Restoration of American Shad to the Susquehanna River

ANNUAL PROGRESS REPORT

— 1986 —

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SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COMMITTEE

JANUARY 1987

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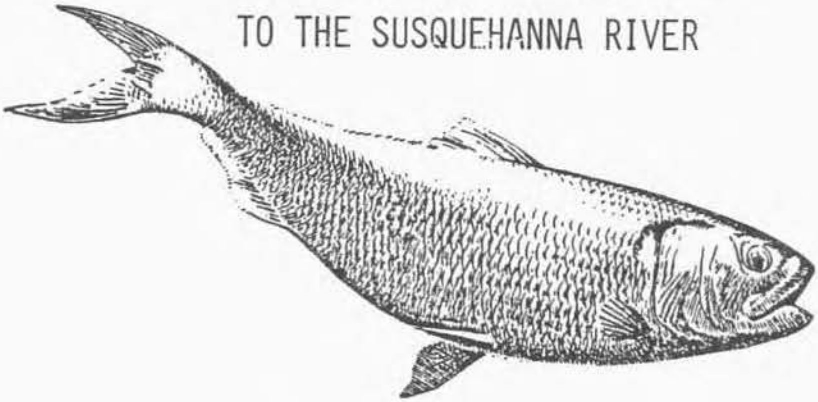

ANNUAL PROGRESS REPORT

1986

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

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

FEBRUARY 1987

This Annual Report presents results of numerous activities undertaken by contractors and member agencies of the Susquehanna River Anadromous Fish Restoration Committee during 1986. These efforts represent a continued commitment on the part of interested state and federal agencies and private utility companies to rebuild stocks of American shad and other diadromous fishes in the Susquehanna River system. Restoring shad to historic spawning and nursery waters requires substantial stocking of the river above hydroelectric dams. This was accomplished by collecting and transferring prespawn adult shad from the lower Susquehanna River and from out-of-basin sources and through hatchery culture of fry and fingerlings. Abundance, growth, movements and distribution of juvenile outmigrants was monitored at numerous locations and the relative contribution of young shad from both sources (adult transfer and culture) was evaluated.

Adult Transfers and Instream Movements

Between 22 April and 11 May, almost 5,800 prespawned adult shad were hauled from the Hudson River and stocked at Beach Haven, PA on the North Branch Susquehanna. Transport survival was 92%. These shad were held in net pens at the site for periods ranging from 11 hours to 9 days prior to release with delayed mortality measured at 6.5%. The purpose for confinement of Hudson shad was to relieve stress associated with capture and transport and thus to avoid the downrunning behavior exhibited in 1985. Twenty shad were radiotagged at the net pen and tracked upon release. An estimated 25-30% of the shad remained upriver long enough to have spawned and a few shad eggs were collected from the Beach Haven area. The remaining tagged fish reached York Haven Dam (112 miles downstream) within 12 days of release. Spent adults and eggs were collected at York Haven indicating that some spawning occurred in this area.

The American shad population in the upper Chesapeake Bay and lower Susquehanna River was estimated to number about 21,000 fish in 1986. This was based on recapture of 85 marked individuals (78 from the Conowingo lift) from a tagged population of 336 shad. Most fish were tagged in the Conowingo tailrace, being captured by angling. This estimated stock size is almost double that of 1985 and three times larger than 1983.

The fish trap and lift at Conowingo (river mile 10) operated on 59 days between 1 April and 12 June. Gizzard shad made up almost 94% of the 1.83 million fish collected. Catch of Alosa species included 5,195 American shad, 6,327 blueback herring, 2,822 alewife and 45 hickory shad. The American shad catch was the highest recorded for this facility since it was built, almost equalling the total of the previous 14 years combined. Daily catch exceeded 300 shad on six dates whereas this had never occurred before. Peak catch periods were 8-11 May and 29 May to 1 June with a total of 3,514 shad collected on these eight dates. The catch per effort in 1986 was five times higher on weekends as opposed to weekdays (off-peak vs. on-peak generation) and over half the shad were taken at water temperatures below 65°F.

A total of 4,172 American shad was transported above dams to Harrisburg with 2% mortality. Twenty-five fish were radiotagged and tracked in the river to determine movements, dispersal and spawning congregations. Unlike Hudson River transplants most of these fish remained upstream for extended periods. Twelve tagged shad stayed at or above the release site for more than 2 weeks and seven fish were there longer than 30 days. Movements were highly variable with numerous shad staying within 15 miles of the release site; three reached the Sunbury area 50 miles upstream; one traveled to Beach Haven (+ 101 miles); and four entered the Juniata River. Shad eggs were not taken in net samples near Harrisburg whereas successful collections at York Haven may have included eggs from both adult sources. One larval shad was taken a few miles north of Harrisburg on 22 May and five small juveniles (30-42 mm) were seined near Three-Mile Island in June.

Hatchery Production and Cultural Research

The intensive culture program at the Pennsylvania Fish Commission's Van Dyke Hatchery near Thompsontown on the Juniata River contributed substantially to the upriver stocking of shad in 1986. Also for the first time, a large share of the fry cultured here was stocked below Conowingo Dam to avoid potential turbine losses during outmigration.

During the period 7-30 April, 6.883 million eggs were collected from spawning shad on the Pamunkey and James rivers in Virginia and shipped to Van Dyke in 20 lots. Overall viability was 56%. The Delaware River contributed 5.865 million eggs during 7-14 May (58% viable), and collections from the Columbia River in Oregon produced 39.964 million eggs during 2-20 June (14 shipments with overall viability of 36%). The 52.7 million eggs delivered in 1986 was the largest number taken since development of the hatchery in 1976.

All shad produced at Van Dyke were marked with 50 ppm concentration of oxytetracycline in consecutive day 12-hour baths. The 9.9 million fry planted into the Juniata River at age 15 to 19 days were marked on days 5-9. The 5.17 million fry stocked at Lapidum, MD received this treatment and a second 5-day bath on days 15-19. Total fry production of 16.6 million was a record for the hatchery and included fish sent to the Lehigh and Schuylkill rivers (796,300), to rearing ponds at Elkton, MD (166,000), and for fingerling culture and research at Van Dyke, Thompsontown, Benner Spring, and Wellsboro (566,100). Of the fingerlings produced (age 76-202 days), about 33,000 were stocked into the Juniata and almost 40,000 were used for research purposes, principally turbine mortality trials at Safe Harbor Dam.

Research conducted at Van Dyke and Benner Spring (PFC) in 1986 included alternate tagging strategies (feed tags and high concentration immersion with OTC), feed research, controlled quick-release stocking, egg enumeration techniques and incubation densities. The Van Dyke facility was considerably expanded in 1986 and Juniata River water was delivered to the station to augment spring water supplies.

Juvenile Assessment and Mark Rates

A considerable amount of effort was devoted to assessing abundance, growth, movements and source of juvenile American shad during late nursery and outmigration periods in 1986. Seining and electrofishing in the north branch between Sunbury and Beach Haven was conducted on five dates between 19 August and 9 September. No American shad were collected in these attempts or from impingement monitoring at Susquehanna and Sunbury SES plants.

A seine site on the lower Juniata River at Amity Hall was sampled on seven dates between 5 August and 21 October. Juvenile shad were collected on every attempt except for the last date when water temperature reached 51°F. The 206 fingerlings taken averaged 93mm (FL) and ranged in size from 51-135mm. Catch per effort ranged from 5 to 21 shad per haul on successful days.

Shad were collected with electrofisher and seine at Wrightsville below York Haven Dam on six dates between 31 July and 23 October. Cast net sampling in the York Haven forebay produced shad on each attempt after 9 October. Over 200 fish were taken here in 20 throws of the net in five weekly samples. These shad averaged 135mm (FL) and ranged in size from 101-175mm. Only 34 shad were netted at Safe Harbor on seven dates and cooling water strainers at that project took an additional 28 shad between mid-October and mid-November.

Just as was seen in 1985, juvenile shad stacked up behind Holtwood Dam and were easily collected with cast nets on all sample dates in October and November. These fish averaged 141mm and ranged in size from 98-179mm. An 8-ft. x 8-ft. lift net was used to live capture shad at Holtwood. This gear was effective on all sample dates between 10 October and 5 December at water temperatures of 62-40°F. Thousands of shad were available for capture here. Travelling screens at Peach Bottom Atomic Power Station impinged 341 American shad in 1986 compared to an average of only 43 fish per year collected here during 1981-1985. Two shad were taken from strainers at Conowingo Dam.

During the preceding 5 years, only three young American shad were collected with seines and trawls below Conowingo during summer-fall-winter juvenile surveys. In 1986, 23 shad were taken. Of these, 17 were captured in the lower river and upper Bay during July thru October sampling and 6 were collected incidentally in striped bass gill net surveys, mostly in December. The Maryland DNR outmigration assessment at select river and Susquehanna Flats locations during November and early December produced no young shad in 30 seine sets and 8 otter trawl runs.

Retention of the OTC mark applied at the hatchery was determined to be 98% based on examination of 346 fingerlings from hatchery-held controls. From shad collections made at all river and bay sites, 274 fish were examined for the OTC tag and 78% possessed at least one mark. Collections analyzed from Amity Hall, York Haven, Safe Harbor and Holtwood displayed the single mark in 85% of fish examined (165 of 193; range 82-95%). The mark rate was 47% at Wrightsville (8 of 17 fish) and 71% at Peach Bottom (30 of 42 fish). From this it appears that some natural production occurred in the Juniata River (Conowingo transfers) and in the vicinity of York Haven (both adult sources), but hatchery stocking still accounted for the great majority of juveniles in the outmigrating population.

Of 22 shad examined from collections made below Conowingo Dam, 11 (50%) carried the double OTC mark indicating that they were stocked as fry at Lapidum; one fish had a single outer mark, which may be from a Juniata River stocking of 201,000 fry made on 9 June; and 10 were unmarked and presumably of natural origin.

A hydroacoustic evaluation of juvenile shad movement and passage at the York Haven project was conducted during 13 October thru 3 November. Mobile acoustic and current studies indicated that juvenile shad followed a water path with velocities of 1-2 feet per second and approached the powerhouse at the downstream end nearest Units 1-4. A horizontally aimed transducer "looking" diagonally from the transformer building to the upper corner of the powerhouse calculated that an average 10,600 shad per day passed downstream into the lower forebay. Vertically aimed transducers mounted on the trashracks at Units 1, 5, 10, and 17 calculated turbine passage at the rate of about 12,000 shad per day with most fish (78%) using the first four units. Average rates of passage through the powerhouse were greater at dawn and dusk than during day and night periods. Fish movements could not be correlated to environmental factors analyzed and controlled spills at the trash sluice (dusk and dawn) were not effective in passing young shad when turbines were operational.

Conclusions

Records were set in 1986 for most live adult shad transferred to the Susquehanna from out-basin sources, greatest number of shad collected and transported from the fish lift at Conowingo, largest number of eggs collected for the culture program, and the most hatchery production of shad in any season since Van Dyke was built. Positive upstream migration of some transplanted adults from Conowingo indicated that these fish are of critical importance in expanding natural production above dams in the river.

Most hatchery produced shad were effectively marked with oxytetracycline and over one-third of the entire fry production was distinctively marked and stocked below all dams for the first time. The large majority of juvenile shad collected from all sites above Conowingo were of hatchery origin and the stocked complement of double-marked fry below Conowingo contributed substantially to juvenile collections in the upper Chesapeake. It was shown that hydroacoustics may be a useful tool in assessing abundance, movements and passage rates of shad at dams.

Hudson River adult transfers, radiotelemetry studies, egg collection, hatchery operations and improvements, hydroacoustic evaluation and much of the juvenile assessment effort were funded from the settlement agreement reached with upstream licensees in 1984. Philadelphia Electric Company covered costs for fish lift operations and shad transfers from Conowingo, and juvenile recovery at Peach Bottom and Conowingo. Maryland DNR funded the adult shad population assessment and juvenile shad surveys below Conowingo Dam. The PA Fish Commission contributed substantially to hatchery improvements, mark detection analysis and juvenile recovery.

Additional information on activities reported herein can be obtained from individual Job authors or by contacting the Susquehanna River Coordinator, U.S. Fish and Wildlife Service, P.O. Box 1673, Harrisburg, PA 17105.

Richard A. St. Pierre
Susquehanna River Coordinator

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Lancaster, Pennsylvania

1.1 BACKGROUND OF ADULT SHAD TRANSFER OPERATIONS ON THE SUSQUEHANNA RIVER

Adult shad transplant operations were first conducted from the Connecticut River to the Susquehanna River on an experimental basis in 1980. A total of 193 adult American shad were transplanted in three trips. In 1981, the Technical Committee, SRAFRC, set a minimum goal to transfer 1,000 gravid shad with a survival of 75%. It was desired that the sex ratio be 1:1, male to female. A total of 1,486 shad were transported to the Susquehanna from the Connecticut in 1981, the survival rate was 78%. In 1982, the Hudson River was added to the transport operation and 2,287 and 1,176 shad were transferred from the Connecticut and Hudson rivers respectively.

From 1980 through 1985, 19,648 adult shad were transferred from out-of-basin sources and released to the Susquehanna River; for the purpose of establishing a run of American shad upon fish which had been spawned in the river.

1.2 HUDSON RIVER SHAD TRANSFER PROGRAM, 1982-1985

From 1982 through 1985, prespawned adult shad were successfully captured from the Hudson River and transferred to a release site on the upper Susquehanna River. A total of 13,373 shad were presumed alive at release, resulting in a survival rate of 81%. Past experience 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

1.2 Continued

for capture of adult shad other than netting. In 1982, operations began utilizing gill-nets as the primary gear, however shad capture was shifted to haul seine when low survival resulted. The success of the haul seine as a means to capture live shad and improvements in transport methods and quality control made the Hudson River a viable source for the adult shad transport program.

1.3 ADULT SHAD TRANSPLANT PROGRAM, 1986

In 1986, the Hudson River was used as the sole source of prespawn adult shad for out-of-basin transfers. All three transport units were used to haul shad to Beach Haven and Tunkhannock, PA during a 4-week period in April and May. Best handling, water conditioning and transport practices developed in past years were used. A new river-side holding pen, utilizing a 300-foot x 7-foot x ½-inch beach seine, was set up at the Susquehanna SES Biological Laboratory at Beach Haven, PA. The majority of transports were released into the holding pen for conditioning and concentrating adult shad prior to release. The objective was that holding and concentrating adult shad may relieve them of the urge to press downstream prior to spawning.

1.3.1 Site, Schedule and Collecting Methods

Shad were collected from two locations near Hudson, NY in the vicinity of the Greendale Landing and immediately north of the Rip Van Winkle Bridge, on the west shore of Rodgers Island. Operational timetables were contingent on tidal conditions. Generally, fishing activities took place between 0600 and 2000 hours.

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

Shad collected in the seine were immediately hand-brailed from the bag to water filled tanks mounted in 18-foot boats. One system consisted of a 400-gallon oval fiberglass tank; the other boat supported two 245-gallon round galvanized stocktanks. Water was circulated by 3-HP trash pumps, which drew water from the bottom center of the tank to an intake valve on the top inside tank wall. The oxygen injection system consisted of an LK oxygen cylinder, regulator and a section of BioWeave tubing. Air flow was controlled by the regulator and an in-line ball valve with oxygen dispersion through the BioWeave tubing at the base of each tank.

The number of fish in each tank was determined by several factors including water temperature, river conditions, and site location. The typical

1.3.1. Continued

load for the 400-gallon oval tank was 70 fish and 40 fish for each of the 245-gallon round tanks. The shuttle boats, after loading, were driven to a landing site at the Catskill Marina, Catskill, NY.

At the shoreline 3-5 shad were individually hand-brailed from the stock tank into a 15-gallon round galvanized metal wash tub filled with water. Transport trucks were backed down to the river bank and the tubs of shad were lifted to the opening of the transport tank and fish deposited into the tank. The process was continued until all shad were loaded.

1.3.2 Description of Transfer Equipment

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

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

1.3.2. Continued

problem with the Fresh-Flo aerators.

1.3.3 Water Procurement and Conditioning

Water for each of the transport units was procured at the ICC Quarry, Hudson, NY. Water from the quarry was typically 5-10 degrees F below that of the Hudson River.

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

1.3.4 Temperature/Oxygen Monitoring

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 was maintained by an aeration system which is an integral part of the transport tank. Dissolved oxygen (ppm) and temperature (degrees F) were monitored daily for the Hudson and Susquehanna rivers and each of the transport tanks.

1.3.5 Release of Fish

Beach Haven, PA, was used as the primary release site. At Beach Haven each truck was backed down the access ramp to the shoreline and circulation systems shut down. The hatch cover was removed and the release shoot attached. Before the release hatch was raised, visually dead shad were removed. Some mortality was unavoidable during transfer.

1.3.5 Continued

Shad were released directly from the transport units into the net pen, and were contained for an average of 12-24 hours (Table 2). The net pen also provided a vehicle to assess transport and delayed mortality, as well as a means to easily concentrate and retrieve dead shad.

1.3.6 Quality Control

To ensure optimum conditions for capture and transport of American shad, quality control was a significant part of the JOB I program design. Improvements were a cooperative effort between various agencies. The NYDEC, USF&WS, and the PFC were available for consultation as necessary during the program. The PFC was also active in transport and evaluating the various parameters in increasing survival during transport.

Gear modifications, the addition of new and improved transport equipment and containing shad prior to release are some of the changes that were incorporated into the program over the years. Quality methods and procedures and the identification of an additional seine site have resulted in an efficient and successful operation.

1.4 RESULTS

1.4.1 Shad Transplant and Survival

Shad were collected from the Hudson River between 22 April and 11 May. Collection operations were started earlier than in past years to ensure that a greater number of prespawn shad could be transferred. A total of 5,796 prespawned shad were transported from the Hudson River. Transport mortality for all shipments was 8.2% (478 fish). Of the 5,796 shad hauled, some 4,965 (86%) were released alive into the Susquehanna River (Table 2).

1.4.1 Continued

The time necessary to conduct transport operations on the Hudson River depended on the number of fish taken in the haul seine, the location of the seining site, and weather conditions. The average operational day took 4-6 hours, and typical travel time from the Hudson River (NY) to Beach Haven (PA) was 5-6 hours.

The primary release site on the Susquehanna River was at the Susquehanna SES Biological Lab at Beach Haven, PA. This site was used for all Susquehanna River transports excluding two loads (250 fish) to Tunkhannock, PA. All transports to Beach Haven were deposited into the river side net pen and held for a period of 11 hours to 9 days prior to release to the river. The average holding period was 12-15 hours. Delayed mortality was 6.5% for fish contained in the pen. Mortality after release was impossible to assess.

1.4.2 Water Temperature and Dissolved Oxygen

Water temperature (degrees F) and dissolved oxygen (ppm) were monitored for all transport units (Table 2). Water temperature data was also recorded at collection and release sites at each of the rivers. Hudson River water temperatures during time of capture ranged from 51-67 degrees F. Water temperatures in the transport tanks did not exceed 64 degrees F. Dissolved oxygen levels decline significantly when temperatures exceed 65 degrees F, therefore, transport tanks were filled at the ICC Quarry, a source that was typically 5-10 degrees F colder than the Hudson River. Dissolved oxygen at transport end averaged 11 ppm (range 10-13 ppm). The water temperature at the Susquehanna River release site ranged from 54-67 degrees F.

1.5 SUMMARY

The number of shad transferred from out-of-basin sources to the Susquehanna River has increased from 193 in 1980 to 5,796 in 1986. The 5,796 shad transferred in 1986 brings the 7 year total to 25, 444. Survival to stocking during this period averaged 79% (Table 1).

In 1986 the Hudson River was used as the sole source of prespawn adult shad for out-of-basin transfers. The Hudson River was first utilized for the program in 1982, a total of 1,176 shad were collected in that year by haul seine and transferred to the Susquehanna River with a survival rate of 82%. The success of this effort and the effectiveness of seining for shad encouraged the SRAFRC to expand the operation throughout the years.

The majority of shad collected in 1986 were stocked at the Susquehanna SES Biological Lab ramp at Beach Haven, PA. These fish were released into a river-side net pen (approximately 1/5 acre) and contained for a period of several hours to several days prior to release to the river. The net pen was utilized to contain shad after transport in order to reduce stress prior to release.

TABLE 1. Total number and survival of prespawned adult American shad transferred from the Connecticut and Hudson Rivers to the Susquehanna River.

YEAR	CONNECTICUT RIVER			HUDSON RIVER			TOTAL BOTH RIVERS		
	Number Transported	Total Live Fish	Percent Survival	Number Transported	Total Live Fish	Percent Survival	Number Transported	Total Live Fish	Percent Survival
1980	193	114	59	-	-	-	193	114	59
1981	1,486	1,165	78	-	-	-	1,486	1,165	78
1982	2,287	1,573	69	1,176	992	84	3,463	2,565	74
1983	1,946	1,187	61	3,691	3,123	84	5,637	4,310	76
1984	299	185	62	4,372	3,592	82	4,671	3,777	81
1985	64	62	97	4,134	3,158	76	4,198	3,220	77
1986	-	-	-	5,796	4,965	86	5,796	4,965	86
TOTAL	6,275	4,286	68	19,169	15,830	83	25,444	20,116	79

TABLE 2. Data on prespawned adult shad transferred from the Hudson River to the Susquehanna River, 1986.

DATE	RELEASE SITE	NUMBER HAULED	TRANSPORT MORTALITY	ARRIVAL TIME	TOTAL TANK TIME Hrs: Min.	TEMPERATURE Hudson River	TEMPERATURE Tank End	TEMPERATURE Susq. River	TANK D.O.(PPM) Start	TANK D.O.(PPM) End	TIME/DATE FISH REL. FROM NET PEN DATE	TIME/DATE FISH REL. FROM NET PEN TIME	LATENT MORTALITY	TOTAL LIVE FISH
April 22	Beach Haven	124	5	1330	5:00	51	49	54	10	13	April 23	0900	24	175
	Beach Haven	80	-	1430	5:20	52	50	54	10	13	April 23	0900		
April 24	Beach Haven	125	6	1720	5:20	53	52	54	11	12	April 25	0900	7	229
	Beach Haven	125	8	1750	5:20	53	55	54	10	12	April 25	0900		
April 25	Beach Haven	127	25	1450	5:15	56	58	53	10	11	April 26	0920	10	172
	Beach Haven	135	55	1655	5:45	54	60	53	11	11	April 26	0920		
April 26	Beach Haven	125	8	1630	5:15	56	55	54	10	13	April 27	1000	3	240
	Beach Haven	135	9	1630	5:30	56	57	54	10	13	April 27	1000		
April 27	Beach Haven	125	25	1750	4:30	57	61	54	11	11	April 28	0900	4	199
	Beach Haven	128	25	1750	5:30	58	61	54	11	12	April 28	0900		
	Beach Haven	115*	15			58	61	54	11	12	-	-	-	100
April 29	Beach Haven	125	19	1850	4:05	59	61	55	11	12	May 1	N/A	46	164
	Beach Haven	125	21	1920	4:30	60	61	55	10	11	May 1	N/A		
	Beach Haven	125*	3	2010	4:10	60	61	55	10	12	-	-	-	122
April 30	Beach Haven	125	15	2015	5:00	60	64	62	11	11	May 1	N/A	10	100
	Tunkhannock	125	23	2100	4:30	-	-	-	12	13	-	-	22**	188
	Tunkhannock	125	17	2100	3:30	-	-	-	10	11	-	-		
May 1	Beach Haven	125	7	2157	4:45	59	56	63	10	11	May 2	1100	25	204
	Beach Haven	125	14	2157	4:45	59	56	63	12	11	May 2	1100		
May 2	Beach Haven	125	5	2120	4:30	59	53	58	10	12				
	Beach Haven	125	10	2145	4:15	59	53	58	10	11	May 3	1115	10	335
	Beach Haven	125	15	2210	4:15	56	53	58	10	11				
May 3	Beach Haven	125	2	2215	5:00	55	52	55	10	11				
	Beach Haven	125	11	2310	4:10	55	50	55	11	11	May 4	N/A	23	334
	Beach Haven	125	5	2341	4:00	55	50	55	11	12				
May 4	Beach Haven	125	5	2325	4:45	55	52	55	10	11				
	Beach Haven	125	11	2335	5:20	56	52	55	10	13	May 5	1100	113	235
	Beach Haven	125	11	2415	4:00	56	52	55	11	13				

TABLE 2. Data on prespawned adult shad transferred from the Hudson River to the Susquehanna River, 1986. (continued)

DATE	RELEASE SITE	NUMBER HAULED	TRANSPORT MORTALITY	ARRIVAL TIME	TOTAL TANK TIME Hrs: Min.	TEMPERATURE Hudson River	Tank End	Susq. River	TANK D.O.(PPM) Start	End	TIME/DATE FISH REL. FROM NET PEN DATE	TIME	LATENT MORTALITY	TOTAL LIVE FISH
May 6	Beach Haven	125	7	1215	4:30	60	60	61	10	11				
	Beach Haven	125	7	1245	4:00	61	61	61	10	11	May 7	N/A	37	311
	Beach Haven	125	13	1355	4:00	62	61	61	10	11				
May 7	Beach Haven	125	1	1330	4:30	62	61	64	10	12				
	Beach Haven	125	-	1400	4:00	63	60	64	11	12	May 8	0800	2	372
	Beach Haven	125	-	1445	4:00	64	62	64	11	10				
May 8	Beach Haven	130	2	1430	4:00	64	59	64	11	10				
	Beach Haven	130	9	1440	4:00	63	59	64	10	12	May 9	N/A	5	369
	Beach Haven	125	-	1530	4:00	64	59	64	10	11				
May 9	Beach Haven	125	9	1530	4:30	65	58	66	11	10				
	Beach Haven	125	3	1530	4:00	65	58	66	11	12	May 10	0906	1	374
	Beach Haven	140	3	1700	4:00	66	58	66	10	11				
May 10	Beach Haven	135	9	1610	4:15	65	61	67	11	12				
	Beach Haven	130	3	1630	4:00	65	59	67	10	11	May 19	N/A	2	379
	Beach Haven	132	3	1805	4:00	66	63	67	10	11				
May 11	Beach Haven	130	15	1630	4:00	66	62	66	10	12				
	Beach Haven	135	18	1800	4:30	66	63	66	11	13	May 19	N/A	9	363
	Beach Haven	140	-	1835	4:00	67	63	66	10	12				
TOTALS		5796	478										353	4965

* Fish release outside net pen due to low water.

** On 30 April, 250 fish were stocked at Tunkannock, Pa. Based on mortality of 25% for loads at Beach Haven on 29 April - 1 May we have assumed 188 of these 250 fish survived.

OVERALL TOTALS: A total of 5,546 shad (44 truck loads) of which 4,777 survived and 769 died. Sex ratio was 1.2% favoring males. As well as, 250 fish to Tunkannock of which we have assumed 188 survived.

GRAND TOTAL: 5,796 SURVIVORS: 4,965 MORTALITIES: 831 SURVIVAL: 85.7%

Job II. AMERICAN SHAD EGG COLLECTION PROGRAM

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2.1 REVIEW OF HISTORIC EFFORTS TO UTILIZE ARTIFICIALLY FERTILIZED EGGS OF THE AMERICAN SHAD IN RESTORATION, 1963-1985.

A program for introducing artificially fertilized eggs of the American shad to the Susquehanna River was was initiated by Carlson (1968) in 1963. The principal objectives were to (1) determine the suitability of the Susquehanna River between and above the existing dams to support populations of American shad, Alosa sapidissima and (2) determine the tolerances of egg and larval stages of shad to selected potential limiting factors in the environment. The source of eggs was the Columbia River near Washougal, Washington, the Connecticut River near Wilson, Connecticut and the Susquehanna Flats near Havre-de-Grace, Maryland. In the period 1963-1965 he introduced 30.6 million eggs, 21.3 million of which were introduced in 1964. Eggs were stocked at Falls, Sunbury, Clarks Ferry, Retreat and Wyoming on the Susquehanna River and Mifflintown on the Juniata River. Egg survival to the advanced eyed stage averaged 51% in the Juniata and Susquehanna Rivers. Shad eggs hatched at all locations tested. Thus, water quality on the Susquehanna River was found to be suitable for the hatching of shad.

The development of the shad in the Susquehanna and Juniata rivers was determined by sampling for young shad during the expected period of their emigration from the River. Carlson attempted to collect young shad using various gear including shocker, seine, trawl, gillnet, hoopnet, dipnet and traps. Basically, he moved downstream as water temperature decreased in the sampling program at York Haven, Safe Harbor, Holtwood and Conowingo Dams. At all dams he attempted to collect shad with a variety of gear. He also

2.1 Continued

collected shad at Safe Harbor and Holtwood cooling water intakes.

From September 1963 to January 1965, Carlson collected 1,156 young shad (3 to 8.9 inches) in the Susquehanna and Juniata Rivers. Of these, 310 were captured upstream from Harrisburg and 846 were taken downstream in the tailraces of the four dams.

2.1.2 Objective of Program

In September 1970, an agreement was signed between the various utilities (Philadelphia Electric Power Company, Susquehanna Electric Company, Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, Metropolitan Edison Company, the States (Maryland, Pennsylvania and New York), and the Department of Interior for the implementation of a program for restoration of the American shad to the Susquehanna River. Part of the agreement called for a program to annually obtain 50 million or more artificially fertilized American shad eggs for transplantation to areas above existing dams on the Susquehanna River. The objective was to artificially develop a population of American shad which, as adults, would return to the river with the urge to migrate upriver above Conowingo and the other hydroelectric dams. The program began in the spring of 1971 and has continued annually to date. The 1986 results are included in this report.

2.1.3 Numbers of Eggs Collected

A total of 411.2 million eggs was collected from 9 rivers (Table 3) from 1971 to 1985. During that period, the Columbia River provided the greatest number of eggs (178.1 million). On the east coast, the Pamunkey, James and Delaware rivers were the most reliable sources of eggs; 68.5 million eggs

2.1.3 Continued

were obtained from the Pamunkey River, 62.9 million eggs from the James River, while the Delaware supplied over 11 million eggs from 1983-1985. Most eggs were collected at river water temperatures of 58-67 degrees F.

2.1.4 Direct Transplants to Susquehanna River

From 1971 through 1974 all shad eggs were transplanted to the Susquehanna River and released at various sites. (Beginning in 1975 a few eggs were delivered to a hatchery for experimental culture and by 1978 virtually all eggs were delivered to hatcheries for culture and rearing.) Sites recommended by the Pennsylvania Fish Commission as most suitable for shad egg development, based on the previous experience of Carlson, were used. These were in the Susquehanna River or its tributaries above the hydroelectric dams. The primary sites were in the Juniata River at Muskrat Springs and the Yellow Breeches Creek at Hogestown; other sites were also used. Occasionally, sites not ulitized by Carlson were selected where water quality was believed to be acceptable. The main concern was that the water temperature at release sites be compatible with water temperature at collection sites on the various source rivers. When conditions permitted, eggs were released at water temperatures of 55 to 70 degrees F. Water temperature normally differed less than 5 degrees F between collection and release sites.

2.1.5 Monitoring of Success of Direct Transplants

Hatching boxes were placed at release sites to estimate hatching success, following procedures used by Carlson (1968). A subsample of eggs was placed in each box. Boxes were anchored in knee deep riffle areas and sampled daily until all viable eggs hatched. Hatching success was determined from

2.1.5 Continued

examination of daily samples.

2.1.6 Hatchery Program

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

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

It was demonstrated at Harrison Lake that shad eggs could be hatched and young cultured in ponds. On the basis of this work, the Van Dyke Research Station for Anadromous Fishes was constructed in 1976 at Thompsontown, Pennsylvania, staffed by the Pennsylvania Fish Commission. The site was

2.1.6 Continued

selected because it was desirable to culture shad at a location on the Susquehanna River above the hydroelectric dams. By this means shad would be raised in water of a quality to which these shad would home as adults. Prior to full operational capability of the Van Dyke facility, a total of 1 million eggs was flown from the Delaware River to Erie, Pennsylvania for incubation in the Union City Hatchery. Ultimately, 5 million eggs from the Columbia River were transferred to Van Dyke in 1976. The facility was improved in 1977 and the Pennsylvania Fish Commission also equipped their Huntsdale Hatchery, Huntsdale, Pennsylvania to rear shad. By 1978, most eggs collected were delivered to Van Dyke.

2.2 AMERICAN SHAD EGG COLLECTION, 1986

The SRAFRC goal for 1986 was to obtain 30-50 million shad eggs over a three month period. Egg collection was to be conducted on the James and Pamunkey Rivers (Virginia), the Delaware River (Pennsylvania-New Jersey), and the Columbia River (Oregon-Washington). Eggs were to be delivered to the Van Dyke Hatchery. The fish released from the hatchery will supplement the development of the shad population below the Conowingo Dam with the urge to migrate upstream past the dams to spawn.

The 1985 effort from East and West Coast egg collection activities resulted in the incubation of 25.6 million American shad eggs. Of these a total of 7.9 million fry and 115 thousand fingerlings were stocked.

2.3 METHODS

2.3.1 Egg Collection

Eggs were artificially fertilized in essentially the same manner

2.3.1 Continued

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

Small battery operated air pumps with airstones were utilized to provide continuous aeration and agitation to the eggs during the water hardening process. Once the eggs were hardened (about 1 hour), the water was drained and five liters each of eggs and clean water was placed in double plastic bags.

Pure oxygen was put into the bag containing eggs and the bag securely tied with castrator rings. The bags were shipped in cardboard boxes with styrofoam container inserts. Each box was labeled to show river name, date, number of liters of eggs, water temperature and sex ratio of spawned fish.

2.3.2 Collection Areas

2.3.2.1 Pamunkey River, Virginia

NES biologists began egg collection efforts on the Virginia Rivers on 4 April, upon confirming reports that shad had been taken by fishermen in spawning condition. Biologists worked with commercial fishermen at

2.3.2.1 Continued

Thompson's Landing, New Kent, Virginia, located approximately 4-6 miles upstream of Lester Manor. Up to 20 gill-nets, 4 3/4-6 inch mesh were set at any one time over a 2 mile stretch of river to catch adult shad. Netting was usually conducted between 1530 and 2200 hours on a seven day per week schedule. As fish were captured, they were shuttled to the shoreline as quickly as possible. Fish in spawning condition were then processed.

2.3.2.2 Mattaponi River

In 1973-1974, the Mattaponi River provided some 13.3 million shad eggs (Table 3) to the collection program. However, the American shad run on the Mattaponi River suffered a significant decline in number in the mid-1970's. The last year that any shad eggs were collected from the Mattaponi River was 1977 (0.57 million). Collection efforts on the system were terminated because fishermen believed it was in their best interest not to provide any spawning shad to the SRAFRC program, but to fertilize and place all ripe shad eggs in hatching boxes in the Mattaponi River.

In 1986 efforts were undertaken to contact the fishermen on the Mattaponi Reservation, for the purpose of collecting American shad eggs for the SRAFRC program. An arrangement was made that biologists would be provided half of all spawning shad when ten or more were collected in a given night. A crew was sent to the Mattaponi River on 15 April upon confirmation from fishermen that spawning shad were taken in gill-nets.

2.3.2.3 James River

Grants Crossing and Berkley Plantation landings, two sites where spawning shad had been collected in previous years' efforts by commercial fishermen

2.3.2.3 Continued

were investigated. Berkley Plantation is in the Charles City-Hopewell section of Virginia, directly below the Benjamin Harrison Bridge. Grants Crossing is approximateely 10 river miles down river from Berkley Plantation.

Egg collection efforts on the James River began on 25 April at Berkley Plantation Landing. Grants Crossing was not utilized because commercial fishing operations at the landing were only conducted during the early hours of the day, a period when it would be unlikely to find any spawning shad.

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

2.3.2.4 Delaware River

In 1986, SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative to collect some 5 million shad eggs from the Delaware River. PFC biologists conducted the collection program at Smithfield Beach, 8 miles upstream from East Stroudsburg, Pa., from 7 to 14 May. Shad were captured with 200 foot long x 6 feet deep anchored gill-nets, with sections of 4 3/4 - 6 inch mesh, set parallel to the current. Nets were set between dusk and midnight. Spawning shad were shuttled to the shore for processing.

2.3.2.5 Columbia River

The egg collection program on the Columbia River, Oregon-Washington was initiated on 2 June. Netting for shad was conducted on the north shoreline

2.3.2.5 Continued

approximately two miles upstream at the Camas-Washougal Reef (Troutdale area). Shad were captured by gill-nets, as in previous years. The nets utilized during the 1986 operation were 150 fathoms in length, tapered in depth, with sections of 4 3/4 - 5 3/4 inch monofilament mesh. Typically, three 45-60 minute drifts were made nightly. Gill-netting was conducted from 1700 to 2300 hours.

2.4 TRANSPORTATION

2.4.1 Pamunkey, James and Delaware Rivers

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

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

2.4.2 Columbia River

After packaging the eggs from the Columbia River, the boxes were transported by van to the Eastern Airlines Terminal at the Portland International Airport. Eggs were flown from Portland on Eastern Airlines (Sprint Services) to Philadelphia. These arrangements were chosen because the shipments were transported directly to Philadelphia without any carrier change, consequently reducing handling and possible problems with connecting flights. Secondly, the shipments were not required at the Airport until 12:30 AM, which allowed field personnel sufficient time to secure and process large

2.4.2 Continued

quantities of eggs. Upon arrival of the shipments into Philadelphia, eggs were transported by van to the hatchery. Approximate shipping time was 11-13 hours.

2.5 COLLECTION SCHEDULE

The shad egg collection schedule was based on experience gained over a 12 year period. Initiation of collection activities on any river was determined through communications with commercial fishermen and/or participation in fishing activities which documented that spawning shad were available in sufficient numbers. Collection activities usually began when water temperature reached 55-60 degrees F.

East Coast egg collection operations were terminated when less than 5 liters of eggs were taken on a number of consecutive nights or it was apparent that shad had concluded spawning activities. The West Coast operation was based on the number of fishing days that the budget could support and/or the quality and quantity of eggs available.

2.6 RESULTS AND DISCUSSION

2.6.1 Pamunkey River

Collection efforts began on 4 April on the Pamunkey River, Virginia and continued throughout the duration of the annual adult spawning run. Water temperature ranged from 57 to 71 degrees F (Table 4). Egg collection efforts were halted on 2 May when commercial fishermen no longer caught shad in gill-nets. A total of 5.6 million eggs, were collected from the Pamunkey River.

The 5.6 million eggs in 1986 marks the fourth straight year that the Pamunkey River has supplied at least five million shad eggs to the program.

2.6.1 Continued

Since 1973, Pamunkey River field collection efforts have averaged 5.7 million (Table 3).

2.6.2 Mattaponi River

A collection crew was available to process American shad eggs on the Mattaponi River from 15-19 April. Less than ten spawning shad were taken on any night during that period. No shad eggs were collected. Fishing operations on the Mattaponi were halted on 19 April, due to a disabling illness to the fisherman. Although very few spawning shad were taken over that period, a total in excess of 75 green or gravid shad were collected per night by the fisherman.

2.6.3 James River

The James River at Berkley Plantation provided some 1.1 million shad eggs from 25 April to 5 May 1986 (Table 5). Water temperature during the period of collection ranged from 59-72 degrees F.

It is important to note that in 1986, commercial fishing operations on the James River were cut back significantly due to an abundance of striped bass. As a result of the moratorium on striped bass in Virginia, fishermen on the James River limited their shad fishing during the later part of April and May (the same period when spawning shad would be taken), because of the high number of striped bass taken in their gill-nets.

Over the last three years, the James River has become an inconsistent source of eggs. Consequently, the length of field operations on that river must be assessed at the completion of the Pamunkey River operation.

2.6.4 Delaware River

Pennsylvania Fish Commission biologists conducted shad egg collection efforts on the Delaware River over a period of six days, from 7-14 May. Some 5.9 million eggs (Table 6) were shipped to the Van Dyke Hatchery over that period.

From the 5.9 million shad eggs collected, some 552 thousand fry were stocked in the Lehigh River and 246 thousand fry stocked in the Schuykill River, as part of the restoration of shad to those river systems.

2.6.5 Columbia River

Egg collection on the Columbia River began 2 June and continued through 20 June. Water temperature ranged from 62-65 degrees F. (Table 7). Some 40 million shad eggs were sent to the Van Dyke Hatchery in 14 shipments.

The significant increase in the number of shad eggs from last year (12 million -85 vs 40 million -86) can be attributed to several factors. (1) By conducting the collection effort during the first three weeks in June, the low river level that had hampered net employment late in the month was avoided, (2) the gill-net constructed for this year's program was superior to nets used in previous years and (3) the 1986 flight arrangements allowed field crews substantial time to harvest and process a greater number of shad.

The Columbia River has provided approximately 218 million eggs to the program in some 10 years. That number represents almost half of the total number of eggs for all rivers combined to date. The reliability of the Columbia River throughout the years makes it an excellent candidate should the SRAFRC want a regular supply of eggs late in May.

2.6.5 All Rivers Combined

The shad egg collection program was conducted on three East Coast rivers and the Columbia River between 4 April and 20 June. Over that period a total of 52,520,900 (Table 2) American shad eggs were collected from the various rivers. THe James (1.1 million), Pamunkey (5.6 million), and the Delaware (5.9 million) rivers combined, produced some 12.6 million eggs, while approximately 40 million eggs were obtained from the Columbia River.

The 53 million eggs collected in 1986 represents the highest total number of American shad eggs in the last ten years.

2.7 REFERENCES

Carlson, F.T. 1968. Report on the biological findings Pages 4-41IN: Suitability of the Susquehanna River for restoration of shad. U. S. Dep. Int.; Md. Board Nat. Resour.; NY Conserv. Dep.; PA Fish Comm.

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

TABLE 1. Sampling period for East and West Coast rivers for collection of American shad eggs, 1986.

	SAMPLING SCHEDULE	
RIVER	DATES	TOTAL FISHING DAYS
Pamunkey	4 April - 2 May	28
James	25 April - 5 May	11
Delaware	7 May - 14 May	6
Columbia	2 June - 20 June	15

TABLE 2. Collection data of the total volume and number of American shad eggs on the Pamunkey, James, Columbia and Delaware rivers, 1986.

RIVER	VOLUME OF EGGS SHIPPED (L)	TOTAL NUMBER OF EGGS
Pamunkey	178.83	5,616,782*
James	30.56	1,075,618*
Delaware	171.11	5,864,600
Columbia	1,162.20	39,965,900
TOTALS	1,542.70	52,522,900

*Two shipments from the James River were erroneously processed with shipments from the Pamunkey. Totals presented here are estimates based on both field and hatchery data.

TABLE 3. Total number (millions) of American shad eggs collected from the Pamunkey, Mattaponi, James, Potomac, Susquehanna, Delaware, Connecticut, Hudson and Columbia Rivers, 1971-1986.

Year	Pamunkey	Mattaponi	James	Potomac	Susquehanna	Delaware	Connecticut	Columbia	Hudson	Totals
1971	--	--	--	--	8.42	--	--	--	--	8.42
1972	--	--	--	--	7.10	--	--	--	--	7.10
1973	8.45	6.48	--	34.64	4.74	--	4.30	--	--	58.61
1974	9.75	6.80	19.20	5.56	--	--	0.53	8.18	--	50.02
1975	1.88	--	7.15	5.70	--	--	--	18.42	--	33.15
1976	--	--	--	--	--	4.10	--	54.80	--	58.90
1977	4.40	0.57	3.42	--	--	--	0.35	8.90	--	17.64
1978	6.90	--	10.11	--	--	--	--	--	--	17.01
1979	3.17	--	4.99	--	--	--	--	--	--	8.16
1980	6.73	--	6.83	--	--	--	--	--	--	13.56
1981	4.58	--	1.26	--	--	--	--	5.78	--	11.62
1982	2.03	--	1.25	--	--	--	--	22.57	--	25.85
1983	5.49	--	5.91	--	--	2.40	--	19.51	1.17	34.48
1984	9.83	--	0.74	--	--	2.64	--	27.88	--	41.09
1985	5.28	--	2.05	--	--	6.16	--	12.06	--	25.55
1986	5.62	--	1.07	--	--	5.86	--	39.97	--	52.52
	74.11	13.85	63.98	45.90	20.26	21.16	5.18	218.07	1.17	463.68

TABLE 4. Collection data from American shad eggs taken on the Pamunkey River, 1986.

