h	HWT-07 Jun 0950 h	12 Jun 0954 h
770.2	F	6 June	1430 h	1619 h	07 Jun 0522 h	-------------	07 Jun 0636 h	HWT-07 Jun 0919 h	16 Jun 1520 h
770.3	F	6 June	1430 h	1551 h	07 Jun 1718 h	-------------	08 Jun 0312 h	-------------	-------------
790.2	F	6 June	1430 h	1628 h	-------------	-------------	-------------	-------------	-------------
+ 790.3	M	6 June	1430 h	1655 h	06 Jun 2357 h	-------------	07 Jun 0744 h	HWT-07 Jun 1622 h	09 Jun 0940 h
810.2	M	6 June	1430 h	1441 h	07 Jun 1254 h	07 Jun 1355 h	07 Jun 1725 h	HWT-08 Jun 1319 h	10 Jun 1021 h
810.3	F	6 June	1430 h	1459 h	07 Jun 0525 h	-------------	07 Jun 0705 h	HWT-07 Jun 1625 h	07 Jun 1625 h
830.2	M	6 June	1430 h	1445 h	-------------	-------------	-------------	-------------	-------------
830.3	M	6 June	1430 h	1445 h	07 Jun 0346 h	-------------	07 Jun 0433 h	HWT-07 Jun 0940 h	12 Jun 0954 h
850.2	M	6 June	1430 h	1621 h	07 Jun 2018 h	-------------	08 Jun 0659 h	HWT-08 Jun 1030 h	09 Jun 0935 h
850.3	M	6 June	1430 h	1625 h	-------------	-------------	-------------	-------------	-------------
870.2	F	6 June	1430 h	1508 h	06 Jun 2351 h	-------------	07 Jun 0155 h	HWT-07 Jun 1627 h	14 Jun 1657 h
870.3	F	6 June	1430 h	1502 h	06 Jun 1819 h	-------------	07 Jun 2057 h	HWT-08 Jun 0748 h	16 Jun 1517 h
***890.2	M	6 June	1430 h	1508 h	07 Jun 0012 h	-------------	07 Jun 0057 h	HWT-07 Jun 0942 h	12 Jun 1240 h
+ 890.3	M	6 June	1430 h	1512 h	07 Jun 0024 h	-------------	07 Jun 0742 h	HWT-08 Jun 1040 h	09 Jun 0930 h
910.2	M	6 June	1430 h	1509 h	07 Jun 1054 h	-------------	-------------	-------------	-------------
910.3	M	6 June	1430 h	------	07 Jun 1905 h	-------------	-------------	-------------	-------------

* Recaptured at Conowingo Fish Lift on 4 June
** Recaptured at Conowingo Fish Lift on 6 June
*** Recaptured in pound net near mouth of the Potomac River

+ indicates shad which made more than one trip from Conowingo Dam >16 km upriver

Note-HWT=Holtwood Tailrace, HWS=Holtwood Spillpool

Table 2

Comparison Of Upstream Movement Between Groups Of American Shad Released Into Conowingo Pond, 1989. Percentages Are In Parentheses.

Distance Traveled	Group 1	Group 2	Group 3	Total
N =	14	22	24	60
16.1 km	14 (100)	9 (41)	20 (83)	43 (72)
MRPSS (19.4 km)	14 (100)	9 (41)	19 (79)	42 (70)
NWB (21.7 km)	12 (86)	9 (41)	17 (71)	38 (63)
Holtwood Tailrace or Spillway (21.8 km)	9 (64)	6 (27)	16 (61)	31 (52)

Table 3

Residency Times Of Twenty American Shad In The CMD Monitoring Area At The Holtwood Hydrostation, 1989.

Fish Num.	Number Of Fixes At The Holtwood CMD	Total Residency Times Near The Holtwood CMD	Mean Residency Time Near The Holtwood CMD *
1-610	1	1 min	1 min
1-530	1	1 h 39 min	1 h 39 min
2-870	2	5 min	3 min
3-690	3	3 min	1 min
2-650	6	3 h 49 min	38 min
2-550	8	3 h 45 min	28 min
1-630	9	7 h 5 min	47 min
3-630	9	1 h 7 min	7 min
1-910	11	1 h 19 min	7 min
1-570	12	8 h 16 min	41 min
1-710	12	17 h 15 min	1 h 26 min
2-890	14	1 h 11 min	5 min
1-890	15	3 h 55 min	16 min
1-590	16	10 h 43 min	40 min
1-810	22	3 h 2 min	8 min
1-870	22	1 h	3 min
3-830	29	2 h 28 min	5 min
2-570	42	23 h 17 min	32 min
2-770	48	23 h 37 min	29 min
2-530	64	24 h 52 min	23 min

* Mean Residency Times Are Rounded To The Nearest Minute.

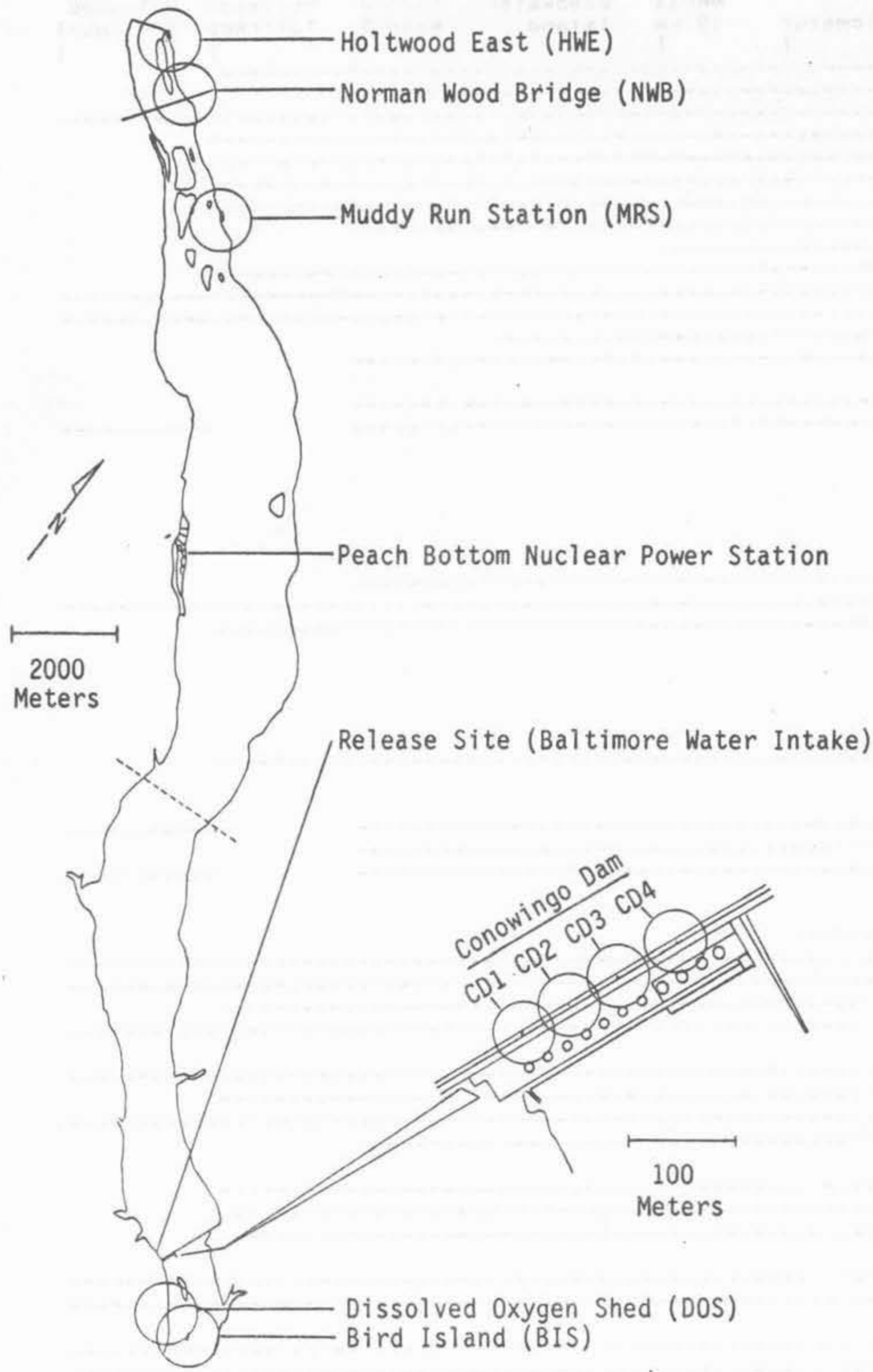


FIGURE 1

Continuous monitor locations throughout Conowingo Pond, 1989.

```
Fish    16               MRPSS     Deepwater     Norman      Holtwood    Holtwood
Num.     Kilometer       19 km     Island         Wood B.    Tailrace     Spillpool
                   |          |              |            |           |             |
530.1----------------------------------------------------------------
550.1----------------------------------------------------------------
530.2------------------------------------------------------------------------------
570.1----------------------------------------------------------------
590.1----------------------------------------------------------------
610.1----------------------------------------------------------------
630.1----------------------------------------------------------------
650.1----------------------------------------------------
690.1------------------------
710.1----------------------------------------------------------------
550.2------------------------------------------------------------------------------
570.2------------------------------------------------------------------------------
590.2---------------------------------------
610.2----------------------------------------------------

730.1----------------------------------------------------
750.1----------------------------------------------------             -------------
770.1

790.1
810.1
830.1
850.1
870.1----------------------------------------------------
890.1------------------------------------------------------------------------------
910.1----------------------------------------------------------------
530.3
550.3
570.3
590.3
630.2
650.2----------------------------------------------------------------
670.1
670.2
690.2----------------------------------------------------             -------------
710.2----------------------------------------------------
730.2----------------------------------------------------             -------------
750.2

610.3-------------
630.3------------------------------------------------------------------------------
650.3------------------------------------------------------------------------------
670.3----------------------------------------------------------------
690.3------------------------------------------------------------------------------
710.3
730.3------------------------------------------------------------------------------
750.3----------------------------------------------------------------
770.2------------------------------------------------------------------------------
770.3----------------------------------------------------
790.2
790.3----------------------------------------------------------------
810.2----------------------------------------------------------------
810.3----------------------------------------------------------------
830.2
830.3------------------------------------------------------------------------------
850.2------------------------------------------------------------------------------
850.3
870.2------------------------------------------------------------------------------
870.3------------------------------------------------------------------------------
890.2----------------------------------------------------------------
890.3------------------------------------------------------------------------------
910.2------------------------
910.3------------------------
```

Figure 2

Maximum Upstream Movements Of Adult American Shad Released At BWI In 1989.

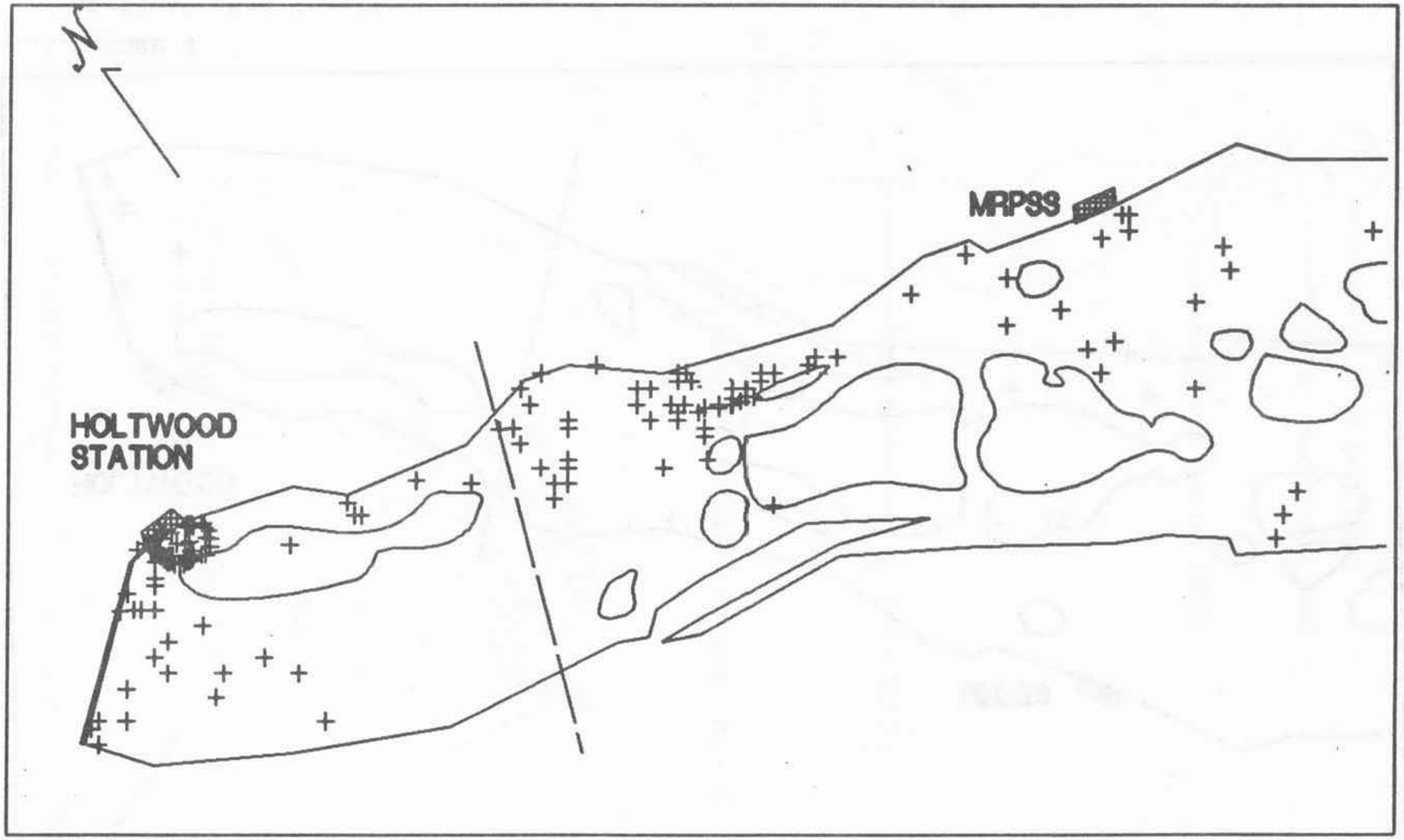


FIGURE 3

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

RMC

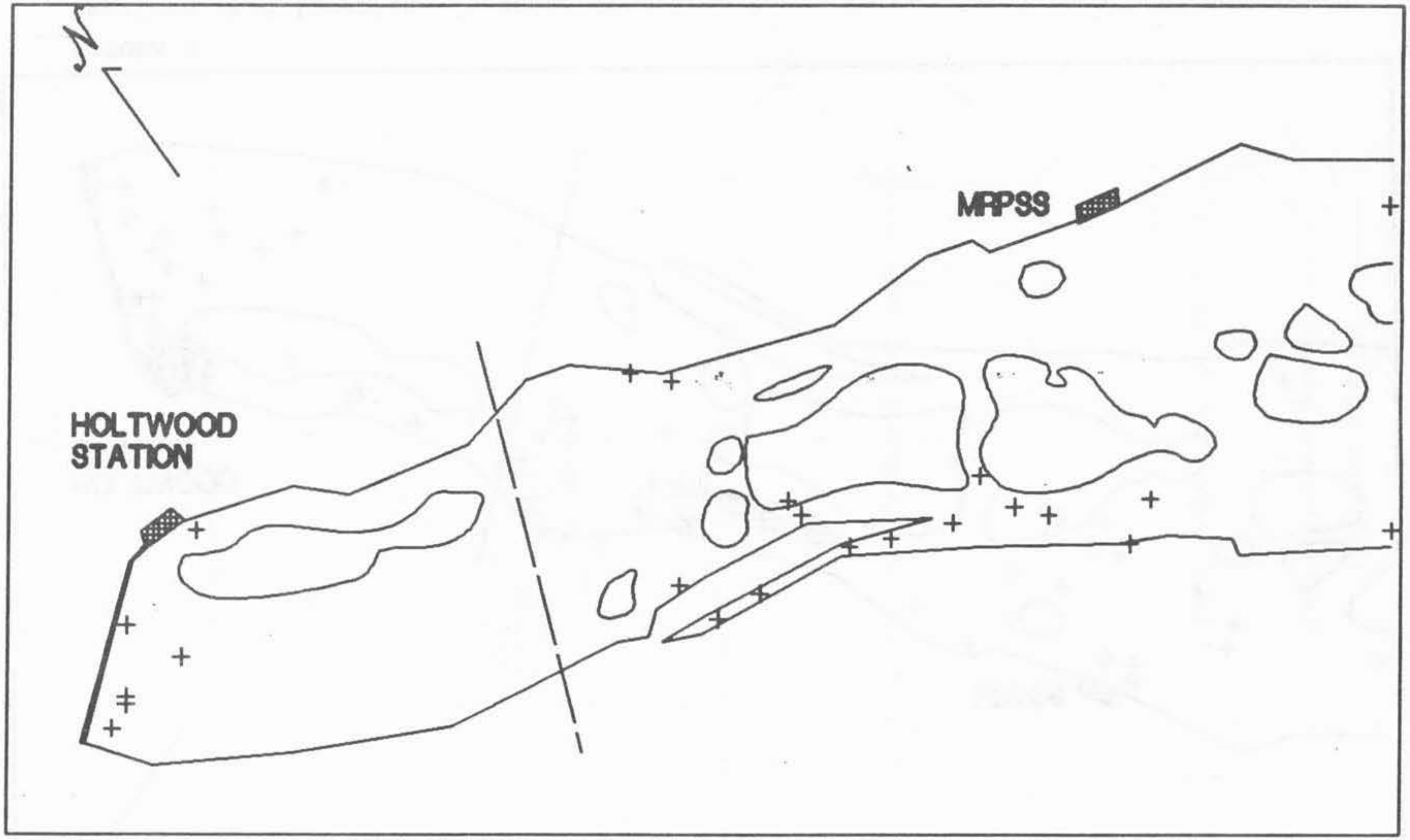


FIGURE 4

American shad locations in upper Conowingo Pond, Holtwood tailrace, and Holtwood spillway when river flows were >55,000 cfs, 1989.

RMC

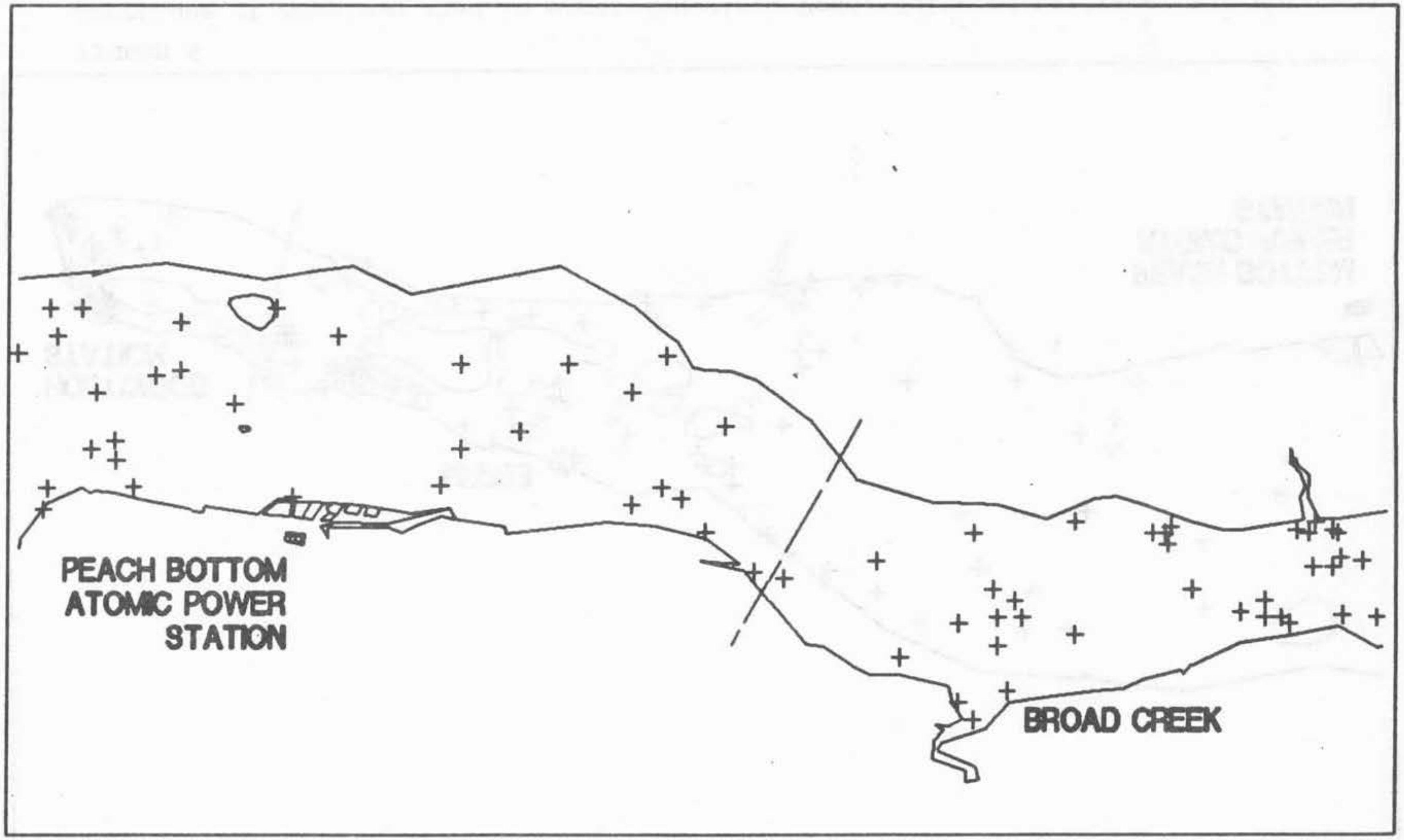


FIGURE 5

Locations of American shad in the middle and lower Conowingo Pond, 1989.

RMC

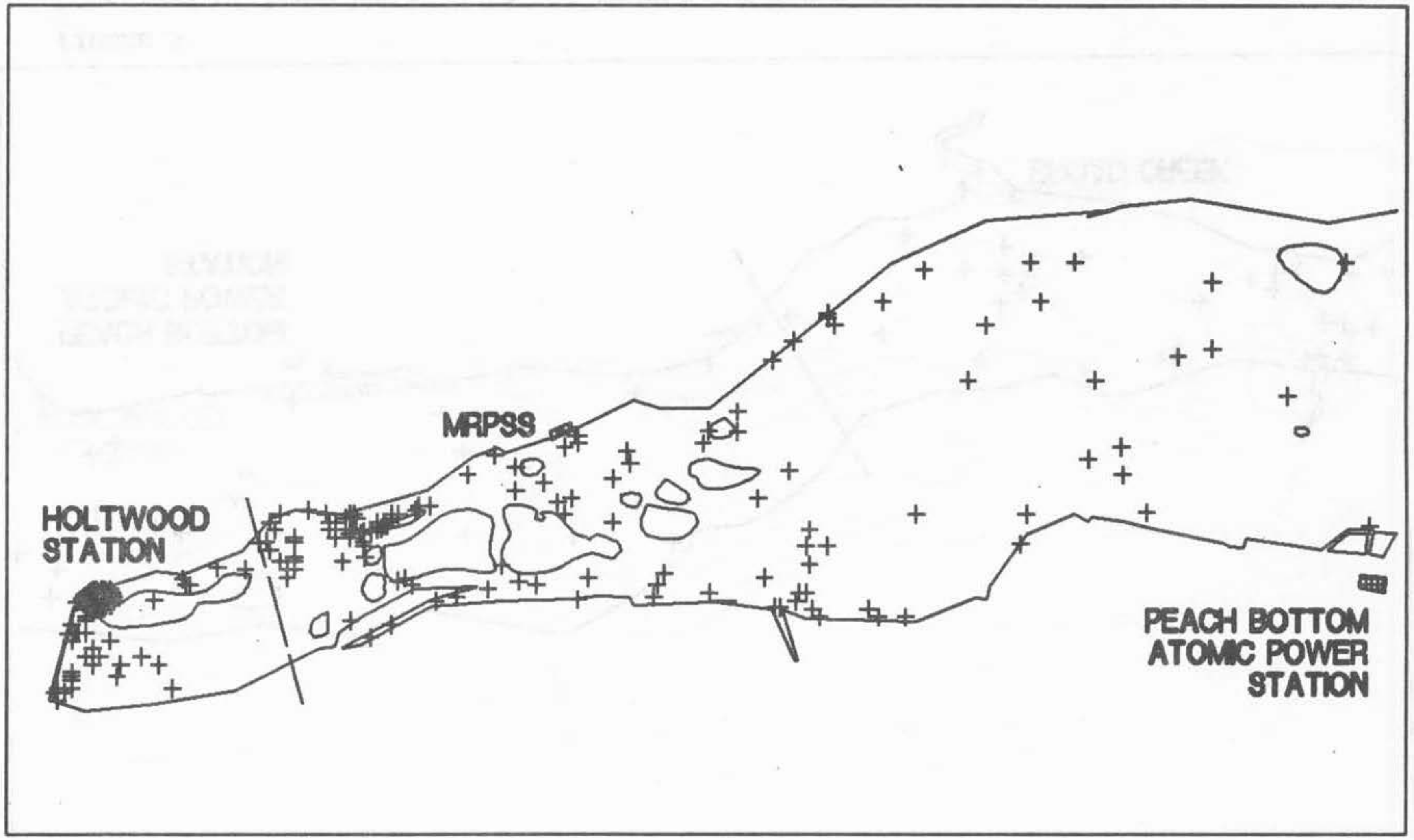


FIGURE 6

Locations of American shad in upper Conowingo Pond, Holtwood tailrace, and Holtwood spillway, 1989.

RMC

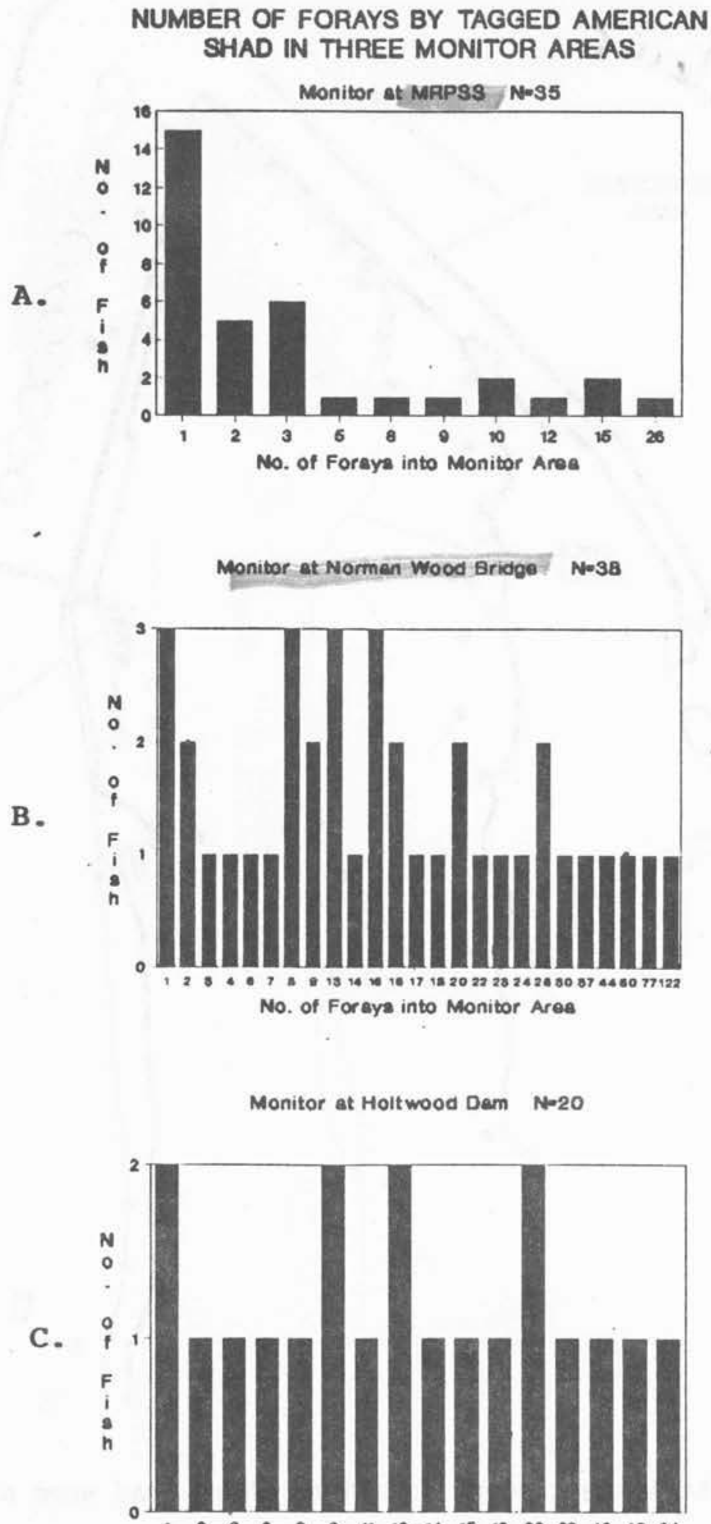


FIGURE 7

Numbers of fish logged by continuous monitors at Muddy Run Pumped Storage Station, Norman Wood Bridge, and Holtwood tailrace, 1989.

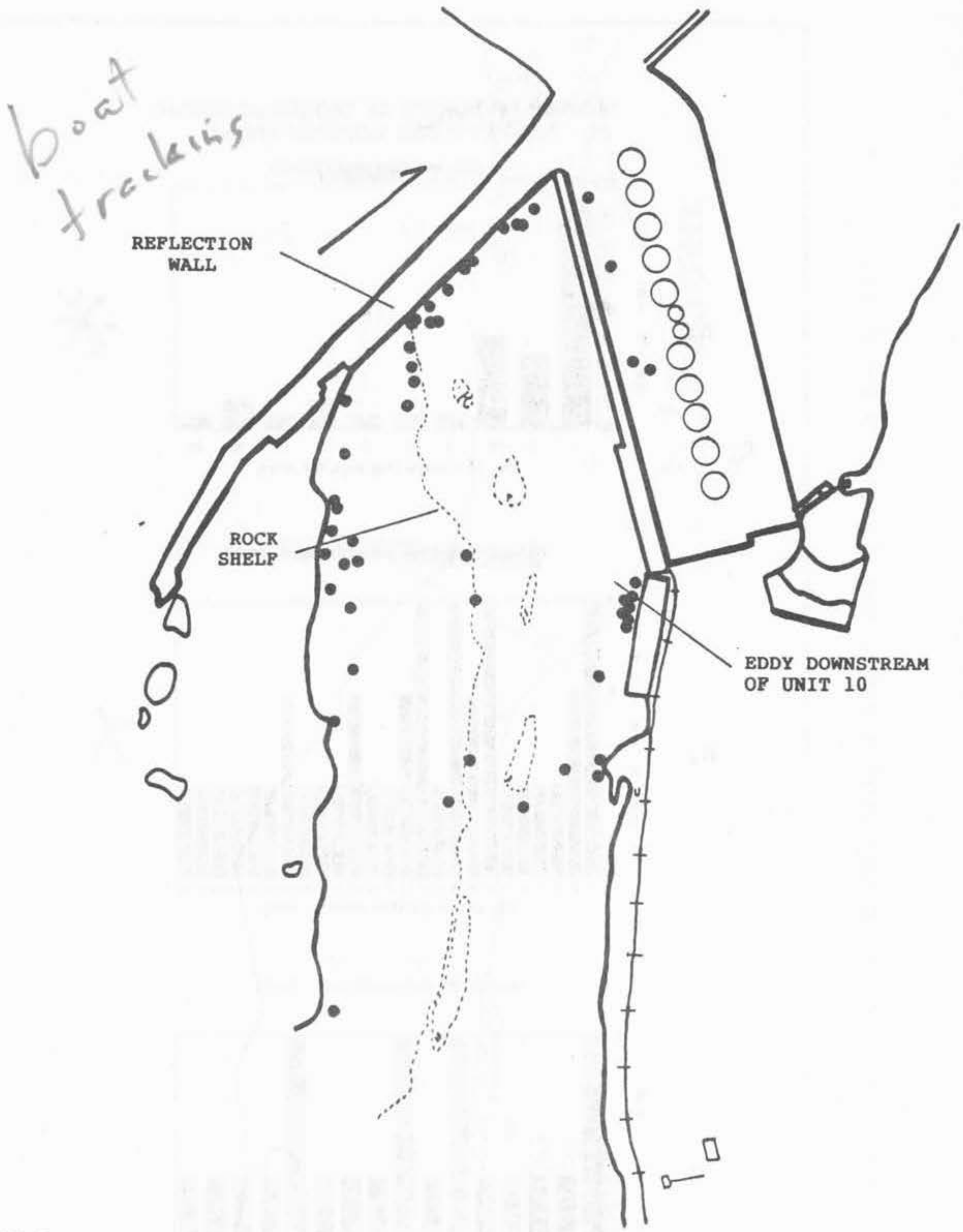


FIGURE 8

Map of Holtwood tailrace showing locations where shad were predominantly located, 1989.

