Restoration of American Shad to the Susquehanna River

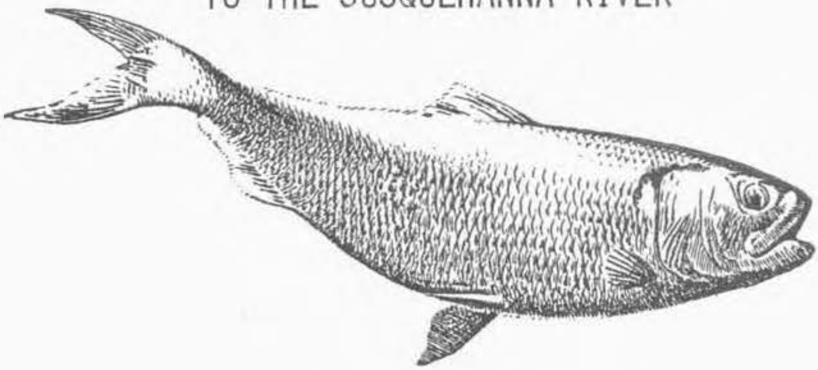
ANNUAL PROGRESS REPORT — 1983 —

SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

JANUARY 1984

RESTORATION OF AMERICAN SHAD

TO THE SUSQUEHANNA RIVER



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SUSQUEHANNA RIVER

ANADROMOUS FISH RESTORATION COMMITTEE

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

JANUARY 1984

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER

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ERRATA SHEET

Summary (page ii) - first paragraph -

"A total of 5,910 prespawned adult American shad were collected from the Hudson and Connecticut rivers in May and June of 1983 and transported to the upper Susquehanna River. Hudson River fish (3,691) were collected near Catskill-Hudson, NY by commercial haul seine and stocked at Owego, NY (rm309). The fish lift at Holyoke Dam on the Connecticut River provided 1,641 shad which were delivered to Tunkhannock, PA (rm216) and 578 shad delivered to Owego, NY. . . . "

Job I - (page 1-11, bottom) -

"An additional 4 truckloads (578 fish) were taken from Holyoke in early June and stocked at Owego, NY. No mortality assessment was performed on these stockings."

Job I - (page 1-15, end of 1st paragraph) -

"Four truckloads (578 fish) were also taken from Holyoke on June 6-7 and stocked at Owego, NY."

INTRODUCTION

This Annual Report discusses the numerous activities undertaken by member agencies of the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) during 1983. These efforts represent a continued commitment on the part of interested state and federal agencies and public utility companies to rebuild stocks of American shad to the Susquehanna River system. The program is based on the premise that a population of shad can be developed through natural reproduction of stocked adults and production of hatchery reared fry and fingerlings. Young shad resulting from these stockings should be imprinted to the Susquehanna River and will hopefully migrate to sea and return in future years as spawning adults.

The SRAFRC restoration program in 1983 was similar to that of past years and is separated into seven major work elements, plus supporting research. Collection and transplantation of prespawn adult shad from out-of-basin sources, collection of fertile shad eggs and delivery to the hatchery, shad culture and stocking, and juvenile outmigration evaluation studies above Holtwood Dam are financially supported by Pennsylvania Power & Light Company and Safe Harbor Water Power Corporation as part of a settlement agreement with the Pennsylvania Fish Commission and Susquehanna River Basin Commission.

Operation of the fish collection facility (trap and lift) at Conowingo Dam, transport of prespawn adult shad and herring upstream from that site, and juvenile shad assessment in Conowingo Pool and tailwaters is funded by the Philadelphia Electric Company and conducted by contractors to PECO. Assessment of population size and characterization of the American shad stock returning to the upper Chesapeake Bay - lower Susquehanna River is conducted by the Tidal Fisheries Division of the Maryland Department of Natural Resources as a cost-shared Federal Aid project. Shad cultural research, mark development studies, genetic characterization, immunological and histological analyses are being conducted and funded by the U.S. Fish and Wildlife Service, Pennsylvania State University, and the Pennsylvania Fish Commission.

Record achievements were recorded in 1983 for out-of-basin adult shad transferred to the Susquehanna River; eggs collected and delivered to the PFC Van Dyke hatchery; production of fingerling shad; abundance of juvenile outmigrant shad in the North Branch Susquehanna River and hydroelectric forebays at Holtwood, Safe Harbor, and York Haven projects. Problems were experienced with operation of the Conowingo fish lift and adult shad tagging in the lower river; shad fry culture at Van Dyke; long-term retention of the rare earth element samarium as a marking agent in cultured shad; and, collection of outmigrant juveniles below the Holtwood project.

SUMMARY OF ACCOMPLISHMENTS

A total of 5,332 prespawn adult American shad were collected from the Hudson and Connecticut rivers in May and June of 1983 and transported to the upper Susquehanna River. Hudson River fish (3,691) were collected near Catskill-Hudson, NY by commercial haul seine and stocked at Owego, NY (rm309). The fish lift at Holyoke Dam on the Connecticut River provided 1,641 shad which were delivered to Tunkhannock, PA (rm216). Mortality monitoring assessment at Tunkhannock indicated that survival of trucked adults averaged 64% for the 7-9 hour trip from Holyoke. This is less than that perceived in prior years (75-95%) and considerable variation was exhibited (41-89% survival). Paired tests using several water conditioning factors and controlled velocity of transport tank water indicated that best survival was achieved with a constant perimeter flow velocity of 0.5 fps and addition of 1% salt to the transfer water. Test results should be viewed cautiously as they may have been affected by numerous equipment failures during trials.

A total of 34.5 million shad eggs were collected in 1983 and delivered to the Van Dyke hatchery. Eggs were taken from the James River (5.9 M), Pamunkey River (5.5 M), Hudson River (1.2 M), Delaware River (2.4 M), and Columbia River (19.5 M). The Delaware River was a first time effort and results indicate that this source can be a useful addition to future year egg collections. Attempts to take prespawn adults on the Delaware failed. The Van Dyke hatchery produced and stocked 4.048 million shad fry and 5,000 fingerlings. Double cropping the canal pond at Thompsontown resulted in 72,000 fingerlings being stocked, and Benner Spring Research Station (PFC) produced an additional 21,000 fingerlings from raceway and pond rearing investigations. Serious fry mortalities were experienced at Van Dyke and are believed to be associated with gas supersaturation caused by heating water. These unexpected losses prevented a record hatchery production in 1983.

Unusually high river flows in April and several mechanical failures at the fish lift at Conowingo Dam resulted in only 430 American shad being captured there in 1983. Only two attempts were made to transfer shad upriver from Conowingo and 36 live shad were stocked at Harrisburg. Numbers of all other anadromous fish except striped bass were reduced in the trap catch as compared to prior years.

Maryland DNR biologists also experienced problems in capturing adult shad in the lower Susquehanna River for population assessment. In five nights of gill netting, 217 shad were tagged. A total of 10 tagged fish were recaptured (none in the Conowingo trap), and the upper Bay - lower river population was calculated to be 7-8,000 fish in 1983. Although total shad catch was down, the catch per unit effort for gill nets was the highest recorded for the 4 years of stock assessment.

Juvenile shad monitoring in the Fall of 1983 resulted in confirmation of natural reproduction in the North Branch Susquehanna River (from adult transplants) with 83 fish taken by seine during late August and early September. The fish ranged in size from 93 to 133mm and most fish were taken at Coxton Yards (Duryea-Pittston) and Wilkes-Barre. No young shad were collected above Tunkhannock. Daily monitoring of power plant intakes at Susquehanna SES, Hunlock Creek SES, and Sunbury SES produced no young shad.

As in past years, the Juniata River at Amity Hall was sampled with seines to confirm growth and migration of hatchery-produced shad. During two sampling days in September, shad were collected which represented two distinct size classes (50mm and 100mm).

Weekly sampling from October through mid-December in the three upper hydroproject forebays resulted in the capture of hundreds of juvenile shad. These fish, taken with a 20-ft. diameter cast net averaged 127mm fork length in mid-November and ranged in size from 75-155mm. Experimental spilling at the first regulating gate at Safe Harbor on several occasions appeared to move shad over the dam from the gatewell area.

Compared to 1982, very few shad were collected on the intake screens at Peach Bottom Atomic Power Station. One shad was taken at Conowingo Dam, none in the pond or in the river below Conowingo. A considerable amount of effort was expended to collect outmigrants both at the dam (experimental discharge sampling net) and in the lower river (gill nets, trawls, and seines). Though collections upstream from the Holtwood project indicated that juvenile shad were in record abundance, successful outmigration to Chesapeake Bay was not demonstrated.

Investigating the efficacy of marking young American shad with the rare earth element samarium, researchers at Lamar Fish Cultural Development Center (USFWS) were able to "tag" fish using laced diets. Initial analyses of whole fish and specific tissues indicated very high samarium concentrations. However, concentration diminished as time progressed and by day 210 post-marking, samarium in samples was at background levels. Other research activities conducted in 1983 and reported herein include: cultured shad larval mortality, nutrition, and feeding behavior; rearing density studies in ponds and raceways; harvesting and transport of fingerlings; immunization, genetic strain evaluation and histopathological analysis.

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

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1.1 INTRODUCTION

In 1981 and 82 over 4,600 pre-spawned shad were transported from the Connecticut (1981-82) and Hudson rivers (1982) and released to the Susquehanna River. The success of previous efforts led to an expansion of the Adult Shad Transfer Program in 1983. A minimum of 5,000 pre-spawned adults were to be captured and trucked to the Susquehanna River. Handling and transport mortality was to be limited to 25% or less and sex ratios were to be determined whenever possible.

The Hudson River was expected to provide about 2,000 shad by haul seine operations and the Connecticut River approximately 3,000 fish from the lift at Holyoke. The Delaware River was also to be included on an experimental basis.

The Connecticut River operation was a continuation and expansion of the 1981-82 out-of-basin transfer program. This operation was conducted by the PFC, using Pleasant Mount Fish Cultural Station as a center of operations. The techniques and logistics for the Connecticut River (Holyoke Dam) were based on previous years' efforts, though considerable mortality monitoring was conducted at the release site. PFC also examined water conditioning factors and controlled tank velocities in 1983 (see Appendix I-A).

The Hudson River out-of-basin transfer program was in its second year. This program was conducted by NES, utilizing methods proven adequate in 1982. Fish were seined from the vicinity of Hudson-Catskill, NY and commercial fishermen were employed for this operation.

The Delaware River Program was initiated on an experimental basis by the PFC and USFWS utilizing haul seines at the Smithfield Beach Access Area (PA), immediately above the Delaware Water Gap. Although operations on the three rivers were conducted independently, plans were made to integrate use of transportation facilities (trucks and tanks) to best take advantage of the availability of adult shad from all rivers.

1.2 HUDSON RIVER SHAD TRANSFER PROGRAM

In 1982 NES successfully captured pre-spawned adult shad from the Hudson River and transferred them to a release site on the upper Susquehanna River, in New York, on an experimental basis. Some 992 fish were presumed alive at release, resulting in a survival rate of 32%. Past experience by NES on the Hudson River indicated that a substantial adult shad population was available for the transfer program. However, unlike the Connecticut River, there was no means for capture of adult shad other than by netting. In 1982, NES began operations utilizing gill-nets as the primary gear, however, shad capture was shifted to haul seine when low survival resulted. The overall success of the haul seine and the operation in general led to its expansion in 1983.

1.2.1 Schedule and Collecting Methods

The Hudson River program was conducted from 3-21 May on a seven day per week basis. Operational timetables were contingent on tidal conditions; i.e. when the tide was running full haul seines could not be used effectively. Generally, fishing activities took place between 0900 and 2000 hours. Sampling days were utilized to the fullest in order to reach the proposed goal. Only one day in the 18 day period was lost, due to mechanical problems with the transport truck.

American shad were collected from the Hudson River in the vicinity of Greenport, NY. Crews ranging from 10-12 technicians worked cooperatively with commercial fishermen contracted to collect shad. Crews worked to capture shad, transport them to a shore-based site and load the tank truck.

A 500 x 12 ft. haul seine with 2 in. square mesh wings and 1 in. square mesh bag was utilized to collect shad. The seine operation was directed through mutual agreements with commercial fishermen and NES to ensure that the operation was carried out in the most effective manner. Site selection was based on an area of river that was found to have large numbers of shad in the 1982 operations. The seine was hauled along the shoreline as soon as the tide changed from ebb to uptide. This tidal condition is used to minimize manpower needs in hauling the seine.

Three people were needed to lay out the net from a boat captained by a fisherman, while an additional 5-6 individuals pulled the opposite end of the net along the shoreline. An entire area was encircled and the net ultimately pulled to the shore. The shad were concentrated in the bag section.

Shad collected in the haul seine were immediately dip-netted or hand brailed from the bag to a 400 gallon oval fiberglass tank mounted in a 16-ft. boat. Oxygen was provided by a 3 HP trash pump which drew water from the bottom center of the tank to an intake valve on the top inside tank wall. As many as 150 shad were loaded into the stock tank. The number of fish loaded was determined by several factors including water temperature, number of shad available and distance from the capture site to the tank truck. It was ultimately determined that 75 shad were the maximum number to transfer in any one load. The boat and tank, after loading, was driven by one NES personnel to a shore based loading site. A large cylinder of oxygen was mounted in the shuttle-boat and was used to increase D.O. during transport.

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

The minimum load to be transferred to the Susquehanna River was 50 shad. They were accumulated in the transport until that number was reached. The capacity of the tank was about 150 shad.

1.2.2 Description of Transfer Equipment

The transport tank has a 1,100 gallon capacity and is about 4-ft. high and 8-ft. in diameter. The top is removable and shad are loaded through a 2-ft. square hatch on the top. Unloading is accomplished by removing the outside circular cap by a gate release located on the back of the tank. A portable cylindrical shoot, which extends 2 ft. beyond the truck bed, is attached below the unloading hatch and directs both water and shad into the Susquehanna River.

Water circulation is created by two 3 HP gasoline driven centrifugal pumps. Each pump has an individual pressure discharge to the tank, located tangential along the inner tank wall. Pressure discharges are located at different heights to create equal current throughout the water column in the tank. A common return suction to the pumps is located at the bottom center of the tank. Each pump is equipped with a bleeder valve which introduces air into the system during pumping.

Aeration of the system is controlled by air intake valves on the suction side of each pump. An inverse relationship exists between the amount of aeration and strength of the current. Opening air valves and increasing the amount of air in the lines causes a reduction in the current and increases the rate of aeration. Approximately 80% water and 20% air are continually delivered to the tanks by the pumps.

1.2.3 Temperature/Oxygen Monitoring and Release of Fish

Temperature in the transport tank is not controllable. However, no cooling is necessary until water temperature is more than 70° F, a situation which did not occur. Water temperature differential between the Hudson River and the Susquehanna River was measured and every effort was made to minimize increases in temperature during transport. Dissolved oxygen (DO) was maintained by an aeration system which is an integral part of the transport tank.

Dissolved oxygen (DO) and temperature were monitored with a YSI Model 57 oxygen meter. A small opening on the top edge of the tank provided access to the release hatch cover. Measurements were made prior to securing the tank for transport and at 2-hour intervals thereafter until transplantation to the release site was completed. A final water temperature and dissolved oxygen reading was made in the tank prior to stocking.

Shad were released to the Susquehanna River at Owego, New York. At the release site, the truck was backed down the access ramp to the shoreline. The circulation pumps were shut down, release cover raised and shad and water released into the Susquehanna River. Some mortality was unavoidable during transfer. Drivers waited approximately 15 minutes to retrieve any fish which died in transit or release. It is probable that all dead fish are not recovered in this manner.

1.2.4 Results

The Hudson River adult transfer operation was initiated on May 3, 1983 and continued through May 21. When the operation was terminated the number of shad transferred had well exceeded the goal. A total of 3,691 pre-spawned shad were transferred from the Hudson River to the Susquehanna River primarily by NES (2,716) and the PFC (750). Shad were also trucked on an experimental basis by the USFWS (225) utilizing a rectangular aluminum trout transport tank. The number of fish trucked by NES/PFC ranged from 136 to 160 per truck (Table 1) and up to 75 by the USFWS (Table 2). Of these fish, a total of about 3,123 were presumed alive at release. Mean survival was 88% (range 37% to 99%) for the fish trucked by NES, and 81% by the USFWS (range 77% to 88%). Data were not taken on four of the five shipments made by the PFC but an estimate of 80% survival is used herein. The average presumed survival for Hudson River fish was 84%.

The primary release site on the Susquehanna River was at Owego, NY. This location was utilized for all but two loads. Of these two loads, one was examined for instantaneous mortality of shad by the PFC and released at the Tunkhannock release site (75% survival). Another truckload of shad was delivered by NES to a ½ acre earthen pond at Pleasant Mount Fish Culture Station for determination of delayed mortality. Only 50 of the 155 fish hauled survived the stocking (32%), but most of these fish lived for 5 days in the pond.

The condition of fishes taken by haul seine appeared to be extremely good. The haul seine, though labor extensive, is an excellent device for shad capture. It is a practical means of capturing large quantities of fish with a minimal amount of handling. Gill-net operations place a relatively greater amount of stress on the shad.

The average time for loading the tank truck depended on the number of fish taken in the haul. If sufficient numbers of fish were taken to fill the tank, the entire operation would take approximately two hours. The travel time from the Hudson River collection site to Owego was typically about four hours.

Water temperature during the time of capture ranged from 50-63° F (Table 3). Unseasonally low water and air temperatures generally kept the increase in temperature during transit to a minimum. Water temperatures in the Susquehanna and Hudson rivers were usually within 1-2° of one another. These aforementioned factors were possibly a factor in the increased survival of fish over 1982.

Dissolved oxygen averaged 5.3 ppm (range 4.6 - 7.2 ppm) on the Hudson River and increased to an average of 5.5 ppm (range 3.9 - 6.8 ppm) in transit (Table 3). This was probably a result of the aeration provided by the trash pumps and low air temperatures. Dissolved oxygen was not believed to be a limiting factor in the trucking of shad between the two rivers.

1.2.5 Interagency Cooperation

The NYDEC was available for technical consultation, as necessary, during the course of the Hudson River Program. A NYDEC biologist was also involved with the project during the Department's population structure studies of shad and striped bass in the Hudson River.

The Hudson River adult transfer program was a cooperative effort between various agencies. The PFC and USFWS were available for technical advice, as well as assisting in the transfer operations. The PFC was also involved in research on improving transport survival, in addition to delayed mortality studies.

1.2.6 Experimental Haul Seine Operation

The SRAFRC technical committee expressed a desire to locate new sectors of the Hudson River where large numbers of shad could be effectively taken by haul seine. During May 23-30 experimental haul seining operations were conducted by NES. Commercial fishermen and the NYDEC suggested that a 10-mile section of river, north of the Rip Van Winkle Bridge to Columbiaville be sampled. Operations were conducted at slack tide over a period of seven days. Crews of 8-10 biologists and two commercial fishermen with boats were utilized for the program.

Rationale for selected sites was based on various factors. For example: (1) a loading area with a hard substrate is necessary if the net is to be effectively pulled into shore. A soft muddy substrate is unsuitable since mud collects in the gills of fish resulting in high mortality; (2) the seining area must be free of submerged debris, rocks and obstacles that could possibly snag the net; and, (3) the location of the haul must be within a reasonable distance to an accessable area for the shad transport tank, in order that the fish may be loaded into the tanks as quickly as possible.

With consideration of all factors above, some 20 sites were examined. Though many of the sites explored were historic seining areas, only one site produced significant numbers of shad. This area was located on the northwest side of Rodgers Island on the east side of the river channel. Approximately 800 - 1,000 shad were netted in one haul on May 25. This area is interesting for future considerations since it possessed not only a good landing area and hard substrate, but an access point for the transport truck on the opposite bank of the river.

1.3 CONNECTICUT RIVER SHAD TRANSFER PROGRAM

1.3.1 Introduction

The Pennsylvania Fish Commission conducted the transfer of adult American shad from the Holyoke Dam fish lift to the Susquehanna River in 1983. Rather than providing money to the University of Massachusetts Cooperative Fishery Research Unit to defray cost of loading trucks, this year the PFC assigned a biologist to the project at Holyoke during the period May 13-31. This person provided assistance in loading shad for transfer to the Susquehanna as well as those taken by fishery agencies from Rhode Island, Massachusetts and New Hampshire for their programs. This assistance was well received and appreciated by the CFRU.

1.3.2 Methods and Schedule

Two new shad transport tanks were purchased for SRAFRC and mounted to PFC trucks. Both units were involved in the Connecticut River transfer. Appendix I-A describes the equipment as modified for the 1983 effort. Due to unusually cool and wet spring weather in 1983, the shad run up the Connecticut was delayed and transport did not begin until May 18. From this date until May 31, PFC transported shad on ten separate days. On May 26-27, shad were transported by PFC upstream to the Vernon pool. On each of the remaining eight days fish were transported to the Susquehanna River and released at Tunkhannock (12 truckloads).

Pennsylvania operated one truck from May 18 to May 20 and two trucks on all days thereafter. Loading was completed between 1:00 and 4:00 pm on most days. Between 119-150 shad were hauled per truckload (average 126).

One truckload of Connecticut River shad (122 fish on May 19) was stocked into a flow-thru pond at Pleasant Mount Fish Cultural Station. The remaining 12 loads were delivered to Tunkhannock. Mortality assessment was conducted for each load using a net/corral device placed in the water immediately downstream from the tank discharge. One PFC truckload from the Hudson River was also delivered to Tunkhannock for mortality assessment and one NES truckload (Hudson) was delivered to the Pleasant Mount pond.

In 1983 attempts were made to refine the mode of transportation and to determine which variables could be controlled or altered to enhance survival of trucked shad. Studies reported in Appendix I-A were conducted to compare addition of salt, antifoam, MS-222 and ice and to evaluate how these alterations in transport water affected survival. Water velocity in the tanks was adjusted and held at 0.5 fps for all Connecticut River trips. Finally, a length of flexible plastic hose (18-in. diameter) was fitted to the tank release hatch to minimize contact of live fish with the river bottom during discharge.

1.3.3 Results

The PFC hauled 1,519 shad from Holyoke to Tunkhannock in 12 truckloads between May 18-31. Only 921 of these shad (61%) were alive following stocking (Table 4). Immediate mortality for the one PFC truckload (122 fish) stocked in the Pleasant Mount pond was 11%. The survival rate of these fish after 5 days in the pond was 97%.

Though we have not yet received an accounting of the male:female ratio of shad at the Holyoke lift, dead specimens examined at Tunkhannock were 56% (338) male and 44% (261) female. Trip by trip mortality by sex and with mean lengths and weights of dead shad is provided in Table 5.

Results of the water conditioning trials are presented in Appendix I-A. While these results are not definitive, it appears that shad survival during transportation over a 7-9 hour time interval is enhanced by the addition of 1% salt and antifoam while maintaining the tank perimeter velocity (current) at 0.5 fps. From this years effort we can project that at least 60% of the shad hauled from Holyoke should survive the trip to Tunkhannock and that greater than 80% of those healthy fish planted should survive to spawn.

Though we exhausted our Job I funds for the Connecticut River program during the last 2 weeks of May while the shad run was depressed, it is interesting to note that by mid-June the Holyoke lift was setting a new record for numbers of shad passing that structure (528,000). This accounts for our inability to reach the target (3,000 shad) and points to the difficulty in planning and scheduling manpower and equipment.

1.4 DELAWARE RIVER SHAD TRANSFER PROGRAM

An experimental effort was conducted on the Delaware River in 1983 by personnel from the USFWS, PFC and a local volunteer group to collect and transfer up to 1,000 prespawned adult shad to the Susquehanna River. Numerous attempts were made to collect fish with a 450-ft. haul seine on the river in the vicinity of Smithfield Beach - Bushkill, PA. Work crews seined in daylight and evening hours at several locations between May 9-12 but no shad were collected. One of the PFC transport units stood by during these trials.

High river flows and reduced water temperatures (52-56°F) apparently spread the shad run thin throughout the sampling area and recreational fishermen reported taking shad over a 100 mile stretch of river in reduced abundance. New Jersey's shad tagging effort and live transfer of shad from Lambertville, NJ to the Raritan River was similarly affected with few fish available.

There are only limited access sites to suitable seining areas along the middle reaches of the Delaware. Numerous snags and uneven bottom contours hampered seining operations. Also, large numbers of recreational fishermen and boaters are encountered throughout the upper basin during shad season.

The Delaware River shad population appears significantly smaller than that on the Hudson where one seine haul may produce 1,000 fish or more. New Jersey's shad population estimate for the Delaware in 1983 was 250,000 fish, a dramatic decrease from the 1981-82 levels of ½ million each year.

1.5 SUMMARY

1.5.1 Hudson River

In 1982 the Hudson River was added to the adult shad transfer program on an experimental basis. A total of 1,176 prespawned American shad were collected by haul seine and transferred to the Susquehanna River with a survival rate of about 82%. The success of this effort and the effectiveness of seining encouraged SRAFRC to expand the effort. In 1983, a goal of 2,000 gravid (green) adult shad were to be captured from the Hudson and trucked to Owego, NY with at least 75% survival.

Adult shad were collected by haul seine near Greensport, NY by NES and transferred to the Susquehanna River. All fish were taken to Owego except for two shipments used for mortality tests. During the period May 3-21, a total of 2,716 shad were hauled by NES, 750 by PFC, and 225 by USFWS. The number transferred per load ranged from 136 to 160 by NES/PFC and up to 75 by the USFWS which utilized a standard compartmentalized rectangular trout distribution tank on an experimental basis. The grand total of shad transferred was 3,691 of which 3,123 were presumed alive at release. The average survival rate during transfer was 84%.

Water temperature on the Hudson River during this period ranged from 50-64°F (average 55°F). Approximately a 2°F increase occurred during transfer. Dissolved oxygen levels in tank water averaged approximately 5.5 ppm when shad were loaded and increased slightly during the trips.

1.5.2 Connecticut River

The Pennsylvania Fish Commission stationed a biologist at Holyoke Dam during May 13-31 to assist in operating the fish lift and loading transport trucks. Twelve truckloads of shad (1,519) were transferred to the Susquehanna River at Tunkhannock, PA during May 18-31. One additional load of 122 fish was stocked into a flow-thru pond at Pleasant Mount Fish Cultural Station (PFC) on May 19.

Complete assessment of mortality at the stocking sites using nets revealed that only 61% of the shad hauled survived the transport from Holyoke. Delayed 5-day mortality of trucking survivors at Pleasant Mount was only 3%. Several tests were conducted with various water conditioning agents in an effort to determine which factors might improve survival. Preliminary results indicated that addition of 1% salt and antifoam were beneficial.

The shad run on the Connecticut River was slow to develop in 1983 because of high spring flows and reduced temperatures. The bulk of the run arrived late (June) and a new lift record for shad was established at Holyoke.

1.5.3 Delaware River

An experimental effort was conducted on the Delaware River in 1983 by personnel of the USFWS, PFC and volunteers. Attempts were made to collect adult shad with a 450-ft haul seine during May 9-12 near Smithfield Beach. No shad were collected. The Delaware River shad run was weak in 1983 and operations were hampered by swift currents, high waters, uneven bottom contours and snags, and crowded conditions.

Table 1. Data on Prespawned Adult Shad Transferred from the Hudson River to the Susquehanna River at Owego, NY in 1983 by National Environmental Services, Inc.

DATE	NUMBER TRANSPORTED	NUMBER DEAD	NUMBER ALIVE	PERCENT SURVIVAL
5/3	153	56	97	63
5/5	136	1	135	99
5/6	154	8	146	95
5/7	145	4	141	97
5/8	151	12	139	92
5/9	141	2	139	99
5/10	146	5	141	97
5/11	150	18	132	88
5/12	150	21	129	86
5/13 *	150	95	55	37
5/14	150	8	142	95
5/15	155	11	144	93
5/16	155	11	144	93
5/17	160	24	136	85
5/18	155	9	146	94
5/19	155	16	139	90
5/20	155	17	138	89
5/21	155	28	127	82
Total	2,716	346	2,370	$\bar{x}$=87

* stocked into Pleasant Mount pond

Table 2. Data on prespawned American shad transferred from the Hudson River to the Susquehanna River in 1983 by the U.S. Fish and Wildlife Service. Fish released at Owego, New York.

DATE	MAY 17	MAY 20	MAY 21
NO. FISH LOADED	75	75	75
NO. SURVIVORS	59 (78%)	58 (77%)	66 (88%)
MORTALITIES	16	17	9
POOR FISH @ START	8	6	5
LOAD/TRAVEL TIME	5½ hrs.	5 hrs.	3½ hrs.
ADDITIVES	1% salt	1% salt	1% salt

WATER CHEMISTRY

	Before Fish loaded	After fish loaded	During transport	After release	Receiving water
MAY 17					
TEMP (F)	57	57	57	55	54
pH	8.2	8.2	8.2	8.2	9.2
O_2 (ppm)	9.4	9.7	12.0	10.4	9.1
CO_2 (ppm)	80	160	512	120	80
NH_3 (ppm)	0.3	0.8	1.6	2.3	0.15
MAY 20					
TEMP. (F)	58	59	60	60	57
pH	9.3	8.8	8.8	8.7	9.2
O_2 (ppm)	9.4	9.5	9.5	9.4	9.1
CO_2 (ppm)	80	80	120	120	80
NH_3 (ppm)	0.3	0.3	1.1	2.4	0.15
MAY 21					
TEMP. (F)	59	-	-	60	59
pH	9.2	-	-	9.0	9.2
O_2 (ppm)	9.4	-	-	8.8	9.1
CO_2 (ppm)	80	-	-	160	80
NH_3 (ppm)	0.3	-	-	0.3	0.15

TABLE 3.
Record of Dissolved Oxygen and Temperature During Transport of Adult American Shad by National Environmental Services, Inc. from the Hudson River to the Susquehanna River, 1983.

		DISSOLVED OXYGEN (PPM)				TEMPERATURE (°F)				
DATE	TRIP #	START	2 HRS	4 HRS	FINISH	START	2 HRS	4 HRS	FINISH	SUSQUEHANNA RIVER
MAY 3	1	5.9	5.0	5.0	5.0	63	64	64	64	56
5	2	4.6	4.6	3.9	3.9	57	56	56	57	56
6	3	5.6	5.4	6.0	5.6	53	53	54	55	52
7	4	5.9	5.9	5.9	6.0	52	53	58	58	54
8	5	5.0	5.4	5.4	5.4	54	54	56	57	54
9	6	5.4	5.5	5.2	5.2	51	51	50	50	54
10	7	5.7	5.6	5.4	5.4	51	51	51	51	51
11	8	5.2	5.2	5.2	5.2	50	51	52	52	51
12	9	5.0	5.4	5.7	5.7	52	53	54	54	52
13	10	4.6	6.7	6.2	6.2	55	57	62	62	53
14	11	6.3	4.8	4.2	4.2	57	61	63	63	57
15	12	5.2	7.1	6.8	6.8	56	61	58	58	51
16	13	4.8	7.1	6.1	6.1	54	54	55	55	55
17	14	5.0	5.5	6.4	6.4	56	56	56	56	53
18	15	7.2	6.1	5.7	5.7	57	60	59	59	54
19	16	7.2	5.6	4.0	4.0	56	56	55	55	54
20	17	5.6	5.6	5.4	6.2	59	59	60	60	55
21	18	5.4	4.9	5.7	5.7	59	59	59	59	57
TOTALS		$\bar{x}$=5.3			$\bar{x}$=5.5	$\bar{x}$=55			$\bar{x}$=57	$\bar{x}$=55

Table 4. 1983 ADULT AMERICAN SHAD TRANSPORTATION - MORTALITY ASSESSMENT

Date	Water Conditioning Agent	Origin[a] of Fish	Release[b] Site	# Fish Hauled	Temperature, °F		Immediate Mortality			
					Init.	Final	# Males	# Females	Total #	Total Percent
5/12	Salt + Antifoam	Hudson	Tunk #2	150	50	54	26	11	37	24.7
5/13	None[c]	Hudson	Pl.Mt. Lag.	155	-	-	61	44	105	67.7
5/18	Salt + Antifoam	Holyoke	Tunk #1	125	52	58	7	7	14	11.2
5/19	Salt + Antifoam	Holyoke	Pl.Mt. Lag.	122	52	54	5	8	13	10.7
5/20	Salt + Antifoam	Holyoke	Tunk #2	125	51	59	28	20	48	38.4
5/21	Salt + Antifoam	Holyoke	Tunk #2	125	55	62	34	18	52	41.6
5/21	None	Holyoke	Tunk #2	123	55	62	42	31	73	59.3
5/22	None	Holyoke	Tunk #2	123	57	-	24	20	44	35.8
5/22	MS 222 + Buffer	Holyoke	Tunk #2	125	57	64	37	30	67	53.6
5/23	Ice	Holyoke	Tunk #2	125	59	64	32	21	53	42.4
5/23	None	Holyoke	Tunk #2	124	52	59	31	17	48	38.7
5/24	Ice	Holyoke	Tunk #2	124	-	-	34	28	62	49.6
5/24	Salt + Antifoam	Holyoke	Tunk #2	150	-	63	36	21	57	38.0
5/31	Salt + Af.[d]	Holyoke	Tunk #2	125	47	51	15	26	41	32.8
5/31	Ice + Salt + Af.	Holyoke	Tunk #2	125	47	50	18	21	39	31.2

Note:

[a]Hudson implies fish captured by Everett Nack et al. along Hudson River shoals near Germantown, New York. Holyoke implies Connecticut River fish entrapped at the Holyoke Power Station fish lift operation in Holyoke, Massachusetts.

[b]Tunk #2 implies release site at the "lesser developed" upstream access area in Tunkhannock, Pennsylvania. This site is excellent for mortality assessment during high-water conditions.
Tunk #1 implies release site at the "more frequented" downstream access area in Tunkhannock, Pennsylvania. This site is best suited for mortality assessment during low-water conditions.
Pl. Mt. Lag. implies release site at the Commonwealth of Pennsylvania's Pleasant Mount Fish Culture Station where American shad were planted into a control pond receiving high volumes of water to simulate river conditions (to assess instantaneous and delayed mortality estimates).

[c]Except for 5/13/83, all data reflects PFC operations; NES driver considered their 5/13 load to be very good when fish arrived at Pleasant Mount.

[d]Af. = Antifoam

Table 5. 1983 ADULT AMERICAN SHAD

TRANSPORTATION - MORTALITY ASSESSMENT BY SEX

IMMEDIATE MORTALITY

				Males				Females			
Date	Fish[a] Hauled	#[b] Dead	% Dead	# Dead	% of Total # Dead	Mean Length (inches)	Mean Weight (pounds)	# Dead	% of Total # Dead	Mean Length (inches)	Mean Weight (pounds)
5/12	150	37	24.7	26	70.3	19.3	2.9	11	29.7	22.5	4.9
5/13	155	105	67.7	61	58.1	19.8	3.0	44	41.9	22.5	4.7
5/18	125	14	11.2	7	50.0	19.4	2.4	7	50.0	22.4	4.9
5/19	122	13	10.7	5	38.5	18.8	2.8	8	61.5	22.3	5.3
5/20	125	48	38.4	28	58.3	19.4	3.3	20	41.7	22.4	5.2
5/21	125	52	41.6	34	65.4	19.2	3.1	18	34.6	21.5	4.7
5/21	123	73	59.3	42	57.5	19.5	3.1	31	42.5	22.2	4.9
5/22	123	44	35.8	24	54.5	19.0	2.9	20	45.5	22.4	5.1
5/22	125	67	53.6	37	55.2	19.3	3.1	30	44.8	22.0	4.8
5/23	125	53	42.4	32	60.4	19.5	3.1	21	39.6	22.4	5.2
5/23	124	48	38.7	31	64.6	19.1	3.0	17	35.4	21.7	4.5
5/24	124	62	49.6	34	54.8	19.3	3.1	18	45.2	21.7	4.9
5/24	150	57	38.0	36	63.2	19.0	3.1	21	36.8	21.1	4.5
5/31	125	41	32.8	15	36.6	19.5	2.8	26	63.4	22.2	4.6
5/31	125	39	31.2	18	46.2	19.4	3.0	21	53.8	22.0	4.6
Overall	1,946	753	38.7	430	57.1	19.3	3.0	323	42.9	22.1	4.8

Remarks:

a) The "Holyoke run" of American shad had been considered to be over on June 1; however it suddenly reappeared a few days later. Subsequently, four loads of American shad (141 + 147 + 145 + 145) totalling 578 fish were transported from Holyoke, Massachusetts to Owego, New York, but no mortality assessment was made.

b) Delayed mortality assessment was based on the formula {(# fish after IM - # fish alive after 5 days) ÷ (# fish after IM)}

NES Transport of 5/13/83 — {(50 - 39) ÷ (50)} = 11/50 = 22%, 5-day post stocking mortality.
PFC Transport of 5/19/83 — {(109 - 106) ÷ (109)} = 3/109 = 3%, 5-day post stocking mortality.