Collection Date	Water Temperature (Degrees F)	Number of Adult Shad Male	Female	Volume of Eggs Received at Hatchery (liters)	Weather Condition Air Temperature (degrees F)
April 4	64	8	9	No shipment	Overcast 72
April 5	62	-	-	No shipment	Overcast 50
April 7	65	4	10	4.24	Overcast 74
Apirl 8	65	4	11	No shipment	Overcast 58
April 9	62	6	15	6.68	Overcast 52
April 10	60	8	13	No shipment	Overcast 46
April 11	58	11	9	7.00	Overcast 55
April 12	60	5	6	No shipment	Clear 65
April 13	60	19	8	8.90	Overcast 64
April 14	60	13	23	9.70	Overcast 64
April 15	60	15	42	18.50	Rain 64
April 16	60	11	16	10.34	Rain 45
April 17	58	-	-	No shipment	Overcast 40
April 18	57	10	20	10.00	Clear 61
April 19	59	4	7	4.16	Clear 60
April 20	61	10	26	13.50	Clear 64
April 21	63	9	30	11.04	Overcast 64
April 22	62	-	-	No shipment	Overcast 50
April 23	60	-	-	No shipment	Clear 49
April 24	58	-	-	No shipment	Clear 60
April 25	59	7	11	2.30	Overcast 64
April 26 *	61	8	16	7.50	Clear 75

Table 4. Continued

Collection Date	Water Temperature (Degrees F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume of Eggs Received at Hatchery (Liter)	Weather Condition Air Temperature (degrees F)
April 27*	65	22	42	22.12	Clear 80
April 28	67	22	39	26.75	Clear 75
April 29	67	4	11	6.80	Clear 75
April 30	70	2	4	2.30	Clear 76
May 1	71	-	-	No shipment	Clear 74
May 2	71	-	-	No shipment	Clear 73
			338	184.93L	6,215,300
				.55L/♀	18,400 Eggs/♀

* Totals presented here are estimates based on field and hatchery data.

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TABLE 5. Collection data from American shad eggs on the James River, 1986.

Collection Date	Water Temperature (Degrees F)	Number of Adult Shad Male	Female	Volume of Eggs Received at Hatchery (Liters)	Weather Condition Air Temperature (degrees F)
April 25	59	2	1	0.65	Overcast 64
April 26*	61	7	16	5.00	Clear 75
April 27*	63	6	8	8.00	Clear 80
April 28	65	-	-	No shipment	Clear 75
April 29	67	4	15	5.45	Clear 75
April 30	70	4	20	11.46	Clear 75
May 1	70	-	4	No shipment	Clear 75
May 2	71	-	-	No shipment	Clear 76
May 3	71	2	4	No shipment	Clear 64
May 4	71	-	-	No shipment	Clear 71
May 5	72	-	-	No shipment	Clear 75
			60♀	17.56L	667,300
				.29L/♀	11,000 eggs/♀

* Totals presented here are estimates based on field and hatchery data.

TABLE 6. Collection data for American shad eggs taken on the Delaware River, 1986.

Date Shipped	Date Received	Volume Received (liters)	Eggs
May 7	May 8	14.85	451,400
May 8	May 9	13.42	381,600
May 11	May 12	34.04	1,277,200
May 12	May 13	30.35	1,034,400
May 13	May 14	32.35	1,184,000
May 14	May 15	46.10	1,536,000

TABLE 7. Collection data for American shad eggs taken on the Columbia River, 1986.

Collection Date	Water Temperature (Degrees F)	Number of Adult Shad Male	Number of Adult Shad Female	Volume of Eggs Received at Hatchery (Liter)	Weather Condition Air Temperature (degrees F)
June 2	65	120	123	56.00	Clear 78
June 3	63	165	178	75.80	Overcast 75
June 4	63	134	136	77.80	Overcast 75
June 5	62	178	198	93.00	Overcast 65
June 6	62	170	173	87.00	Overcast 60
June 9	63	165	180	90.00	Clear 73
June 10	66	201	231	116.50	Clear 79
June 11	66	160	170	89.63	Clear 81
June 12	66	185	193	96.40	Clear 79
June 16	63	146	149	80.00	Overcast 62
June 17	63	129	136	60.00	Overcast 59
June 18	64	140	148	63.50	Rain 56
June 19	64	163	178	89.10	Overcast 63
June 20	64	148	159	87.50	Overcast 65
			2352	1162.23L	39 964 500

.496L/♀ 17,000 eggs/♀

JOB III. AMERICAN SHAD HATCHERY OPERATIONS

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INTRODUCTION

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

Production goals for 1986 included the stocking of 10^+ million 18-day-old shad fry, and 25 thousand fingerlings for use in turbine mortality studies at Safe Harbor Dam. All hatchery-reared American shad fry were marked by immersion in oxytetracycline (OTC) bath treatments in order to distinguish hatchery reared outmigrants from juveniles produced by natural spawning of transplanted adults. Procedures were continued in

1986 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources.

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

Research conducted at Van Dyke in 1986 focused on refinement of oxytetracycline tagging, development of quick-release capabilities for fry, and improvement of feeding regimes. Oxytetracycline (OTC) tagging research included the following tests: 1) Treatment of 5-day old fry for 6 hours at 200 and 400 ppm OTC vs a control treated at the standard 50 ppm, 12 hours/day at 5-9 days of age to evaluate treatment induced mortality and marking efficiency; 2) treatment of fry at 50 ppm OTC at 5-9 and 15-19 days of age to verify marking efficiency for our standard double tag; 3) feeding OTC laced feed to pond-reared fingerlings for 7 days at rates of 6, 9 and 12 grams OTC per pound of food and 6 grams OTC/lb food plus .75 grams glucosamine (potentiator)/ lb food to attempt to produce a unique mark for fingerlings.

"Controlled quick-release" research was initiated to develop the capability to release fry from a rearing tank to a transport tank and then to the river via a flexible hose. Two replicates were conducted using outdoor tanks as "simulated rivers" and evaluating 5 day post-stocking survival for tanks released by conventional water brailing into plastic bags and styrofoam coolers vs controlled quick-release.

Research continued to evaluate the use of milled Artemia flakes vs larval AP100 as dry diets to supplement feeding with live Artemia nauplii.

EGG SHIPMENTS

A record 52.7 million eggs (1535.7 L) were received in 40 shipments at Van Dyke in 1986 (Table 1). By comparison, 25.6 million eggs were received in 1985 (Hendricks et al., 1985) and 41.1 million eggs were received in 1984 (Wiggins et al., 1984[a]) (Table 2). Overall egg viability (defined as the percentage which ultimately hatches) was 40.7, compared to 40.9% in 1985 and 45.2% in 1984. Egg viability for the Pamunkey River was 55.3% as compared to 64.5% in 1984 and 62.5% in 1985. Egg viability for the James River was 59.5% as compared to 63.9% in 1984 and 52.6% in 1985. Egg viability for the Delaware River was 57.9% as compared to 31.2% in 1984 and 50.5% in 1985. Egg viability for the Columbia River was 35.5% as compared to 39.2% in 1984 and 24.5% in 1985, and was responsible for the overall low viability. Low egg viabilities for the Columbia River were related to the extremely large numbers of eggs shipped. Large shipments required incubation of larger numbers of eggs per jar resulting in lower viabilities and will be discussed later. In addition, larger egg shipments tax our ability to provide proper care for individual lots of eggs.

PRODUCTION

Survival, production, and stocking of American shad fry are presented in Tables 2, 3, and 4. Survival of all fry from viable eggs to stocking was 75.6% (Table 3) compared to 76.2% in 1985 and 72.8% in 1984. Total fry production in 1986 was a record 16.6 million (Table 3) compared to 7.9 million in 1985 and 13.5 million in 1984. The majority of the fry produced were stocked in the Juniata River (9.9 million). Large Columbia River egg shipments necessitated stocking 3.4 million of these early (12-15 days of age) to make room for more hatching fry. Stocking of 5.2 million fry in the Susquehanna River below Conowingo Dam marked the first time Van Dyke fry were transported below all four Susquehanna power dams. These fry were uniquely double marked by immersion in tetracycline antibiotic. Fry were also released into ponds at Van Dyke (290,000) and Benner Spring (212,000) for research and production of fingerlings. Wellsboro National Fishery Research and Development Center also received 65,000 fry for research purposes. Delmarva Ecological Lab received 166,000 double marked fry for pond fingerling production and eventual release into the Elk River. In addition, fry from Delaware River sources were transported to the Lehigh River (550,000) and Schuylkill River (246,000).

Total fingerling production in 1986 was an estimated 72,525 (Tables 2 and 3), compared to 115,000 in 1985 and 30,500 in 1984. Fingerlings from Benner Spring ponds (Table 3) were provided to Ecological Analysts (10,800), released directly into the turbines at Safe Harbor Dam (18,400), or stocked in the Juniata River at Thompsontown (5,750). Fingerlings from Van Dyke and Thompsontown were stocked in the Juniata River (37,095). A small number (500) of fingerlings were also provided to Radiation Management Corporation for use in radiotelemetry studies.

SURVIVAL

Survival of all fry was 75.6% (Table 3) compared to 76.2% in 1985, and 72.8% in 1984. Tanks of shad fry were grouped according to their survival patterns and displayed in Figure 1. Groups 1, 2 and 3 exhibit typical patterns of higher mortality during the transition from endogenous to exogenous nutrition at 9 to 14 days of age (Wiggins et al., 1985). Group 4 (3 tanks) exhibited high post-hatch mortality (to 2 days of age) followed by more typical mortality to 18 days of age. This mortality pattern is similar to that exhibited by some outdoor tanks in 1985 (Hendricks et al., 1985). It was postulated that higher illumination levels outdoors caused premature hatching and resulted in high post-hatch mortalities. In contrast, all three tanks which exhibited this type of survival in 1986 were indoor tanks in the new rearing room. Interestingly, Tank I3 exhibited this type of survival pattern during two of the three times it was used. Tank I3 is close to an outside door and may receive somewhat higher illumination levels, however, Tank I4 is closer to the door than I3 and did not exhibit this problem nor did any outside tank. No explanation for these atypical mortality patterns is tendered at this time. Similar mortality patterns in future years will be investigated and may offer some explanation.

During the rearing of the last Virginia River egg shipment, unusually high mortalities were recorded during OTC tagging beginning at an age of 7 days. This is 2 days earlier than the typical 9-14 day mortalities associated with the transition from endogenous to exogenous feeding (Wiggins et al., 1985). Ultimately, four tanks were seriously affected and assigned to this survival category (Group 5, Figure 1). However, fry in many other tanks were seriously stressed as evidenced by erratic swimming and dense schooling at the surface. Fortunately, we quickly discovered that addition of salt to form a .25% solution provided immediate relief and kept mortalities to a minimum. Careful monitoring of dissolved oxygen and pH in the next several weeks eliminated these variables as a possible cause for the stress. The observation that several tanks exhibited stress after the addition of buffer but before the addition of OTC lead us to conclude that the stress resulted from the buffer. Investigation revealed that orders for sodium phosphate (dibasic) heptahydrate had been changed to sodium phosphate (dibasic) annhydrous. Although there was no difference in resultant pH, we speculate that the annhydrous form of sodium phosphate was responsible for the stress.

OTC TAGGING/RESEARCH

Most American shad fry destined for stocking in the Juniata River received a single tag at 50 ppm OTC, 12 hours/day, 5-9 days of age. One lot of fry (200,910) received a single tag at 15-19 days of age. All fry destined for stocking below Conowingo Dam in the Susquehanna or Elk Rivers (D.E.L. fingerlings) were tagged again at 15-19 days of age. Tags received by other lots of fish are summarized in Table 4.

Research efforts directed at refining OTC tagging continued in 1986. We attempted to improve the logistics of OTC tagging by utilizing higher concentrations of OTC for a shorter duration, administered on one day only. Hettler (1984) achieved 100% tag efficiency with spot *Leiostomus xanthurus* by immersion in 250 ppm for 2 hours. For pinfish *Lagodon rhomboides*, 500 ppm was required to achieve 100% marking. Siegfried and Weinstein (1985) achieved 99% marking of spot by immersion in 400 ppm OTC for 24 hours. We attempted tagging by immersion of 5-day-old American shad in 200 and 400 ppm OTC for 6 hours. Approximately 5,000 fry from each lot were transferred to Benner Spring raceways at 14 days of age for grow-out and otolith analysis. The remainder were tagged again from 15 to 19 days of age (50 ppm, 12 hour bath) and released in the Lehigh River.

Survival of American shad fry subjected to experimental concentrations of OTC is depicted in Figure 2. Nineteen day survival of the lot treated at 200 ppm was 86.9% compared to 81.0% for the lot treated at 400 ppm. A control tank from the same egg shipment, treated at 50 ppm 12-hour baths, days 5 to 9 exhibited 19 day survival of 76.9%.

Tagging rates were 100% for fry treated at both 200 and 400 ppm OTC (Table 5). These rates were higher than the observed rate for the 5 day, 50 ppm production tag (97.8%, Table 5).

Approximately 5,000 American shad fry, from the lots which were sent to D.E.L. for pond grow-out at Elkton, were retained in a Benner Spring raceway to verify the production double tag (50 ppm, 12 hour bath, days 5-9 and 15-19). A total of 77 of the 79 otoliths examined (97.5%) exhibited the initial tag (days 5-9) while 100% exhibited the secondary tag (days 15-19). Thus, it could be expected that 2.5% of the hatchery fry stocked below Conowingo Dam would exhibit only a single tag.

Attempts to develop a unique tag for fingerlings, by feeding OTC laced feed continued in 1986. In 1985 we failed to produce a tag by feeding juveniles feed containing 3 grams OTC per pound of food. In 1986, we attempted feeding at 6, 9, and 12 (2 ponds) grams OTC per pound of food and 6 grams OTC plus .75 grams glucosamine (potentiator) per pound of food (Table 5). Six grams OTC per pound of food was fed to the fingerlings reared in the rearing pond at Van Dyke (RP) while 9 and 12 grams per pound were fed to fingerlings in the Canal Pond (CP) at Thompsontown (first and second crops, respectively). These fingerlings were fed twice daily by hand. Six grams OTC plus .75 g glucosamine per pound of food was fed to fingerlings reared at Benner Spring Pond 1 (BSP1). Twelve grams OTC per pound of food was fed to fingerlings reared in the Van Dyke settling pond (SP). These two ponds were fed via an automatic feeder timed to feed every 5 minutes. All OTC feedings were continued for a 7 day duration and fish fed to satiation.

Analysis of otoliths indicated that the only lot successfully tagged was the lot reared in Benner Spring Pond 1 (fed 6 g OTC/lb food plus .75 g glucosamine/lb food). A total of 28 of 37 otoliths examined (75.1%) exhibited the tag. The tag was characterized by a diffuse band exhibiting a faint flourescent glow. The flourescent band was very wide in comparison to the narrow bands produced by the immersion tags. This was the result of much faster growth and correspondingly wider daily rings during the period when the tag was administered (66 to 72 days of age). We believe the feeding regime used in this lot of fish to be as important in producing a tag as the use of the potentiator glucosamine. The pond in question was put on an automatic feeder at an early age (34 days of age) and fed much larger quantities of food than the other ponds in an effort to stimulate as much growth as possible. As a result the fingerlings were much larger than the other lots when exposed to the OTC laced feed and were feeding much more vigorously. While present in 75.7% of the otoliths examined the tag produced was considered too faint and diffuse to be reliable. Research efforts in 1987 will focus on refining the tag by using higher concentrations of OTC and feeding strictly by automatic feeder. Quality control from pond to pond may be a major problem. Our inability to handle (and therefore census) the fish population in a pond will make it impossible to determine the dosage of OTC received by each individual fish. This is confounded by the presence of external food sources and our inability to measure the amount of food that is not consumed.

FEED RESEARCH

Research to further refine feeding techniques continued at Van Dyke in 1986. The use of the larval diet AP100 (150 micron size) as a supplement to live Artemia was investigated in 1984 (Wiggins et al., 1984b), and incorporated into production feeding regimes in 1985. Milled Artemia flakes have advantages over the AP100 larval diet in that they are vacuum packed and thus, easier to store and handle and less susceptible to spoilage. The use of milled Artemia flakes as a substitute for AP100 was first investigated in 1984 but the size used was increased progressively during the test and was too large to be effectively used by the fry (Wiggins et al., 1984b). Two-hundred micron milled Artemia flakes were first used in 1985 and resulted in 84.0% survival to 19 days of age, compared to 86.1% for AP100 (Hendricks et al., 1985). This test was replicated two times in 1986. Results are presented in Figure 3 and Table 6. Nineteen day survivals were 83.0% and 91.6% for milled Artemia flakes as compared to 82.1% and 79.4% for AP100.

As a result of these excellent survivals, a full scale research/production test was contemplated for 1987 to include feeding one-half of the tanks AP100 and one-half milled Artemia flakes. This would have the advantage of eliminating feed shortages such as occurred in 1986 as a result of the record egg shipments and production. Extra milled Artemia flakes could be ordered and stored over winter if necessary. Unfortunately, the manufacturer has recently discontinued production of milled Artemia flakes due to lack of demand. Another potential substitute for AP100 will be tested in 1987. Future availability will be considered in the choice of the diet tested.

Continued research into the importance of dry diet size was scheduled for 1986, but was postponed as a result of the extreme workload and feed shortages caused by the record egg shipments. Many of the latter Columbia River shipments were cut to 1/2 ration of dry diet (32.25 g/250,000 fish-day) with the live Artemia ration increased proportionately to 15 shrimp/fish-day. These feeding changes were instituted for all production tanks on June 19 and terminated upon the arrival of additional feed on July 9. Thirteen tanks were exposed to this feeding regime for their entire rearing period. Eighteen-day survival for these fish ranged from 72.5% to 90.4% and averaged 81.2%, indicating that survival was not adversely affected by the altered feeding regime.

"CONTROLLED QUICK-RELEASE" STOCKING OF FRY

Current methodologies used in stocking American shad fry involve partial draining of the rearing tank, addition of salt, crowding the fry, and water brailing fry into 5-gallon buckets (for trips to Thompsontown Access area) or plastic bags (for longer trips to Benner Spring or below Conowingo Dam). Fry stocked at Thompsontown are then transported via truck to the site, tempered and stocked from the bucket, while those destined for longer trips are double-bagged with oxygen and transported in styrofoam coolers with ice packs (if necessary). Tempering and stocking is accomplished in the clear plastic bags. Much emphasis is placed on minimizing stress by the addition of salt, careful handling of the fry, and minimizing turbulence, while minimizing the length of time fry are crowded. The entire process is painstakingly slow and requires excessive manpower. Trips to Lapidum, MD routinely require two vehicles, two men for 12 to 14 hours and 4 hours for a third man to assist in loading. Survival of fry stocked into riverine systems is unknown, however Wiggins et al. (1984[b]) experienced a 3-day survival of 88.7% for a tank of American shad fry transported for 3 to 5 hours in oxygen-filled bags and stocked into tanks similar to those used at Van Dyke.

In an effort to expedite the stocking process and reduce handling we developed a method for "controlled quick-release" stocking of American shad fry. Quick-release fittings were installed in two rearing tanks and capped prior to the rearing season. Prior to stocking, a plastic plate was installed to prevent the tank from draining while the cap was removed and a clear, flexible 4 inch hose attached to the quick-release fitting. Next, the plastic plate was adjusted to allow the hose to fill slowly. Water level in the hose was controlled by suspending the hose from a tripod using a chain hoist. The rearing tank was then partially drained via the center standpipe, salt added to form a 0.25% solution, and the fry crowded to the area immediately in front of the quick-release fitting. At this point, the fry were transferred to a fiberglass tank mounted on a gooseneck trailer by lowering the chain hoist slowly, thereby allowing the rearing tank to drain through the 4 inch hose and into the gooseneck unit. Close monitoring of the flow in the hose ensured that the fry were subjected to minimal turbulence. Fry could be readily seen as they passed through the clear hose. A cushion of water was provided to break the fall of the first shad into the gooseneck unit.

Fry were held in the gooseneck unit for 4 hours to simulate a typical trip to Lapidum, MD. During that time one 30 minute trip was made to Thompsontown to simulate the agitation produced during travel. Pure oxygen was bubbled into the tank via a bioweave airstone to ensure adequate dissolved oxygen. After 4 hours, the fry were released into an outdoor shaded rearing tank via the 4 inch hose using the same "controlled quick-release" methodology.

For each tank of quick released fry a control tank was selected from the same egg shipment with similar densities and survival to 20 days. Control tanks were transported and stocked by "conventional" methodology (double-bagged with oxygen and styrofoam coolers). Control tanks were held for four hours and taken on the same 30 minute trip as the test tanks. Outdoor tanks were plumbed and fry cultured in the same manner as indoor production tanks. Survival of the test and control groups was monitored for at least 4 days by estimating mortality using standard Van Dyke methodology (volumetric sample).

Test results are depicted in Figure 4 and Table 7. Survival to 20 days (prior to quick-release) for the test tank in the first replicate was a disappointing 49.8% compared to 63.6% for the control tank (Table 7). No reason for these low survivals is apparent, and their affect, if any, on post test survival is unknown.

We experienced problems flushing the fry from the gooseneck unit during replicate 1. In an effort to minimize stress, the gooseneck tank was drained so slowly that fry were able to swim against the current and were reluctant to leave the tank. As the tank drained, the fry became very crowded and in danger of being stranded. In order to prevent stranding, we gently flushed the fry out of the tank with spring water using a garden hose. Unfortunately, the spring water was approximately 10°F cooler than tank water and resulted in some cold shock. This may account for the low 4-day survival of 62.9% (Table 7). Four-day survival in the control tank was 71.8%. During replicate 2 we drained the tank somewhat faster and flushed the fry out of the tank using a siphon and bucketed water at the same temperature as the test tank. Four-day survival for replicate two was 79.6%. The control tank for replicate 2 experienced a water flow blockage which resulted in a 4-day post-test survival of 12.7%. We consider the test survival for replicate two to be acceptable, although it did not approach the 88.7% 3-day survival experienced by Wiggins et al. (1984[b]).

Projected time savings for the "controlled quick-release" methodology were not realized primarily due to the time required for equipment set-up. On a production basis, however, four or five tanks would be stocked per day, effectively decreasing set-up time per tank. Additional time will be saved as the procedure becomes routine. The new procedure is definitely "work-saving" as it eliminates carrying boxes of fry and the entire water brailing process. Additional replicates will be tested in 1987 to gather more information on survival before a decision is made to incorporate the methodology into the production cycle.

EGG DISINFECTION

Disinfection of all American shad eggs for 10 minutes at 100 ppm free iodine has been standard practice at Van Dyke since 1984. The purpose of this effort is to prevent the spread of infectious diseases, particularly IHN, from the egg source rivers to Van Dyke and the Susquehanna River. Experience in 1985 emphasized the importance of close monitoring of pH during the disinfection process. In 1986, several tests were conducted to determine the effect of disinfection on egg viability under neutral pH conditions.

Fertilized American shad eggs were disinfected immediately upon arrival at Van Dyke in a solution of the appropriate concentration of Argentyne iodophore, buffered to pH 7.1 with sodium bicarbonate (Piper et al., 1982). Eggs were first tempered in a trough filled with water from the egg battery and then placed in a net in lots of 20 liters or less. The net was then lifted out of the trough, drained and placed in the disinfection solution. After 10 minutes, the net was lifted from the trough, drained and removed from the disinfection room to the incubation room where it was placed in a trough of fresh water for measuring into incubation jars. Eggs were measured volumetrically using graduated cylinders with screen bottoms. Each incubation jar received 2.5 liters of eggs more or less depending on egg shipment size. The number of eggs per liter was calculated from a modified Von Bayer table based upon the number of eggs layed end to end in a 12 inch trough. On the sixth day after fertilization, egg jars were removed to the rearing tanks for hatch. Dead eggs layered on the surface and were removed on the second and sixth days after fertilization. Dead eggs were enumerated by the same modified Von Bayer method as live eggs. After hatch any dead eggs remaining were again removed and enumerated. Percent viability was calculated by subtracting the total number of dead eggs removed from the initial egg density dividing by the initial egg density and multiplying by 100.

Results of the tests conducted in 1986 are depicted in Figure 5 and Tables 8 and 9. In test 1 (Table 8) jars disinfected at 100 ppm free iodine experienced a viability ranging from 46.8% to 54.2%, with an overall viability of 50.4%. Undisinfected controls experienced viabilities ranging from 74.3% to 78.9%, with an overall viability of 76.3%. Jar viabilities were tested using Wilcoxin's Sign Rank Test (Ott, 1977) and found to be significantly different at the .05 level.

In test 2 (Table 9) jars of eggs disinfected at 50 ppm experienced viabilities ranging from 31.3% to 52.0% with an overall viability of 41.1%. Eggs disinfected at 75 ppm experienced viabilities ranging from 37.7% to 47.6% with an overall viability of 42.5%. Eggs disinfected at 100 ppm experienced viabilities ranging from 37.9% to 44.3% with an overall viability of 40.8%. These data were tested by ANOVA (Ott, 1977) using the number of viable eggs in each jar as the test statistic and included only jars in which 102,300 eggs were incubated. As is apparent from the data, there was no significant difference in viability between the three treatment levels at the .05 level ($F = .278$, d.f. = 2,11).

At this point, we offer no explanation for the apparent disparity between the two tests. Further testing will be scheduled for 1987 using 0, 25, 50, 75 and 100 ppm free iodine.

EGG INCUBATION DENSITIES

Large egg shipments such as those received from the Columbia River require incubating more eggs per jar and combining eggs from several jars as dead eggs are removed, in order to free up jars for incoming shipments. Decreases in egg viabilities during the latter Columbia River shipments and problems encountered in handling egg jars loaded with three liters of eggs led us to conduct a study to determine the optimal loading density for May-Sloan egg jars. Jars were loaded at densities of 1.5, 2.0, 2.5 and 3.0 liters of eggs per jar, using the last shipment (shipment 41) of Columbia River eggs. Dead eggs were taken off and enumerated on the second and sixth days after fertilization and again after hatch. On the sixth day after fertilization, prior to moving the jars (eggs) to the tanks for hatch, eggs from jars of similar low loading densities were combined to prevent overloading the water supply network with too many jars per tank. Eggs from three jars were combined to make one "full" jar at loading densities of 1.5, 2.0 and 2.5 liters per jar, while two jars were combined for loading densities of 3.0 liters per jar. Dead eggs removed after egg combination constituted a maximum of 3.9% of the total mass of dead eggs indicating that combining jars did not contribute to egg mortality.

Results of these tests are depicted in Figure 6 and Table 10. Overall egg viability for jars incubated at 1.5, 2.0, 2.5 and 3.0 liters per jar was 39.4%, 37.0%, 38.4% and 26.1% respectively. Since proportions tend to be binomially distributed, the data were transformed using the arc-sin transformation (Snedecor, 1956) and analyzed using ANOVA. While egg viability for jars loaded at 3.0 liters per jar appears to be lower than the other loading densities (Figure 6), the difference was not significant at the .05 level (F = 2.98, d.f. = 3, 7). Nevertheless, loading jars at a maximum density of 2.5 liters per jar has other advantages. First, dead eggs do not layer properly at loadings of 3 liters per jar resulting in difficulty when removing dead eggs. This results in the removal of live eggs with dead eggs and may account for some of the apparent decrease in viability. Second, jars loaded at 2.5 liters per jar can usually be combined three jars to one, resulting in the incubation of 7.5 liters of eggs (initial volume) in one jar. Jars loaded at 3.0 liters per jar can only be combined two to one, resulting in 6.0 liters of eggs incubating in one jar. This clearly frees up more jars for use in incoming shipments. As a result of these considerations, jars will be loaded at a maximum of 2.5 liters of eggs per jar.

EGG ENUMERATION STUDIES

The validity of all our research efforts and production totals at Van Dyke is based upon our system of enumeration. Basically, we enumerate egg shipments as they are measured into incubation jars then subtract dead eggs and dead fry as they are removed from the jars or rearing tanks. The remainder for each tank is then taken as the final density for totaling production or analysis of research. Obviously, this system relies on our ability to accurately estimate numbers of eggs and dead fry. Wiggins (pers. comm.) felt that the system was generally very good but noted that some tanks appeared to have more fry than the estimate would indicate. This could result from under-estimation of egg numbers or overestimating mortalities. Research plans for 1986 included evaluation of several methods for enumerating eggs and estimating mortalities. Manpower limitations forced postponement of the evaluation of methods for estimating mortalities.

Seven methods of enumerating eggs were compared to the Von Bayer (1908) dry volume method (standard method at Van Dyke). Two one-half liter lots of eggs from different shipments were hand counted and then subjected to each enumeration method. Von Bayer methods involved placing a sample of eggs end to end in a 12 inch trough, counting the number of eggs in 12 inches and using tables supplied by Von Bayer (1908) to determine the number of eggs per liter based on the volume of a sphere. Total number of eggs in the lot is then obtained by multiplying the number of eggs per liter by the dry or wet (as appropriate) volume of the lot. Dry volume (Van Dyke standard) was measured in a graduated cylinder screened on the bottom and allowed to drain. Wet volume (volume of egg mass covered in water) was used for comparison since Von Bayer's (1908) procedure was unclear in this respect.

The wet volume method simply compared the wet volume of the entire lot to the wet volume of a known number of eggs measured in a 25 ml graduated cylinder. One hundred and three hundred egg samples were collected with a 100 egg sampler constructed from a plexiglass plate (11 cm x 11 cm x 2 cm) with 100, 11/64 inch diameter holes, screened on the bottom. Each sample was examined to ensure that all holes were filled, and extra eggs removed. Total number of eggs in the lot was then estimated by dividing the number of eggs in the sample (100 or 300) by the sample wet volume and multiplying by the total wet volume.

The displacement method (Burrows, 1951) compared the volume of water displaced by a known number of eggs to the water displaced by the entire lot. Displacement of the sample was measured in a 25 ml buret while displacement of the lot was measured in a 1000 ml graduated cylinder. Both 100 and 300 egg samples were used, collected as before. Both samples, and the entire lots were drained for one minute to eliminate excess water. Total number of eggs in the lot was estimated by dividing the displacement of the entire lot by the displacement of the sample and multiplying by the number of eggs in the sample.

The displacement/wet volume method utilized the sample displacement from the displacement method and the wet volume of the entire lot from the wet volume method to estimate the number of eggs in the lot. The estimate was determined by multiplying the wet volume of the lot by the number of eggs in the sample divided by the sample displacement. This method has no logical basis but had, in our test, greater accuracy than either method and greater precision than the displacement method.

The results of these tests are reported in Appendices 1-4 and summarized in Table 11. The methods used are evaluated on the basis of the accuracy (% error of estimate) of the overall estimate (based on 3 to 6 samples) and the variability between samples (coefficient of variation). As expected by Wiggins (pers. comm.) the estimated number of eggs using the Von Bayer (dry) method was 13.6% and 5.4% low for the two lots of eggs. The coefficient of variation was 8.88 and 6.48 respectively. These were the standards by which the other methods were evaluated.

The Von Bayer (wet) estimates were 20.9% and 23.9% high, with coefficients of variation of 9.04 and 6.70, clearly no better than the standard Von Bayer (dry) method. The wet volume (100 egg sample) estimates were 29.0% and 24.8% low, with coefficients of variation of 8.24 and 3.69, also inferior to the standard method.

The wet volume (300 egg sample) estimates were 25.7% and 19.9% low, but had excellent coefficients of variation (2.94 and 2.22). This suggests the possibility of using this method with a correction factor; however, testing on additional lots of eggs is needed before such a procedure could be recommended.

The displacement (100 egg sample) estimates were 32.1% and 24.5% low with coefficients of variation of 6.38 and 6.22, clearly inferior to the standard method. The displacement (300 egg sample) estimates were 31.4% and 22.3% low, with coefficients of variation of 0.09 and 6.20. Again, further testing is needed before a correction factor could be developed.

The displacement/wet volume (100 egg sample) estimates were appealingly accurate at 1.0% low and 6.8% high. Coefficients of variation were unacceptable, however, at 8.24 and 22.70. The displacement/wet volume (300 egg sample) estimates were 0.1% and 9.9% high with extremely low coefficients of variation (0.73 and 3.96). Unfortunately, this method has no logical basis and the cautious approach dictates that further testing be pursued prior to changing our procedures.

In summary, three methods, wet volume (300 egg sample), displacement (300 egg sample) and displacement/wet volume (300 egg sample)warrant further testing. The variability found in the number of eggs per 12 inches for the Von Bayer (dry) method has immediate application. For example, lot A counts varied from 92 to 98 eggs per 12 inches resulting in estimates ranging from 2.3 to 19.3% low (Appendix 1). In the past, a single count was made for each egg shipment. Beginning in 1987, the average of three counts will be used to determine the number of eggs per liter by the Von Bayer (dry volume) method.

SUMMARY

A total of 40 egg shipments (52.7 million eggs) was received at Van Dyke in 1986. Total egg viability was 40.7% and survival to stocking was 75.6%, resulting in production of a record 16.6 million fry. The majority of the fry were stocked in the Juniata River (9.9 million) with lesser numbers stocked in the Susquehanna River below Conowingo Dam (5.2 million), the Lehigh River (550,000) and the Schuylkill River (246,000).

Fingerling production was 72,525, with the majority of these stocked in the Juniata River (42,845). Fingerlings were also released directly into the turbines at Safe Harbor Dam (18,400), supplied to Ecological Analysts (10,800), and supplied to RMC (500).

All American shad stocked above Conowingo Dam received a single tag by immersion in 50 ppm OTC for 12 hours/day usually from 5 to 9 days of age. Overall marking efficiency for the production single tag was 97.4% (261 of 267). All shad stocked below Conowingo received a double tag at 5-9 and 15-19 days of age. Marking efficiency for the production double tag was 97.5% for the initial tag and 100% for the secondary tag. Efforts to produce a tag by immersion in 200 or 400 ppm OTC for 6 hours on day 5 only were successful. Both concentrations produced 100% marking efficiency. A unique tag, albeit "weak", was produced in fingerlings by feeding OTC laced feed at 6 g OTC per pound of food plus .75 g glucosamine per pound of food.

Results of feed research indicated that survival of fry fed _Artemia_ nauplii plus milled _Artemia_ flakes was comparable to survival of fry fed _Artemia_ nauplii plus AP100 larval diet. Unfortunately, milled _Artemia_ flakes are no longer available from the manufacturer and another substitute for AP100 may have to be tested.

"Controlled quick-release" stocking of American shad fry was investigated as a substitute for conventional water brailing into plastic bags. Results are as yet inconclusive due to the loss of the control tank in the second trial but the methodology is promising and will be tested again in 1987.

Egg disinfection research indicated that egg viability was significantly lower for eggs disinfected at 100 ppm free iodine (50.4%) than for undisinfected controls (76.3%), but there was no significant difference in egg viability for eggs disinfected at 50, 75, or 100 ppm free iodine (41.1%, 42.5%, 40.8% respectively). Research will be conducted in 1987 to further address this issue.

Research to determine optimal loading densities for May-Sloan egg jars indicated that there was no significant difference in egg viability for jars loaded at 1.5, 2.0,. 2.5 and 3.0 liters of egg per jar. However, 2.5 liters per jar appears to be optimal from a logistics standpoint.

Egg enumeration studies suggested that three methods warrant further testing: wet volume (300 egg sample), displacement (300 egg sample) and displacement/wet volume (300 egg sample). In the interim, we will continued to utilize the von Bayer method using the average of 3 twelve-inch counts, instead of one.

Recommendations for 1987

1) Continue to disinfect all incoming egg shipments. Monitor pH carefully to ensure survival.

2) Continue to investigate the effects of disinfection on egg viability. Test 0, 25, 50, 75 and 100 ppm free iodine.

3) Continue to stock one-half of production fry below Conowingo Dam (up to 5 million fry).

4) Mark all production fry destined for upriver sites at 200 ppm OTC, 6 hour baths, at day 5.

5) Mark all production fry destined for below Conowingo Dam at 200 ppm OTC, 6 hour baths at 5 and 12 days of age.

6) Mark all fingerlings destined for the Juniata River at 200 ppm OTC, 6 hour baths at 5, 12 and 19 days of age.

7) Mark all fingerlings destined for below Conowingo Dam at 200 ppm OTC, 6 hour baths, at 5 and 19 days of age.

8) Continue to attempt to refine marking techniques for fry to improve mark efficiency and logistics.

9) Continue research to develop an OTC tag for fingerlings using OTC laced feed.

10) Continue research into "controlled quick-release" stocking of fry.

11) Choose and test a commercially available substitute for AP100 larval diet.

12) Time permitting, continue testing enumeration methods for eggs and mortalities.

13) Incubate eggs at 2.5 liters of eggs per May-Sloan jar.

14) Time permitting, construct and evaluate a new egg incubation battery that may permit the successful incubation of greater numbers of eggs.

Literature Cited

Burrows, R. E. 1951. A method for enumeration of salmon and trout eggs by displacement. Prog. Fish. Cult. 13(1): 25-30.

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

Hettler, W. F. 1984. Marking otoliths by immersion of marine fish larvae in tetracycline. Trans. Am. Fish. Soc. 118: 370-373.

Mandis, T. and L. E. Harris. 1984. Accuracy of various rainbow trout egg-counting methods. Fishery Information Leaflet No. 37. Colorado. Dept. of Nat. Res. 2pp.

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

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard. 1982. Fish Hatchery Management. U. S. Fish and Wildlife Service, Washington, D.C. 517 p.

Seigfried, R. C. II., and M. P. Weinstein. 1985. Comparison of methods used in the documentation of daily otolith rings. International Symposium on Age and Growth, Des Moines, Iowa. 9-12 June 1985. (Abstr.)

Snedecor, G. W. 1956. Statistical Methods. Iowa State College Press, Ames, Iowa. 534 p.

von Bayer, H. 1910. A method of measuring fish eggs. Bull. U.S. Fish. 18 (1908) (2): 1011-1014.

Wiggins, T. A., T. R. Bender, and V. A. Mudrak. 1984a. Job III. American shad hatchery operations. In Restoration of American Shad to the Susquehanna River, Annual Progress Report, 1984. Susquehanna River Anadromous Fish Restoration Committee.

Wiggins, T. A., T. R. Bender, and V. A. Mudrak. 1984b. Job V. American Shad Cultural Research. In Restoration of American Shad to the Susquehanna River, Annual Progress Report, 1984. Susquehanna River Anadromous Fish Restoration Committee.

Wiggins, T. A., T. R. Bender, Jr., V. A. Mudrak, and J. A. Coll. 1985. The development, feeding, growth, and survival of cultured American shad larvae through the transition from endogenous to exogenous nutrition. Prog. Fish-Cult. 47(2): 87-93.

Figure 1. Survival for five groups of American shad fry, Van Dyke, 1986.
Group 1 - S ≥ 85% (n=18)
2 - 65% ≤ S < 85% (n=43)
3 - S < 65% (n=5)
4 - S < 65% (n=3) high post-hatch mortality
5 - S < 65% (n=4) stressed during OTC tagging

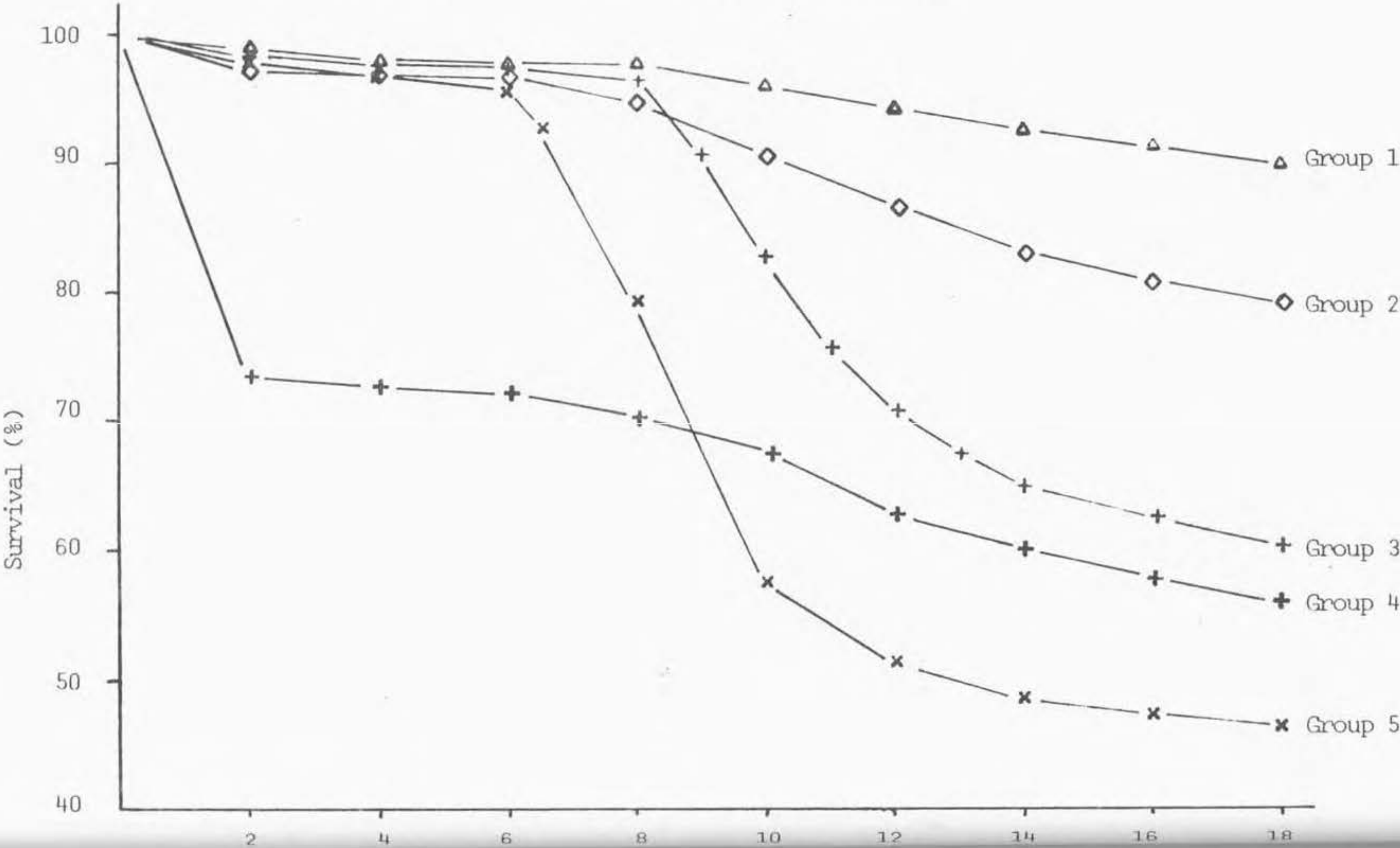

Figure 2. Survival of American shad fry tagged by immersion in experimental concentrations of oxytetracycline, Van Dyke, 1986.