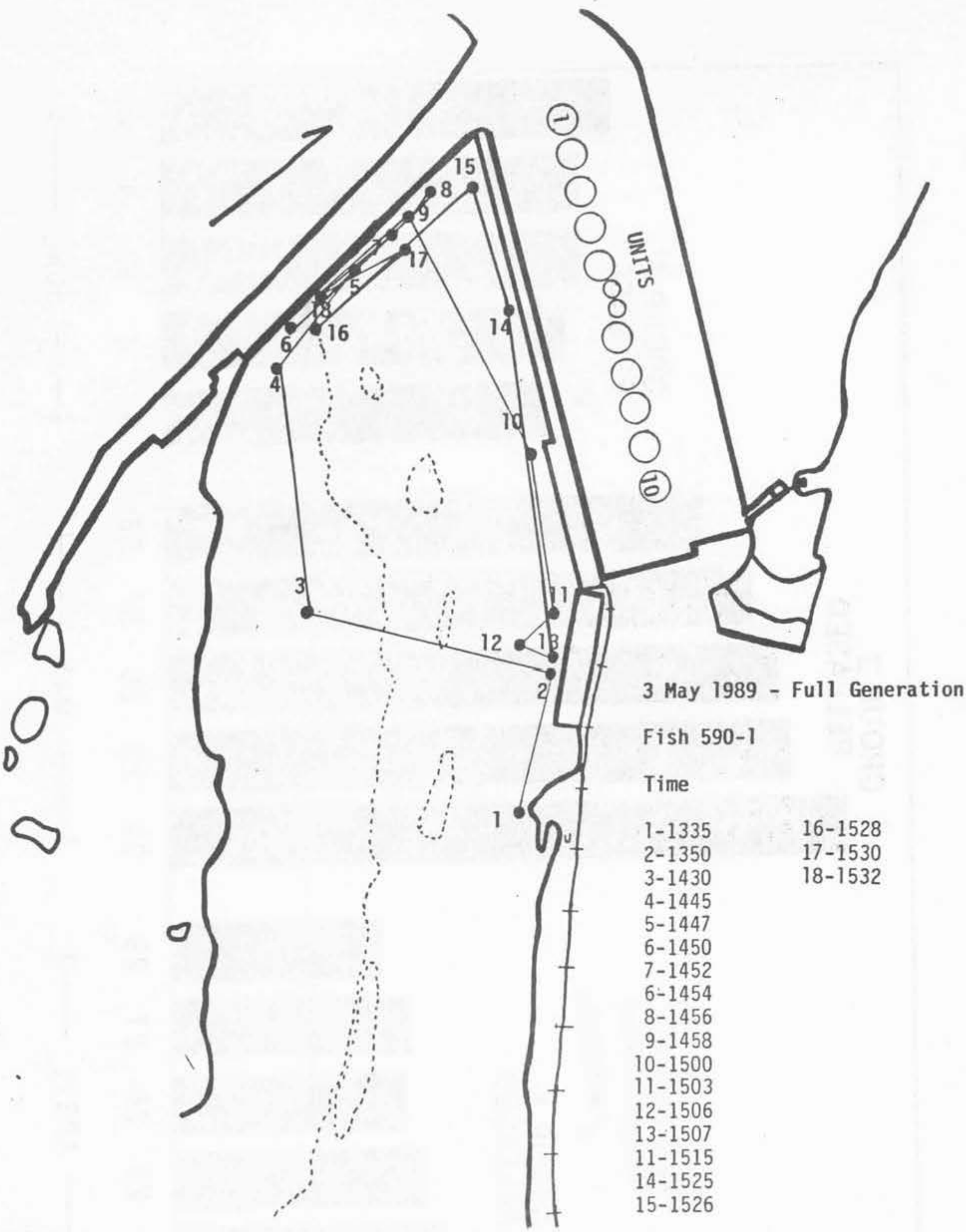
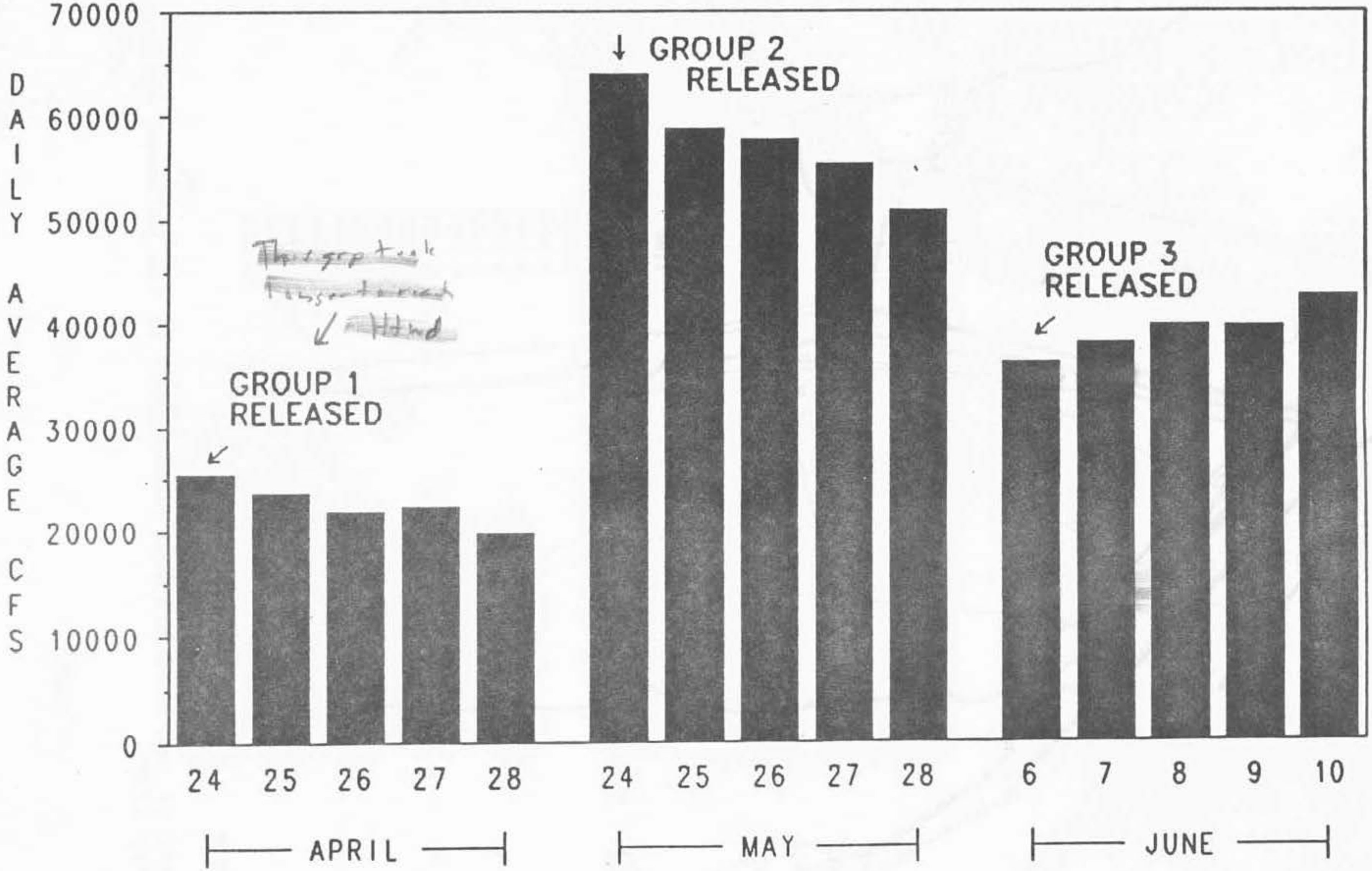


FIGURE 9

Movement of one shad tracked intensively in the Holtwood tailrace on 3 May 1989.

FIGURE 10

Daily average Susquehanna River flows for the five days following release of each group of shad, 1989.



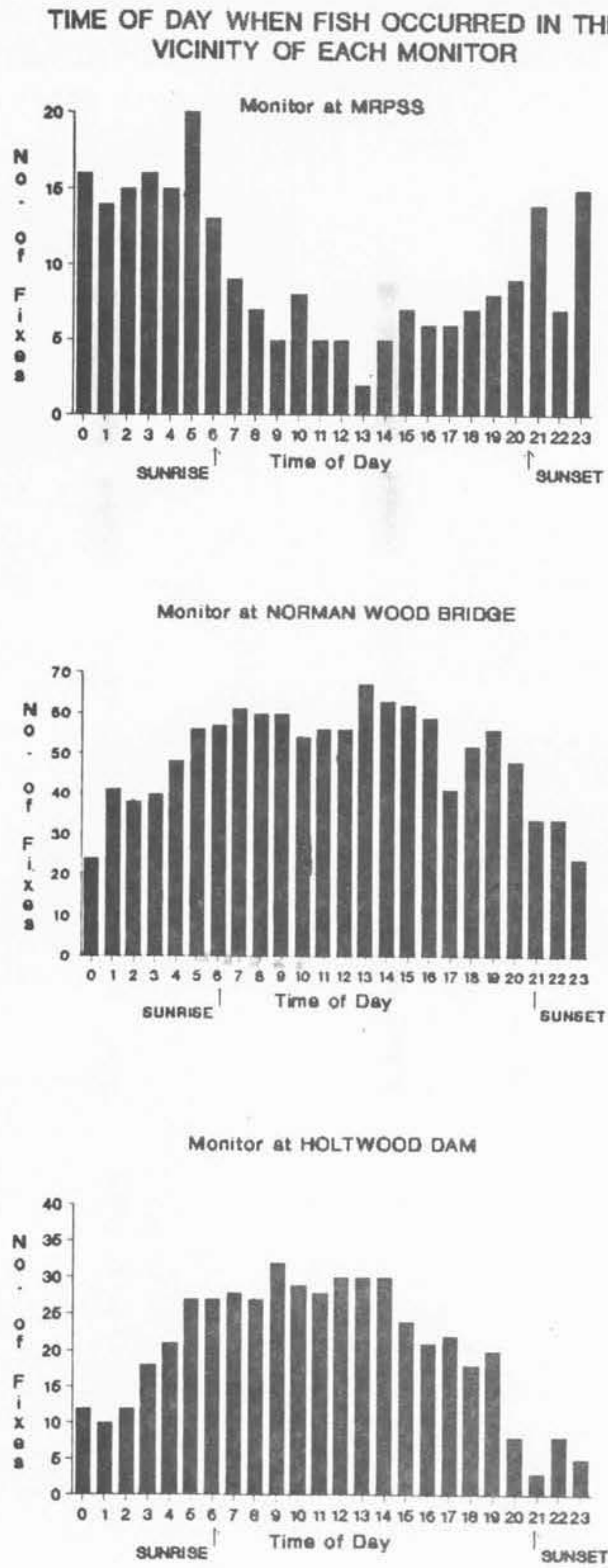


FIGURE 11

Diurnal movement patterns of shad between Muddy Run Pumped Storage Station and Holtwood Dam, 1989.

BIOLOGICAL FIELD EVALUATION OF STROBE LIGHTS YORK HAVEN HYDROELECTRIC PROJECT

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE - JOB 5 TASK 2

PREPARED FOR

THE ELECTRIC POWER RESEARCH INSTITUTE AND

METROPOLITAN EDISON COMPANY

PREPARED BY

STONE & WEBSTER ENGINEERING CORPORATION

BOSTON, MASSACHUSETTS

FEBRUARY 1990

BIOLOGICAL FIELD EVALUATION
OF STROBE LIGHTS
YORK HAVEN HYDROELECTRIC PROJECT

INTRODUCTION

In 1988, the Electric Power Research Institute (EPRI), Metropolitan Edison Company (Met-Ed) and the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) co-funded a study of sound devices and strobe lights for repelling and mercury lights for attracting juvenile American shad outmigrants at Met-Ed's York Haven Hydroelectric Project. The objective of the study was to determine whether these devices could be used to divert fish away from the plant turbines or toward an existing trash sluiceway through which they would be provided safe passage to the tailrace. The results of testing in 1988 showed that the strobe light effectively and consistently repelled the juvenile American shad in the forebay.

The purpose of the 1989 program is to demonstrate the effectiveness of a strobe light array to guide downstream migrating American shad to a trash sluice bypass. The effectiveness of the system was to be tested with both underwater hydroacoustic sampling and netting. The continuously operating hydroacoustic system yields the greatest volume of useful data but the netting is used to evaluate the relative effectiveness of the sluice gate in passing fish.

MATERIALS AND METHODS

Demonstration System

The demonstration test system consisted of six 20 foot long, rigid foam ballasted wooden floats and the ten by fifteen foot test float used in 1988. Five of the floats were arranged in line in about eight to ten feet in front of units 2 through 7 while the two remaining floats jogged out into the forebay between units 1 and 2 to form an embayment around the unit 1 and trash gate sluice area. Two strobe lights mounting poles were attached on each float. Two strobes lights were mounted on each light pole and oriented out into the forebay. Four additional strobes were mounted on the ten by fifteen foot float and oriented toward the sluice gate.

The purpose of this arrangement was to provide continuous strobe illumination along the unit 2 through 7 units. Since under typical operating conditions the shad accumulate in the area in front of units 1 to 5, this repulsion system left only the embayment near unit 1 as an area where shad could congregate. The lights in the embayment area were not intended to be illuminated until the aggregation was large enough to flush out through the sluice gate.

Hydroacoustic Monitoring System

The hydroacoustic system used to evaluate fish deterrence consisted of two WESMAR 300 Series Scanning Sonar units. These units were positioned on the float array near units 1 and 6. Data from these units was collected on a Panasonic time lapse recording video cassette recorder. The hydroacoustic monitoring system was left in operating mode prior to the shad outmigration period and monitored daily by Metropolitan Edison personnel for aggregations of shad in the forebay. When shad abundance in the forebay was noted, the testing plan was initiated and Stone & Webster personnel collected and recorded data for all test conditions.

Netting of the Sluice Gate

The discharge of the gate slot was sampled using a 300 by 8 foot seine that was deployed in the lower pool where the flow from the trash spill gate discharges. This area had a large number of tree stumps and other snags which made netting difficult. Also under typical operating conditions there is a large shallow area over which the discharge from the sluice gate spills. The velocity of the water through this area was much too great to be contained even with this relatively large seine. After a few attempts this procedure was discarded as a valid method to check on the effectiveness of the sluice as a bypass route.

SAMPLING PROCEDURES

A simple cross over design blocked within each 24 hour sampling period (testing day) was used to evaluate the effectiveness of the strobe array. Studies in 1988 have shown that except during the peak outmigration period, daily passage rates can be highly variable. Therefore blocking by day controls for this effect. There were four treatments that relate to the operating characteristic of the strobe lights. In the control treatment the lights were not operated. The other three treatments involve operation of the strobe lights at flash rates of 100, 300 and 600 flashes per minute. These four test conditions were to have been tested two or three times during each testing day in a balanced crossover design to eliminate day to day variability.

In addition to controlling for day to day variability and flash rate, testing was conducted over different portions of the time of day. Within each testing day sampling took place over a variety of times from 3 P.M. to 7 A.M..

Each test was to have a duration of 30 minutes. Control tests did not have the strobe lights illuminated. Gate control tests include opening of the gate without the illumination of the strobe lights.

Hourly average plant flow rates as well as water temperature, wind speed, direction and the occurrence of storm events were noted in a daily log book. Water velocity and direction in the top five feet of water in the forebay was also recorded. Light mapping in the area of influence of the strobe lights was also recorded.

During each test, volume of targets as measured with the hydroacoustic equipment was recorded continuously on magnetic media.

RESULTS

The hydroacoustic monitoring system was activated in early September. The system showed no aggregations of fish targets until September 20, 1989. At this time there were intermittent periods of moderately high target abundance. There was some "dimpling" of the water surface of the forebay which is indicative of aggregation of shad, however the aggregations were relatively small compared to those observed in previous years and were of short duration. Aggregations of shad would form for as long as 20 minutes, and were becoming more frequent when some qualitative system tests were initiated by Stone & Webster personnel on September 29, 1989.

One of the major differences in operation that had great potential to modify the behavior of out-migrating shad was the unplanned outage of Unit 1. This unit went down with a major short in the field winding in mid-September and was not operational during any of the testing. The effect of the outage was to limit aggregations of fish in front of Unit 1 and the sluice gate.

In addition, Units 2 through 6 were operational only due to a great effort by Metropolitan Edison to recover from a transformer fire in the Summer of 1989. The effect of these outages was to limit flow through the plant to a maximum of 5,000 cfs. During normal full station operation the plant is capable of passing up to 20,000 cfs. River flows during the test period are typically in the 8,000 to 15,000 cfs range and except for minimum release requirements, all flow would pass through the plant.

Heavy rains fell in the Susquehanna watershed in the last week of September and the first few days of October. The rain in this period changed the river flow in the period from September 29 to October 5 from 8,000 cfs to approximately 90,000 cfs. As river flows rose in this period, the limited aggregations of shad that had been observed became even less common. Since shad are known to go with the greatest flows, it is presumed that most of the fish that would have been encountered in this period had passed over the dam instead of through the headrace and hydro station.

All testing was terminated on the morning of October 5, 1989. The hydroacoustic monitoring equipment continued to monitor for aggregations of shad in the forebay. Even after the high river flows had subsided, no aggregations of fish were seen in the forebay. Water temperature at the time of the highest flows was about 10 degrees C. It is presumed that with the high flows and favorable outmigration temperatures that most of the juvenile shad passed over the dam at York Haven instead of through the forebay.

The limited qualitative testing conducted showed that as in 1988, the shad were quickly repelled from the area of influence of the strobe lights. However, even these qualitative observations have limited value because the few aggregations of shad that were observed tended to break up quickly.

JOB V, Task 3

Use of Human Chorionic Gonadotropin to Induce Spawning in American shad

Thomas W. H. Backman

National Fishery Research and Development Laboratory

U. S. Fish and Wildlife Service

R.D.# 4, Box 63

Wellsboro, PA 16901 USA

and

Chung-fu Liu

West Virginia University

Morgantown, WV 26506 USA

Introduction

This study was initiated to test the efficacy of human chorionic gonadotropin (HCG) in inducing egg maturation and spawning in American shad (Alosa sapidissima), with the objective of providing fertilized eggs to the Pennsylvania Fish Commission's Van Dyke hatchery (Thompsontown, PA) for culture and eventual stocking of the fry into the Susquehanna River basin. Artificial propagation of American shad has produced larval and fingerling shad for use in restoration of the Susquehanna River population. Eggs have been collected from rivers along the Atlantic coast and from the Columbia River. The effort and cost of collecting the eggs are substantial. Restoration would be facilitated if a technique to induce spawning in shad of Susquehanna River origin were developed. Human chorionic gonadotropin (HCG) is a relatively inexpensive sex steroid that has been widely used to induce spawning in fishes (Henderson-Arzapalo and Colura 1987; Hervey and Hoar 1979; Piper et al. 1982). The use of HCG on American shad has not been reported. We discuss the effect of HCG treatment on egg maturation and ovulation, and problems associated with long-distance transportation of shad.

Restoration efforts in the Susquehanna River include the stocking of fry and fingerling American shad produced in hatcheries. The hatchery program has been restricted to obtaining eggs from out-of-basin wild brood stock. In 1988 the viability of these eggs was less than 39% (Hendricks et al. 1989). Although the viability of eggs from Atlantic seaboard fish has generally been better than that of eggs of Columbia River origin, the supply of eggs from Atlantic stocks has not been dependable, necessitating reliance on Pacific brood stock (Hendricks et al. 1989). Poor egg viability could be due to some combination of handling stress, shipment delays, and fractional spawning by shad. Since American shad are believed to return to their natal river to spawn, the Susquehanna River

Anadromous Fish Restoration Committee considers shad taken from the lift at Conowingo as valuable to their restoration program.

Spawning in recirculating tank systems has been successful for various species (Hoff et al. 1972; Arnold et al. 1976; Roberts et al. 1978; Bromage et al. 1982; Worthington et al. 1982; Henderson-Arzapalo and Colura 1987). Spawning in tanks has been induced by manipulation of two environmental variables--temperature and photoperiod (Hoff et al. 1972; Arnold et al 1976; Roberts et al. 1978)--as well as by HCG injection (Henderson-Arzapalo and Colura 1987). To our knowledge, induced artificial spawning of American shad under controlled conditions has not been tried.

The development and refinement of holding, maturation, and spawning methodologies for adult American shad, as well as the maintenance of wild-caught brood stock would enhance restoration efforts. Successful application of egg-maturation and spawning methods would provide increased numbers of eggs of Susquehanna River origin. Ultimately, controlled maturation and spawning of captive American shad would reduce the reliance on out-of-basin wild brood stock, supplement fry and fingerling production, and contribute to the scientific knowledge of shad biology. The primary objective of the present study was to determine if mature adult American shad can be induced to reach full maturation. This objective is a prerequisite to the commitment of significant resources by the Susquehanna River Anadromous Fish Restoration Committee towards a program of induced maturation and spawning.

Methods

Transportation of adult shad

American shad were collected from the Susquehanna River fish lift below Conowingo Dam, a 95-ft high dam with 512 Mw hydroelectric power production, 10 miles from the river mouth in Maryland. Three shipments of adult shad (here termed lots 1, 2, and 3), were made to the National Fishery Research and Development Laboratory (NFRDL) in 1989. The first shipment (lot 1; 187 fish), was delivered to the Laboratory by RMC Environmental Services, on May 30, 1989, a private consulting firm hired by the Conowingo Dam licensees to operate the fish lift and transfer shad upstream in the basin. The shad were transported in an insulated circular tank 2.44 m in diameter. Shad were randomly placed into four similar dimensioned tanks supplemented with pure oxygen aeration. Rock salt was used to maintain tank water at about 10 parts per thousand (ppt) salinity. The trip from Conowingo Dam to NFRDL took about 5 hours.

The second shipment (lot 2), delivered by NFRDL staff, consisting of 48 females, was transported on June 6 from the Conowingo fish lift in an insulated (Peterson) tank containing four square 950-L compartments. Water salinity during transportation was held at 10 ppt with Bio-crystals salt (Marine Enterprises, Inc.[1]), and dissolved oxygen was maintained at about 9 ppm. During the first hour of transport, water temperature remained at about 22°C and pure oxygen was supplied at 2.5 pounds per square inch (psi); nine fish died during this period. During the rest of the transport period (4 hours), ice was added to keep the temperature near 18°C and oxygen pressure was increased to 5 - 10 psi.

[1] Mention of manufacturers or trademarks does not imply Government endorsement of commercial products.

A third shipment (lot 3), delivered by NFRDL staff, consisting of 17 males, was transported to NFRDL on June 12. A transport tank similar to the Peterson tank, but with only two smaller 475-L compartments, was used. Salinity was again raised to 10 ppt with rock salt.

Experimental procedure

On June 2, 9 female shad of lot 1 were randomly divided into three groups of three each. Shad from two groups were given an intramuscular injection of HCG at 4.4 and 2.2 IU/g. The third (control) group received no injections. After injection, the fish were held in nine circular tanks 1.22 m in diameter. Each tank contained one of the females and three untreated males. The tanks received little inflow (well water at 8.5°C) to allow warming of the water to 17°C. Unfortunately, all fish died overnight, presumably due to handling-induced stress and oxygen deficiency.

The 48 females received at NFRDL on June 6 (lot 2) were randomly placed into four 2.44 m circular tanks (12 fish per tank). On June 8, four females in each tank were given an intramuscular injection of HCG at one of four doses: 4.4, 3.3, 2.2, and 1.1 IU/g. One female fish in each of four tanks was injected with sterile saline water as a control, and one female fish in each tank was not injected. Shad were given different fin clips for identification. On June 12, 1 or 2 males from lot 3 were added to each tank. Thus, each tank contained one female from each treatment group and 3 to 5 males (a total of nine experimental fish per tank and 3 controls). All males were given HCG injections of 2.2 IU/g. Water temperatures were held at 17°C, and dissolved oxygen was kept at saturation levels by placing two air stones in each tank. A second HCG injection of the same dosage as the first was given to healthy fish 48 hours after the initial treatment. Fish in poor physical condition were not given a second HCG injection (Table 1). Before injecting the females, we obtained a few eggs by cannulating the oviduct with a 5-mm-diameter glass tube. When this procedure indicated that a female was ripe, we stripped gametes manually from the female and a male for fertilization. Total length, body weight, and gonad weight were recorded after gonadectomy. Scales and otoliths were taken to check the age and previous spawning record. To estimate fecundity, we counted the number of eggs larger than 0.2 mm in diameter in a weighed sample and applied the result to the total gonad weight.

Results

Transportation

The American shad in lot 1 (May 30) were injured and lost many of their scales during the 5 to 6 hours of transport. About 40% of the fish died within 24 hours. Mortality after the first day was about 15 fish per day. Most of the shad in lot 2 (June 6) appeared healthy. Scale loss and injury were less than in fish from lot 1. Fish in lot 3 (June 12) showed scale loss and signs of hemorrhage less serious than that in the fish from lot 1. Nevertheless, 10 of 17 (59%) of the transported fish died during transport. Fungal infections and "red head" (presumed hemorrhaging) were observed by the third day after arrival at NFRDL.

Treatment with HCG

Most of the American shad died before they reached the ovulation stage (Table 1). There was no distinct relation between the HCG dosage used and duration of survival. Among the injected females, eggs could be stripped from three shad when heavy pressure was exerted; however, most of the eggs were not ripe (Table 2). Two treated shad and a control were seen spawning in the tanks. One female (our No. 2004, Table 1), released a few eggs about 120 h after the first HCG injection. Eggs sampled before the first injection showed that ovulation was partly complete; however, eggs could not then be stripped from the fish. One shad (our No. 4005) was the only fish that spawned without receiving HCG treatment; however, it had reached partial ovulation at the start of the experiment. Examination of egg samples under a dissecting microscope showed that the process of gonad development in this fish was very close to that of No. 2004 which spawned after 120 h. Shad 3004 spawned about 90 h after the second injection. It was estimated that about half its ripe eggs were released in the tank before the rest were stripped. Examination of eggs sampled from shad 3004 before and after HCG injection showed that vitellogenesis and ovulation had been induced by HCG treatment. Other shad failed to ovulate before they died (Table 3). Shad 1005, treated with saline water in the first injection, was accidentally given an HCG injection of 3.3 IU/g. The size of its eggs had increased markedly at the time of its death compared to the size before the fish was injected with HCG. The group of fish that received the highest dosage of HCG had the highest Gonadosomatic Indices (GSI; ratio of ovarian weight to total fish weight) (Fig. 1). The testes of males treated with 2.2 IU/g HCG were degenerated and brownish (indicating possible hemorrhage).

Discussion

Transporting shad

Handling and transporting American shad have long been considered difficult. In the present study, water temperatures were held at 15° to 22°C during transportation; however, mortality was not necessarily related directly to water temperature. Fish died during the first hour of transport on June 6 (lot 2), suggesting that adult shad may require a much higher concentration of dissolved oxygen when stressed. The dead fish also may have been weakened prior to transport.

The amount of dissolved oxygen was important to survival; however the mechanics remain uncertain. For example, in the wild a shad may swim faster to compensate for low dissolved oxygen, to allow more oxygen to reach the gill surfaces. During transportation, the shad may require more oxygen due to stress, and their swimming speeds are reduced, thus magnifying the oxygen deficit. Unfortunately, the exact concentration of oxygen required for long-distance transport of adult shad is not known.

We used two forms of salt to prepare 10°/oo saline water. We suspect that rock salt contributed to the poor survival of lots 1 and 3 in the transport. We used commercial rock salt, which is slow to dissolve and may have contained an anti-caking agent that injured fish during long-distance transport. Undissolved salts can be abrasive if shad contact it. Most of the shad transported to NFRDL in lot 2 (June 6) after the addition of artificial sea salts had little scale loss and looked normal, possibly due to the use of the finer crystal salt to increase salinity during transport. Heavy scale loss and serious injuries were seen in fish in lots 1 and 3 (May 30 and June 12). Although many factors could have caused scale loss, such as contact with other fish, tank walls, etc., we suspect that salt type was a major contributor. In future transportation, particular attention should be paid to the form of salt used, as well as to fish density, oxygen concentration, and temperature.

Fecundity

Fecundity varied widely among the experimental shad. The average fecundity was low compared to that of shad from other river systems (Lehman 1953; Davis 1957). Overall shad fecundity was probably underestimated because eggs less than 0.2 mm in diameter were not counted. Although there is no known method of determining whether the shad had spawned before they were caught in the fish lift, some may have done so, considering the wide variation observed in ovarian weights and the number of eggs per gram of ovary. Some fish had small ovaries and relatively large eggs, indicating that they might have spawned. Leggett and Carscadden (1978) proposed a latitudinal variation in egg development, where northern-river fish have fully developed gonads at the start of migration, whereas southern-river shad transfer their energy from somatic tissue to the gonads during the upriver migration. If so, Susquehanna River shad (in middle latitude) enter freshwater with their ovaries partly to fully developed. Also, these trapped fish may be part of the lower-river spawning population. A delay of upriver migration due to environmental factors might force these shad to spawn in the lower end of Susquehanna River when water temperatures increase.

Maturation and ovulation

Ova were more advanced in female shad treated with HCG than in fish of the control group. Shad treated with high-dose HCG had GSI values double those of the control group (Fig. 3). The present experiment is the first documentation in which HCG was used to induce ovarian maturation and spawning in American shad. The results indicate that the administration of HCG probably can induce maturation in some fish. Because most of the shad died before their eggs reached ovulation stage, the potential for using HCG to trigger ovulation in this species is not clear. Prostaglandins and other steroids have been considered to be the principal substances regulating final ovulation for other species (Jalabert and Szollost 1975). However, the effects of prostaglandins and other sex steroids in inducing ovulation vary from species to species, and direct evidence of environmental factors affecting sex-hormone secretion is scant (Jalabert 1976, Stacey 1984). Future work must reduce the effects of handling and transport stress if the HCG treatments are to be fully evaluated. Also, the direct mechanism of ovulation requires further investigation.