APPENDIX I-A. ADULT AMERICAN SHAD TRANSPORTATION STUDIES - 1983

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An evaluation of Pennsylvania Fish Commission shad hauling units was conducted in 1983 to determine in-transit mortalities (see Job I) and the efficacy of water conditioning agents used during transportation. Purpose of these studies is to define conditions which will maximize survival during long-range transfers.

METHODS

Duplicate trucks carried 1,100 gallon capacity circular tanks equipped with two 5 hp circulating pumps and a Hayward S-200 high-rate sand filter, used as a reservoir for conditioning agents. The water velocity in each tank was determined using a Pygmy Gurley Meter. The tanks were filled to a depth of 25 inches, the normal level prior to the loading of shad. The tangential flow velocities were then adjusted to 0.7 feet per second (fps) at a point 19 inches above the tank bottom, adjacent to the tank wall at the lower right hand side of the tank access door. When the tanks were filled to normal capacity the resultant velocity was 0.5 fps. The velocities in both trucks were rechecked daily using the same procedure.

The following conditioning agents were obtained for addition to the transportation tanks via the Hayward S-200 reservoir:

1. Salt - Agway solar salt, approximately 80 pounds/truck (0.9% solution)

2. Antifoam - 100 ml of Argent silicone based antifoam solution per truck (diluted to 500 ml with distilled water)

3. MS-222 - 56.1 grams of tricaine methane sulfonate per truck - yielding approximate concentrations of 14 mg/l.

4. Buffer - 1,419 grams of sodium bicarbonate per truck (approximately 356 mg/l $NaHCO_3$)

5. Ice - approximately 100 pounds non-chlorinated ice per truck

A research technician traveled daily on one of the two trucks to assure that the proper number of fish (125) and conditioning agents were added to the transportation units, and that water samples and data were properly collected. Moreover, dissolved oxygen concentrations, temperature, and gas saturation values were determined by this technician at both the loading and stocking points; carbon dioxide and pH concentrations were measured at the loading point only.

A second research technician worked with representatives of the Fish Culture Research Unit at the Tunkhannock stocking site on the Susquehanna River in a netting procedure to enumerate instantaneous mortalities and to determine length, weight and sex ratios of those mortalities. A temporary field laboratory was established in a nearby motel where pH, alkalinity, hardness, carbon dioxide, ammonia nitrogen, and urea nitrogen analyses were performed nightly (approximately 10 pm to 6 am). Chloride analyses were performed at a later date at the Benner Spring Fish Research Station at Bellefonte.

Water samples were collected daily from each transportation unit according to the following schedule:

Sample Number	Sample Description
1	Transportation tank "fill water" - water collected from the tank prior to the addition of chemical conditioning agents or fish.
2	Transportation tank water collected after the addition of fish, but prior to the addition of chemical conditioning agents.
3	Tank water collected approximately 1 hour after the addition of fish and chemical conditioning agents.
4	Tank water collected just prior to the discharge of fish at the Tunkhannock release site.

Samples were collected in duplicate, and one of the two samples was acidified with 0.8 ml sulfuric acid per liter. All samples except one[1] were immediately stored in foam containers and cooled using Blue Ice freezer packs. Samples number one and two from truck A were analyzed for carbon dioxide and pH at the Holyoke Dam site using a Beckman Electromate pH meter with a Corning 476051 pH electrode. The pH meter was recalibrated daily and the sodium hydroxide titrant was prepared and standardized daily. With the exception of chlorides, all other analyses were performed at the temporary lab site at Tunkhannock, where the following equipment was utilized:

> Orion model 701 pH meter with an Orion Model 95-10 ammonia electro
> Beckman Century SS-1 pH meter with Beckman 39502 combination pH electrode, and a Beckman Model 76 and 96 thermocompensator.

[1]Samples collected from Truck B on May 22, 1983 were stored at ambient temp.

The following analytical procedures from the 14th Edition of Standard Methods for the Examination of Water and Wastewater were followed: pH - glass electrode method; alkalinity - potentiometer titration method; hardness - EDTA titrametric method; carbon dioxide - titrametric method. Ammonia nitrogen analysis was performed following the selective ion method from the EPA Methods for Chemical Analysis of Water and Wastewater, 2nd Edition. Urea nitrogen concentrations were determined by neutralizing the preserved samples to pH 7.0 followed by urease digestion as described in the Folin and Youngburg Modified Procedure[2] using a 50 ml sample. Total ammonia nitrogen was then determined using the ammonia electrode. Urea nitrogen values were calculated by subtracting the ammonia nitrogen values for the undigested sample from the corresponding ammonia nitrogen values for the urease digested sample. Chloride analyses were performed using the Beckman pH equipment described above and following the mercuric nitrate high and low range procedures from the 14th Edition of Standard Methods.

RESULTS AND DISCUSSION

As originally scheduled, the chemical conditioning agent study was to have taken place several weeks after the shipping of adult shad from the Holyoke Dam to the Susquehanna River had begun. This would have permitted the temporary employees hired as truck drivers to become familiar with the equipment, route, and stocking procedures before data collection began, and also would have allowed the correction of early

[2]Hawk, Oser, and Summerson, Practical Physiological Chemistry, 1954 Maple Press Co., York, PA.

mechanical problems. Unfortunately, high river conditions on the Connecticut River resulted in a delay of the initiation of shad shipments, making it necessary to utilize inexperienced drivers and equipment with only a few hours of seasonal use. This resulted in minor equipment failures on three (May 22, 23, and 24) of the four scheduled test days. In addition, confusion over stocking of Vernon Pool on the Connecticut resulted in unequal tank densities on May 24th. As a result, the validity of duplicate truck comparisons conducted in 1983 is questionable due to the number of unexpected variables introduced into the evaluation. However, the 1983 study does provide a legitimate reference point inasmuch as the results as reported, reflect valid baseline criteria and can be used to project logical approaches to enhance the restoration effort. The following summarizes the results of data collected in the transportation study:

1. A tangential flow velocity of 0.5 fps may be satisfactory for the transportation of shad in a circular tank. Since instantaneous mortalities had not been enumerated in prior years, there was no reference point for comparison; however, an average survival rate of 64% for a 7-hour stocking run was considered acceptable. Previous reports of fish becoming fatigued and changing their orientation seems to indicate that tank current velocity should be a parameter of concern.

2. The addition of salt to the transportation tanks seems to reduce mortalities in long duration stocking trips. The May 21 evaluation with duplicate trucks yielded 58% survival for the 10½-hour trip, as compared to a 41% survival for the 9-hour trip without salt added.

3. MS-222 plus buffer did not result in an increased survival on the May 22 stocking comparison, however pump failures may have influenced these results.

4. Ice, in the quantity used in this study, did not increase the percent survival in the May 23 evaluation. However, the trip duration for the truck utilizing the ice was approximately 1½-hours longer than that for the comparison trip. Also, abnormally low air temperatures may have masked any significant effect of using ice. Future evaluation of more efficient cooling systems might prove worthwhile (e.g. ice, insulation, refrigeration).

5. Gas supersaturation of tank water was not a problem in this study. Apparently the pressure relief mechanisms were working well.

6. The decreases in dissolved oxygen concentrations in the transport tanks were relatively consistent (2.5 to 3.2 ppm) on those days for which data are available. While oxygen does not seem to be limiting, experience with small shad demonstrated a positive response when <u>pure O_2 with little agitation</u> replaced aerators in the transport unit.

7. The low pH of the transportation tank was a contributing factor to maintaining un-ionized ammonia concentrations below toxic levels.

8. Carbon dioxide concentrations remained relatively low.

<u>SUMMARY OF TRANSPORT TANK WATER QUALITY AT TUNKHANNOCK RELEASE SITE</u>

Trip duration (hours)	6 2/3 to 10 1/3
% survival	41 to 64
pH (S.U.)	6.1 to 7.3
Alkalinity (mg/l)	27 to 187
Hardness (mg/l)	34 to 52
Carbon dioxide (mg/l)	10 to 17
Dissolved oxygen (mg/l)	6.4 to 7.0
% gas saturation	101
Temperature (°C)	15.0 to 17.5
Ammonia-N (mg/l)	2.2 to 3.6
Chloride (mg/l)	11 to 5889

Results of replicate tests on water conditioning factors studied and water quality parameters measured are provided on the following data sheets.

DAILY TRIP SUMMARY

May 21, 1983:

All equipment functioned well. Conditioning the water with salt yielded a higher percent survival even though the duration of the trip was approximately 1-1/3 hrs longer than that of the second truck with untreated water.

May 22, 1983:

Transportation Unit A with MS 222 and buffer added suffered a complete failure of one recirculating pump approximately four hours into the trip. The second pump failed periodically during the trip. The dissolved oxygen meter failed due to pinched line from the probe. The decrease in tank flow caused by the pump failures may have influenced the high mortalities observed in the transportation unit. Therefore, valid comparison is not possible.

May 23, 1983:

Transportation Unit A with a replacement recirculating pump was adjusted to the appropriate flow rate; however, after approximately 4 hours of operation it was necessary to readjust the pump. The second recirculating pump continued to fail periodically. The 100 lb of ice which was added directly to tank A resulted in a temperature increase of only 2.6^{o}C for the 9 hour trip, versus an increase of 3.9^{o}C in tank B which was not conditioned during its 7-1/2 hour trip.

May 24, 1983:

Due to confusion over stocking obligations at Vernon pool, truck B was loaded with 150 fish (as compared with 125 fish for truck A) thus introducing another variable into the comparison. Transportation unit A suffered complete failure of one of its recirculating pumps, resulting in reduced flow velocity in the tank. Truck A also suffered a mechanical failure thus increasing the trip duration.

Carbon Dioxide, mg/l

Date:	5/21/83	5/22/83	5/23/83	5/24/83[2]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	5[1]	5[1]	7[1]	5
A2	8[1]	10[1]	11[1]	12
A3	10	13	14	15
A4	10	10	13	16

Date:	5/21/83	5/22/83[3]	5/23/83	5/24/83[4]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	6	6	5	N/A
B2	13	12	10	13
B3	16	13	14	16
B4	17	14	13	15

1. Analysis performed at time of sample collection.
2. 124 fish transported.
3. 123 fish transported.
4. 150 fish transported.

Percent Gas Saturation

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	104	104	104	-
A4	101	101	101	-

Dissolved Oxygen, mg/l

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	10.2	10.2(10.2)[1]	9.2	N/A
A4	7.0	7.0(7.0)[1]	6.4	N/A
Δ	3.2	3.2	2.8	-

1. Adjusted for salinity.

Urea-N/Ammonia-N Ratio

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Sample				
A4	.27	.17	.33	.59
B4	.14	.32	.27	.62

Number of Fish Transported

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Truck				
A	125	125	125	124
B	125	123	124	150

Combined Loading and Transit Time (approx. hours)

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Truck				
A	9	7-3/4	9	N/A
B	10-1/3	7	7-1/2	6-2/3

Mortalities (% Survival)

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Truck				
A	73 (41%)	67 (46%)	53 (58%)	62 (50%)
Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Truck				
B	52 (58%)	44 (64%)	48 (61%)	57 (62%)

Alkalinity, mg/l (as $CaCO_3$)

Date:	5/21/83	5/22/83	5/23/83	5/24/83[1]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	21	21	18	23
A2	21	21	19	26
A3	23	189	21	33
A4	30	187	27	34

Date:	5/21/83	5/22/83[2]	5/23/83	5/24/83[3]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	21	20	20	N/A
B2	21	22	18	27
B3	22	22	20	30
B4	31	25	27	39

1. 124 fish transported.
2. 123 fish transported.
3. 150 fish transported.

Chloride, mg/l

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	14	148	6	6
A2	29	97	21	7
A3	28	636[1]	23	9
A4	34	688[1]	N/A	11

Date:	5/21/83	5/22/83	5/23/83	5/24/83
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	89	182	6	N/A
B2	50	115[1]	7	7
B3	5784[1]	120[1]	8	5315[1]
B4	5889[1]	130[1]	13	5628[1]

1. High range analysis procedure.

pH, S. U.

Date:	5/21/83	5/22/83	5/23/83	5/24/83[2]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	6.6[1]	6.7[1]	6.6[1]	6.5
A2	6.4[1]	6.3[1]	6.4[1]	6.0
A3	6.0	7.2	6.9	6.1
A4	6.1	7.3	6.2	6.1

Date:	5/21/83	5/22/83[3]	5/23/83	5/24/83[4]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	6.8	6.9	6.8	N/A
B2	6.2	6.3	6.2	6.1
B3	6.4	6.2	6.0	6.5
B4	6.6	6.4	6.2	6.7

1. Analysis performed at the time of sample collection.
2. 124 fish transported.
3. 123 fish transported.
4. 150 fish transported.

Ammonia-N, mg/l

Date:	5/21/83	5/22/83	5/23/83	5/24/83[1]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	0.10	0.12	0.08	0.04
A2	0.20	0.24	0.17	0.33
A3	0.85	0.83	0.84	1.47
A4	2.6	2.3 (.015)[4]	2.7	2.2

Date:	5/21/83	5/22/83	5/23/83	5/24/83[3]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	0.14	0.29	0.13	N/A
B2	0.35	0.40	0.30	0.41
B3	1.28	0.78	0.66	1.1
B4	3.6	2.8	2.9	2.9

1. 124 fish transported.
2. 123 fish transported.
3. 150 fish transported.
4. Un-ionized ammonia-N.

Urea-N, mg/l

Date:	5/21/83	5/22/83	5/23/83	5/24/83[1]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	0.13	0.05	0.08	0.19
A2	0.01	0.04	0.24	0.45
A3	0.10	0.17	0.34	0.09
A4	0.7	0.4	0.9	1.3

Date:	5/21/83	5/22/83[2]	5/23/83	5/24/83[3]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	0.13	0.12	0.19	N/A
B2	0.07	0.17	0.24	0.67
B3	0.34	0.37	0.19	1.1
B4	0.5	0.9	0.8	1.8

1. 124 fish transported.
2. 150 fish transported.
3. 123 fish transported.

Hardness, mg/l (as $CaCO_3$)

Date:	5/21/83	5/22/83	5/23/83	5/24/83[1]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
Sample				
A1	32	32	32	34
A2	36	32	32	34
A3	32	36	32	32
A4	36	40	36	34

Date:	5/21/83	5/22/83[2]	5/23/83	5/24/83[3]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
Sample				
B1	32	32	32	N/A
B2	32	32	32	30
B3	48	36	32	44
B4	52	36	36	48

1. 124 fish transported.
2. 123 fish transported.
3. 150 fish transported.

<u>Temperature, °C.</u>

Date:	5/21/83	5/22/83	5/23/83	5/24/83[1]
Conditioning Agent:	None	MS222 + Buffer	Ice	Ice
<u>Sample</u>				
A1	12.9	13.9	14.9	N/A
A4	16.5	17.5	17.5	N/A
△	3.6	3.6	2.6	-
Date:	5/21/83	5/22/83[2]	5/23/83	5/24/83[3]
Conditioning Agent:	Salt + Antifoam	None	None	Salt
<u>Sample</u>				
B1	12.8	N/A	11.1	N/A
B4	15.6	N/A	15.0	N/A
△	2.8	-	3.9	-

1. 124 fish transported
2. 123 fish transported
3. 150 fish transported

JOB II. AMERICAN SHAD EGG COLLECTION PROGRAM

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2.1 INTRODUCTION

The objective of the Shad Egg Collection Program was to obtain viable, artificially fertilized shad eggs to support the hatchery culture program operated by the Pennsylvania Fish Commission. Fish released from the hatchery will supplement the development of the shad population below the Conowingo Dam with the urge to migrate upstream past the dams to spawn. In 1982, 25.9 million eggs collected from East and West Coast rivers resulted in the release of 5.35 million fry and 41,000 fingerling shad. The SRAFRC goal for 1983 was to obtain 25 - 50 million eggs, based on the previous years' viability and production rate, to reach a target of 5 - 10 million fry and 50 - 100,000 advanced fry and fingerlings. Eggs were to be primarily collected from the James and Pamunkey rivers on the East Coast and the Columbia River on the West Coast. Other East Coast rivers were investigated for the feasibility of obtaining eggs and it was determined that efforts be limited to the Delaware and Hudson rivers. Operations on the Mattaponi River were terminated for 1983.

2.2 METHODS

2.2.1 Egg Collection

Eggs were collected from shad in spawning condition taken in gill-nets by commercial fishermen. Eggs were artificially fertilized in essentially the same manner established by Kilcer (1973), although minor revisions were employed. Modifications were made as a result of consultation with the PFC and fish culture experts on the West Coast. A brief description of the procedure follows.

Eggs were stripped from three or four spawning females into a dry collecting pan and fertilized with sperm from one or more males. After dry mixing eggs and sperm for several minutes, the eggs were allowed to set for 2-3 minutes to allow for optimum fertilization. A small amount of water was then added to the mixing pan and the gametes stirred, again. After the eggs settled, the water was drained and clean water added. This rinsing process was repeated 3-4 times to remove dead sperm, unfertilized and broken eggs, and debris. Fertilized eggs were then poured into large plastic buckets filled with clean river water and allowed to soak for several hours to become hardened. During this period, water was periodically drained, clean water added and agitated to provide aeration.

Once the eggs were hardened, the water was drained and debris, such as scales and sticks, removed. Then, five liters each of eggs and clean water was placed in a plastic bag which had an outer plastic bag for protection in shipping.

Pure oxygen was put into the bag containing eggs and the bag securely tied with two castrator rings. The package was then placed into styrofoam containers, sealed with tape and placed in cardboard boxes for shipment. Each box was labelled to show river name, date, number of liters of eggs, water temperature and ratio of females to males.

2.2.2 Collection Areas

2.2.2.1 Pamunkey River, Virginia

NES biologists began egg collection efforts on the Virginia rivers on 9 April 1983. Biologists worked with commercial fishermen at Thompson's Landing, New Kent, Virginia, located approximately 4-6 miles upstream from Lester Manor. This area has proven throughout the years to be a viable location for catching adult spawning shad. Netting was usually conducted between 1530 and 2200 hours from Monday through Sunday. NES biologists operated from the shoreline at Thompson's Landing. As fish were captured, fishermen brought adult shad to biologists on the shoreline as quickly as possible.

2.2.2.2 James River, Virginia

Experience in past years has proven that shad migrate up the James River to spawn when shad are completing spawning activity on the Pamunkey River. An overlap of approximately a week is not uncommon. Throughout the Pamunkey River Egg Collection Program, communication between commercial fishermen on the James and NES biologists was maintained, to determine when collection efforts on the James River should begin.

Egg collection efforts on the James River began on 26 April. There was an eight day period when both the James and Pamunkey rivers were fished simultaneously. The Berkley Plantation Landing on the James River was utilized for the program. Berkley Plantation is in the Charles City - Hopewell area of Virginia, just below the Benjamin Harrison Bridge.

Commercial fishermen using gill-nets and biologists worked together out of small row boats during egg collection operations, so eggs could be taken from spawning shad immediately. Gill-netting was conducted from 1530 to 2200 hours.

2.2.2.3 Hudson River

Shad egg collection on the Hudson River was conducted from 21 May - 2 June. Since previous years of egg collection on the Hudson River had not been highly successful, NES biologists and commercial fishermen experimented with various gear, times of day and locations in an attempt to net spawning shad. Initially, shad were inspected during the Adult Transfer Program (3-21 May) as to their state in regard to spawning condition. Once it was determined by NES biologists that shad were ripe, egg collection was initiated.

Intensive efforts for egg collection began on 21 May utilizing haul seines, gill-nets and sink nets at different times of the day. After three days, it was evident that a greater amount of spawning shad were taken between 1800 and 2200 hours and that gill and sink nets were by far more effective than the haul seine. Basically, the problems associated with the haul seine stem from the amount of manpower needed, the high number of fish taken per net and the liveliness of the fish. An expansion of these problems and sampling practices follows.

In regard to manpower - during haul seining operations a minimum of 10-12 persons plus one boat is necessary to complete the procedure. In gill or stake-netting, only 2 fishermen, a boat and one biologist are utilized. Also, the haul seine has the potential to capture up to 1,000 fish per seine which must be checked for spawning condition. During this period, high mortality can result. In addition, the fish taken from the haul seine are very lively, making them difficult to handle.

Throughout the operation, 21 May - 2 June, NES kept in contact with commercial fishermen from the area of Kingston-Rhinecliff Bridge to Catskill-Hudson, New York. The NYDEC also agreed to assist with the egg collection efforts. During their experimental haul seine operation for shad, the NYDEC and NES worked cooperatively on various nights. The NYDEC also supplied information as to the condition of shad captured either during their operations or from conversations with commercial fishermen.

Based on this information, it was decided that the best area to sample was the stretch of river from Coxsackie-Castleton area south to Kingston, NY. Commercial fishermen and NES biologists worked cooperatively out of small JON boats during the gill-netting operation. Fishermen drifted 500-750 foot gill-nets in the river channel, a distance of approximately five river miles. Monofilament nylon gill-nets with mesh sizes between 4.75 and 5.75 inches were drifted from a half hour to three hours, depending on tidal conditions and ship/barge traffic in the fishing area. Two or three drifts were made daily. At slack tide, 500-750 ft. by 20-25 ft. sink-nets with mesh size of 5½ inches were drifted perpendicular to the shoreline for approximatley one half hour.

2.2.2.4 Columbia River

The Egg Collection Program on the Columbia River (Washington and Oregon) for 1983 was expanded to a four-week period by the SRAFRC Technical Committee. Operations on the Columbia River in 1973-74, 1977 and 1981-82 indicated that it was a reliable source for eggs.

Three biologists with collection equipment were flown to Portland, Oregon on 3 June 1983. These biologists met with commercial fishermen on 6 June at a mooring area 15 miles east of Portland on the south shore of the Columbia River. Egg collection operations began on this date. Two boats were utilized.

Crews consisted of one commercial fisherman per boat and two biologists on one boat and one on another.

Netting for shad was conducted on the north shoreline approximately two miles upstream in an area known as the Camas-Washougal Reef. This reef is characterized by 10-30 foot water depths with rocky substrate and scattered logs and trees underlying the netting area. Shad were captured by two means. One boat utilized a 100 fathom x 1 fathom x 5 3/4 inch mesh nylon gill-net drifted downriver over the reef, while the other utilized a 100 fathom x 1½ fathoms x 5½ inch mesh monofilament gill-net. It was found that the monofilament net was by far more effective in fish capture as well as in increasing the catch of males. A series of two to five drifts were made, depending on the amount of fish available and drift time. Unlike the East Coast rivers, there is no tidal action on the Columbia River at Washougal Reef. The nets are drifted from the boat, with fishermen having to be very careful to avoid contact with sport fishermen, docks and debris.

2.2.2.5 Delaware River

An experimental effort was conducted on the Delaware River at the Smithfield Beach by personnel of the U.S. Fish and Wildlife Service, PA Fish Commission and a local volunteer group to collect American shad eggs. Smithfield Beach is located about 8 miles upstream NE from East Stroudsburg, PA.

The sampling program was initiated on 23 May and terminated on 3 June; a total of eight days effort was expended. Shad were captured by six anchored gill-nets (100 ft long, 5 ft deep, with 4½ - 5½ in. mesh). Nets were generally set between dusk and midnight. Fish were removed from nets and shuttled by boat to shore in wash tubs.

2.3 TRANSPORTATION

2.3.1 Pamunkey and James Rivers

Shad eggs collected from the Pamunkey and James rivers were transported by automobile, instead of by aircraft as in previous years. (See Quality Control section.) Eggs collected at the rivers were driven to Sandston, Virginia. Arrangements were made to deliver the eggs from Sandston to the Van Dyke Hatchery. NES personnel in Virginia notified the hatchery every evening to verify that there was a shipment, the estimated volume of eggs shipped and the ETA of the delivery. The average trip from Virginia to the hatchery was six hours.

2.3.2 Hudson - Delaware River

Egg shipments from the Hudson and Delaware rivers were transported in the same manner as in Virginia. Eggs were delivered by automobile from Hudson, NY to the Van Dyke Hatchery. On shipment nights, NES personnel would contact PFC - USF&WS collectors on the Delaware River to verify an egg delivery. On nights when eggs were collected from both rivers, NES personnel would deliver both the New York and Delaware River eggs to the hatchery. Shipments from the Hudson and Delaware rivers to the hatchery averaged 5 to 6.5 hours.

2.3.3 Columbia River

After packaging the eggs from the Columbia River, the boxes of eggs were transported by van to the United Airlines Freight Terminal at Portland International Airport. Eggs were delivered to the airport between 2215 and 2230 hours, five days per week, (Monday through Friday) and shipped United Airlines First Freight from Portland to Washington, D.C.

In previous years, eggs were shipped United Airlines Small Package Delivery to Baltimore. However, NES found it more feasible to ship eggs on United Airlines Air Freight to Washington. Air Freight to Washington, D.C. did not result in a plane change in Chicago, thus reducing handling and possible problems with connecting flights.

Upon arrival of egg shipments into Washington, D.C., eggs were transported by van to the hatchery. Approximate shipping time was 10-12 hours.

2.4 COLLECTION SCHEDULE

The shad egg collection schedule was based on experience gained over a ten year period. Initiation of collection activities on any river was determined through communication with commercial fishermen, who would inform NES when shad in spawning condition had been taken. Collection activities usually began when water temperatures reached 55 - 60°F (Table 1).

East Coast egg collection operations were terminated when less than 5 liters of eggs were taken on five consecutive nights. The West Coast operation was terminated when quality and quantity of eggs declined. Manpower allocation was based on the quantity of eggs collected and was decreased after the peak, however, at least one collector remained available until conditions for departure were met.

2.5 QUALITY CONTROL

In 1983 a cooperative effort was made to follow procedures proven effective in collection, artificial fertilization and shipment of American shad eggs. In previous years the viability of eggs from the East Coast rivers had been good, thus demonstrating that previous quality control measures were utilized. However, results of viability were disappointing on the Columbia River in 1981-82 and special measures were taken to assure improved viability for the entire program.

NES met with experts from various agencies to discuss how viability might be improved. It was agreed that minor revisions in the procedures of artificial fertilization be employed. NES worked closely with PFC personnel at the Van Dyke Research Center to maintain and improve, where possible, quality control relative to the egg collection operations. The following considerations were given to this matter:

(1) Egg collection procedures were reviewed in detail with various agencies before beginning egg collection efforts on both the East and West Coast rivers and minor revisions employed.

(2) Fishermen's equipment (nets) on the West Coast was modified to capture more male shad and decrease the male to female ratio. This was agreed by all agencies to be a major problem in previous years' efforts.

(3) Shipment procedures were evaluated and it was determined that transporting eggs by automobile from East Coast rivers, though more time consuming, would reduce handling as during air transport.

(4) Transferring shipment of West Coast eggs from United Airlines Small Package Delivery to United Airlines First Freight, thus eliminating the transfer of egg boxes in Chicago to another plane, consequently reducing handling and possible plane connection problems.

2.6 RESULTS

2.6.1 Pamunkey and James Rivers

Egg collection efforts on the Virginia rivers began on

9 April and continued throughout the duration of the annual adult spawning runs. More eggs were collected than in recent years. A total of 5.49 million eggs were collected from the Pamunkey River (Table 2). Water temperature during the period of collection ranged from 50 - 69° F. Pamunkey River eggs were sent to the Van Dyke Hatchery in eleven separate daily shipments from 11 April to 2 May (Table 4).

Some 5.91 million eggs were collected from the James River between 26 April - 17 May(Table 2). These were sent to the Van Dyke Hatchery in ten separate daily shipments (Table 5). Water temperature during this time ranged from 52-71° F.

In 1983 a total of 11,400,600 were collected from the two Virginia Rivers.

2.6.2 Hudson River

Throughout the month of May NES biologists in Hudson, NY checked the condition of shad captured during the Adult Transfer Program (Job I). On 21 May, biologists and New York commercial fishermen confirmed that shad had begun their annual spawning runs; water temperature was 59° F. Vigorous attempts to collect shad eggs from the Hudson River were made through a cooperative effort between NES, and NYDEC and commercial fishermen. Various gear, locations and sampling times were tested. It was found that gill and sink nets utilized between 1800 and 2200 hours were most effective. Egg collection efforts extended over a 35 - 40 mile stretch of river from Kingston, north to Coxsackie-Castleton, NY. The most eggs, since the initiation of egg collection on the Hudson River, were collected in 1983. A total of 1,172,400 shad eggs were delivered to the Van Dyke Hatchery over a ten day period (Table 2).

2.6.3 Delaware River

Over 2.6 million eggs were collected in efforts on the Delaware River (Table 2). Approximately 1.25 million (48%) were viable. Some 6.8% were shipped to the U.S. Fish and Wildlife National Fisheries Research Development Laboratory, Wellsboro, PA for the culture of shad to be used for experimental purposes while 19.6% were given to the local volunteer group involved with shad restoration efforts on the Lehigh River.

High river flows (excessive rainfall) and low water temperatures (low 50's) apparently disrupted the normal pattern of migration of shad to the upper Delaware River; shad were not present in large numbers on any predictable basis. In spite of this situation, over 600 adult shad (239 males and 322 females) were captured (Table 6).

2.6.4 Columbia River

Egg collection on the Columbia River was conducted for a seventeen day period from 6 - 28 June. The river water temperature during this time ranged from 59 to 64° F. Modifications in procedures and shipping were employed to help increase viaibility from the disappointing totals of the previous two years. Reports from the PFC indicate that viability was increased this year to approximately 55%. This is an improvement over that of 15% in 1981 and 31% in 1982. (For more information on viability data and discussion consult American Shad Culture and Research at the Pennsylvania Fish Commission Van Dyke Hatchery [Job III]).

A total of 19,509,600 eggs (Table 2) were sent to the Van Dyke Hatchery in 17 separate shipments (Table 7). Collection activities were cancelled on 28 June, when egg quality and quantity declined over a three day period.

2.6.5 All Rivers Combined

The entire shad egg collection operation was conducted on four East Coast rivers and the Columbia River (Oregon-Washington) between 9 April and 28 June. Over the three month period a total of 34,484,700 eggs were collected from the various rivers. Of these some 19.51 million were obtained from the Columbia River, while the four East Coast rivers combined produced 14.97 million. The Columbia River again produced the highest number of eggs (56%).

2.7 COMPARISONS WITH PREVIOUS YEARS' COLLECTION EFFORTS

The total number of eggs collected in 1983 was the largest number obtained since 1976 (Table 3). This is a result of the improved catches on the Pamunkey and James River, Virginia, the Hudson River, New York and the addition of the Delaware River. The Virginia Rivers' production was up 347% over last year, while the Hudson River produced its first eggs since its inclusion in the Program in 1981. The Delaware River was also an important addition to the Program, supplying 2.4 million eggs. Over the past eleven years, the reliability of the East Coast rivers as a source of eggs has been erratic. Though this year was a good year for the East Coast rivers, the Columbia River remains the most reliable source of artificially fertilized shad eggs.

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

RIVER	SAMPLING SCHEDULE DATES	TOTAL FISHING DAYS
Pamunkey	9 April - 3 May	23
James	28 April - 19 May	28
Hudson	21 May - 2 June	10
Columbia	6 June - 28 June	16
Delaware	23 May - 3 June	8

TABLE 2 Collection data of the total volume and number of American shad eggs taken on the Pamunkey, James, Hudson, Delaware and Columbia rivers, 1983*

River	Volume of Eggs Shipped (L)	Total Number of Eggs (Millions)
Pamunkey	145.9	5.49
James	154.7	5.91
Hudson	26.6	1.17
Delaware	49.0	2.40
Columbia	562.4	19.51
Totals	938.6	34.48

* Delaware and Hudson River egg data provided by Pennsylvania Fish Commission

TABLE 3 Total number (millions) of American shad eggs collected from the Pamunkey, Mattaponi, James, Potomac, Susquehanna, Delaware, Connecticut, Hudson and Columbia rivers, 1971-1983.

YEAR	PAMUNKEY	MATTAPONI	JAMES	POTOMAC	SUSQUEHANNA	DELAWARE	CONNECTICUT	COLUMBIA	HUDSON	TOTAL
1971	-	-	-	-	8.42	-	-	-	-	8.4
1972	-	-	-	-	7.00	-	-	-	-	7.1
1973	8.45	6.48	-	34.64	4.74	-	4.30	-	-	58.6
1974	9.75	6.80	19.20	5.56	-	-	0.53	8.18	-	50.0
1975	1.88	-	7.15	5.70	-	-	-	18.42	-	33.2
1976	-	-	-	-	-	4.10	-	54.80	-	58.9
1977	4.40	0.57	3.42	-	-	-	0.35	8.90	-	17.6
1978	6.90	-	10.11	-	-	-	-	-	-	17.0
1979	3.17	-	4.99	-	-	-	-	-	-	8.2
1980	6.73	-	6.83	-	-	-	-	-	-	13.6
1981	4.58	-	1.26	-	-	-	-	5.78	-	11.6
1982	2.03	-	1.25	-	-	-	-	22.57	-	25.8
1983*	5.49	-	5.91	-	-	2.40	-	19.51	1.17	34.48

* 1983 data on numbers of eggs collected provided by Pennsylvania Fish Commission

TABLE 4 Collection data for American shad eggs taken on the Pamunkey River, 1983.

Collection date	Water Temperature (°F)	Number of Adult Shad		Estimated Volume of Eggs Shipped (in liters)	Weather Conditions Air Temp (°F)	Number of Commercial Fishermen And Boats	
		Male	Female			Fishermen	Boats
April 11	55	13	42	20	cloudy 35-40	2	1
12	56	23	50	30	clear, calm 40-45	5	3
14	55	6	16	5	warmer, windy 45-48	2	1
24	55	10	25	10	drizzle, calm 51-53	2	1
25	53	6	19	5	very windy 50-53	3	2
26	56	10	24	15	windy, clear	3	2
27	57	14	33	20	calm, clear 60-61	2	1
28	60	12	33	17	calm, clear 78-80	3	2
29	62	11	37	15	calm, clear 78-80	2	2
30	64	14	33	5	calm, clear 70-75	2	1
May 2	68	6	21	10	calm, clear 70-75	3	2

TABLE 5 Collection data for American shad eggs taken on the James River, 1983.

Collection date	Water Temperature (°F)	Number of Adult Shad		Estimated Volume of Eggs Shipped (in liters)	Weather Conditions Air Temp (°F)	Number of Commercial Fishermen And Boats	
		Male	Female			Fishermen	Boats
April 26	60	1	1	1	windy, clear 60-61	2	1
28	60	2	4	3	calm, clear 78-80	2	1
29	64	19	35	20	calm, clear 78-80	2	1
30	66	18	41	27	calm, clear 70-75	2	1
May 6	70	13	26	14	cool, calm 62-64	4	2
7	71	15	40	25	windy, cool 42-44	4	2
9	68	12	47	23	cool, calm 47-49	2	1
10	69	13	40	20	cool, calm 55-57	4	2
11	69	6	16	10	windy, cool 60-63	2	1
17	69	14	39	20	cool, calm 65-66	4	2

TABLE 6 Collection data for American shad eggs taken on the Delaware River, 1983.