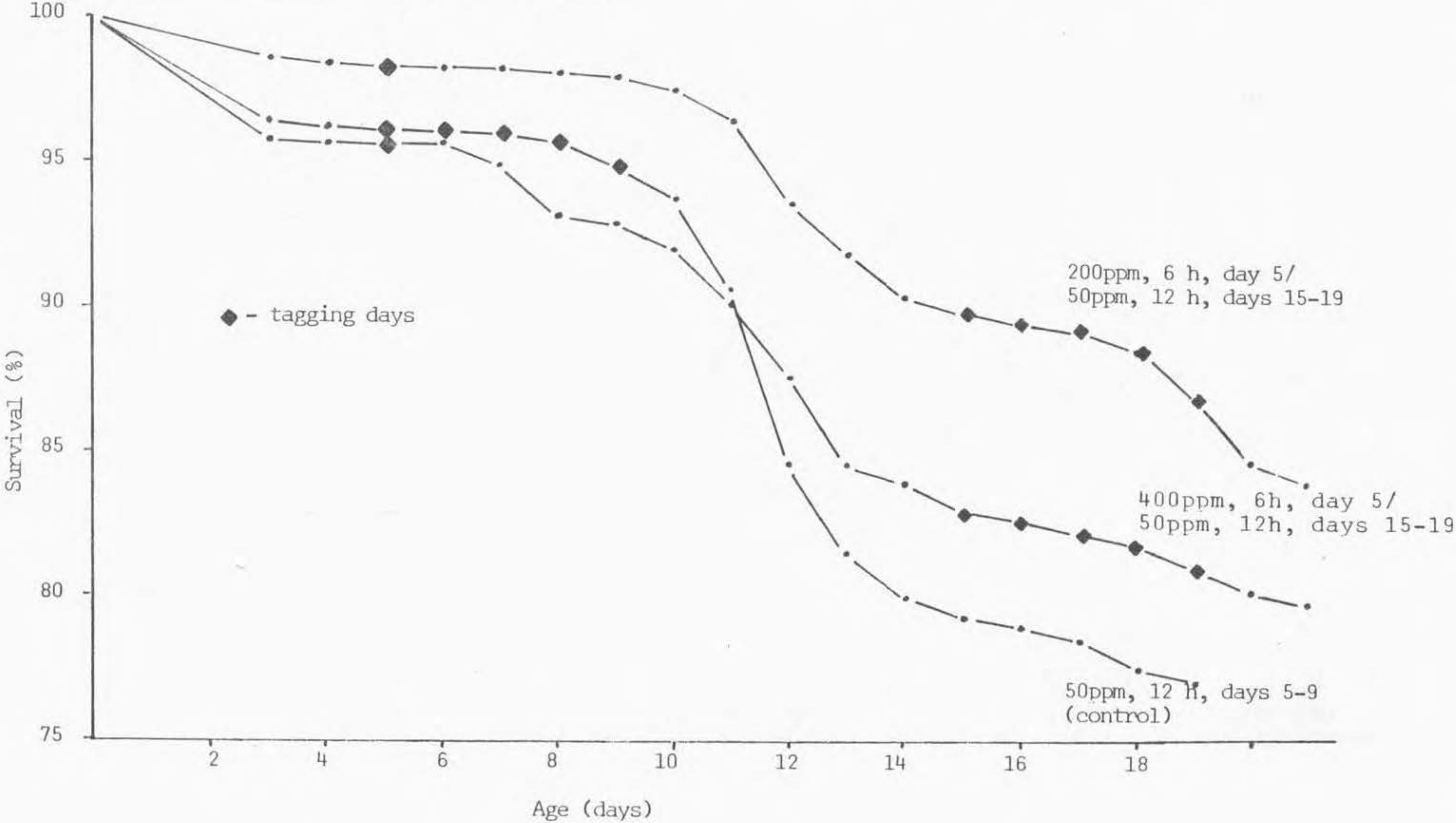

Figure 3. Survival of American shad fry fed live Artemia nauplii (12 nauplii/fish-day) plus 150 micron AP100 larval diet (64.5g/250,000 fish-day) vs. live Artemia nauplii (12 nauplii/fish-day) plus 200 micron milled Artemia flakes (64.5g/250,000 fish-day), Van Dyke, 1985 and 1986.

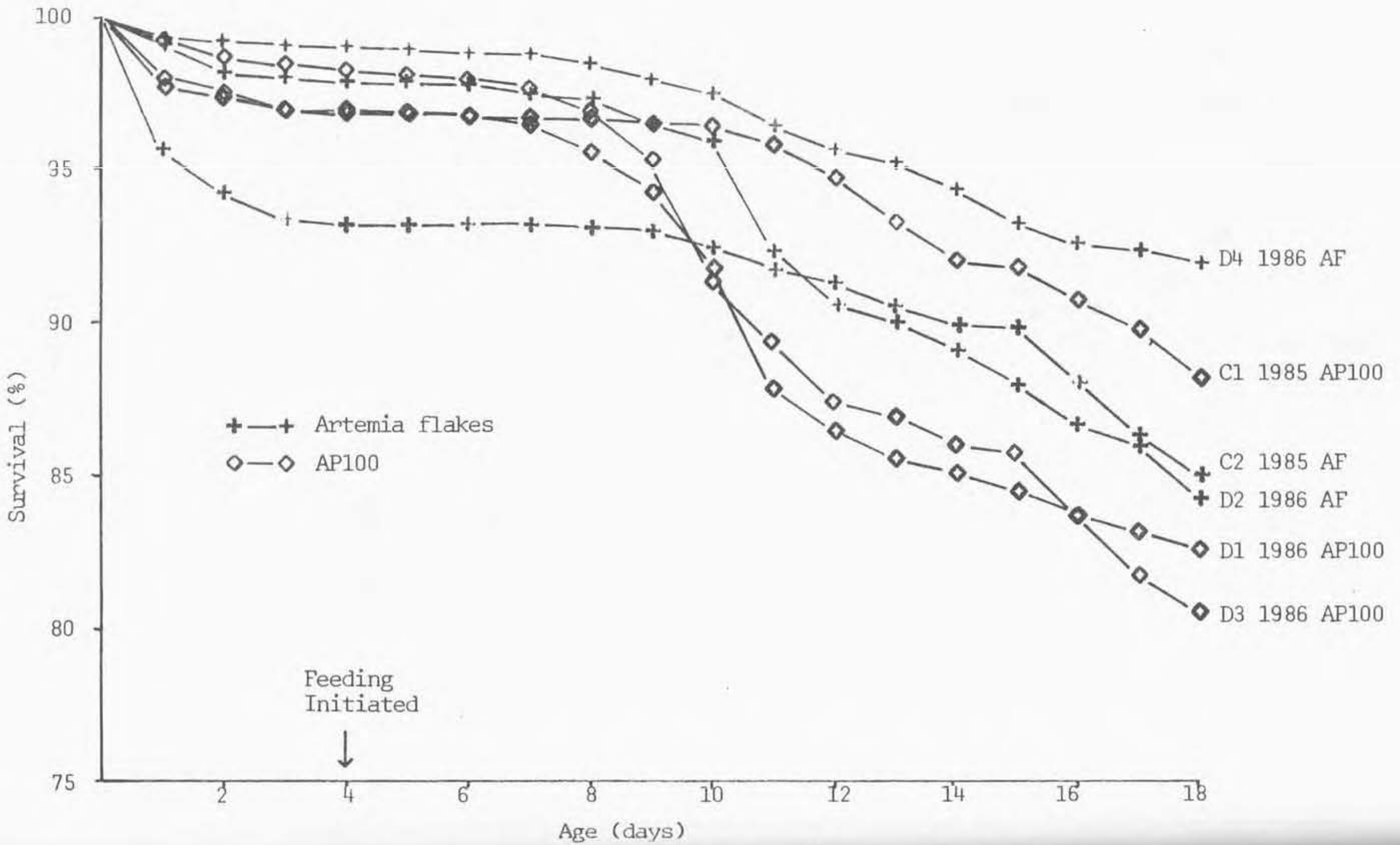

Figure 4. Survival of American shad fry stocked in outdoor tanks at 20 days of age by "controlled quick release" methodology vs. controls stocked by conventional water brailing into plastic bags filled with oxygen, Van Dyke, 1986. Control of replicate 2 not depicted due to near total mortality caused by water supply blockage.

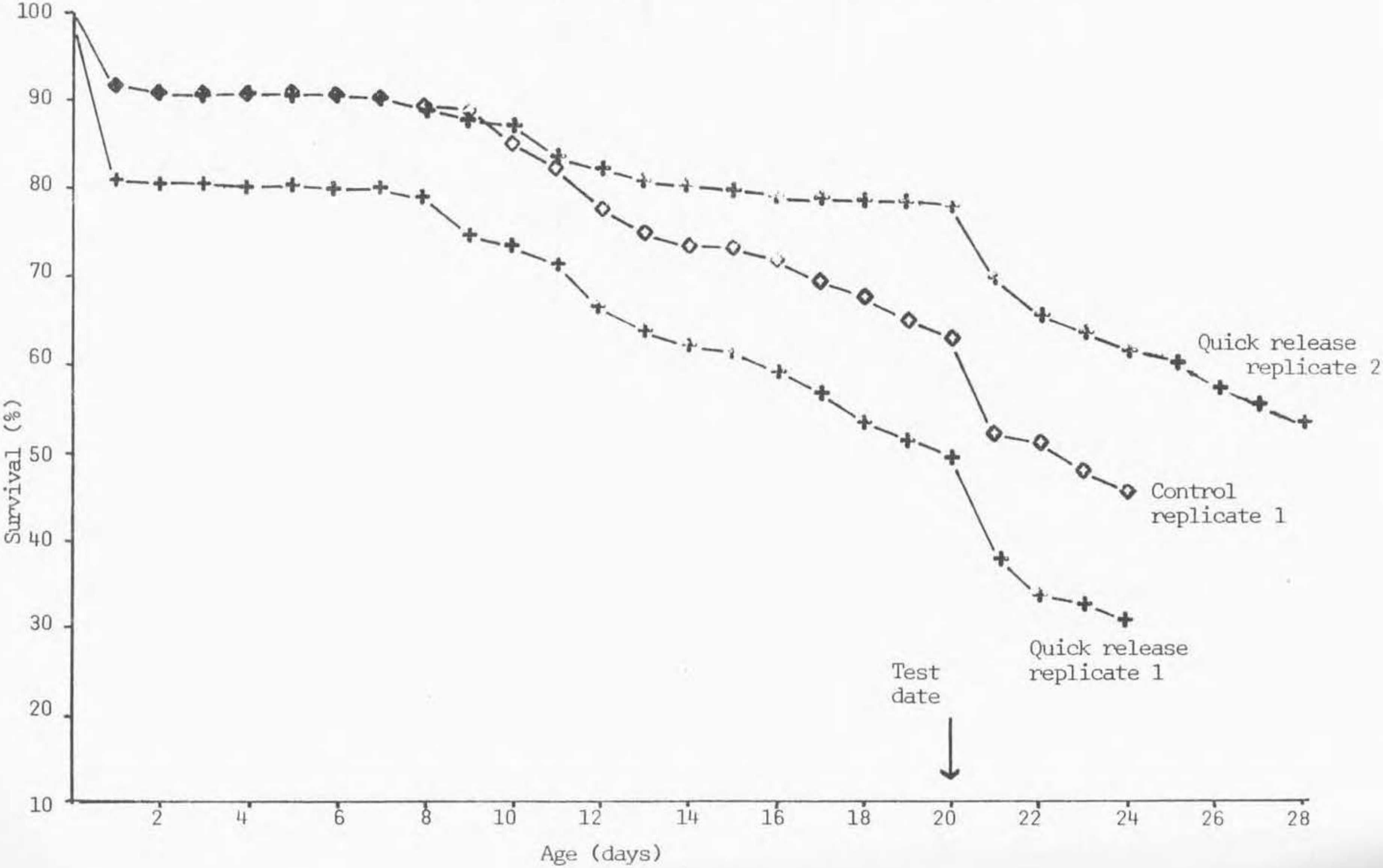

Figure 5. Egg viability (% hatch) of American shad eggs disinfected by 10 minute bath treatments at various concentrations of free iodine, Van Dyke, 1986.

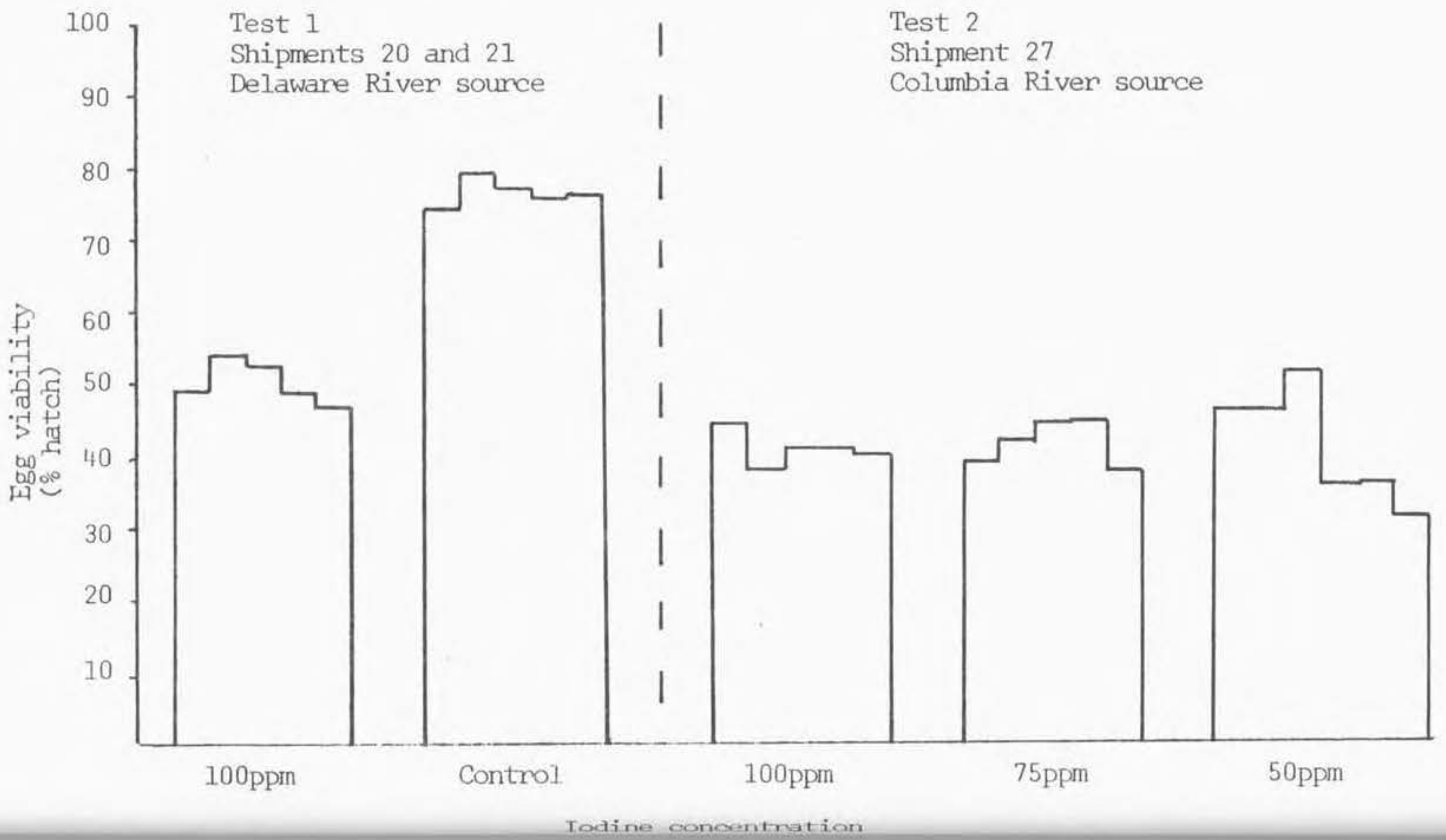

Figure 6. Egg viability (% hatch) of American shad eggs incubated at 1.5, 2.0, 2.5, and 3.0 liters of eggs per jar in May-Sloan egg jars, Van Dyke, 1986. Shipment 40, Columbia River source eggs. Jars were combined prior to hatch to facilitate mounting on rearing tanks.

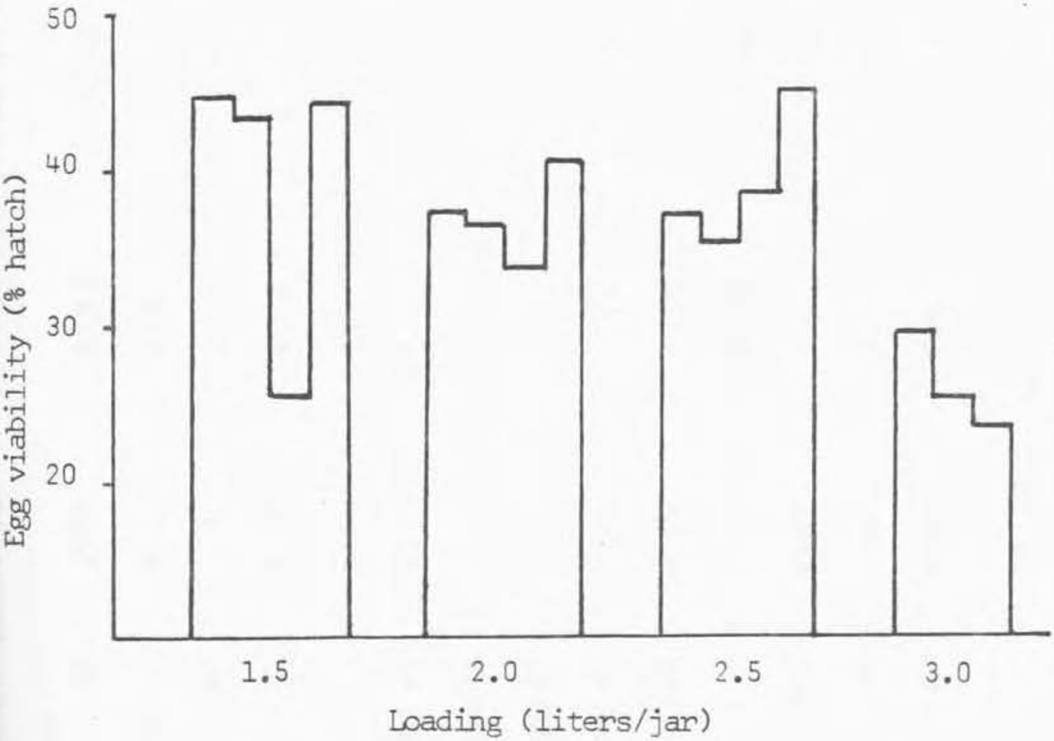

Table 1. Summary of American shad egg shipments received at Van Dyke, 1986.

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
1	Pamunkey	4/7	4/8	4.24	131,800	74.6	98,300	97,500
2	Pamunkey	4/9	4/10	6.68	276,500	55.0	152,100	151,260
3	Pamunkey	4/11	4/12	7.00	227,900	56.7	129,200	127,700
4	Pamunkey	4/13	4/14	8.90	276,600	32.5	90,000	87,900
5	Pamunkey	4/14	4/15	9.70	301,500	37.9	114,900	114,540
6	Pamunkey	4/15	4/16	18.50	825,800	51.6	441,900	440,990
7	Pamunkey	4/16	4/17	10.34	314,300	31.4	88,800	88,380
8	Pamunkey	4/18	4/19	10.00	272,100	38.6	104,900	103,350
9	Pamunkey	4/19	4/20	4.16	120,900	33.1	40,000	38,450
10	Pamunkey	4/20	4/21	13.50	351,600	48.3	169,700	165,400
11	Pamunkey	4/21	4/22	11.04	321,000	59.1	215,000	214,700
12	Pamunkey	4/25	4/26	2.30	62,600	58.6	36,700	35,750
13	James	4/25	4/26	0.65	22,200	35.1	7,800	6,850
14	Pamunkey/ James	4/26	4/27	12.50	447,000	73.7	329,700	314,200
15	Pamunkey/ James	4/27	4/28	30.12	1,102,400	62.8	749,600	733,700

Table 1 (continued).

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
16	Pamunkey	4/28	4/29	26.75	891,300	60.0	537,400	529,900
17	James	4/29	4/30	5.45	225,600	66.0	148,300	147,590
18	Pamunkey	4/29	4/30	6.80	226,600	50.4	114,600	112,500
19	Pamunkey	4/30	5/1	2.30	65,400	44.0	28,800	16,400
20	James	4/30	5/1	11.46	419,500	56.4	241,000	214,200
21	Delaware	5/7	5/8	14.85	451,400	68.1	308,500	267,900
22	Delaware	5/8	5/9	13.42	381,600	62.5	240,100	235,300
23	Delaware	5/11	5/12	34.04	1,277,200	56.9	725,400	716,900
24	Delaware	5/12	5/13	30.35	1,034,400	64.0	660,900	640,400
25	Delaware	5/13	5/14	32.35	1,184,000	46.8	554,200	530,600
26	Delaware	5/14	5/15	46.10	1,536,000	59.0	906,900	888,300
27	Columbia	6/2	6/3	56.00	1,909,600	40.9	781,400	764,000
28	Columbia	6/3	6/4	75.80	2,774,300	43.3	1,200,500	1,176,300
29	Columbia	6/4	6/5	77.80	2,917,600	51.6	1,505,900	1,464,100
30	Columbia	6/5	6/6	93.00	3,096,900	38.0	1,178,100	1,160,200
31	Columbia	6/6	6/7	87.00	3,264,000	43.4	1,415,100	1,403,500
32	Columbia	6/9	6/10	90.00	3,542,600	49.2	1,741,700	1,714,300
33	Columbia	6/10	6/11	116.50	3,770,600	31.1	1,174,900	1,147,700

Table 1 (continued).

Shipment Number	River	Date Shipped	Date Received	Vol. (1) Received (VD)	Eggs	Percent Viability	Viable Eggs	Sac Fry
34	Columbia	6/11	6/12	89.63	2,787,500	17.1	475.700	459,700
35	Columbia	6/12	6/13	96.40	3,212,000	26.0	831,000	802,600
36	Columbia	6/16	6/18	80.00	2,726,400	22.8	620,700	612,650
37	Columbia	6/17	6/18	60.00	1,998,600	36.3	725,900	719,900
38	Columbia	6/18	6/19	63.50	2,067,400	30.3	594,300	585,550
39	Columbia	6/19	6/20	89.10	2,769,200	30.1	834,400	826,900
40	Columbia	6/20	6/21	87.50	3,127,800	36.2	1,122,500	974,200
	Pamunkey River		Totals	184.83	6,215,300	55.3	3,441,600	3,372,620
	James River			17.56	667,300	59.5	397,100	368,640
	Delaware River			171.11	5,864,600	57.9	3,396,000	3,279,400
	Columbia River			1,162.23	39,964,500	35.5	14,202,100	13,811,600
			Grand Total	1,535.73	52,711,700	40.7	21,436,800	20,832,260

Table 2. Annual Summary of Van Dyke production from 1976-1986.

Year	Egg Vol. (L)	Egg No. (x 6)	Egg Viability (%)	No. of Viable Eggs (x 6)
1976	120.3	4.0	52.0	2.1
1977	145.8	6.4	46.7	2.9
1978	381.2	14.5	44.0	6.4
1979	164.8	6.4	41.4	2.6
1980	347.6	12.6	65.6	8.2
1981	286.0	11.6	44.9	5.2
1982	624.3	25.9	35.7	9.2
1983	938.6	34.5	55.6	19.2
1984	1,157.3	41.1	45.2	18.6
1985	814.3	25.6	40.9	10.1
1986	1,535.7	52.7	40.7	21.4

Shad Stocked

Year	Fry	Fingerlings	Total
1976	518,000	266,000	784,250
1977	968,901	34,509	1,003,410
1978	2,124,000	6,379	2,130,379
1979	629,500	34,087	663,587
1980	3,526,275	5,050	3,531,325
1981	2,029,650	23,620	2,053,270
1982	5,018,800	40,700	5,059,500
1983	4,047,610	98,300	4,145,910
1984	11,995,690	30,500	12,026,190
1985	6,959,990	114,538	7,074,528
1986	15,866,935	61,245	15,928,180

Year	Fish Stocked/ Eggs Received	Fish Stocked/ Viable Eggs
1976	19.4	37.3
1977	15.9	34.2
1978	14.0	33.0
1979	10.4	25.1
1980	28.3	43.1
1981	17.7	39.3
1982	19.6	54.8
1983	12.0	21.6
1984	-	72.8*
1985	27.9	68.2*
1986	30.2	74.4

Total Shad Stocked from 1976 to 1986 - 54,400,529

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

Table 3. Production and utilization of juvenile American shad at the Van Dyke Research Station, 1986.

Fry released into the Juniata River	9,899,430
Fry released into the Susquehanna River below Conowingo Dam	5,171,225
Fry released into the Lehigh River	549,880
Fry released into the Schuylkill River	246,400
Fry released into ponds at Van Dyke and Ancillary Facilities	289,690
Fry provided to Benner Spring Research Station	211,550
Fry provided to Delmarva Ecological Lab	166,410
Fry provided to Wellsboro National Fishery Research and Development Center	64,860
Total Fry Production	16,599,445
Total Number of Viable Eggs	21,436,800
Survival (%) of all fry	75.6
Fingerlings Released into the Juniata River:	
From the Van Dyke Facility	1,335
From the Rearing Pond (Van Dyke)	1,270
From the Settling Pond (Van Dyke)	4,490
From the Canal Pond (Thompsontown)	30,000
From the Benner Spring Ponds	5,750
Fingerlings provided to Ecological Analysts	10,800
Fingerlings provided to Radiation Management Corp.	500
Fingerlings released into the Safe Harbor turbines	18,400
Total Fingerling Production	72,525

Table 4. Summary of juvenile American shad stocking and fish transfer activities, 1986. *Fish transferred to ponds, raceways and other facilities.

			OTC Treatment						
Date	Tank	Number	Concentration (ppm)	Duration (hours)	Age (days)	Stocking Location	River of Origin	Age (days)	Size
5/2	A1	71,870	50	12	5-9	Thompsontown	Pamunkey	18	Fry
5/6	A2	31,000	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/6	A2	*10,300	50	12	5-9	Rearing Pond	Pamunkey	19	Fry
5/6	A2	*103,300	50	12	5-9	B.S. Pond	Pamunkey	19	Fry
5/7	A3	*117,910	50	12	5-9	Canal Pond	Pamunkey	19	Fry
5/10	A4	81,110	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/11	B1	85,290	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/14	B2,B3,B4	487,640	50	12	5-9,15-19	Lapidum, MD	Pamunkey	20	Fry
5/16	C1	134,820	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/17	C2,C3	295,840	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/23	D1,D2,C4	292,710	50	12	5-9,15-19	Lapidum, MD	Pamunkey/James	20,21	Fry
5/25	I1,I2	439,090	50	12	5-9	Thompsontown	Pamunkey	19	Fry
5/26	E2,E4	217,610	50	12	5-9	Thompsontown	Pamunkey/James	19,20	Fry
5/27	D3,D4,E1	505,390	50	12	5-9,15-19	Lapidum, MD	Pamunkey/James	22	Fry
5/28	F1	* 5,000	50	12	5-9,15-19	BS Raceway	James	21	Fry
5/28	E3,F1	*166,410	50	12	5-9,15-19	Del.Ecol.Lab	Pamunkey/James	21	Fry
6/3	F2	* 93,250	50	12	5-9	B.S. Pond	Delaware	18	Fry
6/3	F3	* 31,860	50	12	5-9	Wellsboro	Delaware	18	Fry
6/3	F3	47,790	50	12	5-9	Thompsontown	Delaware	15	Fry
6/3	A4	* 5,000	400	6	5	B.S. Raceway	Delaware	15	Fry
6/3	B2	* 5,000	200	6	5	B.S. Raceway	Delaware	19	Fry
6/6	A2	194,230	50	12	5-9	Thompsontown	Delaware	19	Fry
6/7	B1	161,140	50	12	5-9	Thompsontown	Delaware	24	Fry
6/8	K1,K2	119,930	50	12	5-9	Thompsontown	Delaware	22	Fry
6/9	A1	179,930	200/50	6/12	5/15-19	Lehigh River	Delaware	21	Fry
6/9	A4	179,870	400/50	6/12	5/15-19	Lehigh River	Delaware	21	Fry
6/9	B2	190,080	200/50	6/12	5/15-19	Lehigh River	Delaware	22	Fry
6/9	A3	200,910	50	12	15-19	Thompsontown	Delaware	20	Fry
6/10	B3,B4	246,400	50	12	5-9	Schuylkill River	Delaware	20	Fry
6/10	C1	148,290	50	12	5-9	Thompsontown	Delaware	20	Fry
6/11	F4,G1,& G2, G3	371,150	50	12	5-9,15-19	Lapidum, MD	Delaware	20	Fry
6/23	C2,C3,C4	698,620	50	12	5-9	Thompsontown	Columbia	14	Fry
6/24	D1,D2 & D3,D4	1,379,430	50	12	5-9	Thompsontown	Columbia	12	Fry
6/25	E1,I1, & I2,I3	1,341,150	50	12	5-9	Thompsontown	Columbia	13,15	Fry
7/1	E2,E3,E4	700,560	50	12	5-9	Thompsontown	Columbia	19	Fry
7/2	F1	* 33,000	50	12	5-9	Wellsboro	Columbia	19	Fry
7/2	F1,F2	583,840	50	12	5-9	Thompsontown	Columbia	19	Fry
7/3	F3,F4	581,400	50	12	5-9	Thompsontown	Columbia	20	Fry
7/4	G1,G2	632,050	50	12	5-9	Thompsontown	Columbia	18	Fry
7/5	G3,G4,H1	828,770	50	12	5-9	Thompsontown	Columbia	19	Fry
7/7	A1,A2 & A3,A4,B1	923,790	50	12	5-9,15-19	Lapidum, MD	Columbia	20	Fry
7/8	B2,B3,B4	357,700	50	12	5-9,15-19	Lapidum, MD	Columbia	20	Fry

Table 4 (continued).

Date	Tank	Number	OTC Treatment Concentration (ppm)	Duration (hours)	Age (days)	Stocking Location	River of Origin	Age (days)	Size
7/10	H2,H3 & H4,I4	621,470	50	12	5-9,15-19	Lapidum, MD	Columbia	20	Fry
7/13	K1,K2,C1	541,470	50	12	5-9	Thompsontown	Columbia	19	Fry
7/14	J1,J2 & J3,J4	427,475	50	12	5-9,15-19	Lapidum, MD	Columbia	21	Fry
7/15	C2,C3,C4	489,020	50	12	5-9,15-19	Lapidum, MD	Columbia	20	Fry
7/16	D1,D2 & D3, D4	694,880	50	12	5-9,15-19	Lapidum, MD	Columbia	20	Fry
7/18	Canal	20,000	50/9 g/lb	12hr/7day	5-9,66-72	Thompsontown	Pamunkey	91	Fingerlings
7/19	E1	261,920	50	12	5-9	Thompsontown	Columbia	22	Fry
7/24	I3	121,300	50	12	5-9	Thompsontown	Columbia	28	Fry
7/25	K1,K2	*161,480	12	5-9		Canal Pond	Columbia	28	Fry
8/28	F1,F2,F3	130	50	12	5-9	Thompsontown	Columbia	76	Fingerlings
8/29	E2,E3,E4	400	50	12	5-9	Thompsontown	Columbia	78	Fingerlings
9/1	G1,G2, & G3,G4	205	50	12	5-9	Thompsontown	Columbia	77	Fingerlings
9/5	Rearing Pond	1,270	50/6 g/lb	12hr/7 day	5-9,67-73	Thompsontown	Pamunkey	141	Fingerlings
9/15	Settling Pond	1,650	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown)	(Unknown)	Fingerlings
9/17	Settling Pond	660	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown	(Unknown)	Fingerlings
9/18	Settling Pond	520	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown	(Unknown)	Fingerlings
9/18	A2,A4, B2,B4	600	50/6g/lb	12hr/7 day	5-9,71-77	Thompsontown	Columbia	(Unknown)	Fingerlings
9/18	Settling Pond	*500	12g/lb	7 days	(Unknown)	RMC	(Unknown)	(Unknown)	Fingerlings
9/19	Settling Pond	580	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown)	(Unknown)	Fingerlings
9/24	Settling Pond	520	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown)	(Unknown)	Fingerlings
9/29	Settling Pond	560	12g/lb	7 days	(Unknown)	Thompsontown	(Unknown)	(Unknown)	Fingerlings
9/30	Canal Pond	10,000	50/12g/lb	12hr/7 day	5-9,62-70	Thompsontown	Columbia	95	Fingerlings
10/10	BS Pond 2	*1,600	50	12	5-9	E.A.	Pamunkey	176	Fingerlings
10/22	BS Pond 2	*9,000	50	12	5-9	E.A.	Pamunkey	188	Fingerlings
10/29	BS Pond 1	18,400	50/6g/lb+ .75g gluc./lb	12hr/7 day	5-9,66-72	Safe Harbor	Delaware	166	Fingerlings
11/5	BS Pond 1	2,700	50/6g/lb+ 75g gluc./lb	12hr/7day	5-9,66-72	Thompsontown	Delaware	173	Fingerlings
11/5	BS Pond 2	3,050	50	12	5-9	Thompsontown	Pamunkey	202	Fingerlings

Table 4 (continued).

		OTC Treatment				
	Number	Concentration (ppm)	Duration (hrs)	Age (days)	Stocking Location	
Stocking Summary	9,698,520	50	12	5-9	Thompsontown	Fry Stockings
	200,910	50	12	15-19	Thompsontown	Fry Stockings
	5,171,225	50	12	5-9,15-19	Lapidum, MD	Fry Stockings
	370,010	200/50	6/12	5/15-19	Lehigh River	Fry Stockings
	179,870	400/50	6/12	5/15-19	Lehigh River	Fry Stockings
	246,400	50	12	5-9	Schuylkill River	Fry Stockings
	3,785	50	12	5-9	Thompsontown	Fingerling Stockings
	600	50/6g/lb	12/7 days	5-9,15-19/ 71-77	Thompsontown	Fingerling Stockings
	1,270	50/6g/lb	12/7 days	5-9/67-73	Thompsontown	Fingerling Stockings
	20,000	50/9g/lb	12/7 days	5-9/66-72	Thompsontown	Fingerling Stockings
	10,000	50/12g/lb	12/7 days	5-9/62-70	Thompsontown	Fingerling Stockings
	4,490	12g/lb	7 days	Unknown	Thompsontown	Fingerling Stockings
	2,700	50/6g/lb+ .75 g gluc. lb	12/7 days	5-9/66-72	Thompsontown	Fingerling Stockings
	18,400	50/6g/lb+ .75 g gluc. lb	12/7 day	5-9/66-72	Safe Harbor (Turbine injection)	Fingerling Stockings

Table 5. Summary of oxytetracycline tagging research, Van Dyke, 1986. RP- Van Dyke rearing pond, CP1- Canal pond, first crop, BSP1- Benner Spring pond 1, CP2- Canal pond, second crop, SP- Settling pond.

Tank/Pond	Shipment	Tag type	Bath Concentration (ppm)	Bath Duration (h)	Feed Concentration (g OTC/ lb feed)	Feed duration (days)	Age at tagging (days)	18-day survival (%)	Tag efficiency (%) 1°	2°	No. examined for tags	Age (days)
B2/D1	24	bath	200	6	-	-	5	88.5	100.0%	-	60	93
A4/E1	24	bath	400	6	-	-	5	81.8	100.0%	-	60	101
B1	24	control	50	12	-	-	5-9	77.4	-	-	-	-
E3/F1	18	bath	50	12	-	-	5-9/15-19	88.9	97.5%	100.0%	79	107
A2/RP	2	bath/feed	50	12	6	7	5-9/67-73	94.1	97.8%	0.0%	92	112
A3/CP1	3	bath/feed	50	12	9	7	5-9/66-72	91.3	Not analyzed			
F2/BSP1	22	bath/feed	50	12	6 + .75g glucosamine	7	5-9/66-72	77.4	93.9%	75.7%	33/37	168
I1,I2/CP2	40	bath/feed	50	12	12	7	5-9/62-70	79.0/ 84.3	100.0%	0.0%	63	102
-/SP	-	feed	-	-	12	7	- / ?	-	-	0.0%	19	?
Totals		bath	50	12	-	-	5-9	-	97.8	-	267	-
		bath	50	12	-	-	15-19	-	100.0%	-	79	-

Table 6. Survival of American shad fry fed two different dry diets (64.5 g/250,000 fish-day) as a suplement to live brine shrimp (12 brine shrimp nauplii/fish-day) at Van Dyke, 1985 and 1986.

Dry Diet	Tank	Shipment	Hatch Date	Initial Tank Density	19 day Survival
AP100	C1	32	6/25/85	126,700	86.1%
	D1	39	6/26/86	166,900	82.1%
	D3	39	6/26/86	231,000	79.4%
Milled	C2	32	6/25/85	116,700	84.0%
Artemia	D2	39	6/26/86	227,000	83.0%
Flakes	D4	39	6/26/86	209,500	91.6%

Table 7. Four-day survival of quick-released and conventionally released American shad fry.

Replicate	Tank	Initial Density	20 Day Density	20 Day S (%)	24 Day Density	24 Day 4 Day S (%)	Total Survival
1	QR I3/K1	146,300	72,850	49.8	48,850	62.9	31.3
1	Conventional I4/K2	162,200	103,180	63.6	74,080	71.8	45.7
2	QR I1/K2	298,100	232,080	77.9	184,780	79.6	69.1
2	Conventional I2/K1	221,200	184,480	83.4	23,400*	12.7*	12.6

Table 8. Comparison of viabilities of American shad eggs disinfected with 100 ppm iodine (10 minut bath) vs untreated controls.

DISINFECTED

Date Taken	Date Received	River	Shipment	Jar	Number Vol (L)	Number of Eggs	Percent Viable Eggs	Viability	pH
5/7/86	5/8/86	Del.	21	12	2.50	76,000	37,200	48.9	7.1
				13	2.25	68,400	37,100	54.2	7.1
5/8/86	5/9/86	Del.	22	18	2.50	71,100	37,300	52.5	7.1
				19	2.50	71,100	34,600	48.7	7.1
				20	1.60	45,500	21,300	46.8	7.1
				Total	11.35	332,100	167,500	50.4	

NOT DISINFECTED

Date Taken	Date Received	River	Shipment	Jar	Number Vol (L)	Number of Eggs	Percent Viable Eggs	Viability	pH
5/7/86	5/8/86	Del.	21	14	2.50	76,000	56,500	74.3	-
				15	3.00	91,200	72,000	78.9	-
5/8/86	5/9/86	Del.	22	21	2.50	71,100	54,400	76.5	-
				22	2.50	71,100	53,400	75.1	-
				23	1.82	51,700	39,100	75.6	
				Total	12.32	361,100	275,400	76.3	

Table 9. Comparison of viabilities of American shad eggs disinfected with 100 ppm vs 75 ppm and 50 ppm free iodine (10 minute baths).

Date Taken	Date Received	River	Shipment	Jar	Vol.(L)	Number of Eggs	Number of Viable Eggs	Percent Viability	Iodine Conc.
6/2/86	6/3/86	Col.	27	3	3.0	102,300	45,300	44.3	100 ppm
				4	3.0	102,300	38,800	37.9	100 ppm
				5	3.0	102,300	41,700	40.8	100 ppm
				6	3.0	102,300	41,500	40.6	100 ppm
				7	2.0	68,200	27,300	40.0	100 ppm
				Total	14.0	477,400	194,600	40.8	100 ppm
6/2/86	6/3/86	Col.	27	8	3.0	102,300	40,000	39.1	75 ppm
				9	3.0	102,300	43,100	42.1	75 ppm
				10	3.0	102,300	45,400	44.4	75 ppm
				11	3.0	102,300	45,900	44.9	75 ppm
				12	3.0	102,300	38,600	37.7	75 ppm
				13	2.6	88,700	42,200	47.6	75 ppm
				Total	17.6	600,200	255,200	42.5	75 ppm
6/2/86	6/3/86	Col.	27	14	3.0	102,300	47,400	46.3	50 ppm
				15	3.0	102,300	47,500	46.4	50 ppm
				16	3.0	102,300	53,200	52.0	50 ppm
				17	3.0	102,300	36,600	35.8	50 ppm
				18	3.0	102,300	37,100	36.3	50 ppm
				19	3.4	115,900	36,300	31.3	50ppm
				Total	18.4	627,400	258,100	41.1	50 ppm

Table 10. Viability of American shad eggs incubated at densities of 1.5, 2.0, 2.5 and 3.0 liters per jar for May-Sloan egg incubation jars, Van Dyke, 1986. Jars of like loading densities were combined prior to removal to tanks for hatching. Shipment 40, Columbia River origin, hatch date 6/27/86.

Jar	Vol (L)	Number of Eggs	Viable Eggs	Percent Viable
397	1.5	53,600	72,100	44.8
400	1.5	53,600		
403	1.5	53,600		
406	1.5	53,600	69,400	43.2
409	1.5	53,600		
412	1.5	53.600		
415	1.5	53,600	41,600	25.9
418	1.5	53,600		
421	1.5	53,600		
434	1.5	53,600	70,900	44.1
427	1.5	53,600		
430	1.5	53,600		
TOTAL	18.0	643,200	254,000	39.4
398	2.0	71,500	80,200	37.4
401	2.0	71,500		
404	2.0	71,500		
407	2.0	71,500	78,000	36.4
410	2.0	71,500		
413	2.0	71,500		
416	2.0	71,500	72,100	33.6
419	2.0	71,500		
422	2.0	71,500		
425	2.0	71,500	86,900	40.5
428	2.0	71,500		
431	2.0	71,500		
TOTAL	24.0	858,000	317,200	37.0

Table 10 (continued).

Jar	Vol (L)	Number of Eggs	Viable Eggs	Percent Viable
399	2.5	89,400	99,300	37.0
402	2.5	89,400		
405	2.5	89,400		
408	2.5	89,400	94,800	35.3
411	2.5	89,400		
414	2.5	89,400		
417	2.5	89,400	103,100	38.4
420	2.5	89,400		
423	2.5	89,400		
426	2.5	89,400	80,700	45.1
429	2.5	89,400		
Total	27.5	983,400	377,900	38.4
432	3.0	107,200	63,600	29.7
433	3.0	107,200		
434	3.0	107,200	54,700	25.5
435	3,0	107,200		
436	3.0	107,200	49,500	23.1
437	3.0	107,200		
Total	18.0	643,200	167,800	26.1

Table 11. Comparison of American shad egg enumeration methods, Van Dyke, 1986.

Method		% Error of of Estimate	Coefficient of Variation
von Bayer (dry)	A	-13.6	8.88
	B	-5.4	6.48
von Bayer (wet)	A	+20.9	9.04
	B	+23.9	6.70
Wet Volume (100 egg sample)	A	-29.0	8.24
	B	-24.8	3.69
Wet Volume (300 egg sample)	A	-25.7	2.94
	B	-19.9	2.22
Displacement (100 egg sample)	A	-32.1	6.38
	B	-24.5	6.22
Displacement (300 egg sample)	A	-31.4	0.09
	B	-22.3	6.20
Displacement/Wet Volume (100 egg sample)	A	-1.0	8.24
	B	+6.8	22.70
Displacement/Wet Volume (300 egg sample)	A	<0.1	0.73
	B	+9.9	3.96

Appendix 1. Estimated numbers of eggs in two lots of American shad eggs using the von Bayer dry volume and von Bayer wet volume method, Van Dyke, 1986.

			von Bayer Dry Volume			von Bayer Wet Volume		
Lot	Hand Count	# In 12" Trough	Vol.	Estimate	% Error of Estimate	Vol.	Estimate	% Error of Estimate
A	20,158	94	.5L	17,049	-15.4	.7L	23,868	18.4
		98	.5L	19,689	-2.3	.68L	26,777	32.8
		92	.5L	16,274	-19.3	.69L	22,458	11.4
		93	.5L	16,655	-17.4			
			$\bar{x}$	17.417	-13.6		24,368	20.9
		Standard deviation		1547			2,202	
			C.V.	8.88			9.04	
B	16,096	90	.5L	15,198	-5.6	.65L	19,757	22.7
		89	.5L	14,532	-9.7	.65L	18,891	17.4
		89	.5L	14,532	-9.7	.66L	19,182	19.2
		89	.5L	14,532	-9.7	.66L	19,182	19.2
		91	.5L	15,545	-3.4	.65L	20,209	25.6
		94	.5L	17,049	5.9	.66L	22,505	39.8
			$\bar{x}$	15,231	-5.4		19,954	23.9
		Standard deviation		987			1,337	
			C.V.	6.48			6.70	

Appendix 2. Estimated number of eggs in two lots of American shad eggs using the wet volume method with 100 and 300 egg samples, Van Dyke, 1986.