Recommendations

The development of techniques to induce spawning in American shad should continue, and include at least four aspects: (1) further improvement in transporting and holding shad; (2) testing of other sex hormones, such as prostaglandins, for their effect on ovulation; (3) conducting in-vitro studies of the effects of different hormones on egg development; and (4) determining the effect of daily temperature on changes on ovulation.

Acknowledgments

We thank the Susquehanna River Anadromous Fish Restoration Program for providing funding for Chung-fu Liu, and Chris Frese of RMC for arranging the shipment of shad; the Lamar Fish Technology Center for the use of their fish truck; and Dr. Robert Ross for reading the manuscript and making suggestions.

References

Arnold, C. R., J. L. Lasswell, W. H. Bailey, T. D. Williams, and W. A. Fable, Jr. 1976. Methods and techniques for spawning and rearing spotted seatrout in the laboratory. Proceedings of the Annual Conference Southeastern Association of Fish Wildlife Agencies 30:167-178.

Bromage, N., C. Whithead, J. Elliott, B. Breton, and A. Matty. 1982. Investigations into the importance of daylength on the photoperiod control of reproduction in the female rainbow trout. Pages 233-236 in C. J. J. Richter and H. J. Th. Goos, editors. Proceedings of the International Symposium on Reproductive Physiology of Fish - PUDOC, Wageningen, Netherlands.

Davis, W. S. 1957. Ova production of American shad in Atlantic coast rivers. U.S. Fish and Wildlife Service, Research Report 49:1-5.

Henderson-Arzapalo, A., and R. L. Colura. 1987. Laboratory maturation and induced spawning of striped bass. Progressive Fish-Culturist 49:60-63.

Hendricks, M. L., T. R. Bender, and V. A. Mudrak. 1989. Job III. American shad hatchery operations, 1988. Pages 3-1 to 3-61 in R. St. Pierre, editor. Restoration of American shad to the Susquehanna River, Annual Progress Report 1988. Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, Pennsylvania.

Hervey, B. J., and W. S. Hoar. 1979. The theory and practice of induced breeding in fish. International Development Research Center, Ottawa, Canada. 48 pp.

Hoff, F., C. Rowell, and T. Pulver. 1972. Artificially induced spawning of the Florida pompano, *Trachinotus carolinus*, under controlled conditions. Proceedings of the World Mariculture Society 3:53-69.

Jalabert, B., and D. Szollost. 1975. In vitro ovulation of trout oocytes: effects of prostaglandin on smooth muscle-like cells of theca. Prostaglandin 9:765-779.

Jalabert, B. 1976. In vitro oocyte maturation and ovulation in rainbow trout (Salmo gairdneri), northern pike (Esox lucius), and goldfish (Carassius auratus). Journal of Fisheries Research Board Canada 33:974-988.

Leggett, W. C., and J. E. Carscadden. 1978. Latitudinal variation in reproductive characteristics of American shad (Alosa sapidissima): evidence for population specific life history strategies in fish. Journal of Fisheries Research Board Canada 35:1469-1478.

Lehman, B. A. 1953. Fecundity of Hudson River shad. U.S. Fish and Wildlife Service, Research Report 33:1-8.

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard. 1982. Fish hatchery management. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 517 pp.

Roberts, D. E., B. V. Harpster, and G. E. Henderson. 1978. Conditioning and induced spawning of the red drum (Sciaenops ocellata) under varied conditions of photoperiod and temperature. Proceedings of the World Mariculture Society 9:311-332.

Stacey, N. E. 1984. Control of the timing of ovulation by exogenous and endogenous factors. Pages 207 - 219 in Fish reproduction: strategies and tactics. G. W. Potts and R. J. Wootton, editors. Academic Press, London.

Worthington, A. D., N. A. A. Macfarlane, and K. W. Easton. 1982. Controlled reproduction in the roach (Rutilus rutilus L.). Pages 220-223 in C. J. J. Richter and H. J. Th. Goos, editors. Proceedings of the International Symposium Reproductive Physiology Fish. PUDOC, Wageningen, Netherlands.

Table 1. Treatment of shad with human chorionic gonadotropin (HCG) and survival time after first injection (sw = bacteriostatic saline water).

Fish number	Total length (mm)	Weight (g)	HCG concentration (IU/g)	Number of injections	Period of survival (hours)	Ovulation (pt = partial)
1001	505	1413	4.4	1	90	no
2001	500	1946	4.4	1	120	pt
3001	540	1739	4.4	2	72	no
4001	464	1137	4.4	2	150	no
1002	592	1656	3.3	1	30	no
2002	512	1519	3.3	2	84	no
3002	520	1269	3.3	2	70	no
4002	493	1268	3.3	2	90	pt
1003	507	1468	2.2	2	120	no
2003	495	1302	2.2	2	120	pt
3003	557	1844	2.2	2	120	no
4003	540	1831	2.2	2	60	no
1004	539	1668	1.1	2	180	no
2004	462	1042	1.1	2	120	yes
3004	496	1246	1.1	2	144	yes
4004	502	1135	1.1	2	148	no
1005	539	1467	sw/1500*	1/1	120	no
2005	532	1458	sw	1	190	no
3005	506	1212	sw	1	70	no
4005	473	914	sw	1	70	yes
1006	399	603	--	---	190	no
2006	489	1139	--	---	140	no
3006	452	879	--	---	72	no
4006	506	1133	--	---	72	no

* treated with 3.3 IU/g HCG accidentally.

Table 2. Ovary weight and fecundity of stripped shad.

Fish ID Number	Stripped eggs: Number	Stripped eggs: Weight (g)	Stripped eggs: Number per (g)	Estimated number of eggs in ovaries after stripping: Sample weight (g)	Estimated number of eggs in ovaries after stripping: Number per (g)	Estimated number of eggs in ovaries after stripping: Total estimated number	Estimated eggs before stripping
2001	95,760	399	240	72	520	37,440	133,200
4002	30,210	114	265	134	822	110,148	140,358
2003	23,140	130	178	99	613	60,687	83,827
2004	11,970	45	266	99	603	59,697	71,667
3004	40,820	157	260	118	620	73,160	113,980
4005	17,385	95	183	99	760	75,240	92,625
Mean	36,548	156	232	103	656	69,396	105,943
SD	30,710	125	41	21	112	24,084	27,688

Table 3. Ovarian weights and estimates of fecundity for non-spawning shad.

Fish ID Number	Eggs in ovaries: Weight of ovaries (g)	Eggs in ovaries: Number of eggs per gram	Estimated eggs in ovaries
1001	308	561	172,788
3001	381	484	184,404
4001	234	450	105,300
1002	294	904	265,776
2002	252	500	126,000
3002	178	393	69,954
1003	289	333	96,237
3003	304	767	233,168
4003	374	476	178,024
1004	160	452	72,320
4004	221	380	83,980
1005	316	287	90,692
2005	232	563	130,616
3005	182	645	117,390
1006	72	447	32,184
2006	137	750	102,750
3006	116	802	93,032
4006	141	739	104,199
Mean	232	552	125,490
SD	89	177	59,741

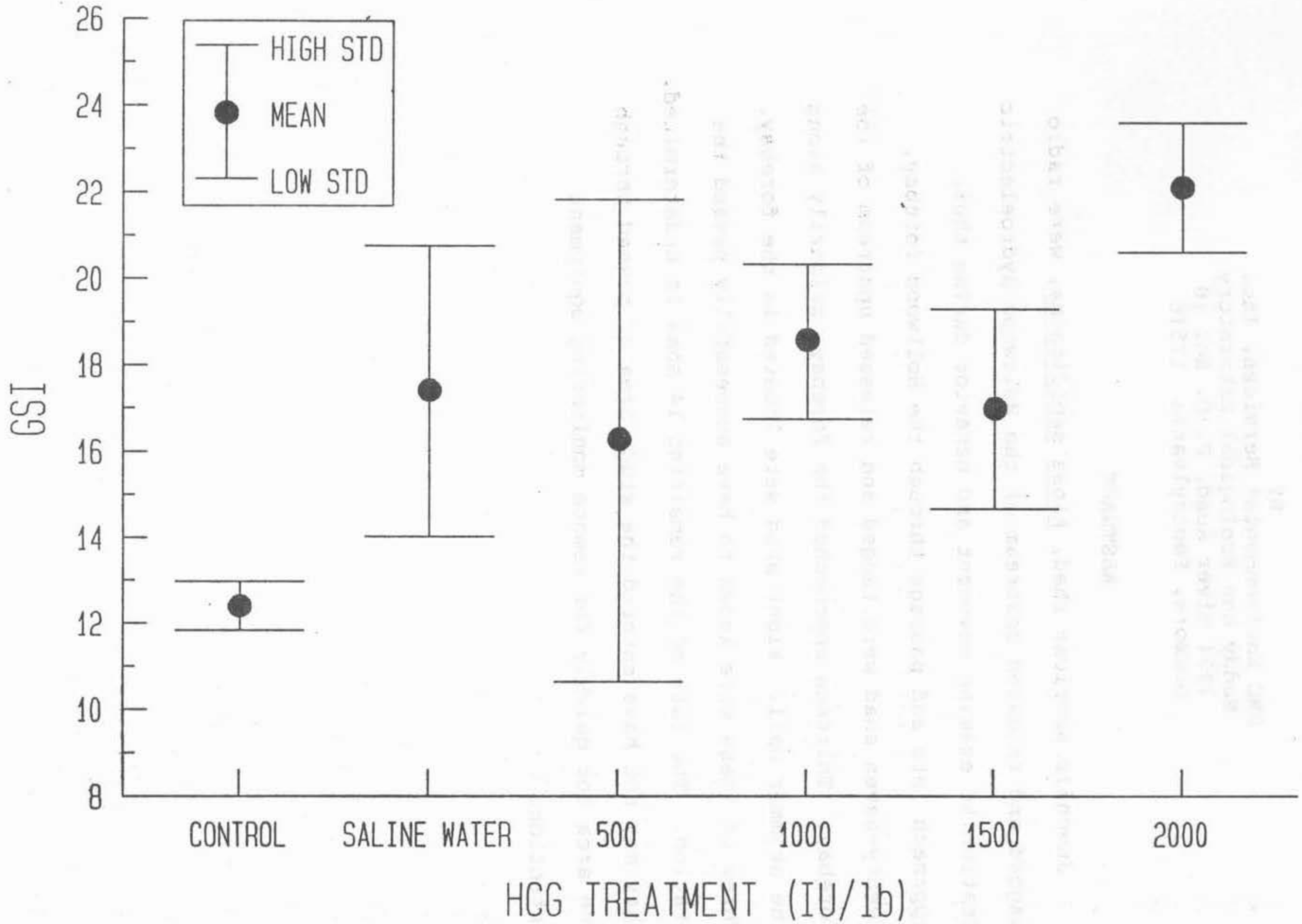


FIGURE 1. Mean gonadosomatic index (GSI) as a function of HCG treatment level.

JOB V(4) - EMIGRATION ROUTES AND BEHAVIOR OF JUVENILE AMERICAN SHAD AT THE HOLTWOOD HYDROELECTRIC STATION, 1989

BY

RMC Environmental Services, Inc.
Muddy Run Ecological Laboratory
1921 River Road, P. O. Box 10
Drumore, Pennsylvania 17518

ABSTRACT

Juvenile American shad, Alosa sapidissima, were radio tagged and released upstream of the Holtwood Hydroelectric Station to examine movement and behavior during their approach into and passage through the Holtwood forebay. Twenty-seven shad were tagged and released upstream of the forebay. Thirteen approached the forebay, primarily along the skimmer wall. Eight shad were located in the forebay. Three of these were known to have successfully passed the station. The fate of the remaining 14 shad is undetermined. They may not have entered the study area or passed through the area too quickly for remote monitoring equipment detection.

INTRODUCTION

The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) has been examining methods to collect and evaluate data on the annual juvenile shad emigration in the Susquehanna River. Past observations have indicated that juvenile American shad (Alosa sapidissima) concentrate in the inner forebay of the Holtwood Hydroelectric Station during fall emigration. However, the proportion of the total run entering either the outer and/or inner forebays is unknown. In addition, movement patterns of juvenile shad and the extent of delay in the vicinity of the station are also unknown. Therefore, collection and analysis of these data are essential to evaluate eventual passage efficiency of young shad at the Holtwood Hydroelectric Station. Knowledge gained at the Holtwood Station may also provide insight to passage of juvenile shad at other hydro facilities on the Susquehanna.

Studies conducted during the last three years by RMC Environmental Services, Inc. (RMC) indicated that externally radio tagged young shad exhibited behavioral patterns similar to untagged specimens and they may be tracked manually to study the movement patterns of the juvenile population as a whole. Consequently, RMC selected external radio tagging technique for the study at the Holtwood Station. The objectives of the Holtwood study were to determine: (1) the behavioral response of young shad that approached the skimmer wall and floating log booms at the outer forebay; (2) the magnitude of delay outside the forebay caused by the skimmer wall and log booms; (3) if shad moved toward and passed through an opened trash sluice gate adjacent to the skimmer wall; (4) the extent of shad congregation in the small inner forebay; and (5) the proportion of shad delayed in the forebay area(s) before passing through a turbine.

MATERIALS AND METHODS

Juvenile shad were collected in a 2.4 m^2 lift net in the inner forebay at Holtwood Hydroelectric Station as described in RMC (1987). Shad were transported to the holding facility at the RMC Muddy Run Ecological Laboratory (MREL) or to holding tanks installed at the station headworks. Holding tanks at the station were continuously supplied with river water passed through an ultraviolet sterilizer.

Shad were externally radio tagged at MREL or the holding facility at the station and transported upstream to the release site (mid-pond approximately 600 m upstream of Holtwood Dam at a Pennsylvania Fish Commission buoy).

Radio transmitters were purchased from Advanced Telemetry Systems, Inc. (ATS), Isanti, Minnesota. On average, transmitters measured 6 x 25 mm, weighed 1.2 g and had 280 mm antennas. Tags had a life span of three days and transmitted between 48 and 49 MHz. Several tags transmitted on the same frequency with varied pulse rates. Tags were modified for external attachment by encapsulation in a No. 2

gelatin capsule coated with "Tool Grip". Air trapped inside the capsule provided buoyancy.

Eight continuous monitoring devices (CMD) were deployed in the vicinity of the Station to record the behavior of tagged shad. CMDs were located at the inner forebay (CMD 1), on the Holtwood headworks (CMDs 2, 3, and 4), the junction of the skimmer wall, dam, and powerhouse (CMD 5), the skimmer wall (CMD 6), the floating log boom (CMD 7), and near Norman Wood Bridge (Figure 1). Each CMD consisted of a data collection computer (DCC) interfaced with an ATS programmable scanning receiver coupled to an antenna array. Individual CMD's with underwater antennas monitored Units 1-3, Units 4-6, Units 7-10, the skimmer wall, the floating log booms, and the inner forebay. Underwater antennas were 13.7 m long 12 gauge copper wire connected to receivers by coaxial cable. They were fastened along a 6.4 mm diameter nylon rope, submerged at concrete columns between the intakes, and anchored with cinder blocks. One CMD connected to a 5-element Yagi or an underwater antenna and located at the junction of the skimmer wall, dam, and Power Station was used to monitor the lower portion of Lake Aldred. The CMD at Norman Wood Bridge utilized a dipole antenna to monitor shad which passed the dam. Receivers at the station were powered by on-site electricity. A 12 V deep cycle battery powered the receiver at Norman Wood Bridge. Each receiver and DCC was placed in either a 20 L plastic bucket with a snap-on lid or a cooler.

The CMDs were programmed to scan each frequency for three seconds. When a signal was received, the DCC compared times between 5 pulses. If the variance between signals was greater than 5,000 milliseconds data were discarded. The DCC logged day, time, frequency, pulse rate and variance in a random access memory only if the variance was <5,000 milliseconds. Data were offloaded onto a Tandy 600 portable computer and stored on 3-1/2 in diskettes.

Fish were occasionally tracked by boat after release using an ATS programmable scanning receiver and 5-element Yagi antenna. Continuous manual tracking, though an effective tool, of each release group was outside the scope of this study.

RESULTS

Movement And Behavior

A total of 27 juvenile shad was tagged and released on three occasions. Seven fish were released on 13 October 1989 (Lot 1), 10 on 1 November (Lot 2), and 10 on 6 November (Lot 3). One shad from Lot 1, three from Lot 2, and four from Lot 3 were not located after release .

Two of the six shad in Lot 1 were located only one time. One was manually located 70 min after release near the release site while the other was recorded by the west headworks CMD the following day. Another shad was manually located 1 h after release near the release site and then logged at the skimmer wall the following day (Figure 2).

The remaining three shad from Lot 1 rapidly moved downstream. One of these was located between the release site and the station 40 min after release and moved near the station 30 min later. Another traveled to within 100 m of the log boom in an hour. The final fish was detected by the skimmer wall CMD 2 min after release. Nine minutes later it was recorded by the log boom CMD 9. A short time later the fish had reurned to a location near the release site. The final location of the fish was at the skimmer wall (CMD 2) 4 h 25 min after release (Figure 3).

Four of seven shad in Lot 2 were initially logged by the log sluice CMD within 4 to 23 min after release. Two of these were subsequntly located at the skimmer wall 1 and 6 min later. One was last located 3 min later at the east headworks CMD while the other was detected by the Norman Wood Bridge 14 min later (Figure 4).

Two additional shad from Lot 2 were initially recorded by the east headworks CMD. One was located 39 min after release then detected by the log sluice CMD 34 min later and remained there for 8 min. The fish was last logged back at the east headworks CMD 2 min later. The other shad was recorded at the east headworks CMD 27 min after release and within 2 min later had moved to the skimmer wall. It was then logged periodically between east headworks and the skimmer wall for 9 min. The last location was at the east headworks CMD 1 h 37 min after release (Figure 5). The remaining shad from Lot 2 was only logged at Norman Wood Bridge 9 min after release.

Five of six shad in Lot 3 rapidly moved downstream after release. Two of these progressed to the dam and subsequently followed the dam west and remained in the general area of the west shore for at least 6 h (Figure 6). The other three moved from the release site towards the forebay area. One was only located once near the log boom. The second shad was tracked from the log boom along the skimmer wall to the vicinity of the log sluice inside the forebay. It's presence was recorded at the log sluice, log boom, and skimmer wall between 22 and 36 min after release. It was last located by the west headworks CMD 1 min later. The final shad which moved toward the forebay was located at the skimmer wall 34 min after release. The fish was last located 30 min later in the tailrace just prior to signal loss (Figure 7).

The remaining shad from Lot 3 moved upstream approximately 400 m toward the east shoreline and remained in this area for about two hours. It was next located directly upstream of the release site 1 h 13 min later. The shad then progressed downstream and was last located 3 h later mid-river near the dam (Figure 8).

In summary, 13 of 27 tagged shad were known to have approached the forebay. Nine were recorded near the skimmer wall either manually or by a CMD. Two of these were last recorded at the log boom CMD. The remaining two were not logged or located along the outer forebay; however, one was logged inside the outer forebay and another was logged by the Norman Wood Bridge CMD.

Eight of 27 shad were known to have entered the outer forebay area. Four of these 10 were last logged by the east headworks CMD. One other was last manually located in the southwest corner of the outer forebay. The remaining three were located in the tailrace; one manually and two by the Norman Wood Bridge CMD.

Juvenile Shad Collection

Juvenile shad were sampled in the inner forebay by the lift net to determine the period of emigration and obtain fish for radio tagging studies. A total of 556 shad was collected on 26 occasions from 22 September through 20 November. Water temperature ranged from 20 C to 7 C and river flows varied from 6,300 to 80,000 cfs (Table 1). The daily catch per unit effort (number/lift net) varied from 0 to 9.3 with an average of 1.9. Daily totals varied from 0 to 426 (collected on 21 October).

DISCUSSION

Movement And Behavior

Nearly half of the tagged juvenile shad were known to have approached the outer forebay. The most common route was near the skimmer wall and may be related to the overall characteristics of the water flow entering the forebay in the area.

Delay of shad caused by the skimmer wall or log boom did not seem excessive from the limited data obtained. All shad which were known to have entered the forebay did so within 1 h 21 min after being located or detected near the skimmer wall and log booms. Most shad were detected inside the forebay in less than 30 min.

The non-detection of slightly more than half of the tagged shad in the impoundment may be explained by several factors. These may include relatively large size of the water body, limited transmitter range, transmitter failure, frequency change, movement of young shad into deeper water eliminating signal reception, movement upstream out of the monitoring area, or simply passed through the monitoring area too quickly to be detected by the CMDs. For example, some shad were logged at a downstream monitor (Norman Wood Bridge) but were not detected by upstream monitors. Past studies on young shad in the lower Susquehanna River never revealed a high failure rate of transmitters. In addition, manual tracking of Lot 3 shad after release indicated some individuals migrated downstream toward the west shore line instead of following the mainstream flow towards the forebay and consequently, they were not logged by the CMDs.

The inaccessibility of the forebay due to Holtwood Hydroelectric Station safety regulations precluded manual monitoring of this area. Although some shad were detected inside the forebay by CMDs, others may have entered and swiftly passed the station before CMD detection. Shad were never located in the forebay by more than one of the three headworks CMDs.

Periodic manual and continuous remote monitoring indicated no radio tagged shad entered the inner forebay. Concurrent lift net sampling in this area also yielded no juvenile shad.

Juvenile Shad Abundance

The juvenile shad CPE at the Holtwood Station in 1989 (1.9/lift) was similar to that in 1987 (2.3/lift) but lower than in 1988 (4.0/lift). High flows may have depressed the catches in 1989. High flow events in the spring during the peak spawning season and during the time juvenile shad were released from Van Dyke Hatchery may have pushed the young shad out of the sampling area. These high flow events affected other species as well. Juvenile gizzard shad abundance in 1989 was also much lower than in 1988. Inspite of a large population of gizzard shad observed in the spring only 162 juvenile gizzard shad were collected in 1989 as compared to 21,971 in 1988.

The peak of the young shad emigration, as determined by our sampling, occurred primarily on a single day when 76% of the total catch was captured. From 13 to 20 October, water temperature ranged from 13.5 to 15.0 C. However, natural river flow increased from 33,700 cfs on 20 October to 80,000 cfs on 21 October. After this high flow event and associated decrease in water temperature numbers of shad collected increased from zero on 20 October to a peak of 426 on 21 October. Although large numbers of shad may have passed the station between 22 and 26 October, high flows prevented lift net sampling . No shad were collected after 26 October (Table 1).

RECOMMENDATIONS

RMC believes non detection of nearly half of the juvenile shad was not solely related to equipment failure. Previous studies of radio tagged juvenile shad in the lower Susquehanna River indicate manual tracking is necessary to actually determine movement and behavior of young shad. Although manual monitoring is more labor intensive, it also provides the most reliable data. Consequently, RMC recommends that any studies conducted in the future include manual monitoring to gather data on movement and behavior of young shad at hydro projects. However, determination of young shad passage at a point or location can be usefully supplemented with continuous monitoring devices.

REFERENCES

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

TABLE 1

Summary of lift net collections in the Holtwood Inner Forebay, 22 September to 20 November, 1989.

Date	Water Temp. (C)	Time	Total Lifts	Total Shad Caught	CPE**	Number Gizzard Shad Collected	River Flow
22 Sep	20.0	1400-1430	10	23	2.3	0	13,400
4 Oct	17.0	1350-1530	10	0	0	0	11,300
5 Oct	17.0	1330-1515	10	4	0.4	0	10,800
6 Oct	16.5	1610-1630	10	33	3.3	3	10,200
13 Oct	15.0	0905-0935	10	25	2.5	0	7,100
13 Oct	15.0	1530-1550	10	0	0	0	7,100
15 Oct	15.0	1850-1950	10	1	0.1	0	6,300
16 Oct	15.0	0940-1025	10	0	0	100	7,500
17 Oct	15.0	1005-1050	10	0	0	0	7,300
17 Oct	15.0	1540-1600	10	0	0	0	7,300
18 Oct	15.0	0935-1010	10	0	0	0	12,800
19 Oct	15.0	0920-0945	10	0	0	0	16,600
19 Oct	15.0	1545-1625	10	0	0	0	16,600
20 Oct	15.0	1010-1040	10	0	0	0	33,700
20 Oct	15.0	1803-1843	10	8	0.8	0	33,700
21 Oct	13.5	1200-1240	10	31	3.1	26	80,000
21 Oct	13.5	1312-1700	46	426	9.3	29	80,000
26 Oct	11.0	0930-0950	10	5	0.5	0	45,800
30 Oct	13.0	1245-1330	10	0	0	0	25,200
30 Oct	13.5	1905-1925	10	0	0	0	25,200
3 Nov	-	1030-1050	10	0	0	0	20,800
6 Nov	11.5	1020-1050	10	0	0	0	21,000
9 Nov	12.0	1150-1205	10	0	0	0	20,300
13 Nov		1505-1530	10	0	0	0	23,600
15 Nov*	10.0	1115-1145	10	0	0	0	25,200
20 Nov	7.0	1517-1540	10	0	0	4	68,200
Totals			296	556	1.9	162	

* Electrified lift net with DC current.
** CPE = average number of juvenile shad captured per haul of the lift net.

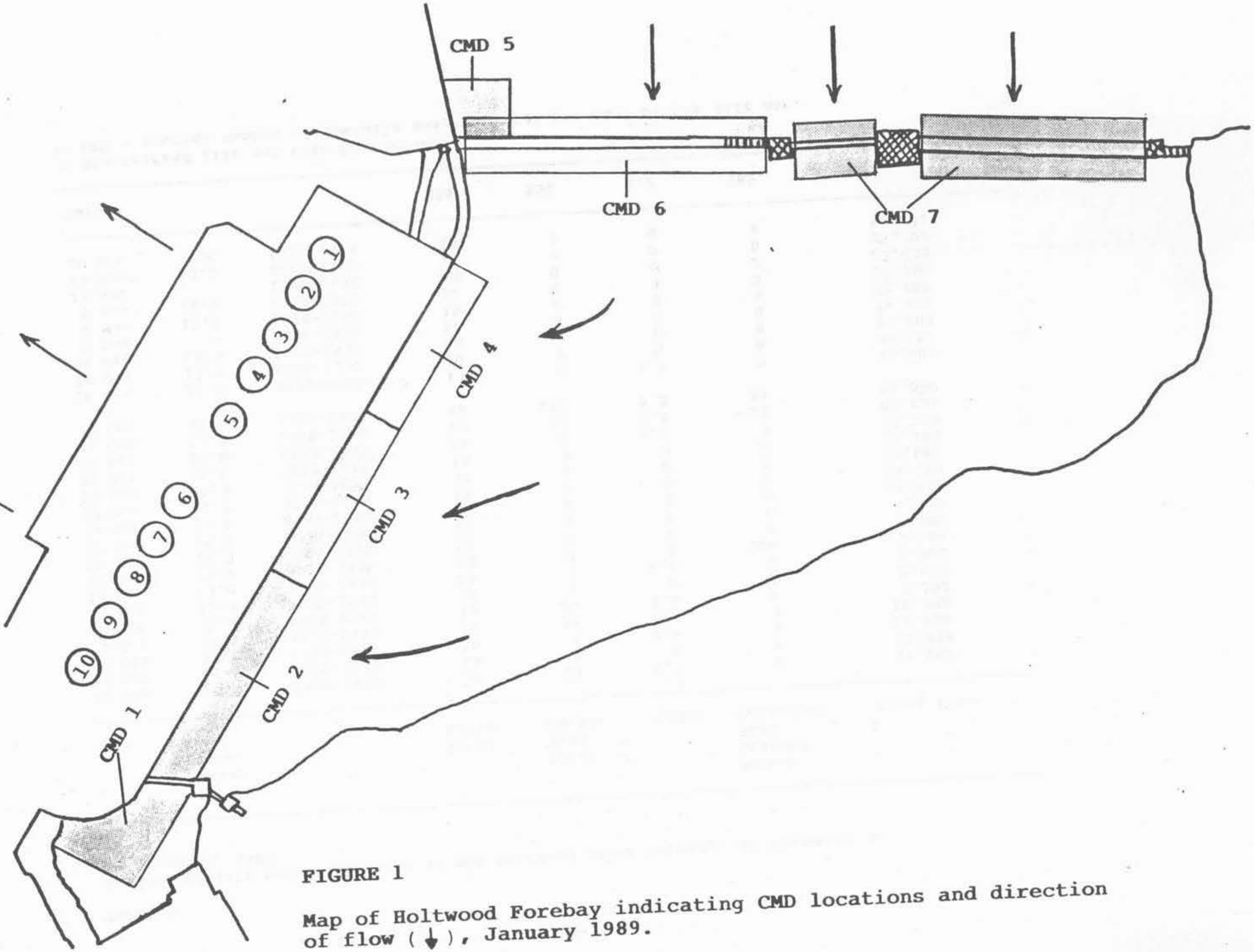


FIGURE 1

Map of Holtwood Forebay indicating CMD locations and direction of flow (↓), January 1989.