DATE	NET SET TIME	NET PULL TIME	WATER TEMP °F	RIVER CONDITIONS	# MALES	#GREEN FEMALES	#SPENT FEMALES	#RIPE FEMALES	TOTAL FISH	TOTAL EGGS(L)	DESTINATION
5/23	20:00	23:00	63	Cloudy (rained all night)	16	5	0	9	30	2.5	Lehigh River
5/24	19:45	23:30	63	Cloudy	32	4	0	12	48	2.5	Lehigh River
5/25	19:30	23:30	64	Slightly Cloudy	84	1	0	23	108	7.1	Van Dyke
5/26	19:30	23:30	63	Cloudy	58	1	10	59	128	13.9	Van Dyke
5/31	20:00	24:00	59	High (up 2') and Cloudy	25	6	10	28	69	9.95	5.95 Van Dyke 4.00 Wellsboro
6/1	20:00	24:00	59	Cloudy (6"-1' lower)	19	1	12	15	47	5.72	4.22 Van Dyke 1.50 Lehigh River
6/2	20:30	24:00	61	Cloudy (6"-1' lower)	26	2	14	34	76	7.64	6.14 Van Dyke 1.50 Lehigh River
6/3	19:45	23:45	63	Cloudy 6"-1' lower)	29	2	12	62	105	15.74	11.74 Van Dyke 3.50 Lehigh River 0.50 Lamar
TOTALS					289	22	58	242	611	65.05	(2.6 million)

TABLE 7 Collection data for American shad eggs taken on the Columbia River, 1983.

Collection date	Water Temperature (°F)	Number of Adult Shad		Estimated Volume of Eggs Shipped (in liters)	Weather Conditions Air Temp (°F)	Number of Commercial Fishermen And Boats	
		Male	Female			Fishermen	Boats
June 6	62	52	160	50	clear, breezy 60's	2	2
7	63	32	120	50	clear, breezy high 60's	2	2
8	62	27	101	45	cloudy, windy low 60's	2	2
9	62	31	129	55	cloudy, drizzle high 50's	2	2
10	61	30	95	40	cloudy, drizzle low 60's	2	2
13	61	38	129	55	sunny, clear low 70's	2	2
14	62	40	132	45	rain high 50's	2	2
15	61	45	144	62	cloudy, breezy low 60's	2	2
June 16	61	28	95	40	cloudy high 60's	2	2
17	62	22	71	25	showers, breezy high 50's	2	2
20	59	24	95	45	rain high 50's	2	2
21	63	25	115	40	cloudy, calm low 70's	2	2
22	61	15	70	15	rain high 60's	2	2
27	64	30	80	30	sunny, breezy low 70's	1	1
28	64	8	12	10	rainy, windy low 60's	1	1

JOB III. AMERICAN SHAD HATCHERY OPERATIONS AND CULTURAL RESEARCH

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INTRODUCTION

The Pennsylvania Fish Commission continues to operate the Van Dyke Anadromous Fish Research Station as part of an effort to restore diadromous fishes to the Susquehanna River system. The objectives of the Van Dyke Station are to develop culture techniques for American shad and to rear juveniles, both fry and fingerlings, for release into the Juniata River. 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. During 1983, the Van Dyke Station incubated a record 34.5 million eggs and released 4.1 million juvenile American shad. In addition, studies conducted in 1983 described the period of developmental transition from endogenous to exogenous nutrition in larval shad, and initiated the development of culture techniques and optimum stocking densities for rearing shad in ponds and raceways. All fish stocked were exposed to phenethyl alcohol, an imprinting agent to be used as a chemical attractant at the Conowingo Dam fish collection facility.

This years effort was supported by funds provided from the settlement agreement between Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, the Pennsylvania Fish Commission, and the Susquehanna River Basin Commission.

Egg Collection, Shipment and Incubation Data

The Van Dyke Research Station received a record 34.5 million American shad eggs in 1983. There were 40 egg shipments, two of which were transferred to Lamar Fish Cultural Development Center (1.3 million eggs) (Table 3-1). National Environmental Services, Incorporated, primarily responsible for egg collection, provided eggs from four sources: the Pamunkey and James Rivers in Virginia, the Hudson River in New York, and the Columbia River, Oregon. The U. S. Fish and Wildlife Service provided eggs from the Delaware River with assistance from the Pennsylvania Fish Commission, the Lehigh River Preservation, Protection and Improvement Foundation, and the Delaware River Shad Fishermen's Association.

The traditional egg sources, the Pamunkey and James Rivers, produced exceptionally well this year, yielding 11 million eggs (330.6 liters) with a 71 percent viability. From April 11 to May 2, the Pamunkey River provided 5.5 million eggs of which 71.8 percent were viable. James River egg shipments began April 26 and continued longer than in past seasons, ending May 17. The James River produced 5.9 million eggs of which 69.6 percent were viable.

An exploratory egg collection effort, conducted on the Hudson and Delaware Rivers, provided 1.2 and 2.4 million eggs respectively. Egg collection on the Hudson River began May 23 and ended May 31. Egg viability was rather high at 72.6 percent. Delaware River eggs were collected from May 25 to June 3. Viability of Delaware River eggs was variable; 13.4 to 82.1 percent, and averaged 48 percent. It was felt that the poor viability in some lots of Delaware River eggs was associated with the use of sperm from dead males or males in poor condition. Both rivers showed promise as future egg sources.

The Columbia River produced 19.5 million eggs during 1983. The potential for a greater egg collection effort existed since eggs were available both prior to and following the June 6-22 collection period. Egg viability was much improved over the past 2 years, averaging 48.2 percent. The ratio of males to females used during the spawning operation was improved this year (from one to 20 in 1981 and 1982, to one to three in 1983) and appears to have been responsible for the improved egg viability.

The egg collection effort in 1983 was successful in many aspects. A record 34.5 million eggs were collected. Average egg viability was 55.6 percent, and resulted in 19.2 million viable eggs (Table 3-2). It was demonstrated that a large number of "quality" eggs could be successfully collected over an extended period of time, April through June, by systematically utilizing the various river systems. In addition, problems such as the use of milt from dead males to fertilize eggs, and the use of milt from one male to fertilize the eggs collected from more than three females have been recognized, and hopefully, will not be repeated in future collection efforts.

Production

Thirty stockings in 1983 resulted in the release of 4.1 million juvenile American shad (Table 3-3); 4 million fry, 8 to 31 days of age (Table 3-4), and 98,000 fingerlings (1 inch or greater in length) (Table 3-5). The fish were stocked in good condition at the Pennsylvania Fish Commission's Thompsontown Access Area, Muskrat Springs Access Area, and Amity Hall Access Area. Shad stocked were exposed to the chemical attractant phenethyl alcohol, which was administered at a concentration of 1 x 10^{-4} ppm for 12 hours each day during the period the fish were cultured in tanks. Additionally, the Van Dyke Station provided 72,000 fry to Skip Bason of the Delmarva Ecological Laboratory, and 5,000 to 6,000 fingerlings to the Lamar Fish Cultural Development Center for study purposes.

The major sources of fingerlings were the canal-pond at Thompsontown and the Benner Spring Fish Research Station. The canal-pond was double-cropped this year and resulted in the release of an estimated 72,000 fingerlings directly into the Juniata River. An additional 21,000 fingerlings were released from the Benner Spring facility following density studies in ponds and raceways, and handling and transport evaluations. The Van Dyke facility produced 5,000 fingerlings for planting into the Juniata River.

The hatchery did sustain higher than normal fry mortality this season with 21.6 percent of the viable eggs eventually resulting in stocked fish (Table 3-6). There were exceptions to the low survival. Virginia river fry, cultured early in the season, comprised most of the fry stockings (Figure 3-1). In addition, fry hatched from the last few Columbia River egg shipments did well and were used for fingerling production (Figure 3-2). Fry survival during the middle of the production season, which included Delaware and Hudson River fish, was low (Figures 3-3 and 3-4).

Several steps were taken in an effort to alleviate, or at least define, the cause of the unusually high mortality of cultured fry. Initially, a pathological examination and a water quality survey (pH, alkalinity, dissolved oxygen, hardness, total dissolved oxygen, hardness, total dissolved oxygen, gas saturation, and heavy metals) were conducted. Neither resulted in conclusive findings, although trace amounts of copper were detected. Two tests were also conducted, one testing the effects of a buffered water supply and the second, the effects of an antibiotic on survival of cultured fry. Finally, differences in survival of fry hatched from Columbia River eggs were examined in an attempt to define a cause/effect relationship.

Buffering the water supply was tested because Van Dyke's water supply is soft (pH was approximately 6 to 7 S.U.), and had little buffering capacity (alkalinity 4 to 10 ppm). The test was designed to determine the effect, if any, of adding buffers (sodium bicarbonate and calcium chloride) to the water (Tables 3-7 and 3-8). Test results were inconclusive since larval survival was similar in test and control tanks.

Since procedures used in isolating systemic bacterial pathogens were limited for larval fishes, a test was designed to determine if a non-specific drug treatment (water soluble neomycin sulfate) would affect survival. At the end of the test larval survival was higher in test tanks (20.6 percent) than in controls (8.4 percent), although low survival in all units indicated that neomycin sulfate was ineffective in reducing the unusually high mortality experienced during the 1983 season (Table 3-9).

Fry hatched early and late in the season followed a "normal" mortality pattern similar to that documented in past years. The sudden improvement in Columbia River survival led to attempts to define a cause/effect relationship. Standard operating procedures had not changed except that the water heating system (thermostatically controlled) was turned off for the season on June 26. All egg shipments received after June 26 exhibited a "normal" mortality pattern (Table 3-10). Survival for fry from the 10 Columbia River shipments received prior to June 26 was 18.8 percent at 18 days of age compared to 59.8 percent for the three egg shipments received after June 26 (Figure 3-5). Mean survival for Columbia River fry in 1982 was 59.7 percent. It is possible that gas supersaturation, caused by heating water may have been responsible for the high fry mortality in 1983.

Facility Improvements

Continued expansion of the hatchery's production goal resulted in the necessity to make facility improvements. Anticipating larger numbers of fish to feed in 1983, a second brine shrimp unit was temporarily added resulting in a 25 percent increase in the production of brine shrimp. Although the additional unit was beneficial, a more streamlined and efficient means of mass producing brine shrimp must be developed to adequately feed ever increasing numbers of fish. Two live food feeders and accessory equipment were installed on all rearing units to better handle the large quantities of feed and to increase feed availability to the fish. The feeders would run more efficiently with the addition of a second air blower which would increase air pressure in the lines.

Research

The following section contains a brief synopsis of the conclusions derived from research conducted in 1983. Each study, including pertinent data, is presented in Appendix III-A.

This year's research defined many aspects in the survival and feeding of larval American shad. The prolarval stage lasted 5 to 6 days characterized by retention of the yoke sac. At 5 days exogenous feeding began although a large percentage of the larvae appeared not to be feeding. The first-feeding larvae demonstrated a size preference when feeding on brine shrimp, generally selecting organisms smaller than the mean. There appeared to be a defined avoidance of larger organisms which comprised approximately 13 percent of the feed. Diel variations in the feeding intensity of first-feeding larvae were noted. The highest level of feeding intensity occurred during the evening (1800-2100 hours) and the lowest level at night (2300-600 hours). Feeding efficiency and intensity increased when larvae were reared in continuous light. There appears to be a period where feeding intensity and growth do not increase, 10 to 14 and 11 and 16 days respectively. An age-specific survival rate demonstrated a period of high larval mortality from 9 to 14 days of age, which closely paralleled the periods when growth and feeding intensity did not increase. These data suggest that survival of cultured larvae may be dependent on the success of first-feeding larvae.

The optimum stocking density when rearing shad to fingerling size appeared to be between 1.9 and 3.1 fish per liter for raceways, and between 160,300 and 246,500 per hectare for ponds. It was also determined that fingerlings could be crowded and transported from raceways with less than 0.7 percent handling mortality after 48 hours. Handling mortality was slightly higher for ponds, averaging less than 3 percent after 48 hours. Approximately 80-95 percent of the ponded shad were successfully harvested. More fish could probably be harvested if the ponds drained completely.

A manuscript written from a study conducted at the Van Dyke Station in 1982, "The Influence of Rolling on the Hatch of American Shad Eggs" by Wiggins et al., 1984, will be published in the Progressive Fish-Culturist, Volume 46(1).

Summary

The Pennsylvania Fish Commission continued to operate the Van Dyke Research Station as a part of the diadromous fish restoration effort on the Susquehanna River drainage. The scope of the Van Dyke program included: incubation and hatch of American shad eggs; rearing and releasing juvenile fish, and the development of more effective culture techniques. Changes improving and broadening the egg collection effort resulted in the incubation of a record 34.5 million American shad eggs at the station. A total of 4.1 million juvenile American shad, 4 million fry and 98,000 fingerlings, were cultured and released in 1983 at three sites on the Juniata River. All fish were exposed to a chemical imprinting agent, phenethyl alcohol, to be used as an attractant at the Conowingo Dam fish collection facility. Studies in 1983 on larval shad began to define the period of first-feeding larval development which may result in more effective feeding regimes and improved larval survival. In addition, culture techniques and optimum stocking densities for both pond and raceway culture of fingerlings are being developed. Including fish released in 1983, a total of 19.4 million juvenile American shad have been released into the Susquehanna drainage since 1976.

RECOMMENDATIONS FOR 1984

1. Culture of 10 million 18-day old American shad followed by direct planting into the Juniata River as river conditions become suitable. To attain this goal, 30 million viable eggs must be provided. The Van Dyke Station can handle 8 million eggs per week.

2. Culture of 200,000 fingerlings (1-inch or larger) using the canal pond at Thompsontown and the Benner Spring Complex.

3. To facilitate the future increases in production and to reduce the likelihood of the recurrence of the high larval mortality experienced in 1983, the following facility improvements are suggested:

   a) 30 to 40 gal/min river water pumped to the warming pond.
   b) Ultraviolet light treatment that can handle 80 gal/min with easy maintenance (removable cover for cleaning).
   c) Air blower to supply live food feeders.
   d) Installation of 6 tanks and an appropriate shelter, wiring, plumbing and platform.
   e) Brine shrimp incubation room with heat, water and electric (possibly a small extension to the furnace room).
   f) Vacuum degasser which can handle 80 gal/min.
   g) Electric pump with float valve at canal pond.

4. Continue research into larval culture techniques, pond density studies and juvenile transportation studies (to be conducted at the Van Dyke facility and the Benner Spring complex).

5. Continue imprinting efforts at Van Dyke using phenethyl alcohol, and coordinate the dispensing of this chemical attractant at the Conowingo fish collection facility (provide pump, chemical, expertise).

6. Evaluate spawning success/potential of adult shad in the circular pond at the Benner Spring Fish Research Station.

ACKNOWLEDGEMENTS

The culture and research duties at the Van Dyke facility intensify each spring causing long, hectic and irregular days. Operation of the facility remained smooth and controlled in 1983, primarily due to the individual efforts of its seasonal employees. A special thanks has to be given to Dave Hampton who has returned each year for 6 years, and John Coll who has returned for 2 years. Both employees have brought with them, not only the willingness to work, but the experience of past years' efforts. Jim Whittington, starting his first season at Van Dyke after serving an internship, followed the patterns set by Dave and John and was soon contributing greatly to the effort. The program's accomplishments would be drastically reduced without the aid and hard work of these individuals.

The Benner Spring staff, and in particular Dave Truesdale and Joe O'Grodnick, must also be thanked for their quick response and contributions when unexplained problems occurred.

TABLE 3-1

VAN DYKE

AMERICAN SHAD EGG DATA

1983

Shipment Number	River	Date Taken	Date Received	Vol. (ℓ) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
1	Pamunkey	4/11	4/12	18.0	659,100	82.0	540,700	434,500
2	Pamunkey	4/12	4/13	25.2	928,700	64.4	598,100	365,100
3	Pamunkey	4/14	4/15	5.5	196,600	80.2	157,700	157,700
4	Pamunkey	4/24	4/25	11.4	447,400	66.2	296,200	293,800
5	Pamunkey	4/25	4/26	5.5	369,200	52.2	192,900	192,600
6	Pamunkey	4/26	4/27	12.4	407,100	63.0	256,300	225,300
	James	4/26	4/28	0.4	14,700	63.3	9,300	-
7	Pamunkey	4/27	4/28	21.1	948,000	75.4	714,900	699,700
8	Pamunkey	4/28	4/29	16.3	503,500	83.9	422,400	421,300
	James	4/28	4/29	2.3	78,400	65.4	51,300	-
9	Pamunkey	4/29	4/30	16.1	589,300	71.1	419,100	860,900
	James	4/23	4/30	19.9	742,600	59.5	441,800	-
10	Pamunkey	4/30	5/1	4.8	150,400	78.5	118,000	679,300
	James	4/30	5/1	27.4	1,002,500	69.4	695,700	-
11	Pamunkey	5/2	5/3	9.6	291,800	77.8	226,900	226,200
12	James	5/6	5/7	14.6	472,600	75.2	355,400	327,500
13	James	5/7	5/8	23.8	1,014,600	76.6	777,300	687,300
14	James	5/9	5/10	21.6	764,600	75.5	577,200	488,000
15	James	5/10	5/11	16.2	687,500	58.2	400,400	373,100
16	James	5/11	5/12	8.3	325,800	74.8	243,800	231,800
17	James	5/17	5/18	20.2	806,200	69.7	562,100	476,000
18	Hudson	5/23	5/24	6.0	182,400	70.1	127,800	124,400

TABLE 3-1 (CONTD.)

VAN DYKE

AMERICAN SHAD EGG DATA

1983

Shipment Number	River	Date Taken	Date Received	Vol. (ℓ) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
19	Hudson	5/24	5/25	5.5	394,000	*		60,000*
20	Hudson	5/25	5/26	6.0	225,000	82.1	184,700	172,200
	Delaware	5/25	5/26	7.1	279,500	81.6	228,000	227,900
21	Delaware	5/26	5/27	13.9	653,300	13.4	87,700	67,600
22	Hudson	5/31	6/1	3.0	118,500	68.2	80,800	79,200
	Delaware	5/31	6/1	6.0	265,600	54.1	143,800	140,600
23	Hudson	6/1	6/2	6.1	252,500	68.0	171,800	171,100
	Delaware	6/1	6/2	4.2	174,700	77.6	135,500	135,000
24	Delaware	6/2	6/3	6.1	368,700	49.5	182,400	180,700
25	Delaware	6/3	6/4	11.7	660,300	56.8	375,300	366,500
26	Columbia	6/6	6/7	50.4	1,861,400	48.0	892,800	777,400
27	Columbia	6/7	6/8	52.2	1,834,400	39.6	726,900	657,800
28	Columbia	6/8	6/9	42.9	1,491,100	47.9	714,500	679,900
29	Columbia	6/9	6/10	58.1	1,854,500	52.9	981,300	879,800
30	Columbia	6/10	6/11	41.6	1,347,800	47.8	644,900	608,500
31	Columbia	6/13	6/14	52.5	1,754,900	54.0	948,600	935,700
32	Columbia	6/14	6/15	47.1	1,573,900	59.5	936,800	891,900
33	Columbia	6/15	6/16	59.3	1,901,600	44.3	843,300	813,000
34	Columbia	6/16	6/17	40.0	1,331,100	44.9	597,400	576,900
35	Columbia	6/17	6/18	19.6	668,400	35.7	238,700	226,100
36	Columbia	6/20	6/21	43.9	1,601,900	42.3	677,500	645,600
37	Columbia	6/21	6/22	33.8	1,520,700	52.9	805,100	730,800
38	Columbia	6/22	6/23	21.0	767,900	52.2	400,700	392,800

*Shipment Number 19 - a large percentage of the eggs received did not water harden precluding accurate egg viability estimates. The number of fry is an estimate.

TABLE 3-2

VAN DYKE

1983

AMERICAN SHAD EGG TOTALS

Total (all rivers)

Number of shipments	38
Number of eggs received	34,484,700
Volume of eggs received	938.6 ℓ
Average percent viability	55.6
Total number of viable eggs	19,183,800
Number of fry	17,681,500
Number of fry stocked	4,047,610

Totals (broken down by river)

Pamunkey River

Number of eggs received	5,491,100
Volume of eggs received	145.9 ℓ
Percent viability	71.8
Total number of viable eggs	3,943,200

James River

Number of eggs received	5,909,500
Volume of eggs received	154.7 ℓ
Percent viability	69.6
Total number of viable eggs	4,114,300

Hudson River

Number of eggs received	1,172,400
Volume of eggs received	26.6 ℓ
Percent viability	72.6
Total number of viable eggs	565,100*
Number of fry	606,900**

Delaware River

Number of eggs received	2,402,100
Volume of eggs received	49.0 ℓ
Percent viability	48.0
Total number of viable eggs	1,152,700
Number of fry	1,118,300

Columbia River

Number of eggs received	19,509,600
Volume of eggs received	562.4 ℓ
Percent viability	48.2
Total number of viable eggs	9,408,500
Number of fry	8,816,200

*Shipment #19 is not included because of inability to accurately access low egg viability on eggs which do not water harden.

**Reflects estimates of fry hatch from shipment #19.

TABLE 3-3

SUMMARY OF VAN DYKE PRODUCTION

1976-1983

	1976	1977	1978	1979	1980	1981	1982	1983
Volume of Eggs Received (liters)	120.3	145.8	381.2	164.8	347.6	286.0	624.3	938.6
Number of Eggs Received (millions)	4.0	6.4	14.5	6.4	12.5	11.6	25.9	34.5
Egg Viability (percent hatch)	52.0	46.7	44.0	41.4	65.6	44.9	35.7	55.6
Number of Viable Eggs (millions)	2.1	2.9	6.4	2.6	8.2	5.2	9.2	19.2
Shad Stocked								
Fry (up to 1")	518,000	968,901	2,124,000	629,500	3,526,275	2,029,650	5,018,800	4,047,61
Fingerling (1" and larger)	266,000	34,509	6,379	34,087	5,050	23,620	40,700	98,30
TOTAL	784,250	1,003,410	2,130,379	663,587	3,531,325	2,053,270	5,059,500	4,145,91
Percent of Eggs Received which were eventually stocked	19.4	15.9	14.0	10.4	28.3	17.7	19.6	12.0
Percent of Viable Eggs which were eventually stocked	37.3	34.2	33.0	25.1	43.1	39.3	54.8	21.6

Total Shad Stocked from 1976 to 1983 - 19,371,310

TABLE 3-4

VAN DYKE HATCHERY

SUMMARY OF STOCKING ACTIVITIES

1983

FRY STOCKINGS

Date	Age (Days)		Number
5/13	25		163,100
5/14	27		191,900
	23		85,100
5/15	17		200,000
5/22	22		251,500
5/29	26		25,700
5/31	30		27,800
6/1	30		91,800
6/2	21		375,000
	26		50,900
	29		289,900
	31		132,500
6/3	18		220,300
	19		259,300
	21		70,800
6/13	21		23,000
6/14	22		40,000
6/15	17		13,300
	15		10,000
6/18	19		59,200
6/19	18		10,000
	13		207,400
6/20	12		73,400
	13		71,800
	21		32,100
6/21	8		54,800
	12		295.500
6/22	19		275,300
6/25	13		189,300
6/26	13		20,400
	14		48,200
7/2	18		45,000
7/5	19		42,000
	19		75,000
7/12	21		26,300
		TOTAL	4,047,600

TABLE 3-5

VAN DYKE HATCHERY

SUMMARY OF STOCKING ACTIVITIES

1983

FINGERLING STOCKINGS

Date	Age (Days)	Size (Inches)		Number
7/10	Not Known	1.5		1,400
7/13	59	1.5		1,750
7/15	70	1.5		52,000
8/30	69	2.0		3,850
8/31	63	1.0		700
9/14	78	1.5-2.0		20,000
9/16	82	2.0		1,100
10/05	98-99	2.0-2.8		17,500
			TOTAL	98,300

TABLE 3-6

VAN DYKE

1983

MEAN PERCENT FRY SURVIVAL

	River(s)			
Age (days)	Pamunkey and James	Hudson	Delaware	Columbia
1	96.2	99.4	98.2	97.0
2	88.2	96.7	96.2	94.3
3	85.9	96.3	95.0	93.3
4	84.8	95.9	93.1	93.1
5	84.3	95.5	91.6	92.9
6	83.7	95.1	89.6	92.5
7	83.2	94.5	88.2	92.2
8	82.5	93.0	86.8	91.7
9	81.4	91.7	85.1	89.2
10	80.2	87.9	81.1	81.2
11	77.7	74.9	72.7	66.5
12	74.3	63.2	63.9	48.7
13	70.8	55.3	59.7	36.7
14	66.9	46.6	54.8	30.0
15	63.0	37.4	39.4	27.4
16	59.3	19.8	25.7	26.4
17	55.8	8.0	12.4	25.9
18	51.6			25.5
19	47.6			25.3
20	42.0			25.1
21	37.1			24.9
22	32.1			24.6
23	28.3			24.3
24	25.1			24.2
25	21.9			24.0
26	19.2			23.8

TABLE 3-7

VAN DYKE

1983

BUFFERED WATER TEST

Water Quality Parameters

Sample Collection Date	pH (S.U.)			Alkalinity (mg/l)			Hardness (mg/l $CaCO_3$)		
	Trough	Untreated Tank	Treated Tank	Trough	Untreated Tank	Treated Tank	Trough	Untreated Tank	Treated Tank
7/3	6.3	6.3	6.3	9.2	8.9	8.9	16	14	14
7/5	6.4	7.1	8.6	9.2	9.2	28.7	16	14	29
7/7	6.7	6.7	6.7	9.2	8.9	17.4	12	14	14
7/9	6.7	6.5	6.6	7.0	6.0	8.0	14	16	16
7/11	6.5	6.7	6.6	6.0	6.0	7.0	16	16	18
7/13	6.6	6.7	6.8	6.0	6.0	9.0	16	16	16
7/15	6.4	6.6	6.6	9.0	9.0	9.0	16	18	18

TABLE 3-8

VAN DYKE

1983

BUFFERED WATER TEST

Mean Percent Fry Survival

Age (days)	Control Tanks #1	Control Tanks #2	Control Tanks #3	Control Tanks Mean	Test Tanks #1	Test Tanks #2	Test Tanks #3	Test Tanks Mean
1	-	96.4	-	98.9	-	96.1	98.8	98.2
2	95.9	96.2	83.2	90.9	97.2	95.7	98.5	97.2
3	95.6	96.1	82.7	90.6	97.0	95.6	98.3	97.1
4	95.6	95.9	82.6	90.5	96.9	95.5	98.2	97.0
5	95.6	95.7	82.4	90.4	96.8	95.4	98.2	96.9
6	95.6	95.7	82.3	90.3	96.6	95.3	98.0	96.8
7	95.5	95.6	82.2	90.2	96.5	95.3	97.7	96.7
8	95.2	94.8	82.1	89.8	95.2	94.9	96.7	95.8
9	92.0	91.9	80.9	87.5	85.9	93.1	95.5	92.1
10	85.9	69.1	80.1	78.5	73.0	88.0	87.0	83.6
11	63.9	49.3	79.6	65.8	58.9	76.0	68.3	68.5
12	38.8	43.3	79.1	56.5	53.0	58.7	57.3	56.8
13	27.7	41.2	78.6	52.4	50.0	46.4	55.2	50.9
14	25.6	40.1	77.9	51.3	47.9	44.6	54.5	49.4
15	24.9	39.7	77.5	50.9	46.5	44.0	54.0	48.6
16	24.5	39.4	77.1	50.5	45.6	43.7	53.6	48.1
17	24.4	39.3	76.8	50.3	45.0	43.6	53.4	47.8
18	24.3	39.2	76.4	50.1	44.4	44.3	53.3	47.5

Mean Density: Control Tanks - 343,800
Test Tanks - 349,600

TABLE 3-9

VAN DYKE

1983

DRUG TREATMENT TEST

Mean Percent Fry Survival

Age (Days)	Control Tanks #1	#2	#3	Mean*	Test Tanks #1	#2	#3	Mean
1	-	97.3	-	-	-	93.1	99.3	97.5
2	98.0	7.5	96.1	96.9	99.3	91.7	90.7	93.8
3	97.7	6.3	91.4	94.9	98.2	91.4	89.8	93.0
4	97.5	6.3	91.0	94.6	97.7	91.3	89.6	92.7
5	97.4	6.3	90.7	94.4	97.3	91.2	89.5	92.5
6	95.1	6.3	90.4	92.6	97.1	91.1	89.4	92.4
7	95.0	6.2	90.3	92.5	97.0	91.0	89.3	92.3
8	95.0	6.2	88.9	91.9	96.9	90.7	88.9	92.0
9	94.8	5.8	82.6	89.3	96.8	82.9	83.7	87.5
10	94.3	4.3	64.1	81.8	96.0	48.6	69.6	79.5
11	87.5	2.5	41.5	68.0	93.2	35.5	57.5	70.0
12	71.1	0	3.4	41.0	67.9	23.3	36.2	50.5
13	48.1	0	0	22.5	46.7	11.9	29.8	37.8
14	34.0	0	0	12.0	35.4	0	27.8	28.3
15	29.7	0	0	8.7	20.4	0	27.1	23.3
16	29.3	0	0	8.5	16.1	0	26.8	21.8
17	29.2	0	0	8.4	13.6	0	26.5	20.9
18	29.2	0	0	8.4	12.9	0	26.2	20.6

Mean Density: Control Tanks - 225,200
Test Tanks - 355,900

*Mean of Control Tanks #1 and #3

TABLE 3-10

VAN DYKE

1983

MEAN PERCENT FRY SURVIVAL (COLUMBIA RIVER)
IN HEATED VS NON-HEATED WATER SOURCE

	Water Treatment	
Age (Days)	Heated Water	Non-Heated Water
1	96.8	95.0
2	93.7	94.1
3	92.6	93.6
4	92.4	93.2
5	92.3	92.5
6	92.0	91.6
7	91.8	90.6
8	91.3	90.0
9	88.6	88.8
10	80.3	83.5
11	64.9	74.4
12	45.2	66.8
13	31.6	62.4
14	24.4	61.3
15	21.0	60.8
16	19.8	60.3
17	19.2	60.0
18	18.8	59.8
19	18.6	59.6
20	18.4	59.4

FIGURE 3-1
VAN DYKE
1983
FRY SURVIVAL - JAMES AND PAMUNKEY RIVER ORIGIN

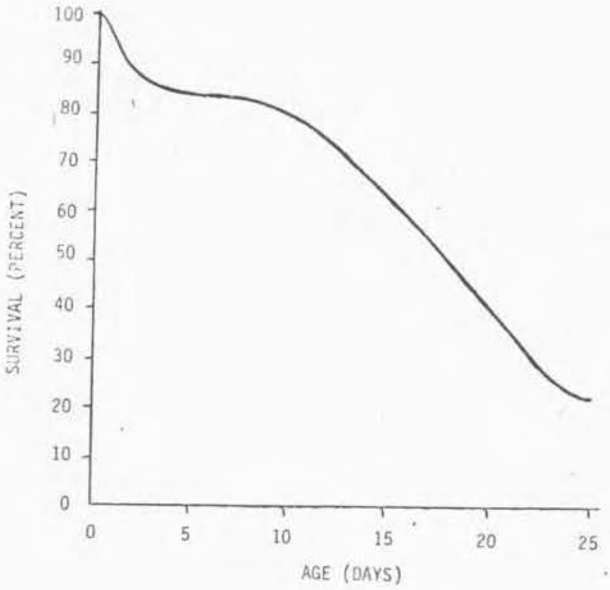


FIGURE 3-2
VAN DYKE
1983
FRY SURVIVAL - COLUMBIA RIVER ORIGIN

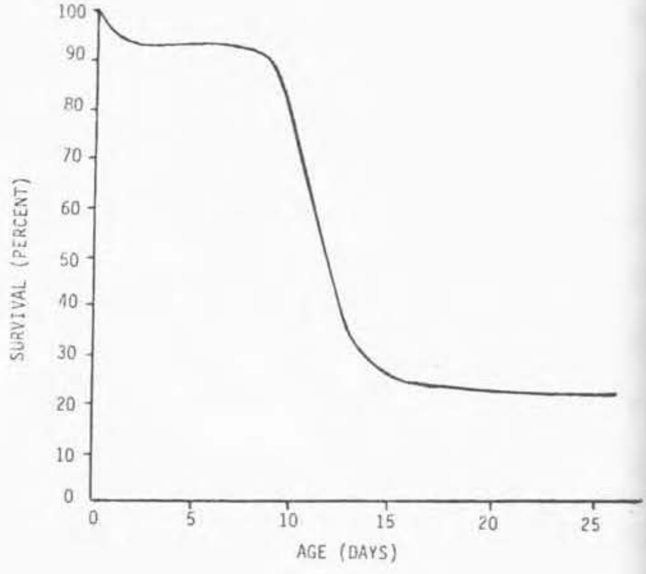


FIGURE 3-3
VAN DYKE
1983
FRY SURVIVAL - DELAWARE RIVER ORIGIN

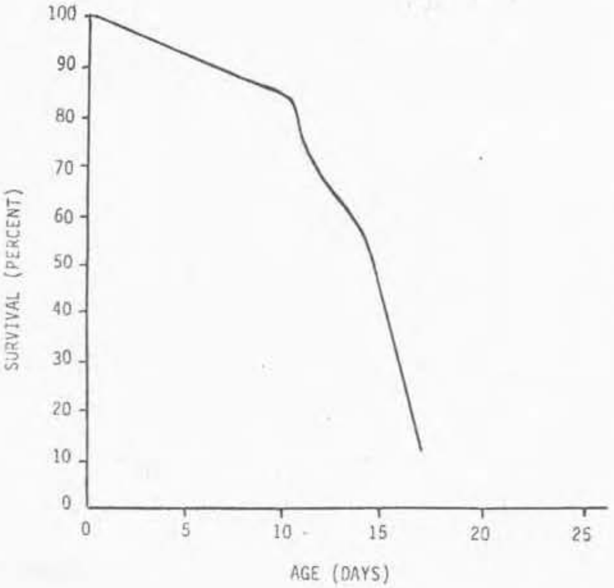


FIGURE 3-4
VAN DYKE
1983
FRY SURVIVAL - HUDSON RIVER ORIGIN

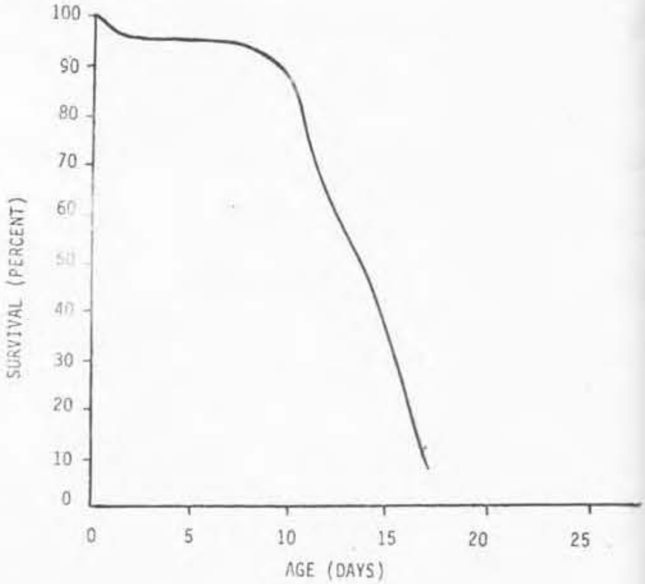
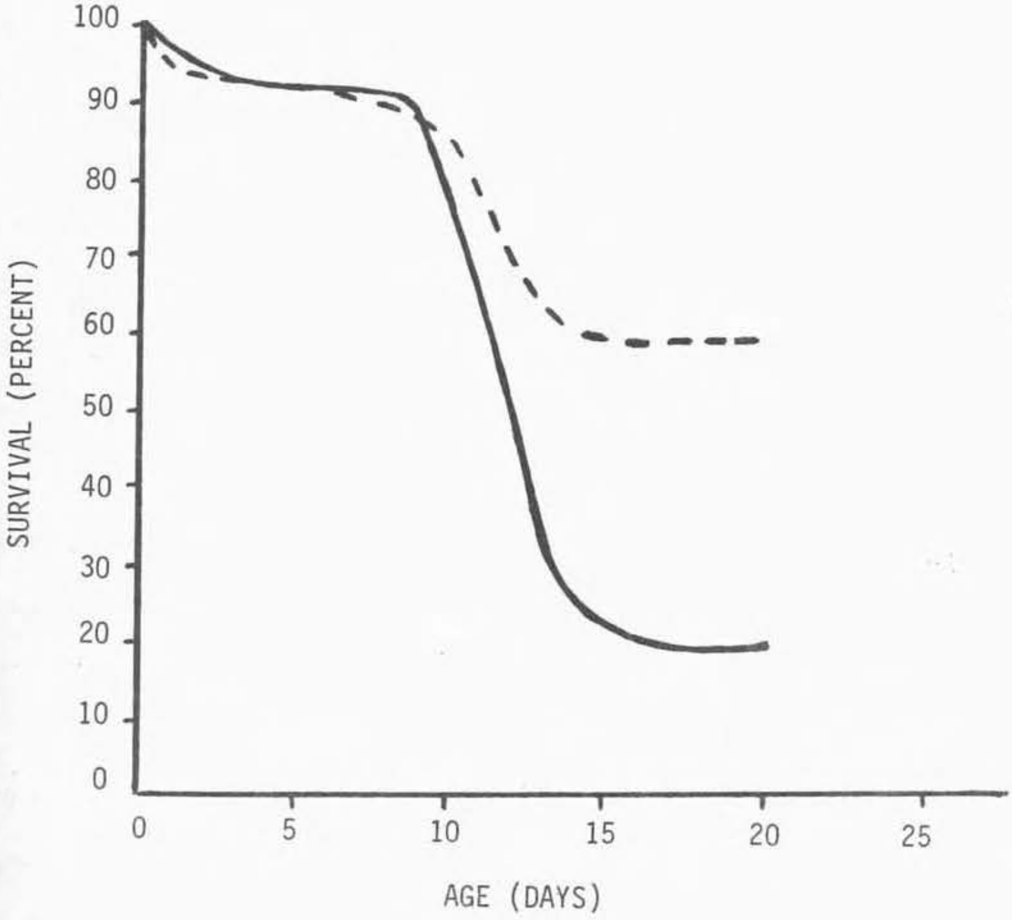


FIGURE 3-5
VAN DYKE
1983
FRY SURVIVAL
COLUMBIA RIVER



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— Furnace Turned On

APPENDIX III-A AMERICAN SHAD CULTURAL RESEARCH

Pennsylvania Fish Commission
Benner Spring Fish Research Station
Bellefonte, PA

Introduction

Effective management of cultured American shad depends on the ability to predict the success of larval survival through given periods of time. First-feeding herring larvae are particularly sensitive to food deprivation (Werner and Blaxter 1980). The term "critical period" has been used to describe the period of developmental transition in larvae from endogenous (pro-larval) to exogenous (post-larval) feeding (May, 1974) which may determine the success of larval survival. Studies at the Van Dyke Research Station in 1983 were designed to define and describe developmental characteristics related to nutrition; temporal growth and mortality patterns of larval shad; incidence of feeding; behavioral and morphological characteristics related to feeding; and, size selectivity of feed organisms by American shad larvae.