		Wet Volume - 100 egg sample				Wet Volume - 300 egg sample			
Lot	Hand Count	Wet vol. Sample	Wet vol. of Lot	Estimate	% Error of Estimate	Wet vol. Sample	Wet vol. of Lot	Estimate	% Error of Estimate
A	20,158	5.0	700	14,000	-30.5	14.5	700	14,483	-28.2
		4.5	680	15,111	-25.0	13.5	680	15,111	-25.0
		5.0	690	13,800	-31.5	13.5	690	15,333	-23.9
			$\bar{x}$	14,304	-29.0		$\bar{x}$	14,976	-25.7
			s.d.	706			s.d.	441	
			C.V.	8.24			C.V.	2.94	
B	16,096	5.0	650	13,000	-19.2	15.5	650	12,581	-21.3
		5.5	650	11,818	-26.6	15.0	650	13,000	-19.2
		5.5	660	12,000	-25.4	15.0	660	13,200	-18.0
		5.5	660	12,000	-25.4	15.5	660	12,774	-20.6
		5.5	660	11,818	-26.6	15.5	660	12,581	-21.8
		5.5	660	12,000	-25.4	15.0	660	13,200	-18.0
			$\bar{x}$	12,106	-24.8		$\bar{x}$	12,889	-19.9
			s.d.	447			s.d.	286	
			C.V.	3.69			C.V.	2.22	

Appendix 3. Estimated numbers of eggs in two lots of American shad eggs using the water displacement method with 100 and 300 egg samples, Van Dyke, 1986.

		Displacement - 100 Egg Sample				Displacement - 300 Egg Sample			
Lot	Hand Count	Sample Displacement	Lot Displacement	Estimate	% Error of Estimate	Sample Displacement	Lot Displacement	Estimate	% Error of Estimate
A	20,158	3.60 ml	480	13,333	-33.9	10.40	480	13,846	-31.3
		3.60 ml	470	13,056	-35.2	10.20	470	13,824	-31.4
		3.20 ml	470	14,688	-27.1	10.20	470	13.824	-31.4
			x	13,692	-32.1		x	13,831	-31.4
			s.d.	873			s.d.	13	
			C.V.	6.38			C.V.	0.09	
B.	16,096	3.85 ml	445	11,558	-28.2	11.10	445	12,027	-25.3
		3.70 ml	445	12,027	-25.3	11.00	445	12,136	-24.6
		3.75 ml	460	12,267	-23.8	11.10	460	12,432	-22.8
		4.05 ml	480	12,852	-26.4	10.85	480	13,272	-17.5
		3.95	460	11,646	-27.6	11.90	460	11,597	-27.9
		3.60	490	13,611	-15.4	10.80	490	13,611	-15.4
			x	12,160	-24.5		x	12.512	-22.3
			s.d.	756			s.d	775	
			C.V.	6.22			C.V.	6.20	

Appendix 4. Estimated numbers of eggs in two lots of American shad eggs using a combination displacement/Wet volume method with 100 and 300 egg samples, Van Dyke, 1986.

		Displacement/Wet Volume Method - 100 egg				Displacement/Wet Volume Method - 300 egg			
Lot	Hand Count	Sample Displacement	Wet Vol. of Lot	Estimate	% Error of Estimate	Sample Displacement	Wet Vol. of Lot	Estimate	% Error of Estimate
A	20,158	3.60	700	19,445	-3.5	10.40	700	20,192	0.2
		3.60	680	18,889	-6.3	10.20	680	20,000	-0.8
		3.20	690	21,563	7.0	10.20	690	20,294	0.7
			$\bar{x}$	19,996	-1.0		$\bar{x}$	20,162	<0.1
			s.d.	1,646			s.d.	149	
			C.V.	8.24			C.V.	0.73	
B	16,096	3.85	650	16,883	4.9	11.10	650	17,563	9.1
		3.70	650	17,568	9.1	11.00	660	17,727	10.1
		3.75	660	17,600	9.3	11.10	660	17,837	10.8
		4.05	660	16,296	1.2	10.85	660	18,248	13.4
		3.95	650	16,456	2.2	11.90	650	16,387	1.8
		3.60	660	18,333	13.9	10.80	660	18,883	17.3
			$\bar{x}$	17,189	6.8		$\bar{x}$	17,683	9.9
			s.d.	3,905			s.d.	701	
			C.V.	22.70			C.V.	3.96	

JOB IV. JUVENILE AMERICAN SHAD OUTMIGRATION ASSESSMENT

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INTRODUCTION

The success of the Susquehanna River Anadromous Fish Restoration Committee's (SRAFRC) efforts to restore American shad (Alosa sapidissima) to the Susquehanna River must ultimately be measured in terms of the abundance of adult shad which return to the Conowingo Dam. However, preliminary indications of the effectiveness of various stocking methodologies and the impact of electric generation facilities in the lower river on shad mortality are being sought through a variety of juvenile shad sampling programs. In addition, these efforts also provide valuable data on such things as juvenile shad growth rates and physiological condition, and the temporal and spatial distribution of the outmigration.

Since 1981 annual juvenile assessment efforts have included some or all of the following aspects: seining and electrofishing in the Susquehanna River above Harrisburg (RM 70); seining and electrofishing in the Juniata River (RM 2-22); seining at Wrightsville (RM 43); cast netting, lift netting, and electrofishing in the York Haven (RM 56), Safe Harbor (RM 32), and Holtwood Dam (RM 25) forebays; impingement collections from water intake strainers and screens at the Susquehanna Steam Electric Station (RM 167), Safe Harbor, Holtwood, Peach Bottom (RM 18), and Conowingo (RM 10) power facilities; and trawling and seining in the Maryland waters of the Susquehanna below Conowingo Dam.

These collections have verified successful reproduction of adults transported from out-of-basin sources in only two years; 1981 and 1983.

Radiotelemetry tracking of Hudson River transfers in 1985 showed that one reason for this poor success rate was the rapid emigration of transplanted adults immediately after stocking and prior to their having spawned (RMC Environmental Services 1986). The successful application of oxytetracycline (OTC) marking techniques to American shad fry by Pennsylvania Fish Commission (PFC) researchers in 1985 further substantiated concerns of reproductive failure by suggesting that the majority of the juvenile shad collected from the lower river were of hatchery origin (St. Pierre 1986).

A number of sites have been identified as consistent collection points for juvenile shad including Amity Hall on the Juniata River; Wrightsville in the Safe Harbor Pool; York Haven, Safe Harbor and Holtwood Dam forebays; Safe Harbor cooling water strainers; and Peach Bottom intake screens. Attempts to establish permanent relative abundance index sites on the Susquehanna River above Harrisburg have yielded little success apparently as the result of very low numbers of juveniles in these waters. Attempts to collect shad below Conowingo Dam have also met with very little success.

The temporal distribution of the outmigration is closely linked to declining water temperature. The initial appearance of shad at York Haven (RM 56), the first dam encountered by outmigrants, usually occurs between mid-September and mid-October at temperatures between 60 and 70°F. Movement accelerates gradually thereafter and abundance between the York Haven and Holtwood Dams peaks prior to November 30 as temperatures decline to the high 40's and flows escalate as a result of fall rains. Shad continue to be observed at least sporadically through mid-December at sites below Safe Harbor (RM 32) but few are seen after temperatures reach 40°F.

Growth rates of juvenile shad collected from the Susquehanna River have been very high, exceeding those observed in most other shad rivers. For example, average lengths of fish collected during the latter stages of the outmigration generally exceed 115-125 mm FL with some fish approaching lengths of 200 mm. This compares to mean lengths in October 1985 from various sites on the Delaware River of 70-81 mm with a maximum length of 112 mm (Art Lupine, personal communication). Juvenile outmigrants on the Connecticut River rarely exceed 80 mm TL in October (Crecco et al. 1982) and a theoretical asymtote of 87-106 mm at 75-100 days of age has been suggested for Connecticut River juveniles (Crecco et al. 1983).

Juvenile shad collected from the Susquehanna River Basin have exhibited a low incidence (<5%) of physical deformities of the lower jaw, operculum, and spine. The etiology of these deformities is yet unclear.

To further improve our knowledge of the outmigration, the 1986 juvenile assessment program included the following elements:

1) Seining and electrofishing in the Susquehanna River above Sunbury (RM 124) to determine if shad transplanted from the Hudson River to Beach Haven (RM 167) and/or upstream from the Conowingo trap (RM 10) to Harrisburg (RM 70) had reproduced in this region. In contrast to previous years, adult shad hauled from the Hudson River were held in a net pen for 2-9 days prior to their release in an effort to suppress their downrunning behavior (see Job I).

2) Seining at Amity Hall (RM 2) on the Juniata River to: collect fish for baseline OTC marking rate information to compare adult and hatchery stocking programs; determine the effect of time of

day on sampling efficiency with seines; and add to our data base on the temporal distribution of outmigration, juvenile shad growth rates, and the incidence of physical deformities.

3) Cast net sampling in the York Haven, Safe Harbor, and Holtwood forebays; seining at Wrightsville and in the Holtwood tailrace; and strainer/screen sampling at Safe Harbor, Holtwood, Peach Bottom, and Conowingo to provide fish for OTC mark rate analysis and update the data base relative to those needs listed in 2 above, and

4) Trawling and seining below Conowingo Dam to: verify the successful passage of shad through all lower river dams; evaluate the effectiveness of initial fry stocking efforts below Conowingo Dam; and develop relative abundance indices of juvenile outmigrants.

In addition to these efforts, information was also solicited from resource agencies and environmental consultants who collected shad in programs not directly related to the juvenile evaluation program.

This report includes information provided by Mike Hendricks (Pennsylvania Fish Commission); Tom Koch and Joe Nack (National Environmental Services, Inc.); Paul Heisey, Chris Frese, and Terry Huston (RMC Environmental Services); Blaine Snyder (EA Engineering, Science, and Technology, Inc.); Ted Jacobsen and Andy Gurzynski (Ecology III, Inc.);

Hal Brundage (Environmental Research and Consulting, Inc.); Dale Weinrich (Maryland Department of Natural Resources); Bob Domermuth and Debbie Runkle (Pennsylvania Power and Light Company); Fred Poli (York Haven Power Company); Frank Sellers (Safe Harbor Water Power Corp.); and plant personnel at York Haven, Safe Harbor, Holtwood, and Conowingo Dams. The author expresses his appreciation to each of these individuals.

METHODS

Susquehanna River - Beach Haven to Sunbury

Efforts to verify reproduction of adult transfers were attempted by PFC and National Environmental Services (NES) personnel on two occasions during 1986. Sampling commenced on 19, 20, and 21, August at Beach Haven (RM 167), Danville (RM 136), and Sunbury (RM 124), respectively (Figure 4.1). Both a 300 ft x 7 ft x 3/8 inch bar mesh haul seine and a 150 ft x 6 ft x 1/2 inch bar mesh bag seine were used. Sampling at Beach Haven consisted of 13 seine hauls distributed among 12 separate locations in the vicinity of the adult shad release site at the Susquehanna Steam Electric Station (SES) Biological Lab. At Danville, 12 seine hauls were made among 11 different locations in the vicinity of the Danville Boat Club. The Danville site sampled in 1985 was not included because an accumulation of debris made it unseinable. Sampling at Sunbury consisted of six seine hauls among five sites distributed between the Fabri-Dam and the Shamokin Dam, located approximately one mile downstream.

Sampling was repeated on 8 September at Danville and 9 September at Sunbury. The Danville site was sampled with the 300 ft seine at seven different locations (seven hauls) by NES/PFC personnel, and by 4.25 hours of night electrofishing (220 V pulsed DC) by Ecology III personnel. At Sunbury, electrofishing was conducted for 3.75 hours beginning near dawn in the area between the Fabri- and Shamokin Dams. Seining was attempted in a region extending 2-3 miles above the Fabri-Dam. Unfortunately, no suitable seining sites were found here.

In addition to these efforts, Ecology III personnel collected qualitative dipnet samples from the shad holding net at Beach Haven on 19 and 20 May prior to release of the last lot of pre-spawn adults; sampled by electrofishing and seining at two sites above and two sites below the Susquehanna SES intakes one time per month in June, August, and October; and sampled trash bar and traveling screen wash water at the power plant intakes each weekday from 2 September through 16 October. Also, as noted in Job V-Task 1, RMC attempted to verify reproduction with ichthyoplankton tows in the vicinity of radiotagged adults near Beach Haven. Finally, Pennsylvania Power and Light Company (PP & L) personnel were contacted concerning shad impingement on the strainers at their Sunbury plant which are checked approximately three times per day on a year-round basis.

Juniata River (Amity Hall)

NES and PFC personnel repeated their routine collection efforts at Amity Hall (RM 2) which were initiated during the 1984 project year (Figure 4.1). On each of seven dates between 5 August and 21 October three hauls were made with a 150 ft x 6 ft x 1/2 inch bar mesh bag seine at the standard site located several hundred yards downstream of the PFC access area. Sampling began each day at 1/2 hour after sunrise and proceeded at 1/2 hour intervals. Fork lengths and total lengths were measured for up to 15 shad from each sample, and fish were subsequently frozen in water to be analyzed later for OTC marks. Fish collected other than shad were identified to species and recorded.

Migration Through Lower Susquehanna River Hydroelectric Impoundments

Sampling areas on the Susquehanna River downstream of the Juniata River confluence (RM 85) are shown in Figure 4.1. NES/PFC cast net sampling at York Haven Dam (RM 56) began on 3 September, continued at biweekly intervals through 29 September, then increased to weekly after the first appearance of shad on 9 October. Sampling was terminated at York Haven on 5 November. Netting commenced at Safe Harbor (RM 32) on 15 September and Holtwood (RM 25) on 17 October. Weekly samples were collected at both sites from 17 October through 19 November. Up to 15 casts were made each day at each site unless a 15 fish sample was collected earlier. Collected fish were measured (FL and TL), frozen in water, and transported to the Benner Spring Fish Research Station for OTC analysis.

PFC and/or NES personnel also sampled at Wrightsville (RM 43) and below Holtwood Dam (RM 25) with the 300 ft x 7 ft x 3/8 inch bar mesh seine. At Wrightsville three hauls were made on both 14 August and 27 August and two hauls were made on 4 September. Six of these hauls were made at the site established in 1985 between the PA Rte 462 and US Rte 30 bridges. The remaining hauls, one each on 14 August and 27 August, were made approximately 1/4 mile upstream of this site. Below Holtwood Dam the seine was deployed once on each side of the river approximately 100 yards downstream of the Norman Wood Bridge. Four casts with the 20 ft. diameter cast net (3/8 inch bar mesh) were made in pooled areas in the same general vicinity as the Holtwood seine samples.

As in past years, Safe Harbor personnel checked cooling water intake strainers for impinged shad daily from 1 September through 25 November. Conowingo strainers were examined once per week by RMC biologists from 15 October to 17 December and Peach Bottom Atomic Power Station (APS) intake screens were examined three times per week from 13 October through 12 December. Also, this year Holtwood plant personnel made daily checks of revolving screens throughout the outmigration period. This change was requested in response to the appearance of substantial numbers of American shad in the trash sluiceway during 1985.

In May, RMC conducted four ichthyoplankton tows near Harrisburg and nine near York Haven as part of their radiotelemetry study (see Job V-Task 1). RMC also electrofished (pulsed DC) in the Wrightsville area on 21 July and 2 October, and in the Accomac Pool (RM 46) on 23 October. To collect juvenile shad for use in experimental radiotagging efforts, RMC deployed an 8 ft x 8 ft lift net in the Holtwood forebay on 20 occasions between 10 October and 19 December.

Two consulting firms, Environmental Research and Consulting, Inc. (ERC) and EA Science, Engineering and Technology (EA), were involved in sampling upstream of Conowingo Dam which was not related to the juvenile assessment program. ERC sampled in the Harrisburg area in studies relative to the proposed Dock St. Dam. Biologists electrofished biweekly from April through September and monthly in October and November at six sites between the present Dock St. Dam (RM 69) and the Rockville Bridge

(RM 75). Seines (10 ft common) were also used during this period at four sites located between City Island (RM 70) and the east side of McCormick Island (RM 74), and trapnets were deployed at two sites near City Island. In addition, weekly ichthyoplankton tows were made from 16 April through 2 September at nine stations between Fort Hunter (RM 77) and the area downstream of the I 83 Bridge (RM 69).

EA, contractors to GPU relative to Three Mile Island (TMI) environmental studies, sampled with seines (4 ft x 8 ft x 1/8 inch bar mesh), electrofishing gear (225 V AC) and ichthyoplankton nets at six, six, and eight sites respectively between York Haven Dam (RM 56) and the PFC Goldsboro access area (RM 59). Seining and electrofishing were conducted monthly in April, July, October, and November, and bimonthly during May, June, August and September. Ichthyoplankton tows were made weekly from April through August.

Fork lengths are used throughout this report in recording the size of fish collected at the above sites. On several occasions only total lengths were recorded in the field. In these instances, total lengths were converted to fork lengths by the following regression developed from a sample of 109 fish:

$$TL = 1.16\ FL - 2.68 \qquad R = 0.9985$$

Juvenile Assessment Below Conowingo Dam

The Maryland Department of Natural Resources (MDNR) continued their two-phased juvenile assessment work below Conowingo Dam (RM 10). The initial phase of this work, which runs from July through October, is a DJ funded study which has been conducted annually since 1980 in lower Susquehanna River, Susquehanna Flats, and Northeast River nursery areas (Job VII). Measuring recruitment of juvenile shad produced naturally in the upper Chesapeake Bay is the primary focus of this effort, but of added significance this year was the stocking of 5.17 million OTC marked fry at Lapidum. The survey consists of weekly collections with haul seines (200 ft x 10 ft x 1/4 inch stretch mesh) at eight sites and a modified otter trawl (16 ft headrope) at six sites (Figure 4.2). As stated in Job VII, a total of 144 seine hauls and 105 otter trawls were made.

The outmigration phase of the MDNR juvenile assessment began on 3 November and continued at weekly intervals through 9 December. Three gear types were utilized during this survey: a modified midwater trawl was used at 11 sites, the 16 ft otter trawl at three sites, and the 200 ft haul seine at six sites (Tables 4.1 and 4.2, Figure 4.3). A total of 30 seine hauls, eight otter trawls, and 41 midwater trawls was made. This compares to 30 seine hauls, 15 otter trawls, and 51 midwater trawls during 1985. The 1986 trawl efforts were reduced due to unfavorable weather conditions.

In addition to these efforts by Maryland, RMC electrofished at various sites in the Conowingo tailrace and Susquehanna Flats as part of PECO's Article 34 studies.

All American shad collected in the above surveys were frozen in water and transported to the Benner Spring Fish Research Station for otolith examination.

OTC Mark Detection Analysis

As noted under Job III, hatchery reared shad were marked with OTC to allow their later differentiation from the progeny of adult transfers. The 9.70 million fry stocked at Thompsontown were given a single otolith mark by a 12 hr, 50 ppm OTC bath either at ages 5-9 days (98 percent of total) or 15-19 days. The 5.17 million fry stocked below Conowingo Dam were given a double immersion tag, administered at 5-9 and 15-19 days. A total of 61,245 fingerlings were stocked. These fish received a variety of immersion and/or feed tags. All marking procedures are summarized in Table 4 of Job III.

Juvenile shad collected from the field were frozen in water and transported to Benner Spring for analysis. Otoliths from up to 13 fish from each daily sample were surgically removed, mounted on slides with permount, ground and polished on both sides, and viewed under UV light for detection of the fluorescent OTC ring(s). A faint mark was graded +, a moderate mark ++, and an intense mark +++.

A total of 22 shad was examined from below Conowingo Dam, 62 from Amity Hall, 17 from Wrightsville, and 42-46 from each of the York Haven, Safe Harbor, Holtwood, and Peach Bottom sites. At Wrightsville, only fish collected prior to October were examined, since after this time significant numbers of shad were present downstream and the need to differentiate fish here from those at other sites was reduced. A total of 346 shad reared in raceways for 93-107 days as controls were also examined.

The marking rates for all sites above Conowingo Dam and the single marked controls were compared using a chi square test for equal proportions. Subsequently, specific differences between sites were evaluated using a Tukey-type multiple comparison test as described by Zar (1984). The significance level was set at $\alpha=0.05$ for all tests.

Sampling Efficiency vs. Time of Day

Increases of an order of magnitude have been observed for seine catches of shad on rivers such as the Delaware in night sampling compared to day. Although preliminary observations have suggested this does not hold true on the Susquehanna, an appropriate study has never been conducted. Knowledge of large differences in catch rate could increase the probability of detecting populations of juvenile recruits that result from stocking adults in the Susquehanna.

Although the catch efficiency of seines in the Susquehanna River was the primary objective of this study, the site at Amity Hall on the Juniata River was chosen since shad can be collected here consistently in fair abundance and the Juniata River is similar to the Susquehanna in depth and substrate composition.

Tests were conducted on 4-5 August, 12 August, and 16 September with samples collected at noon (beginning time 1145-1220), dusk (1625-1950), night (2135-0000), and dawn (1/2 hour after sunrise) on each date. Each sample consisted of three seine hauls with the 150 ft. seine at 1/2 hour intervals. To control for possible bias resulting from the effects of the order of the sample on catch rate, the order of the time of sampling was varied on each date. The null hypothesis of equal catchabilities for each time of day was evaluated using a chi square goodness-of-fit test. A chi square test of heterogeneity was used to determine if distributions in catch were similar among samples.

RESULTS

Beach Haven (RM 167) to Sunbury (RM 124)

Although seining and electrofishing efforts north of Sunbury (RM 124) by PFC, NES, and Ecology III personnel yielded 26 species of fish (Table 4.3), no juvenile American shad were collected (Table 4.4). Efforts by Ecology III to collect shad larvae with dip nets on 19 and 20 May in the adult shad net enclosure at Beach Haven (RM 167) yielded 476 larvae but none were shad. Several unfertilized eggs were collected here on 19 May by Ecology III but positive identification to American shad was never made. Ecology III's trash bar and traveling screen collections at the Susquehanna SES (RM 167) produced one clupeid specimen (100 mm TL) which was too badly damaged to identify to species. No shad were collected at the Sunbury power plant.

The only sampling effort at sites north of Sunbury which did show positive signs of shad reproduction were meter net tows made by RMC as part of their adult shad radiotelemetry study. A total of five shad eggs were identified from collections made in the vicinity of apparent spawning adults at Beach Haven. The adult shad being tracked at this time were of Susquehanna River origin. Another four eggs from these collections were designated as "possible" shad eggs. A detailed account of these collections is presented in Task 1 of Job V.

Juniata River (Amity Hall)

As in previous years, American shad were again readily collected at the Amity Hall site (Juniata RM 2). From 5 August through 14 October shad were collected on every seine haul attempted, resulting in a total catch of 206 fish (Table 4.5). Catches ranged from 5.3 to 21.3 fish per haul as temperatures ranged from 81 to 60°F. No American shad were collected on 21 October as temperatures declined to 51°F, at which time sampling was terminated.

Shad from 51-135 mm FL were collected (Table 4.5). Sample means ranged from 78 mm on 12 August to 103 mm on 14 October, and the combined mean was 93 mm.

Twenty-one other species of fish were also collected at Amity Hall (Table 4.3).

Harrisburg (RM 70) to York Haven Dam (RM 56)

The first evidence of shad progeny in the Harrisburg-York Haven area was the collection of 15 shad eggs and 10 additional "possible" shad eggs by RMC in the vicinity of aggregations of radiotagged adults just upstream of the York Haven Dam between 7 and 14 May (Job V-Task 1).

PFC/NES personnel first collected shad juveniles with cast nets in the York Haven forebay on 9 October despite three previous attempts of 10 casts each dating back to 3 September (Table 4.6). In 20 cast net samples from 9 October thru 5 November over 209 shad were collected. On several occasions hundreds of shad could be seen swimming in front of the trash racks. Water temperatures during this period ranged from 60 to 52°F. All fish except those retained for OTC marking analysis (approximately 15 per day) were released. Although shad were still abundant on 9 November it was determined that adequate samples had been collected for OTC analysis and sampling was terminated.

Shad ranging from 101-175 mm FL were collected. Mean lengths increased from 125 mm on 9 October to 159 mm on 5 November (Table 4.6).

Spotfin shiners (Notropis spilopterus) were the only other species taken with cast nets at York Haven (Table 4.7). Thousands of spotfins were observed through 9 October with very few seen after this date.

In addition to the above collections, a total of 11 juvenile shad were taken by environmental consulting firms involved in studies relative to TMI (RM 57) and the proposed Dock St. Dam (RM 69) (Table 4.8). ERC collected one larval shad (12.5 mm TL) just downstream of the I 83 Bridge (RM 68.5) in Harrisburg on 22 May while EA collected five shad on 25 June with seines and five shad by electrofishing from 23 September to 16 October at various sites in the vicinity of TMI. Shad collected in June ranged from 30-42 mm FL while September/October collections ranged from 140-160 mm. Three dead juveniles were observed by EA personnel along the west shoreline near the shore fishing access immediately downstream of York Haven Dam on 22 October. These fish were not measured.

Wrightsville (RM 43) to Safe Harbor Dam (RM 32)

Forty-four juvenile shad were collected this year at Wrightsville (Table 4.9). Seventeen of these fish were collected between 14 August and 4 September in PFC/NES's seining efforts. Four of the six hauls made at the site established in 1985 between the PA Rte 462 and US Rte 30 bridges were successful in catching at least one shad. Of the two hauls made 1/4 mile upstream of this site, one was successful. RMC collected the remaining shad by electrofishing. One fish was collected on 31 July in the same vicinity as the seine samples, and 25 more were collected there on 2 October. The last fish was collected on 23 October in the upper Accomac pool. Water temperatures during the collection period declined from 80°F on 31 July to 60°F on 23 October.

Shad collected at Wrightsville ranged from 103-147 mm FL. Sample means (more than one fish per sample) ranged from 114 mm on 27 August to 129 mm on 2 October.

Thirty-four shad were collected in cast net samples this year at Safe Harbor (Table 4.10). Although casts were made on 15 September and weekly from 17 October through 19 November, shad were only collected on 17, 20, and 30 October. Water temperatures on these dates ranged from 59 to 57°F. Fork lengths of collected shad ranged from 115-170 mm, and sample means ranged from 128 to 136 mm.

There were a total of 28 shad collected from the Safe Harbor strainers (Table 4.13). These fish were taken between 20 October and 12 November, at water temperatures of 57 to 48°F. Four fish were impinged at the seven old units (2 from unit 4; 1 each from units 3 and 7), and 24 came from the new units (unit 8-7 shad; unit 9-6; unit 10-2; unit 11-8; and unit 12-1). Fork lengths of these fish ranged from 92-166 mm, and daily sample means ranged from 103 mm on 20 October to 152 mm on 12 November.

A total of 10 other species were taken with seines and cast nets from the Wrightsville-Safe Harbor area (Table 4.7). Gizzard shad (Dorosoma cepedianum) were very abundant periodically at both sites, and over 100 striped bass (Morone saxatilis) x white bass (Morone chrysops) hybrids were collected in the Safe Harbor forebay between 7 and 20 October.

Holtwood Forebay and Tailrace (RM 25)

PFC and NES biologists collected over 400 shad from the Holtwood forebay using cast nets (Table 4.11). From 50 to 100 or more shad were collected on every sample date from 17 October through 19 November, at which time cast net sampling was terminated. On all occasions but one no more than two casts were needed to collect over 50 fish. Water temperatures during this period ranged from 58°F on 17 October to 41°F on 19 November. Approximately 15 fish were preserved from each sample for OTC analysis, and all remaining fish were returned alive to the forebay. Fork lengths of those fish preserved ranged from 98-179 mm. Individual sample means varied little, ranging from 130 mm on 10 November to 147 mm on 17 October.

RMC collected 2928 juvenile and two adult shad in a total of 404 lifts with the 8 ft x 8 ft lift net (Table 4.12). One thousand nine hundred thirty-nine of these fish were transported to the Muddy Run Lab for experimental radiotelemetry work and the remaining fish were released. The number of fish collected per lift fluctuated widely through mid-December, ranging from 76.2 on 12 November to 0.1 on both 18 November and 12 December. The weighted mean catch for these lifts was 7.6 fish. Shad were taken at water temperatures ranging from 62 to 40°F. Catches dropped to zero on 19 December, as water temperatures declined to 37°F.

No American shad were observed in daily checks of the revolving screens at Holtwood this year, although many were seen in 1985.

Six species other than American shad were collected from the Holtwood forebay by RMC, NES, and PFC biologists (Tables 4.7 and 4.12). As usual, the most abundant species was gizzard shad, with over 2300 collected in the lift net alone. The percent composition of gizzard shad in the lift and cast net samples varied greatly throughout the year. For example, on six of the 20 lift net sample dates no gizzard shad were collected, while on both 12 November and 25 November they comprised 69 % of the sample.

The only species of fish collected by NES with the 300 ft seine downstream of the Norman Wood Bridge on 9 November were gizzard shad, comely shiners (Notropis amoenus), and spotfin shiners.

Peach Bottom (RM 18) to Conowingo Dam (RM 10)

Three hundred forty-one American shad were collected from the Peach Bottom Strainers in 1986 (Table 4.13). Twenty shad were present in the strainers when the program was set up on 13 October. The highest daily catch after this time was 136 fish on 14 November, followed by 44 fish on 22 October and 20 fish on 29 October. Otherwise, catches ranged from one to 14 fish per day except on 10 December, the last day of the sampling program, when none were taken. Water temperatures had fallen to 40°F by this time, compared to 61°F when sampling commenced.

Fork lengths of fish collected at Peach Bottom ranged from 105 to 185 mm. Daily sample means (more than one fish per sample) ranged from 134 mm on 21 November to 159 mm on 13 October.

In contrast to the high catches at Peach Bottom, only two shad were taken from the Conowingo strainers; one on 26 November and one on 3 December (Table 4.13).

Results Below Conowingo Dam (RM 10)

Twenty-three juvenile American shad were collected this year below Conowingo Dam (Table 4.14). Fourteen of these fish were collected by MDNR in their juvenile recruitment studies between 1 July and 29 October. Fish were taken at six different sites in these studies with the highest numbers collected at Wild Duck Cove (4), Seneca Point (3) and Happy Valley Branch (3). Eight of these fish were taken by haul seine, six by otter trawl. Six shad were collected incidentally in gill nets during MDNR striped bass studies in the Chesapeake Bay. These fish were collected on 22 July at Elk Neck Beach (1 fish), 3-5 December at Hart Miller Island (4 fish), and 18 December at Tollchester Beach (1 fish).

The remaining three fish collected below Conowingo were taken in RMC's electrofishing studies on 19 August, 8 September, and 17 September at West Steel Island near Port Deposit, Havre de Grace, and Roland Island in the Conowingo tailrace, respectively. Surprisingly, the shad collected at West Steel Island (153 mm FL) exhibited an annulus on its otolith.

The fork lengths of shad collected below Conowingo ranged from 57-186 mm. Monthly mean lengths were 72 mm in July, 102 mm in August (84 mm discounting the one age I+ fish), 105 mm in September, 92 mm in October, and 168 mm in December.

Besides American shad, Maryland's seine collections were comprised primarily of various shiner species, gizzard shad, bay anchovies (Anchoa mitchilli), and banded killifish (Fundulus diaphanus). Moderate numbers of blueback herring (Alosa aestivalis), sunfish species, and yellow perch (Perca flavescens) were also caught with seines. The otter trawl catch was predominantly comprised of shiner species , white perch (young-of-the-year) and striped bass (young-of-the-year). The net efficiency of the midwater trawl is questionable. Only five fish were caught out of 41 trawl runs.

OTC Marking Analysis

Results of the OTC marking analysis are presented in Tables 4.14 and 4.15 and Figure 4.4. Two hundred seventy-four shad were examined for marks from sites between Amity Hall and the Chesapeake Bay. Two hundred fourteen of these fish (78%) possessed at least one OTC mark. This compares to marking rates of 98% for both 267 single immersion tagged and 79 double immersion tagged pond and raceway reared fish held at the hatchery.

Marking rates for the individual collection sites were 82% at Amity Hall (Juniata RM 2), 94% at York Haven (RM 56), 47% at Wrightsville (RM 43), 84% at Safe Harbor (RM 32), 83% at Holtwood (RM 25), 71% at Peach Bottom (RM 18), and 50% below Conowingo Dam (RM 10)(Table 4.15). The marking rates above Conowingo all represent fish marked with the single OTC tag. When compared along with the control rate of 98% using a chi square test of equal proportions, the percentages were found to be different at the $\alpha = .05$ level of significance. Individual Tukey-type multiple comparison tests ($\alpha = .05$) revealed that Amity Hall, Holtwood, and Safe Harbor marking rates were not different from one another, and the marking rates at York Haven, although different from that at Amity Hall did not differ significantly from those at Holtwood and Safe Harbor (Table 4.16). Wrightsville, Peach Bottom, and Control marking rates differed from each other and from the rates at all other sites.

Four of the fish collected above Conowingo Dam exhibited the feed tag given fingerlings; one at Holtwood on 4 November and two on 10 November; and one at Peach Bottom on 31 October. Because it is known that these fish were injected into the turbine 11 gatewell at Safe Harbor Dam on 29 October as part of Safe Harbor's plant expansion impact studies, their migration rates can be calculated. The shad collected at Holtwood on 4 November had migrated 7 miles in 6 days (1.2 miles/day); the other two in 12 days (0.6 miles/day). The shad collected at Peach Bottom had traversed 14 miles in only 2 days (7.0 miles/day).

Of the 11 OTC marked fish collected below Conowingo Dam, 10 exhibited the double tag given the hatchery fry stocked at Lapidum (Table 4.14). The remaining fish had a single mark, and was either of upstream origin, or a double-marked fish on which one of the marks was not retained.

Figure 4.4 shows the marking rates at each specific site below Conowingo. The one single-marked fish recovered in this region was collected near Baltimore at Hart Miller Island on 5 December. Two of the double-marked fish were collected at Happy Valley Branch, the remainder in the Susquehanna Flats. Marking rates were higher (50-100%) in the vicinity of Happy Valley Branch, Havre de Grace, Battery Island, and Wild Duck Cove than at Seneca Point and sites north of Port Deposit or south of Battery Island (0-33%).

An interesting observation which was made during the OTC analysis was an apparent difference between hatchery and wild fish in growth patterns on the otolith (M. Hendricks, personal communication). About the first 20 daily (?) rings of hatchery fish were narrower than those laid down later. By contrast, only the first 3-6 rings of wild fish were narrow. Interestingly, it is at the age of 5-6 days that the yolk sac is absorbed and exogenous feeding begins (Wiggins et al. 1984). The differences in ring widths point to a probable growth advantage in the wild compared to the hatchery.

Deformities

Of 699 juvenile American shad examined in 1986, only 11 (1.6%) exhibited deformed jaws or opercula (Table 4.15). Three of these fish were collected at Amity Hall, five at Peach Bottom, two at Holtwood, and one at Seneca Point below Conowingo.

All deformed fish, except those collected at Peach Bottom, were examined for OTC marks. All five shad collected at Amity Hall and Holtwood were marked, while the one collected at Seneca Point was not. The Seneca Point fish exhibited the "wild" otolith growth pattern mentioned above.

Sampling Efficiency vs. Time of Day

Results of the study of the effects of time of day on sampling efficiency at Amity Hall are shown in Table 4.17. Shad were collected on each of the three sample dates and at each time of day within dates. Catch rates ranged from 2.0 fish per seine haul for the noon sample on 12 August to 27.3 fish per haul for the dusk sample on 16 September. The differences between lowest and highest catch rates within days ranged from 21 fish per haul on 16 September to 13 fish per haul on 12 August. Chi square goodness-of-fit tests of the null hypothesis of equal catchabilities revealed that catch rates varied significantly with time of day on each sampling occasion ($p<0.01$). Although an analysis of mean ranks suggested that catches tended to be highest at dawn (mean rank = 1.7) and lowest at noon (mean rank = 3.3), a heterogeneity chi square test showed that these patterns in catchability between dates were not consistent ($p<0.001$). To illustrate this further, although the noon catch was lowest on both 12 August and 16 September, it was the second highest on 4-5

August. Also, on each of the three dates the highest catch was observed at a different time of day; Dawn on 4-5 August, Night on 12 August, and Dusk on 16 September.

DISCUSSION

Abundance

Since 1981, sampling in the Susquehanna River above Sunbury (RM 124) has generally been designed to simply verify reproduction of adult transfers. When attempts were made to standardize sampling in 1984 and 1985 and develop indices of abundance, no shad were collected. Therefore it is impossible to draw conclusions about annual changes in abundance in this section of the river. All that can be said with certainty is that some reproduction occurred here in 1981 and 1983 (Table 4.18) and if adults spawned in any other year, the resulting recruitment was below the detectable limits of the sampling program. Likewise, cast net samples in the forebays of lower river hydroprojects are not suitable for comparing abundance from year to year due to the variability inherent in the sampling gear. Therefore, the only collections from which abundance comparisons may be possible are seine collections at Amity Hall, which have been standardized since 1984; RMC's lift net samples at Holtwood since 1985; and strainer and screen collections at various power plant intakes.

At Amity Hall (Juniata RM 2), mean seine catch per unit effort (C/f) since 1984 has for the most part followed the pattern expected considering the numbers of fry stocked at Thompsontown (Juniata RM 22). The highest C/f (70.4 fish/haul) was observed in 1984, the year of highest stocking, and the lowest catch (8.9 fish/haul) occurred in 1985, when the fewest fry were stocked (Table 4.18). However, because there are only three data points available for this analysis, it is premature to draw any conclusions about a relationship. Actually, unless there is reason to suspect large differences in survival from year to year of fry stocked from the hatchery, the need for an index of abundance in the Juniata River is questionable. The actual number of fish stocked each year is known, and all fish are stocked at ages greater than those at which it is believed most mortalities affecting year class strength occur (Crecco et al. 1983).

The abundance of juveniles in the lower Susquehanna River is much more critical to assess because of the possible effects of hydroelectric turbines on mortality and because all progeny resulting from adult and hatchery sources are combined here. Although the percentage of flow and thereby fish passing through turbines compared to over spillways will vary from year to year depending on total river flow, it may be possible to eventually compare abundance by comparisons of impingement on screens and strainers of hydroproject intakes. In effect, these devices sample continuously throughout the outmigration period. At Safe Harbor Dam, this year's strainer catch of 28 shad was higher than that in 1985 (15) but lower than that in any other year since 1981 (Table 4.18). In reality, only the 1985 and 1986 catches are comparable for the following reason. During 1985, five new units came on line at Safe Harbor and since that time it is through these units that most water has passed. Since the strainers on the new units are situated perpendicular to the flow compared to parallel in the seven old units, it appears they may be much less effective in impinging shad.

The catch in the screens at Peach Bottom this year was almost three times greater than that in any year since 1981 (Table 4.18). Surely this would suggest that abundance here was the highest to date. However, to make accurate year to year comparisons, data on river flow and Peach Bottom's intake volume must be included in the analysis, since both factors could greatly influence impingement. Unfortunately, these data were not available when this report was prepared.

In contrast to the increases in impingement levels at Peach Bottom and Safe Harbor, the mean catch of shad in lift nets at Holtwood in 1986 was lower than in 1985 (7.6 fish/lift vs 9.4 fish/lift) as was the number of shad impinged in Conowingo strainers (2 vs 9). Little can be determined from such low numbers at Conowingo and it is unknown if lift net catches, which are not part of a designed sampling program, are comparable.

Maryland DNR's sampling below Conowingo is a standardized program using the same gears and sites each year. The catch of 14 shad in this program in 1986 as well as an additional nine fish caught incidentally in other sampling programs is a dramatic increase over previous years (Table 4.18). No more than one juvenile shad has been taken below Conowingo in any one year since 1980. The increase in the MDNR catch occurred despite an actual decrease, since last year, in the number of seine hauls (144 vs 213) and otter trawl runs (105 vs 153) during the months of July through October when these fish were taken.

It is obvious that this year's stocking of fry at Lapidum had a substantial impact on the population size since 10 of the 22 fish analyzed were double-OTC marked fish (Table 4.14). The 11 unmarked fish suggest natural reproduction below Conowingo Dam and possibly, but less likely, upstream of Conowingo is on the upswing.

Despite the large increase in catch below Conowingo, the continued lack of fish in this region verified to be of upstream origin remains a matter for concern. Although single OTC marked fish were easily collected as far downstream as Holtwood and Peach Bottom, only one was collected below Conowingo Dam (Table 4.14) and this fish was taken incidentally during a striped bass survey. This compares to 21 fish collected below Conowingo which were either double-marked, representing fish stocked at Lapidum (10 fish), or unmarked and presumably representing fish produced naturally below Conowingo Dam (11 fish).

To compare these catches, the amounts of effort expended in the two phases of the MDNR survey must be included in the analysis. During the July-October phase of the MDNR study (Phase 1), 144 seine hauls produced a total of eight shad for a C/f of .055 shad/haul. One hundred five otter trawl tows were made during this period, yielding six shad for a C/f of .057 shad/tow. This compares to zero shad collected in the November-December outmigration phase of the MDNR study (Phase 2) which consisted of 30 seine hauls and eight otter trawls. If compared on the basis of common sites and gear types (Happy Valley Branch, Tydings Park, Wild Duck Cove, Quarry, and Battery Island for seines; Tydings Park, Wild Duck Cove, and Battery Island for trawls), 90 seine hauls produced six shad (C/f=.067) and 52 trawl tows produced five shad (C/f=.096) during Phase 1, compared to 21 seine hauls and 8 trawl tows which produced no shad during Phase 2 (C/f=0).

Viewed another way, an average of 18 seine hauls were required to collect each shad during Phase 1 for all sites combined and 15 hauls were needed to collect each shad at sites common with those used in Phase 2. Eighteen trawl tows were needed to collect each shad during Phase 1 for all sites combined and 10 tows were needed to collect each shad at sites common to Phase 2. Therefore, if the outmigrating shad population (from above Conowingo Dam) during November-December would have been of a similar magnitude to the hatchery/wild population during the summer and fall months below Conowingo Dam, and if the gear effectiveness at the sites sampled was similar during each phase of the study, then the amount of effort expended in November-December by the MDNR would have been expected to produce a total of only two shad (see below).

All sites combined

(30 seine hauls ÷ 18 hauls/shad) + (8 trawl tows ÷ 18 tows/shad)=2.1 shad

Common sites

(21 seine hauls ÷ 15 hauls/shad) + (8 trawl tows ÷ 10 tows/shad)=2.2 shad

If the outmigrating upriver population was only half as large as the lower river/flats population, then November-December collections would be expected to produce only one fish. Turbine mortality alone could account for such a scenario.

Another underlying factor which must be considered is that shad behavior during the short outmigration period is quite different from that during the earlier periods of the year, and similar amounts of effort and methods of sampling during these periods might not yield catches that are directly comparable.

In conclusion, outmigrant population sizes at least as large as the resident shad population which was present below Conowingo Dam from July through October 1986 may not be detectable at the current levels of sampling effort during November and December. Therefore, much more intensive sampling during the outmigration phase is warranted in this region, as is experimentation with alternate sites and types of gear.