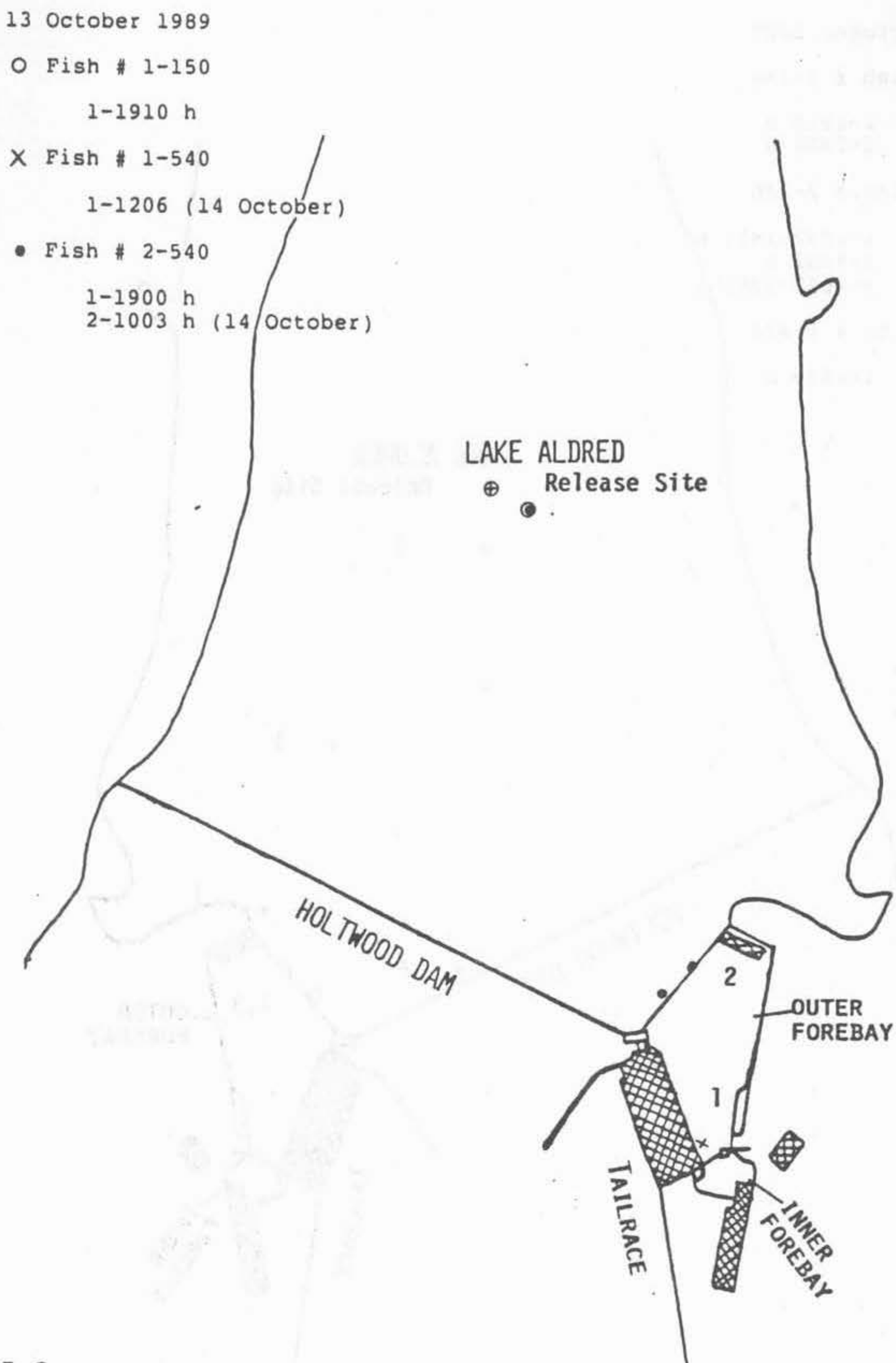


FIGURE 2

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

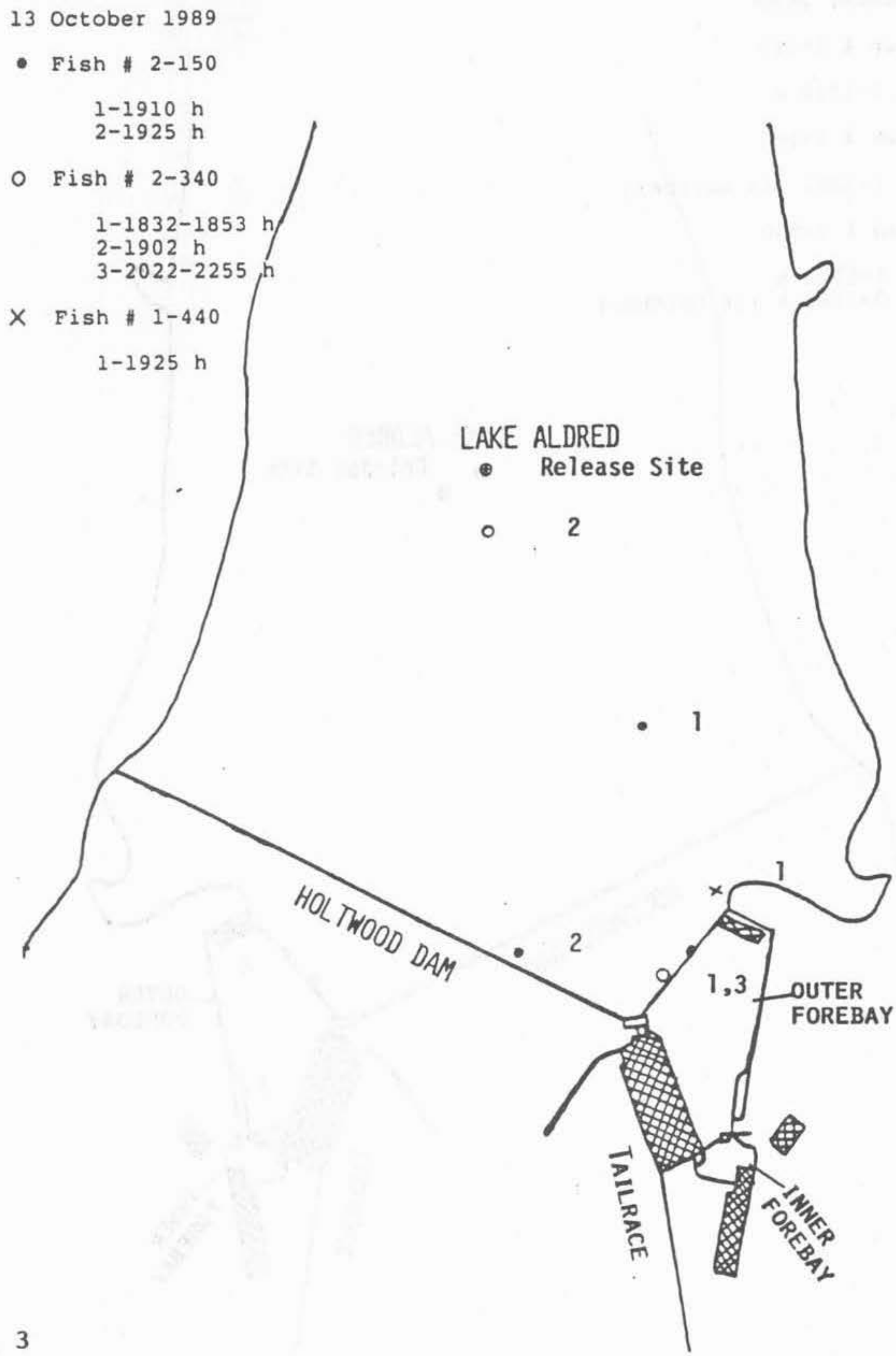


FIGURE 3

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

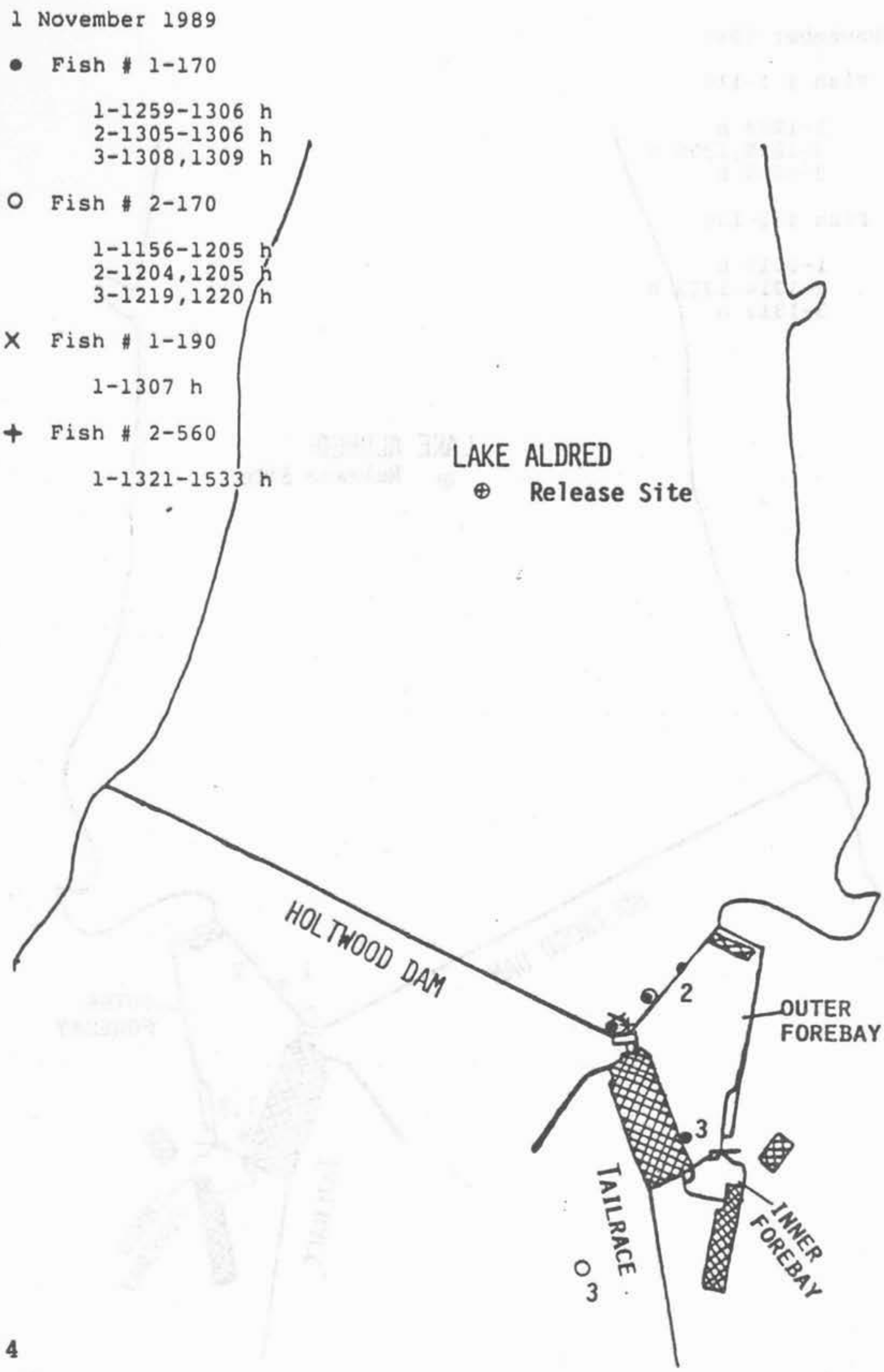


FIGURE 4

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

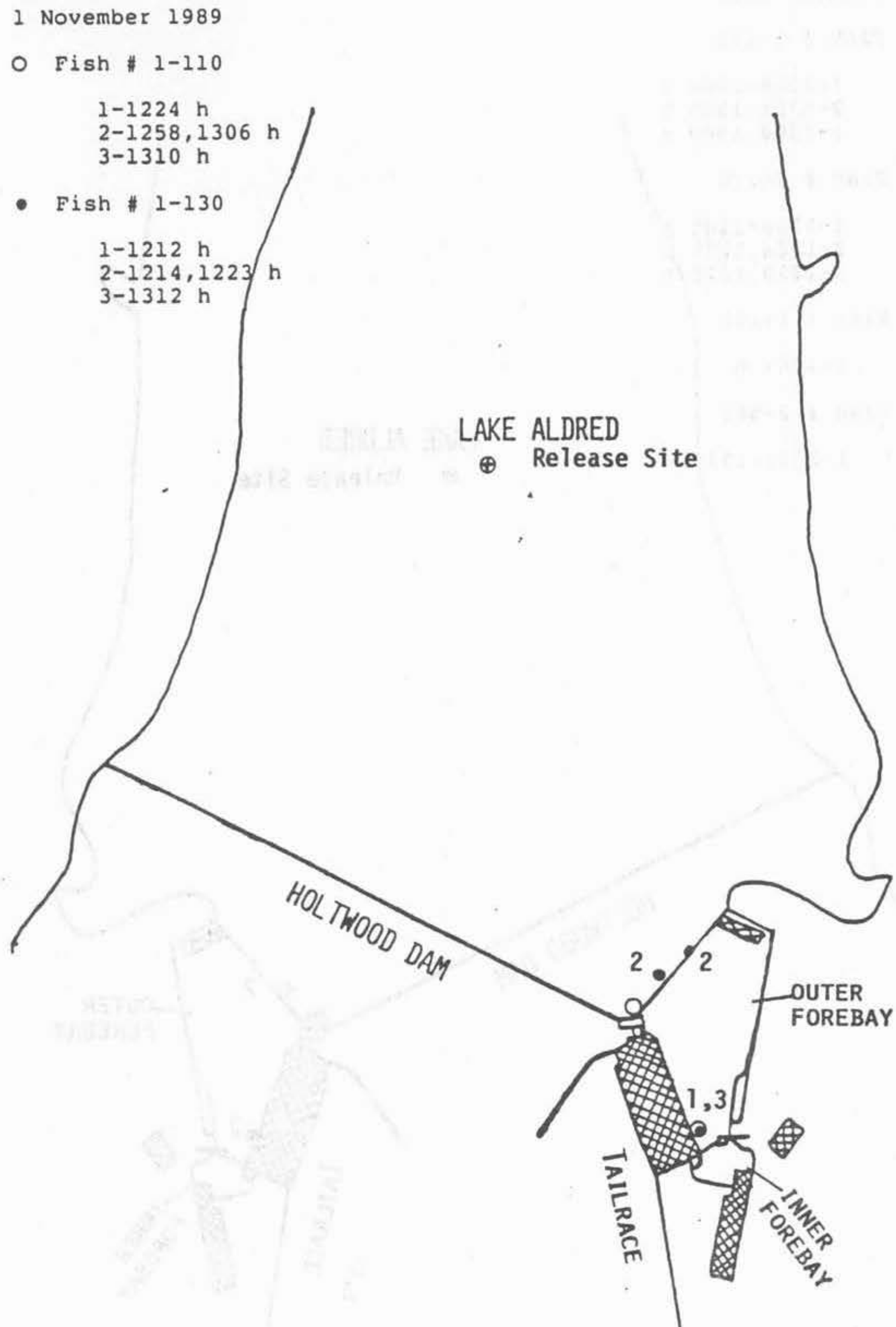


FIGURE 5

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

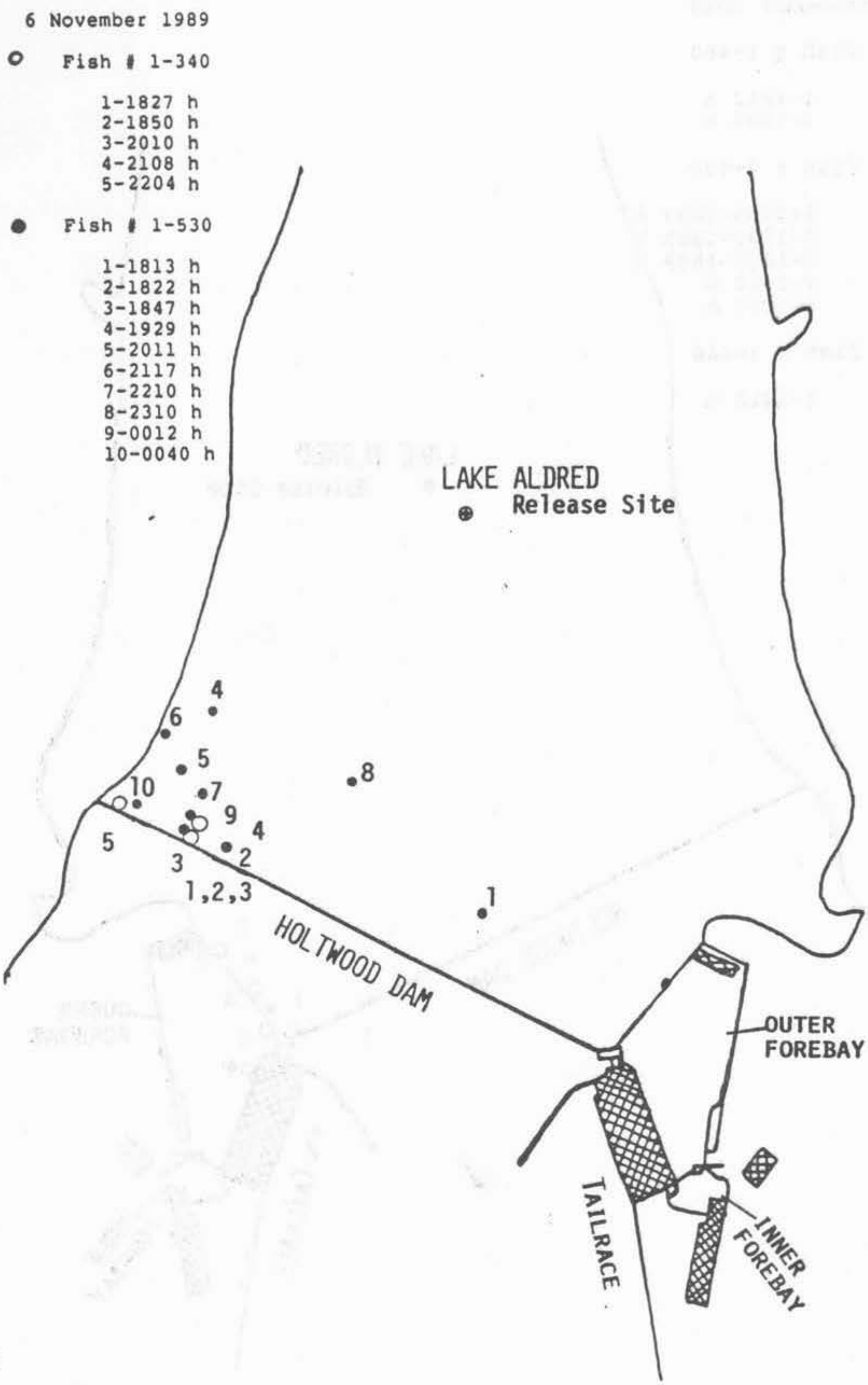


FIGURE 6

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

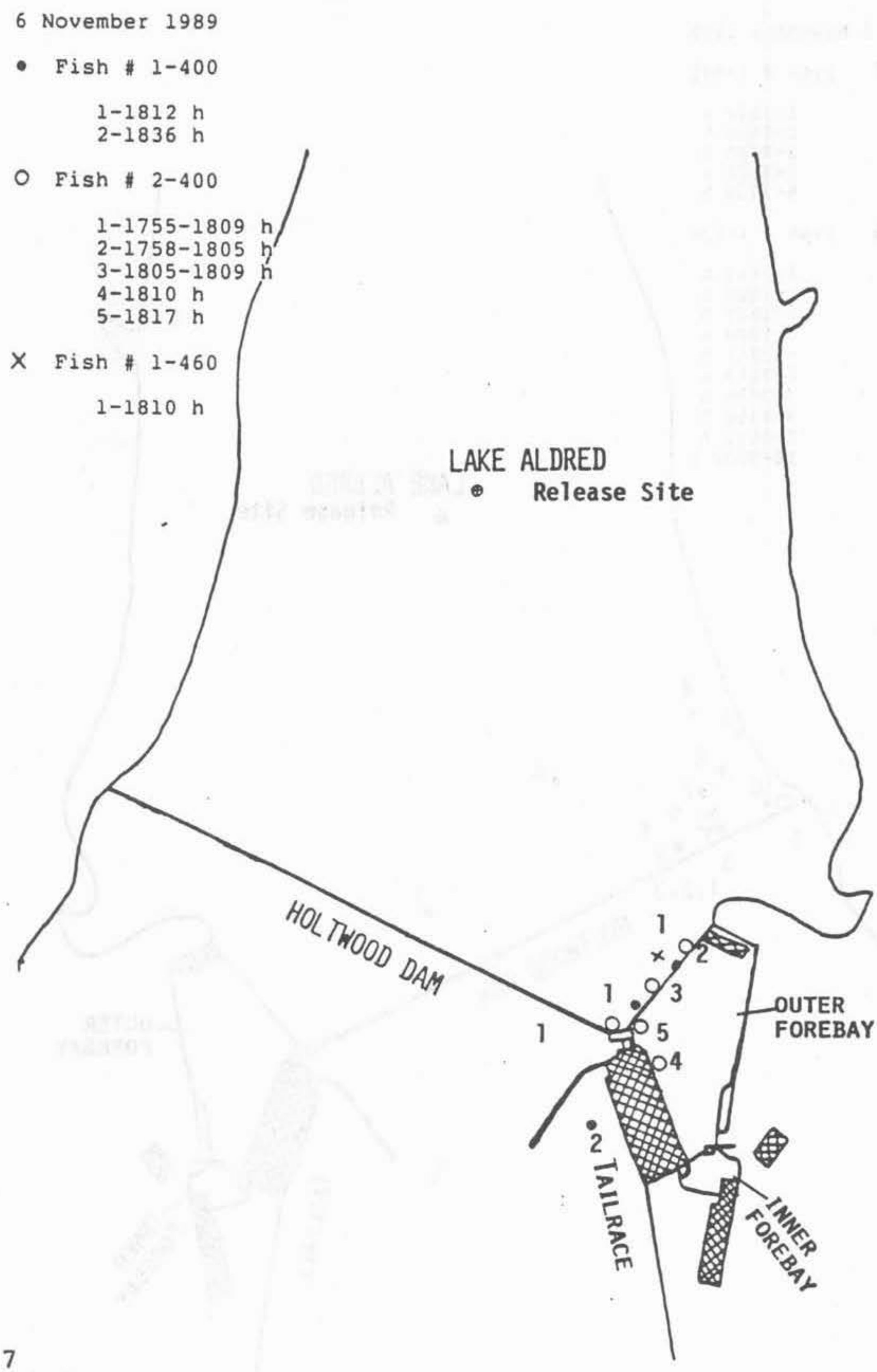


FIGURE 7

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

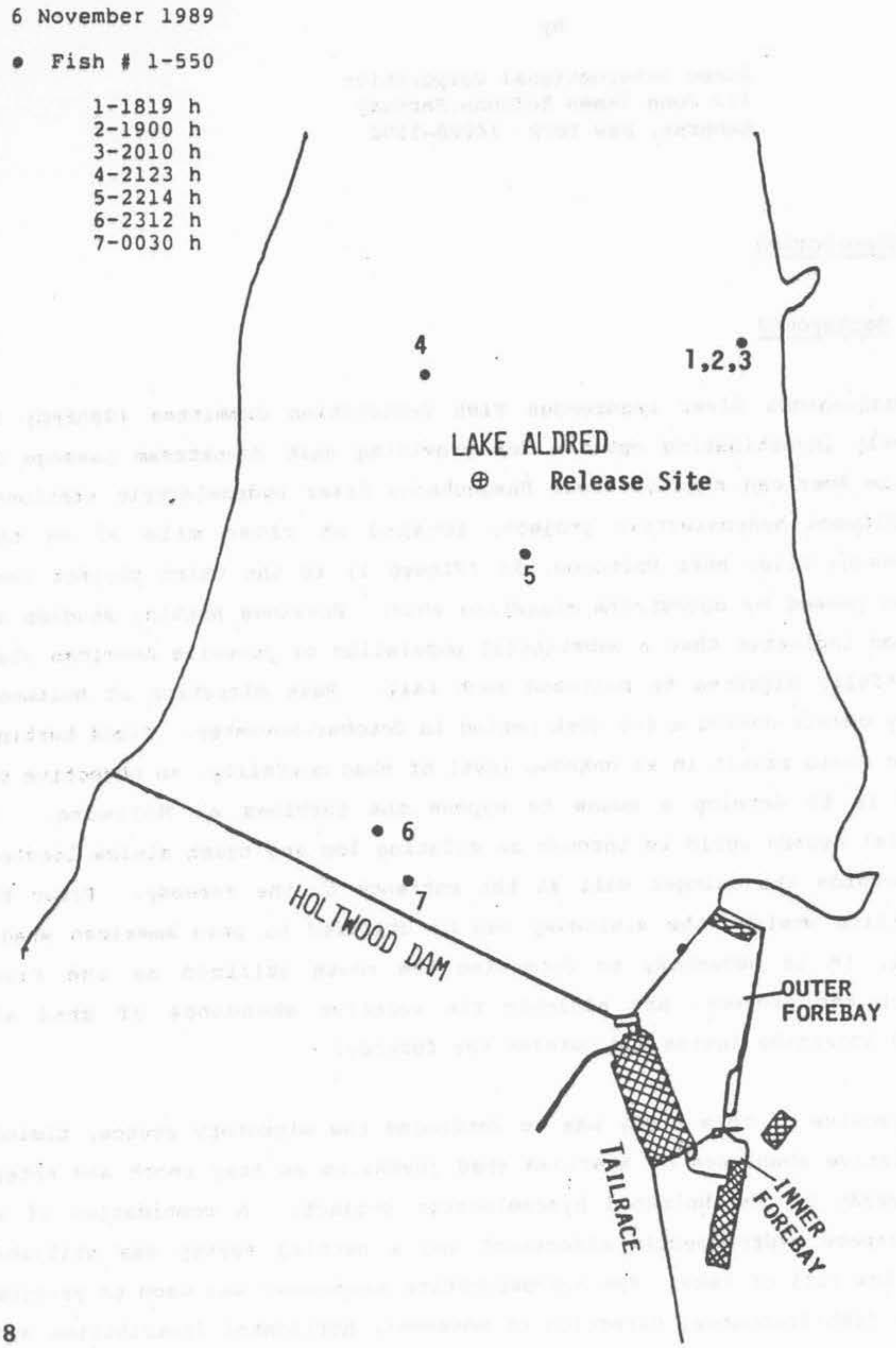


FIGURE 8

Manual and/or CMD fixes on juvenile American shad radio tagged and released during the Fall of 1989.

JOB V, TASK 5 - HOLTWOOD HYDROELECTRIC PROJECT
AMERICAN SHAD OUTMIGRATION STUDY

by

Acres International Corporation
140 John James Audubon Parkway
Amherst, New York 14228-1180

1 - INTRODUCTION

1.1 - Background

The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) is currently investigating options for providing safe downstream passage of juvenile American shad at lower Susquehanna River hydroelectric stations. The Holtwood hydroelectric project, located at river mile 25 on the Susquehanna River near Holtwood, PA (Figure 1) is the third project that must be passed by downstream migrating shad. Previous netting studies at Holtwood indicated that a substantial population of juvenile American shad successfully migrates to Holtwood each fall. Peak migration at Holtwood usually occurs during a 4-6 week period in October-November. Since turbine passage would result in an unknown level of shad mortality, an objective of SRAFRC is to develop a means to bypass the turbines at Holtwood. A potential bypass would be through an existing log and trash sluice located just outside the skimmer wall at the entrance to the forebay. Prior to determining whether the sluiceway can be utilized to pass American shad, however, it is necessary to determine the route utilized as the fish approach the project, and estimate the relative abundance of shad at various locations inside and outside the forebay.

The objective of this study was to determine the migratory routes, timing and relative abundance of American shad juveniles as they reach and enter the forebay of the Holtwood hydroelectric project. A combination of a fixed aspect hydroacoustic assessment and a netting survey was utilized during the Fall of 1989. The hydroacoustics assessment was used to provide data on fish abundance, direction of movement, horizontal distribution and timing of passage. The hydroacoustic equipment does not supply specific information on which species are present in the Holtwood project vicinity.

Gizzard shad, which are abundant in the area during the American shad outmigration period, are only slightly smaller than American shad and cannot be differentiated from American shad by hydroacoustic techniques alone. A gill netting survey was used to estimate the relative composition of American shad in the total "population" of fishes sampled by the hydroacoustic gear.

1.2 - Site Description

The Holtwood dam is a 2392-ft-long, 55-ft-high concrete gravity type dam. The spillway is ungated with crest at elevation 165 ft (USGS datum). The reservoir level is raised to 169.5 ft with wooden flashboards supported by destructible metal pins. The flashboards are usually lost during spring and fall high flow conditions. The powerhouse has a maximum turbine discharge capacity of about 32,000 cfs and produces 108 MW of electricity through 10 units. A concrete arched pier skimmer wall and two log booms form a forebay and protect the turbine intakes from floating debris. The skimmer wall extends approximately 600 ft from the west end of the powerhouse upstream to a jutting point of land.

2 - METHODS

2.1 - Hydroacoustic Assessment

Six transducers were deployed along the skimmer wall and floating booms during the week of October 8th, prior to the onset of the outmigration (Figures 2 and 3). Each transducer was a single-beam type with an effective beam width of 15 degrees. The transducers were mounted approximately one to two meters below the surface of the water. Each transducer was aimed sideways with its axis angled approximately 11 degrees down from the surface and 15 degrees out from the wall along which it was aimed. After deployment and before data collection began, the transducer at position 1 was damaged by debris, and this area was not sampled. Each of the five operational transducers was operated for 10 minutes of each hour while the equipment was active. Sampling was scheduled to begin at 1600 hrs and continue until the recording paper ran out, generally after 0800 the following morning. Hydroacoustic sampling was to be conducted for a period of 2 weeks during the peak of the outmigration.

When triggered by the echo sounder, the high-frequency transducer emits short sound pulses in a cone-shaped pattern aimed toward an area of interest. As these sound pulses encounter fish or other targets, echoes are reflected back to the transducer which then reconverts the sound energy to electrical signals. The returning signals are electrically adjusted to provide the actual signal strength and location of the target. These targets are recorded on chart paper that was sent to the laboratory for processing at the end of the study.

Prior to the study, each transducer was calibrated for use with its respective echo sounder to be used during the study. Calibration assured that an echo from a target of known acoustic size passing through the acoustic axis of any of the transducers produced a known output voltage at the echo sounder. This information was used to equalize the receiving sensitivity of all transducers used in the Holtwood Dam study, so that fish detectability was uniform regardless of the specific transducer or echo sounder being operated.

Estimates of fish passage were standardized for comparative purposes by correcting the differences in the volume (area) attenuated by the transducer field and the time that the transducer was sampling. The standardized estimate was expressed as fish per m^3 (attenuated) per minute. It should be noted that the volume in this rate expression is not related to volume of flow passing the skimmer wall or entering the powerhouse, so estimates of total fish passage cannot be directly calculated.

2.2 - Netting Survey

A netting study was conducted in the Holtwood forebay to determine the relative contribution of American shad to the pelagic "population". Netting was scheduled to be conducted outside the skimmer wall, but high flows and heavy spill over the dam made the area too dangerous to sample.

Netting was scheduled to be conducted on three occasions; one early in the study, one during the peak migration period and one near the end of the study. These dates were selected so changes in the relative species composition could be detected.

Gill nets were the primary sampling gear, although lift netting was also attempted. The gill nets were 75 ft long by 6 ft deep with 25 ft panels of 1/2-inch, 1-inch and 1-1/3-inch bar mesh. Additional floats were put on each net so they sampled the upper 6 ft of the water column. Nets were initially set off the inner (forebay) side of the skimmer wall and allowed to drift, but upwellings and cross-currents made deployment and control difficult. Nets were then tied off between the skimmer wall and the north shoreline to allow easier deployment and more control (Figure 2). Nets were deployed from Boom #2 only, because high flow conditions made working from Boom #1 unsafe. Nets were fished for 30 minutes, if possible, pulled and cleaned and then reset. Lift netting using a 8 ft square net with 1/4-inch mesh was attempted from the boom and north shore but sampling difficulties precluded further use of this gear.

3 - RESULTS

3.1 - Hydroacoustic Assessment

Hydroacoustic sampling was initiated October 24, 1989, subsequent to notification by Holtwood operations personnel and RMC Environmental Services that American shad had arrived in the Holtwood forebay.

Hydroacoustic sampling was conducted each night through October 31. Based on results of the netting survey by Acres, on sampling conducted by RMC and National Environmental Services (NES), and after consultations with the Susquehanna River Coordinator (Mr. Richard St. Pierre), sampling was suspended after October 31, 1989 due to the low numbers of shad apparently present in the project vicinity. Sampling was to resume if monitoring conducted by RMC or NES indicated that shad numbers were increasing in the project vicinity. No significant influx of American shad occurred after that date, however.

Standardized passage rates (number per unit area per minute) at each transducer were calculated for each hour sampled. These data are graphically presented by study date in Figures 4-11. The scheduled start time on each study date was from 1600 to 1700, but the loss of Transducer 1 on October 24 and a malfunction in the chart recorder on October 25 delayed the start times on these dates. To obtain comparable sampling periods for mean passage rate for each study date and for the total study, it was necessary to utilize data collected between 2000 and 0600 hrs only (Figure 12 and Table 1).

The highest passage rates generally occurred in the area under Boom #2 sampled by Transducer 5 (Table 1). The mean total passage rate at Transducer 5 was 0.0124 fish per unit, which is more than twice the next highest mean passage rate, which occurred at Transducer 3 (0.0053 fish per unit). The highest mean passage rate per study date also occurred at Transducer 5, for all dates sampled. The highest hourly passage rate also occurred at Transducer 5 (0.0924 fish per unit at 0100 on October 30).

Transducer 6 also sampled the area under Boom #2 but was directed south towards Transducer 5. Lower passage rates were detected at Transducer 6 than Transducer 5, but changes in mean daily passage rate at Transducer 6 are generally reflected at Transducer 5. Changes in hourly passage rates are not generally comparable, however.

Transducer 2, which sampled along the skimmer wall nearest the powerhouse, generally had the lowest passage rate, although this may reflect the occasional intermittent operation of this transducer. Only on October 24 did fewer fish pass by another transducer. No fish were detected at Transducer 2 during 53 percent of the total hours sampled. No large changes in hourly passage rate that would indicate passage of schools of pelagic fish were observed.