An extensive effort was initiated in 1983 to rear American shad to fingerling size in ponds and raceways, and to determine optimum stocking densities through the use of growth and survival information. Work was also done to determine if suitable techniques could be developed to successfully harvest and transport the delicate shad fingerlings from ponds and raceways.

Developmental Characteristics Related to Nutrition

The objective of this study was to define larval stages related to nutrition and to quantify the incidence of feeding success from 0 to 18 days of age. Hubbs (1943) defined two stages of larval development – a prolarval stage characterized by endongenous nutrition and a postlarval stage characterized by exogenous nutrition. Each day, from hatch to 18 days of age, approximately 50 shad larvae were sampled. Each larvae was examined to determine if a yoke sac was present, if exogenous feeding had occurred (*Artemia* present in the gut), and measured for total length (Tables A-1 and A-2). The prolarval stage lasted 5 days during which time 100 percent of the sample fish exhibited a yoke sac. Days 5 and 6 were characterized by mixed nutrition. It is interesting to note that on day 6, 52 percent of the sample fish had no food in the gut and no visible yoke sac. Following day 6, apparently nutrition was from exogenous feeding – the postlarval stage (Figure A-1). There was a substantial increase in the number of fish feeding on *Artemia* from days 5 to 10 and from day 15 on, between days 10 to 14 there was no apparent increase in the number of fish feeding. The pattern of growth closely resembled that of feeding with increases in length through day 10, little increase in length from day 11 through 16, after which growth again continued (Figure A-2).

TABLE A-1

VAN DYKE

1983

TEMPORAL PATTERNS IN GROWTH OF AMERICAN SHAD LARVAE

Age (Days)	Mean Length (mm)	Range (mm)	Mean Temperature of Rearing Unit (^{O}F)
0	8.7	7.3-9.5	60
1	8.8	7.6-10.1	58
2	9.1	8.2-10.0	57
3	9.2	8.5-10.3	61
4	9.5	8.6-10.5	60
5	9.7	8.9-11.0	62
6	10.2	9.2-11.0	63
7	10.2	9.2-11.2	64
8	10.3	9.4-11.6	66
9	10.4	8.9-12.1	64
10	10.0	8.2-11.4	63
11	10.6	9.2-12.0	63
12	10.1	9.1-11.4	63
13	10.1	9.2-11.3	63
14	10.4	9.2-12.1	63
15	10.2	9.6-11.6	63
16	10.8	9.8-12.0	63
17	10.8	10.0-12.2	64
18	10.4	9.5-12.5	63
-			
21	10.5	9.1-12.0	61
-			
25	12.1	9.4-16.2	63

TAL_ _

VAN DYKE

1983

DEVELOPMENTAL CHARACTERISTICS RELATED TO NUTRITION

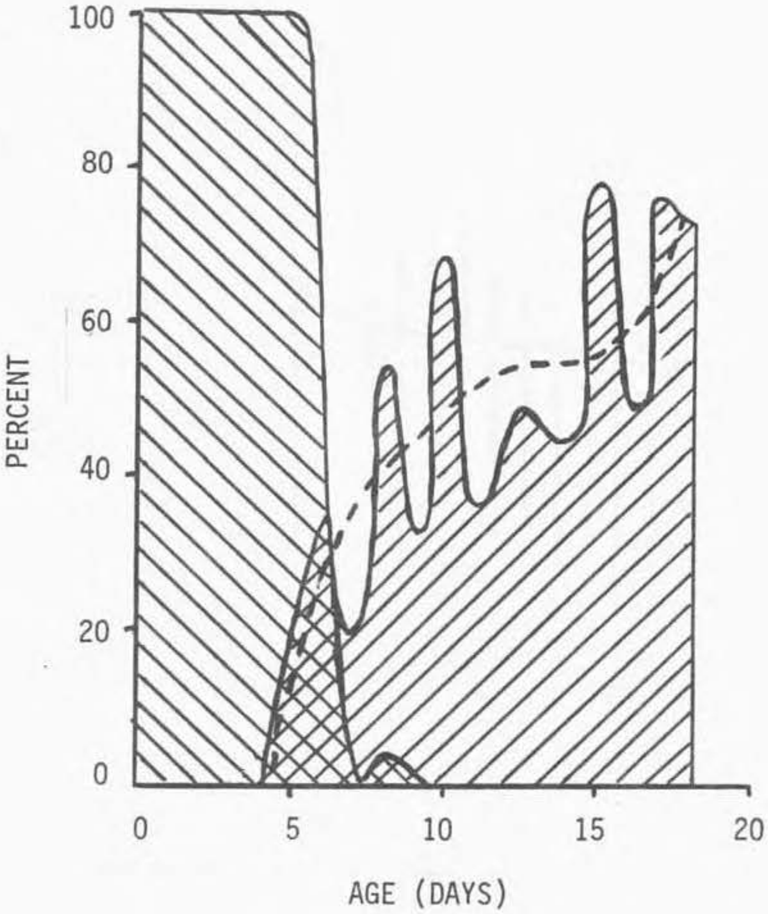
Age (Days)	Endogenous Nutrition (Percent of Sample)	Endogenous and Exogenous Nutrition (Percent of Sample)	Exogenous Nutrition (Percent of Sample)
0	100	0	0
1	100	0	0
2	100	0	0
3	100	0	0
4	100	0	0
5	100	22	22
6	22	8	34
7	0	0	20
8	0	0	54
9	6	0	32
10	0	0	68
11	0	0	36
12	0	0	48
13	0	0	48
14	0	0	44
15	0	0	78
16	0	0	48
17	0	0	76
18	0	0	72

FIGURE A-1

VAN DYKE

1983

STAGES OF NUTRITION



Endogenous Nutrition

Exogenous Nutrition (---Fitted by Inspection)

Mixed Nutrition

No Feed

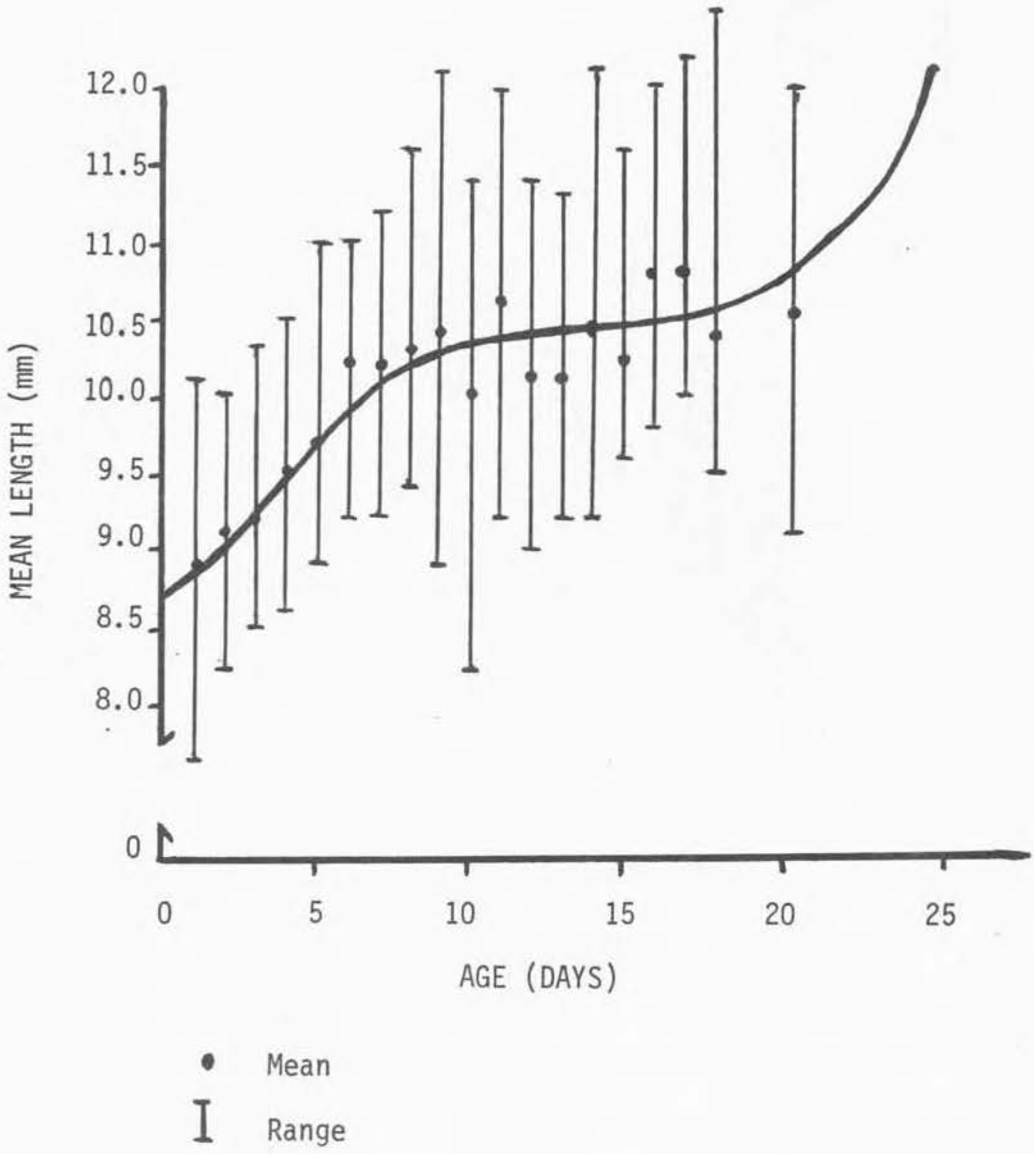
FIGURE A-2

VAN DYKE

1983

GROWTH OF AMERICAN

SHAD LARVAE



Line Fitted by Inspection

Temporal Patterns in Mortality of Larval American Shad

The objective of this study was to determine age specific survival rates for American shad. An estimate of the number of fry (F) hatched into each rearing unit was made using the von Bayer (1910) method of egg enumeration (modified slightly) to enumerate the number of live eggs (E_1) and the number of dead eggs (E_d):

$$F = E_1 - E_d$$

Mortalities were collected daily by syphoning the rearing units. An estimate of fish mortality (M_{td}) was then made volumetrically for each rearing unit:

$$M_{td} = \frac{m_{td}}{v_{td}} (V_{td});$$

where;

m_{td} = number of dead larvae in a subsample for tank (t) on day (d);

v_{td} = volume of subsample (40-50 ml);

V_{td} = total volume of mortality ($\cong$ 2,000 ml).

Survival rate (S, %) was determined for the sampling period, day t_x to day t_{x+i}:

$$S = \frac{N_{x+i}}{N_x} (100);$$

N_x = number of fish alive on day t_x;

N_{x+i} = number of fish alive on day t_{x+i};

i = sampling intervals (days).

The fry in five tanks (from the last three Columbia River egg shipments), reared in unheated water, were used to determine mean age specific survival.

Despite some difference among units, American shad larvae demonstrated temporal patterns in larval mortality (Figure A-3). Initially, there was a slightly higher larval mortality from hatch to 2 days of age (5.9 percent), followed by a period of relatively low daily mortality to 9 days of age (<0.75 percent). From 9 to 14 days of age there was a sharp increase in larval mortality (5.5 percent/day), after which mortality again returned to a low level (<0.3 percent).

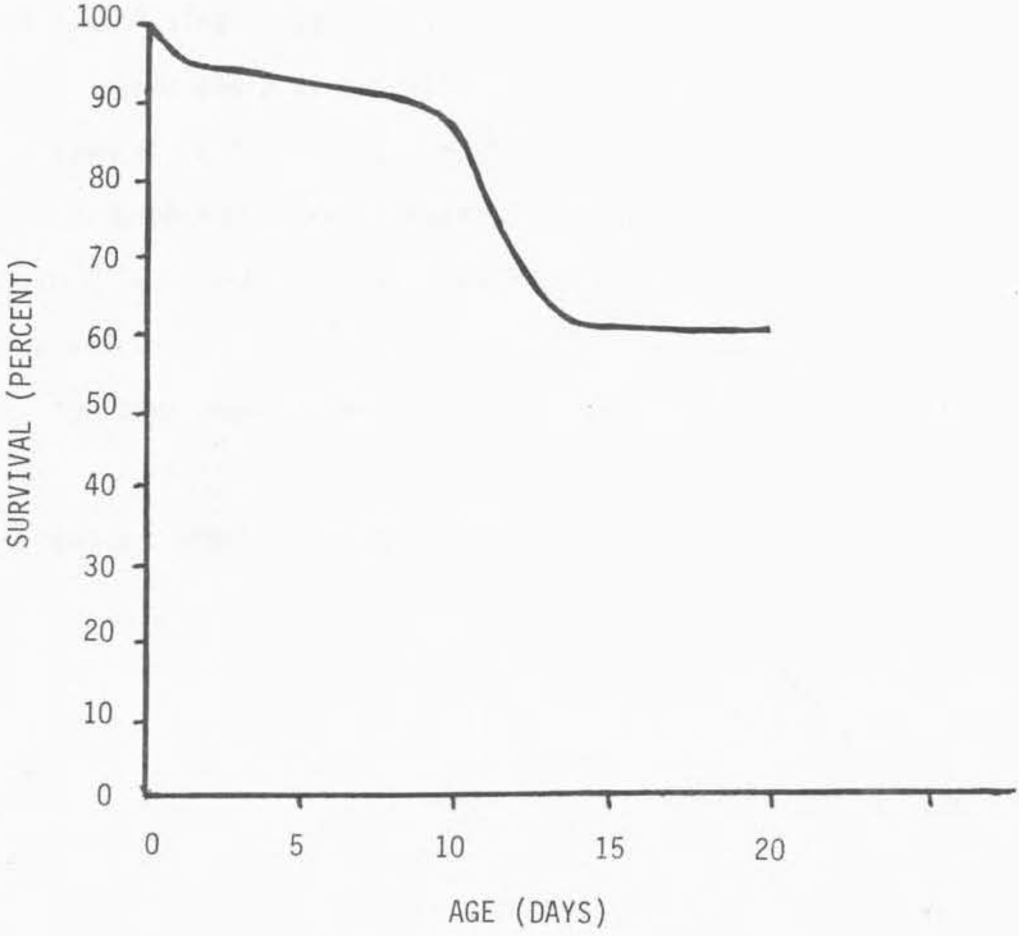
FIGURE A-3

VAN DYKE

1983

TEMPORAL PATTERNS IN MORTALITY

OF LARVAL AMERICAN SHAD



Diel Variations in Feeding Intensity of Larval American Shad

The object of this study was to determine if diel variations in feeding intensity existed and to determine if continuous light affected the feeding intensity of larval American shad. Shad larvae cultured in two sheltered rearing units (roof covered) receiving only indirect natural lighting were compared to larvae cultured in units where artificial lighting was constantly provided. The live food feeders dispensed a brine shrimp (Artemia) suspension to each rearing unit for 5 seconds every 5 minutes, 24 hours each day. At day 6, 12 and 18 days of age, 25 larvae were sampled from each of the test units at 3 hour intervals during a 24-hour period. Samples were examined to determine if feed (Artemia) was present in the gut. Diel variations in feeding intensity in test units were determined using incidence of feeding (IF, %):

$$IF = \frac{F_{ih}}{N_{ih}} (100);$$

N_{ih} = Total number of fry sampled on day (i); hour (h);

F_{ih} = Number of fry with feed in the gut

Total length was determined for each test unit from a sample of 50 larvae on each test day. Daily mortality was recorded for all test units.

The mean percent of larvae feeding increased with age in both natural (30 percent at 6 days, 45 percent at 12 days, and 68 percent at 18 days) and artificial lighting (43 percent at 6 days, 58 percent at 12 days, and 72 percent at 18 days) (Tables A-3 and A-4). At 6 to 12 days of age there were diel variations in feeding intensity with the peak incidence of feeding in the evening hours (1800-2100). At 18 days of age, there was no obvious peak in feeding activity but a more uniform pattern of feeding. Feeding continued but declined in intensity for all ages at night (Figures A-4, A-5, and A-6).

Continuous lighting apparently resulted in a higher incidence of feeding at 6 and 12 days of age. The differences between natural and continuous lighting were much less distinct at 18 days of age. In all cases, but particularly at 12 days of age, continuous lighting resulted in a higher incidence of feeding at night. At 6 days of age, larvae had a mean length of 9.6 mm and at 12 days of age, 10.3 mm for natural light, compared to 9.8 at 6 days of age, and 10.4 at 12 days of age for fish reared in continuous light. Growth was slightly better for larvae reared in continuous lighting. The larvae reared in natural light were 10.8 mm at 18 days of age while larvae reared in the continuous light was 10.7 respectively. There was little difference in mortality between treatments once feeding had begun (Figure A-7).

TABLE A-3

VAN DYKE

1983

DIEL VARIATIONS IN FEEDING INTENSITY OF LARVAL AMERICAN SHAD REARED UNDER NATURAL LIGHT

INCIDENCE OF FEEDING

(PERCENT OF LARVAE WITH FEED IN GUT)

Age (Days	6			12			18		
	Trial			Trial			Trial		
Time	1	2	x̄	1	2	x̄	1	2	x̄
9:00 a.m.	0	56	28	28	56	42	76	56	66
12:00 p.m.	12	44	28	72	32	52	44	88	66
3:00 p.m.	32	32	32	44	48	46	48	84	66
6:00 p.m.	44	24	34	80	40	60	76	84	80
9:00 p.m.	24	56	40	68	72	70	88	84	86
12:00 a.m.	52	16	34	40	52	46	68	84	76
3:00 a.m.	16	32	24	16	32	24	76	72	74
6:00 a.m.	12	24	18	16	16	16	16	44	30
Mean of Sample (%) Feeding			30			45			68

TABLE A-4

VAN DYKE

1983

DIEL VARIATIONS IN FEEDING INTENSITY OF LARVAL AMERICAN SHAD REARED UNDER ARTIFICIAL LIGHT (24 HR)

INCIDENCE OF FEEDING
(PERCENT OF LARVAE WITH FEED IN GUT)

Age (Days)	6			12			18		
	Trial			Trial			Trial		
Time	1	2	$\bar{x}$	1	2	$\bar{x}$	1	2	$\bar{x}$
9:00 a.m.	32	28	30	48	52	50	88	48	68
12:00 p.m.	48	36	42	48	68	58	80	84	82
3:00 p.m.	32	28	30	64	52	58	88	68	78
6:00 p.m.	64	52	58	84	64	74	80	84	82
9:00 p.m.	64	60	62	76	60	68	88	64	76
12:00 a.m.	48	52	50	72	40	56	80	52	66
3:00 a.m.	36	44	40	72	36	54	92	48	70
6:00 a.m.	44	16	30	68	24	46	64	44	54
Mean of Sample (%) Feeding			43			58			72

FIGURE A-4

VAN DYKE

1983

INCIDENCE OF FEEDING FOR 6 DAY OLD FRY

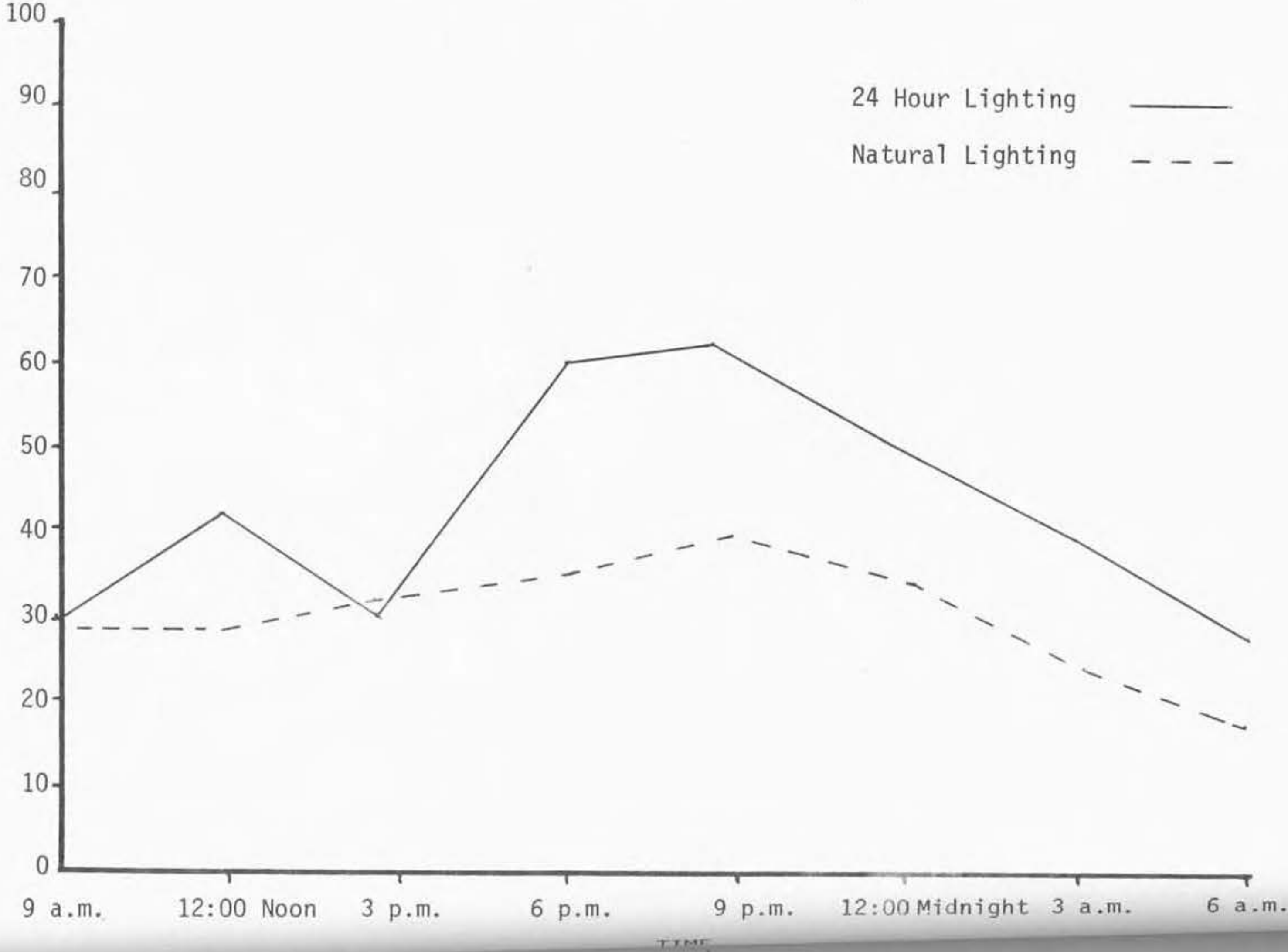


FIGURE A-5

VAN DYKE

1983

INCIDENCE OF FEEDING FOR 12 DAY OLD FRY

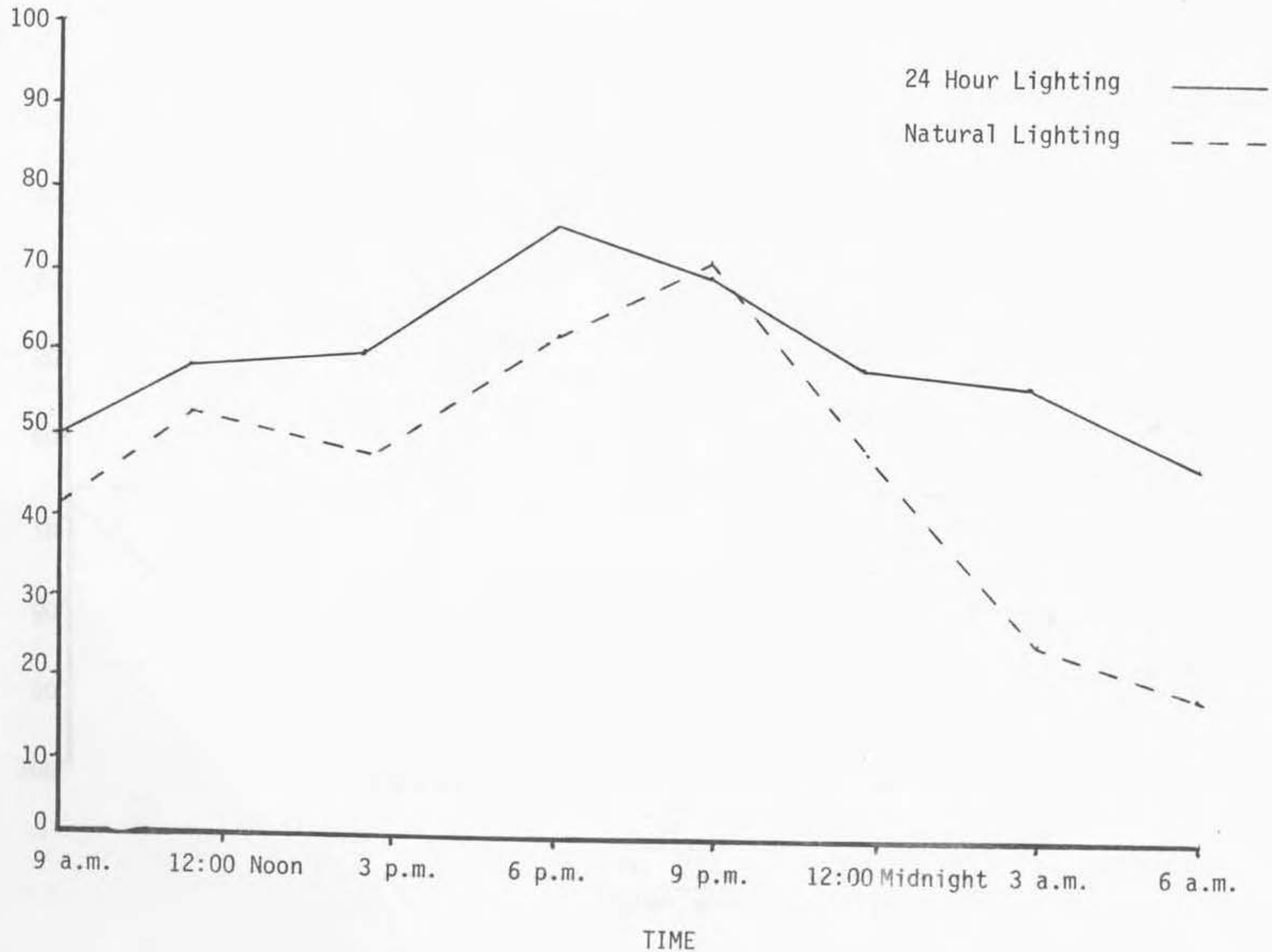


FIGURE A-6

VAN DYKE

1983

INCIDENCE OF FEEDING FOR 18 DAY OLD FRY

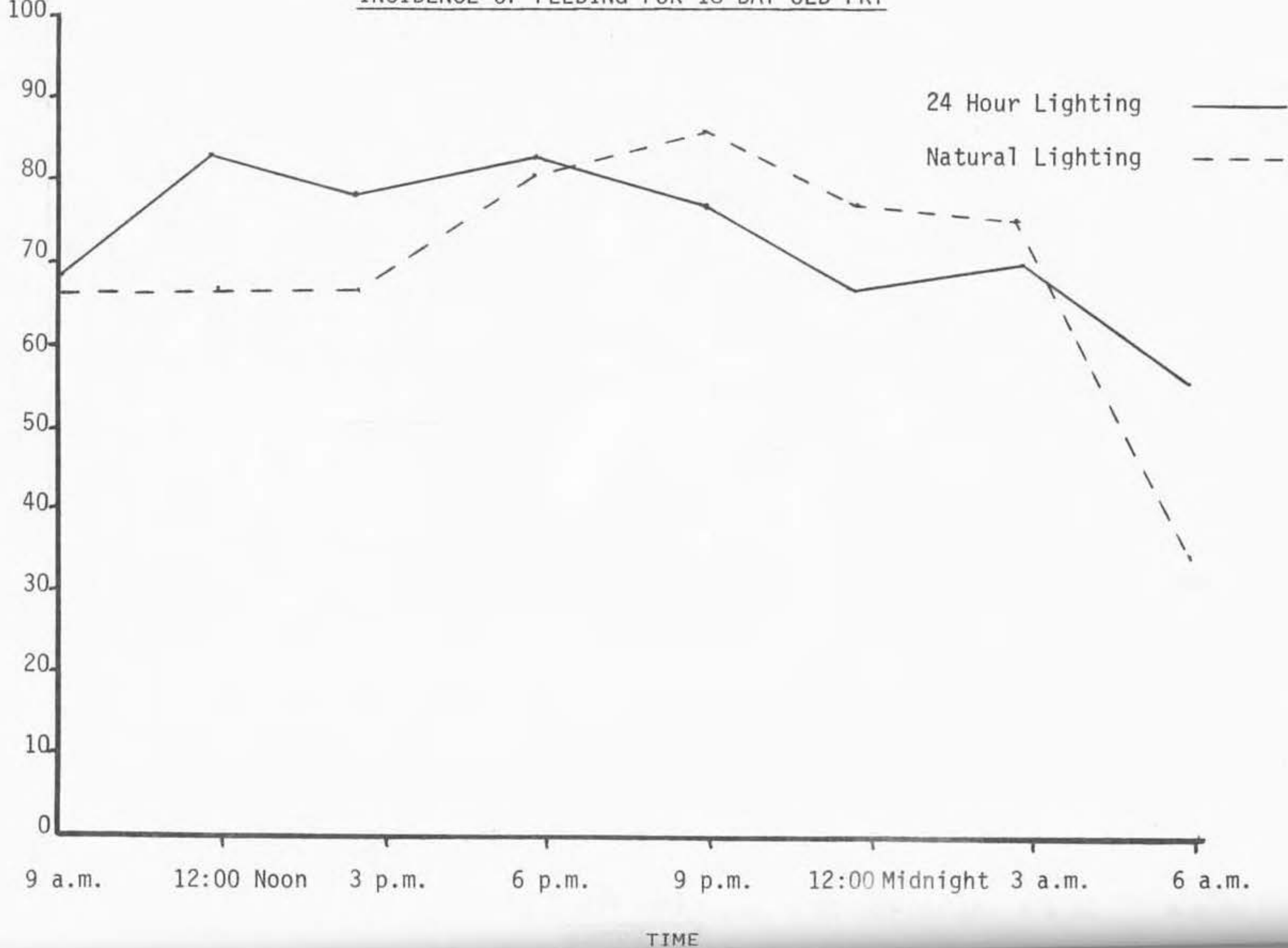
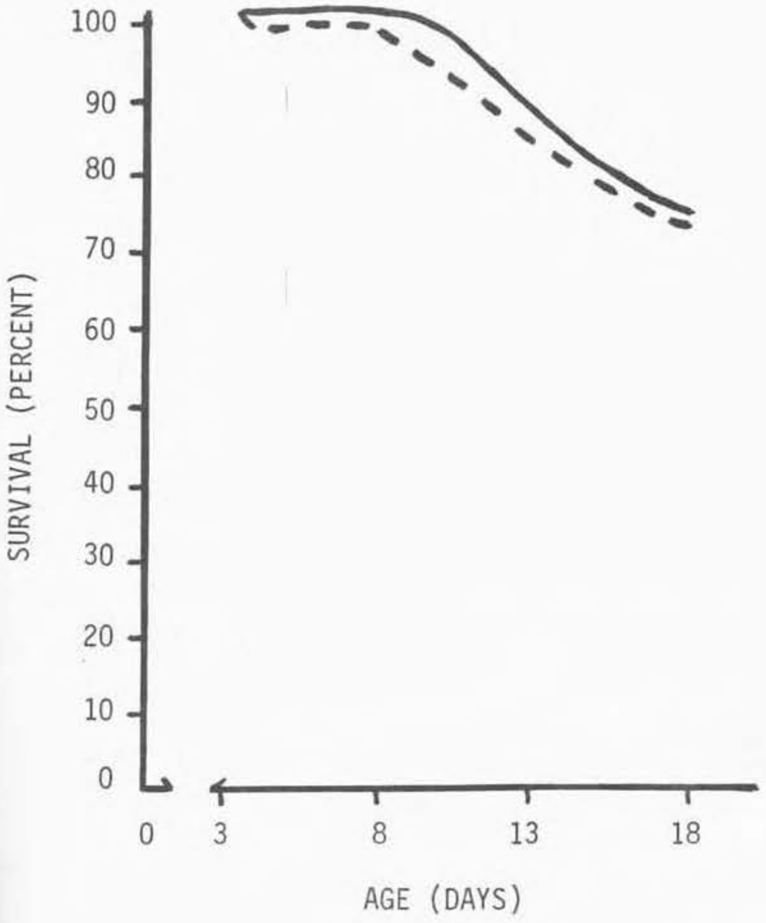


FIGURE A-7

VAN DYKE

1983

SURVIVAL OF AMERICAN SHAD LARVAE REARED UNDER CONTINUOUS LIGHT VS NATURAL LIGHT



— Larvae reared under continuous light

-- Larvae reared under natural light

Behavioral Characteristics Related To Feeding in Cultured American Shad Larvae

The objective of this study was to determine the behavioral characteristics related to feeding in cultured American shad larvae fed brine shrimp. Larvae were cultured in 1.524 m diameter, 1,100 L circular rearing units with a mean water flow of 6 L/min. Fry were fed a brine shrimp suspension from two automatic live food feeders on each tank which released the suspension for 5 sec. every 5 min., 24 hr/day.

The study was conducted with larvae 6 to 12 days of age. On each test day, the mean length and mouth width of the larvae, and the mean length and width of the Artemia (excluding appendage) to be fed were determined. At each age group, seven larvae were individually observed. Each larvae was placed in a 7 L clear plastic cylindrical unit containing 3 L of water, and observed for a period of 1 hour while Artemia were presented in such a manner as to be continually available to the fish (an equal quantity of nauplii were presented to all fish of a particular age group during the test period). The number of orientations between strikes, the amount of time between strikes, the number of strikes and the number of successful strikes were recorded. The physical act of striking was also described for both 6 and 12 day old larvae.