Timing of Migration

The timing and character of the outmigration was comparable this year to that in previous years. In the Juniata River, seine catches again dropped to zero in late October as temperatures approached 50°F. Significant numbers of fish were first observed at lower Susquehanna River hydroprojects between 9 and 17 October as temperatures reached 60°F and few fish were taken after temperatures reached 40°F in early December. It is interesting that marked fish were observed at Peach Bottom (RM 18) and Holtwood Dam (RM 25) within a few days of the first successful cast net collections at York Haven (RM 56), and since shad were collected at the downstream sites on the first sampling attempts, they were probably present there even earlier (Tables 4.6, 4.11, 4.12, 4.13). In addition, marked fish were present below York Haven at Wrightsville (RM 43) at least as early as 24 August. It appears therefore that significant numbers of fish stocked at Thompsontown (Juniata RM 22) move downstream at least 65 miles prior to the fall outmigration. These fish might be moving passively with the current soon after stocking or actively at some later stage.

The occurrence of one age I+ fish in the Conowingo tailrace on 19 August (Table 4.14) suggests that not all juvenile shad are completing the outmigration, and some may be overwintering in the river. Since water temperatures in the Susquehanna River are lower than the American shad's lower thermal tolerance limit of 36°F (Stier and Crance 1985) throughout the winter, it is possible that some fish are overwintering in the heated water discharge plumes at Peach Bottom or perhaps Brunner Island. Further study of this phenomenon may be warranted.

Concerning the movements of shad below Conowingo Dam, it was shown this year that at least some of the fish stocked at Lapidum, as well as those resulting from natural reproduction, remain in the Susquehanna Flats through late October (Table 4.14, Figure 4.4). Little can be said about the timing of the migration from upriver sources through this region, since only one fish from these sources was verified here. However, because shad were observed at Holtwood Dam (RM 25) as late as 12 December (Table 4.12) in 1986 and 19 December in 1985 (St. Pierre 1986), they would have obviously been expected to be present below Conowingo Dam (RM 10) after the last MDNR sample dates of 9 December 1986 (Table 4.1) and 10 December 1985 (St. Pierre 1986). Therefore, it seems the sampling period in this section of the river could be extended for at least two more weeks.

Comparison of Fry and Adult Stocking

Although no juvenile shad were collected from the area north of Sunbury, the analysis of OTC marking rates for sites further downstream suggests that some level of recruitment was realized from the adult transfer. Unless mark retention in the wild is lower than that in hatchery raceways and ponds, approximately 16% of the fish collected at Amity Hall were the progeny of adults transferred to Harrisburg from the Conowingo trap. Migration of a segment of this adult population to the Juniata River was verified in the radiotelemetry study (Job V-Task 1), while no Hudson River adults were observed (or expected) to migrate up the Juniata.

The lowest marking rate observed of 47% at Wrightsville (RM 43) during August is evidence that reproduction occurred either in the Safe Harbor pool or upstream near York Haven. As mentioned earlier, RMC collected 15 shad eggs in the vicinity of York Haven Dam in May. RMC also collected 50 "spent" or "partially spent" adult shad with dipnets from the York Haven forebay between 19 May and 6 June (Job V-Task 1). The Wrightsville site apparently served as a nursery area for these fish. Because marked fish were present at Wrightsville in August, it is conceivable that the progeny of adults which had spawned at least as far upstream as Thompsontown (Juniata RM 22), where fry were stocked, could also have contributed to the unmarked population there. In any event, because the marking rates downstream at Safe Harbor (RM 32) and Holtwood (RM 25) and upstream at Amity Hall (Juniata RM 2) were all higher than that at Wrightsville (RM 43) (Table 4.15, Figure 4.1) it appears that the unmarked fish collected early at Wrightsville were representative of only a small fraction of the total unmarked population.

The marking rate at Amity Hall, where unmarked juveniles should represent the progeny of Conowingo transfers only, was the same as that downstream at Holtwood and Safe Harbor, where the progeny of Hudson River and Conowingo transfers would be mixed (Table 4.15). It appears, therefore, that the Hudson River progeny made little contribution to the year class.

It is unclear why the marking rate at York Haven was higher than that 31 miles upstream at Amity Hall (Table 4.15) when in actuality it should have been equal or even lower. Bias introduced by disproportionate sampling of aggregations of marked and unmarked fish may be responsible.

Although the observed rate at York Haven (94%) was also higher than that downstream at Safe Harbor (84%) and Holtwood (83%), the differences could not be verified statistically (Table 4.16).

The low marking rate at Peach Bottom (71%) in comparison to the other sites upstream can be explained by one of two reasons. Either additional reproduction occurred in the vicinity of Peach Bottom (perhaps reflecting the Hudson River progeny) or, because fish collected at Peach Bottom were frozen as many as three days after their impingement, and in various stages of decomposition, mark retention may have been poorer than that at upstream sites where fish were usually frozen within hours of capture.

The OTC marking rate below Conowingo (50%) was much lower than that observed upstream (71-94% excluding Wrightsville). It is conceivable that if the numbers of fry stocked at Lapidum (5.17 million) would have been closer to the 9.70 million stocked upstream, the marking rates below Conowingo might have approached those upstream. Therefore, if these marking rates are accurate measures of the proportions of the populations made up of hatchery plants, and if recruitment from hatchery fish stocked above Conowingo is similar to that stocked below, then similarly sized stocks of naturally produced fish were present in the two regions. Admittedly, one or both of the above assumptions may be false and these observations must be viewed with caution.

The apparent differences in growth patterns of the otoliths of wild compared to hatchery fish which came to light in this year's OTC analysis may have significant implications for future research. This observation, if verified, will in effect provide another way to differentiate fish from the two sources, and enable further study of the effectiveness of various stocking strategies.

Growth

The growth of juvenile shad in the Susquehanna Basin in 1986 was excellent, with fish averaging approximately 140 mm FL by November (Tables 4.6 and 4.8-4.13). Length frequency distributions for all sites between Conowingo Dam and Amity Hall are compared in Figure 4.5. One of the more interesting observations from this figure is that during October and November the length frequency distributions are skewed to the smaller sizes as one moves upstream. This would suggest the migration of faster growing and/or older fish first. Similar observations have been made by both Chittenden (1969) and Marcy (1976) on other rivers.

Deformities

In past collections in the Susquehanna River the appearance of low numbers of gill cover and lower jaw anomalies was presumed to be caused by some unknown factor related to hatchery rearing. The one unmarked deformed shad collected this year at Seneca Point is the first deformed fish collected in the SRAFRC effort which appears to definitely be of wild origin. This raises the question of whether these deformities may at least partly be environmentally induced. Whatever the cause, the fact that the rate of occurrence remains low (1.6% this year) gives little cause for considering this factor a significant threat to the success of the program.

Sampling Efficiency vs. Time of Day

The expected disparity in catch rates for night sampling compared to day was not observed in the August and September trials at Amity Hall. Juvenile shad tend to move to the surface during periods of low light intensity which tends to make them more vulnerable to seines, particularly if the sample site approaches or exceeds the net's depth. Apparently this is not a limiting factor on the Juniata River which is typically shallow. However, some underlying effect associated with the order of the sample may have influenced the results obtained. As an example, the date of the highest noon catch (4-5 August) was also the only date on which noon was the first time of day sampled. Removal of fish in the sample area on this date, if sufficient to reduce the density of fish available for subsequent samples (i.e. emigration to the area was insufficient to compensate for the loss), could explain the observed catch. This is unlikely however since catch increased later that day, with the last sample yielding the highest catch (Table 4.17).

In practical terms, because the noon catch tended to rank lower than that at the other times, it seems advisable to include periods of low light intensity in future efforts to document reproduction. However, the consistency and magnitude of these differences are not great enough to warrant night sampling to the exclusion of day, especially when the hazards and difficulties associated with seining at night are taken into account.

RECOMMENDATIONS FOR 1987

1. Reconnaissance sampling to verify adult reproduction above the Juniata River confluence (RM 85) should be done during daylight hours, with effort concentrated near dawn and dusk.

2. Continue seine sampling at Amity Hall; cast net sampling at York Haven, Safe Harbor, and Holtwood; and screen/strainer sampling at Safe Harbor, Holtwood, Peach Bottom, and Conowingo in same manner as previous years to evaluate OTC marking rates, shad growth rates, and outmigration timing.

3. Begin sampling at Wrightsville in early July and continue biweekly through October to better evaluate natural reproduction and early migration in this region.

4. Increase sampling effort substantially below Conowingo Dam during November-December and experiment with alternate sites and types of gear. Catch rates observed during July-October 1986 should be considered in November-December 1987 sampling design.

5. Extend sampling effort below Conowingo Dam for two weeks longer than in 1986.

6. Sample Peach Bottom effluent in January for possible occurrence of overwintering shad population.

7. Further evaluate the apparent differences in growth patterns of hatchery and wild shad otoliths.

LITERATURE CITED

Chittenden, M. E., Jr. 1969. Life history and ecology of the American shad. Ph.D. thesis, Rutgers University, New Brunswick, N.J. 458p.

Crecco, V., L. Gunn, and T. Savoy. 1982. The Connecticut River shad study, 1981. Connecticut Dept. of Environmental Protection, Progress Report. D-J Project AFC-13-1. 61p.

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

March, B. C., Jr. 1976. Early life history studies of American shad in the lower Connecticut River and the effects of the Connecticut Yankee plant, p. 141-168 In D. Merriman and L. M. Thorpe, editors, The Connecticut River ecological study: the impact of a nuclear power plant. Am. Fish. Soc. Monogr. 1:252p.

RMC Environmental Services. 1986. Job V. Radio telemetry studies on dispersal, spawning and behavior of American shad transported to the North Branch of the Susquehanna River, 1985. In Restoration of American Shad to the Susquehanna River. 1985 Annual Progress Report. Susquehanna River Anadromous Fish Restoration Committee.

Stier, D. J. and J. H. Crance. 1985. Habitat suitability index models and instream flow suitability curves: American shad. U.S. Fish Wildl. Serv. Biol. Rep. 82 (10.88). 34p.

St. Pierre, R. A. 1986. Job IV. Juvenile American shad outmigration assessment. In Restoration of American Shad to the Susquehanna River. 1985 Annual Progress Report. Susquehanna River Anadromous Fish Restoration Committee.

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

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Table 4.1. Sample dates by gear type and water temperature during the 1986 Maryland DNR juvenile shad outmigration study.

Date	Seine	Midwater Trawl	Otter Trawl	Temperature Range (C)	(F)
November 3	X			10.5-14.0	50.9-57.2
November 4		X	X	12.0-14.0	53.6-57.2
November 11	X			10.0-11.5	50.0-52.7
November 12		X	X	10.0-12.5	50.0-54.5
November 19	X			6.0- 6.5	42.8-43.7
November 20		X	X		
November 25	X			5.1- 6.5	41.2-43.7
November 26		X	X	5.0- 5.6	41.0-42.1
December 4	X			6.0- 7.0	42.8-44.6
December 9	X			5.5- 6.5	41.9-43.7

Table 4.2. Locations sampled and effort by gear during the 1986 Maryland DNR juvenile shad outmigration study.

Gear Type	Station No.	Effort	Station Name (see Figure 4.3)
Haul Seine	1	6	Wild Duck Cove
	5	4	Spoil Island
	6	5	Tydings Park
	7	5	Quarry
	LAP	5	Lapidum
	HVB	5	Happy Valley Branch
Otter Trawl	1	2	Wild Duck Cove
	5	3	Battery Island
	6	3	Tydings Park
Midwater Trawl	1	4	Tydings Park
	2	4	Concord Lt-Perry Pt.
	3	4	Penn Central RR Bridge
	4	4	Garret Is.-Cecil West
	5	4	Garret Is.-Cecil East
	6	4	Garret Is.-Harford East
	7	4	Garret Is.-Harford West
	8	4	I-95 Bridge
	9	3	Port Deposit
	10	3	Port Deposit-Lapidum
	11	3	Lapidum

Table 4.3. List of fish species collected at Amity Hall (RM 2) on the Juniata River and north of Sunbury (RM 120) on the Susquehanna River during American shad juvenile evaluation efforts, 5 August-21 October 1986.

Species	Beach Haven (RM 167)	Danville (RM 136)	Sunbury (RM 120-124)	Amity Hall (RM 2)
Channel catfish		X	X	
Brown bullhead		X	X	X
Yellow bullhead				X
Banded killifish				X
Northern pike	X			
Muskellunge			X	X
Tiger muskellunge		X		X
Gizzard shad		X	X	X
American shad				X
Quillback		X	X	
White sucker	X	X	X	X
Northern hog sucker			X	
Shorthead redhorse			X	
Common carp		X	X	X
Golden shiner				X
Fallfish		X	X	
Comely shiner		X		X
Common shiner				X
Spotfin shiner	X	X	X	X
Satinfin shiner		X		X
Spottail shiner	X	X		X
Rock bass		X	X	X
Redbreast sunfish			X	X
Bluegill	X	X	X	X
Pumpkinseed		X	X	X
Largemouth bass	X			
Smallmouth bass	X	X	X	X
White crappie	X	X	X	
Black crappie		X	X	X
Walleye	X	X	X	
Yellow perch	X	X	X	
Tesselated darter				X

Table 4.4. Juvenile American shad electrofishing (220 V pulsed DC) and seine (300 ft x 7 ft x 3/8 inch bar mesh; 150 ft x 6 ft x 1/2 inch bar mesh) collections in the Susquehanna River north of Sunbury (RM 120), August-September, 1986.

Date	Location	River Mile	Number American Shad	Gear	Effort[1]	Time	Water Temp (°F)
8/19	Beach Haven	167	0	150' Seine	9	1107-1740	76
			0	300' Seine	4		
8/20	Danville	136	0	150' Seine	11	0930-1630	76
8/21	Sunbury (South of Fiber Dam)	122-120	0	150' Seine	5	0945-1400	-
			0	300' Seine	1		
9/8	Danville	136	0	300' Seine	7	1325-1900	69
			0	Electrofish	4.25	1730-2215	
9/9	Sunbury						
	(South of Fabri-Dam)	122-120	0	Electrofish	3.75	0645-1030	71
	(North of Fabri-Dam)	122-125	0	300' Seine	0[2]	1200-1500	

[1]Effort recorded as number of seine hauls or number of electrofishing hours.
[2]No suitable seine sites were located despite extensive reconnaissance efforts.

Table 4.5. Juvenile American shad seine (150 ft x 6 ft x 1/2 inch bar mesh) collections at Amity Hall (RM 2) on the Juniata River, August-October 1986.

Date	Catch	Mean Fork Length(mm)	Length Range(mm)	Effort (# hauls)	Catch/ Effort	Water Temp(°F)
8/5	64	82	51-105	3	21.3	81
8/12	16	78	62-104	3	5.3	73
9/4	23	88	60-110	3	7.7	-
9/16	64	104	62-127	3	21.3	70
9/29	23	101	75-120	3	7.7	76
10/14	16	103	55-135	3	5.3	60
10/21	0	-	-	3	0	51
Total	206	93	51-135	21	11.4*	

*Calculated 8/5/86-10/14/86 only.

Table 4.6. Summary of juvenile American shad collected with cast nets (20 ft x 3/8 inch bar mesh) in the York Haven forebay (RM 56), September-November 1986.

Date	Shad Catch	Mean Fork Length(mm)	Length Range(mm)	Effort (# casts)	Time	Water Temp(°F)
9/3	0	-	-	10	1900-2000	67
9/15	0	-	-	10	1900-2000	67
9/29	0	-	-	10	1900-2000	66
10/9	49	124	101-155	8	0730-0830	60
10/16	40	124	110-140	2	1020-1035	55
10/20	30+	131	112-163	1	1045	52
10/29	40+	139	120-175	3	1100-1120	54
11/5	50+	159	146-171	6	1430-1650	52
Total	209+	135	101-175	50		

Table 4.7. List of fish species taken in the Susquehanna River between York Haven Dam forebay (RM 56) and the Holtwood Dam tailrace (RM 25) with cast nets (20 ft x 3/8 inch bar mesh) and seine* (300 ft x 7 ft x 3/8 inch bar mesh) during American shad juvenile evaluation efforts, 14 August-19 November 1986.

Species	York Haven Forebay (RM 56)	Wrightsville* (RM 43)	Safe Harbor Forebay (RM 32)	Holtwood Forebay (RM 25)	Holtwood* Tailrace (RM 25)
Channel catfish				X	
Gizzard shad		X	X	X	X
American shad	X	X	X	X	
Comely shiner		X			X
Spotfin shiner	X				X
Spottail shiner		X			
Redbreast sunfish		X			
Pumpkinseed		X			
Smallmouth bass		X			
Crappie sp.			X		
Walleye		X			
Yellow perch		X			
Striped bass x White bass			X		

Table 4.8. American shad collected between Harrisburg (RM 72) and York Haven (RM 56) by private consultants (EA Engineering, Science, and Technology, Inc.; and Environmental Research and Consulting, Inc.) during 1986.

Collector	Date	Fork Length (mm)	Weight (g)	Method of Capture	Location
ERC	22 May	12.5*		Meter net	Downstream of I-83 bridge-Harrisburg
EA	25 June	30	0.3	Seine	Southwest shore of York Haven Reservoir
EA	25 June	30	0.3	Seine	Southwest shore of York Haven Reservoir
EA	25 June	33	0.4	Seine	Southwest shore of York Haven Reservoir
EA	25 June	37	0.7	Seine	Southwest shore of York Haven Reservoir
EA	25 June	42	0.9	Seine	Southwest shore of York Haven Reservoir
EA	23 Sep	153	43.0	AC Electrofisher	Southeast Shelley Island
EA	30 Sep	160	59.0	AC Electrofisher	Southwest shore, downstream of Fishing Creek
EA	16 Oct	146	41.0	AC Electrofisher	West Three Mile Island, TMINS discharge to 500m downstream
EA	16 Oct	145	44.0	AC Electrofisher	West Three Mile Island, TMINS downstream discharge to 500m
EA	16 Oct	140	38.0	AC Electrofisher	West Three Mile Island, TMINS downstream discharge to 500m

*Total length

Table 4.9. Summary of juvenile American shad collected with seines (300 ft x 7 ft x 3/8 inch bar mesh) and electrofishing (pulsed DC) at Wrightsville (RM 43), July-October 1986.

Date	Collector	Shad Catch	Mean Fork Length (mm)	Length Range (mm)	Effort (# hauls)	Time	Water Temp. (°F)
7/31	RMC	1	-	-	*	-	80
8/14	NES	1	110	-	3	1100-1245	78
8/27	PFC/NES	6	114	106-120	3	1325-1435	75
9/4	NES	10	112	103-125	2	1055-1125	71
10/2	RMC	25	129	121-147	*	-	76
10/23**	RMC	1	142	-	*	-	60
Total		44	120	103-147	8		

*Electrofishing
**Accomac Pool (RM 46)

Table 4.10. Summary of juvenile American shad collected with cast nets (20 ft x 3/8" bar mesh) at Safe Harbor Dam (RM 32), September-November 1986.

Date	Shad Catch	Mean Fork Length (mm)	Length Range (mm)	Effort (# casts)	Time	Water Temp. (^{o}F)
9/15	0	-	-	10	1100-1200	71
10/17	17	132	115-170	10	0915-0956	59
10/20	11	136	119-156	15	1500-1555	56
10/30	6	128	120-140	10	1100-1132	57
11/4	0	-	-	8	0955-1020	56
11/10	0	-	-	6	1015-1033	49
11/19	0	-	-	5	1000-1020	41
Total	34	133	115-170	64		

Table 4.11. Summary of juvenile American shad collected with cast nets (20 ft x 3/8" bar mesh) in the Holtwood forebay (RM 25), October-November 1986.

Date	Shad Catch	Mean Fork Length (mm)	Length Range (mm)	Effort (# casts)	Time	Water Temp. (^{o}F)
10/17	55+	147	107-179	2	1300-1305	58
10/20	50+	136	107-162	1	1430	56
10/30	50+	146	116-162	1	0955	58
11/4	100+	145	120-170	1	1100	58
11/10	50+	130	98-165	3	0920-0935	52
11/19	100+	140	125-160	2	1100-1105	41
Total	405+	141	98-179	10		

Table 4.12. Number of young American shad collected by a lift net (8 ft square) from the inner forebay at the Holtwood Electric Station (RM 25), October-December 1986. A sub-sample (1939) of these American shad was transported to the RMC Ecological Laboratory to conduct a feasibility phase on radio-tagging young American shad.

Date	10 Oct	17 Oct	24 Oct	24 Oct	28 Oct	30 Oct	4 Nov	7 Nov	12 Nov
No. Samples (lifts)	6	7	24	29	24	12	38	38	6
Time	1400-1430	1440-1520	1100-1230	1500-1600	1000-1100-	1015-1100	1330-1445	0950-1110	0905-0920
Water Temp (°F)	61.7	59.0	55.4	55.4	59.0	57.2	56.3	52.7	47.3
River Flow (cfs)	25,700	14,900	11,700	11,700	11,700	10,800	12,400	14,300	65,400
Number American Shad	100	212	139	76	204	173	94	157	457
Number/Sample	16.7	30.3	5.8	2.6	8.5	14.4	2.5	4.1	76.2
<u>OTHER SPECIES</u>									
Gizzard shad	-	-	-	-	5	2	4	42	250
Channel catfish	-	-	-	-	2	2	-	-	-
Striped bass hybrid	-	-	-	-	2	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	1
Largemouth bass	-	-	-	-	-	-	-	-	-
Black crappie	-	-	-	-	-	-	-	-	-

Table 4.12. (Continued.)

Date	12 Nov	18 Nov	18 Nov	19 Nov	20 Nov	25 Nov	25 Nov	5 Dec	12 Dec
No. Samples (lifts)	16	15	3	50	50	13	15	13	20
Time	1030-1120	0930-1015	1420-1430	1400-1530	1400-1530	1040-1120	1315-1355	1000-1100	1000-1030
Water Temp (°F)	47.3	41.0	41.0	41.0	46.4-41.0*	40.1	40.1	40.1	40.1
River Flow (cfs)	65,400	32,100	32,100	32,700	37,400	69,100	69,100		
Number American Shad	285	2	36	28	287**	211	281**	185	1
Number/Sample	17.8	0.1	1.20	0.6	5.7	16.2	18.7	14.2	0.1
<u>OTHER SPECIES</u>									
Gizzard shad	640	-	-	5	40	356	750	200	5
Channel catfish	-	-	-	-	-	1	-	-	-
Striped bass hybrid	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-
Largemouth bass	-	-	-	-	-	1	1	2	1
Black crappie	-	-	-	-	-	-	-	-	2

*Increased generation lowered water temperature in inner forebay to ambient.
**Includes 2 adult American shad.

Table 4.12. (Continued.)

Date	12 Dec	19 Dec
No. Samples (lifts)	15	10
Time	1500-1530	1045-1110
Water Temp (F)	40.1	37.4
River Flow (cfs)		
Number American Shad	2	0
Number/Sample	0.1	0
<u>OTHER SPECIES</u>		
Gizzard shad	14	3
Channel catfish	-	-
Striped bass hybrid	-	-
Bluegill	-	-
Largemouth bass	1	-
Black crappie	1	-

Total 2928

Table 4.13. Summary of juvenile American shad collections from strainers at Safe Harbor (RM 32) and Conowingo (RM 10), and screens from Peach Bottom APS (RM 18), October-December, 1986.

	Safe Harbor			Peach Bottom			Conowingo
Date	# Collected	Mean FL (mm)	Temp (°F)	# Collected	Mean FL (mm)	Temp (°F)	# Collected
				20*			
10/13	–	–	–	4	159	61	–
10/15	–	–	–	4	145	58	–
10/17	–	–	–	1	151	56	–
10/20	2	103	56	5	144	57	–
10/21	7	132	55	–	–	–	–
10/22	1	119	56	38	151	57	–
10/24	2	104	56	5	154	57	–
10/27	–	–	–	3	151	59	–
10/29	–	–	–	20	143	56	–
10/30	6	114	57	–	–	–	–
10/31	6	144	57	4	135	55	–
11/3	–	–	–	1	167	53	–
11/7	1	–	51	3	143	51	–
11/8	1	137	50	–	–	–	–
11/10	–	–	–	5	152	48	–
11/12	2	152	48	14	151	44	–
11/14	–	–	–	134	145	42	–
11/17	–	–	–	14	145	42	–
11/19	–	–	–	14	146	41	–
11/21	–	–	–	11	134	41	–
11/24	–	–	–	8	146	41	–
11/26	–	–	–	**	–	–	1
12/1	–	–	–	1	158	42	–
12/3	–	–	–	1	132	41	1
12/5	–	–	–	3	–	39	–
12/8	–	–	–	1	–	42	–
12/10	–	–	–	0	–	40	–
Total	28			341			2

*Present in strainers when sampling program was initiated.
**No samples collected due to excessive trash.

Table 4.14. Summary of juvenile American shad collected below Conowingo Dam (RM 10) by RMC and Maryland DNR, July-December 1986. (Gear Types: EF=electrofishing; HS=Haul Seine; OT=Otter Trawl; GN=Gill Net)

Collector	Date	FL (mm)	Location	Gear	OTC Mark[2]
RMC	8/19/86	153	W. Steel Island (Port Deposit)	EF	0[3]
RMC	9/08/86	83	Havre de Grace	EF	+++ +++
RMC	9/17/86	156	Conowingo Tailrace (Roland Island)	EF	0
MDNR	7/01/86	65	Seneca Point	HS	0[4]
MDNR	7/15/86	92	Happy Valley Branch	HS	0
MDNR	7/15/86	57	Happy Valley Branch	HS	+++ +++
MDNR	7/15/86	73	Happy Valley Branch	HS	++ ++
MDNR[1]	7/22/86	71	Elk Neck Beach	GN	0
MDNR	8/06/86	81	Battery Island	OT	0
MDNR	8/06/86	88	Battery Island	OT	+++ +++
MDNR	8/20/86	84	Wild Duck Cove	HS	+++ +++
MDNR	9/24/86	90	Seneca Point	HS	+++ +++
MDNR	9/30/86	92	Wild Duck Cove	HS	++ ++
MDNR	10/14/86	81	Wild Duck Cove	HS	+++ +++
MDNR	10/15/86	98	Tydings Park	OT	0
MDNR	10/21/86	88	Wild Duck Cove	OT	+++ +++
MDNR	10/29/86	101	Seneca Point	OT	0

Table 4.14. (Continued.)

Collector	Date	FL (mm)	Location	Gear	OTC Mark[2]
MDNR	10/29/86	93	Tydings Park	OT	++ +++
MDNR[1]	12/03/86	177	Hart Miller Island	GN	0
MDNR[1]	12/03/86	138	Hart Miller Island	GN	0
MDNR[1]	12/05/86	179	Hart Miller Island	GN	0
MDNR[1]	12/05/86	160	Hart Miller Island	GN	0 +
MDNR[1]	12/18/86	186	Tollchester Beach	GN[5]	

[1]Maryland Striped Bass Survey
[2]Legend: 0=No Mark; +=faint; ++=moderate; +++=intense; +(outer ring)
+(inner ring)
[3]Age 1+
[4]Both gill covers short
[5]Not examined for OTC marks

Table 4.15. Analysis of OTC marking of juvenile American shad collected in the Susquehanna River Basin, 1986.

	Collection Location						
Week of:	Amity Hall (Juniata RM 2)	York Haven (RM 56)	Wrightsville (RM 43)	Safe Harbor (RM 32)	Holtwood (RM 25)	Peach Bottom (RM 18)	Below Conowingo (RM 10)
06/29	-	-	-	-	-	-	0/1*
07/13	-	-	-	-	-	-	2/3
07/20	-	-	-	-	-	-	0/1
08/03	10/10	-	-	-	-	-	1/2
08/10	9/11	-	0/1	-	-	-	-
08/17	-	-	-	-	-	-	1/2**
08/24	-	-	2/6	-	-	-	-
08/31	7/10	-	6/10	-	-	-	-
09/07	-	-	-	-	-	-	1/1
09/14	10/11	-	-	-	-	-	0/1
09/21	-	-	-	-	-	-	1/1
09/28	7/10	-	-	-	-	-	1/1
10/05	-	10/10	-	-	-	-	-
10/12	8/10	10/10	-	13/13	5/7	7/10***	1/2
10/19	-	9/10	-	11/13	6/7	4/8***	1/1
10/26	-	9/10	-	10/13	7/7	8/8***	1/2
11/02	-	-	-	1/1***	6/7	2/4***	-
11/09	-	5/6	-	1/3***	6/7	9/12***	-
11/16	-	-	-	-	5/7	-	-
11/30	-	-	-	-	-	-	1/4
% Marked	82.2% (51/62)	93.5% (43/46)	47.1% (8/17)	83.7% (36/43)	83.3% (35/42)	71.4% (30/42)	50.0% (11/22)
Gill or Jaw Anomalies	2.78% (3/108)	0.00% (0/81)	0.00% (0/43)	0.00% (0/62)	2.08% (2/96)	1.74% (5/288)	4.55% (1/22)

*Specimen had 2 short gill covers
**Includes one age I+ fish
***Specimens collected from strainers or intake screens
NOTE: 261 of the 267 (97.8%) pond or raceway reared specimens examined exhibited the 5-9 day immersion tag; 79 of 79 (100%) showed at least one of double immersion tags; 73 of 79 (97.5%) showed both marks; 28 of 37 (75.7%) exhibited the feed mark.

Table 4.16. Results of Tukey-type multiple comparison test of OTC marking rates for sites above Conowingo Dam. Marking rates designated with different letters are significantly different at the =.05 significance level.

Site	Number Marked/ Sample Size	Marking Rate	
Wrightsville (RM 43)	8/17	0.471	a
Peach Bottom (RM 18)	30/42	0.741	b
Amity Hall (Juniata RM 2)	51/62	0.823	c
Holtwood (RM 25)	35/42	0.833	c, d
Safe Harbor (RM 32)	36/43	0.837	c, d
York Haven (RM 56)	43/46	0.935	d
Control	261/267	0.978	e

Table 4.17. Results of sampling for American shad at Amity Hall (RM 2) on the Juniata River, 4 August 1986-16 September 1986, to assess the effect of time-of-day on sampling efficiency. Each sample consists of three hauls with a 150 ft x 6 ft x 1/2 inch bar mesh bag seine at 1/2 hour intervals. Approximate starting times are in parentheses accompanying each time-of-day.

	Date							
	4-5 Aug 1986		12 Aug 1986		16 Sept 1986			
Time-of-Day	Order of Sample	Mean Catch	Order of Sample	Mean Catch	Order of Sample	Mean Catch	Sum of Means	Mean Rank
Noon (1145-1220)	1	13.3	3	2.0	2	6.3	21.6	3.3
Dusk (1625-1950)	2	5.0	4	2.5	3	27.3	34.8	2.7
Night (2135-0000)	3	8.7	1	15.0	4	7.0	30.6	2.3
Dawn (1/2 hr after sunrise)	4	21.3	2	5.3	1	21.3	48.0	1.7
Goodness-of-fit chi square	12.3 (p<0.01)		17.6 (p<0.001)		21.4 (p<0.001)			
Heterogeneity chi square							40.6 (p<0.001)	

Table 4.18. Summary of American shad stockings and collections of juvenile American shad at selected sites in the Susquehanna River, 1981-1986.

	Year					
	1981	1982	1983	1984	1985	1986
Stocking						
Out-of-basin adults (estimated live)	1,165	2,565	4,310	3,777	2,834	4,991
Conowingo adults	0	842	64	0	967	4,265
Fry (above Conowingo	2.03M	5.02M	4.05M	11.99M	6.23M	9.70M
Fry (below Conowingo	0	0	0	0	0	5.17M
Fingerlings	23,600	40,700	98,300	30,500	115,200	61,200
Juveniles Collected						
North Branch	yes	no	yes	no	no	no
Amity Hall (Seine C/f)*	-	-	-	70.4	8.9	11.4
Safe Harbor (strainers)	17	36	41	112	15**	28
Holtwood (lift net C/f)***	-	-	-	-	9.6	7.4
Peach Bottom (screens)	7	115	31	38	26	341
Conowingo strainers	1	0	1	3	9	2
Below Conowingo	0	1	0	1	1	23****

*C/f calcualted for last 6 samples prior to the time of 0 occurrence.
**First year five new turbines on line
***RMC lift net C/f during October-December and prior to time of 0 occurrence. Number of lifts = 378 in 1985, 394 in 1986
****14 of these fish collected in regular MDNR Survey; 9 collected incidentally in other surveys

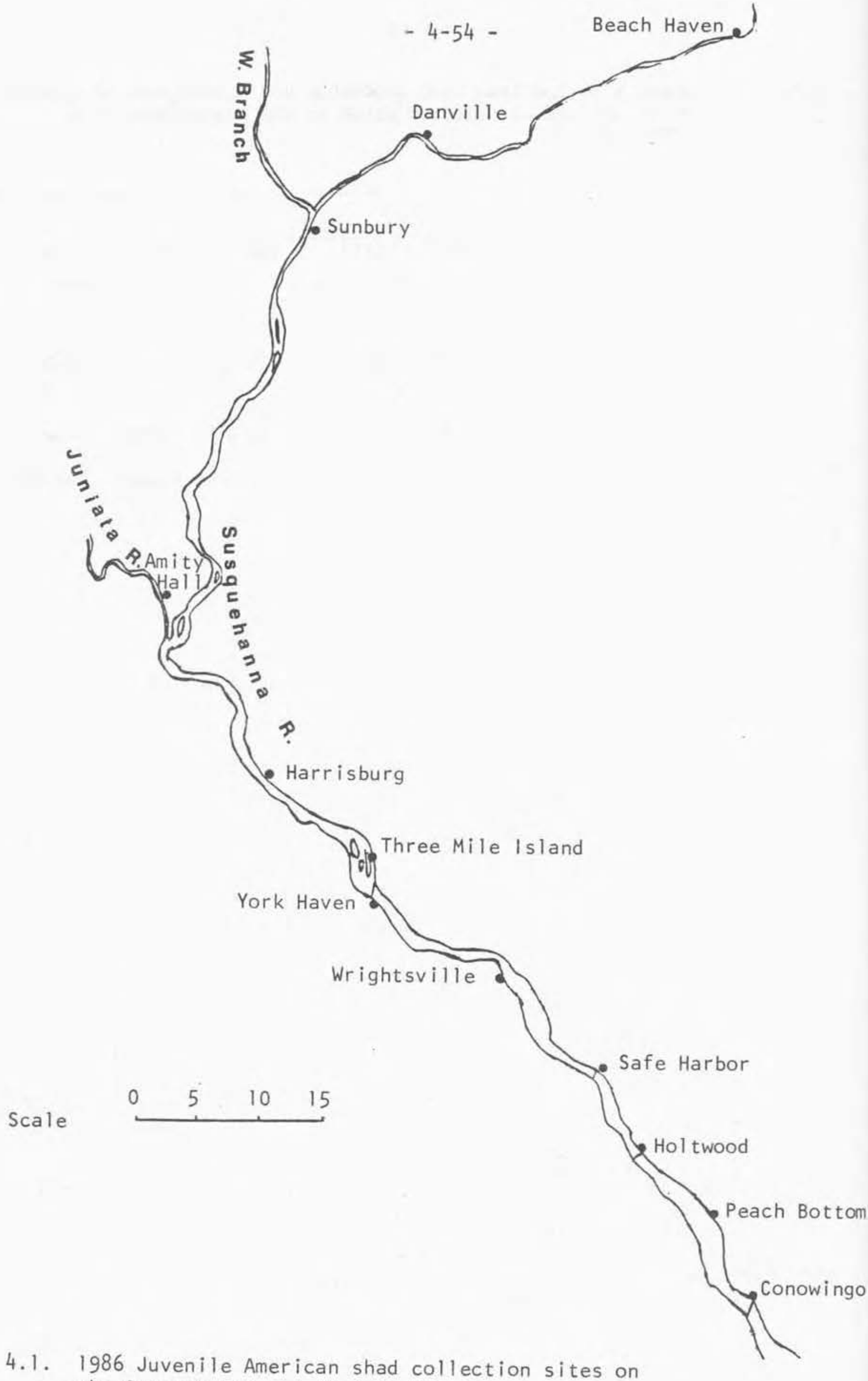

Figure 4.1. 1986 Juvenile American shad collection sites on the Susquehanna and Juniata Rivers.

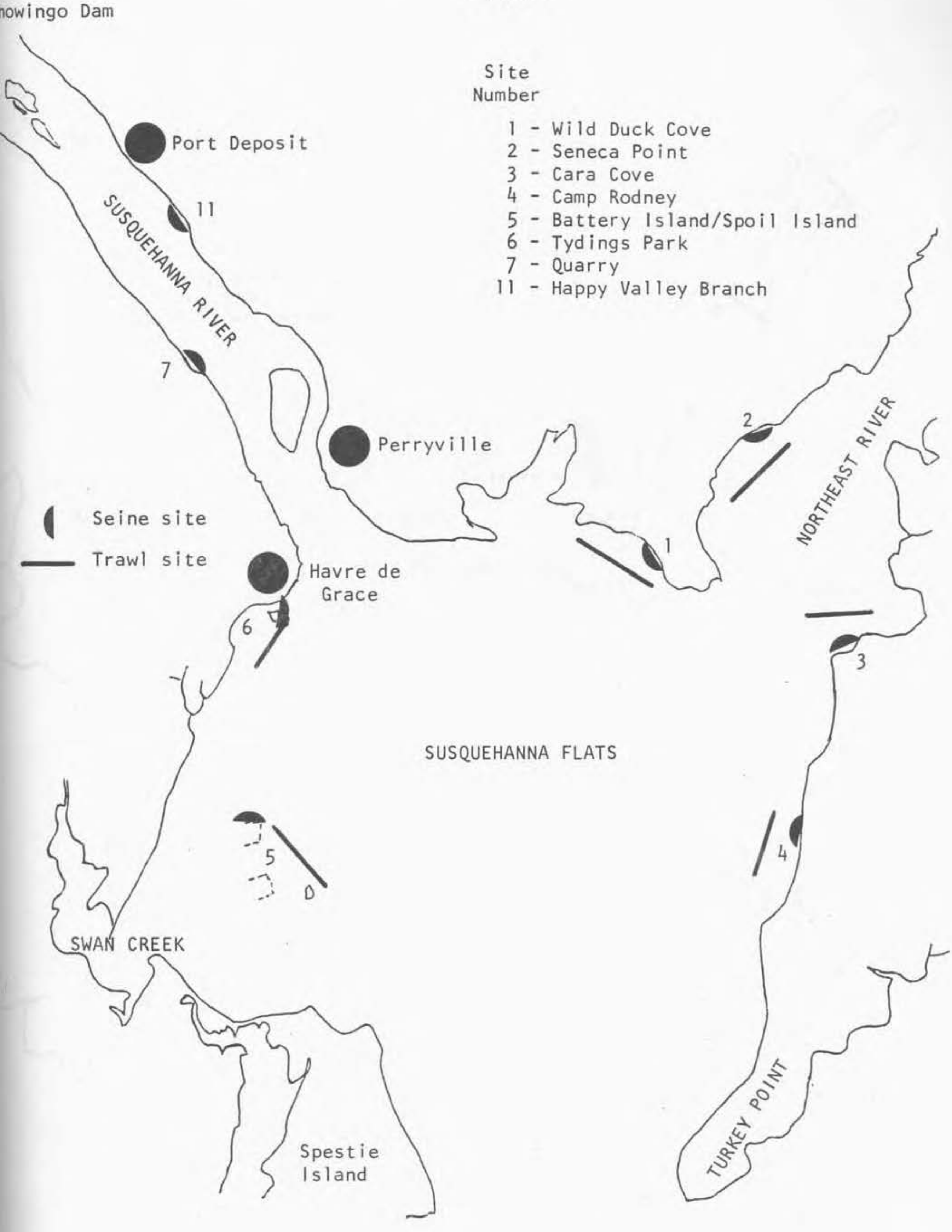

Figure 4.2. Survey stations for the 1986 Chesapeake Bay American shad juvenile recruitment survey.

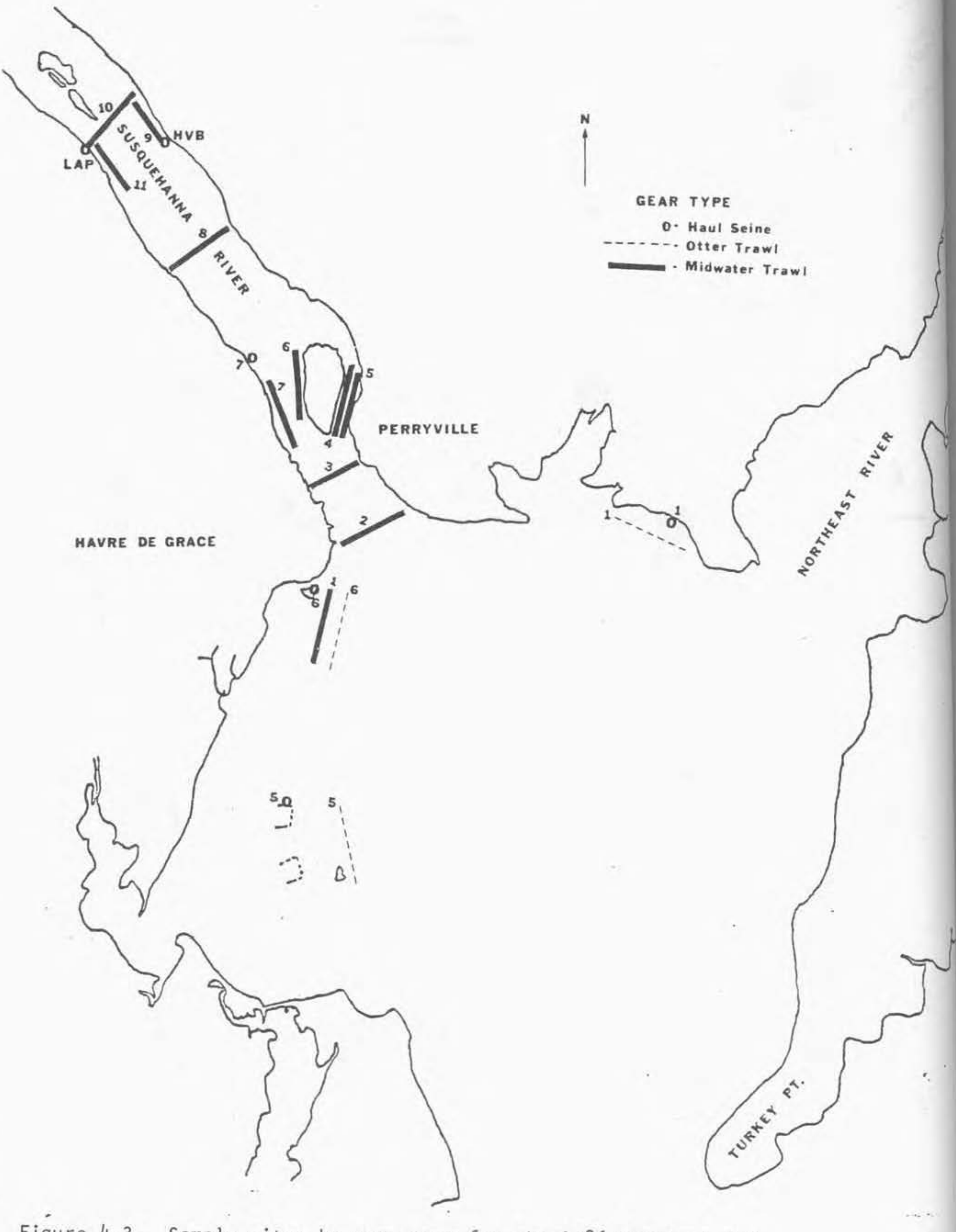

Figure 4.3. Sample sites by gear type for the 1986 Maryland DNR Outmigration Study.