Transducer 3 sampled the inner side of Boom #1 and was directed north. The total mean passage rate at Transducer 3 was 0.0053 and ranged from 0.0102 on October 29 to 0.0015 on October 24. Large increases in hourly rates that would indicate movements of fish into the forebay were evident on five of the dates sampled.

Transducer 4 also sampled the inner side of Boom #1 and was directed towards Transducer 3. Increases in hourly passage rates through the area sampled by Transducer 3 were generally reflected at Transducer 4. Mean passage rates between these transducers were also comparable.

3.2 - Netting Survey

Netting surveys were conducted in the Holtwood forebay on October 24 and October 31, 1989. Lift netting was attempted on October 24, but entanglement of the gear on underwater structures limited the application of this method. Floating gill nets were used on both sample dates.

No fish were collected during 66 minutes of gill net sampling on October 24 (Table 2). A school of fish was observed along the north side of the forebay in an area that could not be sampled. These fish, however, were tentatively identified as gizzard shad. Three juvenile American shad were observed in the trash collected from the traveling screens in the steam station's screen house, but it could not be determined when the fish were collected.

No fish were collected during 205 minutes of gill net sampling on October 31. A single juvenile American shad was observed swimming erratically near the east end of the forebay. No additional fish were observed elsewhere in the forebay, and no shad were seen in the trash from the traveling screens.

4 - DISCUSSION

The results of the hydroacoustic monitoring indicated definite peaks in fish activity in the evening and overnight hours, which would generally coincide with expected peaks in shad passage rates, as reported by other investigations. Due to the lack of success in the gill netting efforts, however, the percentage contribution of outmigrating American shad to the targets sampled by the hydroacoustics cannot be determined. The overall passage rates of all targets into the forebay were generally low, and may only indicate resident fish activity. The lack of juvenile shad in gill net sampling was reflected in the results of RMC's lift net collections taken in the Holtwood forebay during the fall outmigration period (Personal Communication, Paul Heisey, RMC).

RMC conducted lift netting on two dates during the hydroacoustic study. On October 26, a total of five juvenile American shad were collected in the lift net. On October 30, no American shad were collected. Gizzard shad were not collected on either date. The greatest number of juvenile American shad collected at Holtwood by RMC occurred on October 21, immediately prior to the commencement of the hydroacoustic study. No American shad juveniles were captured at Holtwood by RMC after October 26; sampling terminated on November 20, 1989.

The apparent rapid emigration of juvenile American shad through the Holtwood project area could be due to a combination of rapidly falling water temperatures and rapidly rising river flows (Table 3). Temperatures fell from 16°C on October 20 to 13°C on October 21, and to 11°C on October 22. River flow increased from 33,700 cfs to 91,900 cfs over the same period. River temperatures remained low throughout the hydroacoustic study, although moderated to 14°C by the end of the study. River flow decreased after the October 22 peak, but spill over the dam continued through October 28, and the trash sluice remained open throughout the study.

The high flows and heavy spillage over the dam likely provided the juvenile American shad an alternate downstream passage route, to that of passing into the forebay and through the turbines. Juvenile shad may not have been able to detect flow into the powerhouse and instead were attracted to the heavy flows over the dam. It is likely that the majority of the shad outmigration through the Holtwood project area occurred by passing over the dam between October 21 and October 28.

Results of the netting programs conducted for this study and by RMC suggests that relatively few of the targets detected entering the forebay area by hydroacoustics were American shad juveniles. Most of the targets were more likely resident species, such as gizzard shad or cyprinids. Few gizzard shad, however, were taken by RMC and none were collected during the gill netting effort.

Although the original objectives of this investigation were not met due to unfavorable river conditions, this study indicated that hydroacoustics combined with netting techniques can be effective tools for monitoring shad outmigration at Holtwood. With more favorable sampling conditions, further application of these techniques should yield useful information for development of alternatives for downstream fish passage at Holtwood.

TABLE 1

NIGHTLY AND TOTAL STUDY AVERAGES OF ENTRAINED FISH PASSAGE RATES THROUGH ENSONIFIED AREAS AT HOLTWOOD HYDROELECTRIC PROJECT (PASSAGE RATE EQUALS FISH PER MINUTE PER CUBIC METER)

	Transducer				
Date	2	3	4	5	6
10/24	0.0011	0.0015	0.0012	0.0051	0.0010
10/25	0.0005	0.0019	0.0012	0.0050	0.0011
10/26	0.0001	0.0053	0.0023	0.0076	0.0017
10/27	0.0001	0.0034	0.0019	0.0114	0.0036
10/28	0.0003	0.0050	0.0044	0.0124	0.0062
10/29	0.0006	0.0102	0.0062	0.0153	0.0034
10/30	0.0002	0.0095	0.0051	0.0297	0.0095
Total	0.0004	0.0053	0.0032	0.0124	0.0038

TABLE 2

SUMMARY OF GILL NETTING EFFORT
HOLTWOOD PROJECT FOREBAY, 1989

	Time		Minutes	# Nets	# Fish
Date	Set	Out	Fished	Deployed	Collected
10/24	1842	1852	10	1	0
	1936	1957	21	1*	0
	2020	2055	35	1	0
10/31	1812	1912	60	2	0
	1920	2145	145	2	0
TOTAL			271		0

*Only 40 ft deployed.

TABLE 3

AMBIENT RIVER TEMPERATURE AND DAILY RIVER FLOW, SUSQUEHANNA RIVER, HOLTWOOD, OCTOBER-NOVEMBER, 1989

Month	Day	Flow (cfs)	Temp (°C)	Month	Day	Flow (cfs)	Temp (°C)
October	1	12900	18	November	1	21000	14
	2	13500	18		2	20000	14
	3	12600	18		3	20800	14
	4	11300	18		4	20000	13
	5	10800	18		5	21200	13
	6	10200	17		6	21000	11
	7	9500	17		7	20500	11
	8	7600	18		8	19300	11
	9	7800	16		9	20300	11
	10	7800	17		10	22300	11
	11	7400	16		11	22300	11
	12	7400	16		12	24100	11
	13	7100	16		13	23600	10
	14	7600	16		14	24800	9
	15	6300	16		15	25200	9
	16	7500	16		16	31000	10
	17	7300	17		17	30500	11
	18	12800	17		18	37900	11
	19	16600	16		19	66700	7
	20	33700	16		20	68200	6
	21	80000	13		21	58000	6
	22	91900	11		22	49300	4
	23	76800	10		23	43800	3
	24	67500	11		24	39400	3
	25	57200	11		25	36500	3
	26	45800	11		26	34500	3
	27	36400	11		27	31200	3
	28	32300	12		28	29400	3
	29	27200	12		29	27400	4
	30	25200	13	November	30	26800	4
October	31	23000	14				

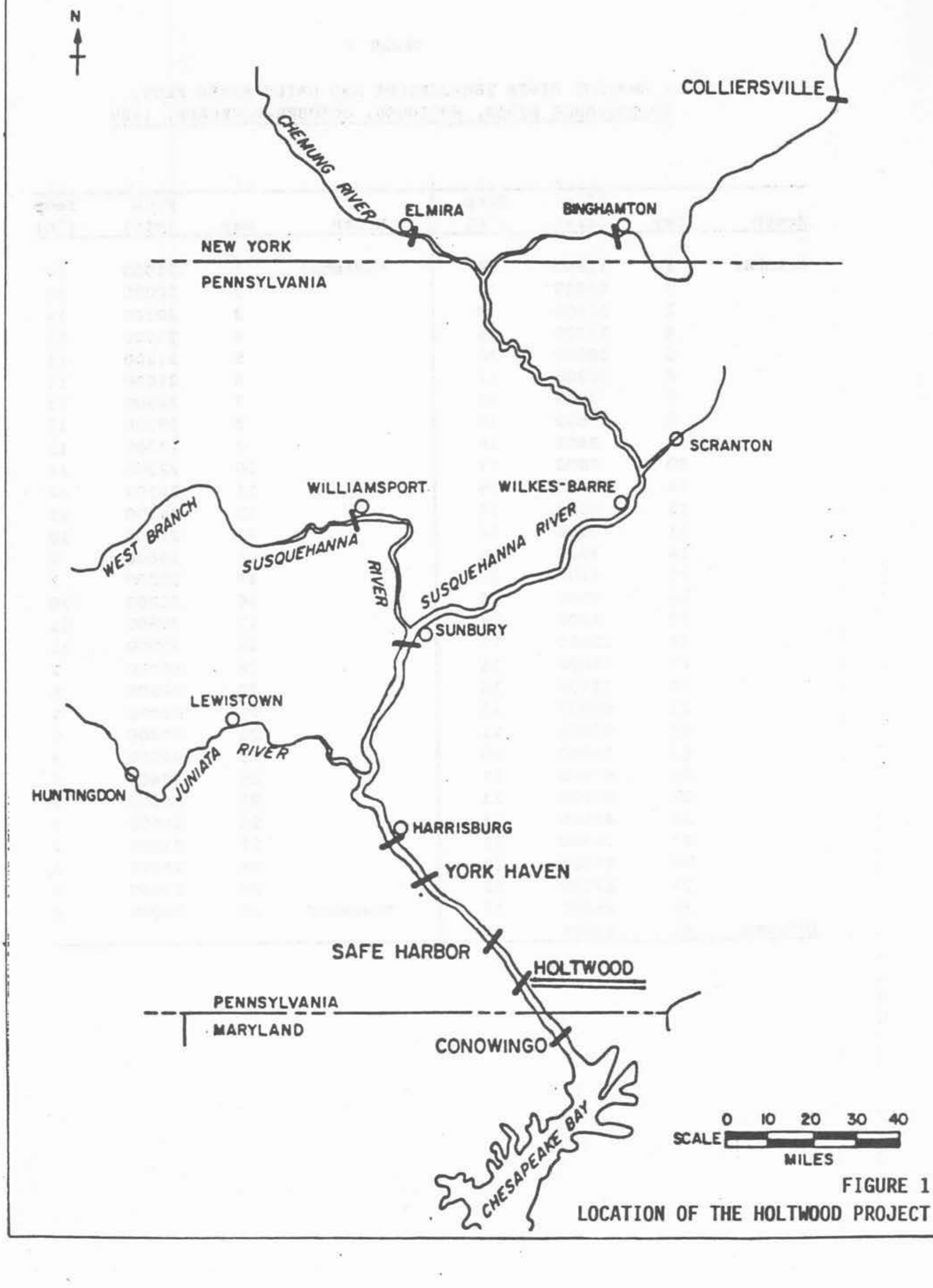
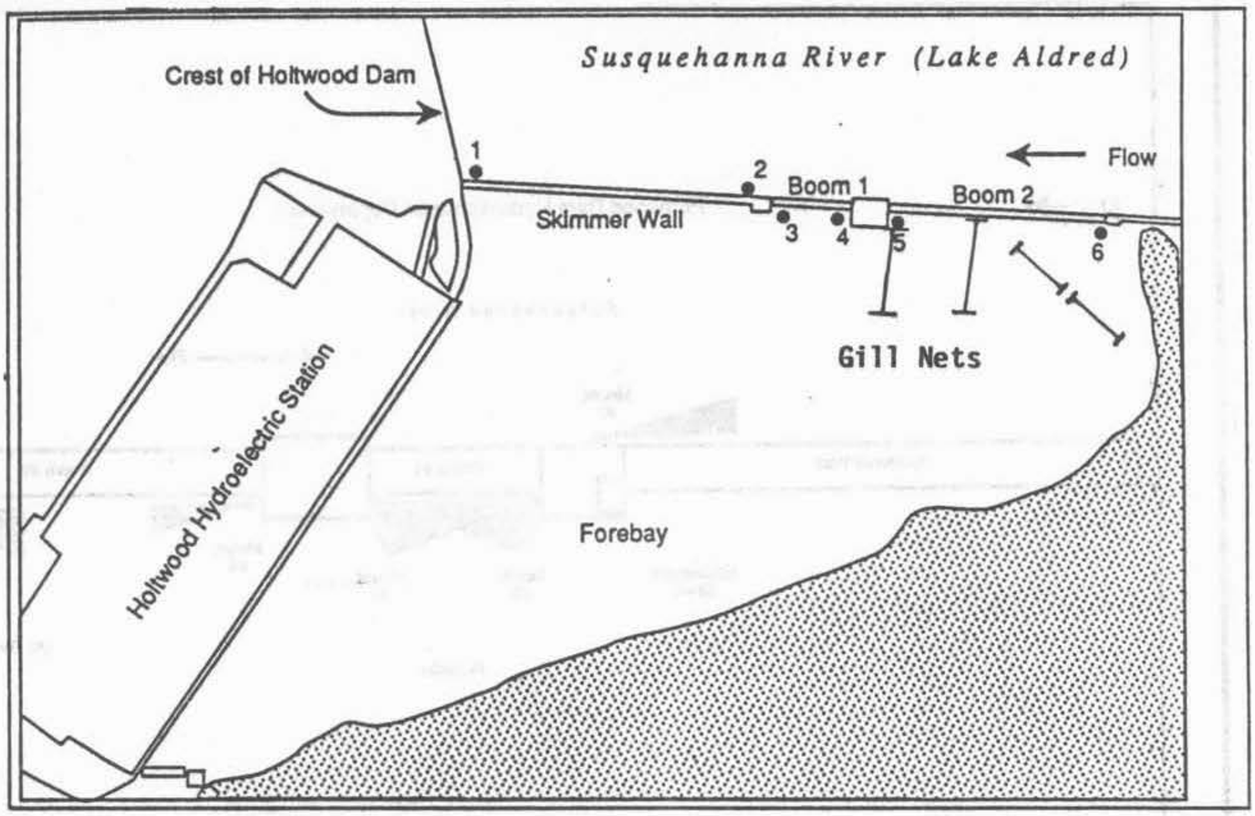


FIGURE 1
LOCATION OF THE HOLTWOOD PROJECT

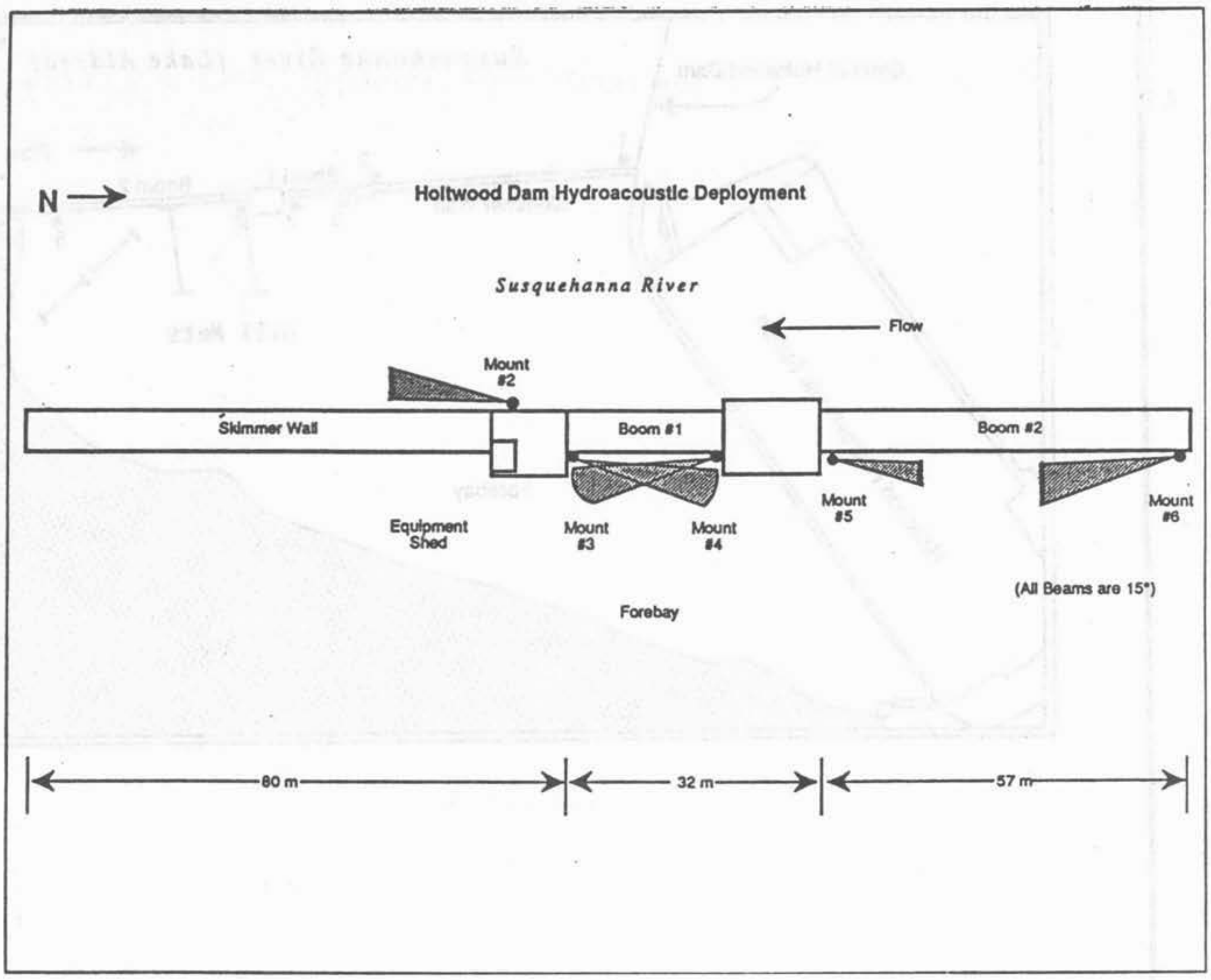


ACRES

PLAN VIEW OF THE STUDY AREA AT THE HOLTWOOD HYDROELECTRIC PROJECT WITH TRANSDUCER MOUNT LOCATIONS SHOWN ON SKIMMER WALL AND FLOATING BOOMS AND GILL NET LOCATIONS

ACRES INTERNATIONAL CORPORATION

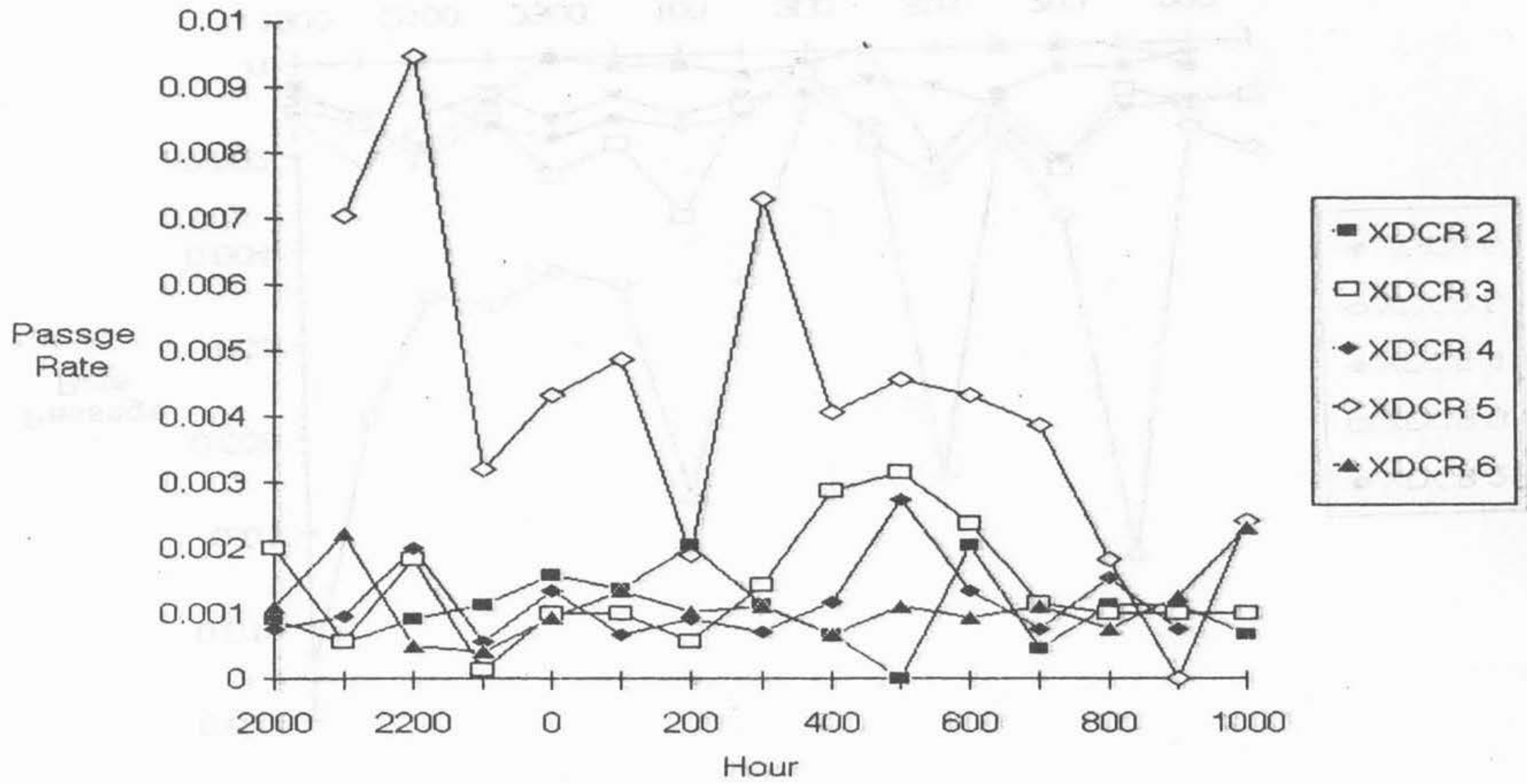
FIGURE 2



DETAILED TRANSDUCER LOCATIONS ON SKIMMER WALL AND FLOATING BOOMS AT HOLTWOOD PROJECT WITH APPROXIMATE AREA SAMPLED

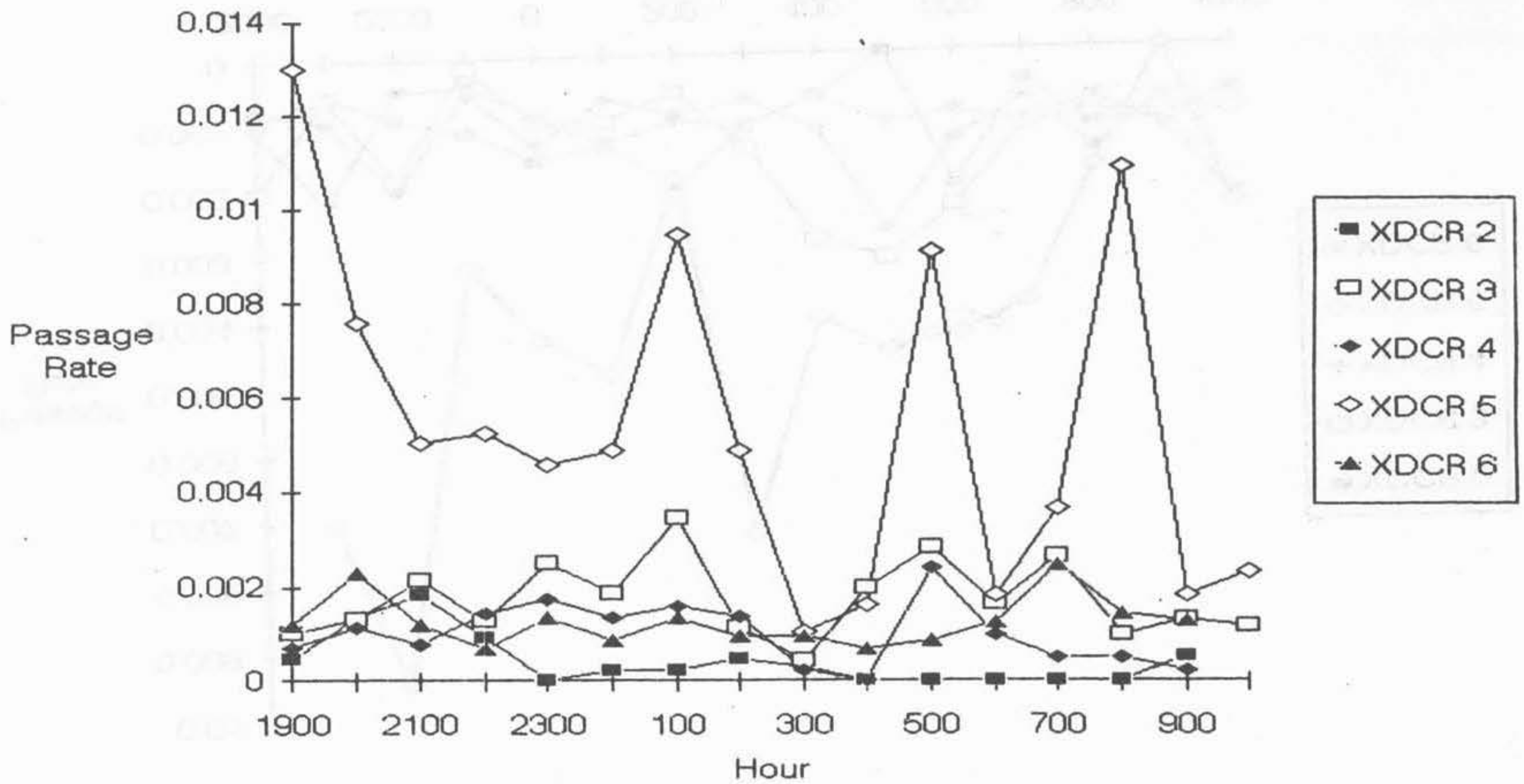
ACRES INTERNATIONAL CORPORATION

FIGURE 3



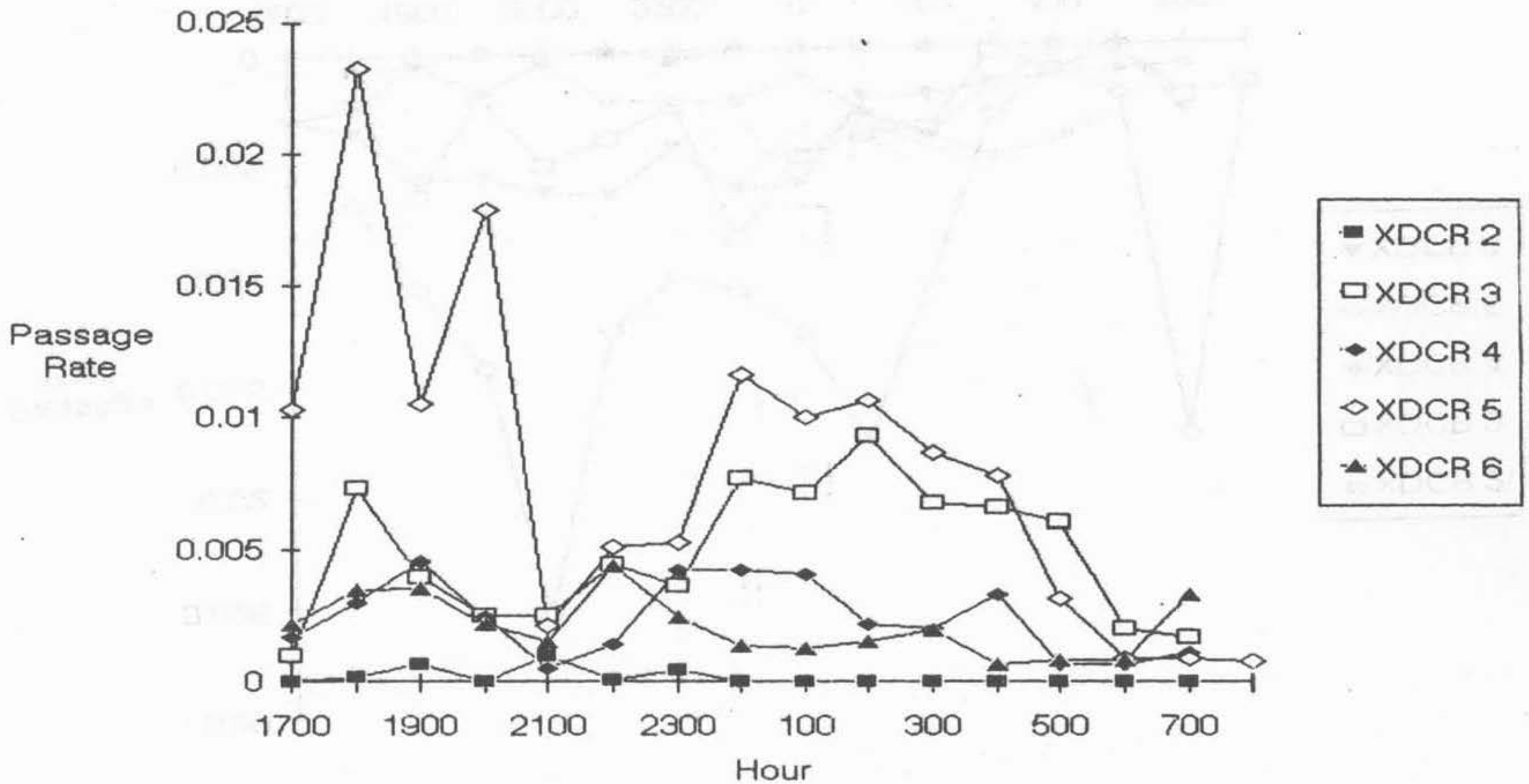
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 24, 1989

FIGURE 4



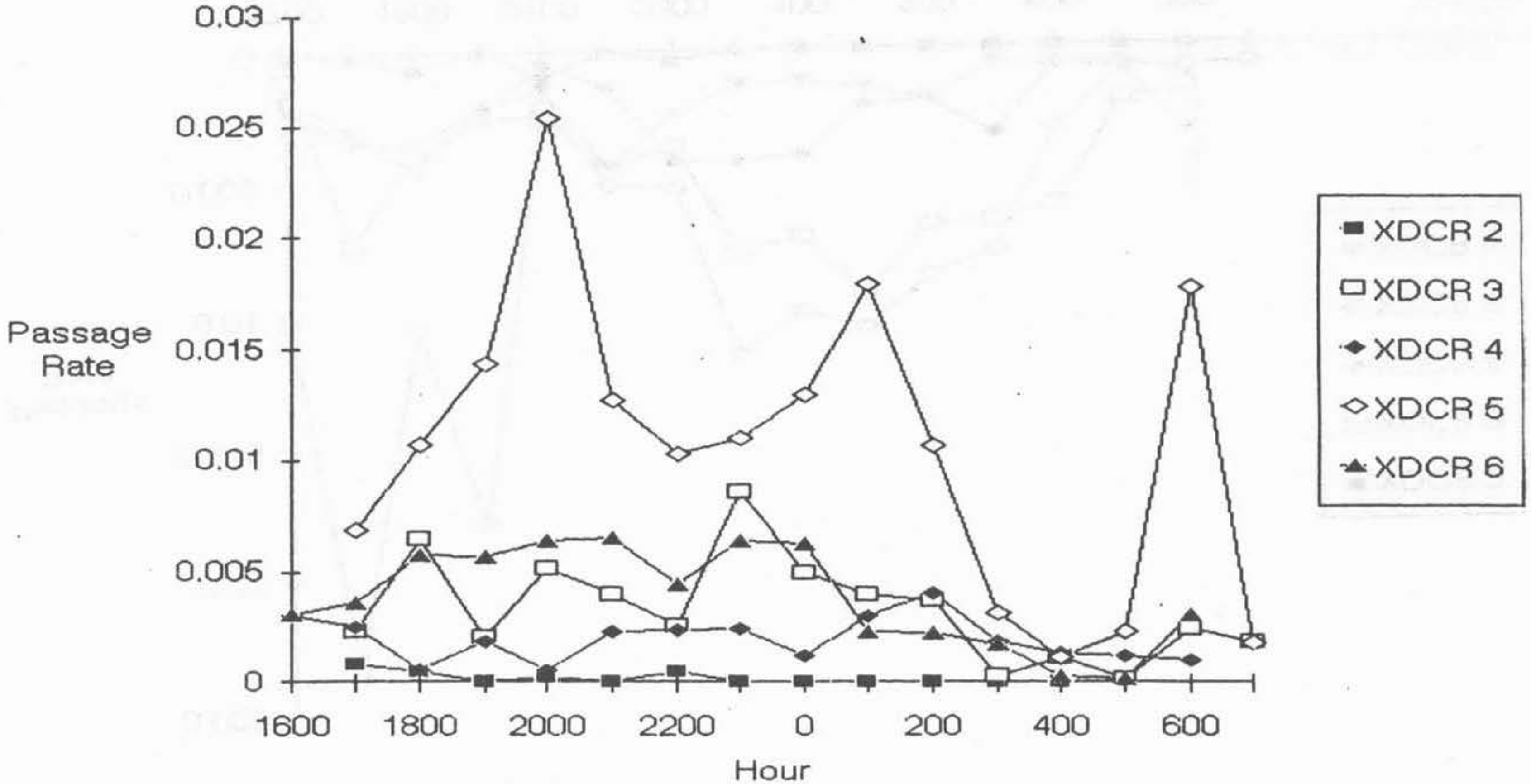
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 25, 1989