At 6 days of age larvae had an average length of 10.3 mm and the horizontal width of the mouth was 0.76 mm. The larvae would strike at Artemia (0.55 mm in mean length, 0.19 mm in mean width) with nothing more than a "sprint swim" or would simply "plow" through the Artemia at the water's surface. The larvae made an average of 16 orientations, and seven strikes, three of which were successful, in the hour observed.

At 12 days of age, larvae averaged 10.5 mm in length and had a mean mouth width of 0.87 mm. When attempting to feed, larvae would orient themselves on an individual shrimp (0.52 mm in mean length, 0.19 mm in mean width), drop back, coil into an "S" shape and strike hard at the prey. The larvae averaged 55 orientations, 18 strikes, and nine successful strikes during the hour observed (Table A-5).

At 12 days of age, shad larvae more actively sought feed as indicated by the increased number of orientations (55), but were more selective in feeding as seen by comparing the mean number of strikes per number of orientations; 0.4 for 6 day old larvae, and 0.3 for larvae to 12 days of age. Older larvae were slightly more efficient at feeding with 50 percent of the strikes resulting in successful capture of prey at 12 days of age, compared to 43 percent at 6 days of age (Table A-6).

TABLE A-5

VAN DYKE

1983

Feeding Characteristics of Cultured Larval American Shad being fed Brine Shrimp (*Artemia salina*)

Age: 6 days

Sample	Number Orientations	Number Strikes	Successful Strikes
1	13	3	0
2	18	8	4
3	17	7	5
4	14	7	3
5	14	4	1
6	22	10	4
7	17	9	4
Means:	16	7	3

Age: 12 Days

Sample	Number Orientations	Number Strikes	Successful Strikes
1	47	16	5
2	60	22	13
3	53	19	11
4	52	16	8
5	50	15	8
6	64	18	10
7	59	17	10
Means:	55	18	9

TABLE A-6

VAN DYKE

1983

Ratio of mean number of Strikes to the mean number of approaches of American Shad Feeding on Brine Shrimp (*Artemia salina*) for 1 hr

Age (days)	Ratio Strikes/Approaches
6	7/16 = .438
12	18/55 = .327

Mean Number of Successful and Unsuccessful Strikes in 1 hr by American Shad feeding on Brine Shrimp (*Artemia salina*)

Age (days)	Successful Strikes	Unsuccessful Strikes
6	3	4
12	9	9

Mean Successful Strike percentage of American Shad feeding on Brine Shrimp (*Artemia salina*) for 1 hr

Age (days)	Successful Strikes (%)
6	43
12	50

Size Selectivity of Feed Organisms By American Shad Larvae

The objective of the study was to determine if there was size selectivity of Artemia by larval American shad. Larvae 6 days of age were selected because of the small size of the fry and at this age the larvae have exhausted the yoke as a nutritional source and will have begun or soon will have to begin to feed exogenously. The electivity index of Ivlev (1961) was used to compare the size distribution of Artemia in the stomach of larvae to its distribution in the feed suspension.

$$\text{Electivity Index} = \frac{(r_i - p_i)}{(r_i + p_i)} \quad ;$$

r_i = the concentration of Artemia, size class i, in the stomach;

p_i = the concentration in feed suspensions.

The index theoretically ranges in value from +0.1 (maximal selection) to -1.0 (maximal avoidance), with a value of 0.0 indicating that an item is eaten in the frequency of its occurrence.

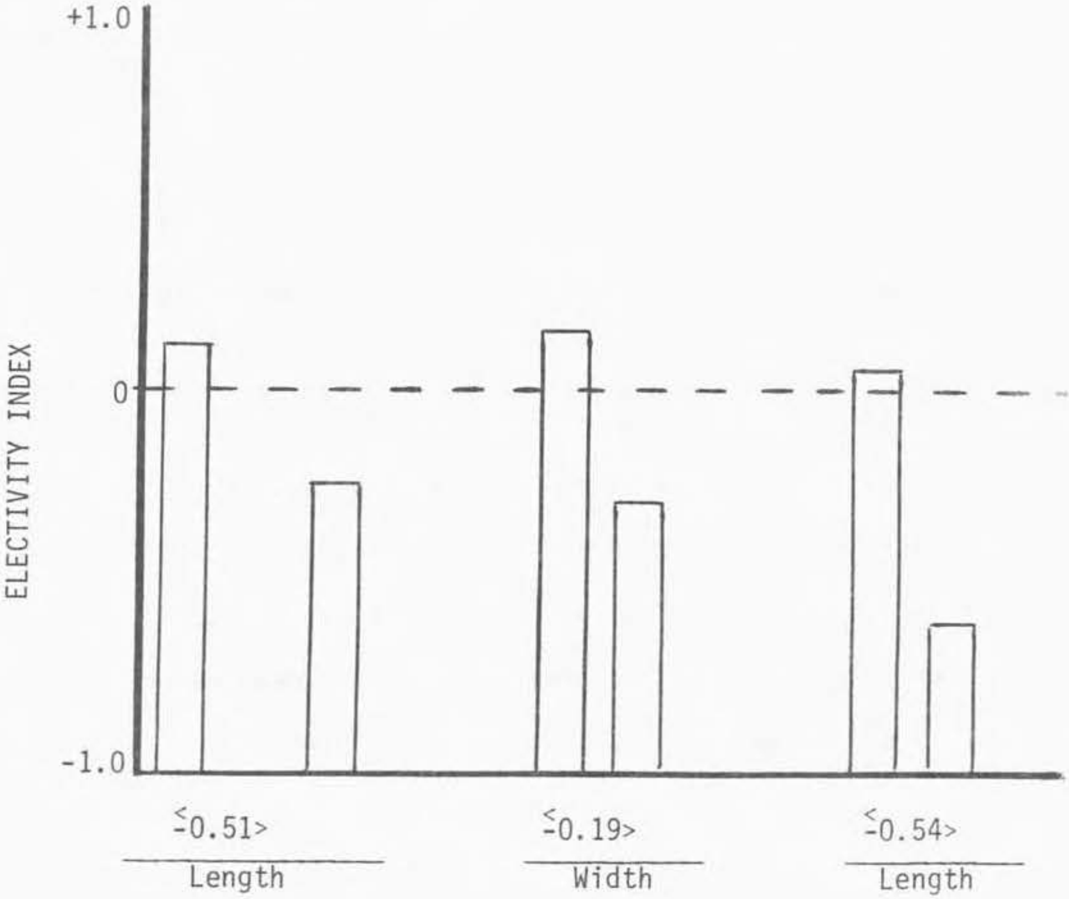
The maximum width and length of Artemia, excluding appendages, were measured. The mean length was 0.51 mm and mean width 0.19 mm. Results of the study suggested that larvae did select slightly for Artemia smaller than the mean length and width (0.13 and 0.15 respectively) with a rejection of those greater than the mean length and width (-0.22 and -0.19 respectively). In addition, the electivity index demonstrated a more definite avoidance (-0.60) of the larger Artemia (>.55 mm) which comprised 13 percent of the sample (Figure A-8).

FIGURE A-8

VAN DYKE

1983

INDEX OF ELECTIVITY



Artemia

0.51 mean length of Artemia

0.19 mean width of Artemia

American Shad Density Study

A. Raceways

The study's objective was to determine, by fish growth and survival, optimum fish density to rear juvenile American shad in raceways. The test was run at the Benner Spring Research Station. Fry were obtained from the Van Dyke Research Station. Total transport time was approximately 3 hours including preparation for shipment. Fry were transported in plastic bags containing approximately 7 to 11 liters of water. The bag was then inflated with oxygen, sealed and placed inside a styrofoam box for shipment.

Shad fry were reared to fingerling size (44 mm+) in four 12.19 m by 2.44 m raceway sections, each with an independent water supply and dishcarge. Water depth was 0.56 m. Water was supplied to each section from two sources, a warming pond which was set to provide 30 L/min and a well which was set to provide 9 L/min. Mean water temperature was 22^{o}C and ranged from 17.8 to 27.2^{o}C (Table A-7).

The shad fry, 26 days of age, were planted at estimated densities of 0.6 fish/L (10,300 fry), 1.2 fish/L (20,600 fry), 1.9 fish/L (30,400 fry), and 3.1 fish/L (51,500 fry) in four raceway sections. The number of fry per shipping container used to stock raceway sections was estimated by dividing the production estimate for a rearing unit by the number of containers. Estimates were made in this manner to facilitate the transfer of fish and reduce handling stress.

Fish were initially fed on natural feed coming in with the water supply, although some brine shrimp were provided during the first few days. Dry feed (Abernathy starter) was hand-fed to excess four times each day for the first week, then increased to eight times daily. Fry were held in the upper half of the raceway until 40 days of age, then allowed to utilize the entire raceway section. At 44 days of age, two MoDo feeders were placed above each section and set to feed 10 sec. (and later changed to 15 sec.) every 10 min. during daylight hours. Fingerlings were harvested at 69 days of age.

To facilitate harvest, the water level was lowered and fish were crowded to the end of a section using a push screen. Fish were counted by water brailing into a transportation unit. Mean percent survival was 10.9 (Table A-8). Growth and harvested density were greatest in the unit initially stocked at 1.9 fish/liter (Figure A-9). The number harvested was proportional to the number stocked except for the highest density (Fig. A-10). The linear relationship of the three low densities indicates that survival was proportional to the stocked densities and that the carrying capacity had not been exceeded. The reduced survival in the highest density unit (3.1 fish/liter) apparently indicates that the carrying capacity was exceeded; therefore, optimum density, under the conditions described appears to be between 1.9 and 3.1 fish/liter in raceway sections. Additional experimentation will have to be done before definite conclusions can be made.

TABLE A-7

BENNER SPRING - 1983

AMERICAN SHAD DENSITY STUDIES

RACEWAY TEMPERATURES

Date	Temperature 8:30 a.m.	Temperature 2:30 p.m.
7/20	24.4	26.7
7/21	27.2	26.7
7/22	23.3	26.7
7/23	22.2	23.4
7/24	23.3	24.4
7/25	22.2	25.6
7/27	23.3	26.1
7/28	21.1	23.3
7/29	21.1	22.2
7/30	21.1	23.3
7/31	21.1	23.3
8/01	21.7	23.3
8/02	20.6	22.8
8/03	20.6	23.3
8/04	20.6	21.7
8/05	20.6	21.7
8/06	20.6	22.2
8/09	21.1	23.9
8/10	20.0	22.2
8/11	20.6	20.6
8/12	21.1	19.4
8/14	17.8	20.6
8/15	17.8	20.6
8/16	18.3	21.1
8/17	17.8	21.7
8/18	18.9	21.1
8/19	20.0	22.8
8/21	20.0	21.1
Mean	21.0^{o}C	22.9^{o}C

TABLE A-8

BENNER SPRING

1983

AMERICAN SHAD DENSITY STUDIES

RACEWAYS

Rearing Unit	Age (Days)		Density				Percent Return	Size (mm) Harvest
			Introduction*		Harvest			
	Introduction	Harvest	Number Fish/L	Stocking Rate	Number Fish/L	Stocking Rate		
1	26	69	0.62	10,300	0.09	1,450	14.1	59 (0.8 g)
2	26	69	1.24	20,600	0.14	2,400	11.7	44 (0.5 g)
3	26	69	1.86	30,900	0.22	3,600	11.6	59 (1.2 g)
4	26	69	3.10	51,500	0.19	3,200	6.2	51 (0.9 g)

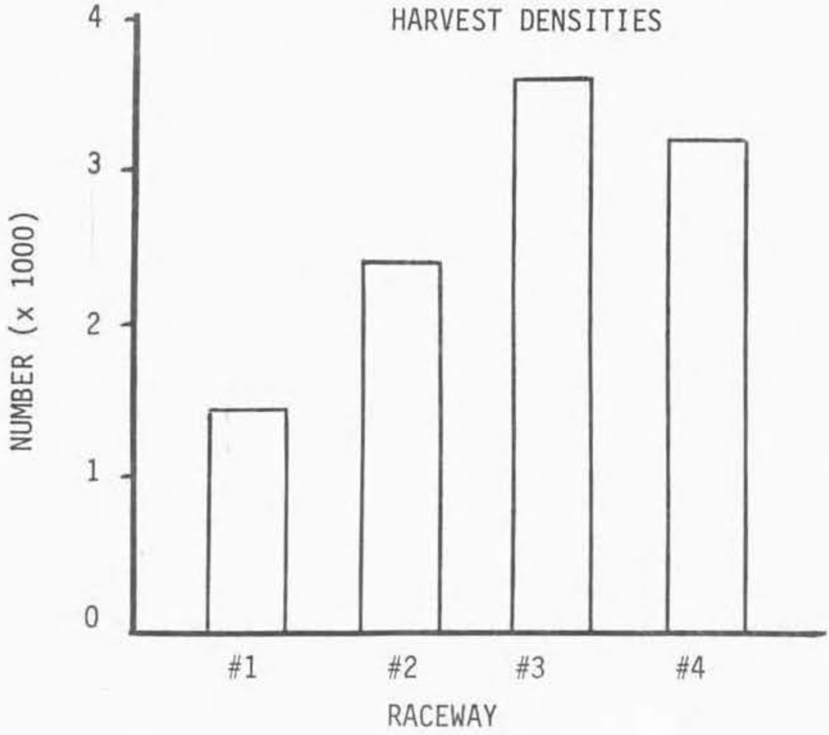
*Estimated density

FIGURE A-9

BENNER SPRING

1983

GROWTH AND HARVESTED DENSITIES OF AMERICAN SHAD REARED IN RACEWAYS



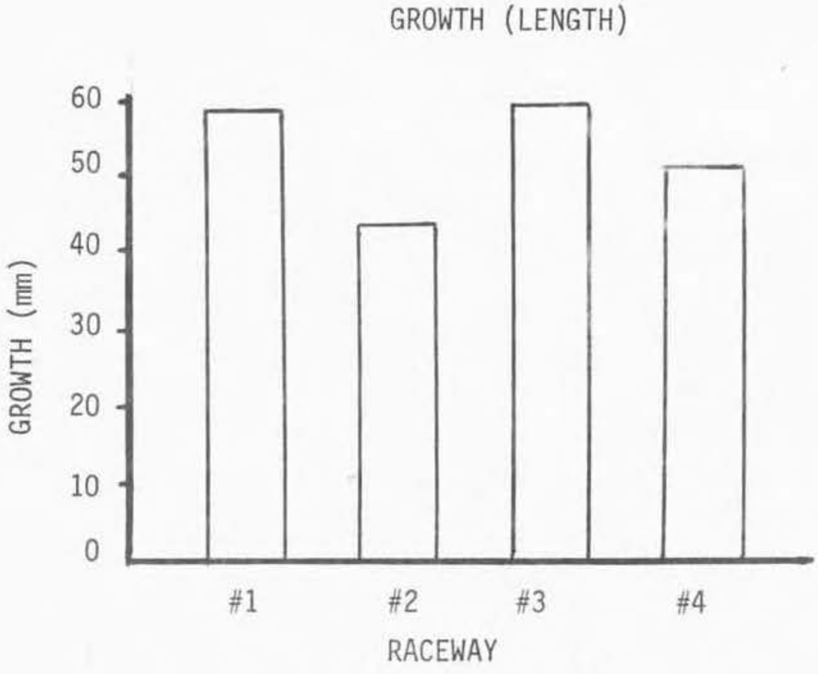
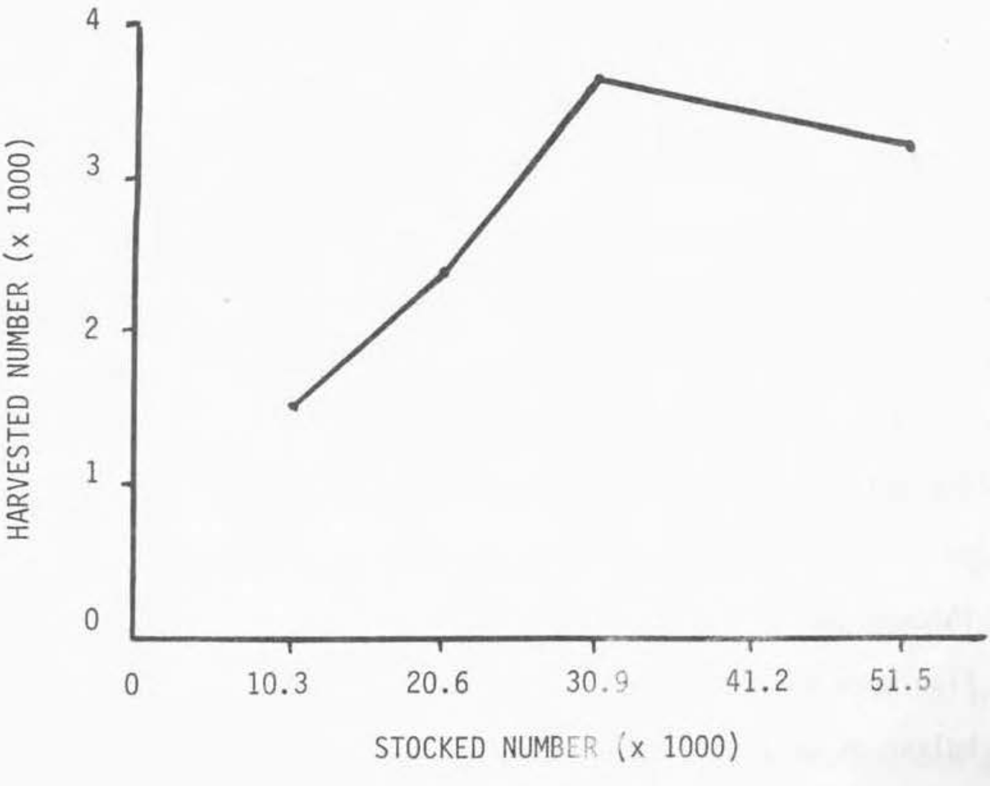


FIGURE A-10

BENNER SPRING

1983

RACEWAY DENSITY STUDY



B. Ponds

The object of this study (to determine optimum fish density in American shad cultured in ponds), shipment of fry, and location of the study were similar to that described for the raceway density study. Shad fry, 19 to 20 days of age, were planted into 0.18 ha ponds with a mean depth of 1.28 m. Water was added to the ponds only to maintain level. Initial stocked densities were 269,000 fry/ha (48,000), 483,000 fry/ha (86,000), 977,000 fry/ha (174,000), and 1,504,000 fry/ha (268,000) in the four ponds respectively. Initial densities were attained in a manner similar to that described for the raceway study. Ponds were fertilized on July 1 with sheep manure immediately prior to filling. Ponds were filled by July 3 and fertilized weekly using inorganic fertilizer (20-20-5). Fertilization was discontinued on August 11 because of excessive growth of filamentous algae. During fry metamorphosis dry feed was used to augment available natural feed. Supplemental feed was discontinued following the filamentous algae problem. Mean water temperature was 26°C, ranging from 21 to 28°C through the season.

Fish were harvested by slowly draining the ponds into kettle type bulkheads which were 1.37 m wide, 3.35 m long, and 0.46 m deep. The kettle basin was cleaned as the water level dropped and the majority of fish moved into the kettle basin. Because of improper grading, the ponds did not drain completely and groups of fish were stranded in shallow pools, primarily located in front of the catch basin. Handling survival during harvest of the four ponds was about 90, 80 to 85, 95, and 95 percent respectively. A 99 percent plus harvest could probably have been achieved with complete pond drainage.

When fingerlings were concentrated in the kettle basin, the water level was lowered and fish were crowded to an end using a push screen. Fish were bucketed from the kettle basin and placed in a small transportation unit equipped with a quick release. The fingerlings were then quick released into a raceway section. Fish remained in the raceways for a sufficient time (72 hours) to evaluate delayed mortality and were then put in stocking units in the manner described for raceways. Total mortality (following harvest) for fingerling shad reared in ponds was 2.2 percent or less after 3 days.

The number of shad fingerlings harvested from the ponds was proportional to the number stocked with the exception of the pond receiving 1,504,000 per ha, the highest density planted. Growth was variable with the largest fish harvested from the lowest density pond (Figure A-11). Mean percent return was 7.8 (Table A-9). The linear relationship of survival for the three low densities indicates that survival was, as in raceways, proportional to the stocked densities and that carrying capacity had not been exceeded. The highest survival, 18,100 fingerlings (101,600 fingerlings per ha), did not result from the highest stocking density; therefore, it would appear that the carrying capacity was exceeded (Figure A-12). The optimum density, under the conditions described, appears to be between 977,000 per ha and 1,504,000 per ha. Further studies should delineate the optimum density.

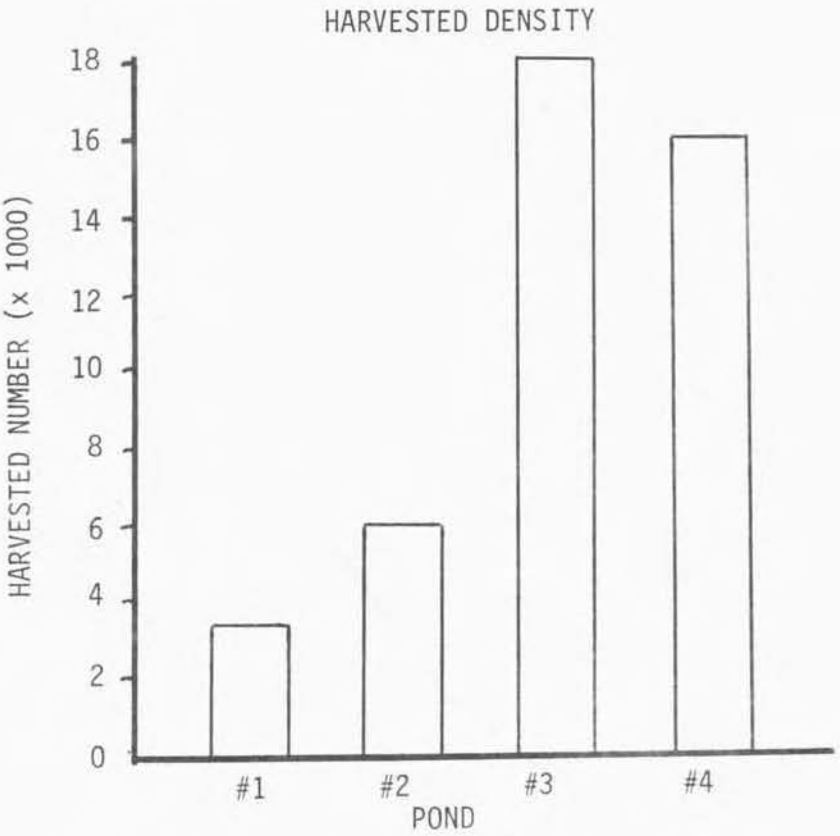
The small standard deviation in percent return for ponds and raceways (1.4 for the three lowest raceway densities and 1.8 for the three lowest pond densities), demonstrated no apparent differences in fish loss (such as transport mortality, escapement or differential mortality among rearing units). The differences in mean percent return, although small, between raceways and ponds (with the exception of the high densities which appeared to have exceeded carrying capacity) may be attributed to different shipments of fish, predation, or different ages at planting. Since the difference in percent return was small (<5 percent) between raceways and ponds, it appears that predation in the ponds did not account for major fish loss during these studies.

FIGURE A-11

BENNER SPRING

1983

GROWTH AND HARVESTED DENSITIES OF AMERICAN SHAD REARED IN PONDS



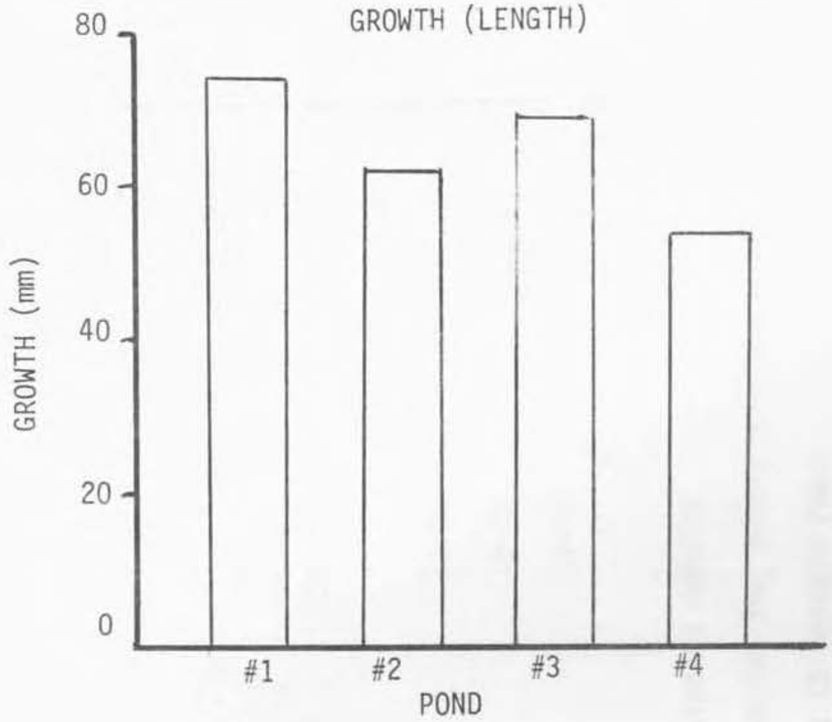


FIGURE A-12

BENNER SPRING

1983

POND DENSITY STUDY

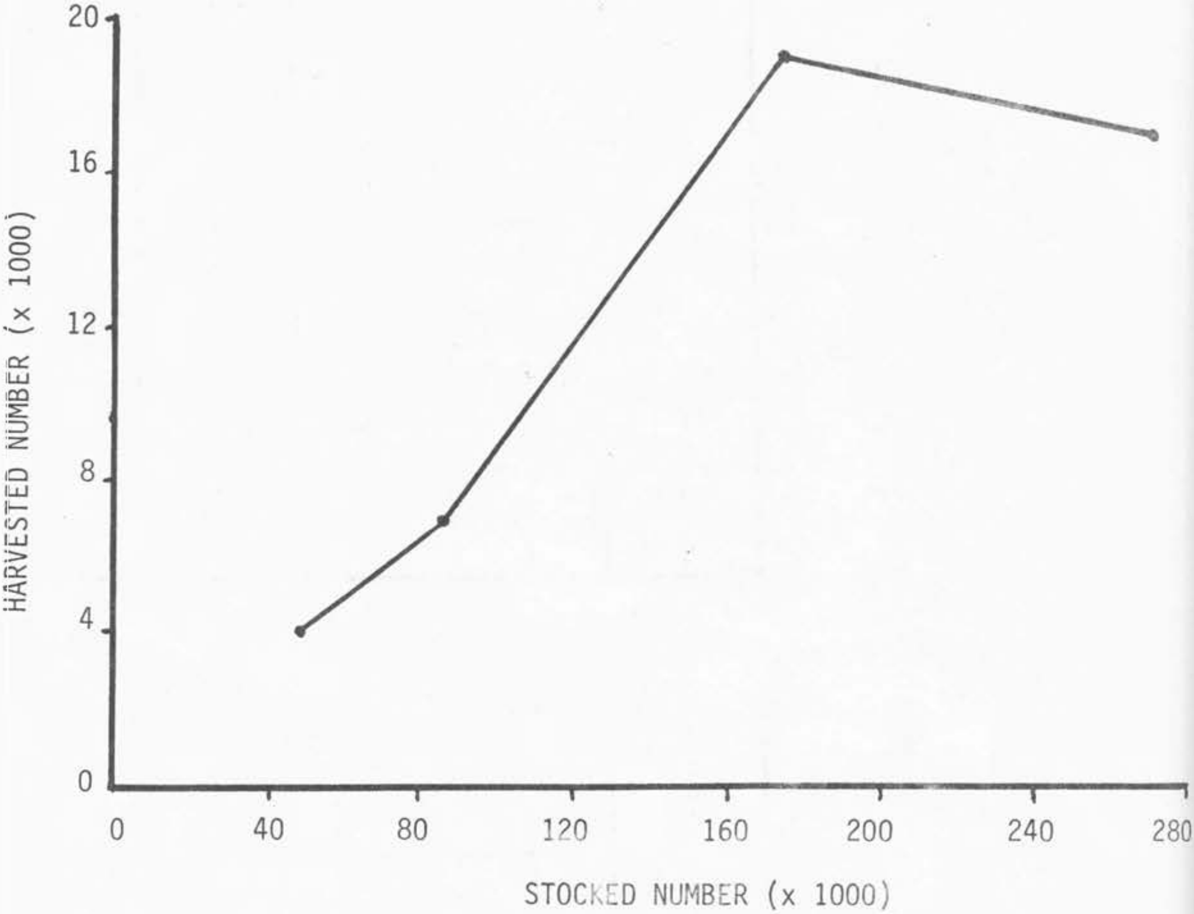


TABLE A-9

BENNER SPRING

1983

AMERICAN SHAD DENSITY STUDIES

PONDS

Rearing Unit	Age (Days) Introduction	Age (Days) Harvest	Density: Introduction* Number Fish/Hectare	Density: Introduction* Stocking Rate ***	Density: Harvest Number Fish/Hectare	Density: Harvest Number*** Harvested	Percent Return	Size (mm) Harvest
1	19	64	269,000	48,000	20,200	3,600	7.5	74 (3.6 g)
2	19-20	68-69	483,000	86,000	34,200	6,100	7.1	62 (2.1 g)
3	19-20	98-99*	977,000	174,000	101,600	18,100	10.4	69 (2.6 g)
4	19-20	71-72	1,504,000	268,000	89,800	16,000	6.0	54 (1.1 g)

*Estimated density

**Samples for growth were collected when fish were 70-71 days of age

***0.18 Hectare Ponds

Evaluation of the Harvesting and Transporting of American Shad Fingerlings from Raceways

There has already been a great deal of work relative to the transportation of American shad fingerlings. This year's efforts were qualitative evaluations designed to determine the success that could be expected when harvesting fingerlings from raceways and trasnporting the fish in a standard, rectangular, Pennsylvania Fish Commission transportation unit.

To harvest fingerlings, the water level was lowered and fish were crowded to the end of a raceway section using a push screen. Fish were counted into the trout hauling unit by water brailing. No water treatments were used. Initially, 3,600 American shad fingerlings, 58 mm in length (1.2 g), were loaded into a standard quick release trout distribution unit. The transportation unit had three compartments with a total volume of 3,780 L. Two compartments have a volume of about 1,080 L each while the third compartment held about 1,620 L. Following loading, the fish were released directly back into the raceway using the quick release system. Instantaneous mortality due to handling was 0.2 percent (seven fingerlings). Mortality after 24 hours was an additional 0.6 percent (20 fingerlings).

A second group of 3,200 fingerlings, 51 mm in length (0.9 g) was counted and loaded. These fingerlings were transported for one-half hour and quick released back into a raceway. Instantaneous mortality was 0.3 percent (nine fingerlings) and 24-hour mortality was an additional 0.4 percent (12 fingerlings). The highest density transported in a standard transportation unit was $\leq$5 fish/L for a 5-hour period. There was no observed mortality.

A qualitative evaluation was made in October on the suitability of a new fiberglass transportation unit (mounted on a gooseneck trailer) for transporting American shad fingerlings. Compartments were loaded so that the effect of the following transportation related items could be noted: 1) Exceeding the carrying capacity of a compartment; 2) aerators vs disfused oxygen for aeration during transport; and 3) the 48-hour mortality following transport.

The shad fingerlings, 45 mm in length (2.6 g), were harvested from a pond October 5, then counted and transported October 6. The fish transportation unit was a six compartment unit; compartments were equal in volume with a total volume of 3,200 L. The quick release was a single, 152 mm manifold on the side of the unit. Compartments were loaded at the following densities: Compartments one and two, 8 fish/L (4,000 fingerlings); compartment three, 4 fish/L (1,800 fingerlings); compartment four, 6 fish/L (3,000 fingerlings); compartment five, 5 fish/L (2,900 fingerlings); and compartment six, 11 fish/L (6,000 fingerlings). Mean loading and transport time was 5.1 hours. Aeration in three compartments was accomplished by lightly bubbling pure oxygen through the water, aerators were used in the remaining compartments. Compartment six, with 6,000 fingerlings, 11 fish/L, was assumed to be over the carrying capacity. The high density compartment was aerated with bubbled oxygen. One compartment, 8 fish/L (4,000 fingerlings), was returned to Benner Spring for a quantitative evaluation. This compartment had a mean loading and transport time of 7 hours and received both types of aeration for equal periods of time.

It was obvious at planting that bubbled oxygen was less stressful to the fish than aerators for aeration. Scale loss was higher in compartments using aerators than in compartments where bubbled oxygen was used. It was also obvious that instantaneous mortality was higher in aerator compartments although no quantitative measurements were taken. The high density compartment (11 fish/L) appeared to have the highest mortality; therefore, it is assumed that 11 fish/L exceeds the carrying capacity for this type of transport unit. Mortality of fingerlings returned to Benner Spring (7 hours transport with the aerator used for 3.5 hours) was 10 percent (400 fingerlings after 24 hours) with an additional 2 percent (70 fingerlings) after 48 hours.

These preliminary tests indicated that, under appropriate conditions, there should be little or no difficulty in harvesting and transporting American shad fingerlings from raceways and ponds.

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JOB IV EVALUATION OF SHAD STOCKING

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INTRODUCTION

The purpose of stocking prespawned adult shad in the upper Susquehanna River and hatchery reared fry and fingerlings in the Juniata River is to produce a stock of shad, imprinted to the Susquehanna system, which will emigrate to sea and later return to the river as spawning adults. Evaluation of the results of these stockings is important for several reasons. North Branch collections of juvenile shad reveal whether or not natural reproduction of transplanted adults has occurred. Abundance and distribution of these progeny and condition of the fish are indicators of the strength of the year class produced and the relative health of the stock. Juniata River collections indicate success of the hatchery effort in producing outmigrant fingerlings. Below the confluence of the Juniata, all shad emigrants intermingle and cannot be differentiated as to source. Collection of young shad at hydroelectric projects in the lower river provides useful information on timing of the migration and survival through impoundments and over (or through) hydrodams. Finally, collection of juvenile shad below Conowingo Dam in late fall indicates success of the program in producing shad which survive the numerous obstacles to emigration from the river. These are the potential recruits to the restoration program.

The 1983 evaluation program in the North Branch was similar to that conducted in 1981-82 in that only a limited amount of effort was expended over a long stretch of river. This was necessary due to funding constraints and the primary need to confirm spawning success. Once juveniles were collected, all effort concentrated on defining those sites which could be worked effectively and sampled repeatedly (with success) to establish relative abundance index stations for future year comparison.

Work done in the lower river hydroproject forebays was designed to establish a technique to catch shad repeatedly at all projects and to better understand movements, timing and success in passing these barriers. Efforts below Conowingo Dam were dramatically expanded in 1983, with Maryland Tidal Fisheries taking a lead role in an attempt to determine suitable collecting sites and gears and to define timing of migration and develop a baseline index of abundance.

The authors extend their appreciation to Tom Koch, Chris Frese, John Foster and Ted Jacobsen for their contributions to this report.

EVALUATION OF SPAWNING SUCCESS OF ADULT SHAD

As in past years, National Environmental Services, Inc. was contracted by SRAFRC to sample the North Branch Susquehanna River for juvenile shad. Ichthyological Associates (Susquehanna River Ecological Study, Berwick, PA) sampled the river near Beach Haven for larvae (biweekly pump samples), juveniles (monthly seining), and adult fishes (monthly electrofishing) throughout the summer. This survey, conducted at several sites, was part of the post-operational impact analysis for PP&L's

new Susquehanna Steam Electric Station. No American shad were taken in any collections here, indicating that young shad were probably further upstream in nursery areas nearer to adult release sites. With only 2 weeks scheduled for the North Branch evaluation, NES initiated sampling at the NY-PA border and worked progressively downriver. Since seines were the principal collecting gear employed, sample locations were typically deepwater pools near river access sites.

<u>North Branch Sampling Schedule and Methods</u>

Juvenile shad sampling began on August 26 and continued through September 11 with a total of 10 collecting days during the period. The area from Sayre to Terrytown was sampled on August 26-28 and on August 29-30, NES personnel moved downriver to sample from West Falls to Duryea. No sampling was conducted from August 31 to September 6. Operations continued on September 7-9 between Duryea and Wilkes-Barre. On September 10, collections were made at the Duryea-Pittston area in the morning and moved upstream later in the day to the river reach from Mehoopany to Tunkhannock. Field sampling ended at Wilkes-Barre on September 11 and NES continued to maintain contact with IA-Berwick in the event that shad were taken in their routine monitoring program. Sampling locations are shown in Figure 4.1.