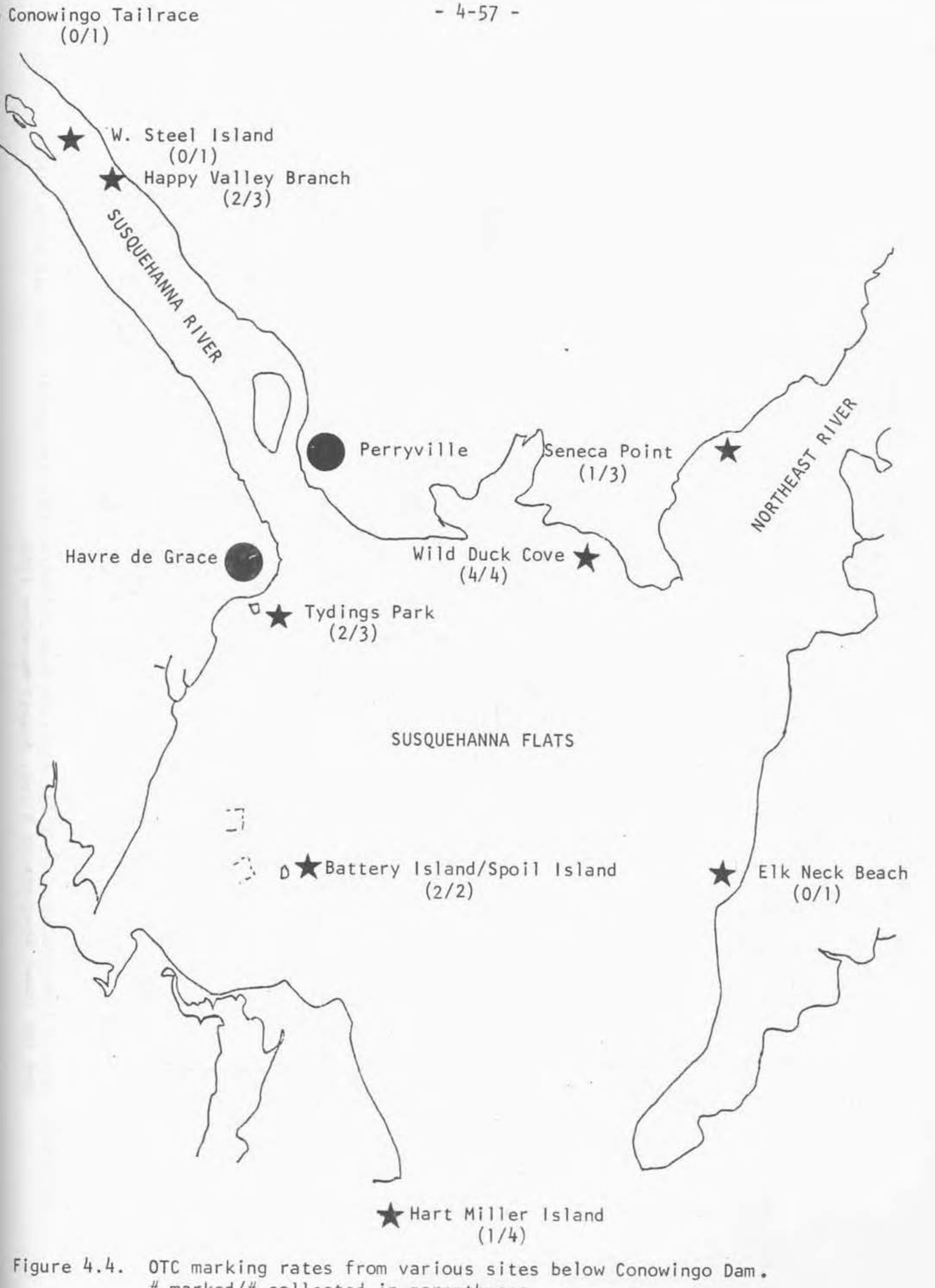

Figure 4.4. OTC marking rates from various sites below Conowingo Dam. # marked/# collected in parentheses.

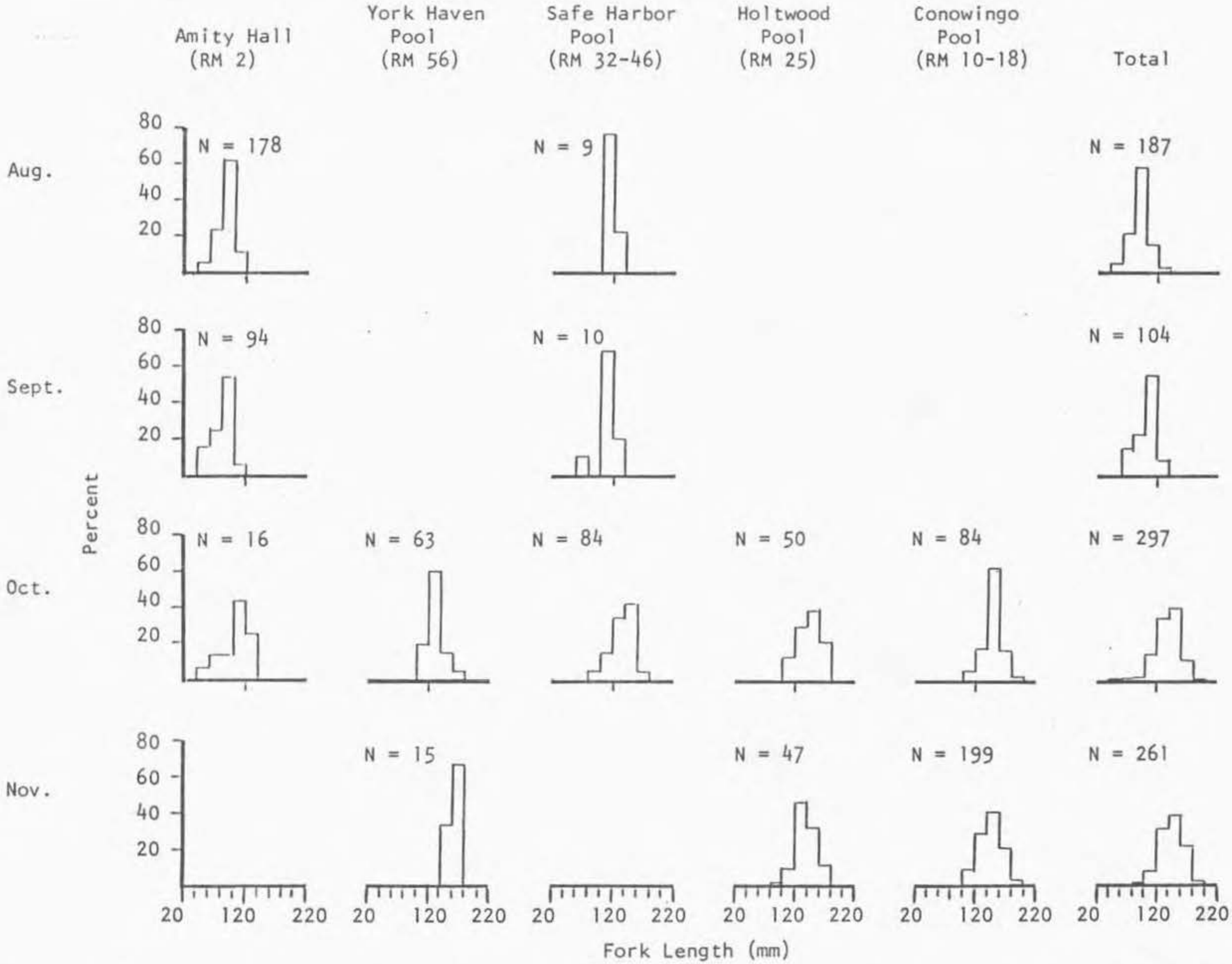

Figure 4.5. Length frequencies of juvenile American shad collected from the Juniata River at Amity Hall and the lower Susquehanna River, August-November 1986.

JOB Va. RADIO TELEMETRY STUDIES ON DISPERSAL AND BEHAVIOR OF ADULT AMERICAN SHAD FROM THE HUDSON AND SUSQUEHANNA RIVERS TRANSPLANTED TO TWO RELEASE SITES IN THE SUSQUEHANNA RIVER, 1986

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INTRODUCTION

Adult American shad have been taken from the Hudson and/or Connecticut rivers and stocked in the North Branch of the Susquehanna River since 1981 to assist in the efforts to restore American shad to the upper Susquehanna River. Spawning success was documented in only two of the five years. A radio tagging study was initiated in 1985 to provide insight into the post stocking behavior of the transported fish and to determine probable reasons for the absence of young shad in the upper Susquehanna River (RMC 1985). This study indicated most of the out-of-basin shad moved rapidly downstream from the release site (RM 217) and eventually congregated in the forebays of the hydroelectric stations, especially York Haven (RM 56) and Safe Harbor (RM 32). The failure of most fish to remain for a sufficiently long period in the upper river to spawn in part explained the absence of young shad in the upper river. It also prompted Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) to change the stocking procedures and release site in 1986. Out-of-basin shad from the Hudson River (hereafter Hudson shad) were not stocked directly into the river but placed one or two days in a net pen positioned in the river. The release site was changed from Tunkhannock (RM 217) to near Beach Haven (RM 167). The intent of these changes was to allow fish time to acclimate prior to release, increase the number of fish released in a school at a given time and provide a better release site. A subsample of the Hudson shad was equipped with radio tags (hereafter tagged) to determine if these changes enhanced the chances of fish spawning in the upper Susquehanna River.

The radio tagging program in 1986 also included monitoring the dispersal and behavior of American shad collected by the fish lift at the Conowingo Hydroelectric Station (RM 10) and transported upstream to Harrisburg (RM 70). American shad have been taken at the fish lift since 1972 and a portion has been released upstream of the four lower river hydroelectric stations. However, little knowledge exists on the post stocking behavior of these transported Susquehanna shad. Earlier studies by Walburg (1954), Whitney (1961) and Carlson (1968) on movements of adult Susquehanna shad captured below Conowingo Dam and released in Conowingo Pond, near Columbia and/or Harrisburg showed that most transplanted fish did not continue upstream movement. However, reported behavioral reactions of these adult shad were attributed to capture, transport and tagging procedures.

In the present investigation, behavior of tagged adult shad at the four hydroelectric stations (York Haven, Safe Harbor, Holtwood, and Conowingo) was monitored. Most data were obtained from York Haven and Safe Harbor stations. Incidentally, estimates of downstream passage mortality associated with these two hydro stations were made. Figure 5-0 shows the locations of the power stations and other areas on the Susquehanna River.

METHODS

Radio Tagging

Subsamples of transported adult American shad from the Hudson and Susquehanna rivers were equipped with radio tags. Susquehanna shad collected at the Conowingo fish lift were released into the Susquehanna River at City Island, Harrisburg (RM 70). Hudson shad were collected by haul seine and released into the Susquehanna River near Beach Haven (RM 167). Shad selected for radio tags were captured and transported in the same manner as untagged fish. Susquehanna shad were tagged at the capture site while Hudson shad were tagged at the release site. Transmitters were inserted into the fishes' stomach. Only healthy specimens were selected for tagging. Fish were carefully netted to a water filled container and then tagged while partially submerged. Tags were cylindrical, and measured approximately 11 x 65 mm with a 210 mm whip antenna. Each tag weighed approximately 13 grams.

Approximately equal numbers of male and female shad were tagged and released. Susquehanna shad (tagged and untagged) were released directly into the river while Hudson shad were released into a net pen positioned in the river. Most fish were released from the pen after one or two days, but some fish escaped soon after stocking. Fish were usually tagged in 4-5 lots of 4-6 fish. A total of 5796 Hudson and 4172 Susquehanna shad were transported to the Susquehanna River. Some 20 Hudson and 25 Susquehanna shad were equipped with radio tags.

<u>Tracking</u>

Tagged shad were tracked from shore, vehicle, airplane, and boat. An Advanced Telemetry programmable scanning receiver connected to either a base loaded whip antenna, a 1/4 wave length loop antenna, or a 2 or 5 element yagi antenna was used to locate tagged fish. Most fix locations were generally accurate to 1/10 of a mile, however, many of the fixes assigned from boat and along shore in the forebay areas at hydroelectric stations were accurate to within several feet. Fish are locations rounded to nearest mile for this report.

Tracking From Shore And Vehicle

Fish locations were determined from shore by scanning a section of the river from several areas. Shore scans were primarily used to determine the presence of a tagged fish in the vicinity of the hydroelectric stations. Fish were located from a vehicle by traveling roads that ran parallel to the river. Signals were received by a roof mounted whip antenna and/or a hand-held loop antenna. Initial movements of the shad released at Beach Haven were determined by traveling along the river between Shickshinny and Danville (RM 170-136). Fish released at Harrisburg were followed by traveling the area between the mouth of the Juniata River and Dock Street Dam (RM 85-69). Susquehanna shad that moved downstream soon after stocking were usually found by checking at the York Haven Station.

Tracking From Air

A Cessna-172 aircraft was used to scan large areas of the Susquehanna and Juniata rivers in a relatively short period. Most searches were conducted at altitudes between 1,000 and 2,000 ft above mean sea level and air speeds of 65 mph. Two loop antennas were mounted on the wing struts of the Cessna. Antennas were mounted in opposing orientation to maximize reception. Fish location was determined primarily by variations in signal strength.

Tracking From Boat

Some of the tagged fish were located and followed by boat near Beach Haven (RM 167), Harrisburg (RM 72-70), York Haven Station (RM 59-56) and Conowingo Station (RM 10). Most of these fish were tracked during dusk and early night to determine possible spawning sites. Fish were located by guiding the boat in the direction of the signal until the tracker was able to obtain the signal with an antenna/receiver combination having a limited range (less than 30 ft).

Monitoring Schedule

The dates, areas and methods used to monitor the tagged fish are shown in Table 5-1. Tagged fish were monitored for about an hour after release to ascertain immediate mortality and initial behavior. Most Susquehanna shad were located several times during the first 12 hours after stocking. Hudson shad were also followed for about 12 hours after the net pen was opened. Fish which escaped the net pen prior to the planned release time were located on the date they were to be released; however, the exact time they left the net pen was unknown. After the initial trackings, an attempt was made to locate all tagged fish at least weekly, usually by airplane and/or truck. Past experience indicated that most fish which moved downstream were detained in the forebays of the lower river hydroelectric stations. Consequently, monitoring efforts were intensified in these areas.

Monitoring effort was most intense at York Haven and Safe Harbor. York Haven was checked almost daily from mid-April through mid-June and Safe Harbor almost every other day from mid-May through mid-June. A few fish were monitored hourly as they moved about the forebay and impounded waters at York Haven and Conowingo stations. Shad movements were also monitored several times when sluice gates were opened to spill trash at the York Haven Station.

Relative abundance of shad (tagged and untagged) at York Haven Forebay was visually estimated when conditions permitted by counting the number of fish swimming along the trash bars in 15-30 minutes or counting all the fish passing through an area in a minute. Counts were made near the middle and/or at several points along the intake structure. Initially, total counts were taken but this became impractical when hundreds of fish arrived in mid-May. Counts per minute were taken after 16 May. These various counts were assigned an index value ranging from 0-5. The number of shad observed per minute for each of these indices were: 0 fish = 0; 1 fish = 1, 2-10 fish = 2, 11-50 fish = 3, 51-100 fish = 4, and >100 fish = 5.

Monitoring Spawning

Spawning areas were confirmed by taking ichthyoplankton samples in the vicinity of tagged fish which moved upstream or congregated with other tagged fish. Some of these fish were tracked for several hours to determine differences in diurnal spawning activity. Samples were taken near Beach Haven, Harrisburg, and York Haven. The ichthyoplankton samples were taken during dusk or early night from an anchored boat with a 1-meter plankton net. The net was fished either slightly below the surface or off the bottom. Ten minute samples were collected and preserved in 10% formalin. Shad eggs were sorted and identified according to Jones et al. 1978; Lippson and Moran 1974, Marcy 1976 and by comparison to fertilized and unfertilized American shad eggs collected from ripe fish held in two 4 x 24 foot circular pools at Muddy Run Ecological Laboratory (MREL).

The spawning condition of untagged fish was determined by collecting specimens in the forebay of the York Haven Station. Ten or more specimens were taken on four different occasions with two circular dip nets ranging from 1/2 to 1 meter in diameter. The nets were plunged along the trash bars as the fish swam past. Captured fish were transported in ice to MREL and processed (length, weight, scale samples, and gonad weight). The spawning condition of each specimen was ascertained by visual inspection and gonosomatic index (GSI):

$$GSI = \frac{\text{Gonad weight (g)}}{\text{Fish weight (g)}} \times 100$$

RESULTS

Dispersal of Hudson Shad

Twenty shad (9 males, 11 females) from the Hudson River were tagged and stocked in the net pen near Beach Haven between 25 April and 8 May (Table 5-2). None of these fish died while in the net pen or upon release prior to arrival at York Haven Station. Five shad were held in the net pen for one day, nine for two days and the remaining six escaped prior to their planned release time. At least one of these shad, possibly all, may have escaped within a few hours. The initial behavior upon release, of many Hudson shad was to stay near the release site for several hours and then drop downriver. A total of 15 fish was tracked during the first 8 to 16 hours after release. Three of these fish moved about 1 mile upriver, one remained within a mile of the release area and the others dropped 1 to 22 miles downstream (Table 5-2).

Extended tracking indicated that none of the Hudson shad moved more than 2 miles upstream from the release site and few fish remained at the release site for more than a few days. Most shad moved downstream and 55% (11) were at York Haven in 2 to 10 days (Table 5-2 and Figure 5-1 to 5-3).

The time period that shad were held in the net pen did not dramatically diminish the drop down phenomenon. Seven of the 14 fish held between 1 to 2 days moved rapidly downstream and reached the York Haven Station within five days (Table 5-2 and Figure 5-2). Fish which escaped from the pen tended to remain upriver longer; only one moved to York Haven within 5 days.

Six Hudson shad did not move rapidly downstream and took about two weeks or longer (13-18 days) to reach York Haven (Table 5-2). Fish which delayed their downstream movement did so in the north branch of the Susquehanna River (Figures 5-1 to 5-3). These fish were found within 42 miles of the release site up to a week after stocking and three remained within 22 miles of the release site for almost a week. Nearly all the fish moved rapidly through the main stem of the Susquehanna River between Sunbury (RM 124) and Harrisburg (Figure 5-1). As an example, four shad were located between RM 85 and 125 on 13 May, by 15 May they were at York Haven.

Dispersal of Susquehanna Shad

Twenty-five Susquehanna shad were released at City Island, Harrisburg (RM 70) from 6 April to 29 May (Table 5-

3). Some 13 males and 12 females were successfully tagged; however, the sex ratio of the total catch at the Conowingo fish lift was approximately 5 males per female.

The first group of shad (4) tagged on 6 April were among 86 other shad taken very early in the season. The next run of shad was not collected at Conowingo fish lift until the beginning of May. The early arriving shad remained upriver 12 days or less and then left the river during a period of high river flows that peaked at 189,000 cfs on 19 April.

Post stocking mortality due to collection, tagging and transport was minimal. Only one tagged fish died within a few days after stocking (Table 5-3). It was retrieved from the trash bars at the York Haven Station three days later.

Direction and distance moved during the first 8 to 16 hours after stocking was obtained on 22 fish (Table 5-3). Eight moved upstream ≥ 1 mile. Eight stayed within a mile of the release site and the remaining 6 moved downstream ≥ 1 mile. The maximum distance shad moved upstream and downstream during this initial period was 8 and 15 miles, respectively. Downstream movement of most fish was usually delayed at the York Haven Station.

Time that shad spent in the vicinity or upstream of the release site was variable (Table 5-3 and Figures 5-4 and 5-5). Within three days of stocking 8 fish had dropped downstream to York Haven. However, nearly half (12) the fish remained upstream for more than 2 weeks. Seven remained upriver longer than 30 days and three were still upstream more than 50 days after stocking.

Distances shad moved upstream from the stocking site were also variable (Table 5-3, Figures 5-4 and 5-5). Fourteen moved ≥ 5 miles; and 10 moved ≥ 15 miles. The maximum distance moved was 101 miles by a female. This shad migrated to Beach Haven (release site for Hudson shad). Three shad (2 females, 1 male) were found between 49 and 52 miles upriver in the vicinity of the Fabre Dam at Sunbury (RM 122).

The Juniata River was utilized by four fish (all males). Fish traveled the 15 miles to the mouth of the Juniata River and then 2 to 44 miles up that river (Table 5-3). One fish moved 14 miles upstream past the Juniata River before dropping down and then ascending the Juniata River. Another fish moved 11 miles up the Juniata, dropped back to the Susquehanna River and then re-ascended the Juniata River to Millerstown (RM 18). Two females were found at least once near the mouth of the Juniata River but never in it. Failure to locate one of these fish (#883) in the Susquehanna River for more than a week suggests that this fish may have been in the Juniata River. The Juniata River was not checked during this time period.

Behavior At Dams

Shad can encounter four hydroelectric dams on the lower Susquehanna River and two low head dams further upriver. The four hydroelectric dams are York Haven (RM 56), Safe Harbor (RM 32), Holtwood (RM 24) and Conowingo (RM 10). The two low head dams, Dock St (RM 70) and Sunbury (RM 122), control water level for recreation. The movements of the shad as they migrated upstream or dropped downriver were studied in relation to these dams.

Sunbury Dam

The Sunbury Dam is 52 miles upstream from the release site for the Susquehanna shad and 45 miles downstream from the release site of the Hudson fish. It consists of an array of large pillows which can be selectively filled with water and thus dam sections or the entire river. Three and probably a fourth (#383) Susquehanna shad reached this dam (Table 5-3, Figure 5-4). One negotiated it and continued 49 miles upstream. Flow conditions were not known when this fish passed. The other fish stopped their upstream movement below this dam. One fish was found in the vicinity of the dam for more than 3 weeks, others remained approximately a week.

Untagged fish also congregated below this dam. Two anglers reported taking 6 shad there on 25 May.

A few tagged Hudson fish delayed their downstream run above this dam but not below it. None ascended this dam (Figure 5-1).

Dock Street Dam

Susquehanna shad were released 0.4 miles upstream of the Dock Street Dam. The dam is breached along the eastern shore. Fish did not pass downstream solely through the opening of the dam. Three Susquehanna shad successfully returned upstream after dropping past the dam. Hudson fish did not delay long in the vicinity of the dam and none ascended it.

York Haven

The York Haven facility concentrated and delayed the downstream run of stocked shad from both rivers. Most shad eventually dropped downstream and entered the forebay of the York Haven Station. A few were never found in the forebay and probably passed over the dam. The number of days shad remained in the forebay was partially dependent upon the frequency and duration of spill of a sluice gate at the downstream end of the forebay and whether the trash bars were clean or clogged with debris.

Downstream passage from the York Haven forebay was via the sluice gate and through the turbines. The oblique flow across the trash bars in front of the generating units probably discouraged turbine passage, especially when the bars were clogged with trash.

Abundance and Residence Time

American shad from both rivers were present in the York Haven forebay for more than 2 months (Tables 5-4 to 5-6). Tagged Susquehanna shad were located from 9 April to 20 April. These fish were the early runners tagged on 6 april. High flows (189,000 cfs) and seven days of continuous spill through the sluice gate in mid-April allowed the shad to pass the station. The remaining fish, tagged in May, were located from 5 May through 10 June at the station. A few fish passed after 10 June that were never located in the forebay. Four Susquehanna shad were still upstream of York Haven in early July.

Susquehanna shad remained in the vicinity of the York Haven Station from 0 to 22 days after their initial appearance in the forebay (Table 5-5). Mean residency time was 6 days. Most were located regularly within the forebay area until they passed through the turbines or sluice gate, but four shad moved upstream 1/2 miles or more from the Station. One fish returned upstream 14 miles to the Dock Street Dam (Figure 5-5A).

Hudson shad were in the York Haven forebay from 28 April to 9 June (Table 5-6). No tagged fish remained above the dam after 9 June. Residency time of the Hudson shad ranged from 0-25 days with a mean of 10 days (Table 6). At least 5 fish returned upstream more than a 1/2 mile after entering the forebay. The greatest movement upstream was 2 miles.

Tagged fish (Susquehanna and Hudson combined) were most numerous in the forebay from 13 through 23 May (Table 5-4). Numbers peaked at 14 individuals on 19 May. Excluding the four Susquehanna fish tagged in early April, 41% (14 of 34) of all fish tagged by 19 May were present in the forebay on that date.

The density of tagged fish (Hudson and Susquehanna combined) in the forebay appeared to be proportional to the total stocked population. Untagged shad were first observed on 28 April (Table 5-4). The index of shad abundance was 0 or 1 (0 or 1 fish observed per minute) through 9 May. Two days later the index increased to 3 (11-50 fish/minute). Tagged fish increased from 4 to 6 individuals during the same period. Eight tagged fish were present and the abundance index increased to 4 (51-100 fish/minute) by 13 May. The index remained ≥4 through 21 May and the number of tagged fish ranged from 8 to 14 during the same time period. The peak index 5 (>100 fish/minute) coincided with maximum number (14) of tagged fish present. Index of abundance and the number of tagged fish present dropped after 23 May and by 6 June only 4 tagged fish were present and the index was

3. No tagged fish were present and few untagged fish were seen after 11 June.

Another indicator of shad abundance in the forebay was obtained by counting a subsample of the fish leaving through the sluice gate. The gate was opened on 9 occasions from 18 April through 11 June. Fish passing during the sluice gate spills was monitored on five of these dates (Table 5-4). Both tagged and untagged fish were counted during a 5 to 10 minute period when the gate was first opened and additional 5 to 10 minute periods at several successive hourly intervals.

An estimated 2,000 shad left in a 4.3 hour spill on 23 May (Figure 5-6). This was only four days after the peak number of tagged and untagged shad were located in the forebay. Later sluice gate spills indicated that considerably fewer fish were present. Less than 300 fish were estimated to have left in each of the last two spills on 9 and 11 June. During this same period three and zero tagged fish were present in the forebay, respectively.

Downstream Passage

Although the present study was not specifically designed to determine the downstream passage of shad at the dams, observations made on movements of tagged fish provided some useful information. Because all tagged fish were not individually tracked as they passed the station, criteria used to assign passage to over dam, through turbine or through sluice gate were developed: (a) a fish most likely passed over the dam if it was located upstream of the dam and then downstream of the station but never in the forebay; (b) turbine passage if a fish was located in the forebay, disappeared, and then found downstream of the station within a time period that the sluice gate was not opened; turbine passage was considered almost certain for individuals that were found dead in the immediate discharge area of the turbines; (c) a fish was assumed to use the sluice gate if it was specifically tracked leaving during a spill or if it was present in the forebay prior to a spill and then absent the following day, with the next location fix downstream of the Station. These criteria, however, were not applicable to 2 fish which apparently passed via the sluice gate during a period of high river flows and extended spill of the sluice gate (7 days). These fish (#54 and 91) were last located in the forebay.

Some 36 tagged shad (17 Susquehanna and 19 Hudson) were known to have reached the forebay and/or dam, but 4 died while in the forebay and the probable exit routes were ascertained for 30 of the shad (Tables 5-4 to 5-7). The exit route could not be ascertained for 2 fish. Thirteen (41%) of the fish appeared to leave by the sluice spills, 15 (47%) through the turbines, and 2 (6%) over the dam.

Short spills via the sluice gate appear to be an effective way to move shad through the station. Shad were counted on five different sluice gate spills and in each instance the highest passage rate (number/minute) occurred soon after the gate was opened (Table 5-4). During each of these spills the number of fish leaving per minute within the first 5-10 minutes of spill was more than twice that exiting an hour later. The 4.3 hour spill on 23 May which passed an estimated 2,000 shad exemplified the phenomenon of high passage at the commencement of spill. A passage of 205 fish was observed in the first five minutes (41/minute). Numbers decreased at succeeding hourly intervals and only two fish (< 1/minute) left during the last count. More than 70% of the fish that passed during this spill were estimated to have departed within the first hour.

Mortality

Mortality of tagged shad was estimated from stationary tags after the fish exited the York Haven Station (Table 5-7). Excluding the fish which died while in the forebay, 13 of 32 (41%) fish became inactive after passing the station. Mortality associated with passage via turbine, sluice, or over dam was 67 (10 of 15), 23 (3 of 13), and 0 (0 of 2) percent, respectively. The two fish which left by unknown routes survived passage.

Mortality of tagged and untagged shad was observed in the York Haven forebay (Tables 5-4 to 5-6).Four tagged fish died while in the forebay. Two were found dead on the trash bars soon after entry into the forebay and the other two died after several days residence. Although the trash bars were not consistently checked for dead fish because of debris and turbid waters 89 shad were found dead on the trash bars. Undoubtedly, more dead fish were present in the forebay. A few fish observed swimming in front of the trash racks had sores and were lethargic. These fish probably died. Some of these mortalities are likely due to natural causes associated with post-spawning.

Safe Harbor

Safe Harbor is 24 miles downstream of York Haven. Water was spilled through the regulating gates at the dam during a period of high river flow in mid-April; in addition, a small amount of water was spilled over one or two of the regulating gates for trash removal. These spills usually occurred near midnight every other day for about 5 minutes. The gates were lowered to pass only surface water. Because no tagged shad exited during similar spills in 1985 (RMC 1985) these spills were not monitored in 1986.

Abundance and Residency Time

Most fish which passed York Haven arrived at Safe Harbor in one or two days. A total of 17 (7 Susquehanna, 10

Hudson) tagged shad reached Safe Harbor (Table 5-8). Another 6 shad which were lost upstream may have passed Safe Harbor undetected. Tagged fish were first present on 13 May and the last one passed around 20 July (Tables 5-8 and 5-9). Five or more fish were present from 24 May through 13 June with a peak abundance of 8 individuals on 10 June.

The design of the forebay and intake area are not conducive for visually observing shad at Safe Harbor. However, early in the morning of 7 June a large school of shad was seen moving back and forth across the lower end of the forebay. The water was calm and clear and the station was shutdown. The school contained hundreds of untagged fish and four tagged individuals. Two other tagged fish were present in the forebay that were not in this school. The fish moved in a "V" shaped formation with individuals occasionally breaking the surface of the water.

The residency period of the tagged fish ranged from less than 1 to 45 days, with a mean of 5 and 18 days for the Susquehanna and Hudson fish, respectively (Table 5-8). Eighty-five percent of the Susquehanna shad moved downstream of Safe Harbor within 10 days while only 40% of the Hudson fish did likewise. Residency period was a day or less for 4 Susquehanna and one Hudson shad.

Downstream Passage

Downstream passage of shad at the Safe Harbor Station appeared to be primarily via the turbines. Dead fish located downstream of the station were on the powerhouse side of the river.

Thirteen tagged fish were located downstream of the station and presumed to have passed via the turbines. The remaining 4 fish were present in the forebay and then disappeared (Table 5-8). Most likely these fish passed through the station.

Some 6 shad ceased activity after passing the Safe Harbor Station (Table 5-8). Based on these limited data the estimated mortality at the Safe Harbor Station may have been 35% (6 of 17). In 1985, the estimated mortality was 18 percent.

Holtwood

The Holtwood Station was monitored for tagged shad on 26 days from 29 April through 25 July (Tables 5-1 and 5-9). Fish can leave this station via the turbines or spills over the dam. The spill and tailrace areas are separated for about a mile downstream by an island. Several periods of high river flows resulted in spills over the dam.

Seven tagged shad (4 Susquehanna, 3 Hudson) reached Holtwood Station. Several other fish may have passed undetected (Tables 5-2, 5-3, and 5-9). The first tagged shad was found at Holtwood on 23 May and the last on 22 July. The most fish present at one time was two and that was for only one day. Residency period was one day or less for all but one fish (#543) which remained 26 days. This fish was from the Hudson River.

The exit route was known for only one fish (#644) which was located in the tailrace (Tables 5-2 and 5-3). This fish ceased activity after passage through the turbines. Two other fish were located downstream at Conowingo, but the status of the remaining four fish is unknown.

Conowingo

Conowingo Station was checked for tagged shad on 19 days between 29 April and 22 July (Tables 5-1 and 5-9). Only two tagged shad (Susquehanna) were found in the vicinity of the station (Tables 5-3 and 5-9). One fish was located two days (16 and 18 May) while the other remained in the area for around 36 days. This fish (#223) was not always found when the area was monitored. This shad was active and did not remain at the dam. The dam did not spill during the period tagged shad were present. Consequently, the two shad passed through the turbines. Only one fish (#223) was located once about 1.5 miles downstream of the station (Table 5-3).

Shad Spawning

Some 20 ichthyoplankton samples were taken in the vicinity of Beach Haven, Harrisburg, and York Haven from 7

May through 19 May (Table 5-10). Spawning was documented for shad at Beach Haven and in the vicinity of the York Haven Station.

Five shad eggs and possibly four more were collected at Beach Haven (Table 5-10). Shad eggs were collected on 8 May in mid-river off the release site for the Hudson shad. No tagged shad were in the area at this time. On 1 May shad eggs were collected in the same vicinity near a female Susquehanna shad (#138). This particular fish migrated the farthest upriver of all the tagged Susquehanna shad and was located near Beach Haven from 13 May to 27 May.

Shad eggs were taken on all three sampled nights near York Haven (Table 5-10). Eggs (3) were taken above the station in the vicinity of a female (#563) and male (#441) Hudson shad on 7 and 14 May, respectively. Seven and possibly another 6 eggs were taken from the tailrace on 19 May. Fourteen tagged shad (2 Susquehanna, 12 Hudson) and probably several thousand untagged fish were present in the forebay of the station at this time. This sample coincided with the period of peak shad abundance (tagged and untagged fish) in the York Haven forebay (Table 5-4).

No shad eggs were taken in the vicinity of Harrisburg (Table 5-10). Collections were taken on 8 and 14 May near 3 male and 1 female Susquehanna shad (#'s 160, 201, 273, 283). Three of these fish later moved a considerable distance upriver from Harrisburg. A male and female (#'s 160, 283) migrated to Sunbury and another male (#273) went up the Juniata River. These fish may have spawned upriver.

Areas where shad congregated and/or remained for several days could also indicate spawning sites. The ichthyoplankton samples verified spawning at two of these areas: North Branch of the Susquehanna near Beach Haven and York Haven Station. Besides the Beach Haven area, some of the Hudson fish may have spawned at other areas in the North Branch of the Susquehanna from the release site downstream to Sunbury (RM 167-122). However, once past Sunbury, no Hudson fish appeared to remain long enough to spawn in the main stem of the Susquehanna River upstream of Harrisburg (Figures 5-1 and 5-2).

Susquehanna shad appeared to congregate and/or remain in a given area more than Hudson fish (Figures 5-4 and 5-5). Besides the concentration of Susquehanna fish at Harrisburg and York Haven, three fish migrated to Fabre Dam at Sunbury. The presence of other untagged fish in the same area during the same time indicated that this was a likely spawning site. Shad may have also spawned in the Juniata River. Fish were located from 2 to 44 miles up this river. Two individuals (#232, 273) were located in the same reach between river mile 16 and 18; but the one was there 22-27 May and the other 10-17 June. Both tagged fish were males.

If untagged females were available in the vicinity these males may have spawned there.

The spawning condition of fish collected in the York Haven Forebay was determined on 19, 21, 28 May and 6 June. A total of 15, 10, 10, and 17 shad was collected on these respective dates (Table 5-11). Females were common in the first and third collections and males were common in the other two collections. Overall the sex ratio was almost even (27 females, 25 males). Males ranged from 388 to 532 mm fork length with a mean length of 444 mm and females were 408 to 546 mm, mean of 480 mm.

The spawning condition of shad indicated that many spawned around 19 May (Table 5-11). Egg samples collected at York Haven also supported this spawning time. Two males and two females collected were spent on that date. One male and one female were ripe. The remaining fish were partially spent. Only two days later (21 May) most were spent. No ripe fish were collected after 19 May. The ripe male and female shad had the highest GSI values of 3.4 and 11.0, respectively (Table 5-11). GSI's were highest during the first collection on 19 May and decreased rapidly thereafter.

Water temperature at the York Haven Station rose rapidly from 62 F to 74 F (Table 5-12) between the 16 and 19 May which should have encouraged spawning.

SUMMARY OF FINDINGS (1985 and 1986)

1. Post stocking dispersal of Hudson shad in 1986 was similar to that in 1985 even though the fish were retained in a net pen in 1986 (Figure 5-7). No fish moved more than 2 miles upstream from the release sites. Most fish moved downstream soon after stocking and reached York Haven Station in 3-22 and 3-18 days during 1985 and 1986, respectively.
2. An estimated 25-30% of the Hudson shad appeared to remain upriver long enough to spawn, primarily in the North Branch of the Susquehanna between Sunbury and Beach Haven. Shad eggs were collected from the Beach Haven area.
3. Many Hudson shad appeared to spawn in the forebay area of the York Haven Station. Shad eggs were collected there in both years and fish collections from the forebay area during the expected spawning period progressively contained more spent individuals.
4. Susquehanna shad behaved differently than the Hudson shad (Figure 5-7). About half of the Susquehanna fish moved 5 miles or more upriver from the release site (Harrisburg). One fish migrated 101 miles to the 1986 release site for the Hudson shad. Three migrated about 50 miles to the Fabre Dam at Sunbury and 4 others moved into the Juniata River.

5. Some Susquehanna shad moved into upstream reaches of the Susquehanna River that the Hudson shad passed rapidly through. For example, a Susquehanna shad remained near the 1986 Hudson shad release site for at least 2 weeks while most Hudson fish left this area within a few days.

6. Many Susquehanna shad remained at or above the release site for longer periods than Hudson shad. Almost half the Susquehanna shad remained upriver more than 2 weeks and 4 fish stayed more than 50 days. In contrast, no Hudson fish remained upriver more than 22 days.

7. About half the Susquehanna shad did not move upriver and many of these dropped downstream to the York Haven Station within a few days. A higher percentage of the fish stocked near the beginning and end of the run moved downstream shortly after stocking. High river flows (189,000 cfs) and low numbers of fish stocked (86) may have contributed to the downstream dispersal of the early stocked fish. High water temperature (above 70 F) and advanced spawning condition may have contributed to the drop down of the late running shad.

8. Susquehanna shad may have spawned in several areas where they remained for extended periods. These include the Beach Haven area, downstream of Sunbury Fabre Dam, Harrisburg area, York Haven Station, and in the Juniata River. Ichthyoplankton collections were taken at Beach

Haven, Harrisburg, and York Haven. Only the samples from Harrisburg did not contain any shad eggs.

9. The congregation of 3 tagged shad and the simultaneous capture of untagged shad below the Sunbury Dam made this area a likely spawning site.

10. Most of the Susquehanna shad that dropped downriver soon after stocking were also retained at the York Haven Station; consequently, some of these fish probably spawned in this area along with the Hudson shad.

11. Although about half the Susquehanna fish behaved in a manner that could be construed as a spawning run, the fish dispersed over such a large area that the chances of both sexes congregating in large numbers upstream of Harrisburg was minimal.

12. Even though the present study was not designed to estimate mortality rate of shad via turbine passage, residency period at dams, and passage around the dams, tagged shad from both rivers provided incidental information on these parameters.

13. Hudson shad readily passed downstream through the Sunbury Fabre Dam during both years. Only one fish ceased movement after passage. Although migrating Susquehanna shad were concentrated below this dam, one fish did negotiate it. Under certain river conditions

Sunbury Dam can be a barrier to upstream movement of fish.

14. The Dock Street Dam did not slow down the downstream exodus of Hudson fish, but many Susquehanna fish stocked just upstream of this structure appeared to be temporarily detained by it. The present design of this facility did not appear to adversely affect the movement of shad. Three fish that dropped below this dam returned above it.
15. Fish from both rivers were retained and concentrated at the York Haven Station. Approximately 85% of the fish tagged in 1985 and 1986 were located in the forebay of the station; the remaining fish apparently passed directly over the dam.
16. Shad remained in the York Haven forebay area from 1 to almost 60 days. The mean period of residence was about 10 days for the Hudson shad during both years and 6 days for the Susquehanna fish.
17. Hundreds (possibly thousands) of shad were observed swimming along the trash bars in the forebay of the York Haven Station. Relative abundance of shad seen in the forebay was proportional to the tagged fish present.
18. Fish left the York Haven Forebay by passing during spills of a sluice gate at the downstream end of the forebay or pass through the turbines. The primary

exodus route was the sluice gate in 1985 and the turbines in 1986.

19. Two years of observations at York Haven indicated that a greater proportion of the shad are likely to leave at the commencement of sluice gate spills and fish will apparently pass more readily through the turbines when the trash bars are free of debris.

20. Mortality associated with downstream passage at York Haven was different between 1985 and 1986; 18 % and 41%, respectively. Some of this mortality may have resulted from the fish being in a weakened condition after spawning, particularly in 1986.

21. Generally, shad which successfully passed York Haven arrived at Safe Harbor Station within a day or two.

22. Shad were quite mobile at Safe Harbor and moved throughout the forebay. Some made excursions into the impoundment.

23. Shad remained in the vicinity of Safe Harbor forebay from 1 to 61 days during the two years of the study. The mean residency period was 18 days for Hudson fish and only 5 days for Susquehanna fish.

24. Shad passed the Safe Harbor Station primarily by the turbines. Eighteen (3 of 17) and 35 (6 of 17) percent of the fish ceased activity after passing the station in 1985 and 1986, respectively.

25. Some 34% and 16% of all tagged fish were known to have reached the Holtwood Station in 1985 and 1986, respectively. Some fish probably passed this facility undetected because the residency period of most fish was short. Many fish were found only one day.

26. Few tagged fish were located at the Conowingo Station. Two fish in each year were located at the dam and an additional 2 fish were found in the impoundment (Conowingo Pond). Two fish tracked by boat were quite mobile and did not stay close to the dam.

RECOMMENDATIONS

1. If the goal of the program is to maximize production of juveniles which may be imprinted to the upper Susquehanna River, many more Hudson shad will have to be stocked to compensate for the estimated 75% that rapidly exit the release area.
2. If it proves infeasible to obtain and transport more than 15,000 Hudson shad, an alternative procedure should be considered to modify the present stocking practice. Hudson fish could be stocked in a section of the river or a tributary that is sufficiently blocked off to prevent downstream escape. This blocked off section should be large enough to accommodate all the stocked fish. Shad retained in such an area should produce viable eggs and larvae if the system is properly maintained and managed. Our experience indicates that shad will spawn in enclosed areas with minimum maintenance. As an example, prespawned shad retained in 4 x 24 foot circular plastic-lined pools at MREL produced viable eggs in 1985 and 1986.
3. Should these recommendations prove futile, then the Hudson River should be abandoned as a source of out-of-basin adult shad. Other rivers should still be considered as a source of out-of-basin fish, especially

the Delaware. Some shad freely move between the Susquehanna and Delaware rivers via the Chesapeake and Delaware Canal.

4. The wide dispersal of Susquehanna shad throughout a large portion of the river along with the down running of others soon after stocking, warrant the testing of several stocking procedures that may concentrate these fish and possibly enhance spawning.
5. A portion of the Susquehanna shad could be held in net pens. This should permit release of fish in a large school during the beginning of the run and on other occasions when catches at the fish lift are low.
6. The chances of Susquehanna fish congregating in higher numbers in a riverine environment could possibly be achieved by stocking a proportion of the fish in the impoundment (Lake Clarke) above Safe Harbor Dam. When these fish migrate upriver both sexes would be concentrated below the York Haven Dam and should result in successful spawning. Movement of these fish would also provide an indication of the usability of the area between the two dams for spawning. Additionally, stocking some shad in one of the lower river impoundments would also provide information on their urge to move upstream through impoundments.

7. The collection of shad eggs at Beach Haven and York Haven and the congregation and/or delay of shad between Beach Haven and Sunbury, below Sunbury Dam and in the Juniata River indicate that fall sampling for young shad should be concentrated in these areas. Because eggs and young tend to disperse downstream the specific sampling sites should be several miles below the probable spawning sites.

8. Failure to locate more fish at Holtwood and Conowingo stations may be due to shorter residency periods of shad at these facilities, less intensive monitoring and/or poorer reception of tags due to electrical interference and depth of impounded waters. In order to better ascertain the movements of down running adult shad through these impoundments, monitoring must be intensified if future radio tagging studies are undertaken.