FIGURE 5



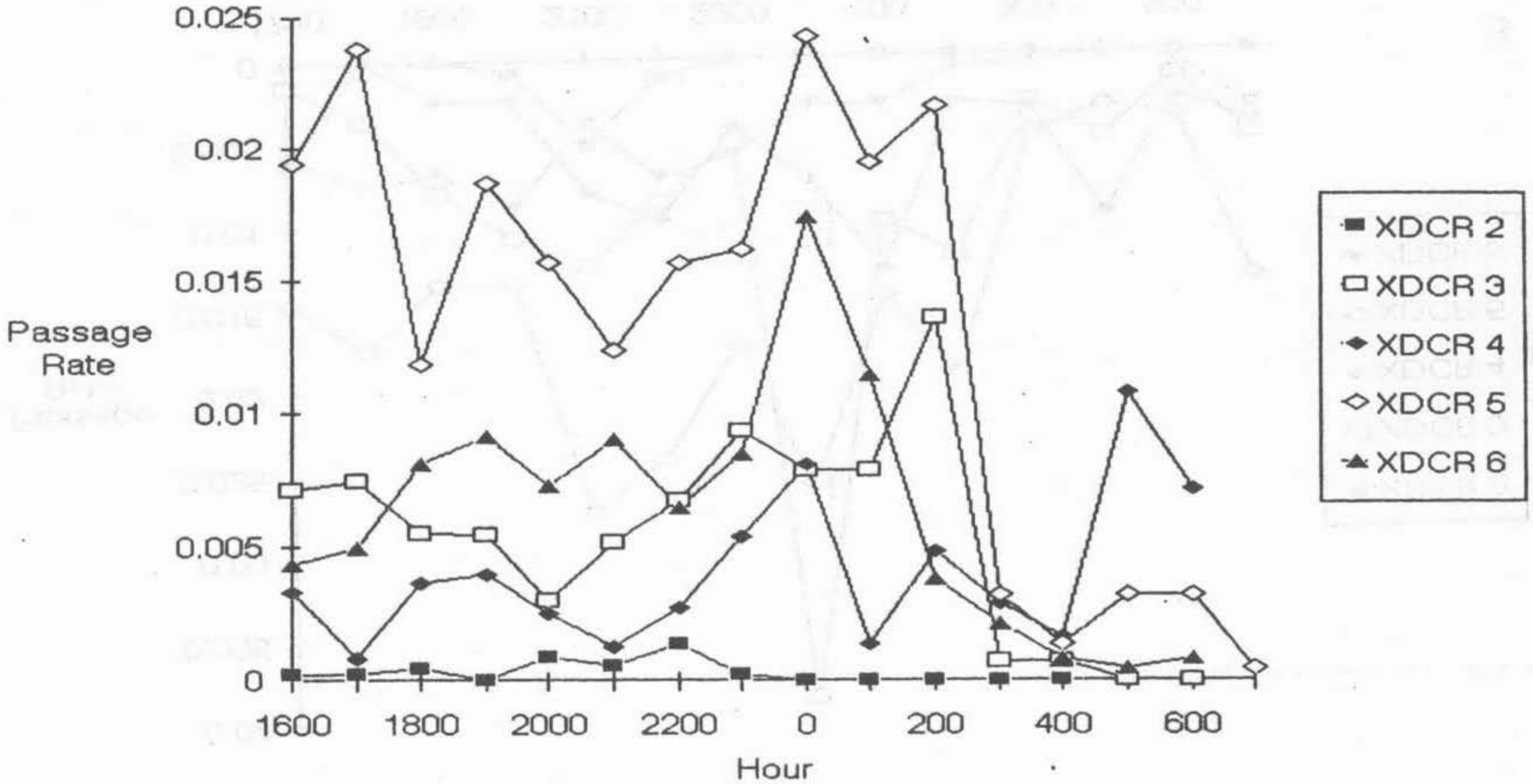
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 26, 1989

FIGURE 6



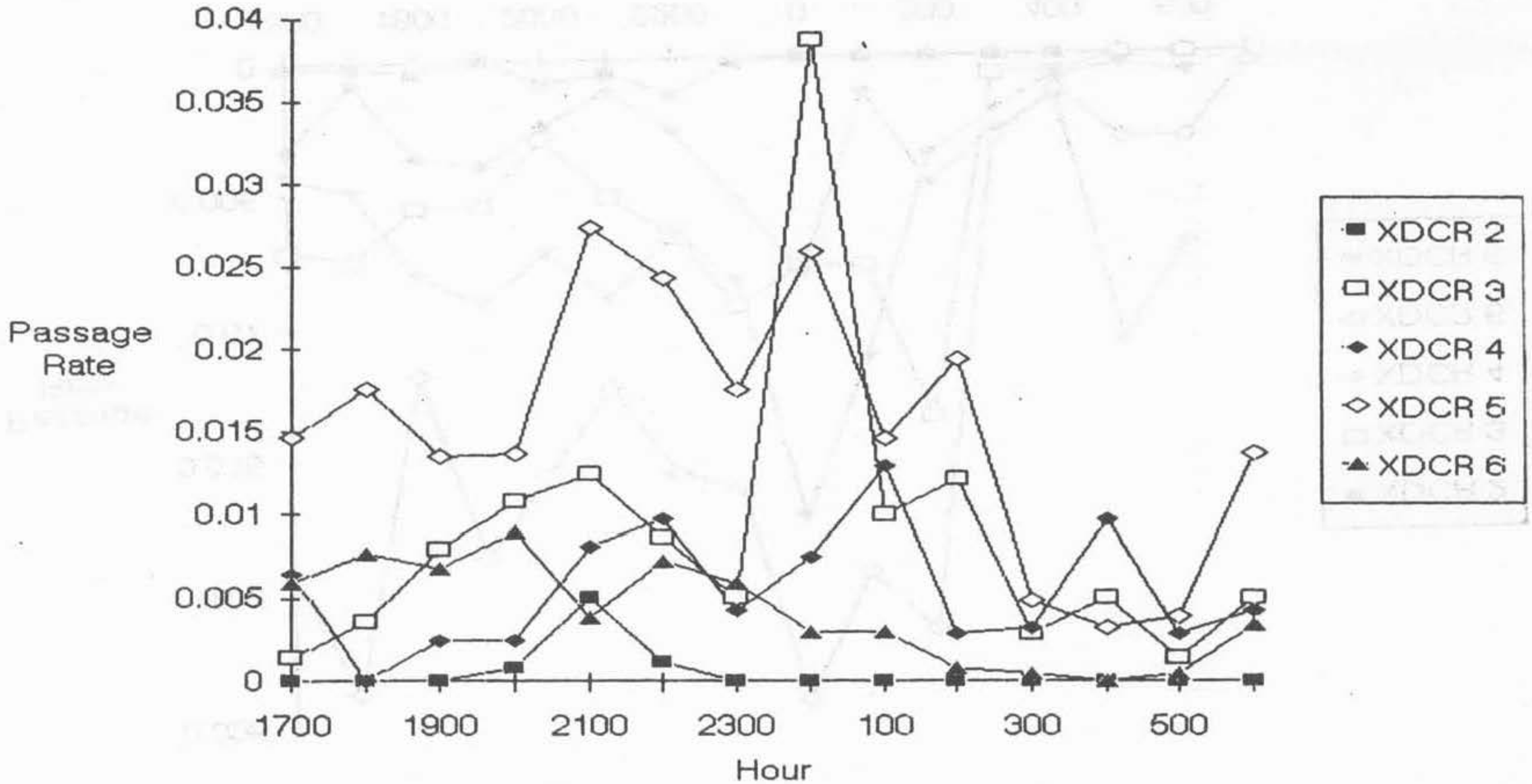
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 27, 1989

FIGURE 7



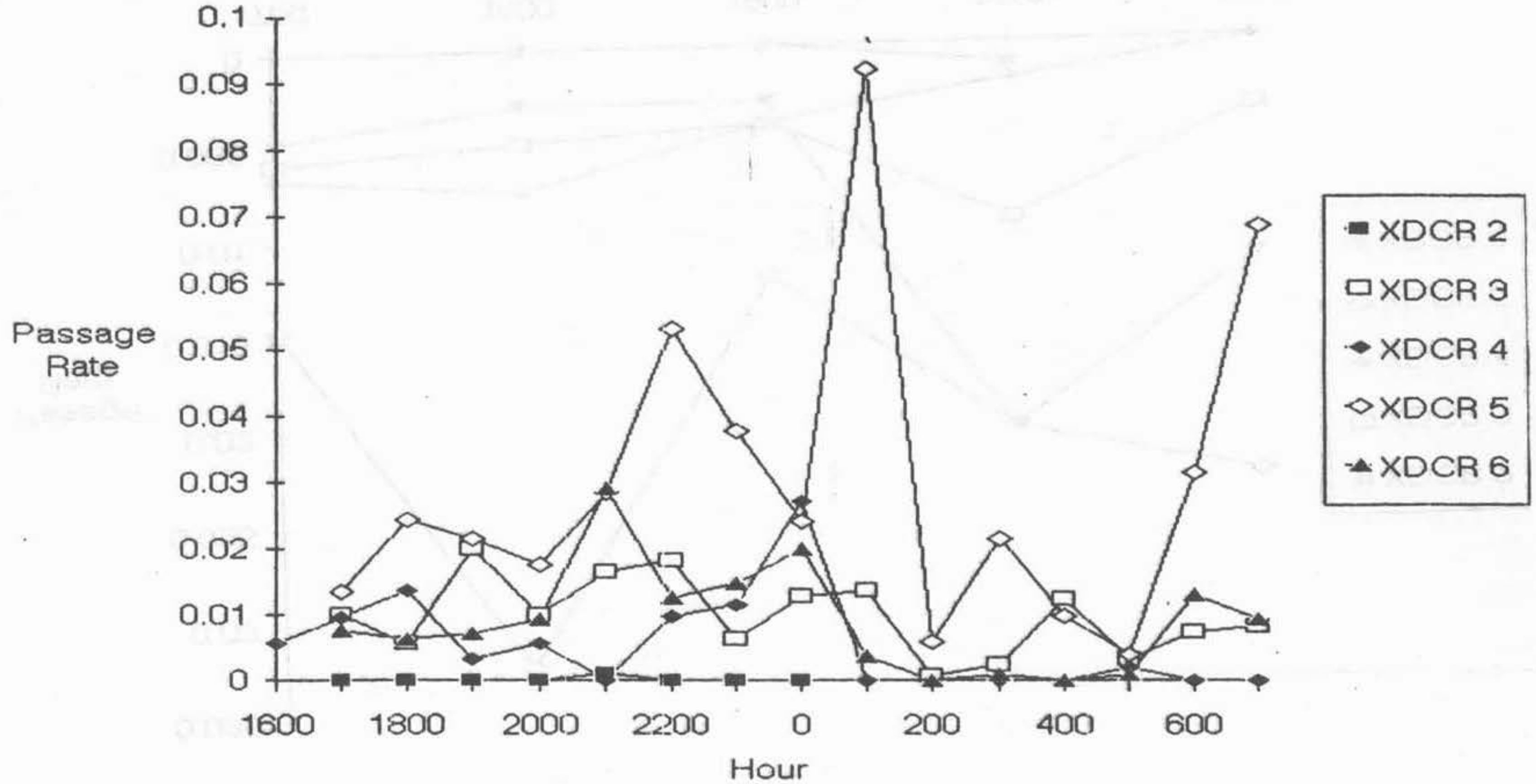
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 28, 1989

FIGURE 8



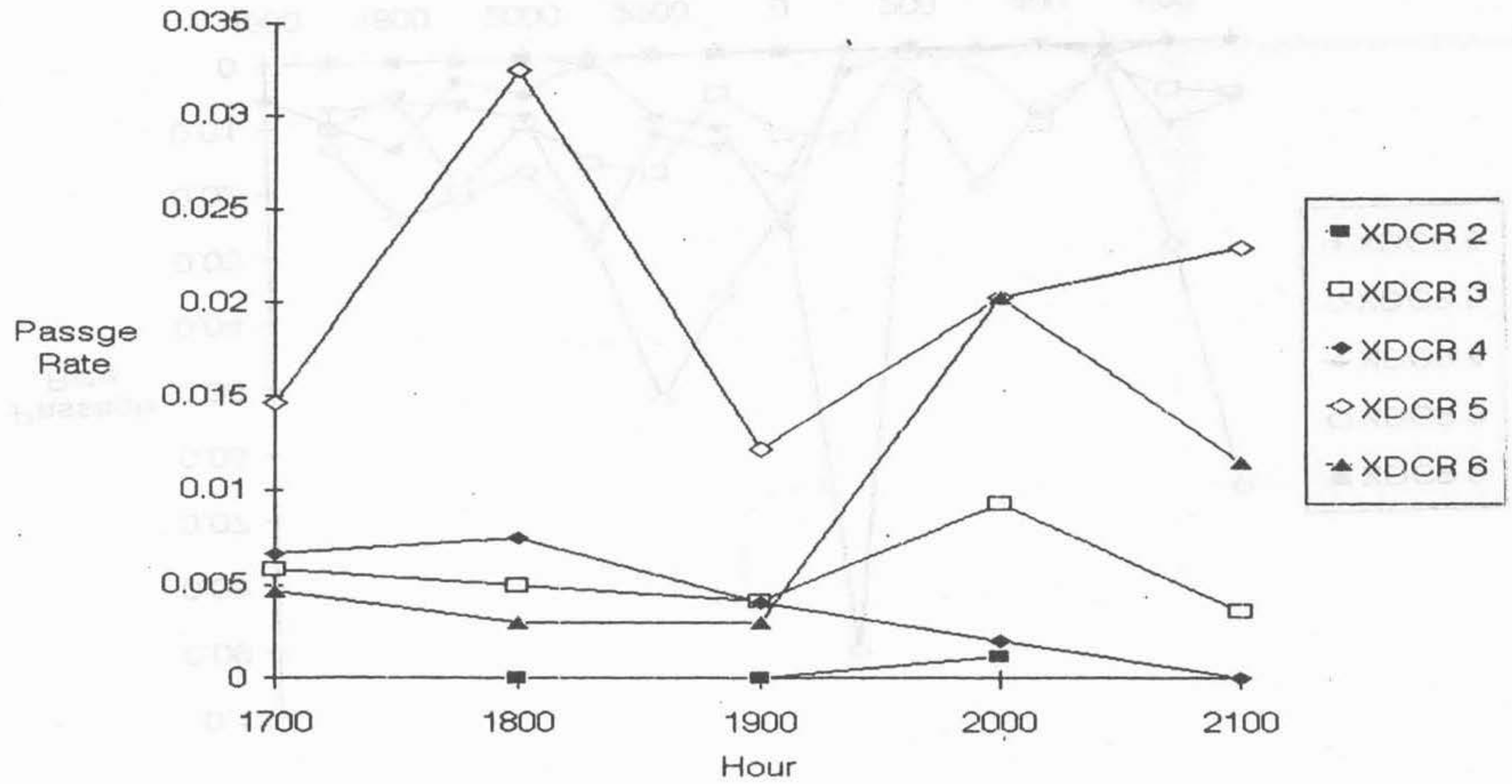
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 29, 1989

FIGURE 9



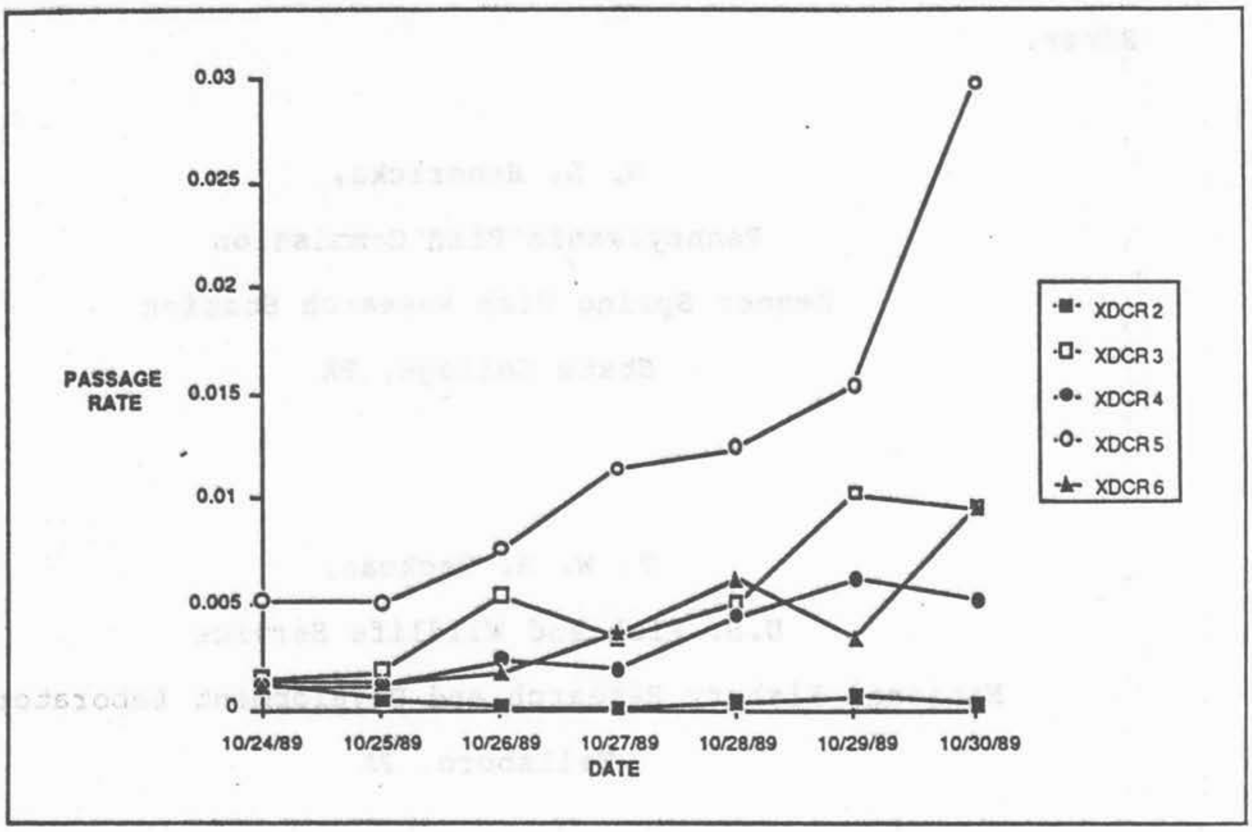
HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 30, 1989

FIGURE 10



HOURLY PASSAGE RATES AT HOLTWOOD PROJECT, OCTOBER 31, 1989

FIGURE 11



ACRES

RATE OF PASSAGE OF FISH THROUGH ESONIFIED AREAS AT HOLTWOOD HYDROELECTRIC PROJECT. (RATE EQUALS FISH PER MINUTE PER CUBIC METER.)

ACRES INTERNATIONAL CORPORATION

FIGURE 12

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

M. L. Hendricks,

Pennsylvania Fish Commission

Benner Spring Fish Research Station

State College, PA

T. W. H. Backman,

U.S. Fish and Wildlife Service

National Fishery Research and Development Laboratory

Wellsboro, PA

and D. L. Torsello,

Pennsylvania Fish Commission

Benner Spring Fish Research Station

State College, PA

Introduction

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

In order to evaluate and improve the program it is necessary to know the relative contribution of these programs to the overall restoration effort. Toward that end, the Pennsylvania Fish Commission developed a physiological bone tag which could be applied to developing fry prior to release (Wiggins et al., 1985; Hendricks et al., 1986; Hendricks et al., 1987). The tag is produced by immersion in tetracycline antibiotics to mark the otoliths of hatchery-reared fry. Analysis of otoliths of outmigrating juveniles allows discrimination of "wild" vs hatchery reared fish. The first successful application of tetracycline tagging at Van Dyke was conducted in 1984. Tagging on a production basis began in 1985 but was only marginally successful. In 1986, 97.8% tag retention was achieved and analysis of outmigrants indicated that 83% of the upstream production (above Conowingo Dam) was of hatchery origin vs 17% wild (Young, 1987). Similar data has been collected in subsequent years. The contribution to the overall adult population below Conowingo of hatchery-reared and wild fish resulting from restoration efforts is more complicated. The adult population of shad below Conowingo Dam includes: 1) Wild upper bay spawning stocks which are a remnant of the formerly abundant Susquehanna River stock; 2) "wild" fish of upstream origin which are progeny of adults from out-of-basin or trap and transfer efforts, 3) hatchery-reared fish originating from stockings in the Juniata River and 4) hatchery-reared fish originating from stockings below Conowingo Dam. The latter group are fish which received a "double" tetracycline tag and were first planted below Conowingo Dam in 1986.

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

In spring 1987 it was observed that otoliths of "wild" Susquehanna River juvenile American shad (as determined by the absence of an OTC tag) appeared to have different microstructural characteristics than hatchery-reared shad. Specifically, the increments formed during the first 10-15 days appeared to be wider and more distinct in wild juveniles than in hatchery-reared fish. In addition, hatchery-reared fish exhibited an increase in increment width and definition somewhere around increment 20-25, possibly as a result of increased growth rate after stocking. In this study we developed a method to distinguish between wild and hatchery-reared American shad based solely on otolith microstructure. This report represents work accomplished during the first two years of the study. Several of the tasks have not yet been completed. A full report will be prepared for submission with the 1990 reports.

Literature Review

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

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

(Dunkelberger et al., 1980). The discontinuous zone is apparently formed around sunrise due to reduction in the deposition of calcium (Mugiya et al., 1981).

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

Date of formation of the first increment is also of interest to the present study. Neilson and Geen (1982) found that the first increment in chinook salmon was formed before hatching, but in anchovies the first increment was formed at the time of first feeding (Brothers et al., 1976).

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

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

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

Checks or discontinuities can also occur in otoliths. Non-periodic check formation is usually associated with stress or sexual maturity (Pannella 1980; Campana 1983b). Hatch checks have been documented in sockeye (Marshall and Parker, 1982) and chinook (Neilson and Geen, 1982) salmon and represent physiologically stressful events (Campana and Neilson, 1985). Periodic check formation has also been documented and linked to the lunar cycle (Pannella, 1980; Campana, 1984a).

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

The relationship between fish growth and otolith increment width has been addressed by many researchers. In summary, otolith growth may represent a "running average" of fish growth inasmuch as otoliths continue to grow during periods of starvation when linear fish growth has stopped (Brothers, 1981; Campana 1983a).

Otoliths have also been used in taxonomic studies. McKern et al. (1974) used otolith nucleus diameter, otolith growth, and changes in otolith density during freshwater growth to separate summer from winter steelhead or hatchery from wild steelhead.

Rybock et al. (1975) used otolith nuclear size to distinguish between juvenile steelhead and rainbow trout. West (1983) found significant differences among linear regressions of (ln) fork length versus (ln) total otolith length between various sockeye salmon stocks. Campana and Neilson (1985) suggest that the measurement of individual increment widths would have exhibited the same differences. Uchiyama and Struhsaker (1981) used otolith microstructure to conclude that skipjack tuna from different areas grow at different rates. A number of authors have noted that otoliths from wild fish have more distinct increments than laboratory-reared fish (Campana, 1983a; Laroche et al., 1982; Radtke and Dean, 1982). J. Casselman (pers. comm.) routinely uses otolith microstructure to differentiate between hatchery-reared and wild walleye in Ontario. Hatchery walleye are reared in ponds, moved to raceways for a short time and then stocked into natural waters. Otolith increment width in these fish typically show fast growth initially, followed by a gradual reduction in growth as the natural forage in the pond is consumed. A "check" is formed corresponding to pond harvest and handling, followed by resumption of growth in the wild.

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

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

Van Dyke is equipped with a furnace and heat exchanger to maintain water temperatures conducive to growth. The furnace maintains water temperatures at or above 64°F except during extreme cold when the furnace is over-taxed and temperature may drop to 58°F. Breakdowns and power failures can result in even lower temperatures. Typically, during April (Virginia River egg deliveries) when the thermostat is calling for heat, temperatures fluctuate 4°F with 3 to 4 hour periodicity. During May (Delaware and Hudson River egg deliveries) daytime water temperatures reach 64°F and these 3-4 hour cycles occur only at night and on cool days. During June, (Columbia River egg deliveries) the furnace is no longer needed and diel temperature fluctuations occur.

When temperatures approach 72-75°F, spring water is mixed with warming pond water to maintain temperatures at approximately 70°F. Diel fluctuations continue due to solar heating and nighttime cooling of the warming pond. A new furnace and heat exchanger are scheduled to be installed prior to the 1990 rearing year which could produce minor alterations in the above scenario.

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

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

Test 1. <u>Validation of daily increment formation for American shad reared at the Van Dyke Research Station.</u>

Tetracycline tags, administered by 6 hour immersion in 200 ppm TC, were used to mark increments 5, 12 and 19. The daily ring hypothesis was validated by counting increments between tetracycline tags and comparing the results to the known number of days between administration of the tags. The inherent assumption is that the tetracycline is laid down only in the increment formed on the day of tagging. To test this assumption we examined tags at 450x with a Reichert Microstar IV microscope under UV light. Micrometer hairlines were used to mark the width of the tetracycline tag. Under white light the hairlines were then compared to the discontinuous zones on either side of the incremental zone containing the tetracycline tag. Ten specimens were examined for the day 5 tag, ten for the day 12 tag and ten for the day 19 tag. In all 30 cases the visible flourophore was confined to a single incremental zone, thus satisfying the assumption that the tetracycline is laid down in a single increment.

Validation of the daily ring hypothesis was accomplished by identifying two tags under UV light and setting micrometer hairlines adjacent to each. A white light was then switched on and the number of increments between the hairlines counted and compared to the expected number. The experiment was repeated for groups of shad from Virginia River egg sources reared under the three different lighting regimes present at Van Dyke (Table 1). The number of increments counted was identical to the number expected under the assumption of daily increment formation in 226 of 249 (91%) of the samples (Table 1). Mean counts were identical to those expected in

five of the six samples from the old rearing room and outdoor areas. The sixth count (old rearing room, number of increments to day 5 tag) was within 0.04 of the expected count. The largest differences between mean counts and those expected under the daily increment hypothesis were for the new rearing room which was lighted by 24-hour fluorescent lights without skylights. Despite the lack of a natural photoperiod mean increment counts were within 0.26 increments of the expected count. Adding across the row (Table 1) for the new rearing room, nineteen day-old fry exhibited a mean of 19.1 increments. Thus, there is no apparent deviation from daily increment formation between the three rearing areas at Van Dyke.

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

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

American shad larvae from three different egg-source rivers were collected immediately after hatch, at sunrise the next day, and at sunrise on day 7. Otoliths were extracted, mounted in immersion oil, and viewed without grinding under 450x. Newly hatched larvae and larvae collected at sunrise the next day exhibited no distinct increments, although faint and diffuse increments were usually present. Otoliths from 7-day-old larvae exhibited increments, but they were more difficult to distinguish than in older specimens which had been mounted in permount and ground.

As a result, we relied on the experiments in Test 1 (Table 1 and 2) to determine date of first otolith increment formation. Under UV light we adjusted a micrometer hairline on a day 5 tetracycline tag. We then switched on a white light and counted incremental zones starting with the tagged incremental zone and ending with the first incremental zone after the first distinct discontinuous zone. The number of increments counted was five for 132 of the 170 samples (78%). Mean number of incremental zones was within 0.26 increments of five for all samples.

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

Test 3. <u>Determine the relationship between fish length and otolith length and describe American shad growth at Van Dyke.</u>

It is generally accepted that otolith growth represents at least a "running average" record of fish growth (Campana and Nielson, 1985). To test this assumption for American shad reared at Van Dyke we regressed otolith radius against total length for shad fry from the Virginia and Columbia river egg sources. Shad were sampled at hatch and on days 6, 12, and 18 for Virginia river fry and at hatch and on days 6, 13 and 15 for Columbia

River fry. Each larva was measured to the nearest 0.1 mm using a dissecting microscope and a micrometer. Saggitae were then extracted and otolith radius measured using a micrometer at 450x. Otolith radius was plotted against total length (Figure 1). No differences were observed between the two egg sources so data were pooled. The resultant regression (y = 81.1 + 9.9x) exhibited a high correlation coefficient (r = .90) indicative of a strong relationship between total length and otolith radius. The slope of the regression was significantly different from 0 (t = 17.0, df = 7.7; Ott, 1977).

Growth of shad larvae reared at Van Dyke was plotted for two tanks of Virginia River fry and two tanks of Columbia River fry (Figure 2). These represent the environmental extremes encountered early in the season (Virginia River fry hatched in late April) and late in the season (Columbia River fry hatched in late June). Columbia River fry appear to be smaller at hatch and again at 15 and 18 days of age (Figure 2); however, the data was pooled for comparison to wild Connecticut River shad (Crecco et al., 1983). The resultant regression (y = 10.36 + .16x, r = .94) predicts a mean length of 12.6 mm at 14 days of age and 13.7 mm at 21 days of age. By comparison, Connecticut River shad ranged from 15.0 to 17.0 mm at 14 days of age and from 18.1 mm to 19.6 mm at 21 days of age for the period 1979 to 1982 (Crecco et al., 1983). It is clear that wild Connecticut River fish exhibit better growth than Van Dyke hatchery fish.

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

Test 4. <u>Determination of key characteristics to be used to discriminate between wild and hatchery-reared American shad.</u>

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

Optical Pattern Recognition System

The first approach to Test 4 involved use of the Biosonics Optical Pattern Recognition System (OPRS). To date, 40 otoliths from the 1987 collections, including 20 wild and 20 hatchery specimens have been analyzed.

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

Since luminance was measured only along the transect, blemishes in the otolith could result in errors in marking discontinuous zones. These errors were corrected by manually removing marks which did not correspond to discontinuous zones and adding marks which were missed by the automatic OPRS software. Mean increment width (distance between discontinuous zones) for the first 15 increments was then calculated. Mean increment width (2.9 um sd. 1.1 um) for hatchery-reared shad was significantly ($p = 0.0001$) smaller than that of wild shad (4.7 um sd. 1.8 um). Similar analysis will be conducted for shad from the 1986 and 1988 samples.

Visual Classifications

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

Three trials were conducted. Trial 1 included wild otolith specimens from 1987 and 1988 and hatchery otolith specimens from 1986, 1987 and 1988. Microstructure classification was 95% correct (Table 3). Ninety-six percent of the hatchery otoliths were classified correctly while 91% of the wild otolith classifications were correct. No wild otoliths were classified as hatchery.