The principal gear used to sample for juvenile shad in the upper Susquehanna River were seines, electroshocker, and cast nets. Electrofishing gear was an AC/DC backpack unit (100-150 volts AC) equipped with two 5-ft. probes, modified to be used from a boat. Cast nets of

14, 16, and 20-ft. diameter were used in areas not practical for use of electrofishing gear or seines. Prior year efforts on the Susquehanna and Juniata rivers showed that seines were the most successful gear for sampling juvenile shad. Haul seines were the principal gear used in 1983 and the three nets measured 50'x4'(¼"mesh), 50'x4'(3/8"mesh), and 150'x6' (½"mesh). The nets were used interchangeably as topography and water depth dictated.

A 10-18 mile stretch of river was sampled daily with a typical days operation consisting of 15-20 seine hauls and 1-2 hours electrofishing. The length of time needed to execute one haul ranged from 15-25 minutes, depending on substrate, the number and size of fish taken, and flow conditions. Generally fishing operations were conducted between 0900 hours and 2000 hours. Night sampling occurred between 2000-2300 hours on two occasions.

IA-Berwick continued monthly electrofishing surveys near Beach Haven throughout the fall. In addition to field collections, contact was made with PP&L and UGI to monitor intake screens for impinged shad at power plants located at Sunbury, Beach Haven, and Hunlock Creek. Personnel from IA conducted the survey at Susquehanna SES between August 22 and October 14. Screens were washed three times daily (once each shift) and cumulative washes were examined daily. UGI personnel monitored intake screen washes three times each day at Hunlock Creek SES between August 17 - October 14, and PP&L employees followed the same procedure at Sunbury SES between September 13 - October 31.

Results of North Branch Sampling

Between August 29 and September 11, 83 juvenile shad were collected from the upper Susquehanna River over a 50-mile stretch of river. Shad were first collected at Falls, PA on August 29 and continued to be taken every sampling day thereafter. All shad were collected with haul seines (Table 4.1), and the number of fish taken per haul ranged from one on August 29-30 at Falls to 26 on September 10 at Duryea. Shad were taken on seven consecutive sampling days over a lengthy river reach suggesting that spawning was successful and the fish were broadly distributed.

Shad grew well in the Susquehanna River. Juveniles collected on the upper river ranged in length from 93-133 mm FL (Table 4.2). Mean length during the evaluation was 108 mm in August and 116 mm in September. Water temperature ranged from 75-80°F during this sampling period.

One of the objectives of the 1983 evaluation was to locate sample stations which could serve as monitoring sites for relative abundance analysis from year-to-year. These stations are characterized as areas where seines can be used effectively, are easily accessible by boat, and produce abundant numbers of shad on more than one occasion. Four areas meeting these criteria were identified. They are located over a 50-mile stretch of river from Tunkhannock to Wilkes-Barre. One area which produced best results is located at Coxton Yards near the Duryea/Pittston border. Shad were taken on every sampling occasion there. A total of 57 shad were taken from this stretch of river on four sample days.

Another apparent useful location is the Wilkes-Barre site where shad were taken during both the 1981 and 1983 surveys. A total of 18 shad were taken on the 2 sampling days at this site in 1983. Two other potential relative abundance survey locations are at Falls and Tunkhannock where small numbers of shad were taken on sampling days this year. Of particular interest is that all sites previously mentioned are located within 50 yards of a rapid water area and/or are deep backwater pools.

IA-Berwick reported taking one shad (127 mm) at Beach Haven on September 22 using electrofishing gear. No shad were taken from any of the intake screen samples at Hunlock Creek, Susquehanna SES, or Sunbury.

EVALUATION OF HATCHERY STOCKED SHAD IN THE JUNIATA RIVER

A survey of the lower Juniata River conducted in the late summer of 1981 indicated that juvenile shad from the Van Dyke hatchery were readily available to capture by haul seine near the river mouth at Amity Hall. This one site was successfully sampled in 1982 and again in 1983. The purpose of collecting shad in the Lower Juniata is to determine whether or not hatchery-reared fish grow normally and migrate downstream in the fall similar to their naturally produced counterparts.

Personnel from the Pennsylvania Fish Commission, Susquehanna River Basin Commission, and U.S. Fish and Wildlife Service were involved in the Juniata River collection program. Sampling difficulties precluded establishment of a relative abundance index in 1983.

Sampling Schedule and Methods

Sampling with seines at Amity Hall was loosely scheduled to occur bi-weekly during September and early October as personnel and equipment were available. In 1982, a similar schedule was cut short once confirmation of juvenile shad in the area was achieved (2 sample days). This same format was followed in 1983 with successful seining occurring on September 8 and 23.

The four-man seine crew met at the PFC Amity Hall access area in the early morning, and working with a 75' x 6' x ¼" mesh seine, made 6-8 hauls each day at several locations near a cove downstream from the boat ramp. Numerous difficulties were encountered with submerged snags, winds and currents. In most instances the net set poorly and could not be considered as a successful set - taking advantage of the full dimensions of the gear. A second boat was needed to help detach the leadline from snags, but was not available during this survey. Thus, no relative abundance baseline index was established for 1983.

Results

On September 8, 3 American shad averaging 105 mm FL were collected at Amity Hall in six hauls of the seine. On September 23, 11 shad representing two distinct size groups were collected in eight hauls. These fish averaged 50 mm (n=6) and 96 mm (n=5). One of the larger fish had a deformed lower jaw. Numerous juvenile cyprinids and centrarchids were taken in these collections and water temperatures were 69-75°F.

EVALUATION OF DOWNSTREAM MIGRATION THROUGH HYDROELECTRIC IMPOUNDMENTS

This phase of the evaluation program is important to determine if shad from upstream sources have moved to the lower river and whether or not they are successfully passing through hydroprojects and impoundments on their way to Chesapeake Bay. Hatchery and naturally produced shad cannot be differentiated and fish collected in the lower Susquehanna are attributed to both sources.

National Environmental Services, under contract to SRAFRC sampled hydroelectric project forebays at Holtwood, Safe Harbor, and York Haven during October through early December. Safe Harbor Water Power Corporation employees made daily inspections of turbine cooling water strainers at that project, and Radiation Management Corporation (RMC) biologists from the Muddy Run Lab (under contract to PECO) sampled the Peach Bottom Atomic Power Station (PBAPS) water intake screens, Conowingo Dam strainers, and the Conowingo forebay area immediately above the dam. Below Conowingo, RMC sampled for shad with an experimental incline net in the turbine discharge, and with gill nets in the tidal river. Maryland DNR (Tidewater Fisheries) conducted extensive sampling for juvenile shad using traditional collecting gear in the tidal river and Susquehanna Flats. The 1983 juvenile shad assessment from York Haven to the river mouth was much more comprehensive than in past years.

Methods and Sampling Schedule

York Haven Project - NES personnel sampled the trash rack area using a 20-ft. diameter nylon cast net (½" mesh) on three occasions in October and three in November.

Safe Harbor Project - NES personnel sampled the trash gatewell inside the forebay; the first two regulating gatewells outside the forebay; and on occasion, both sides of the forebay skimmer wall using a 20-ft. diameter cast net during late October and November (6 sample days). On November 30 and December 8 a 16-ft. diameter cast net (mono) was used in the trash gatewell. Safe Harbor personnel made daily checks of cooling water intake strainers for impinged shad during October 1 through December 15. Controlled spills were provided at the trash gate on several sampling occasions in November.

Holtwood Project - The turbine intake area was sampled by NES with a 20-ft. diameter cast net on four occasions during late October through mid-November and with a 16-ft. cast net on two dates in late November and early December.

Peach Bottom Atomic Power Station - Intake screens washings at Peach Bottom were examined on 24 occasions between October 14 and December 12. All impinged fish were accounted for by RMC during this 2 month period.

Conowingo Project and Lower River - Strainer samples were monitored weekly between October 14 and December 16. Sampling in the penstock areas with cast net (16-ft. diameter) was conducted by RMC on six occasions between November 9 and December 6. A 5-ft x 5-ft experimental incline net was set in the Conowingo tailrace approximately 300-ft. below the discharge of turbine No. 2 during 3 days in November. RMC personnel fished floating gill nets in the tidal river during 5 days in November and 2 in December (total 11.1 hours). Nets measured 200-ft (¼" and ½"), and 250-ft experimental (½" to 2½", 50-ft panels).

Sample stations used by Maryland DNR during the expanded November-December study were the same as those used in their ongoing shad monitoring program with the exception of an added seine site located at Lapidum in the Susquehanna River (site 8). Six sites were sampled using a 16-ft semi-balloon otter trawl (1½" stretch mesh body; 1¼" stretch mesh cod end with ½" mesh cod end liner), and eight sites were sampled using a 200-ft haul seine (10-ft deep with ½" stretch mesh). In addition, an anchor gill net and a drift gill net (both 200-ft x 6-ft x 2-in. mesh) were utilized in the Susquehanna River in the area between Port Deposit and the U.S. Route 40 bridge crossing. All locations are shown in Figure 4.2.

Single seine pulls and trawl runs were made at each sampling station with the exceptions of November 9, 10, and 14 when replicate seine pulls and trawl runs were made. On any one sampling day either trawl or seine stations were sampled. Sampling gear used on any given day was dependent on conditions such as wind speed and direction, fog and tide stage. An effort was made to use the trawl and seine as equally as possible. The seine was used a total of 7 sample days covering a total sweep area of 1.77 hectares, while the trawl was used on 9 sample days and covered a total sweep area of 7.78 ha. Sampling effort was concentrated on trawl stations 1, 5 and 6 and seine stations 1, 5, 6, 7, and 8. These stations are located along deeper channels where juvenile American shad are believed most likely to be found in cold water.

In addition to seine and trawl samples, the anchor and drift gill nets were fished a total of 9 days in the river below Port Deposit. Table 4.3 shows the sampling effort during this study by date, gear and location.

Results

York Haven - The forebay at this project was first sampled on October 6 and no shad were taken. By mid-October shad "flashing" was reported at the project during early morning hours, and on October 21, 50 shad averaging 127 mm (FL) were collected in front of the trash racks. Water temperature was 63°F and river flow 8,000 cfs. This area was successfully sampled on October 26 (70 fish; mean length 132 mm; 55°F); November 3 (2 fish); and November 16 (4 fish; $\bar{x}$=146 mm; 46°F). On November 30, after the project had been continuously spilling for 10 days, no shad were collected at York Haven Project.

Safe Harbor - The first sample day with cast net at Safe Harbor was October 26 when 39 shad were taken ($\bar{x}$=120 mm). On November 3, 61 shad were collected. Since shad juveniles appeared to congregate at the first gatewell (inside the skimmer wall) prior to major generation startup each morning, SHWPC was asked to provide a controlled spill at this gate to facilitate moving fish downstream. Spills of about 2,500 cfs (5-10 minutes) were provided on November 5, 7, and 9 following confirmation that shad were present. On these days, 44, 60, and 70 shad were taken at this regulating gate prior to the spill and none afterwards. On November 5, net samples of shad were also taken in small numbers on either side of the forebay skimmer wall. Sampling continued at Safe Harbor on November 16 and 30, and December 8, but no shad were collected on these dates (water temperatures 41-46°F).

SHWPC personnel inspected turbine cooling water strainers for impinged shad each day between October 1 and December 15. Three shad were collected on October 21, and between November 3-15, an additional 38 shad were found. Most fish (31) were taken on November 11-14 when water temperature was 50°F. These fish averaged 127 mm and ranged in size from 110 mm to 145 mm. Safe Harbor project maintained a continuous release of 3,000 cfs throughout the autumn sampling period.

Holtwood - Cast net collections were made at Holtwood in an area immediately adjacent to the turbine intake No. 1. Shad were taken there on each of 6 sampling days starting on October 26 (37 shad; $\bar{x}$=123mm) and ending on December 8 (40 shad; $\bar{x}$=127mm). A total of 251 shad were collected with cast net at Holtwood in 1983. Exceptionally high flows on December 15 precluded sampling on that scheduled day (see Figure 4.3). Very small shad measuring 60-85 mm were collected at Holtwood in late November and early December along with larger fish. Holtwood maintained a 3,000 cfs continuous release during the fall.

Peach Bottom Atomic Power Station - Between October 14 and December 12, RMC biologists examined intake screen washes at Units 2 and 3 each 2-3 days at PBAPS. The first shad was collected on November 2 and the last on December 5. A total of 31 American shad were taken here in 1983 compared to 115 in 1982. Gizzard shad were predominant in the catch.

Conowingo - Strainer samples were monitored for impinged American shad at Conowingo Dam once each week between October 14 - December 16 (10 sample weeks). A total of 8,648 fish representing 10 species were collected of which 99% were gizzard shad. Only one American shad was taken on November 25. Continuous releases were discontinued here on September 15 in keeping with a FERC order.

Cast net samples were taken in the areas approximating each of the eleven penstocks and one sample was taken in the extreme west corner of the dam. Collecting attempts were made by RMC personnel on November 9, 14, 17, 22, 23, and December 6. Gizzard shad and bluegills were the only species captured.

A new experimental collecting program was conducted on November 9, 10, and 11 in the Conowingo tailrace. A 5-ft x 5-ft incline net was set about 300 feet below the turbine No. 2 discharge and was successful at capturing 34 gizzard shad which presumably passed through the turbine. No American shad were collected.

Tidal River - RMC biologists set floating drift gill nets in the lower river off Wiley's (about 1 mile above the I-95 bridge) on November 2, 7, 9, 16, 29, and December 2 and 8. Total fishing time for the three nets deployed was 665 minutes and no American shad were collected.

The Maryland DNR sampled for juvenile shad in the lower Susquehanna River and Susquehanna Flats area from November 9 through December 14. During this 5-week period, 30 seine hauls and 29 trawl runs were completed. Also, anchor gill nets were set a total of 27 hours and drift nets were set a total of 4 hours. All sampling gear combined captured a total of 85,644 fish representing 22 species. Of the total fish collected, the seine accounted for 84,710 (99%), the trawl took 904, and the gill nets collected 30 fish. Gizzard shad accounted for 99% of the fish taken and no American shad were collected in the lower river or Flats.

Table 4.4 summarizes all American shad collections made in the lower river between York Haven and Conowingo during the fall of 1983. Figure 4.3

displays average daily flows (Marietta gauge) and water temperatures during the period September 15 - December 15, 1983.

DISCUSSION

Reproduction of transplanted adult shad in the North Branch Susquehanna River was confirmed in 1983 as it was in 1981. All of the 84 shad collected during late August and September were taken between Beach Haven and Tunkhannock. Though twice as many adults were stocked at Owego, NY (Hudson fish) compared to Tunkhannock (Connecticut River fish), no juveniles were collected within 75 miles of the upper release site. This may indicate that (1) adult survival was poor for Hudson River fish; (2) water conditions were not as favorable for reproduction near Owego compared to Tunkhannock; (3) juvenile sampling upstream was insufficient to detect the presence of shad; or, (4) shad produced in or near New York waters of the river migrated downstream and were a component of the successful collections made below Tunkhannock. Though we cannot resolve this question, SRAFRC should consider stocking all adult shad at Tunkhannock - if for no other reason, to shorten the distance from nursery areas to the river mouth. Even from Tunkhannock juvenile shad must swim 218 miles to the Chesapeake Bay and an additional 200 miles to the ocean. No other East Coast shad stock is faced with a migration of this magnitude.

During the 1983 North Branch survey, two prime collecting sites were identified for future relative abundance comparison. These sites, Coxton Yards near Duryea and Wilkes-Barre, should be extensively sampled on a fixed schedule with a set piece of gear in future years. Further effort should be devoted to sampling at Tunkhannock and Falls, PA to determine the usefulness of these sites for the same purpose. Intensive sampling of power plant cooling water intakes at Hunlock Creek, Susquehanna SES, and Sunbury SES produced no shad and this effort can probably be dropped in future years.

Fewer shad were taken in Juniata River collections in 1983 compared to 1982 and this may partially be explained by problems experienced during netting. Not enough money, equipment or manpower were devoted to the Juniata in 1983. Although the Amity Hall site has produced shad each year since 1981, irregular bottom contour and numerous snags in the prime collecting location preclude adequate setting of seines for effective samples. Electrofishing trials here in 1981-82 produced no shad.

Collection of large numbers of shad at York Haven (126), Safe Harbor (324), and Holtwood (251) was very encouraging. Many more shad (perhaps thousands) could have been taken with the 20-ft cast nets which proved very effective in the dam forebays, particularly during early morning hours prior to generation startup. These collections provided a good basis for determining timing of the downstream migration, size of fish, and affects of project operation on movements. From a preliminary view at Safe Harbor, it appears that controlled spills may be effective in passing shad over the dam. Further work needs to be done on this and it will be desirable to investigate survival associated with spilling as well as passing shad through turbines.

Although large numbers of shad were collected at the three upstream projects in 1983, very few were taken below Holtwood Dam. The Peach Bottom impingement collections (31 American shad) were only 27% of that taken in 1982 where we had little indication of major downstream movement. This may indicate a problem with turbine mortality at the Holtwood Project, disorientation in Conowingo Pond, or entrainment at Muddy Run.

Perhaps of most serious concern was the fact that no shad were collected in the lower tidal Susquehanna River, even with extensive efforts on the part of RMC and Maryland DNR to catch this species. This is very discouraging and regardless of positive results upstream in the North Branch and hydroproject forebays - we must once again assume that few American shad are successfully making their way to Chesapeake Bay.

CONCLUSIONS

1. Transplanted adult shad successfully spawned in the North Branch Susquehanna River. Progeny resulting from this reproduction grew rapidly and were readily captured at several locations during late August and September.

2. Hatchery produced shad fry and fingerlings exhibited normal growth in the Juniata River and migrated at least to Amity Hall by mid-September. Some incidence of deformity (short gill covers, crooked mandible) was detected in hatchery, Juniata and hydroproject collections. These may be related to production techniques (diet, stress, etc).

3. Young shad were available for capture in substantial numbers using cast nets at select forebay locations at York Haven, Safe Harbor, and Holtwood projects during October through early December. Fish exhibited a wide range of sizes and were taken at water temperatures of 41-65°F.

4. Peach Bottom Atomic Power Station intakes are a valuable collecting location, though numbers of shad taken there in 1983 were considerably reduced compared to 1982.

5. We cannot document that shad produced in the Susquehanna River system in 1983 have successfully completed migration to Chesapeake Bay.

Table 4.1 Data on Juvenile Shad Collections in the Upper Susquehanna River in 1983.

Date	No. shad	Length range (mm)	Location	Method of capture	Water Temp.(F)	Unit of Effort* S	E	CN
8/26	0	-	Sayre-Ulster	-	80	20	-	-
8/27	0	-	Ulster-Wysox	-	80	20	1.0	-
8/28	0	-	Wysox-Terrytown	-	79	18	2.0	-
8/29	4	114-115	Falls	seine	79	20	-	-
8/30	2 (am) 7 (pm)	98-99 104-109	Falls Duryea/Pittston	seine	79	22	-	10
9/7	4	113-127	Duryea/Pittston	seine	78	7	-	-
9/8	12	94-118	Duryea/Pittston	seine	77	14	1.5	5
9/9	17	93-127	Wilkes-Barre	seine	75	19	1.5	7
9/10	30 (am) 4 (pm)	96-133 123-125	Duryea/Pittston Tunkhannock	seine	75	21	2.5	-
9/11	3	120-123	Wilkes-Barre	seine	75	15	1.0	-

* S = seine (#); E = electrofishing (hrs); CN = cast net (# throws)

Table 4.2 Length-frequency distribution of juvenile American shad taken on the upper Susquehanna River - 1983

Fork Length (mm)	AUGUST 29	30	SEPTEMBER 7	8	9	10	11	Totals
91 - 95	-	-	-	1	1	2	-	4
96 - 100	-	2	-	-	2	-	-	4
101 - 105	-	3	-	-	2	-	-	5
106 - 110	-	4	-	1	1	3	-	9
111 - 115	4	-	1	3	5	7	-	20
116 - 120	-	-	2	7	4	11	1	25
121 - 125	-	-	-	-	1	7	2	10
126 - 130	-	-	1	-	1	3	-	5
131 - 135	-	-	-	-	-	1	-	1
Totals	4	9	4	12	17	34	3	83

August mean length - 108 mm (n=13)

September mean length - 116 mm (n=70)

Table 4.3 Sampling effort by date, gear, and location for evaluation of juvenile shad outmigration from the Susquehanna River in 1983.

DATE	Seine sites sampled	Trawl sites sampled	Anchor gill net set	Drift net set
November 9	5,6,7			
November 10		1,5,6		
November 14	1,2,3,4			
November 15			3.0 hrs.	
November 17			3.0 hrs.	
November 18		1,2,5,6		
November 21		5,6	6.5 hrs.	1.0 hr.
November 22	5,6,7,8		8.5 hrs.	
November 23		1,5,6		1.0 hr.
November 28		1,5,6		1.0 hr.
November 29	5,6,7,8			1.0 hr.
November 30	7,8		3.0 hrs.	
December 1		1,5,6		
December 2		1,5,6		
December 5	5,6,7,8		3.0 hrs.	
December 8	6,7,8			
December 9		5,6		
December 14		3,4,5		

Table 4.4 Summary of Juvenile American Shad collections in lower Susquehanna River during October - December, 1983.

DATE	FLOW[a] (cfs)	TEMPERATURE[b] (°F)	Number of Shad taken by Location and Gear						
			YORK HAVEN (cn)	SAFE HARBOR (cn)	SAFE HARBOR (st)	HOLTWOOD (cn)	PBAPS (int)	CONOWINGO (cn)	CONOWINGO (st)
10/6	4410	68	0		0				
10/14	5480	66					0		0
10/17	6800	64					0		
10/19	9990	63					0		
10/20	8300	63	50						
10/21	7960	61			3		0		0
10/24	10600	58			0		0		
10/26	10200	56	70	39	0	37	0		
10/27	9520	54			0		0		
10/28	8670	54			0				0
10/31	6970	52			0		0		
11/2	6000	52			0		1		
11/3	5890	52	2	61	1	68			
11/4	5710	52			1				0
11/5	5200	52		53	1				
11/7	6170	51		60	0		0		
11/8	6230	51			1				
11/9	6260	51		70	0	25	0	0	
11/10	6390	50			2				0
11/11	7940	50			10		4		
11/12	11900	49			12				
11/14	14500	49			9		11	0	
11/15	16100	47			1				
11/16	20600	45	4	0	0	45	8		
11/18	27800	44					1	0	0
11/21	24700	46					0		
11/22	32700	49						0	
11/23	37400	49					2	0	
11/25	38600	49							1
11/28	40800	46					0		
11/30	46300	46	0	0		36	1		
12/2	51600	43					2		0
12/5	45400	40					1		
12/6	47000	41						0	
12/7	59500	41					0		
12/8	71800	41		0		40			
12/9	77400	40					0		0
12/12	55400	41					0		
12/16	305000	45							0
TOTALS			126	283	41	251	31	0	1

Notes: a - flow measured at USGS Marietta gage; b - temp measured at Safe Harbor Dam.
cn = cast net; st = strainer; int = intake

Figure 4.1 Location map showing adult stocking sites and juvenile shad collecting locations on the North Branch Susquehanna River - 1983.

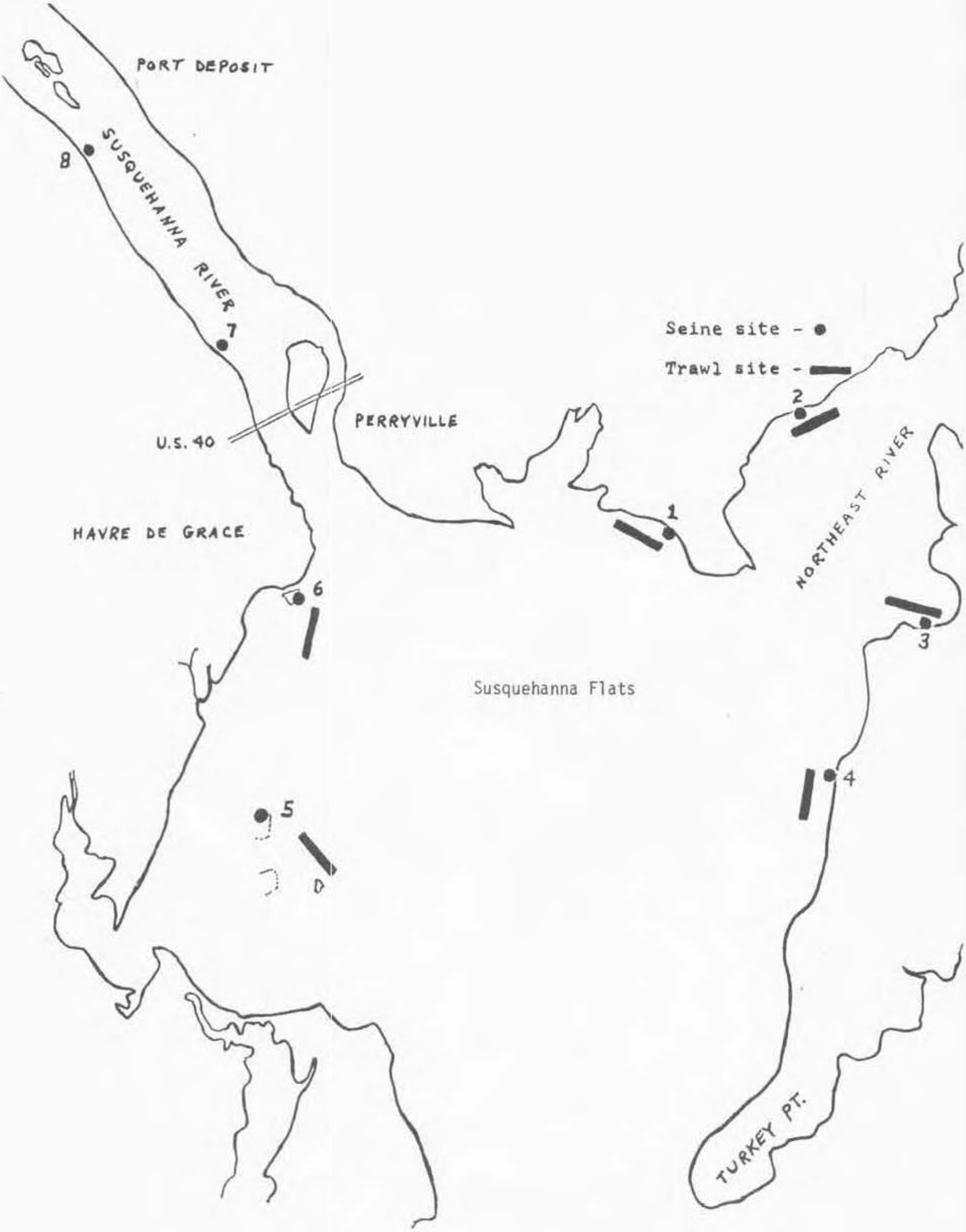
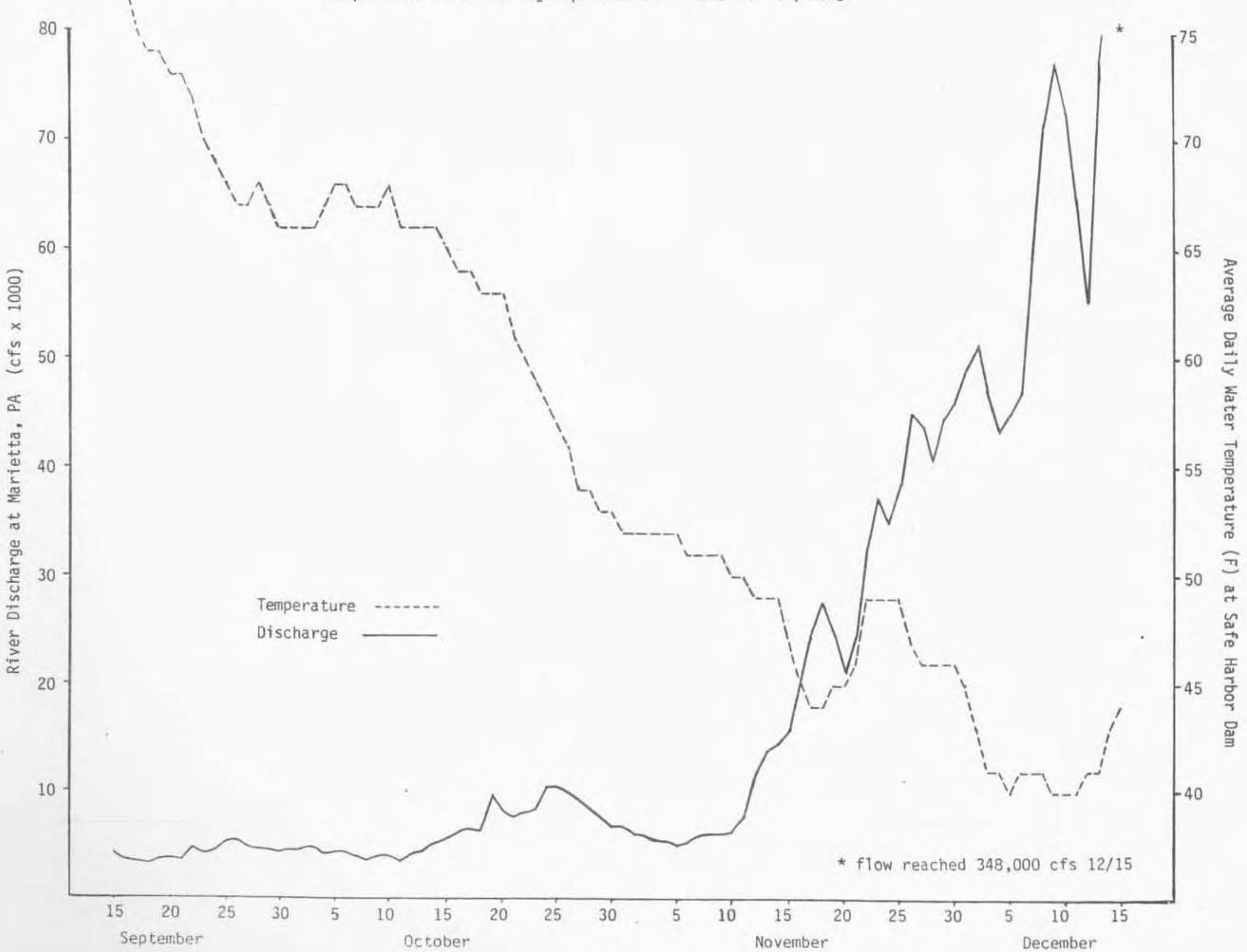


Figure 4.2 Sample station locations for Maryland DNR 1983 juvenile shad survey of the lower Susquehanna River and Flats.

Figure 4.3 Average daily flow and water temperature in the lower Susquehanna River during September 15 - December 15, 1983.



JOB V. LAMAR FISHERY TECHNOLOGY CENTER INVESTIGATIONS

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INTRODUCTION

The Fishery Technology Center at Lamar (formerly Fish Cultural Development Center) continued studies in 1983 directed toward developing and modifying American shad intensive culture, transportation techniques, and marking investigations as part of SRAFRC's cooperative effort to restore American shad to the Susquehanna River system.

Testing continued in an effort to evaluate the rare earth element samarium for marking juvenile American shad and Atlantic salmon. Studies included testing various means of incorporating samarium into fish tissue (immersion baths, constant flows, laced diets) and subjecting fish to higher samarium concentrations than were tried in 1982.

Other Technology Center studies included evaluating the immune response of American shad to various antigens; transportation techniques for juvenile and adult shad; and genetic strain variations of shad from three stocks. FTC personnel took a lead role in coordinating and conducting the shad egg collection effort on the Delaware River in May and participated in adult shad transportation tests using standard rectangular (compartmented) trout distribution tanks (see Job I).

MARKING JUVENILE SHAD WITH SAMARIUM

A method of mass marking juvenile anadromous fish, particularly American shad, is needed to evaluate recent restoration efforts. The rare earth element samarium (Sm) is being tested at the Fishery Technology Center as a means of marking sensitive fish such as shad. Methods proven successful with other species of fish such as physical tagging and staining have been unsuccessfully tried with shad. Scale loss, susceptibility to stress and other unexplained mortalities contribute to the difficulties in marking shad at a very young and vulnerable stage of life. Marking techniques being tested eliminate the necessity of direct handling and facilitate mass marking large numbers of fish. Atlantic salmon are also being exposed to samarium to test the feasibility of marking species other than shad.

Last year, samarium was incorporated into a formulated test diet (Abernathy salmon diet) at a concentration of 30 mg $SmCl_3 \cdot 6H_2O$/gram diet and fed to American shad for 30 days. Two groups of shad (25 mm and 57 mm) were marked and fish were sampled at 30-day intervals and tested for samarium content. Samples were analyzed using Neutron Activation Analysis (NAA). Results indicated that shad can be marked using samarium but a retention time of only 210 days was achieved (Fig. 5-1).

Our goal this year is to extend the retention time so that a persistent mark is attained. Various methods of incorporating samarium into the juvenile shad have been tested using higher concentrations. One method of treatment involved exposing 4-day old sac fry (6-7mm) to a constant low of samarium chloride solution for 1-hour daily for 18 consecutive days. Since no previous results were available, a starting concentration of 5ppm $SmCl_3 \cdot 6H_2O$ (2ppm Sm) was used. The solution was placed into a holding vessel and dripped into the tank using a syringe tip, with incoming water. Water flow was adjusted to 5 L/min and maintained for the 1-hour marking period. Thus far this method has proven successful with a minimum of shad mortality.

Another application method tested this year was an immersion bath in a samarium chloride solution. Various concentrations were tested indicating a maximum survival rate at 100ppm $SmCl_3 \cdot 6H_2O$ (40 ppm Sm)(Fig. 5-2). American shad (15-18mm) and Atlantic salmon (75mm) were immersed in this concentration for three minutes at two different times.

Along with these two methods of treatment, Sm was also incorporated into formulated test feed (W-16 Spearfish Diet) at two higher concentrations than were used the previous year. American shad (25-40mm), which were fully converted to formulated feed, were fed this diet at 50 and 100 mg samarium chloride hexahydrate per gram of diet for 30 days. Atlantic salmon (75mm) were also treated with Sm by incorporating the same concentrations into the appropriate formulated feed for that species (ASD2-3(The laced diet was prepared in batches by carefully mixing the appropriate concentration of $SmCl_3 \cdot 6H_2O$ solution into the feed and adding oil for adhesion. Diets were refrigerated and the proper amounts were fed to the fish daily by hand. The fish were converted to regular formulat feed after the 30-day marking period.

Since previous testing showed that 4-day old American shad could be marked using a constant flow method, both Atlantic salmon (mean length 97mm) and larger shad (average 51mm) are in the process of being exposed to higher concentrations of Sm. The advantage of this method is a greater overall exposure to Sm for a longer time than with immersion. It is also uncertain what levels of Sm the treated fish are actually taking up via the laced diet as the fish feed at different rates and amounts.

On five separate occasions small constant flow tests were set up in egg hatching jars to determine a suitable concentration for exposure. Twenty shad (15-25mm) were subjected to concentrations ranging from 10-1000ppm $SmCl_3 \cdot 6H_2O$ (Fig. 5-3). The solution was placed into a holding vessel and administered for 1-hour using calibrated syringe tips and inserted in such a way that the Sm solution entered the egg hatching jar with the incoming water through the bottom and circulated out through the top. Mortalities after a 24-hour period were plotted and optimum survival was indicated at a concentration of 60ppm $SmCl_3 \cdot 6H_2O$ (24ppm Sm). A dosage of half this concentration (12ppm Sm) was also tested to determine whether tag retention can be achieved using a smaller amount of Sm.

Atlantic salmon (97mm) and American shad (51mm) were exposed to these concentrations. Samarium chloride solutions (30 and 60 ppm) were dripped into the tanks with the incoming water with a flow rate of 2L/min. Nearly 100% mortality occurred in the shad tanks while salmon exhibited no mortality. Increase in size of the shad and physiological differences (metamorphosis) that occurred since the small-scale constant flow tests were conducted were the probable cause of the shad mortalities. Further testing with fish of this size should be done at a reduced concentration of 15 ppm $SmCl_3 \cdot 6H_2O$ (6ppm Sm).