LITERATURE CITED

Carlson, Frank T. Biological studies to determine the suitability of the Susquehanna River for the restoration of the American shad. U.S. Dept. of Interior, Washington, D.C. v + 60 pp.

Jones, P. W., F. D. Martin, and J. D. Hardy, Jr. 1978. Development of fishes of the mid-Atlantic Bight: An atlas of egg, larval, and juvenile stages. Vol. 1. U.S. Dept. of Interior. FWS/OBS-78/12.

Lippson, A. J., and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Martin Marietta Corp., Baltimore, MD.

Marcy, B. C., Jr. 1976. Early life history studies of American shad in the Lower Connecticut River and the effects of the Connecticut Yankee Plant, pages 141-168. IN: D. Merriman and L. M. Thorpe, eds. The Connecticut River Ecological Study. The impact of a nuclear power plant. Monograph No. 1, American Fishies Society, Washington, D.C. xi + 252 pp.

RMC. 1985. Radiotelemetry studies on dispersal, spawning and behavior of American shad transported to the North Branch of the Susquehanna River. Drumore, PA. 44 pp.

Walburg, C. H. 1954. Experimental transportation of live shad past Susquehanna River dams. U.S. Fish and Wildlife Service, Spec. Sci. Rpt. Fish. (114): 14 pp.

Whitney, Richard R. 1961. The Susquehanna Fishery Study, 1957-1960. A report of a study on the desirability and feasibility of passing fish at Conowingo Dam. Md. Dept. Res. and Ed., Solomons, Maryland. Contrib. 169. 81 pp.

TABLE 5-1.

Monitoring schedule and methods of tracking to determine the behavior of adult radio-tagged American shad released into the Susquehanna River. Some 20 shad from the Hudson River and 25 from the Susquehanna River were stocked near Beach Haven (RM 167), and Harrisburg (RM 70), respectively, during April and May 1986.

Date	Locations Monitored	Method
6-7 Apr	Rt 81 Bridge to Rt 83 Bridge (RM 75-70)	Vehicle
	Tagged 4 Susquehanna R. shad (released RM 70)	
9 Apr	Halifax to Safe Harbor Dam (RM 90 to 32) and lower 20 miles of Juniata River	Airplane
	York Haven Station (RM 56)	Shore
11 Apr	Rt 81 Bridge to Rt 83 Bridge (RM 75-70)	Vehicle
	York Haven Station (RM 56)	Shore
14 Apr	York Haven (RM 56)	Shore
15 Apr	Rt 81 Bridge to Rt 83 Bridge (RM 75-70)	Vehicle
	York Haven Station (RM 56)	Shore
18 Apr	City Island (RM 70)	Vehicle
	York Haven and Safe Harbor Stations (RM 56 and 32)	Shore
21 Apr	York Haven and Holtwood Stations (RM 56 and 24)	Shore
22 Apr	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
25-26 Apr	Shickshinny to Sunbury (RM 170-124)	Vehicle
	Tagged 6 Hudson River shad (released RM 167)	
27 Apr	York Haven Station (RM 56)	Shore
28 Apr	York Haven Station (RM 56)	Shore
29 Apr	Nanticoke to Port Deposit (RM 182 to 5)	Airplane
30 Apr	York Haven Station (RM 56)	Shore
	Shickshinny to Berwick (RM 170-160)	Vehicle
	Tagged 4 Hudson River shad (released RM 167)	
1 May	York Haven Station (RM 56)	Shore
2 May	Shickshinny to Sunbury (RM 170-124)	Vehicle
3 May	Goldsboro to York Haven (RM 59-56)	Vehicle
4 May	Conowingo Station (RM 10)	Shore
	Tagged 5 Susquehanna shad (released RM 70)	
5 May	Rt 81 Bridge to York Haven (RM 75-56)	Vehicle
6 May	Shickshinny to Safe Harbor Dam (RM 170-32)	Airplane
	Tagged 5 Hudson River shad (Released RM 167)	

continued

TABLE 5-1.

Continued.

Date	Locations Monitored	Method
7 May	York Haven and Holtwood Stations (RM 56 and 24)	Shore
	Harrisburg and York Haven Forebay (RM 75-70 and 57-56)	Boat
	Sampled for shad eggs (RM 57)	Boat
8 May	Shickshinny to Danville (RM 170-135)	Vehicle
	Sampled for shad eggs (RM 167 and 72-70) Tagged 5 Hudson River shad (released RM 167)	Boat
9 May	York Haven Station (RM 56)	Shore
10 May	Shickshinny to Berwick (RM 170-160)	Vehicle
	Sampled for shad eggs (RM 167)	Boat
11 May	York Haven Station (RM 56) Tagged 6 Susquehanna River shad (released RM 70)	Shore
12 May	Mouth of Juniata River to York Haven (RM 85-56)	Vehicle
13 May	Tunkhannock to Safe Harbor Dam (RM 217-32)	Airplane
	York Haven Station (RM 56)	Vehicle
	Sampled for shad eggs (RM 167)	Boat
14 May	Harrisburg and Three Mile Island to York Haven Station (RM 72-70 and 59-56)	Boat
	Sampled for shad eggs (RM 71 and 57)	Boat
15 May	York Haven Station (RM 56)	Shore
	Sampled for shad eggs (RM 56)	Boat
16 May	Tagged 3 Susquehanna River shad (released RM 70)	
17 May	Rt 81 Bridge to York Haven Station (RM 75-56)	Vehicle
	Shickshinny to Safe Harbor (RM 170-32)	Airplane
19-20 May	York Haven and Safe Harbor Stations (RM 56 and 32)	Shore
	Mouth of Juniata River to Rt 83 Bridge (RM 85-70)	Vehicle
	Sampled for shad eggs (RM 56)	Boat
21 May	York Haven Station (RM 56)	Shore
22 May	York Haven Station (RM 56)	Shore
	Shickshinny to Safe Harbor Dam (RM 170-32) and lower 40 miles of Juniata River	Airplane
23 May	York Haven, Safe Harbor, and Holtwood Stations (RM 56, 32, and 24)	Shore

Continued

TABLE 5-1.

Continued.

Date	Locations Monitored	Method
24 May	Safe Harbor (RM 32)	Shore
25 May	York Haven Station (RM 56)	Shore
	Tagged 1 Susquehanna River shad (released RM 70)	
26 May	Safe Harbor Station (RM 32)	Shore
27 May	York Haven, Safe Harbor, and Holtwood Stations (RM 56, 32, and 24)	Shore
	Shickshinny to Safe Harbor Dam (RM 170-32) and lower 20 miles of Juniata River	Airplane
28 May	York Haven and Holtwood Station (RM 56 and 24)	Shore
29 May	York Haven, Safe Harbor, Holtwood and Conowingo Stations (RM 56, 32, 24, and 10)	Shore
	Harrisburg (RM 72-70	Vehicle
	Tagged 6 Susquehanna River shad (released RM 70)	
30 May	York Haven and Safe Harbor Stations (RM 56 and 32)	Shore
	Fishing Creek to Rt 81 Bridge (RM 77-70)	Vehicle
31 May	York Haven Station (RM 56)	Shore
1 Jun	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
	Conowingo Station (RM 10)	Boat
2 Jun	York Haven and Safe Harbor Station (RM 56 and 32)	Shore
3 Jun	Sunbury to Mouth of Susquehanna River (RM 124-0)	Airplane
4 Jun	York Haven Station (RM 56)	Shore
5 Jun	Safe Harbor, Holtwood and Conowingo Stations (RM 32, 24, and 10)	Shore
6 Jun	York Haven and Holtwood Stations (RM 56 and 24)	Shore
7 Jun	Safe Harbor Station (RM 32)	Shore
8 Jun	York Haven Station (RM 56)	Shore
9 Jun	York Haven, Holtwood, and Conowingo Stations (RM 56, 24, and 10)	Shore
10 Jun	Safe Harbor Station (RM 32)	Shore
	Sunbury to Mouth of Susquehanna River (RM 124-0) and lower 40 miles of Juniata River	Airplane
11 Jun	York Haven and Conowingo Stations (RM 56 and 10)	Shore
12 Jun	Safe Harbor Station (RM 32)	Shore
13 Jun	Safe Harbor, Holtwood and Conowingo Stations (RM 32, 24 and 10)	Shore
15 Jun	Safe Harbor Station (RM 32)	Shore
16 Jun	York Haven, Holtwood and Conowingo Stations (RM 56, 24, and 10)	Shore

continued

TABLE 5-1.

Continued.

Date	Locations Monitored	Method
17 Jun	Sunbury to Safe Harbor (RM 124 to 32) and lower 40 miles of Juniata River	Airplane
18 Jun	Safe Harbor to Mouth of Susquehanna River and Upper Chesapeake Bay (RM 32-0)	Airplane
20 Jun	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
22 Jun	York Haven Station (RM 56)	Shore
23 Jun	Holtwood Station (RM 24)	Shore
24 Jun	Safe Harbor, Holtwood and Conowingo Stations (RM 32, 24, and 10)	Shore
	Conowingo Pond (RM 20-10)	Vehicle
25 Jun	Conowingo Pond (RM 11-10)	Boat
26 Jun	Holtwood Station (RM 24)	Shore
	Conowingo Station Tailrace (RM 10-8)	Boat
28 Jun	York Haven Station (RM 56)	Shore
29 Jun	Safe Harbor Station (RM 32)	Shore
30 Jun	Holtwood Station (RM 24)	Shore
1 Jul	Selingsgrove to Conowingo Dam (RM 122-10) and lower 15 miles of Juniata River	Airplane
3 Jul	York Haven and Holtwood Stations (RM 56 and 24)	Shore
7 Jul	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
8 Jul	Conowingo Station Tailrace (RM 10-8)	Boat
9 Jul	York Haven Station (RM 56)	Boat
11 Jul	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
15 Jul	Conowingo Station Tailrace (RM 10-8)	Boat
22 Jul	Safe Harbor and Holtwood Stations (RM 32 and 24)	Shore
	Conowingo Station Tailrace (RM 10-8)	Boat
23 Jul	York Haven Station (RM 56)	Shore
25 Jul	Holtwood Station (RM 24)	Shore

TABLE 5-2.

Movement patterns of radio tagged adult American shad collected from the Hudson River and released into the Susquehanna River near Beach Haven (RM 167), April and May 1986.

Fish Number	Sex	Tag Date	Release Date	Days In Net Pen	Farthest Distance (miles) From Release Point After 8-16 hrs*	Maximum Distance Located Upstream From Release Site (miles)
441	M	Apr 25	Apr 25**	<1	-8	0
463	F	Apr 25	Apr 26	1	+1	1
472	M	Apr 25	Apr 26	1	-19	0
482	M	Apr 25	Apr 26	-	-10	0
493	F	Apr 25	Apr 26	1	0	0
524	F	Apr 25	Apr 26	1	-21***	0
534	M	Apr 30	(Apr 30)**	(<1)	-	0
543	M	Apr 30	(Apr 30)**	(<1)	-	0
563	F	Apr 30	(Apr 30)**	(<1)	-	0
573	F	Apr 30	(Apr 30)**	(<1)	-	0
602	F	May 6	May 8	2	-3	0
612	F	May 6	(May 6)**	(<1)	-	0
624	M	May 6	May 8	2	-2	0
644	F	May 6	May 8	2	+1	1
668	M	May 6	May 8	2	-22	0
693	F	May 8	May 10	2	-5	0
727	F	May 8	May 10	2	-2	0
744	F	May 8	May 10	2	+1	1
764	M	May 8	May 10	2	-4	0
783	M	May 8	May 10	2	-1	0
Mean					-7	0

TABLE 2.

Continued.

Fish Number	Days Until Arrival At York Haven Station	Other Hydro Stations		Last Fix		
		Station	Residency Period	Date	Location (River Mile)	Status
441	10	-	-	May 27	Below York Haven (48.0)	Dead
463	(9)	Safe Harbor	May 13-24	May 24	Below Safe Harbor (31.7)	Dead
472	3	Safe Harbor	May 23-24	May 24	Safe Harbor Forebay (32.2)	Alive
482	-****	-	-	Apr 29	Harrisburg (73.5)	Alive
493	18	-	-	May 23	Below York Haven (53.0)	Dead
524	2	-	-	May 5	York Haven Forebay (55.7)	Dead
534	11	-	-	May 21	Below York Haven (55.6)	Dead
543	15	Safe Harbor Holtwood	May 23-30 Jun 5-Jul 1	Jul 1	Holtwood Area (24.0)	Alive
563	7	-	-	May 23	Below York Haven (55.6)	Dead
573	13	Safe Harbor	May 23-Jun 10	Jun 10	Safe Harbor Forebay (32.2)	Alive
602	13	Safe Harbor	May 29-Jul 7	Jul 7	Above Safe Harbor (33.5)	Alive
612	5	-	-	May 12	York Haven Forebay (55.7)	Dead
624	9	Safe Harbor	Jun 2-Jul 1	Jul 1	Safe Harbor Forebay (32.2)	Alive
644	15	Safe Harbor Holtwood	May 23-Jul 7 Jul 11	Jul 11	Below Holtwood (23.9)	Dead
668	3	Safe Harbor	May 24-26	May 26	Below Safe Harbor (31.9)	Dead
693	5	-	-	Jun 7	Above Safe Harbor (32.4)	Dead
727	4	-	-	May 23	Below York Haven (43.0)	Dead
744	13	Safe Harbor Holtwood	May 26-Jun 1 Jun 3	Jun 3	Above Holtwood (25.0)	Alive
764	5	-	-	Jun 10	Below York Haven (55.0)	Dead
783	12	Safe Harbor	May 26-Jun 18	Jun 18	Below Safe Harbor (31.9)	Dead
Mean	9					

* - Plus (+) indicates upstream and minus (-) indicates downstream
** - Fish escaped net pen; dates in parentheses are estimates
*** - Seven hour period
**** - Fish arrived at Harrisburg (RM 73) in 3 days

TABLE 5-3.

Movement patterns of radio tagged adult American shad from the Susquehanna River collected at Conowingo Dam (RM 10) and released at Harrisburg (RM 70), April and May 1986. Data in parentheses, except river miles, are best estimates.

Fish Number	Sex	Tag Date	Furtherest Distance From Release Point After 8-16 hrs (miles)[a]	Maximum Distance Located Upstream From Release Site (miles)		Days Until Arrival At York Haven	Other Hydro Stations		Last Fix		
				Susquehanna R.	Juniata R.		Station	Residency Period	Date	Location (Description & River Mile)	Status
39	M	Apr 6	0	0	-	3	-	-	Apr 21	Below York Haven (55.6)	Dead
54	F	Apr 6	0	0	-	3	-	-	Apr 18	York Haven Forebay (55.7)	Alive
82	F	Apr 6	+5	5	-	-[b]	-	-	Apr 11	Harrisburg (69.8)	Alive
91	M	Apr 6	0	0	-	12	-	-	Apr 18	York Haven Forebay (55.7)	Alive
102	F	May 4	+1	5	-	9	-	-	May 30	Below York Haven (55.6)	Dead
114	M	May 4	-15	0	-	1	Safe Harbor	May 27-Jun 20	Jun 20	Below Safe Harbor (31.9)	Dead
138	F	May 4	0	101	-	(39)	Safe Harbor	Jun 13	Jun 13	Below Safe Harbor (31.8)	Dead
160	M	May 4	0	52	-	-[c]	-	-	Jul 1	Dalmatia (107.5)	Alive
183	M	May 4	-11	0	-	1	-	-	May 7	York Haven Forebay (55.7)	Dead
201	M	May 11	+1	1	-	8	Safe Harbor Holtwood	(May 22) May 23-May 29	May 29	Holtwood Forebay (24.0)	Alive
223	M	May 11	0	0	-	2	Safe Harbor Holtwood Conowingo	May 24 May 27-28 Jun 9-Jul 15	Jul 15	Below Conowingo (8.5)	Dead
232	M	May 11	+5	29	18	-[c]	-	-	Jul 1	Mouth Juniata R. (85.5)	Alive
273	M	May 11	+1	15	18	-[c]	-	-	Jul 1	Near Harrisburg (76.0)	Alive
283	F	May 11	-1	7	-	20	Safe Harbor Holtwood Conowingo	Jun 10-13 (Jun 14) Jun 16-18	Jun 18	Conowingo (10.0)	Alive
342	F	May 11	+8	16	-	-[d]	-	-	May 17	Above Harrisburg (79.8)	Alive
73	M	May 16	+1	15	2	17	-	-	Jun 11	Below York Haven (55.6)	Dead
363	F	May 16	0	52	-	-[e]	-	-	Jun 3	Near Harrisburg (75.0)	Dead
383	F	May 16	+2	49	-	17	Safe Harbor	Jun 10-18	Jun 18	Below Safe Harbor (31.5)	Dead
63	F	May 25	-	0	-	-[f]	-	-	Jun 10	Harrisburg (69.9)	Alive
812	M	May 29	0	15	44	(47)	Safe Harbor Holtwood	(Jul 20) Jul 22	Jul 22	Holtwood Forebay (24.0)	Alive
825	M	May 29.	-15	0	-	1	-	-	Jun 4	York Haven Forebay (55.7)	Dead
838	M	May 29	-15	0	-	1	-	-	Jun 3	Below York Haven (41.5)	Dead
866	F	May 29	-15	0	-	1	-	-	Jun 3	Below York Haven (54.0)	Dead
883	F	May 29	-	15	-	-[g]	-	-	Jul 19	Middletown (61.0)	Dead
893	F	May 29	-	6	-	(30)	-	-	Jun 28	Below York Haven (55.6)	Dead
Mean			-2	+15	+20	(12)[h]					

a = Plus(+) indicates upstream and minus(-) indicates downstream
b = Lost upstream of York Haven 5 days after release
c = Still active on 1 July upstream of York Haven 50 days after release
d = Lost upstream of York Haven 6 days after release
e = Found dead upstream of York Haven 18 days after release
f = Lost upstream of York Haven 16 days after release
g = Found dead upstream of York Haven 51 days after release
h = Including all fish mean is 18 days

TABLE 5-4.
Abundance of American shad in the forebay of the York Haven Station and the number that exited via the sluice gate, April through June 1986.

Date	Number of Tagged Shad Present	Index of Abundance*	Sluice Gate Spill: Total Time (hrs)	Tagged Shad That Exited: Number	Tagged Shad That Exited: Assigned Number	Visual Monitoring: Time	Visual Monitoring: Total Number of Shad Exiting	Visual Monitoring: No./Minute	Number of Dead Fish On Trash Racks
9 Apr	2	-	-	-	-	-	-	-	-
11 Apr	2	0	-	-	-	-	-	-	-
14 Apr	2	0	-	-	-	-	-	-	-
15 Apr	2	-	-	-	-	-	-	-	-
18 Apr	3	-	168.0**	3	39,54,91	-	-	-	-
21 Apr	0	-	-	-	-	-	-	-	-
27 Apr	0	-	-	-	-	-	-	-	-
28 Apr	1	1	-	-	-	-	-	-	-
29 Apr	1	-	-	-	-	-	-	-	-
30 Apr	2	-	-	-	-	-	-	-	-
1 May	2	-	-	-	-	-	-	-	-
3 May	1	-	-	-	-	-	-	-	-
5 May	3	1	-	-	-	-	-	-	-
6 May	4	-	-	-	-	-	-	-	-
7 May	4	1	-	-	-	-	-	-	-
9 May	4	1	-	-	-	-	-	-	-
11 May	6	3	-	-	-	-	-	-	8
12 May	6	-	-	-	-	-	-	-	-
13 May	8	4	-	-	-	-	-	-	8
14 MAy	9	-	-	-	-	-	-	-	-
15 May	13	4	0.2	0	0	-	-	-	-
17 May	12	4	-	-	-	-	-	-	20
19 May	14	5	-	-	-	-	-	-	2
21 May	11	4	-	-	-	-	-	-	-
22 May	12	-	0.1	1	201	-	-	-	3
23 May	11	-	4.3	3	223,472	0800-0805	205	41	20
					573	0900-0905	27	5	2
						1005-1010	20	4	-
						1105-1110	11	2	
						1200-1205	2	<1	
25 May	5	-	-	-	-	-	-	-	
27 May	5	-	2.5	2	114,602	-	-	-	-
28 May	4	3	-	-	-	-	-	-	-
29 May	4	-	-	-	-	-	-	-	4
30 May	7	-	2.0	2	102,624	1255-1305	48	5	-
						1400-1410	9	1	1
31 May	6	-	-	-	-	-	-	-	
2 Jun	5	3	-	-	-	-	-	-	-
3 Jun	4	-	-	-	-	-	-	-	9
4 Jun	6	3	-	-	-	-	-	-	-
6 Jun	4	3	0.2***	0	0	1005-1012	37	4	2
						1107-1112	0	0	10
8 Jun	3	-	-	-	-	-	-	-	-
9 Jun	3	-	7.0	2	764,383	0834-0844	16	2	-
						0940-0950	1	0	-
						1030-1040	4	<1	-
10 Jun	1	-	-	-	-	-	-	-	-
11 Jun****	0	-	5.6	0	0	0824-0834	18	2	-
						0920-0930	7	1	-

* - Relative abundance of shad in forebay estimated by counting fish as they swam along trash racks. Index assigned to these counts as follows: 0 = 0 fish/minute; 1 = 1 fish/minute; 2 = 2-10 fish/minute; 3 = 11-50 fish/minute; 4 = 51-100 fish/minute; and 5 = 100 fish/minute.

** - Sluice gate opened Apr 16-23 during period of high river flows.

*** - Sluice gate opened for two short periods.

**** - 16, 17, 22, 28 June and 1, 9, 23 July-no active tagged fish present.

TABLE 5-5.

Residency period and exodus route at the York Haven Hydroelectric Station of radio-tagged, adult Susquehanna American shad. Shad were collected at Conowingo Dam (RM 10) and released at Harrisburg (RM 70), April and May 1986. Data in parentheses are best estimates.

Fish Number	Date Released	Date Arrived	Date Departed	Days Present	Exodus Route	Status at Exodus
39	Apr 6	Apr 9	(Apr 20)	(11)	(Sluice Gate)	Dead
54	Apr 6	Apr 9	(Apr 19)	(10)	(Sluice Gate)	Unknown
82[a]	Apr 6	-	-	-	-	-
91	Apr 6	Apr 18	(Apr 19)	(1)	(Sluice Gate)	Unknown
102	May 4	May 13	May 30	17	Sluice Gate	Dead
114	May 4	May 5	May 27	22	Sluice Gate	Alive
138	May 4	(Jun 12)	(Jun 12)	(0)	Unknown	Alive
160[b]	May 4	-	-	-	-	-
183[c]	May 4	May 6	May 7	1	None	Dead
201	May 11	May 19	May 22	3	(Sluice Gate)	Alive
223	May 11	May 13	May 23	10	Sluice Gate	Alive
232[b]	May 11	-	-	-	-	-
273[b]	May 11	-	-	-	-	-
283	May 11	May 31	Jun 6	6	(Turbine)	Alive
342[d]	May 11	-	-	-	-	-
73	May 16	Jun 2	Jun 10	8	(Turbine)	Dead
363[e]	May 16	-	-	-	-	-
383	May 16	Jun 2	Jun 9	7	(Sluice Gate)	Alive
63[f]	May 25	-	-	-	-	-
812	May 29	(Jul 15)	(Jul 15)	(0)	Unknown	Alive
826[c]	May 29	May 30	Jun 4	5	None	Dead
838	May 29	May 30	(Jun 1)	(2)	(Turbine)	Dead
866	May 29	May 30	(Jun 1)	(2)	(Turbine)	Dead
883[g]	May 29	-	-	-	-	-
893	May 29	(Jun 28)	(Jun 28)	(0)	(Turbine)	Dead

Total Number That Arrived At York Haven 17 Mean Number Days Present (6)

a = Last location Harrisburg (RM 70), 11 April
b = Still active on 1 July when last located above Harrisburg (RM>70)
c = Did not leave, found dead in forebay
d = Last location near Harrisburg (RM 80), 17 May
e = Found dead near Harrisburg (RM 75), 13 June
f = Last location Harrisburg (RM 70), 10 June
g = Found dead Middletown (RM 61), 19 July

TABLE 5-6.

Residency period and exodus route at the York Haven Hydroelectric Station of radio-tagged adult American shad. Shad were collected from the Hudson River and released into the Susquehanna River near Beach Haven (RM 167), April and May 1986. Data in parenthesis are best estimates.

Fish Number	Date Released	Date Arrived	Date Departed	Days Present	Exodus Route	Status After Exodus
441	Apr 25	May 5	May 19	14	(Turbine	Dead
463	Apr 26	(May 5)	(May 5)	(0)	(Over Dam)	Alive
472	Apr 26	Apr 29	May 23	24	Sluice Gate	Alive
482*	Apr 26	-	-	-	-	-
493	Apr 26	May 14	May 15	1	(Turbine)	Dead
524**	Apr 26	Apr 28	May 5	7	None	Dead
534	Apr 30	May 11	May 19	8	(Turbine)	Dead
543	Apr 30	May 15	May 22	7	(Turbine)	Alive
563	Apr 30	May 7	May 22	15	(Turbine)	Dead
573	Apr 30	May 13	May 23	10	(Sluice Gate)	Alive
612**	May 6	May 11	May 12	1	None	Dead
602	May 8	May 21	May 27	6	(Sluice Gate)	Alive
624	May 8	May 17	May 30	13	Sluice Gate	Alive
644	May 8	(May 23)	(May 23)	0	(Over Dam)	Alive
668	May 8	May 11	May 22	11	(Turbine)	Alive
693	May 10	May 15	Jun 4	20	(Turbine)	Dead
727	May 10	May 14	(May 20)	6	(Turbine)	Dead
744	May 10	May 23	May 23	0	(Turbine)	Alive
764	May 10	May 15	Jun 9	25	Sluice Gate	Dead
783	May 10	May 22	May 23	1	(Turbine)	Alive

Total Number That Arrived At York Haven 19 Mean Number of Days Present 10

* = Last location Harrisburg (RM 73), 29 April
** = Did not leave, found dead in forebay

TABLE 5-7.

Estimated downstream passage mortality of adult radio-tagged American shad at the York Haven Hydroelectric Station, 1985 and 1986.

Exodus* Route	1985			1986			Combined		
	No. Passed	No. Dead Downstream	Percent Mortality	No. Passed	No. Dead Downstream	Percent Mortality	No. Passed	No. Dead Downstream	Percent Mortality
Over Dam	4	1	25	2	0	0	6	1	17
Sluice Gate Spill	14	1	7	13	3	23	27	4	15
Turbine	4	2	50	15	10	67	19	12	63
Unknown	1	0	0	2	0	0	3	0	0
Total	23	4	18	32	13	41	55	17	31

*Fish exodus routes are not absolutely known for all fish, some are based on circumstantial evidence such as location prior to and after periods of sluice gate spill and locations upstream and subsequent downstream during period of no sluice gate openings.

TABLE 5-8.

Residency period and exodus route at the Safe Habor Hydroelectric Station of radio-tagged adult American shad. Shad were collected from the Hudson and Susquehanna rivers and released near Beach Haven (RM 167) and Harrisburg (RM 70), respectively, April and May 1986.

Fish Number	Date Released	Date Arrived*	Date Departed*	Days Present	Exodus ** Route	Status After Exodus
Susquehanna						
114	May 4	May 27	Jan 20	24	(turbine)	Dead
138	May 4	Jun 13	Jun 13	<1	(turbine)	Dead
201	May 11	(May 22)	(May 22)	(<1)	(turbine)	Alive
223	May 11	May 24	(May 24)	(<1)	(turbine)	Alive
283	May 11	Jun 10	Jun 13	3	(turbine)	Alive
383	May 16	Jun 10	Jun 18	8	(turbine)	Dead
812	May 29	(Jul 20)	(Jul 20)	(<1)	(turbine)	Alive
Mean				(5)		
Hudson						
463	Apr 26	May 13	(May 24)	(11)	(turbine)	Dead
472	Apr 26	May 23	May 24	1	–	Unknown
543	Apr 30	May 23	May 30	7	(turbine)	Alive
573	Apr 30	May 23	Jun 10	18	–	Unknown
602	May 8	May 29	Jul 7	39	–	Unknown
624	May 8	Jun 2	Jul 1	29	–	Unknown
644	May 8	May 23	Jul 7	45	(turbine)	Alive
668	May 8	May 24	May 26	2	(turbine)	Dead
744	May 10	May 26	Jun 1	6	(turbine)	Alive
783	May 10	May 26	Jun 18	23	(turbine)	Dead
Mean				(18)		

* - Dates represent day first and last located, dates in parentheses are best estimates.

** - Individuals located downstream probably passed through turbines, those lost also probably passed through the turbines.

TABLE 5-9.

Number of active radio-tagged adult American shad in the forebay area of the Safe Harbor (RM 32), Holtwood (RM 24) and Conowingo (RM 10) Hydroelectric Stations, April-July 1986.

Date	Station			Date	Station		
	Safe Harbor	Holtwood	Conowingo		Safe Harbor	Holtwood	Conowingo
9 Apr	0	–	–	9 Jun	–	1	1
18 Apr	0	–	–	10 Jun	8	1	0
22 Apr	0	–	–	11 Jun	–	–	1
29 Apr	0	0	0	12 Jun	7	–	–
4 May	–	–	0	13 Jun	6	1	0
6 May	0	–	–	15 Jun	4	–	–
7 May	–	0	–	16 Jun	–	0	2
13 May	1	–	–	17 Jun	4	–	–
17 May	0	–	–	18 Jun	–	1	2
19 May	0	–	–	20 Jun	3	0	–
22 May	0	–	–	23 Jun	–	0	–
23 May	4	1	–	24 Jun	2	0	1
24 May	6	–	–	25 Jun	–	–	1
26 May	5	–	–	26 Jun	–	0	1
27 May	5	1	–	29 Jun	2	–	–
28 May	–	2	–	30 Jun	–	0	–
29 May	6	1	0	1 Jul	3	1	0
30 May	7	–	–	3 Jul	–	0	–
1 Jun	6	0	0	7 Jul	2	0	–
2 Jun	6	–	–	8 Jul	–	–	0
3 Jun	–	1	0	11 Jul	0	0*	–
5 Jun	5	1	0	15 Jul	–	–	0**
6 Jun	–	1	–	22 Jul	0	1	0
7 Jun	6	–	–	25 Jul	–	0	–

* - Fish Number 644, dead in tailrace
** - Fish Number 223, below dam

TABLE 5-10.

Eggs collected by a 1-meter plankton net fished from an anchored boat near Beach Haven, Harrisburg and York Haven, 7-19 May 1986.

Location	Beach Haven (RM 167)			Harrisburg (RM 70-72)	
Date	8 May	10 May	13 May	8 May	14 May
Number of Samples	2	1	4	2	2
Time(s)	2100-2110 hr 2140-2150 hr	2026-2036 hr	2045-2055 hr 2125-2135 hr 2220-2230 hr 2245-2255 hr	0050-0100 hr 0115-0125 hr	2103-2113 hr 2138-2148 hr
Water Temperature (F)	67.1	62.6	65.3	67.1	64.0
Number of Shad Eggs*	1	0	4	0	0
Number of Possible Shad Eggs**	1	0	3	0	0
Other Eggs (unidentified)	2	2	6	0	1
Radio Tagged Shad in Area	None	744(F)	138(F)	160(M)	201(M),273(M),283(F)
Origin of Fish		Hudson	Susquehanna	Susquehanna	Susquehanna

Location	York Haven Area (RM 56-60)				
Date	7 May	14 May	15 May	19 May	Totals
Number of Samples	2	1	2	4	20
Time(s)	2110-2120 hr 2157-2207 hr	2337-2347 hr	0050-0100 hr 0145-0155 hr	2250-2300 hr 2310-2320 hr 2330-2340 hr 2349-2359 hr	
Water Temperature (F)	69.9	64.0	64.0	74.0	
Number of Shad Eggs*	1	2	0	7	15
Number of Possible Shad Eggs**	0	0	0	6	10
Other Eggs (unidentified)	1	2	0	126	140
Radio Tagged Shad in Area	563(F)	441(M)	114(M)	14 Tagged Fish*** in Forebay	-
Origin of Fish	Hudson	Hudson	Susquehanna		

* = Based on diameters >2.8 mm, likeness to known shad eggs and references
** = Based on diameters 2.5-2.8 mm and likeness to known shad eggs
*** = Susquehanna Fish (114(M) and 223(M); Hudson Fish 441(M), 472(M), 534(M), 543(M), 201(M), 563(F), 573 (F), 624(M), 668(M), 693(F), 727(F), and 764(M)

Spawning condition of American shad collected by dip net from the forebay of the York Haven Hydroelectric Station, 19 May-6 June 1986.

Date	Fork Length (mm)	Weight (g)	Sex	Gonad Weight (g)	GSI*	Spawning Condition
19 May	490	1650	M	16	1.0	Spent
	436	1135	M	39	3.4	Ripe
	410	930	M	8	0.9	Spent
	449	1140	M	24	2.1	Partially spent
	481	1630	M	36	2.2	Partially spent
X̄ =	453	1297		25	1.9	
	439	940	F	24	2.6	Spent
	494	1635	F	60	3.7	Partially spent
	486	1370	F	85	6.2	Partially spent
	462	1360	F	86	6.3	Partially spent
	471	1270	F	39	3.1	Spent
	493	1520	F	76	5.0	Partially spent
	520	1670	F	184	11.0	Ripe
	413	895	F	50	5.6	Partially spent
	450	1440	F	66	4.6	Partially spent
	546	2490	F	163	6.5	Partially spent
X̄ =	477	1459		83	5.5	
21 May	437	1000	M	7	0.7	Spent
	461	1170	M	12	1.0	Spent
	516	1670	M	11	0.7	Spent
	446	1180	M	15	1.3	Spent
	450	1395	M	27	1.9	Partially spent
	455	1290	M	34	2.6	Partially spent
X̄ =	461	1284		18	1.4	
	497	1470	F	24	1.6	Spent
	518	1920	F	80	4.2	Partially spent
	505	1450	F	32	2.2	Spent
	511	1570	F	26	1.7	Spent
X̄ =	508	1602		40	2.4	
28 May	490	1500	M	15	1.0	Spent
	428	855	M	7	0.8	Spent
	456	1150	M	10	0.9	Spent
	419	940	M	7	0.7	Spent
X̄ =	448	1111		10	0.8	
	467	1290	F	20	1.6	Spent
	472	1160	F	32	2.8	Spent
	517	1335	F	16	1.2	Spent
	481	1240	F	68	5.5	Partially spent
	426	895	F	34	3.8	Spent
	452	1060	F	31	2.9	Spent
X̄ =	470	1163		34	3.0	
6 June	419	880	M	4	0.4	Spent
	388	610	M	7	1.1	Spent
	395	750	M	4	0.5	Spent
	447	1160	M	7	0.6	Spent
	409	810	M	10	1.2	Partially spent
	394	710	M	4	0.6	Spent
	447	1020	M	5	0.5	Spent
	532	1895	M	13	0.7	Spent
	408	975	M	28	2.9	Partially spent
	434	1060	M	7	0.7	Spent
X̄ =	427	987		9	0.9	
	490	1150	F	43	3.7	Spent
	485	1370	F	25	1.8	Spent
	451	1030	F	17	1.6	Spent
	501	1340	F	51	3.8	Spent
	494	1320	F	31	2.3	Spent
	498	1780	F	107	6.0	Partially spent
	408	915	F	20	2.2	Spent
X̄ =	475	1272		42	3.1	

* $GSI = \frac{\text{Gonad wt}}{\text{Fish wt}} \times 100$

TABLE 5-12.

Water temperature recorded by plant personnel at the York Haven Hydroelectric Station. Daily temperature (F) is the average of temperatures obtained every two hours beginning at midnight.

Date	Temperature (F)	Date	Temperature (F)
Apr 27	55	May 19	74
28	59	20	75
29	64	21	72
30	64	22	70
May 1	66	23	68
2	65	24	67
3	59	25	67
4	57	26	69
5	59	27	69
6	62	28	69
7	66	29	73
8	68	30	76
9	67	31	78
10	67	Jun 1	79
11	67	2	78
12	68	3	71
13	67	4	71
14	66	5	74
15	64		
16	62		
17	66		
18	71		

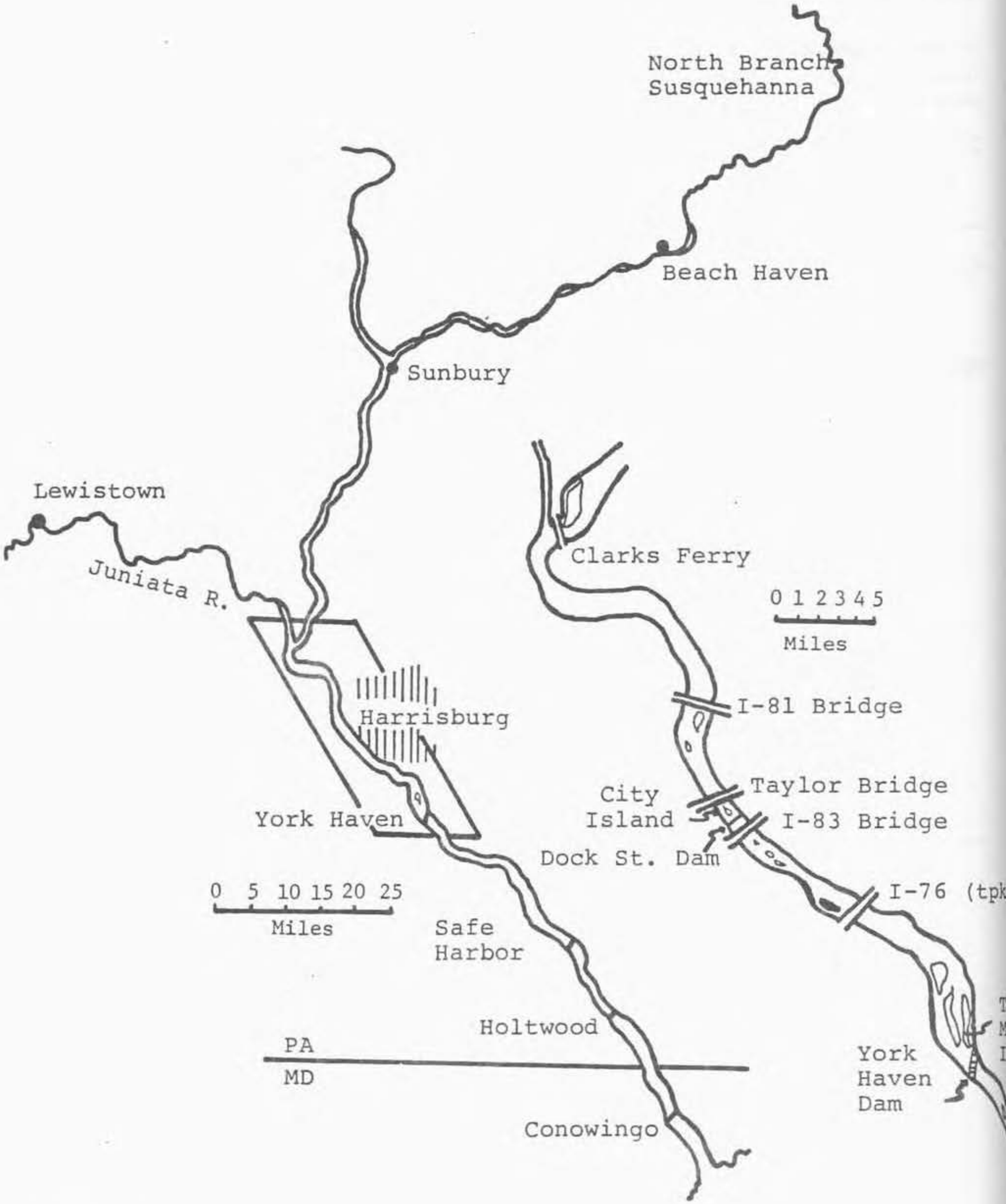


FIGURE 5-0.

The portion of the Susquehanna and Juniata Rivers checked for radio tagged American shad.

FIGURE 5-1. Dispersal patterns of adult radio-tagged American shad collected from the Hudson River and released into the Susquehanna River near Beach Haven (RM 167). Fish were located April to July, 1986.

RMC

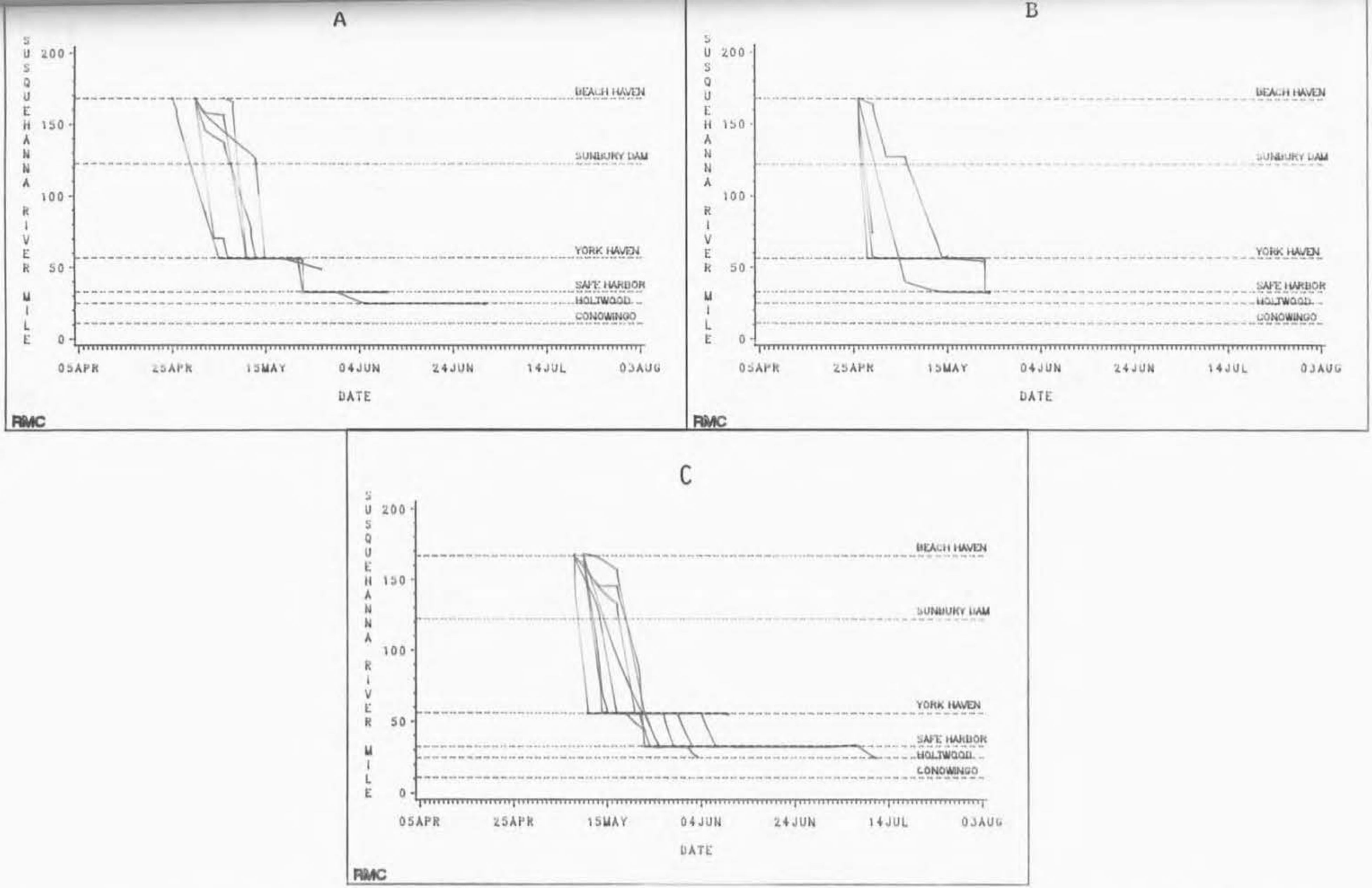


FIGURE 5-2. Dispersal patterns of radio-tagged American shad collected from the Hudson River and released into the Susquehanna River near Beach Haven (RM 167). These adult shad were retained in an instream net pen for less than one day (Figure A); one day (Figure B); and two days (Figure C) prior to release and then located April to July, 1986.