Trial 2 included wild otolith specimens from 1986 and hatchery otolith specimens from 1986, 1987 and 1988. Since researchers were aware of the approximate number of wild specimens to be used in the trial the number of hatchery specimens was chosen randomly from 20 to 80. Specimens were given to researchers in groups of 15 so the researchers were not aware of the total number of specimens included in the trial. Microstructure classification was 71% correct for Trial 2 (Table 4). Ninety-six percent of the hatchery otoliths were classified correctly but only 56% of the wild fish were classified correctly. Thirty-nine percent of the wild fish were classified as hatchery fish.

As a result of the disappointing results of Trial 2 we photographed 69 wild and 75 hatchery otoliths to attempt to identify more subtle characteristics which would help us in classification.

Use of otolith photographs allowed faster and more direct comparisons of microstructural features as opposed to the time-consuming process of viewing otoliths under the microscope. Although no additional distinguishing characteristics were identified, the photographs helped as a study and practice aid.

A third trial was conducted (Trial 3) using the otoliths from Trial 2 plus additional hatchery specimens from 1986, 1987 and 1988. In addition, four wild otoliths from Trial 2 were eliminated from Trial 3. Two of these were eliminated inadvertently during the re-numbering process. Both of these had been classified correctly in Trial 2. Two others were eliminated during Trial 3 because the focus was ground out or severly cracked. One of these had been classified correctly in Trial 2 and the other incorrectly. Overall microstructure classification in Trial 3 was 90% correct. Ninety-eight percent of the hatchery otoliths were classified correctly and 76% of the wild otoliths were classified correctly. We attribute this success to additional experience provided by inspection of the photographs.

Test 5. Determination of the origin of adult American shad collected at the Conowingo Dam Fish Trap in 1989.

A representative sample of adult shad from the Conowingo Dam Fish Trap was obtained by sacrificing every 50th shad to enter the trap. These samples were augmented with otoliths from shad which died in transport. Otoliths were removed on site by consultants and stored in microcentrifuge tubes. Otoliths were delivered to Benner Spring Fish Research Station where they were mounted on microscope slides and ground to produce a thin sagittal section. Otoliths were then viewed under white light at 450x and classified wild or hatchery based on visual observation of otolith microstructure. As in Test 4, classification was made by two independent researchers, followed by an attempt to reach concensus if the researchers disagreed. After classification according to microstructure the otolith was examined under UV light for the presence of a tetracycline tag.

A total of 317 otoliths were examined (Table 5). Six otoliths were poorly ground or missing from the storage tubes. Researchers could not reach concensus on two otoliths (microstructure unknown). Of the remaining 309 otoliths, 49 (16%) exhibited wild microstructure and 260 (84%) exhibited hatchery microstructure. Of the 260 otoliths which exhibited hatchery microstructure, 16 exhibited a tag in the 5 to 8 day area, 40 exhibited a tag in the 15 to 18 day area, one exhibited a double tag, and two exhibited tags which were noted by one observer but not the other. The double-tagged individual could have been from a group of 812 thousand double-tagged fry released in Conowingo Reservoir in 1985 or from the many millions of double-tagged fry released below Conowingo Dam in 1986 and subsequent years.

Analysis of the tagging and microstructure data (Table 5) by age and sex has not yet begun. Statistical analysis of the known samples from the 1986 and 1988 year classes using the OPRS will also be undertaken. Results of these efforts will be reported next year. It should be noted that the findings in Test 5 of this report are tentative and may be altered by results of further study.

Summary

Hatchery-reared American shad lay down their first otolith increment, a prominent "hatch check," at hatch. Increments are formed on a daily basis thereafter. Otolith growth is proportional to linear growth in length, and Van Dyke hatchery-reared fry grow slower than do wild fry from the Connecticut River. Mean otolith increment width for 1987 year class hatchery shad was significantly smaller than that of wild shad for the first 15 increments. Using visual observation of otolith microstructural characteristics we correctly classified 95% of the otoliths from a group including 1986, 1987 and 1988 hatchery fish and 1987 and 1988 wild fish. Otoliths from wild 1986 year class fish were problematic. In an initial trial (Trial 2) including wild fish from 1986 and hatchery fish from all 3 years, we classified 71% of the otoliths correctly. After additional study and practice we correctly classified 90% (Trial 3) of the otoliths from a group including otoliths from Trial 2 plus additional hatchery otoliths. Eighty-four percent of a sub-sample of 309 otoliths from adult shad caught in the Conowingo Dam fish trap in 1989 exhibited hatchery microstructure. Fifty-seven (18% of the total) otoliths examined exhibited tetracycline tags.

Literature Cited

Brothers, E. B., C. P. Mathews, and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. Fish. Bull. U.S. 74: 1-8.

Brothers, E. B. 1981. What can otolith microstructure tell us about daily and subdaily events in the early life history of fish? Rapp. P. V. Reun. Cons. Int. Explor. Mer 178: 393-394.

Campana, S. E. 1983a. Feeding periodicity and the production of daily growth increments in the otoliths of steelhead trout (Salmo gairdneri) and starry flounder (Platichthys stellatus). Can. J. Zool. 61: 1591-1597.

Campana, S. E. 1983b. Calcium deposition and otolith check formation during periods of stress in coho salmon. Oncorhynchus kisutch. Comp. Biochem. Physiol. 75A: 215-220.

Campana, S. E. 1984a. Lunar cycles of otolith growth in the juvenile starry flounder. Platichthys stellatus. Mar. Biol. 80: 239-246.

Campana, S. E. 1984b. Interactive effects of age and environmental modifiers on the production of daily growth increments in the otoliths of plainfin midshipman. Porichthys notatus. Fish. Bull. U.S. 82(1): 165-177.

Campana, S. E., and J. D. Neilson. 1982. Daily growth increments in otoliths of starry founder (Platichthys stellatus) and the influence of some environmental variables in their production. Can. J. Fish. Aquat. Sci. 39: 937-942.

Campana, S. E., and J. D. Neilson. 1985. Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci. 42: 1014-1032.

Casselman, J. M. 1987. Determination of age and growth. Pages 209-242 In A. H. Weatherly and H. S. Gill. The biology of fish growth. Academic Press, London. 446 p.

Crecco, V., T. Savoy, and L. Gunn. 1983. Daily mortality rates of larval and juvenile American shad (Alosa sapidissima) in the Connecticut River with changes in year-class strength. Can. J. Fish. Aquat. Sci. 40:1719-1728.

Dunkelberger, D. G., J. M. Dean, and N. Watabe. 1980. The ultrastructure of the otolithic membrane and otolith in the juvenile mummichog, Fundulus hetroclitus. J. Morphol. 163: 367-377.

Geffen, A. J. 1982. Otolith ring deposition in relation to growth rate in herring (Clupea harengus) and turbot (Scophthalmus maximus) larvae. Mar. Biol. 71: 317-326.

Hendricks, M. L., T. R. Bender, and V. A. Mudrak. 1986. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, and V. A. Mudrak. 1987. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Ichii, T., and Y. Mugiya. 1983. Effects of dietary deficiency in calium on growth and calcium uptake from the aquatic environment in the goldfish, Carassius auratus. Comp. Biochem. Physiol. 74A: 259-262.

Laroche, J. L., S. L. Richardson, and A. A. Rosenberg. 1982. Age and growth of a pleuronectid, Parophrys vetulus during the pelagic larval period in Oregon coastal waters. Fish. Bull. U.S. 80: 93-104.

Marshall, S. L., and S. S. Parker. 1982. Pattern identific in the microstructure of sockeye salmon (Oncorhynchus ner otoliths. Can. J. Fish. Aquat. Sci. 39: 542-547.

McKern, J. L., H. F. Horton, and K. V. Koski. 1974. Development of steelhead trout (Salmo gairdneri) otoliths a their use for age analysis and for separating summer from winter races and wild from hatchery stocks. J. Fish. Res.Bc Can. 31(8): 1420-1426.

Mugiya, Y. N., Watabe, J. Yamada, J. J. Dean, D. G. Dunkelberger and M. Shimuzu. 1981. Diurnal rhythm in otolith formation in the goldfish, Carassius auratus. Comp. Biochm. Physiol. 68A: 659-662.

Neilson, J. D., and G. H. Geen. 1982. Otoliths of chinook salmon (Oncorhynchus tshawytscha): daily growth increments and factors influencing their production. Can. J. Fish. Aquat. Sci. 39: 1340-1347.

Neilson, J. D., and G. H. Geen. 1985. Effects of feeding regimes and diel temperature cycles on otolith increment formation in juvenile chinook salmon (Oncorhynchus tshawytscha). Fish. Bull. 83(1): 91-101.

tt, L. 1977. An introduction to statistical methods and data analysis. Duxberry Press, Belmont, CA. 730 p.

Pannella, G. 1971. Fish otoliths: daily growth layers and periodical patterns. Science (Wash. DC) 173: 1124-1127.

Pannella, G. 1980. Growth patterns in fish sagittae. Pages 519-560 In D. C. Rhoads and R. A. Lutz [eds.] Skeletal growth of aquatic organisms; biological records of environmental change. Plenum Press, New York, NY.

Radtke, R. L., and J. M. Dean. 1982. Increment formation in the otoliths of embryos, larvae and juvenile of the mummichog, Fundulus heteroclitus. Fish. Bull. U.S. 80: 201-215.

Rybock, J. T., and H. F. Horton, and J. L. Fessler. 1975. Use of otoliths to separate juvenile steelhead trout from juvenile rainbow trout. Fish. Bull. 73(3): 654-659.

Simkiss, K. 1974. Calcium metabolism of fish in relation to ageing. Pages 1-12 In T. B. Bagenal [ed.] Ageing of fish. Unwin Brths. Ltd., London.

Tanaka, K., Y. Mugiya and J. Yamada. 1981. Effects of photoperiod and feeding on daily growth patterns in otoliths of juvenile Tilapia nilotica. Fish. Ful. U.S.79: 459-466.

Taubert, B. D., and D. W. Coble. 1977. Daily rings in otoliths of three species of Lepomis and Tilapia mossambica. J. Fish. Res. Board Can. 34: 332-340.

Uchiyama, J. H., and P. Struhsaker. 1981. Age and growth skipjack tuna, Katsuwonus pelamis, and yellowtin tuna, Thunnus albacares, as indicated by daily growth incremen sagittae. Fish. Bull. U.S. 79: 151-162.

West, C. J. 1983. Selective mortality of juvenile sockeye salmon (Oncorhynchus nerka) in Babine Lake determined from body-otolith relationships. M.Sc. thesis, University of British Columbia, Vancouver, B.C. 63p.

Wiggins, T. A., T. R. Bender, D. D. Truesdale, K. R. Stark and V. A. Mudrak, 1984. American shad hatchery operations and cultural research. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1983. Susquehanna River Anadromous Fish Restoration Committee.

Wiggins, T. A., T. R. Bender, R. D. Lorson, and V. A. Mudrak, 1985. American shad cultural research. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1984. Susquehanna River Anadromous Fish Restoration Committee.

ild, A., and T. J. Foreman. 1980. The relationship between otolith increments and time for yellowfin and skipjack tuna marked with tetracycline. Inter-Am. Trop. Tuna Comm. 17: 509-541.

Young, L. M. 1987. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Figure 1. Regression of otolith diameter on total length of American Shad fry reared at Van Dyke, 1989. Y= - 81.1 + 9.9X r= .90

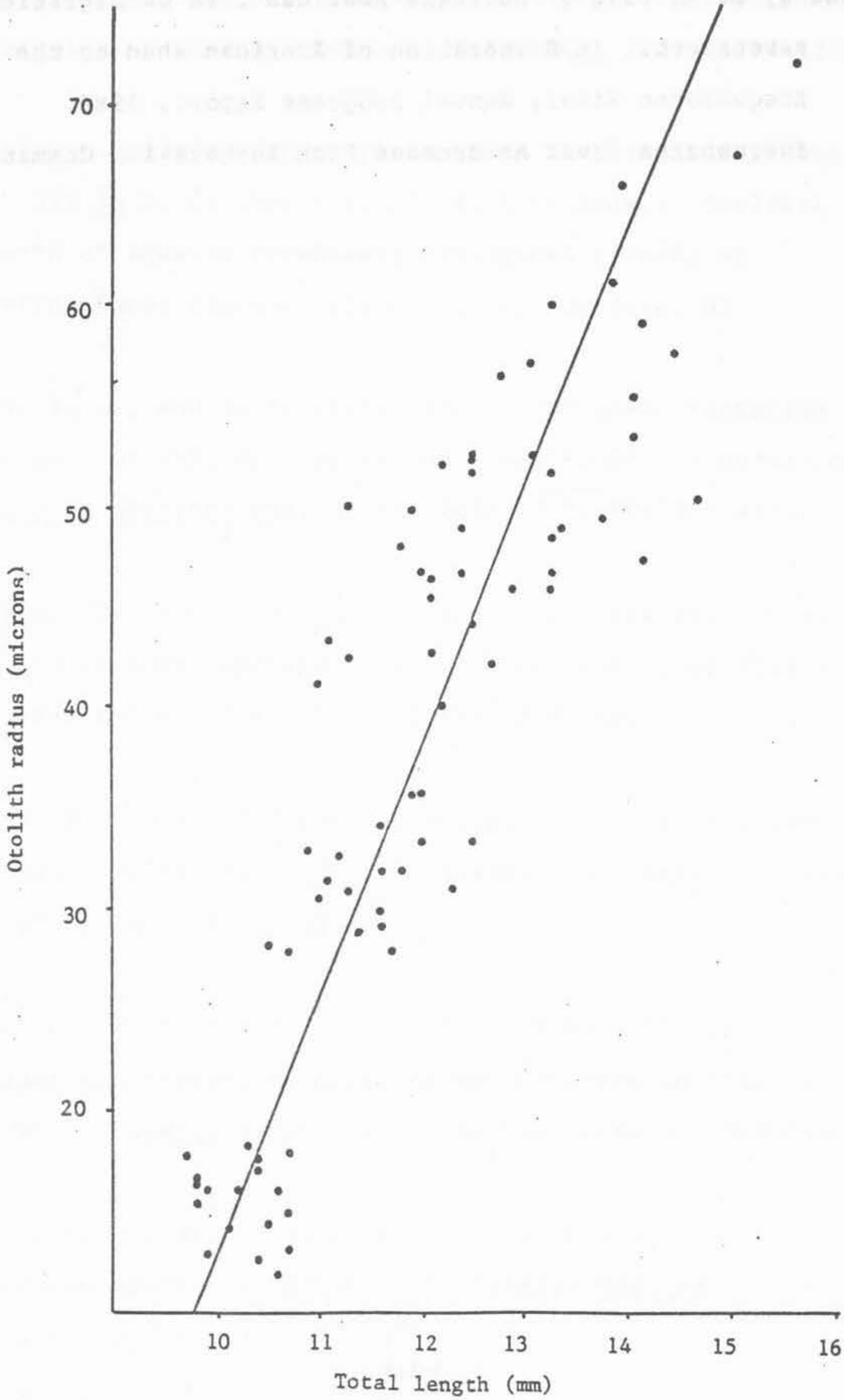


Figure 2. Growth of American shad fry reared at Van Dyke, 1989.
O Virginia River fry ☐ Columbia River fry
Y= 10.36 + .16X r= .94

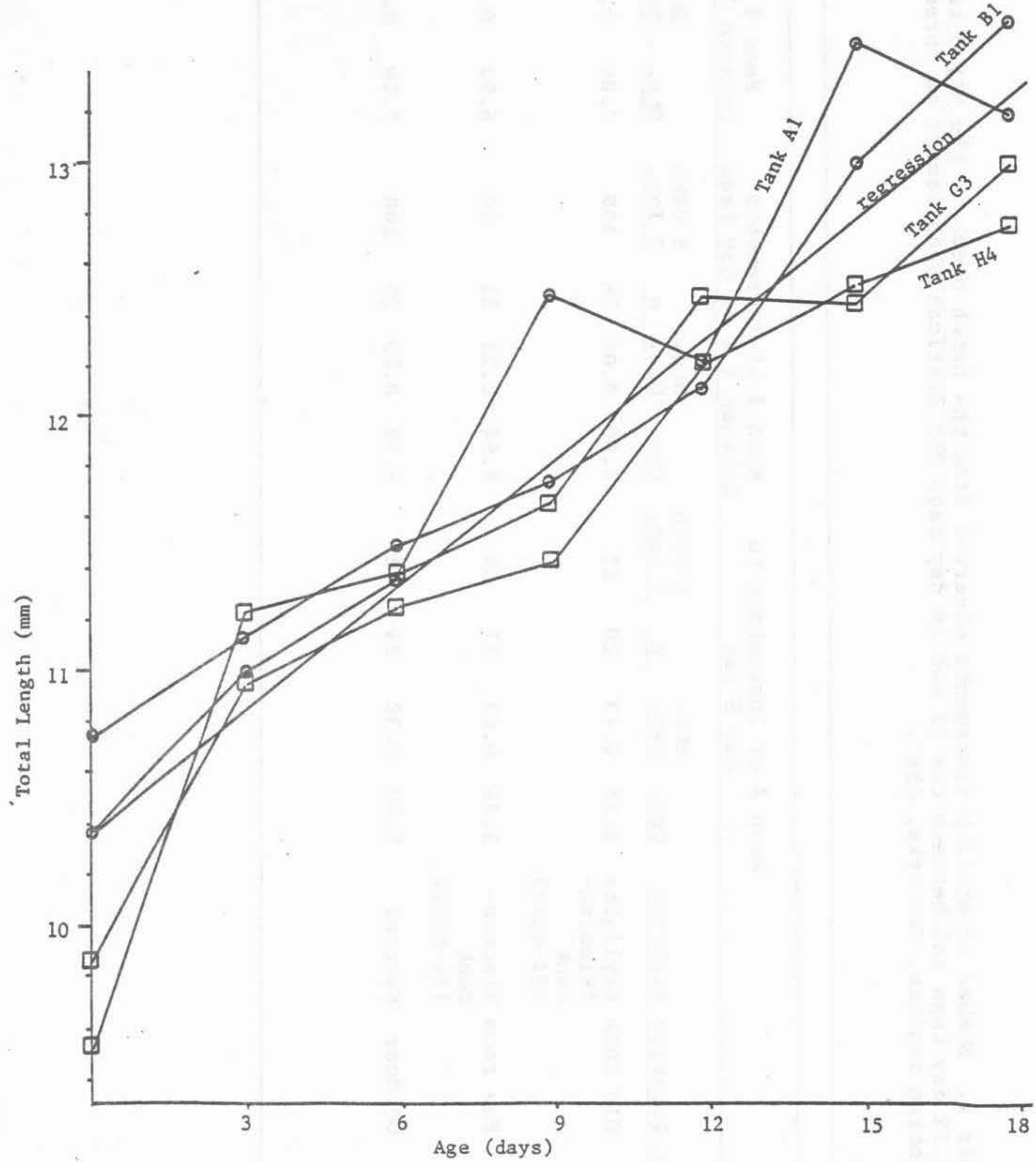


Table 1. Number of otolith increments observed from the hatch check to the day 5 tag, between the 5 and 12 day tags and between the 12 and 19 day tags for American shad reared in three different lighting regimes, Van Dyke, 1987.

			Mean # of Increments to day 5 tag				Mean # of Increments between 5 & 12 day tags				Mean # of Increments between 12 and 19 day tag			
Tank	Location	Lighting	Obs.	Std. Dev.	n	% with 5 Inc.	Obs.	Std. Dev.	n	% with 7 Inc.	Obs.	Std. Dev.	n	% with 7 inc.
B1	Old room	Skylights (Fluores-cent (24-hour)	4.96	0.43	28	82	7.00	0.00	28	100	7.00	0.00	27	100
F3	New room	Fluores-cent (24-hour)	5.26	0.63	31	65	6.94	0.25	31	94	6.90	0.09	31	90
J1	Outdoor	Natural	5.00	0.30	24	92	7.00	0.00	25	100	7.00	0.00	25	100

Table 2. Number of otolith increments observed from the hatch check to the day 5 tag, between the 5 and 9 day tags, between the 9 and 13 day tags, and between the 13 and 17 day tags for American shad reared from three egg source rivers, Van Dyke, 1988.

		Mean # of increments to day 5 tag				Mean # of increments between 5 and 9 day tags			
Pond	Egg source river	Obs.	Std. Dev.	n	% with 5 Inc.	Obs.	Std. Dev.	n	% with 4 Inc.
BSP2	Virginia	5.10	0.40	30	83.3	4.07	0.37	30	96.7
USCP1/ USCP2	Delaware	5.17	0.59	30	73.3	3.97	0.18	30	96.7
VD	Columbia	5.11	0.42	28	82.1	4.00	0.00	30	100

		Mean # of increments to 9-13 day tags				Mean # of increments between 13 and 17 day tags			
Pond	Egg source river	Obs.	Std. Dev.	n	% with 4 Inc.	Obs.	Std. Dev.	n	% with 4 Inc.
BSP2	Virginia	4.00	0.37	30	86.7	4.03	0.32	30	90.00
USCP1/ USCP2	Delaware	4.07	0.25	30	93.3	-	-	-	
VD	Columbia	-	-	-	-	-	-		

Table 3. Classification of American shad otoliths by two researchers based on microstructure during the first 20 days after hatch; Trial 1, 1989. Samples were assigned blind numbers and included hatchery (marked) fish from 1986, 1987, 1988 and wild (unmarked) fish from 1987 and 1988.

Known Origin	Consensus Microstructure Classification Hatchery	Wild	Disagreed	Total	Correct
Hatchery (Marked)	172	5	3	180	96%
Wild (Unmarked)	0	30	3	33	91%
				213	95%

Table 4. Classification of American shad otoliths by two researchers based on microstructure during the first 20 days after hatch; Trial 2, 1989. Samples were assigned blind numbers and included hatchery (marked) fish from 1986, 1987, 1988 and wild (unmarked) fish from 1986.

Known Origin	Consensus Microstructure Classification Hatchery	Wild	Disagreed	Total	Correct
Hatchery (Marked)	24	1	0	25	96%
Wild (Unmarked)	16	23	2	41	56%
				66	71%

Table 5. Classification of American shad otoliths by two researchers based on microstructure during the first 20 days after hatch; Trial 3, 1989. Samples included all but four wild (1986) otoliths from Trial 2 plus additional hatchery otoliths.

Known Origin	Consensus Microstructure Classification: Hatchery	Wild	Disagreed	Total	Correct
Hatchery (Marked)	61	1	0	62	98%
Wild (Unmarked)	9	28	0	37	76%
				99	90%

Table 6. Microstructure classification and tetracycline tagging of American shad otoliths collected at the Conowingo Dam Fish Trap, 1989.

		Hatchery Microstructure								
Collection Date	Wild Micro-structure	No Tag	5-8 Day Tag	15-18 Day Tag	Double Tag	Other Tag	Total Hatchery	Micro-structure Unknown	Otolith Missing or Unreadable	Total
4/09/89	1	–	–	–	–	–	–	–	–	1
4/19/89	–	1	–	–	–	–	1	–	–	1
4/20/89	–	–	–	–	–	–	–	–	1	1
4/21/89	–	2	–	–	–	–	2	–	–	2
4/22/89	–	4	–	–	–	–	4	–	–	4
4/23/89	–	2	–	–	–	–	2	–	–	2
4/24/89	–	5	–	–	–	–	5	–	–	5
4/25/89	1	3	1	–	–	–	4	–	–	5
4/26/89	2	2	–	–	–	–	2	–	–	4
4/27/89	1	4	3	1	–	–	8	–	–	9
4/28/89	–	7	1	1	–	–	9	–	–	9
4/29/89	2	5	2	1	–	–	8	–	–	10
4/30/89	2	3	1	–	–	–	4	–	–	6
5/01/89	1	6	–	2	–	1*	9	–	–	10
05/02/89	4	19	2	1	–	–	22	–	1	27
05/03/89	2	4	–	1	–	–	5	–	–	7
05/04/89	–	1	–	–	–	–	1	–	1	2
05/05/89	–	1	–	–	–	–	1	–	–	1
05/21/89	–	2	–	–	–	–	2	–	–	2
05/22/89	1	1	–	–	–	–	1	–	–	2
05/23/89	2	–	–	–	–	–	–	–	–	2
05/24/89	1	–	–	–	–	–	–	–	–	1
05/25/89	–	1	–	–	–	–	1	–	–	1
05/26/89	2	3	–	2	–	–	5	–	–	7
05/27/89	–	–	–	1	–	1*	2	–	–	2
05/28/89	–	1	–	1	–	–	2	–	–	2
05/29/89	2	4	–	1	–	–	5	1	–	8
5/30/89	–	4	1	–	–	–	5	–	–	5
5/31/89	–	4	1	1	–	– ~~6~~	– 6	–	–	6
6/01/89	–	1	1	1	–	– ~~3~~	– 3	–	1	4
6/02/89	2	9	–	1	–	–	10	–	–	12
6/03/89	–	17	–	3	–	–	20	–	–	20

Table 6 (continued).

Collection Date	Wild Microstructure	Hatchery Microstructure: No Tag	5-8 Day Tag	15-18 Day Tag	Double Tag	Other Tag	Total Hatchery	Microstructure Unknown	Otolith Missing or Unreadable	Total
6/04/89	4	15	2	9	-	-	26	1	-	31
6/05/89	6	46	1	12	-	-	59	-	-	65
6/06/89	1	4	-	-	-	-	4	-	1	6
6/07/89	2	2	-	-	-	-	2	-	-	4
6/08/89	1	-	-	-	-	-	-	-	-	1
6/09/89	1	-	-	-	-	-	-	-	-	1
6/10/89	1	-	-	-	-	-	-	-	-	1
6/11/89	-	1	-	-	-	-	1	-	-	1
6/12/89	-	2	-	1	-	-	3	-	-	3
6/13/89	5	15	-	-	1**	-	16	-	1	22
6/14/89	1	-	-	-	-	-	-	-	-	1
6/16/89	1	-	-	-	-	-	-	-	1	1
Total	49 (16%)	201 (65%)	16 (5%)	40 (12%)	1 (<1%)	2 (1%)	260 (84%)	2	6	317

* Researchers disagree on presence of 5-8 Tag.
**Tag at 5-8 days of age and 15-18 days of age.

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

Dale Weinrich, James Mowrer, Anthony Jarzynski, Mark Howell, Randy Hochberg; Fisheries Division, Maryland Department of Natural Resources

INTRODUCTION

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

METHODS AND MATERIALS

Collection procedures for adult American shad assessment in 1989 were nearly identical to those in 1988. The only difference was the elimination of the Romney Creek pound net site and the addition of a second pound net along the lower eastern shore of the Susquehanna Flats (Figure I). Hook and line sampling in the

Conowingo tailrace continued unchanged from 1988. Tagging procedures and data collection followed the methodology established in past years and is described in previous SRAFRC reports.

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

RESULTS

Pound net tagging effort in 1989 was initiated on 22 March and continued until 21 May while hook and line activity began on April 25 and ended 5 June. Of the 676 adult American shad captured, 559 (83%) were tagged and 62 (11%) subsequently recaptured (Table 1). Recapture data for the 1989 season is summarized as follows:

a. 56 fish recaptured by the Conowingo Fish Lift
   (does not include 7 double recaptures)
   4 fish recaptured by pound net
   1 fish recaptured by hook and line from Conowingo tailrace
   1 fish recaptured from the Delaware River

b. 46 fish recaptured were originally caught by hook & line

16 fish recaptured were originally caught by pound net

c. 47 fish recaptured in the same area as initially tagged

14 fish recaptured upstream of their initial tagging

d. shortest period at large: 2 days

longest period at large: 66 days

mean number days at large: 16.8

e. number of double recaptures: 9

Population estimates for adult American shad in the upper Chesapeake Bay for 1989 using the Petersen Index and Schaefer method were 75,329 and 79,973, respectively (Tables 2 and 3). Population estimates for those fish captured, marked and recaptured only from the Conowingo tailrace (angling and fish trap) were 42,516 Petersen and 43,040 Schaefer (Tables 4 and 5). The 1989 estimates were the highest recorded to date for both tailrace and upper Bay and represent a 55% increase over those for 1988 (Figures IV and V).

Effort, catch, and catch-per-unit-of-effort (CPUE) by gear type for adult American shad in the upper Bay during 1989 and comparison with previous years is presented in Table 6. Catch per angler hour has increased every year since 1984 and the 6.5 fish rate represents a 170% increase over 1984. The shad catch per pound net day for all three nets combined was also the highest recorded for any of the six years that this gear has been utilized to capture adult fish.

A total of 612 adult American shad (268 hook and line, 344 pound net) were examined for physical characteristics in 1989. Of the 393 males examined, 96% were ages III, IV, or V with age group IV predominating (Table 7). As in 1988, the pound net tended to capture a greater percentage of older males (age group V) while three year old males were more frequent in hook and line samples. Hook and line captured males tended to have a slightly larger incidence of repeat spawning than their pound net counterparts (Table 8). Nearly all of the 219 female shad examined were in age groups IV, V, and VI (Table 7). As with the males, capture of younger females (age group IV) was greater by hook and line while the pound net collected a higher percentage of older females (age group VI). Identical percentages of repeat spawning was noted for females captured by both gear types (Table 8).

Juvenile alosid sampling in the upper Chesapeake Bay during 1989 indicated increased numbers of young-of-the-year American shad. Table 9 presents results from haul seine and otter trawl sampling during 1989 broken down into catch, catch by station, and associated CPUE. Comparison of 1989 results with previous years indicates that the juvenile shad catch and CPUE for both gears was greater than for any previous year (Table 10). The DNR electrofisher was also used to sample for juvenile American shad in the upper Bay in 1989. Of the 97 juvenile shad collected by this gear, 58% were collected near the mouth of Swan Creek and at Carpenter Point. Table 11 and Figure III presents information concerning location, effort, and catch by this gear. Supplemental haul seine sampling was done by the department's juvenile striped bass survey. This effort collected 67 young-of-the-year American shad with a 100' x 4' x 1/4" haul seine. These fish were collected from Poplar Point (26) and Plum Point (14) on August 16 and from Plum Point (27) on September 13 (Figure II).