In all samarium tests (immersion, constant flow, and diet) fish are being held and sampled monthly for neutron activation analysis and/or atomic absorption spectroscopy. The NAA method, performed under contract by the University of Michigan, was used on fish samples marked with samarium laced diets last year. In this analysis, samples are dried at 110 C for 24-hours and Sm detection is carried out after samples have been bombarded with thermal neutrons. The radioactivity of ^{153}Sm in the sample is measured with a gamma-ray spectrometer 48-hours after irradiation. The Sm content is then determined by comparing the gamma-ray spectrogram with that of a standard sample (Michibata and Hori, 1981).

Neutron activation analysis has the advantage over atomic absorption in that it is more sensitive to low levels of Sm (detection in parts per billion). The drawback to this analysis is the $25 cost per sample which when added to the high cost of samarium makes the method impractical. Atomic absorption is much less expensive but the minimum detection level is 0.5ppm.

In the atomic absorption analysis fish are ashed at 500 C and digested with concentrated nitric acid. A second ashing is performed after which hydrochloric acid is added. Samples are diluted to 10 ml with a potassium solution which acts as an ionization suppressant. The liquid is then aspirated through a nitrous oxide acetylene flame where it is vaporized and detected using a hollow cathode lamp specifically designed for samarium. The absorbance read is converted to ppm based on standard values stored in the AA.

The peak height method of AA analysis which is now being tested at the Northeast Fishery Research and Development Laboratory at Wellsboro, allows Sm in fish samples to be concentrated to several times the original concentration. Very small sample amounts can be aspirated at shorter integration times. This registers on a recorder as a peak, with the higher peaks indicating higher concentrations. The procedure indicates only presence or absence of Sm and is not as quantitative as the standard AA procedure. Advantages of the peak height method are that it is very cost-effective and that smaller amounts of Sm can be detected later in the study. A graphite furnace being purchased by the Wellsboro Lab will be used with the peak height AA analysis. This will provide a non-flame technique with potential sensitivity increases of 1000-fold. It also allows direct disintegration of dried fish samples placed in the furnace.

As results indicate thus far, Sm can be used to mass mark juvenile American shad using several methods of application. The length of time the element is retained however, is inadequate and requires further work. Rare earth elements do show promise for short-term marking studies such as might be necessary for turbine mortality assessment or evaluation of outmigration of juvenile shad.

IMMUNE RESPONSE STUDY

In 1982, a project was designed by Doug Anderson (Leetown National Fish Health Lab) to investigate the immune response in American shad and study the possibilities of tracing migration through immunizing the fish. Testing was completed in 1983 and the results are summarized here. Six-month old shad (average 89mm) were immunized by injection with two potent immunogens, the hapten DNP (dinitrophenyl) conjugated to the carrier carbohydrate molecule, Ficoll; and the O-antigen extract of the fish bacterial disease agent, *Yersenia ruckeri*. The immune response was monitored by the passive hemolytic plaque assay (Jerne test) for numbers of splenic or anterior kidney and antibody producing cells (APC) and by passive hemagglutination to follow the titers of humoral antibody.

Four weeks after immunization, numbers of APC were highest in the anterior kidney with only a few found in the spleen. Humoral antibody titers were also detectable in the fish at this time, and were still present in samples taken 4 months after immunization. In contrast to the rainbow trout standard model, the shad were slower in mounting an immune response, and the spleens showed a more primitive morphology. These tests demonstrate that shad have an adequate immune response for detection, although certain adaptations of the immunological tests are required. Immunization regimens could be monitored for the detection of specific antibody, and possibly young fish could be traced in river systems for a few months. Data about how long after immunization the specific reactions could be traced is still incomplete.

AMERICAN SHAD STRAIN EVALUATION

American shad stocks from several east and west coast rivers are being utilized in the Susquehanna River restoration program. Little or no information is available at this time on differentiation of the various stocks. Physiological or genetic differentiation could possibly be used to identify adult shad that return to the Susquehanna River to spawn each year. In the future, strain evaluation information could be used in conjunction with fishery management and hatchery production data to determine any strain superiority.

Both physiological and genetic differences and similarities of the various American shad stocks or strains need to be demonstrated. In a cooperative study between the FTC and Penn State University, American shad from the Delaware River (40 fish), Columbia River (70 fish), and the Waccamaw River, SC (40 fish) were examined by Ken Johnson (PSU) for genetic variation using horizontal starch get electrophoresis. Electrophoretic techniques and genic nomenclature followed that detailed in May, Wright, and Stoneking (1979). Twenty-three enzymes coded by approximately 32 gene loci were resolved in muscle, liver, or eye tissue using three different buffer systems (Table 5-1). Nine of these enzymes exhibited variation. However, the variation observed for the enzyme EST did not fit any simple genetic model and therefore was not used in subsequent analyses.

The observed variation for the enzymes AAT, CK, ME, MPI, PEPS, PGK, PGM, and SDH could easily be interpreted in terms of simple monogenic polymorphisms (Fig. 5-4). Allele frequencies for these eight polymorphic loci are given in Table 5-2 for the Columbia River, Delaware River, and Waccamaw River samples. Only the allele frequencies at the PEPS locus were significantly different among the three samples. The similarity of allele frequencies in samples collected from distant geographic locations suggests that the American shad does not form discrete, non-interbreeding populations. At least a small amount of straying and inter-mingling of stocks from different river systems on each coast would appear to occur to account for the observed allele frequency homogeneity.

Samples of shad from all three rivers exhibited very low levels of genetic variability. Average heterozygosity (the average proportion of loci heterozygons per individual) based on the 32 loci examined was 0.025 for the Columbia River sample, 0.018 for the Delaware River sample, and 0.029 for the Waccamaw River sample. These values are similar to that reported for gizzard shad (Hatfield et al, 1982), but lower than that reported for other fish species (Selander, 1976; Nevo, 1978; Allendorf and Utter, 1979).

The similarity of allele frequencies among the samples of American shad examined in this study, coupled with the low degree of genetic variability exhibited in these samples, precludes the possibility of using isozyme markers to identify the native rivers of particular spawning runs of this species.

HISTOLOGICAL PROFILE OF JUVENILE AMERICAN SHAD

Histopathology is an essential tool in the study of infectious and non-infectious diseases. Histopathological examination of tissues from fishes infected with bacterial, viral, or parasitic pathogens reveals microscopic cell and tissue changes caused by pathogens, shows target cells and organs of the disease agent, and indicates virulence mechanism. Histopathology also provides valuable information on tissue changes associated with nutritional imbalances, environmental toxicity, and stress mediated diseases. Finally, histopathology can serve to provide valuable clues to the cause of unexplained mortality in fish populations.

Intensively cultured American shad exhibit increased mortality at a developmental stage referred to as metamorphosis. Infectious agents do not appear to be responsible. The objective of this study is to evaluate histological/histochemical techniques as tools in diagnosis of causes of mortalities of American shad under hatchery conditions.

Juvenile American shad were reared at the Lamar FTC from hatch through the metamorphosis developmental stage (24-32mm). Samples of healthy and dying fish were collected each week, fixed in Bouin's solution for 24 hours, stored in 65% ethyl alchohol, and mailed to the National Fish Health Research Lab (Leetown). Histological examinations will be conducted by Dr. Roger Herman to determine if developmental or morphological abnormalities might explain the increased mortality associated with metamorphosis. Results are expected during 1984.

IMPROVEMENTS IN AMERICAN SHAD CULTURE

In past years, the FTC usually had fewer shad fry on hand for experimental studies than we assumed survived from hatch. Even though some modifications were made to the Von Bayer egg enumeration method, it appears that the number of viable eggs capable of hatching may still be routinely overestimated. Consequently, the actual number of fry that hatch is less than the quantity assumed to have hatched.

To verify whether or not this was actually happening, the FTC conducted a test using a random hatch of artificially fertilized shad eggs collected from the Delaware River. Ten samples of 10ml of eggs each were counted and yielded an average of 336 ± 39 eggs. A volume of 350ml eggs (11,589) was placed in a 6L egg hatching jar. Water temperature was held at a constant 17 C and eggs were treated with 1667ppm formalin (1:600) for 17 minutes daily until just prior to initial hatch. Dead eggs were removed and enumerated before and after hatch.

A total of 162.5ml of dead eggs (5460) were removed from the incubation jar and volumetrically enumerated. The remaining 6,129 eggs were considered viable and capable of hatching as fry. However, only 4,833 fry were actually counted in the rearing tank and incubation jar 11 days after the test was initiated and 780 of these fry were dead (shad egg hatch is completed within 10 days at 17 C). This left 4,053 live swimming fry at completion of egg hatch -- only 66% of the number of fry expected to hatch.

These results are similar to those obtained by Tom Wiggins of the PFC Van Dyke Anadromous Fish Research Station (personal communication) and observed at Lamar in past years. A small percentage ($<5\%$) of the difference in number of fry expected at hatch is attributable to error in enumeration of viable eggs on hand. The volume of dead eggs is generally subtracted from the total number of eggs. The number of viable eggs on hand is overestimated because dead eggs are more flaccid and smaller in diameter than turgid, water-hardened live eggs which are used to measure the volume and total number of eggs on hand.

The difference in number of fry expected and actual number of fry on hand following hatch is quite significant particularly considering the scope of the Susquehanna River shad hatchery program (i.e. 30-50 million eggs per year). However, the problem can be negated by simply multiplying the number of viable eggs on hand at hatch by 0.65-0.70, depending on the method used to determine the number of viable eggs. With this correction, a more accurate count of total live fry at hatch will be obtained.

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TABLE 5-1. Tissues and buffer systems that best resolved the enzyme loci examined in this study

Enzyme	Abbreviation	Locus	Tissue[1]	Buffer[2]
Aspartate Aminotransferase	AAT	1,2	E,M,L	R
Adenylate Kinase	AK	1	M	C
Alcohol dehydrogenase	ADK	1	L	R
Creatine kinase	CK	1,2	M,E	R,M
Diaphorase	DIA	1	L	C
Esterase	EST	?	E(M,L)	R
Fructose diphosphatase	FDP	1	L	M
Glycerol-3-phosphate dehydrogenase	G3P	1,2	M	C
Glucosephosphate isomerase	GPI	1,2	M	R
Isocitrate dehydrogenase	IDH	1,2	M,E	C
Lactate dehydrogenase	LDH	1,2,3	M,E	R
Malate dehydrogenase	MDH	1,2,3	M	C
Malic enzyme	ME	1,2	M	C
Mannosephosphate isomerase	MPI	1	E	M
4-Methylumbelliferyl phosphate	MUP	1	L	C
Phosphogluconate dehydrogenase	PGD	1	M	C
Phosphoglycerate kinase	PGK	1	M	C
Phosphoglucomutase	PGM	1	M	C
Peptidase A	PEPA	1	M	R
Peptidase D	PEPD	1	E	M
Peptidase S	PEPS	1	E	M
Sorbitol dehydrogenase	SDH	1	L	R
Superoxide dismutase	SOD	1	L	R

1 M = muscle L = Liver E = eye 2 R = described by Ridgway et al. 1970 C = described by Clayton and Tretiak 1972 M = described by Markert and Faulhaber 1965

TABLE 5-2. Allele frequencies and their 95% confidence intervals for the polymorphic loci examined in this study.

Locus	Allele	Columbia River	Delaware River	South Carolina
Aat-1	100	1.00(.98-1.00)	1.00(.97-1.00)	0.99(.96-.99)
	145	0	0	0.01
CK-1	100	0.94(.90-.98)	0.99(.96-.99)	0.90(.84-.96)
	136	0.06	0.01	0.10
Me-1	100	0.99(.97-.99)	0.95(.90-.98)	0.98(.95-.99)
	70	0.01	0.05	0.02
Mpi	100	0.99(.97-.99)	0.99(.96-.99)	0.99(.96-.99)
	111	0.01	0.01	0.01
Pep S	100	0.60(.47-.73)	0.83(.74-.92)	0.67(.57-.77)
	157	0.40	0.17	0.33
PgK	100	0.96(.93-.98)	0.96(.92-.99)	0.90(.84-.96)
	43	0.04	0.04	0.10
Pgm-1	-100	0.99(.97-.99)	1.00(.97-1.00)	0.99(.96-.99)
	300	0.01	0	0.01
Sdh	100	0.96(.92-.98)	0.95(.90-.99)	0.99(.96-.99)
	62	0.03	0.04	0.01
	124	0.01	0.01	0

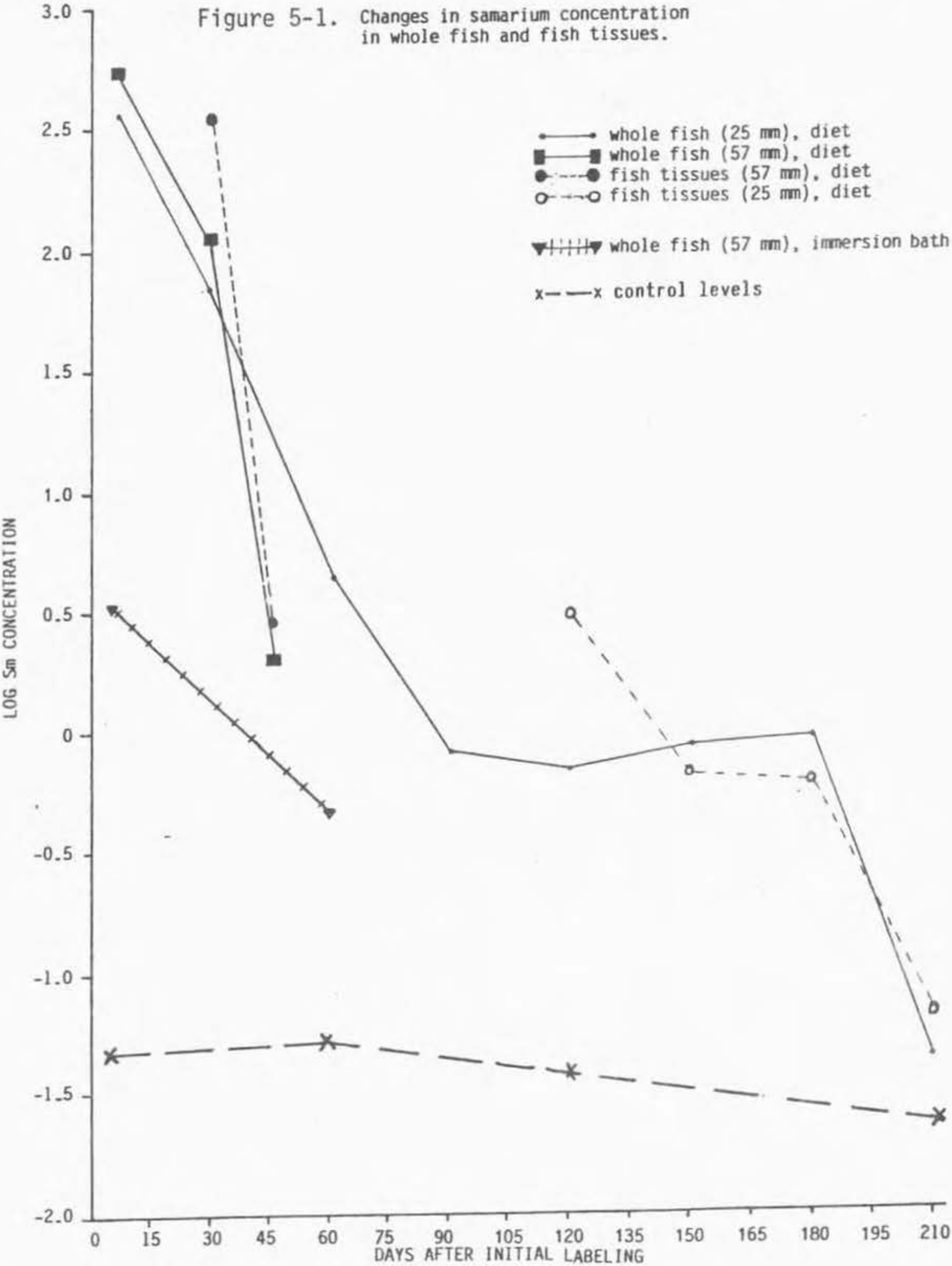


Figure 5-1. Changes in samarium concentration in whole fish and fish tissues.

Figure 5-2. Survival of 15-18 mm American shad immersed in various $SmCl_3 \cdot 6H_2O$ solutions for 3 min.

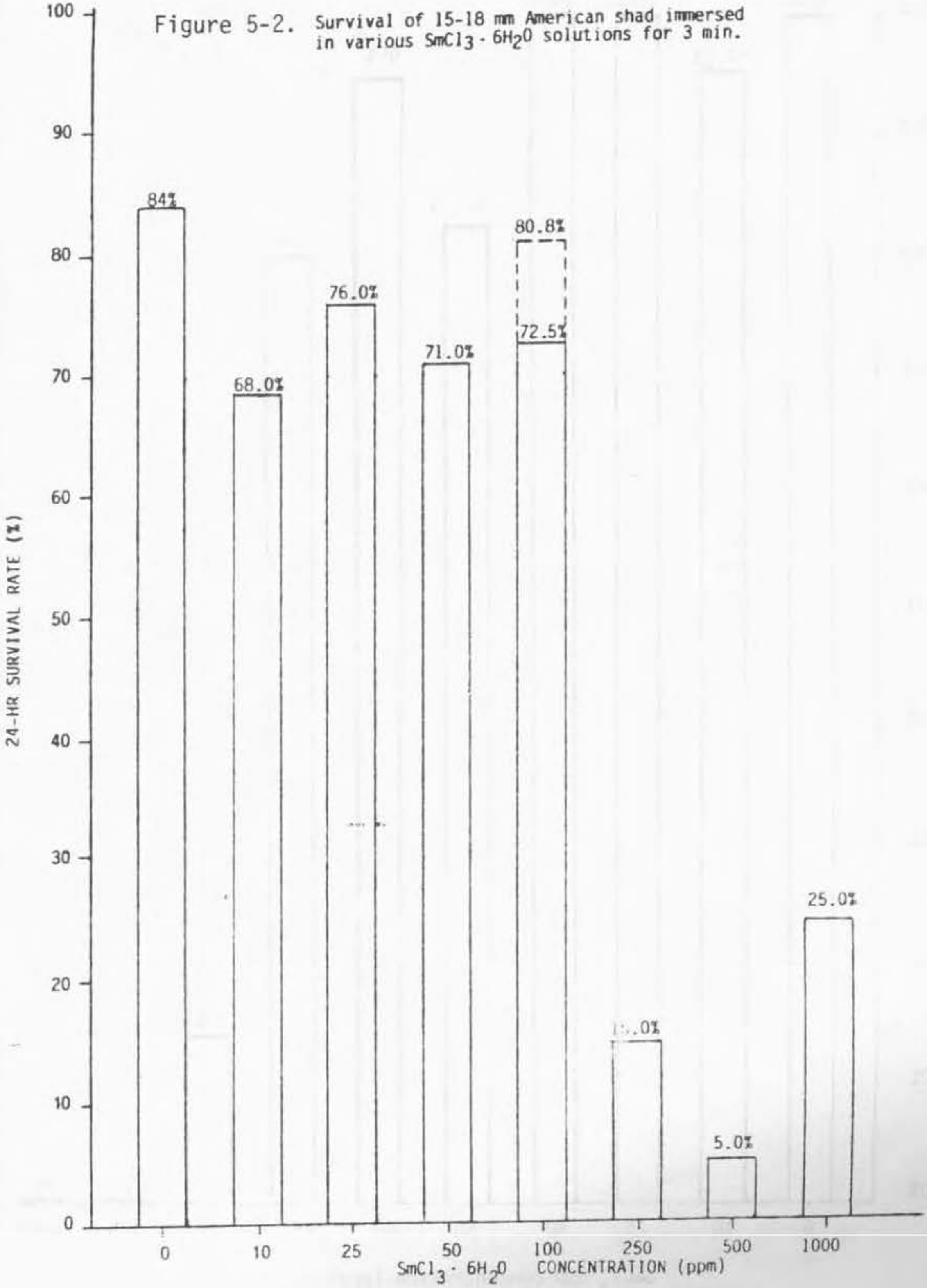
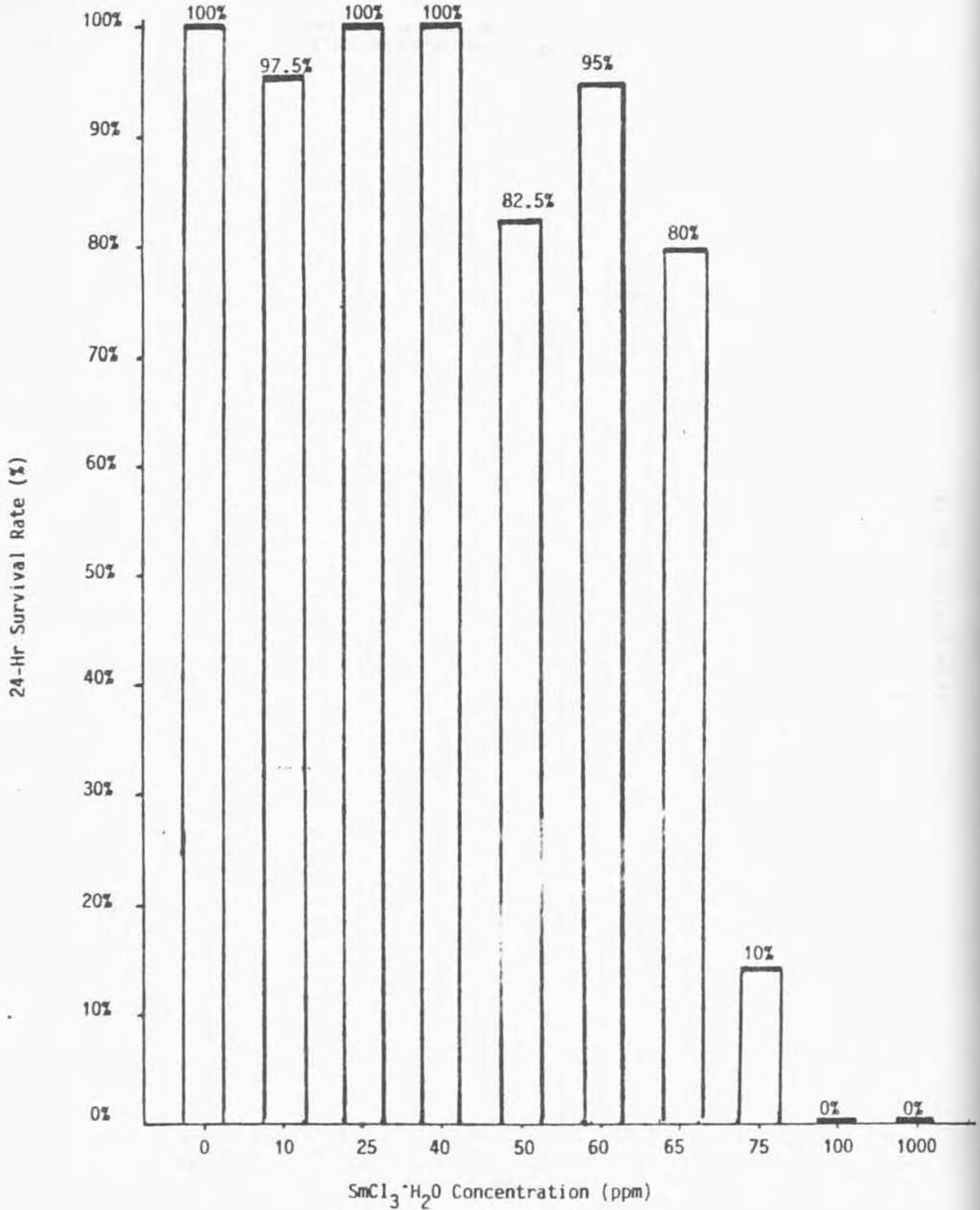


Figure 5-3. Survival of 15-25 mm American shad Exposed to Various Concentrations of $SmCl_3 \cdot H_2O$ via Constant Flow Method with a One Hour Dosage Period.



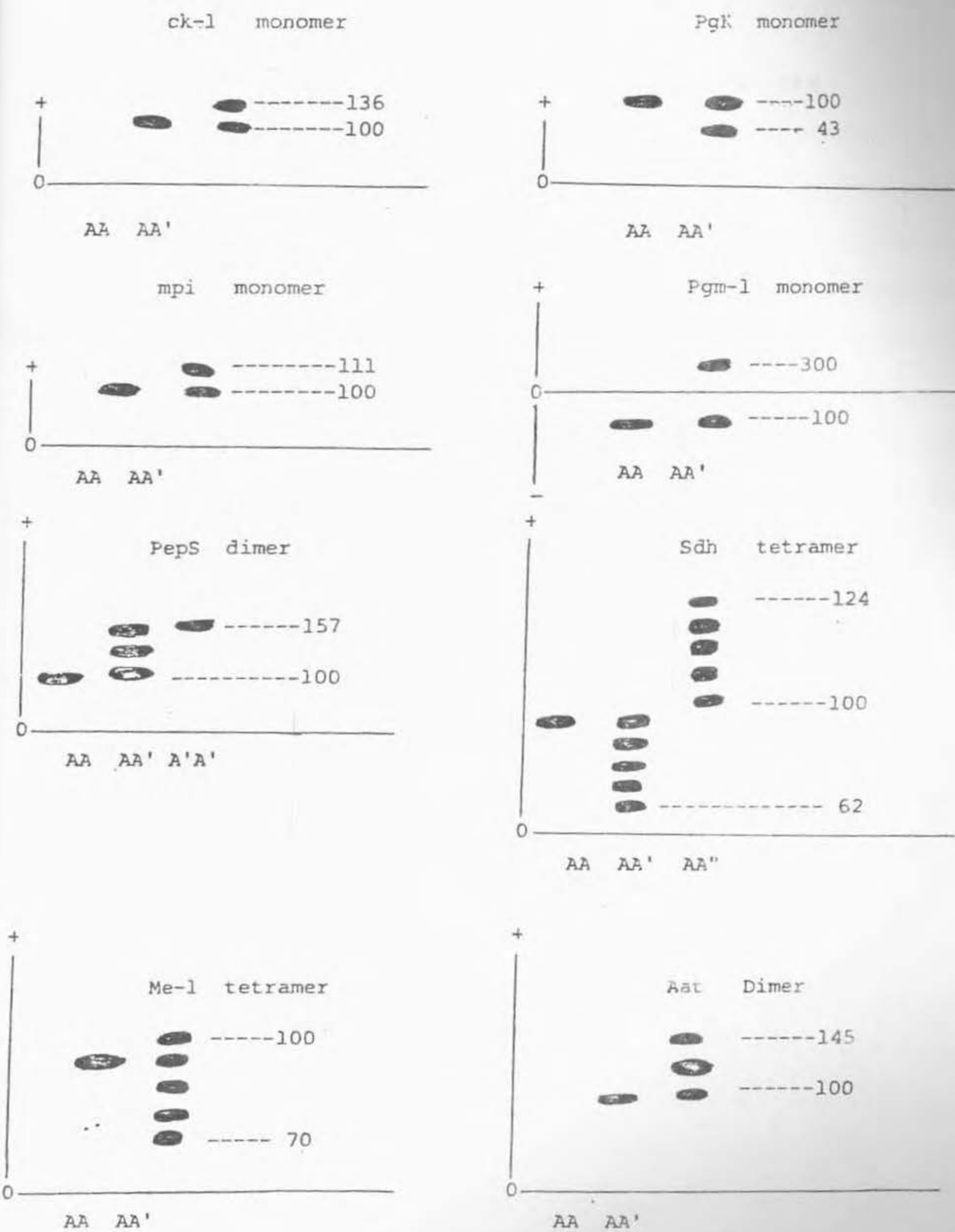


Figure 5-4. Observed electrophoretic banding patterns and proposed genotypes for each of the polymorphic enzyme loci examined.

JOB VI

SUMMARY OF OPERATION OF THE CONOWINGO DAM FISH LIFT IN SPRING 1983

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INTRODUCTION

The Conowingo Dam Fish Passage Facility (hereafter Fish Lift) has been in operation since 1972 as part of a cooperative private, state, and federal effort to restore American shad to the upper Susquehanna River. The operational goal of the Fish Lift has been to monitor fish populations below Conowingo Dam and transport as many migratory fishes (American shad, herrings, hickory shad, striped bass, and American eel) upriver as possible according to the restoration plan for the Susquehanna River. Operation of the fish lift is one of many long term commitments by Philadelphia Electric and Susquehanna Electric companies to aid in the restoration of migratory fishes to the Susquehanna River.

Objectives of the 1983 operation were to monitor (1) relative abundance of Alosa species in the Conowingo Dam tailrace, (2) species composition of fishes in Conowingo Dam tailrace (3) obtain life history information from selected migratory fish species and resident species, (4) contribute to restoration efforts by trap and transfer of prespawned American shad and other migratory fishes to upstream localities, and (5) assist Maryland Tidewater Administration in their American shad population assessment in the upper bay by capture of tagged individuals.

Methods

Prior to the operation of the lift various surveys were conducted in the spring to detect the arrival of alosids to the lower river area. Personnel at Owen's Fish House (Perryville, Maryland) were contacted on alternate weekdays starting on 14 March to determine if commercial fishermen were catching these species in the river or Susquehanna Flats. Few fisherman were active due to Maryland's closure of the shad fishery and the limited numbers of river herring available at the time. The majority of commercial fishermen directed their eforts to the white perch fishery. A visual survey of Deer Creek was conducted daily from 16 March to 6 June and intermittently in Octoraro Creek to determine if river herrings were present in the lower river.

The Fish Lift was operational starting 1 April 1983 per the SRAFRC work plan. Operation from 1 to 9 April was on an alternate day basis and started at 0600 each day. Due to the limited number of alosids present in the tailrace operations were halted approximately noon each day. On 9 April 1983 operation was halted at 1300 hrs due to a mechanical breakdown of the hopper. No operation was possible from 10 April to 11 May due to unusually high river flows. From 12 May to 16 June the lift generally operated on a daily dawn to dusk schedule. Some curtailment of this schedule was necessary on 28 May, 22 to 25 May, 1 June and 6 to 14 June due to mechanical failures.

Operation of the Fish Lift was extended from 30 June to 12 July 1983 in response to the presence of large number of juvenile striped bass in the tailrace. This operation assisted in the restoration of juvenile striped bass to upstream nursery areas per the strategic restoration plan for the Susquehanna River (SRAFRC, 1979). This effort, however, was halted on 12 July by the order of the Maryland Department of Natural Resources (via a letter dated 12 July 1983 from Dr. George Krantz to Mr. William McElroy of Philadelphia Electric Company).

The mechanical aspect of fish lift operation was similiar to that described in the 1982 Summary Report (RMC 1983). Fishing time and/or lift frequency was determined by abundance of fishes and the time required to process the catch.

Attraction velocity and flow in 1983 were generally similar to those maintained in 1982 (RMC 1983). Based on the 1982 experience hydrologic conditions were maintained in the area of the lift between the crowder gate and weir entrances similiar to that reported in the latter part of the 1982 trapping season (SRAFRC 1982).

A minimum flow of 5,000 cfs from Conowingo Dam has been released from approximately 15 April to 15 June from 1972 to 1983. In the 1983 anadromous fish trapping season the continuous flow of 5,000 cfs was discharged via Unit No. 5. The release of 5,000 cfs from Unit No. 5 was based on 1982 experience which showed lift efficiency increased when the competition between the attraction flow from the lift and continuous release was reduced.

The chemical attractant, phenethyl alcohol, was scheduled for release from the fish lift during every other scheduled day of operation from start up until water temperatures reached 68°F as outlined in SRAFRC's 1983 work plan. Equipment malfunction prevented release of the attractant until 13 May at which time it was released according to the specified procedure. On 4 June releases were terminated due to water temperature criteria being exceeded.

Fishes were processed as reported in RMC (1983). Fishes were enumerated by counting and/or estimation based on their abundance and released back to the tailrace. When large numbers of fishes were present, the number was estimated and fishes released to minimize handling. Length, weight, sex and scale samples were taken from blueback herring, alewife, striped bass, and striped bass x white bass hybrid as in

1982. Common names of fishes (Bailey et al 1970) are used throughout the text and tables. A list of common and scientific names given in Table 1.

American shad were counted and held in one of three circular tanks continually supplied with river water. If a sufficient number of green or gravid shad (50) were collected in a day they were transported upriver to City Island, Harrisburg, for release. All shad not transported were tagged and released back to the tailrace. Only healthy, active fish were tagged with floy anchor tags. Prior to their release length, weight, sex, and spawning condition were determined as conditions permitted. Scale samples were taken when possible.

Shad scales were cleaned, mounted and aged as in 1982. Samples were given per request to Maryland DNR. This exchange of samples will allow both parties to verify that the same criteria is used in age determinations.

Transportation of migratory fishes to upstream spawning and nursery areas was accomplished using one of two circular transfer units. One unit had a 800 gallon capacity and the other 500 gallons. Stocking sites varied according to species. American shad and American eel were released at City Island, Harrisburg, PA. River herrings were released above Safe Harbor Dam. Juvenile striped bass were released at City Island and above Safe Harbor Dam.

Results

In 29 days (1 April to 15 June) of Fish Lift operation 1,028,090 fish representing 41 taxa were caught in 648 lifts with a total fishing time of 288 hours (Table 2). Predominate species were gizzard shad, white perch, carp, and channel catfish. Alosids (alewife, American shad, blueback herring, and hickory shad) comprised a small portion of the total catch.

The relative abundance of fishes as measured in the Fish Lift catches has changed since 1972. In the early seventies the lift collected large numbers of alosids (primarily blueback herring), white perch and channel catfish. Recently, the catch has been dominated by the carp and gizzard shad.

The total catch of 985 alosids in 1983 was lower than in 1982 but similar to the catch in 1980 and 1981 (Table 2). Blueback herring (517) and American shad (413) dominated the alosid catch. The catch of alewife and hickory shad was 50 and 5 individuals, respectively.

Most of the American shad (381) were captured between 19 May and 5 June (Table 3). Water temperatures at this time ranged from 62-68°F, while river flows ranged from 40,000 to

80,000 cfs. Over 66% of the American shad were collected on three days, 22 May, 30 May, and 5 June. The highest single day catch of American shad was 111 on 5 June 1983 at a water temperature over 66°F. An additional 24 American shad were collected between 16 June and 12 July at water temperatures exceeding 75°F.

Phenethyl alcohol was released as an attractant on 6 days between 13 May and 5 June 1983 (Figure 2). During this period a total of 412 American shad was caught. Only 34 American shad were caught on days when the attractant was used while 378 were caught on days of no release.

A total of 14,725 migratory fishes was transported above Conowingo Dam in 1983 (Table 4). Some 64 American shad were transported and released at City Island, Harrisburg, PA; thus bypassing the four hydroelectric dams. The limited number of shad transported was a result of equipment malfunction and the advanced sexual condition of the American shad collected. Some 2,500 American eel were transported, 600 released above Safe Harbor Dam and the remainder at City Island. Additionally, over 11,800 juvenile striped bass were transported to the aforementioned release site with the verbal approval of SRAFRC.

Floy tagging of American shad continued in 1983. Two hundred thirty-two American shad collected were tagged and released to the tailrace (Table 4). Of these, 24 were eventually recaptured, three of them twice. Fourteen fish were recaptured at the Fish Lift while seven were recaptured in the lower river by the Maryland DNR. Commercial fishermen returned three tags, two from the Chespeake Bay and one from the Delaware Bay.

The capture of the American shad in the Fish Lift appears to be dependent upon their time of arrival and availability. As an example, prior to 10 April 1983 13 alosids were captured in the Fish Lift, two hickory shad and 11 alewife. No American shad were captured. River flows ranged from 55,000 cfs to 71,000 cfs during this time. However, within a similar range of river flows between 19 May and 5 June 1983 381 shad were captured. Some 120 American shad were captured in the four days of operation between 22 May to 28 May 1983 when river flows ranged from 52,000 cfs to 31,000 cfs. This suggests that if shad had been present in the tailrace prior to April 10, 1983, some of them would have been captured in the Fish Lift.