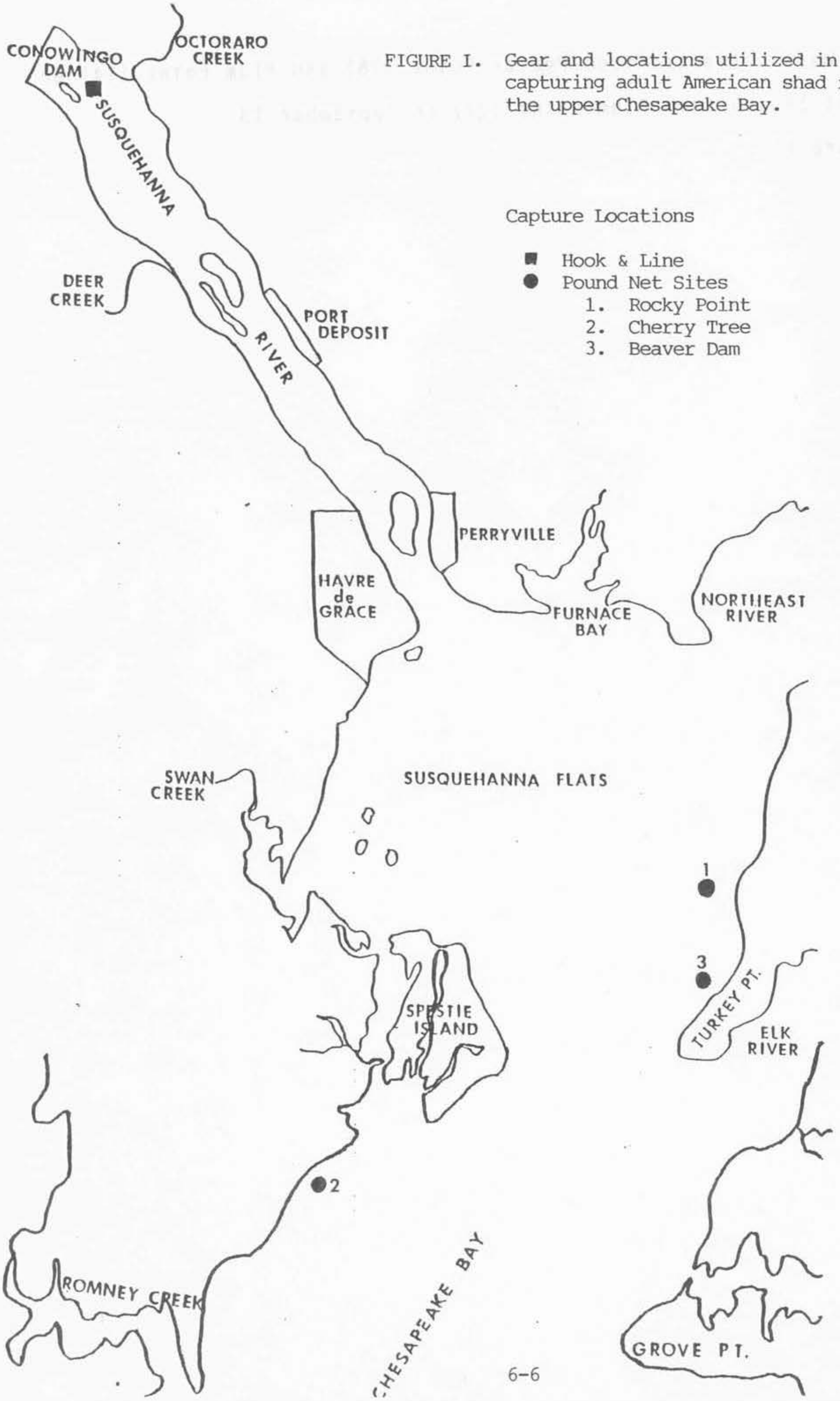
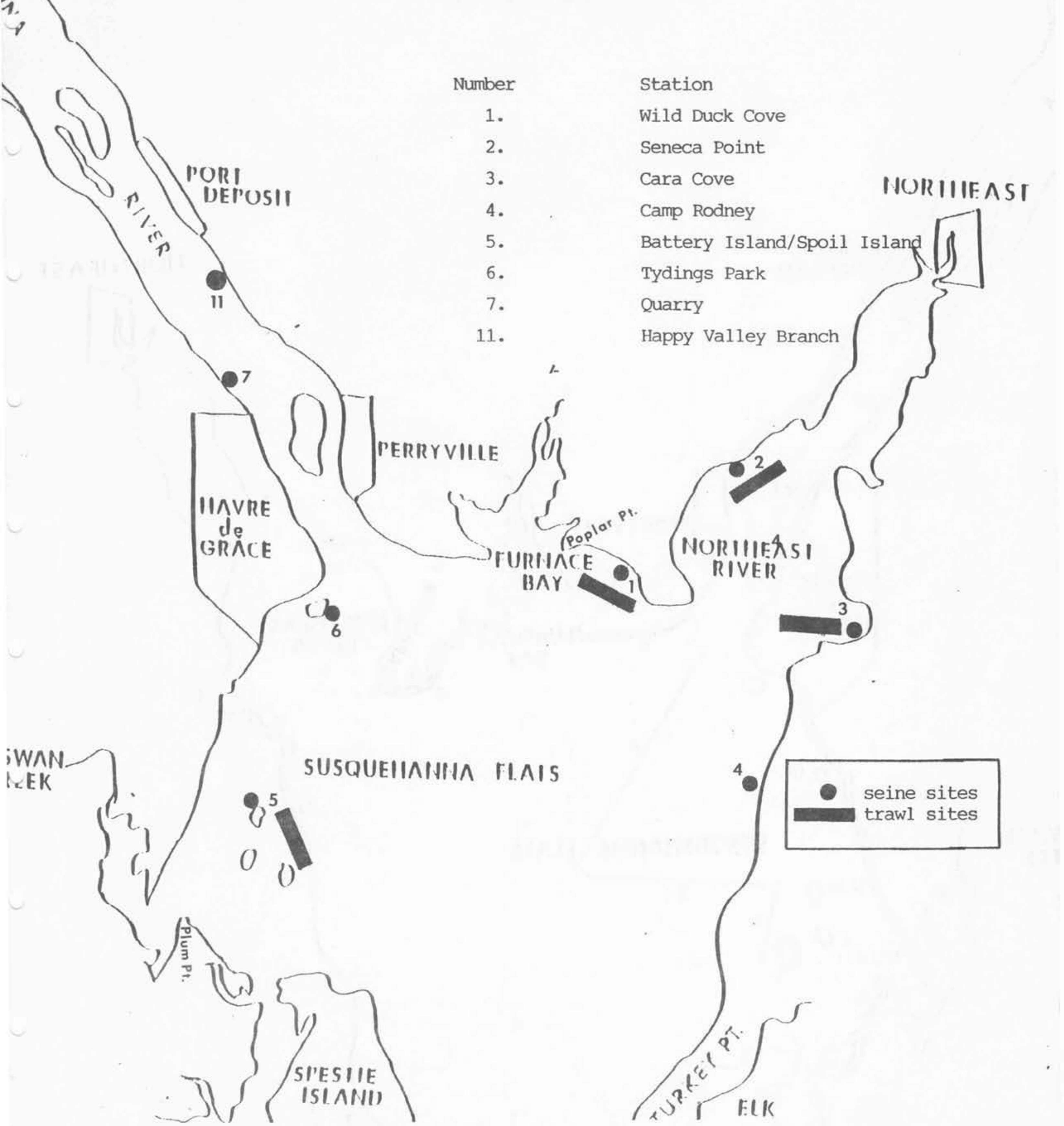


FIGURE I. Gear and locations utilized in capturing adult American shad from the upper Chesapeake Bay.

FIGURE II SEINE AND TRAWL* SITES SAMPLED DURING THE 1989 JUVENILE RECRUITMENT SURVEY.

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



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

FIGURE III. ELECTROFISHING SITES UTILIZED IN CAPTURING JUVENILE ALOSIDS DURING THE 1989 JUVENILE RECRUTIMENT SURVEY.
(Refer to Table 11)

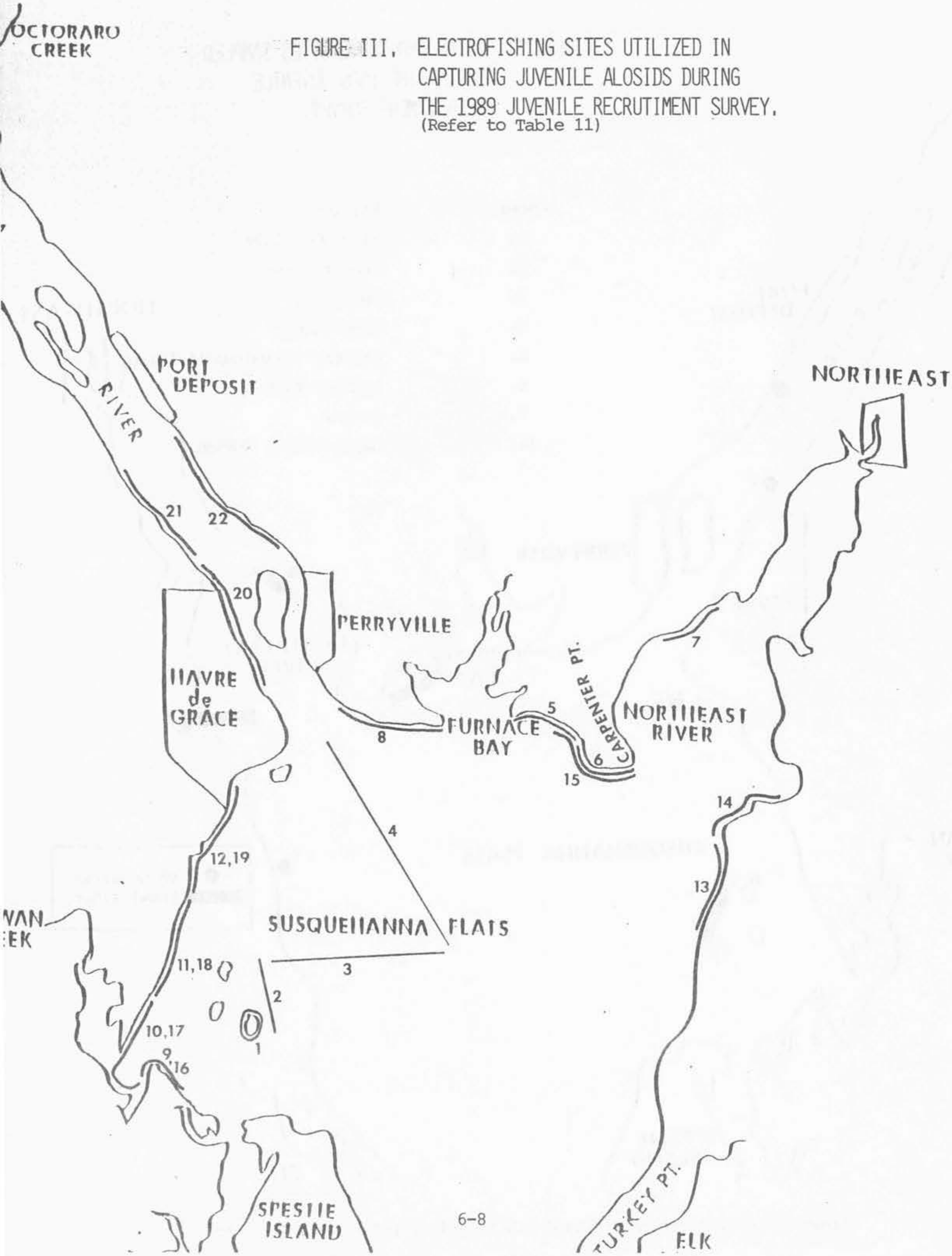
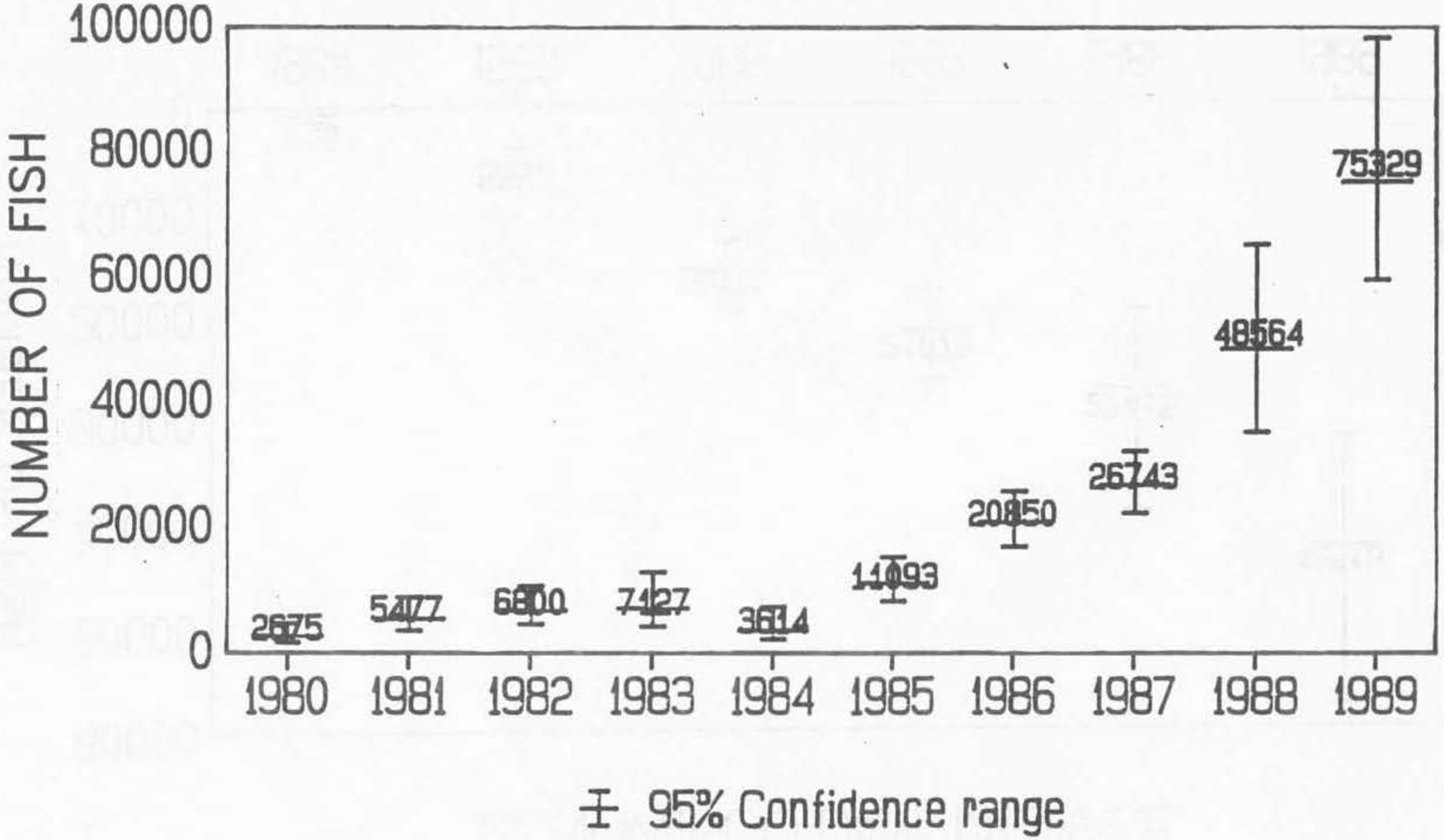


FIGURE IV. YEARLY COMPARISONS OF THE ADULT AMERICAN SHAD POPULATION ESTIMATES IN THE UPPER CHESAPEAKE BAY.



6-9

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

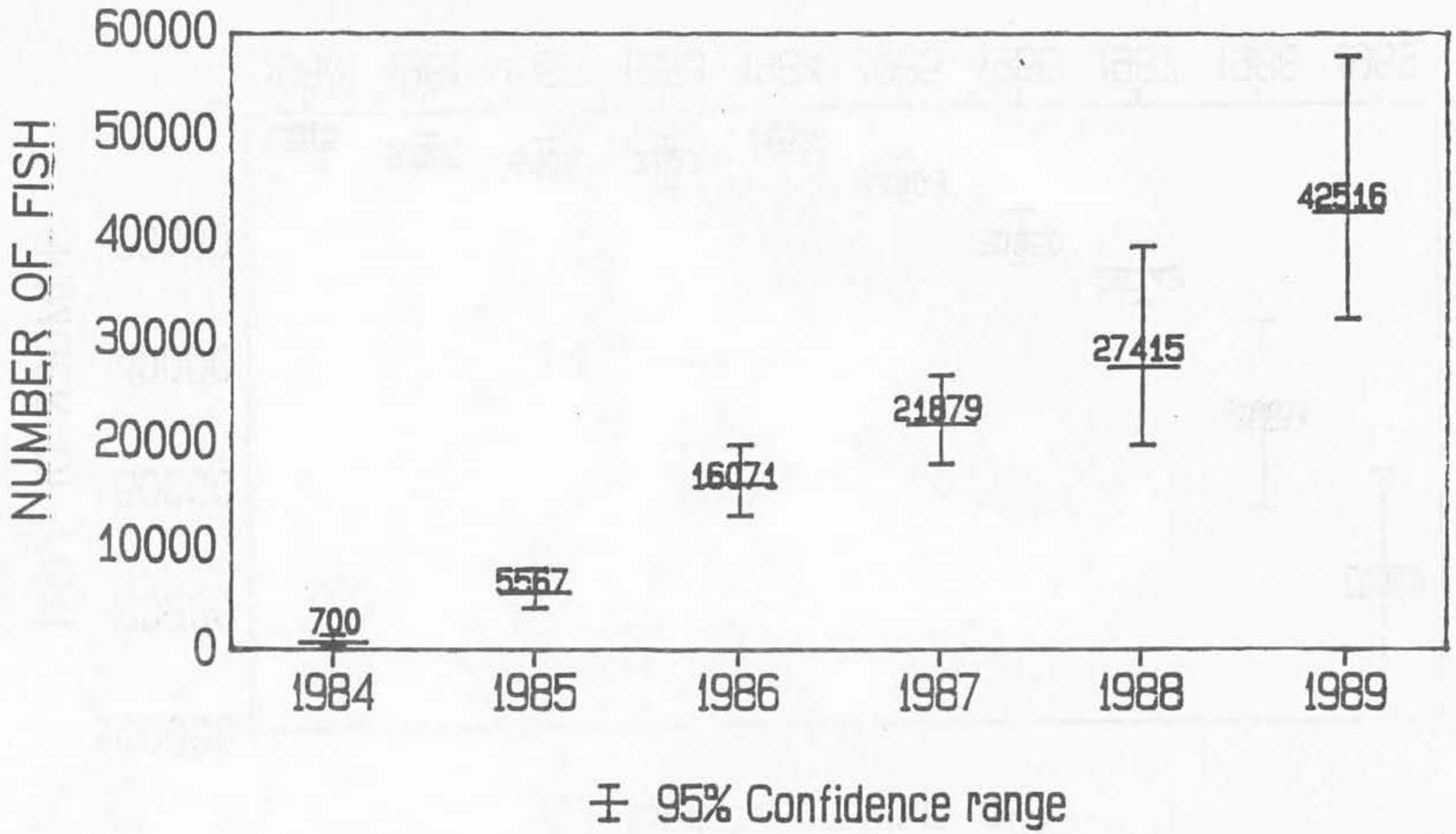


Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1989.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Beaver Dam	14	13
	Cherry Tree	295	217
	Rocky Point	91	68
	Total	400	298
Hook and Line	Conowingo Tailrace Susquehanna River	276	261
Fish Lift	Conowingo Tailrace Susquehanna River	8222	
	TOTALS	8898	559

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1989 using the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1989 survey-

C = 8339
R = 61
M = 559

Therefore-

$$N = \frac{(559 + 1)\ (8339 + 1)}{(61 + 1)}$$

$$= 75,329$$

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)

$$\text{Upper } N^* = \frac{(559 + 1)\ (8339 + 1)}{78.35 + 1} = 98,345$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(559 + 1)\ (8339 + 1)}{47.49 + 1} = 59,609$$ @ .95 confidence limits

Table 3. Population estimate of adult American shad in the upper Chesapeake Bay during 1989 using the Schaefer method.

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

	Week of Tagging										Tagged Fish Recov. (Ri)	Total Fish Recov. (Ci)	Ci/Ri
	1	2	3	4	5	6	7	8	10	11			
Week of Recovery													
1											0	673	0
2											0	47	0
3											0	34	0
4		2									2	124	62
5											0	698	0
6		1	1	3	5						10	3121	312
7	1			1	1						3	451	150
8						1					1	23	23
9							2				2	249	124
10	1			1		5	3		2		12	883	74
11					1	1	1		13	4	20	2658	133
12				1			2		3	5	11	673	61
Tagged Fish Recovered (Ri)	2	3	1	6	7	7	8	0	18	9			
Total Fish Tagged (Mi)	12	38	19	99	74	120	73	12	72	40			
Mi/Ri	6	13	19	16	11	17	9	0	4	4			

Table 3. (continued)

B. Computed totals of adult American shad in the upper Chesapeake Bay during 1989 using the Schaefer Method.

Week of Recovery (j)	Week of Tagging (i) 1	2	3	4	5	6	7	10	11	Total
1										0
2										0
3										0
4		1571								1571
5										0
6		3953	5928	15444	16489					41814
				2480	1589					4069
7	902									902
8						394				394
9							2273			2273
10	441			1214		6306	2015	589		10565
11					1405	2278	1213	6911	2360	14167
12				1009			1117	734	1358	4218
Totals	1343	5524	5928	20147	19483	8978	6618	8234	3718	79973

Table 4. Population estimate of adult American shad in the Conowingo tailrace during 1989 using the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1989 survey-

C = 7626
R = 46
M = 261

Therefore-

$$N = \frac{(261 + 1)\ (7626 + 1)}{(46 + 1)}$$

= 42,516

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)

$$\text{Upper } N^* = \frac{(261 + 1)\ (7626 + 1)}{33.6 + 1} = 57,754$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(261 + 1)\ (7626 + 1)}{61.3 + 1} = 32,075$$ @ .95 confidence limits

Table 5. Population estimate of adult American shad in the Conowingo tailrace during 1989 using the Schaefer method.

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

	Week of Tagging 1	2	3	4	5	6	7	Tagged Fish Recovery (Ri)	Total Fish Recovery (Ci)	Ci/Ri
Week of Recovery										
1	2							2	1661	830
2	4							4	1859	465
3								0	0	0
4								0	0	0
5		2						2	283	142
6	2	4				2		8	842	105
7	2	1				13	4	20	2629	131
8						1	2	3	223	74
9		2				2	3	7	479	68
Tagged Fish Recovered (Ri)	10	9	0	0	0	18	9	46		
Total Fish Tagged (Mi)	50	99	0	0	0	72	40			
Mi/Ri	5	11	0	0	0	4	4			

Table 5. (continued)

B. Computed totals of adult American shad in the Conowingo Tailrace during 1989 using the Schaefer Method.

Week of Recovery (j)	Week of Tagging (i) 1	2	3	4	5	6	7	Total
1	8305							8305
2	9295							9295
3								0
4								0
5		3113						3113
6	1053	4631				842		6526
7	1315	1446				6835	2335	11931
8						297	660	957
9		1505				547	911	2963
Totals	19968	10695				8521	3906	43090

Table 6. Catch, effort and catch per unit effort (CPUE) for adult American shad by hook and line and pound net during the 1980-1989 tagging program in the upper Chesapeake Bay.

A. Hook & Line

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPAH*	CPUE HTC**	POP. EST.
1982	***	88	-	-	6800
1983	***	11	-	-	7127
1984	52.0	126	2.42	0.41	3614
1985	85.0	182	2.14	0.47	11093
1986	147.5	437	2.96	0.34	20850
1987	108.8	399	3.67	0.27	26743
1988	43.0	256	5.95	0.17	48564
1989	42.3	276	6.52	0.15	75347

B. Pound Net

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POP. EST.
1980	Rocky Pt.	26	50	1.92	2675
1981	Rocky Pt.	38	50	0.86	5477
1982	Rocky Pt.	27	62	2.29	6800
1985	Rocky Pt.	10	30	3.00	11083
1988	Rocky Pt.	33	87	2.64	
	Cherry Tree	41	75	1.83	
	Romney Cr.	41	8	0.20	
	1988 Total	115	170	1.48	48564
1989	Rocky Pt.	32	91	2.84	
	Cherry Tree	62	295	4.76	
	Beaver Dam	11	14	1.27	
	1989 Total	105	400	3.81	75347

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

Table 7. Catch and age composition by sex and gear type for American shad collected during the 1989 tagging program in the upper Chesapeake Bay.

Sex Gear	AGE GROUPS II	 III	 IV	 V	 VI	 VII
Male						
Hook and Line						
Number caught	-	45	94	49	7	-
Percent age comp.	-	23	48	25	4	
Pound net						
Number caught	-	26	100	66	6	-
Percent age comp.	-	13	51	33	3	
Trap						
Number caught	1	23	112	118	31	3
Percent age comp.	<1	8	39	41	11	1
All gears combined						
Number caught	1	94	306	233	44	3
Percent age comp.	<1	14	45	34	6	<1
Female						
Hook and Line						
Number caught	-	1	23	37	12	-
Percent age comp.		1	32	51	16	
Pound net						
Number caught	-	1	19	75	47	4
Percent age comp.		1	13	51	32	3
Trap						
Number caught	-	-	13	54	44	15
Percent age comp.	-	-	10	43	35	12
All gears combined						
Number caught		2	55	166	103	19
Percent age comp.		1	16	47	30	6

Table 8. Age frequency, number and repeat spawners by gear type and sex for adult American shad collected during the 1989 upper Chesapeake Bay tagging program.

GEAR TYPE	SEX	SEX RATIO	AGE GROUPS II	III	IV	V	VI	VII	% REPEAT SPAWNERS	TOTALS
Hook & Line	M			45	94	49	7	0		195
	Rpts.			0	0	6	3	0	4.6	9
		1 : 0.37								
	F			1	23	37	12	0		73
	Rpts.			0	0	0	2	0	2.7	2
Pound Net	M			26	100	66	6	0		198
	Rpts.			0	0	4	1	0	2.5	5
		1 : 0.73								
	F			1	19	75	47	4		146
	Rpts.			0	0	2	0	2	2.7	4
Trap	M		1	23	112	118	31	3		288
	Rpts.		0	0	4	12	3	0	6.6	19
		1 : 0.47								
	F		-	-	13	51	44	15		126
	Rpts.				0	3	3	3	7.1	9
Totals	M		1	94	306	233	44	3		681
	Rpts.		0	0	4	22	7	0	4.9	33
		1 : 0.83								
	F		0	2	55	166	103	19		345
	Rpts.		0	0	0	5	5	5	4.4	12
								TOTALS	4.7	1026 48

Table 9. Catch and catch per unit of effort (CPUE) by gear type* and sampling station for juvenile American shad, blueback and alewife herring, striped bass, and white perch during the 1989 upper Chesapeake Bay juvenile recruitment survey.

A. Catch by Gear Type

Species	Gear	Station 1	2	3	4	5	6	7	11	Total
American	HS	1	0	4	6	1	0	0	0	12
shad	OT	2	0	0	NA	14	NA	NA	NA	16
blueback	HS	202	2	8	107	36	49	3	131	538
herring	OT	13	21	16	NA	46	NA	NA	NA	96
alewife	HS	1	0	12	22	0	0	0	0	35
herring	OT	3	7	5	NA	0	NA	NA	NA	15
striped	HS	11	8	1	13	8	3	0	0	44
bass	OT	6	2	4	NA	6	NA	NA	NA	18
white	HS	150	219	249	453	30	23	0	0	1124
perch	OT	372	1177	1058	NA	518	NA	NA	NA	3125

B. CPUE by Gear Type

Spp.	Gear	Station 1	2	3	4	5	6	7	11	Tot.
Amer.	HS	0.11	0	0.44	0.67	0.11	0	0	0	0.17
shad	OT	0.29	0	0	NA	2.00	NA	NA	NA	0.57
bluebk.	HS	22.44	0.22	0.89	11.89	4.00	5.44	0.43	16.38	7.80
herring	OT	1.86	3.00	2.29	NA	6.57	NA	NA	NA	3.43
alwife.	HS	0.11	0	1.33	2.44	0	0	0	0	0.51
herring	OT	0.43	1.00	0.71	NA	0	NA	NA	NA	0.54
striped	HS	1.22	0.89	0.11	1.44	0.89	0.33	0	0	0.64
bass	OT	0.86	0.29	0.57	NA	0.86	NA	NA	NA	0.64
white	HS	16.67	24.33	27.67	50.33	3.33	2.55	0	0	16.30
perch	OT	53.14	168.1	151.1	NA	74.00	NA	NA	NA	111.61

* Otter trawl data provided by Maryland estuarine fisheries yellow perch project. HS: haul seine; OT: otter trawl.

Table 10. Total catch and catch-per-unit-of-effort for five juvenile species by gear type during the years 1980-1989 in the upper Chesapeake Bay juvenile recruitment survey.

	YEAR								
SPECIES	1980	1981	1982	1983	1984	1985	1986	1987	1989
A. TOTAL CATCH									
Alosa sapidissima (American shad)									
seine	0	0	0	0	0	0	8	0	12
trawl	0	0	1	0	0	1	6	3	16
Alosa aestivalis (blueback herring)									
seine	108	2	130	1	40	96	3484	40	538
trawl	27	0	8	2	17	16	1988	3	96
Alosa pseudoharangus (alewife herring)									
seine	194	108	14	4	11	99	175	6	35
trawl	38	35	19	6	49	171	241	13	15
Morone americana (white perch)									
seine	1315	174	1631	208	914	228	1686	101	1124
trawl	1453	347	3973	553	2410	1014	3028	457	3125
Morone saxatilis (striped bass)									
seine	55	8	235	8	22	8	60	6	44
trawl	8	0	49	2	10	1	37	1	18
B. CATCH-PER-UNIT-OF-EFFORT									
Alosa sapidissima (American shad)									
seine	0	0	0	0	0	0	0.06	0	0.17
trawl	0	0	0.01	0	0	0.02	0.06	0.03	0.57
Alosa aestivalis (blueback herring)									
seine	0.59	0.02	0.79	0.01	0.30	0.67	24.19	0.31	7.80
trawl	0.23	0	0.08	0.02	0.30	0.16	18.93	0.03	3.43
Alosa pseudoharangus (alewife herring)									
seine	1.07	0.78	0.09	0.03	0.10	0.69	1.22	0.05	0.51
trawl	0.38	0.38	0.18	0.06	0.70	1.71	2.30	0.13	0.54
Morone americana (white perch)									
seine	7.23	1.26	9.95	1.53	7.20	1.58	11.71	0.78	16.30
trawl	14.39	3.77	37.84	5.53	35.40	10.14	28.84	4.62	111.6
Morone saxatilis (striped bass)									
seine	0.30	0.06	1.43	0.06	0.20	0.06	0.42	0.05	0.64
trawl	0.08	0	0.47	0.02	0.20	0.01	0.35	0.01	0.64

Table 11. Electrofishing data collected in the upper Chesapeake Bay during 1989.

DATE	LOCATION	WATER QUALITY			GENERATOR TIME	SHOCK TIME	TOTAL CATCH	CPUE**
	See Fig. III	Temp	Sal	Cond	Hrs	Sec		
8/15/89	1	25.5	0	230	0.8	1344	0	0
	2	27.5	0	250	0.4	761	0	0
	3	27.5	0	250	1.0	1512	0	0
	4	26.0	0	260	0.7	1486	0	0
Totals						5103	0	0
8/30/89	5	26.5	0	265	0.9	1722	9	18.8
	6	29.0	0	280	0.9	1711	15	31.3
	7	29.5	0	305	0.8	1850	0	0
	8	31.0	0	210	0.9	1762	1	2.0
Totals						7045	25	12.8
9/14/89	9	24.5	0	290	0.9	1701	16	34.0
	10	26.5	0	280	1.3	2300	10	15.6
	11	25.5	0	290	1.0	2030	11	19.6
	12	26.5	0	285	1.0	2170	6	10.0
Totals						8201	43	18.9
9/21/89	13	23.0	1.5	2750	0.8	1508	0	0
	14	24.0	1.3	2650	0.6	1507	0	0
	15	25.0	0	315	?	1730	2	4.2
Totals						4772	2	1.5
10/4/89	16	17.5	0	270	1.2	2300*	11	17.2
	17	18.5	0	250	0.8	1700*	3	6.3
	18	18.0	0	330	0.9	1873	10	19.2
	19	-	-	-	0.8	1600*	3	6.8
Totals						7473	27	13.0
10/31/89	20	13.5	0	155	0.9	1298	0	0
	21	13.9	0	152	0.5	1067	0	0
	22	14.2	0	160	1.1	1910	0	0
Totals						4275	0	0
Yearly Totals						33252	97	10.5

* Estimated shock time based on 1 hour generator time (2000 sec).
** CPUE is number of American shad captured per shock hour.

LAST
PAGE