Discussion

The low numbers of alosids caught at the Fish Lift in 1983 compared with that in 1982 were in part due to the high springtime natural river flows. Table 5 indicates that from 10 April to 8 May in 1982 natural river flows averaged 51,000 cfs and the Fish Lift captured 563 American shad. However, in 1983 in this same period river flow was near or exceeded 100,000 cfs and no operation of the trap was possible. River flow remained higher in 1983 when from 9 May to 5 June it averaged 56,500 cfs and 412 American shad were captured in the Fish Lift. In contrast, the river flow averaged 30,000 cfs in 1982 and the catch of American shad was 1,475.

The high river flow in 1983 necessitated electrical generation from more than one unit at Conowingo Dam for most of the spring. As in 1982 the rate of capture of American shad was much lower at generations of two or more units than at one unit or less (Table 6). At one unit or less the rate of capture was 12 fish per hour but at two units or more the rate was slightly over one per hour.

LITERATURE CITED

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TABLE 1. List of scientific and common names of fishes collected at the Conowingo Fish Lift, Spring 1972-1982 (according to Bailey, et al., 1970).

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
Salmo gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
S. fontinalis x S. namaycush	Splake
Family - Coregonidae	White Fishes
Coregonus artedii	Lake herring
Family - Esocidae	Pikes
Esox niger	Chain pickerel
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
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. Continued.

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

TABLE 1. Continued.

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

TABLE 2. CONOWINGO DAM FISH COLLECTION FACILITY 1972-1983
COMPARISON OF ANNUAL CATCH AND EFFORT EXPENDED, APRIL 1 TO JUNE 15.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
NO. DAYS	58	77	73	55	83	78	36	31	32	43	50	29
LIFTS	922	1645	928	514	857	894	369	322	415	545	754	648
OPER. TIME(HR.)	678	1050	594	307	487	519	219	209	230	305	534	285
FISHING TIME(HR)	354	663	291	189	325	322	141	132	122	202	362	224
# SPECIES	42	44	42	41	38	41	44	33	42	48	48	41
AMERICAN EEL	1198	2250	126448	64375	187687	16607	6023	1952	1047	15685	9641	1080
BLUEBACK HERRING	58786	353326	344108	69916	39609	30756	13130	2481	503	618	25255	517
HICKORY SHAD	429	739	219	20	-	1	-	-	1	1	15	5
ALEWIFE	10107	145027	16729	4311	235	185	5	36	10	129	3433	50
AMERICAN SHAD	285	77	128	87	91	195	55	65	141	329	2041	413
GIZZARD SHAD	37007	60172	122539	139222	414593	790068	56933	76318	293236	1228810	1256214	950252
ATLANTIC MENHADEN	-	-	113	-	578	11855	-	21	17	50	-	1
TROUTS	1	-	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	47	67	21	24	60	306	72	15	23	219	23	2
BROWN TROUT	181	300	525	219	494	738	266	324	258	207	221	225
BROOK TROUT	1	3	4	1	-	2	23	-	4	3	5	2
TROUT	-	-	-	-	-	-	-	-	-	2	-	-
CHAIN PICKEREL	-	1	10	-	-	1	-	-	-	1	-	-
NORTHERN PIKE	-	2	2	-	-	2	2	4	3	-	5	1
MUSKELLUNGE	20	106	9	7	14	48	14	5	27	1	4	-
MINNOWS	-	-	-	-	-	-	-	-	-	-	1	-
GOLDFISH	-	27	2	9	8	1	-	-	-	1	-	-
CARP	6671	19473	37158	15114	14129	17430	12036	15766	8783	19128	17549	16273
RIVER CHUB	-	-	-	-	-	-	-	-	1	-	-	-
GOLDEN SHINER	185	532	506	751	2209	1051	221	306	40	227	104	216
COMELY SHINER	5	252	3870	2079	841	769	1177	1707	761	297	15129	3176
SPOTTAIL SHINER	34	137	2331	268	1743	8107	8506	1533	849	31	315	2132
SWALLOWTAIL SHINER	-	-	-	-	-	-	-	-	-	3	-	-
ROSYFACE SHINER	1	-	-	1	-	-	-	-	-	-	8	-
SPOTFIN SHINER	103	40	3585	1231	59948	11408	3796	41	314	532	1162	501
BLUNTNOSE MINNOW	-	-	-	-	-	-	4	-	-	-	-	-
BLACKNOSE DACE	-	-	-	-	-	-	-	-	-	-	2	-
LONGNOSE DACE	-	-	1	-	-	-	4	-	-	-	-	-
SHINERS	264	3	-	-	-	-	-	-	-	-	6	-
QUILLBACK	7283	29085	15177	8388	10300	6913	2381	5135	2930	4021	2670	4679
WHITE SUCKER	324	1034	286	152	452	290	189	906	1145	1404	583	412
CREEK CHUBSUCKER	2	3	1	-	-	-	-	-	-	4	2	-
NORTHERN HOG SUCKER	-	2	-	1	5	-	3	6	13	1	-	-
SHORTHEAD REDHORSE	1097	4420	434	445	1276	1725	697	2168	1394	6543	6974	7558
WHITE CATFISH	3533	7393	2424	6178	2052	3200	1006	518	605	2462	648	224
YELLOW BULLHEAD	7	45	42	32	12	47	25	13	18	56	79	10
BROWN BULLHEAD	813	7443	1848	740	608	3029	131	287	675	686	384	179
CHANNEL CATFISH	123510	79560	101556	74042	90600	114505	55918	38711	40099	85425	46762	12559
MARGINED MADTOM	-	-	-	-	-	-	-	-	-	-	7	-
MADTOMS	-	-	-	-	-	-	-	-	-	-	1	-
TADPOLE MADTOM	-	-	-	-	-	-	-	-	-	-	1	-
MUMMICHOG	-	-	-	-	1	-	-	-	-	-	1	-
TIDEWATER SIVERSIDE	-	-	-	-	-	1	-	-	-	-	-	-
WHITE PERCH	57953	688291	907905	511699	581616	234501	115991	43132	26998	84548	53745	23151
STRIPED BASS	4985	3404	2018	174	58	2603	1274	1528	999	5394	557	23
ROCK BASS	72	57	52	46	259	129	50	68	85	433	148	269

TABLE 2. CONTINUED

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
NO. DAYS	59	77	73	55	80	78	36	31	32	43	50	29
LIFTS	922	1645	1928	514	857	894	369	322	415	545	794	645
OPER. TIME(HR.)	678	1050	594	307	437	519	219	203	230	305	534	288
FISHING TIME(HR)	358	663	291	189	325	322	141	132	122	202	362	224
# SPECIES	42	44	42	41	39	41	44	39	42	48	48	41
REDBREAST SUNFISH	859	3142	1734	3040	5429	10401	4350	3512	1555	1482	1747	401
GREEN SUNFISH	4	11	6	39	133	239	26	-	16	81	125	16
PUMPKINSEED	280	6870	3210	1000	1392	4193	558	374	446	672	1164	225
BLUEGILL	696	2104	1486	3058	3625	9043	1473	883	967	2161	1677	587
SMALLMOUTH BASS	182	304	127	153	348	716	264	375	456	900	1120	1003
LARGEMOUTH BASS	87	82	25	19	33	14	22	23	41	23	26	17
WHITE CRAPPIE	4371	2374	5928	9290	4406	2176	742	390	110	335	491	450
BLACK CRAPPIE	8	43	38	45	90	469	120	62	15	85	72	46
SUNFISHES	1	-	-	-	-	-	-	-	-	-	-	-
PERCHES	1	-	-	-	-	-	-	-	-	-	-	-
TESSELLATED DARTER	-	1	4	1	-	-	1	-	-	2	-	-
YELLOW PERCH	5958	1137	750	494	3495	1196	525	385	373	1478	872	387
LOGPERCH	-	-	-	-	-	-	27	-	-	-	-	-
SHIELD DARTER	-	-	-	-	-	-	-	-	-	1	-	-
WALLEYE	2320	3807	1790	369	2692	3062	1017	2546	4157	2789	569	663
BANDED DARTER	-	-	-	-	-	-	1	-	-	-	-	-
ATLANTIC NEEDLEFISH	1	-	-	1	-	-	-	-	-	2	-	-
LAMPREYS	-	-	-	-	-	-	-	-	-	-	-	2
SEA LAMPREY	-	2	-	2	29	11	1	3	1	56	56	5
LAKE HERRING	-	1	-	-	-	-	-	-	-	-	-	1
STRIPED BASS X WHITE BASS	-	-	-	-	-	-	389	343	2674	48	176	355
TIGER MUSKIE	-	-	-	-	-	-	13	133	34	53	67	16
	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======	=======
	329875	1423149	1705149	917043	1431450	1287826	288462	202105	392027	1467420	1451857	1028090

TABLE 3. CONOWINGO DAM FISH COLLECTION FACILITY APRIL 1 TO 12 JULY, 1983. DAILY CATCH SUMMARY OF ALOSIDS CLEANOUT LIFTS INCLUDED

DATE	04/03/83	04/05/83	04/07/83	04/09/83	05/13/83	05/14/83	05/15/83	05/16/83
NO. LIFTS	10	12	11	8	36	34	18	31
FIRST LIFT	620	610	605	912	555	508	510	515
LAST LIFT	1200	1200	1200	1315	1655	1658	1440	1915
OPERATING TIME	5.67	5.83	5.72	4.05	11.00	11.83	9.50	13.00
FISHING TIME(HR)	4.42	5.00	5.08	3.17	8.10	9.00	8.08	8.67
AVE RIVER FLOW	55300	64900	62500	70800	59800	51900	48000	47500
AVE WATER TEMP.	46.4	46.4	50.0	51.8	59.0	59.0	60.8	61.7
ATTRACTANT USED?	NO	NO	NO	NO	YES	NO	NO	YES
BLUEBACK HERRING	-	-	-	-	-	1	8	3
HICKORY SHAD	-	1	-	1	-	1	-	-
ALEWIFE	1	4	4	2	-	-	2	-
AMERICAN SHAD	-	-	-	-	1	5	2	6
	1	5	4	3	1	7	12	9

DATE	05/17/83	05/18/83	05/19/83	05/20/83	05/21/83	05/22/83	05/26/83	05/27/83
NO. LIFTS	36	13	24	27	26	14	13	23
FIRST LIFT	510	455	635	500	506	506	1030	500
LAST LIFT	1900	1000	1805	1820	1835	1240	1800	1900
OPERATING TIME	13.83	5.08	11.50	13.33	13.48	7.57	7.50	14.00
FISHING TIME(HR)	10.50	3.83	9.17	10.00	10.95	6.25	5.58	9.83
AVE RIVER FLOW	48000	48900	46900	47400	48300	51600	80500	67500
AVE WATER TEMP.	61.7	61.7	62.6	61.7	61.7	62.6	62.6	62.6
ATTRACTANT USED?	NO	NO	NO	YES	NO	NO	NO	YES
BLUEBACK HERRING	14	1	6	10	8	20	1	2
HICKORY SHAD	-	-	-	-	-	1	-	1
ALEWIFE	11	-	1	3	-	1	-	-
AMERICAN SHAD	13	4	30	12	14	96	2	7
	38	5	37	25	22	118	3	10

TABLE 3. CONTINUED

DATE	05/28/83	05/29/83	05/30/83	05/31/83	06/01/83	06/02/83	06/03/83	06/04/83
NO. LIFTS	34	27	25	39	11	24	24	23
FIRST LIFT	505	505	500	506	506	500	455	505
LAST LIFT	1913	1755	1900	1839	1110	1904	1840	1823
OPERATING TIME	13.22	12.83	14.00	13.55	6.07	14.07	13.75	13.38
FISHING TIME(HR)	9.25	10.25	11.58	9.13	4.75	11.33	10.58	10.75
AVE RIVER FLOW	56300	48700	47300	43700	38700	39600	33100	34500
AVE WATER TEMP.	62.6	64.4	64.4	65.3	65.3	64.4	65.3	68.0
ATTRACTANT USED?	NO	NO	NO	YES	NO	NO	NO	YES
BLUEBACK HERRING	6	16	70	9	12	33	42	32
HICKORY SHAD	-	-	-	-	-	-	-	-
ALEWIFE	-	-	1	-	-	-	-	-
AMERICAN SHAD	15	12	67	6	2	4	1	2
	======	======	======	======	======	======	======	======
	21	28	139	15	14	37	43	34

TABLE 3. CONTINUED

DATE	06/05/83	06/06/83	06/15/83	06/16/83	06/30/83	07/08/83	07/09/83	07/10/83
NO. LIFTS	23	6	21	11	14	11	9	8
FIRST LIFT	507	500	730	500	610	615	609	600
LAST LIFT	1820	755	1855	1100	1155	1200	1040	1002
OPERATING TIME	13.22	2.92	11.42	6.00	5.75	5.75	4.52	4.03
FISHING TIME(HR)	10.75	2.25	5.08	4.75	4.08	4.75	3.83	3.03
AVE RIVER FLOW	39000	34100	22000	17900	47300	17100	16900	16900
AVE WATER TEMP.	66.2	68.0	74.8	75.2	77.9	76.3	77.0	75.2
ATTRACTANT USED?	NO	NO	NO	NO	NO	NO	NO	NO
BLUEBACK HERRING	206	16	1	7	-	-	3	1
HICKORY SHAD	-	-	-	-	-	-	-	12
ALEWIFE	16	3	1	-	-	-	-	-
AMERICAN SHAD	111	-	1	17	2	2	1	-
	======	======	======	======	======	======	======	======
	333	19	3	24	2	2	4	13

TABLE 3. CONTINUED

DATE	07/11/83	07/12/83	TOTALS
NO. LIFTS	9	9	752
FIRST LIFT	605	605	
LAST LIFT	1011	1035	
OPERATING TIME	4.10	4.50	347.25
FISHING TIME(HR)	3.58	3.75	261.86
AVE RIVER FLOW	15300	11200	
AVE WATER TEMP.	77.0	77.0	
ATTRACTANT USED?	NO	NO	
BLUEBACK HERRING	-	-	528
HICKORY SHAD	-	-	17
ALEWIFE	-	-	50
AMERICAN SHAD	1	1	437
	1	1	1,032

TABLE 4. CONOWINGO DAM FISH COLLECTION FACILITY - 1983
CATCH TOTALS, APRIL 1 TO JULY 12, 1983.

NO. OF DAYS	NO. OF LIFTS	TOTAL FISHING TIME(MIN)	COMMON NAME	NUMBER COUNTED	TOTAL NUMBER (ESTIM)	NUMBER TRANSP	LENGTH DATA	AGE & GROWTH DATA	NUMBER TAGGED	RECAPS
33	689	14018	AMERICAN EEL	1	3994	2500	0	0	0	0
			BLUEBACK HERRING	0	528	0	348	348	0	0
			HICKORY SHAD	15	15	0	3	3	0	0
			ALEWIFE	0	39	0	15	15	0	0
			AMERICAN SHAD	437	437	114	300	315	232	14
			GIZZARD SHAD	0	1076105	300	1197	914	345	82
			ATLANTIC MENHADEN	0	1	0	0	0	0	0
			RAINBOW TROUT	0	2	0	0	0	0	0
			BROWN TROUT	0	208	0	0	0	0	0
			BROOK TROUT	0	1	0	0	0	0	0
			NORTHERN PIKE	1	1	0	0	0	0	0
			CARP	0	16124	0	110	110	0	0
			GOLDEN SHINER	0	246	0	0	0	0	0
			COMELY SHINER	0	3202	0	0	0	0	0
			SPOTTAIL SHINER	0	2381	0	0	0	0	0
			SPOTFIN SHINER	0	924	0	0	0	0	0
			QUILLBACK	0	4219	0	0	0	0	0
			WHITE SUCKER	0	249	0	0	0	0	0
			SHORTHEAD REDHORSE	0	6636	0	0	0	0	0
			WHITE CATFISH	0	294	0	0	0	0	0
			YELLOW BULLHEAD	0	32	0	0	0	0	0
			BROWN BULLHEAD	0	235	0	0	0	0	0
			CHANNEL CATFISH	2	23237	0	807	821	799	18
			WHITE PERCH	0	24764	0	498	501	0	4
			STRIPED BASS	0	20165	11811	418	342	0	0
			ROCK BASS	0	355	0	0	0	0	0
			REDBREAST SUNFISH	0	1110	0	0	0	0	0
			GREEN SUNFISH	0	32	0	0	0	0	0
			PUMPKINSEED	0	805	0	0	0	0	0
			BLUEGILL	0	1933	0	0	0	0	0
			SMALLMOUTH BASS	0	971	0	627	778	569	160
			LARGEMOUTH BASS	0	22	0	0	0	0	0
			WHITE CRAPPIE	0	922	0	0	0	0	0
			BLACK CRAPPIE	0	203	0	0	0	0	0
			YELLOW PERCH	0	832	0	0	0	0	0
			WALLEYE	0	811	0	531	617	358	94
			LAMPREYS	0	2	0	0	0	0	0
			SEA LAMPREY	0	6	0	0	0	0	0
			LAKE HERRING	0	1	0	0	0	0	0
			STRIPED BASS X WHITE BASS	0	433	0	236	240	204	6
			TIGER MUSKIE	22	22	0	0	0	0	0
*TOTAL 1983				478	1192499	14725	5090	5004	2507	378

TABLE 5.

Comparison of mean daily river flow and total catch of American shad early and late spring, 1982 and 1983.

10 April to 8 May	1982	1983
River flow (cfs x 1000)	51	> 100
American shad	563	no operation
9 May to 5 June		
River Flow (cfs x 1000)	30	56.5
American shad	1,475	412

TABLE 6. COMPARISON OF THE AMERICAN SHAD CATCH, CATCH PER EFFORT, AND EFFORT BETWEEN LOW (ONE OR LESS UNIT GENERATION) AND HIGH DISCHARGES (TWO OR MORE UNIT GENERATION) AT THE CONOWINGO FISH LIFT, 1 APRIL TO 15 JUNE, 1983.

GENERATION STATUS	# SHAD CAUGHT	TOTAL MINUTES FISHED	NUMBER OF LIFTS	SHAD CATCH PER/HR
ONE OR LESS	126	615	46	12.29
TWO OR MORE	287	12822	645	1.34
	====	=====	===	=======
	413	13437	691	1.84

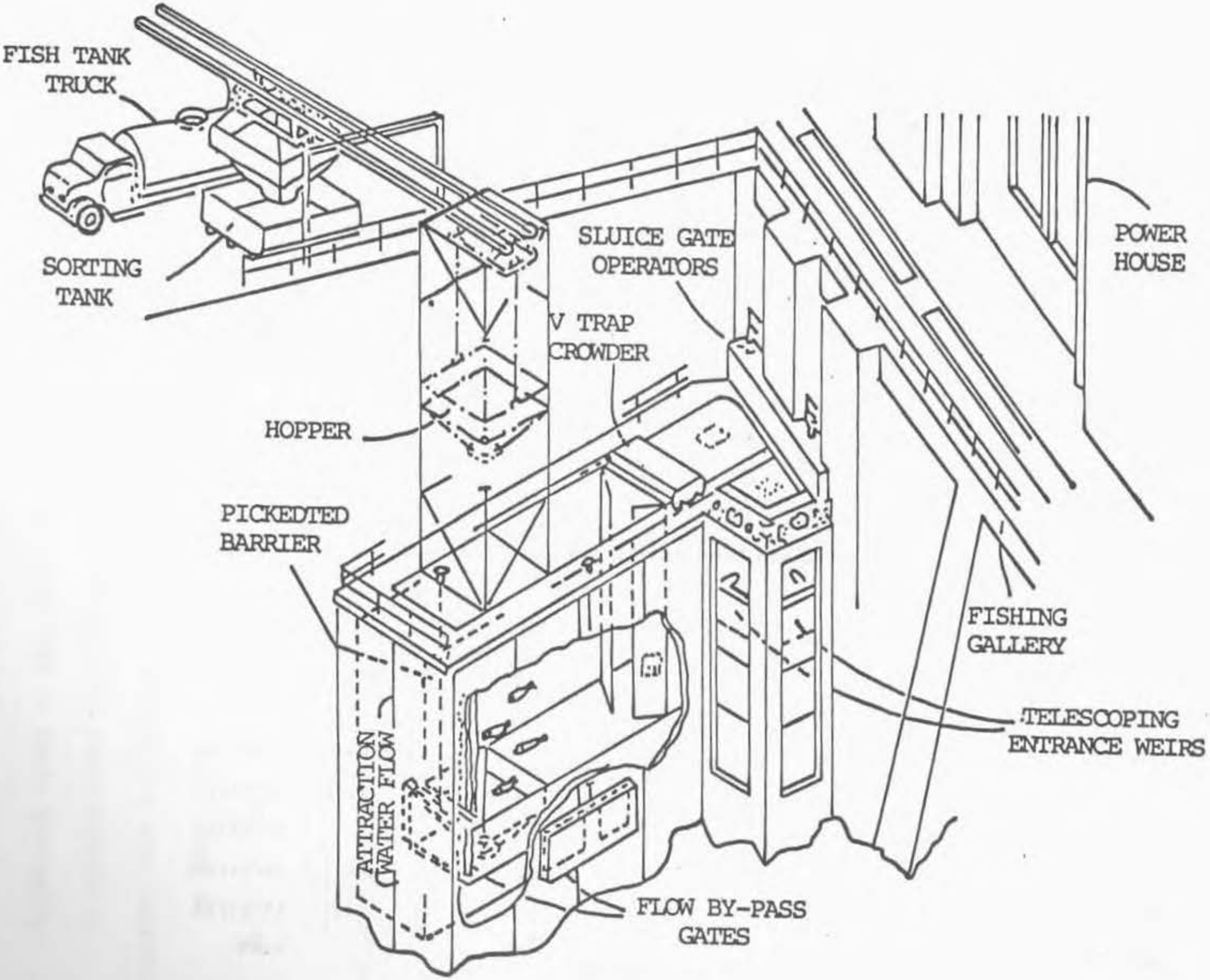

FIGURE 1

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

FIGURE 2. CONOWINGO DAM FISH COLLECTION FACILITY - 1983
AMERICAN SHAD CATCH DURING THE PERIOD OF ATTRACTANT USE

FACILITY NOT OPERATED ON DAYS MARKED M
USE OF ATTRACTANT IS INDICATED (Y/N) WHEN SHAD WERE CAUGHT

BAR CHART OF SUMS

DATE		SHAD SUM
05/13/83	Y	1.0
05/14/83	NNN	5.0
05/15/83	N	2.0
05/16/83	YYY	6.0
05/17/83	NNNNNNN	13.0
05/18/83	NN	4.0
05/19/83	NNNNNNNNNNNNNNN	30.0
05/20/83	YYYYYY	12.0
05/21/83	NNNNNNN	14.0
05/22/83	NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN	96.0
05/23/83		M
05/24/83		M
05/25/83		M
05/26/83	N	2.0
05/27/83	YYYY	7.0
05/28/83	NNNNNNNN	15.0
05/29/83	NNNNNN	12.0
05/30/83	NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN	67.0
05/31/83	YYY	6.0
06/01/83	N	2.0
06/02/83	NN	4.0
06/03/83	N	1.0
06/04/83	Y	2.0
06/05/83	NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN	111.0

0.0 20.0 40.0 60.0 80.0 100.0
SHAD SUM

JOB VII. POPULATION ASSESSMENT OF ADULT AMERICAN SHAD IN THE UPPER CHESAPEAKE BAY - 1983

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7.1 INTRODUCTION

Prior to 1980, few population estimates for American shad in Maryland waters had been made. Walburg's (1954) estimates of the pounds of shad in Maryland waters from 1944-1952 were based on a single tagging experiment. St. Pierre (1979) estimated the average population of American shad in the Susquehanna River and extreme northern portions of Chesapeake Bay from 1890 to 1904 based on the average commercial landings in this area during the 15 years examined.

Realizing the need to update this data base concerning American shad in the upper Chesapeake Bay, and because of the drastic decline in stock size experienced since the late 1960's, the Tidal Fish Division of the Maryland Department of Natural Resources has conducted studies beginning in 1980 designed to estimate the number of spawning shad in this area. These capture-mark-recapture efforts are designed not just for population estimation but can also be utilized for other management needs such as predicting exploitation, survival, and fishing rates, various catch per unit effort parameters for various fishing gears, and recruitment to the population. Maryland commercial and sport fisheries for shad remained closed during 1983. This paper is concerned with our adult population estimations and the procedures and techniques used in their derivation. Results of a sport angling survey and juvenile abundance survey for shad in the upper Bay - lower river are also presented.

7.2 METHODS AND MATERIALS

Basic capture, holding, and tagging procedures for 1983 differed little from the previous year (see 1982 SRAFRC report). Fish captured by the anchor gill net were placed in a round holding tank and transported away from the netting area in order to avoid immediate recapture. The holding tank/bilge pump system utilized in 1982 (Weinrich et al, 1983) was again in operation for 1983. The only major change in the 1983 gill netting effort was our attempt to reduce the high perceived net mortality of the previous three years. During past years, anchor gill nets were set at dusk and fished from 1-3 hours later depending on river flows. However, this delayed our efforts to check the nets and often resulted in large numbers of weakened or dead shad. In an effort to reduce this problem in 1983, our anchor nets were not set until river flows permitted immediate fishing. Pound nets and hook and line capture and tagging procedures remained unchanged for 1983.

7.3 RESULTS

Unusually high river flows during the spring of 1983 greatly hampered our entire tagging operation. The commercial pound netter was unable to assemble and fish his rig until May 25, thereby precluding the use of this gear to capture shad for marking. Hook and line tagging, so successful the previous year was reduced to 2 days effort in 1983 because of the dangerous flow conditions in the tailrace below Conowingo Dam. Likewise, anchor gill net effort was reduced from 11 nights in 1982 to only 5 nights during 1983. Tables 7.1 and 7.2 present catch and effort data for the 1983 tagging operation.

Only 217 shad were marked and released during 1983, 122 less than the previous year. Of these 217, 12 were subsequently recaptured. Specific information concerning these recaptures can be found in Table 7.3. A general summarization of these recaptures is presented below:

a) all 12 recaptures were made by commercial fishermen

b) all 12 recaptures were tagged from gill nets

c) all 12 fish were recaptured in the same general location as they were initially marked

d) shortest period at large was 2 days
longest period at large was 20 days
average period at large was 7 days

Shad population estimates for 1983 were again calculated using both the Petersen Index (7,127) and the Schaefer Method (8,031). The advantage to the Schaefer, a series of stratified Petersen estimates, is that the bias associated with the immigration-emigration of adult spawners can be minimized because of the Schaefer's ability to estimate populations during successive time intervals. Tables 7.4 and 7.5 show how the Pertersen and Schaefer estimates were dervived.

7.4 DISCUSSION

Modification of gill net fishing procedures during 1983 greatly reduced perceived mortality for this particular gear. The 1983 gill net mortality was calculated to be 2.8% as opposed to 55%, 19%, and 30% for 1980, 1981, and 1982 respectively.

As in 1982, the 1983 upper Chesapeake Bay population estimate is somewhat suspect. The high river flows greatly reduced effort by Tidal

Fisheries personnel and RMC trap operation (Job VI). Subsequent decreases in the amount of net fished and trap lifts completed, total catch, and recaptures by both groups was the result of these adverse river conditions.

However, the tremendous increase in Tidal Fisheries gill net catch per unit effort (CPUE) over previous years (Table 7.6) is somewhat contradictory to both our total catch and associated population estimates. Reasons for this substantial change in gill net efficiency could be the result of one of the following:

a) high river flows and low water temperatures kept the adult shad from moving upstream past our netting area

b) netting efforts were coincidental with pushes of adult spawners into the river

c) the run size was larger than estimated

7.5 SUMMARY OF POPULATION ASSESSMENT

-- High river flows during the spring of 1983 greatly hampered DNR efforts to capture adult American shad for marking and their subsequent recapture.

-- The estimates of the number of adult American shad utilizing the upper Chesapeake Bay for 1983 as calculated by the Petersen and Schaefer methods were 7,127 and 8,031, respectively.

-- A su stantial difference was observed in Tidal Fisheries anchor gill net CPUE during 1983 as compared to the previous 3 years. This increase in gill net efficiency somewhat confuses the 1983 adult shad population estimate.

-- Changes in anchor gill netting procedures in 1983 greatly reduced perceived mortality by this gear compared to 1980,1981, and 1982.

7.6 SPORT ANGLING SURVEY

The following information was gathered from interviews with sport anglers fishing the lower Susquehanna River below Conowingo Dam from April 2 to June 24, 1983:

a) Catch/effort data - estimated no. of anglers - 26,778
no. hours fished - 109,180
catch - 226,417 fish

b) Estimated sport catch of American shad:
1980 - 8
1981 - 118
1982 - 266
1983 - 132

c) Catch per angler hour and hours to catch one fish:

species	1982 CPAH	1982 HTC	1983 CPAH	1983 HTC
white perch	0.888	1.1	1.446	0.7
striped bass	0.017	57.0	0.030	33.3
channel catfish	0.159	6.3	0.176	5.7
river herring	0.008	119.0	0.010	100.0
American shad	0.008	119.0	0.001	1000.0

d) Key differences between 1983 - 1982:
- 102% decrease in sport catch of American shad
- marked increase in sport angler success for four important species
- increase in both angler pressure (61%) and total catch (142%)

7.7 JUVENILE RECRUITMENT SURVEY

A comparison of the 1983 juvenile recruitment survey with those conducted in 1980, 1981, and 1982 is presented. These data compare total catch and CPUE for both haul seine and otter trawl for three anadromous and two estuarine species, all important sport and commercial finfish in the upper Chesapeake Bay. The 1983 data includes information from nine biweekly sampling periods that began during the second week of July and continued through the first week of November. No young-of-the-year American shad were collected during the 1983 sampling program. Catch composition for the five important species is given in Table 7.7.

In addition to the eight regular seine stations, six auxiliary locations were sampled during 1983. These sites, located on the periphery of the Flats at Plum Point, Oakington, National Guard Reservation, Stump Point, Charter Hall Point, and Turkey Point, were selected on the basis of previous American shad studies and were sampled during the off-weeks between regular sampling schedule.

Seining techniques and data collection procedures were identical at all 14 sample sites. No juvenile American shad or blueback herring or alewife were collected in any of the 86 seine hauls made at the six auxiliary sites. A total of 147 white perch juveniles and 4 striped bass juveniles were collected at these six sites.

In summary, the 1983 juvenile survey found no American shad; herring catches were greatly reduced over 1982's low level; and a significant decline was noted in both striped bass and white perch CPUE and total catch, as compared to 1982.

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TABLE 7.1 Dates fished by gear type during the 1983 upper Chesapeake Bay American shad tagging operation.

Date	GEAR TYPES		
	POUND NET	ANCHOR GILL NET	HOOK & LINE
May 16		X	
17			
18		X	X
19			X
20			
21		X	
22		X	
23			
24			
25	X		
26			
27			
28			
29			
30			
31		X	

TABLE 7.2 Comparison of the total catch, number tagged, number dead, and percent perceived net mortality by location and gear type for adult American shad captured during the 1983 upper Chesapeake Bay shad tagging program.

Gear Type	Location	Catch	# Tagged	# Dead	Mortality
Pound Net	Susq. Flats	1	0	1	100%
Anchor gill	Susq. River	214	207	6	2.8%
Hook & line	Susq. River	11	10	1	9.1%
Cono. trap	Susq. River	416*	-	-	-
TOTALS		642	217	8	3.6%**

* Fish lift catch minus 14 RMC recaptures of their tagged shad
** Final perceived gear mortality based on DNR efforts only

TABLE 7.3 Capture-recapture dates, locations and gear types for 12 American shad recaptures during 1983 program

Tag Date	Recapture Date	Tagging Location	Gear	Recapture Location	Gear	Days at large
5/16	5/20	Susq. R.	GN	Susq. R.	GN	4
5/16	5/21	Susq. R.	GN	Susq. R.	GN	5
5/18	5/20	Susq. R.	GN	Susq. R.	GN	2
5/21	6/2	Susq. R.	GN	Susq. R.	GN	12
5/21	6/10	Susq. R.	GN	Susq. R.	GN	20
5/31	6/2	Susq. R.	GN	Susq. R.	GN	2
5/31	6/3	Susq. R.	GN	Susq. R.	GN	3
5/31	6/4	Susq. R.	GN	Susq. R.	GN	4
5/31	6/6	Susq. R.	GN	Susq. R.	GN	6
5/31	6/7	Susq. R.	GN	Susq. R.	GN	7
5/31	6/7	Susq. R.	GN	Susq. R.	GN	7
5/31	6/10	Susq. R.	GN	Susq. R.	GN	10

TABLE 7.4 Population estimate of adult American shad utilizing the Susquehanna River, Susquehanna Flats, and the Northeast River for 1983 by the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1983 Survey -

C = 424
R = 12
M = 217

Therefore -

$$N = \frac{(217 + 1)\ (424 + 1)}{12 + 1}$$

$$= 7{,}127$$

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)

LOWER $N^* = \frac{(217 + 1)\ (424 + 1)}{21.0 + 1}$ = 4,211 @ .95 confidence limits

UPPER $N^* = \frac{(217 + 1)\ (424 + 1)}{6.2 + 1}$ = 12,868 @ .95 confidence limits

TABLE 7.5 Population estimate of adult American shad using the Susquehanna River and Flats, and the Northeast River during 1983 by the Schaefer Method.

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

Week of Recovery(j)	WEEK of TAGGING 1	2	3	4	5	6	7	tagged fish recovered (R_i)	total fish recovered (C_i)	C_i/R_i
1								0	7	0.00
2								0	151	0.00
3		3						3	206	68.67
4								0	9	0.00
5								0	139	0.00
6			1		3			4	7	1.75
7			1		4			5	123	24.60
Tagged fish recovered (R_i)	0	3	2	0	7	0	0	12		
Total Fish tagged (M_i)	0	92	84	0	41	0	0	(217)	642	
M_i/R_i	0	30.7	42.0	0	5.9	0	0			

B. Computed totals of American shad in the Susquehanna River and Flats and the Northeast River during 1983.

Week of Recovery (j)	Week of Tagging 1	2	3	4	5	6	7	Totals
1	-	-	-	-	-	-	-	
2	-	-	-	-	-	-	-	
3	-	6,318	-	-	-	-	-	6,318
4	-	-	-	-	-	-	-	
5	-	-	-	-	-	-	-	
6	-	-	74	30	-	-	-	104
7	-	-	1,033	576	-	-	-	1,609
Totals	-	6,318	1,107	606	-	-	-	8,031

TABLE 7.6 Catch, effort and catch per unit effort (CPUE) for adult American shad captured by pound nets and anchor gill nets during the 1980-1983 upper Chesapeake shad tagging program.

Pound Nets	Year	Total Catch	Net days Fished	Catch per pound net day
	1980	120	112	1.07
	1981	103	118	0.87
	1982	79	86	0.92
	1983	1	1	1.00
Anchor Gill Nets	**Year**	**Total Catch**	**Yd^2-hours net fished**	**Yd^2-hours to catch 1 shad**
	1980	115	31,600	275
	1981	228	59,591	261
	1982	277	93,200	336
	1983	213	8,311	39

TABLE 7.7 Juvenile catch composition of five species taken during juvenile recruitment survey in upper Chesapeake Bay and Susquehanna River, 1980-1983.

Species	Gear	1980		1981		1982		1983	
		total	CPUE	total	CPUE	total	CPUE	total	CPUE
American shad	hs	0	0.0	0	0.0	0	0.0	0	0.0
	ot	0	0.0	0	0.0	1	0.01	0	0.0
Blueback herring	hs	108	0.6	2	0.01	130	0.8	1	0.01
	ot	27	0.3	0	0.0	8	0.1	2	0.02
Alewife	hs	194	1.1	108	0.8	14	0.1	4	0.03
	ot	38	0.4	33	0.4	14	0.1	6	0.06
White perch	hs	1315	7.2	174	1.3	1660	10.1	208	1.5
	ot	1453	14.4	347	3.8	3973	37.8	553	5.5
Striped bass	hs	55	0.3	8	0.1	235	1.4	8	0.06
	ot	8	0.1	0	0.0	49	0.5	2	0.02

hs=haul seine; ot=otter trawl

LAST
PAGE