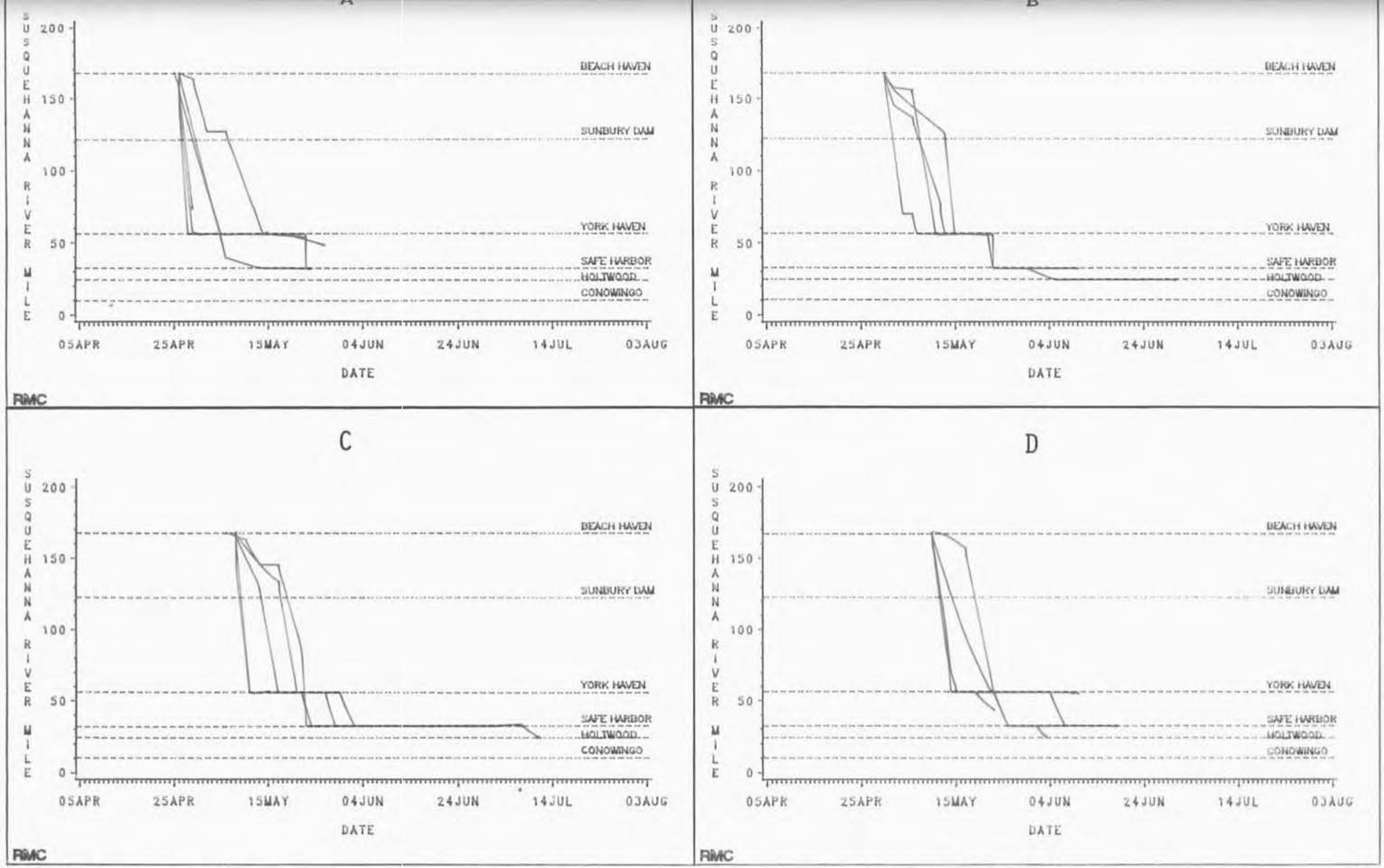


FIGURE 5-3. Dispersal patterns of radio-tagged American shad collected from the Hudson River and released into the Susquehanna River near Beach Haven (RM 167). These adult shad were tagged on 25 April (Figure A); 30 April (Figure B); 6 May (Figure C); and 8 May (Figure D) and located April to July 1986.

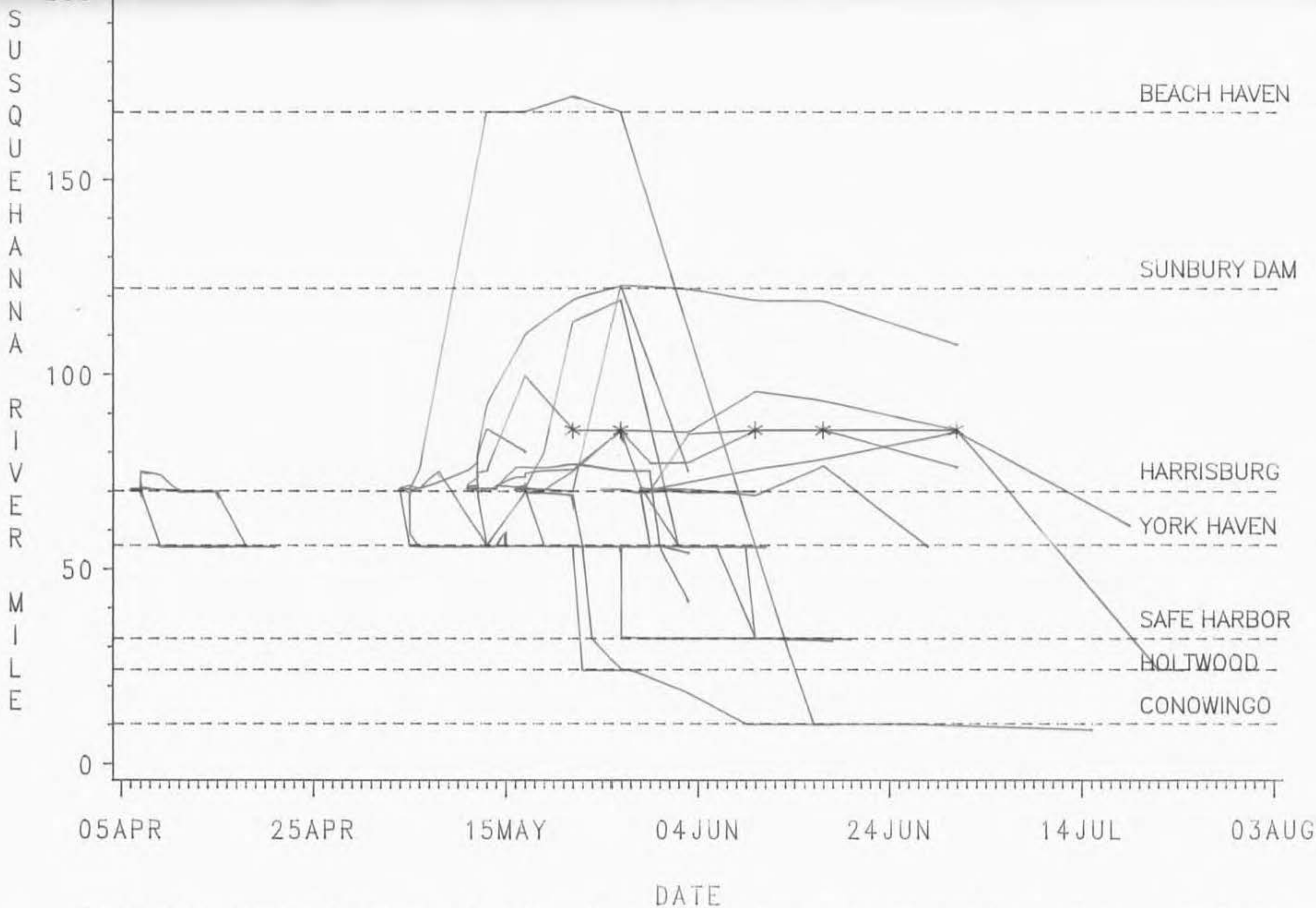


FIGURE 5-4. Dispersal patterns of adult radio-tagged American shad collected by the Conowingo Fish Lift from the lower Susquehanna River (RM 10) and released at Harrisburg (RM 70). Fish were located April to July, 1986. Asterisk (*) indicates shad (one or more) present in Juniata River.

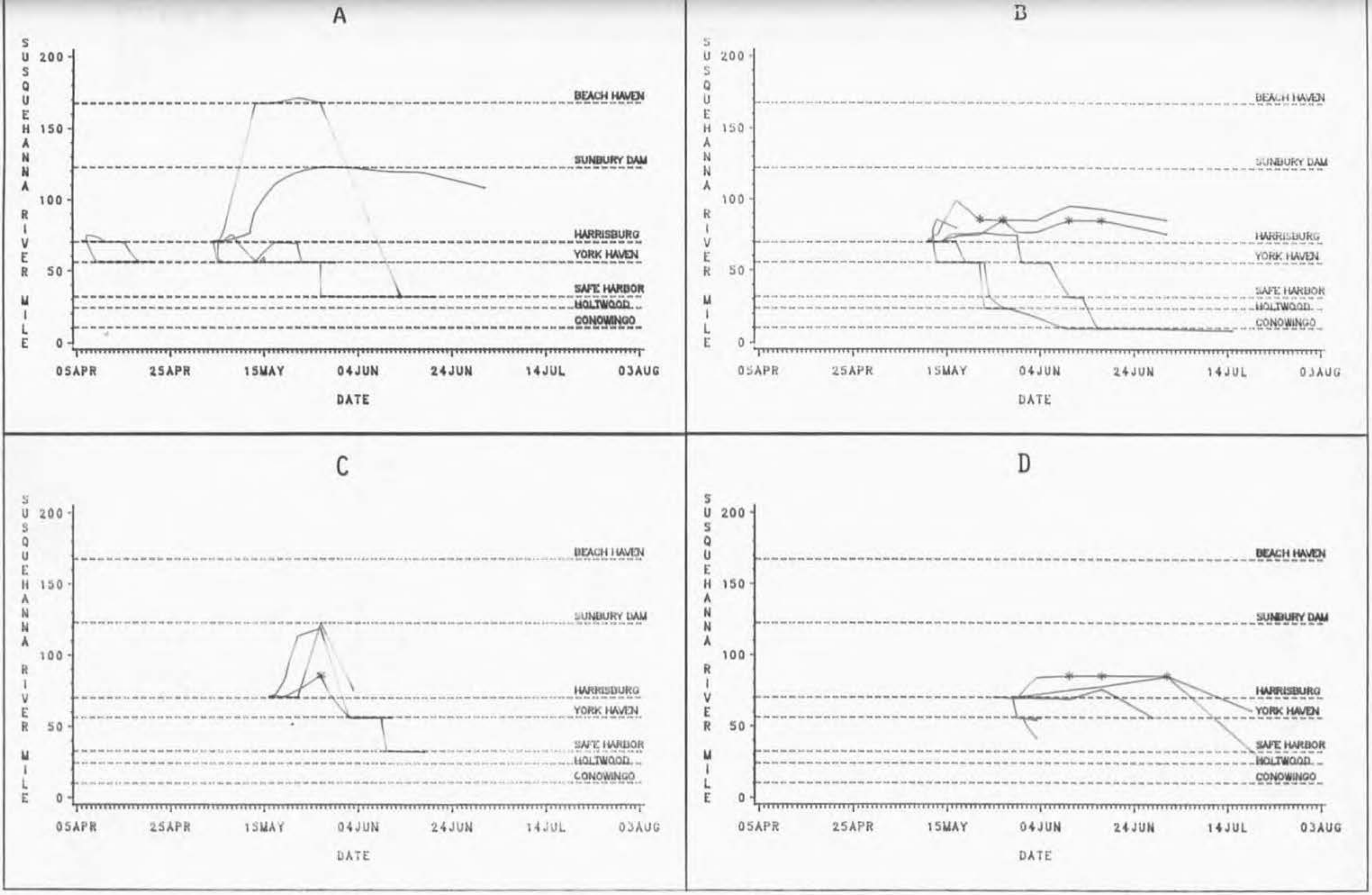
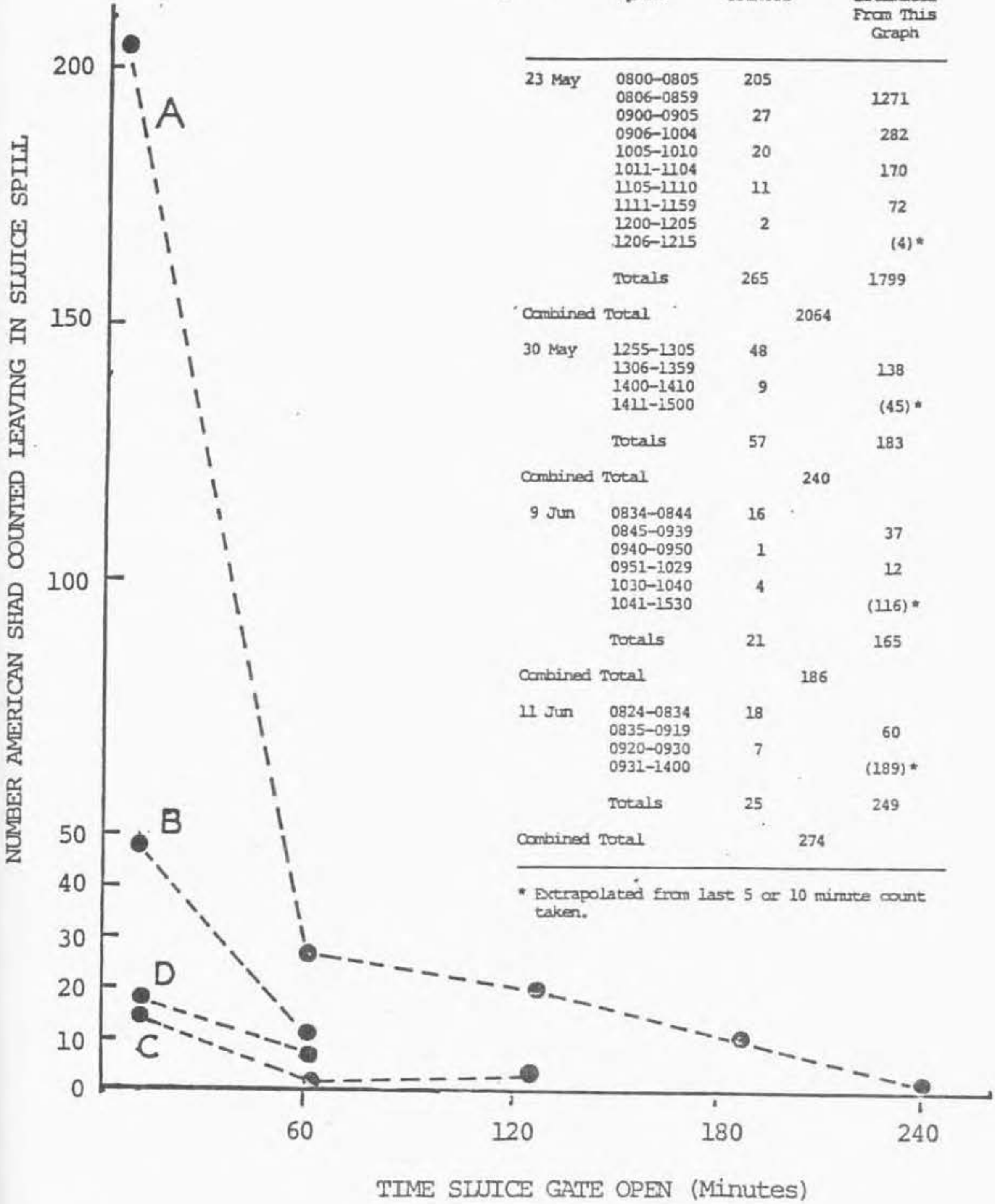


FIGURE 5-5. Dispersal patterns of radio-tagged American shad collected by the Conowingo Fish Lift from the lower Susquehanna River (RM 10) and released at Harrisburg (RM 70), 1986. These adult shad were tagged on 6 April and 4 May (Figure A); 11 May (Figure B); 16 May (Figure C); and 25 and 29 May (Figure D) and then located April to July, 1986. Asterisk (*) indicates shad (one or more) present in Juniata River.



Date	Time of Spill	Number of Shad Exiting: Counted	Number of Shad Exiting: Estimated From This Graph
23 May	0800–0805	205	
	0806–0859		1271
	0900–0905	27	
	0906–1004		282
	1005–1010	20	
	1011–1104		170
	1105–1110	11	
	1111–1159		72
	1200–1205	2	
	1206–1215		(4)*
	Totals	265	1799
Combined Total		2064	
30 May	1255–1305	48	
	1306–1359		138
	1400–1410	9	
	1411–1500		(45)*
	Totals	57	183
Combined Total		240	
9 Jun	0834–0844	16	
	0845–0939		37
	0940–0950	1	
	0951–1029		12
	1030–1040	4	
	1041–1530		(116)*
	Totals	21	165
Combined Total		186	
11 Jun	0824–0834	18	
	0835–0919		60
	0920–0930	7	
	0931–1400		(189)*
	Totals	25	249
Combined Total		274	

* Extrapolated from last 5 or 10 minute count taken.

FIGURE 5-6.

Estimated number of adult American shad which passed the York Haven Station via spills of the sluice gate on 23 May (A), 30 May (B), 9 June (C), and 11 June (D). The number of fish counted in a 5 or 10 minute period is designated by a solid circle (●).

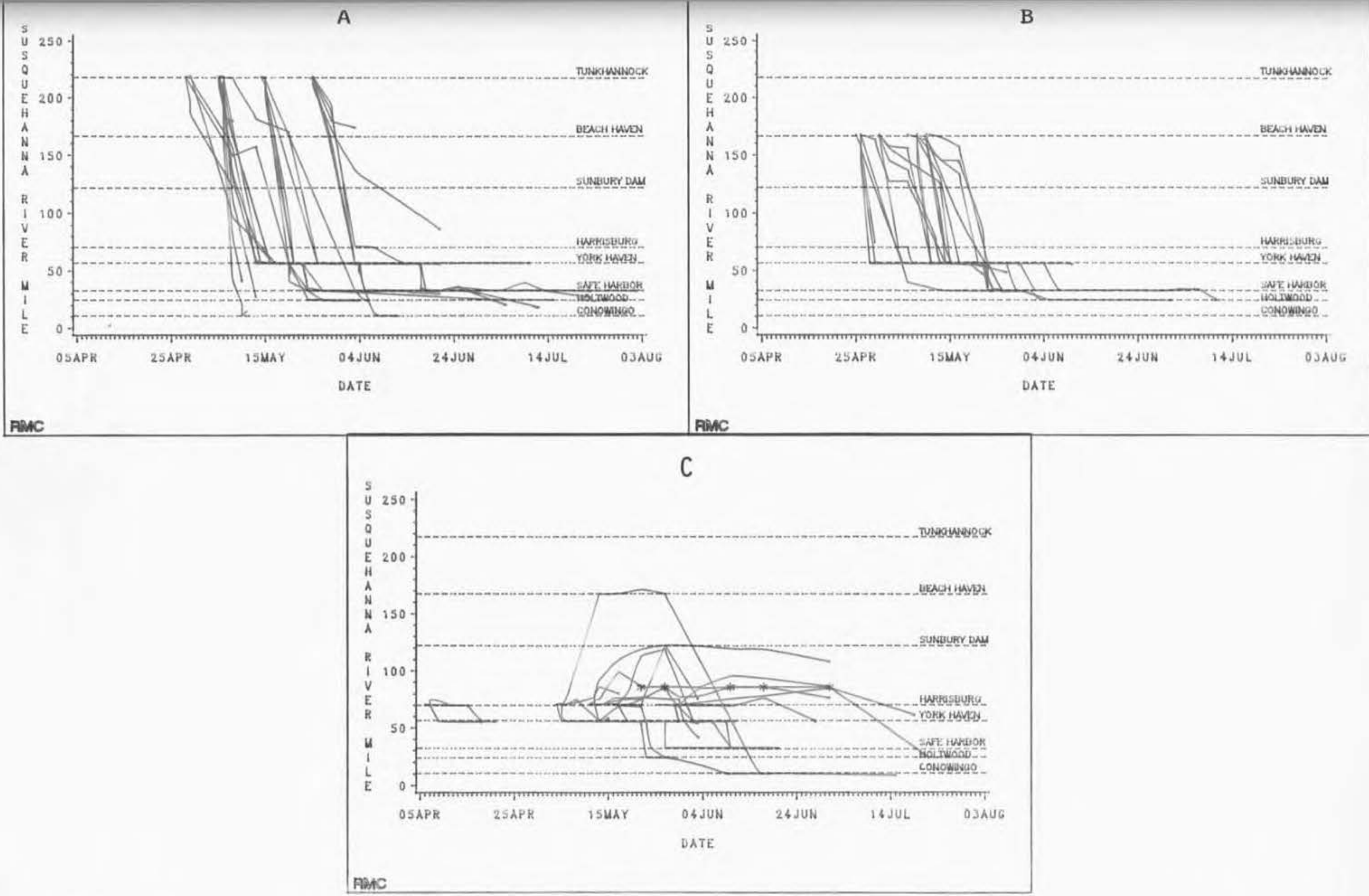


FIGURE 5-7. Comparison of dispersal patterns of adult radio-tagged American shad collected from the Hudson River and lower Susquehanna River and released into the Susquehanna River. Hudson River shad were released near Tunkhannock (RM 217) in 1985 (Figure A) and near Beach Haven (RM 167) in 1986 (Figure B). Susquehanna River shad were released at Harrisburg (RM 70) in 1986 (Figure C). Asterisk (*) indicates shad (one or more) present in Juniata River.

JOB V - TASK 2

HYDROACOUSTIC EVALUATION

of

JUVENILE SHAD MOVEMENT

AND PASSAGE

at the

YORK HAVEN POWER STATION

YORK HAVEN, PENNSYLVANIA

OCTOBER - NOVEMBER 1986

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YORK HAVEN HYDROELECTRIC STATION
FALL 1986

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1. Executive Summary

The executive summary lists pertinent information about the York Haven hydroacoustic monitoring of American shad. This information includes information about the work performed, results obtained, and observations made. Details can be found in the main body of the report.

--Hydroacoustic data were collected at York Haven at 4 locations along the length of the trash racks and one location in the forebay. The forebay location provided information about shad movement into the forebay and the trash rack locations provided information about distribution of shad along the trash racks;

--Mobile hydroacoustic surveys were done on two dates during the study to characterize the pattern of fish movement into the York Haven forebay;

--Current direction and velocity were studied under two operating modes: units 1-3 operating and units 1-3 shut down;

--The trash sluice was evaluated for fish passage under the same operating modes as the current study and at dawn and dusk;

--Distribution of shad seen hydroacoustically and visually at the trash racks was concentrated toward unit #1 (highest trash rack velocity). Approximately 78% of the targets counted were at unit #1. The smallest percentage, 5% was recorded at unit 16-17;

--When units 1-3 were shut down the shad could be seen visually moving away from unit #1 toward unit #4 and acoustically observed in higher concentrations at the unit #5-6 transducer location. When units #1-3 were turned on the shad moved back toward unit #1;

--Shad were observed moving through the forebay along the western side of the forebay along a specific path;

--Shad movements into the forebay seemed to be slightly higher at night than during the day with the greatest movement occurring at dusk;

--The mobile hydroacoustic surveys showed targets (fish) throughout the upper forebay. More targets were found on the east side during the second mobile survey;

--American shad were most abundant in the upper three-fifths of the water column;

--An average index of 10,600 targets (fish) per day passed into the forebay during the study period, as measured by the forebay monitoring station;

--The position and angle of the transducer at the forebay monitoring station showed that juvenile American shad only moved downstream during the study;

--American shad juveniles were seen (visually) to hold position in front of the trash racks at unit #1 before passing through even though the velocity was as high as 4 ft/sec;

--No statistically detected differences were found for fish passage through the trash sluice under any of the tested scenarios;

--No direct relationship based on environmental factors could be correlated to fish movement;

--Average rates of fish passage through the trash racks were greater at dawn and dusk than during the day or nighttime;

--Three periods of peak movement were detected by the forebay monitoring site, occurring on October 15-16, October 20-21, and November 2-3.

2. Introduction

2.1 Plant Description

The York Haven Power Station is located on the Susquehanna River in York Haven, Pennsylvania. It has 20 turbines consisting of 13 units with Francis runners and 7 with Kaplan runners. The rated capacity is 19,600 kilowatts using approximately 16,000 cubic feet of water per second (CFS). The effective head is between 22 and 23 feet.

The York Haven Power Station is oriented almost parallel to the flow of the river. As water enters the intake forebay, it must turn towards the east to enter the turbines. The York Haven Power Station is the first Susquehanna River hydroelectric plant that the emigrating shad must pass on their journey to the sea. Presently, the means of fish passage at the York Haven facility is through the operating units, or over the dam crest at the times when spillage occurs, or through the trash sluice during cleaning operations.

2.2 Hydroacoustics

Fish monitoring, through the technique of hydroacoustics, involves propagating sound energy in an aquatic environment and then processing the resulting echo signals to estimate target (fish) density or numbers. The acoustic equipment produces an electrical signal of a specific frequency, amplitude and duration at the terminals of a transducer, which converts the electrical signal into a dynamic pressure wave of a corresponding frequency, amplitude, and duration. When this pressure wave (or pulse) encounters an object or target whose acoustic properties are different from those of water, a portion of the acoustic energy is reflected or scattered back toward the pulse source. When the backscattered echo hits the transducer, an electrical signal is produced which, after processing, indicates the presence of an object within the acoustic beam.

The acoustic pulse generated by the transducer radiates spherically through the water. The radiated energy is greatest along the transducer acoustic axis (perpendicular to the transducer head) and varies off-axis as a function of the transducer's directional properties (directivity function). The directivity function is the angular width between the acoustic axis of the transducer and the point at which the acoustic intensity is reduced to a specified level. For example, a 10° half-power-beam-width transducer has a directivity such that at a point 5° off the acoustic axis, the acoustic intensity is half the value of the intensity at a point on-axis and the same distance from the transducer (Lozow, 1979).

The pulse echo received at the transducer contains information in the form of differences in amplitude, frequency, duration and time delay between pulse transmission and reception. The time period between transmission and reception is directly related to the distance between the transducer and the target. Changes in frequency indicate a Doppler shift, or movement towards or away from the transducer. Amplitude of the signal is an indication of the intensity of the received echo, thus producing an indication of the size of the target. A smaller target will produce an echo with a smaller amplitude than a larger target. Duration of the signal echo produces information on the density of multiple targets within the acoustic beam. For example, if a single fish target were insonified, (or struck by an acoustic signal) the echo signal would have (in addition to a particular amplitude) a time duration on the order of the transmitted pulse duration. If several targets were packed tightly together, the echo-signal envelope (a curve which bounds the peak amplitudes of the echo signal) would have a larger amplitude than a single target, but would still have a time duration on the order of the transmitted pulse. Conversely, if the targets were uniformly distributed within an insonified volume, the echo-signal envelope could have a time duration considerably longer than the transmitted pulse, as the target echoes would be arriving in a random sequence (Suomala and Lozow, 1979). The fundamental requirement for echo counting is the combined ability of the hydroacoustic apparatus and the received-echo signal processor to resolve or distinguish between the objects to be counted, and then to perform the counting function. At York Haven, counts from the earliest equipment tests (BWEC, 1986) indicated the presence of relatively uniformly-sized targets passing through the intake forebay.

In theory, the acoustic echo signal is the product of the mean target density and the mean backscattering characteristics of the individual targets within the insonified volume.

Estimations of target density should therefore be proportional to the number of the insonified targets. However, data obtained from an echo integrator represent energy scattered not only from fish targets, but from other scatterers in the insonified volume (e.g., plankton, air bubbles, debris) as well as from other sources of extraneous noise (Suomala & Lozow, 1979). At York Haven, debris, air bubbles, and interference from turbulence were not factors which biased the study because of the low amount of debris, and the transducer placement to avoid air bubbles and turbulent flow.

The acoustic/sensor processor described in the Materials section of the 1986 report (BWEC, 1986) is capable of producing useful indices of target flux density for either single (resolved) or multiple (unresolved) targets. The correlation between actual target enumeration and the processor-derived estimation is a function of fish target species, target density, size, and velocity of the fish moving through the detection zone of the acoustic sensor. The last two variables are entered as estimates in the processor, and can be easily changed in the processor at the option of the observer in real-time. The software program, in fact, permits the entry of a number of variables that can change not only between sites but also at the same site. Target speed, target densities, and ranges of detection and background noise, among other variables can change due to variations caused by project operating procedures and natural variations in flow conditions at hydroacoustic sampling sites that would make it necessary for the operator to enter appropriate variables specific for the site conditions.

There are two general types of freshwater hydroacoustics applications: fixed-location and mobile surveys. A fixed-location study is one in which a transducer is mounted to a stationary object, and the water volume moving past this location is sampled. A mobile survey is one in which the transducer and acoustic sensor/processor are mounted onto a boat or barge so that acoustic samples are taken along a transect or type of route along the surface of the body of water.

There were several objectives to the study at York Haven. All were concerned with determining the pattern of movement of downstream migrating juvenile American shad. Movement patterns sought included movement into the forebay area, both on a daily basis and over the course of the migration period. Another objective was to determine the distribution, both spatially and temporally of the juvenile shad within the forebay area. The final objective was to determine the avenues which juvenile shad used to exit the forebay. Possible exit routes include the operating units, the trash sluice gate or the spillway during spill events, and going back upstream.

Objectives were addressed in four phases. The detection of fish targets entering the forebay was done using a fixed-location transducer aimed across the forebay entrance. Thus, fish entering the forebay would cross the path of the transducer beam and be "detected" by the sensor/processor unit. This location was sampled continuously to determine relative numbers of shad moving into the forebay and the direction of fish movement. Distribution of shad in the headrace and forebay areas was studied using a mobile survey. The transducer and sensor/processor was mounted to a boat and transects run. Movement of shad out of the forebay was studied in two parts, movement through the unit intakes and movement through the trash sluice. Movement of shad through the intakes was examined using several fixed-location transducers mounted at the base of the trash rack structures so that the transducer beam was aimed vertically. This set-up allowed information to be collected such that it was possible to examine the distribution of shad along the trash racks, over time, and under varying plant operating conditions. Vertical distribution of shad within the water column could be observed directly from the acoustic sensor/processor. Movement of shad through the trash sluice was examined to determine the effectiveness of the trash sluice as an alternate route for shad emigration. A fixed-location transducer with the beam aimed horizontally across the opening of the trash sluice was used with a sensor/processor to determine the relative numbers of shad utilizing this avenue under various times and operating regimes.

Differences in current and flow may influence the distribution of shad. It was believed from observations made during 1985 that substantial differences in water flow patterns exist during different modes of operation. A program designed to detect water directional movement and velocity was conducted at York Haven concurrent with the hydroacoustic monitoring. The impact of two modes, units 1-3 operating and units 1-3 shut down, on the flow pattern in the power plant forebay were tested in October, 1986.

As part of the study program, several environmental parameters were measured to test correlation with shad movement. Environmental parameters which were collected include water temperature, air temperature, river discharge, water clarity and light intensity. Correlation of any of these parameters with fish movement into the forebay area may aid in determining when to implement fish passage techniques. The examination of environmental parameters, as well as the current study, were utilized to help meet the objectives of determining spatial and temporal fish distribution.

3. Materials and Methods

3.1 Hydroacoustic Monitoring

3.1.1 Equipment and Site Locations

The 1985 report to SRAFRC by Barnes-Williams Environmental Consultants presents a description of the hydroacoustic equipment complete with diagrams and operational theory. These materials and methods describe the applications specific to the York Haven Power Station in 1986.

A total of four sensor/processor systems were used throughout the study. Two of the systems consisted of Koden CVS-8800 Acoustic Sensors connected to a Commodore SX-64 portable computer with a dot-matrix printer. The other two systems consisted of Koden CVS-88 Acoustic Sensors each connected to a Commodore C-64 and dot-matrix printer. All four systems contained identical signal processing software. These systems were individually labeled to facilitate detecting differences between the acoustic sensors and compensating for those differences in the data analyses. The systems were calibrated against each other by suspending a target of known size and acoustic characteristics and generating mean output values for each machine.

Four 10° half-power beam width transducers were attached to the base of the trash racks, one each in front of units 1, 5-6, 10, and 16-17. They were all placed such that the transducer beam was directed vertically (Figure 3.1-1). The transducer cables were attached to the trash rack bars and extended up to the walkway above the trash racks. Identical "quick-connect-disconnect" plugs were attached to the ends of the transducer cables. The partners to those plugs were attached to each sensor/processor system to facilitate connection of the transducer cables to the sensor/processor units.

A fifth 10° beam width transducer was mounted to a length of pvc pipe and suspended approximately midwater in fixed-location such that the signal beam projected across the entrance of the forebay (Figure 3.1-1). The position and direction was such that the signal beam was projected almost perpendicular to the flow as it entered the forebay. The slight deviation of the signal beam from a perpendicular angle to the flow allowed information to be collected concerning the direction of movement of targets into or back out of the forebay.

A sixth 10° transducer was mounted on a length of pvc pipe and suspended in the water such that the signal beam projected horizontally and directly across the opening of the trash sluice (Figure 3.1-1). This transducer was used during the study phase determining the effectiveness of the trash sluice as a fish passage facility.

A seventh 10° transducer was mounted on a work boat owned by the power station and used in the mobile survey phase of the study. The transducer was mounted approximately 6 inches beneath the water surface and positioned such that the signal beam was aimed down 45° from horizontal and perpendicular to and away from the direction of travel by the boat (Figure 3.1-2).

Mobile surveys were conducted twice during October 1986 at York Haven, during the weeks of October 13 and October 20.

3.1.2 Trash Racks - Data Collection and Analyses

Data collection was scheduled to begin during the week of October 6, 1986 and end on October 31, 1986. Although data collection began on October 8, it did not commence at all locations until October 13. Data collection continued until November 4, 1986.

Three sensor/processor units were scheduled to be collecting data at three of the four trash rack sites for each sample day. One sensor/processor unit was always reserved to collect data at the forebay entrance site. A sample day consisted of the 24 hour period beginning at 12:00 noon and ending at 12:00 noon the next day. The equipment was rotated each day to collect data from each site by each sensor/processor unit at least once.

A data set consisting usually of 1000 samples was generated by each operating sensor/processor unit approximately every 30 minutes. The data were reported as flux density. Flux density is the number of targets that pass through a cross-sectional area per unit time (targets/meter^2 /hour). Possible causes of variation in relative flux density values include trash rack location (transducer locations 1, 5, 10, 17), time of day (dawn, daytime, dusk, and nighttime), and differences between sensor/processor units. An analysis of variance was run to statistically determine variability between sites and sensor/processor units (Table 3.1.2-1). Another variable for consideration is the behavior of the shad in front of the trash racks. The shad exhibited the ability to hold position before passing through the trash racks, even where the current was as high as 4.0 ft/sec.

3.1.3 Forebay Entrance Site - Data Collection and Analyses

A sensor/processor was set up at the forebay entrance site almost continuously from the start of the study to the end. Interruption of data collection at this site included times when the sensor/processor units were changed, during calibration tests and during unit component failure. The data collected were examined to detect possible trends in fish movement over time. An analysis of variance was run to determine the variability of relative fish movement over the course of a day. Pearson's correlation matrix (Madigan and Lawrence, 1982) was used to test for correlation between fish movement and water temperature, air temperature, river discharge, and percent sunlight. Water temperature, air temperature, and river discharge data were obtained from daily logs completed by personnel at the York Haven Power Station. Percent sunlight values were collected from the nearest available site, which was the National Weather Service at Harrisburg, Pa.

3.1.4 Mobile Survey - Data Collection and Analyses

A transect was set up to encompass the forebay and headrace areas to detect any patterns or concentrations of fish as they entered the forebay. Transect locations are shown in Figure 3.1-2. The mobile survey was done twice during the study period. The acoustic sensor screen was periodically videotaped during the mobile surveys so that a permanent record of the survey would be available. The data collected and observations made were subjective only, and could not be statistically tested in any way.

3.1.5 Spill Tests - Data Collection and Analyses

The spill test through the trash sluice was such that three variables were tested for affecting shad usage of the sluice. These variables were time of day (dawn or dusk), time after opening of sluice gate (first or second hour), and operating regime (generating units 1-3 on, units 1-3 off). Dawn and dusk periods were used because the shad seem to be most active at these times. Time after opening of sluice gate was included because there were some questions concerning whether the shad would use the sluice gate immediately or after the gate had been opened for some time. Differences in operating regime were tested to determine whether fish were more likely or less likely to use the trash sluice when the first three generating units were left operating. An analysis of variance was calculated using the different combinations of time of day, time after sluice gate opening and operating regime as shown in Table 3.1-1.

3.2 Current Direction and Velocity Study

3.2.1 Direction and Velocity

A current study was conducted in the intake forebay of the York Haven Power Station on October 29, 1986. The study was designed to investigate the direction and velocity of water movements under two modes of operations; with units 1-3 operating and with units 1-3 off. During the first part of the study all units were operating except 12, 18, and 20. For the second part of the study units 1-3 were shut down while the rest of the operation remained the same.

Six drogues were released at even spacing across the intake forebay at the location of the two navigation buoys (Figure 3.2-1). In addition, velocity measurements were taken at 6 locations and two depths along 4 transects perpendicular to the powerhouse extending to the west side of the forebay (Figure 3.2-1). The velocity measurements were taken with a Marsh-McBirney Model 201 current meter. Location A on each transect was used to measure the velocity at the trash racks. Locations B-E were used to measure the current velocity and direction for the purpose of mapping the patterns in the forebay.

4. Results

4.1 Hydroacoustic Monitoring

4.1.1 Results of Trash Rack Monitoring

Data were collected for 58 out of 66 possible machine-days during the study period. Only 8 machine-days were lost due to equipment malfunction such as trash over the transducers or excessive interference from the turbines. The mean flux density (number of targets per square meter of trash rack area per hour) at trash rack site #1 was 2.335 targets/m^2/hr over the entire study period (Table 4.1.1-1). Daily average values ranged from a maximum of 7.97 targets/m^2/hr to a minimum of .11 targets/m^2/hr. Individual data set values ranged from 11.4 targets/m^2/hr to .02 targets/m^2/hr (Table 4.1.1-2). The mean flux density at trash rack site #5 was .381 targets/m^2/hr with daily averages ranging from 2.43 targets/m^2/hr to .02 targets/m^2/hr. Individual data set values ranged from 9.4 targets/m^2/hr to 0 targets/m^2/hr (Table 4.1.1-3). The mean flux density at trash rack site #10 was .13 targets/m^2/hr with daily averages ranging from .85 targets/m^2/hr to .003 targets/m^2/hr. Individual data set values ranged from 4.5 targets/m^2/hr to 0 targets/m^2/hr (Table 4.1.1-4). The mean flux density at trash rack site #17 was .16 targets/m^2/hr with daily averages ranging from .58 targets/m^2/hr to .01 targets/m^2/hr. Individual data set values ranged from 1.3 targets/m^2/hr to .002 targets/m^2/hr (Table 4.1.1-5).

Distribution of targets along the trash racks was concentrated toward trash rack site #1. Approximately 78% of the fish targets counted were counted at site #1, 13% at site #5, 4% at site #10 and 5% at site #17. The fish seemed to be congregating at a point farthest downstream along the trash racks. The shad also seemed to congregate in front of the units which were operating at the time. This was first noticed during the spill test experiments. With units 1-3 operating, schools of shad could be seen, visually in the water and detected on the sensor screens. Most fish seen and detected were in front of unit #1, while few fish were in front of unit #5. When units 1-3 were turned off for the spill test, the schools of shad could be seen moving away from unit #1 toward unit #5. After this movement, the fish exhibited the same behavior as they did at unit #1 when unit #1 was operating. The fish were seen to be maintaining a somewhat stationary position immediately in front of the trash racks, swimming "upstream" at a speed equivalent to the water velocity at the trash racks. As soon as units 1-3 were turned back on, the fish were seen to move along the trash racks back to unit #1. When all the units were on, the sensor screen at unit #5 was almost empty, while the sensor at unit #1 was full of targets. When units 1-3 were off, the sensor screen at site #5 showed many targets, while the sensor screen at unit #1 was almost empty.

Although the estimates of flux density of shad at the trash racks were calculated to compare relative passage rates at the different points along the trash rack, an exercise in estimating the total number of shad passing through the units was possible by manipulating the calculated mean flux densities at the trash rack sites. With approximately 39 m^2 of cross-sectional area in front of each unit, an average of 8,744 targets passed through units #1 through #4 per day through the study period, (2.335 targets/m^2 /hr x 39 m^2 /unit x 4 units x 24 hrs) 1,785 targets/day through units #5 through #9, 605 targets/day through units #10 through #14 and 760 targets/day through units #15 through #19. Adding together the average number of targets per unit, approximately 12,000 targets/day passed through the York Haven Power Station each day during the study period. This "index" of fish numbers may be used to compare relative fish passage from year to year if monitoring were to continue.

Qualitative assessment of diel variation in flux densities indicates that the shad are more active at night than during the day, with peak movement occurring just before dawn.

Diel movement of shad at the trash racks was studied by dividing a sample day into six time periods. These time periods were classified as afternoon, dusk, early evening, late night, dawn and morning periods. Samples started between 1:00 PM and 4:59 PM EDT were considered afternoon samples. Dusk samples were collected between 5:00 PM to 7:59PM EDT, while early evening sampling occurred between 8:00 PM and 12:59 AM EDT. Late night samples were taken between 1:00 AM and 5:59 AM EDT. Dawn samples were taken between 6:00 AM and 8:59 AM EDT, and morning samples were taken between 9:00 AM and 12:59 PM EDT.

Mean flux densities were calculated for each time period from data collected at unit #1 and unit #5. These results are shown in Tables 4.1.1-6 and 4.1.1-7. Mean flux densities calculated for the time periods at unit #1 were extremely variable, ranging from 9.9 to .05 fish/m^2 /hr. This high degree of variability within each time period overwhelmed detection of statistical differences in time period flux densities.

At unit #5, mean flux densities were less variable after October 20. An analysis of variance run on these data show a statistical difference at $p \leq .05$ (95% significance level). As shown in Figure 4.1.1-1, there were peaks at dawn and dusk with lows during the daytime and nighttime periods.

4.1.2 Forebay Monitoring

Data from this portion of the study was collected almost continuously from Oct. 15 through Nov. 3, 1986. Mean daily flux density values ranged from 2.323 targets/m^2 /hr on Oct. 15 to .339 targets/m^2 /hr on Oct. 26 (Table 4.1.2-1). Cross sectional area acoustically sampled was approximately 187 square meters. The average daily flux density over the length of the study period was .687 targets/m^2 /hr. Assuming a total cross-sectional area of 645 m^2 at the monitoring site, an index of approximately 10,600 targets/day passed into the forebay.

The variability of the daily mean flux density values was tested for correlation with certain environmental parameters such as river discharge, water temperature, daily high air temperature, daily low temperature, and percent sunlight

(Table 4.1.2-2). The results are shown in a Pearson's correlataion matrix (Table 4.1.2-3). Julian days were used as a dummy variable to test for linear changes over time. Generally, a correlation value of .8 or higher is considered a high coefficient, a value around .5 is considered moderate, and a value of .3 and below is considered a low coefficient. For the 20 samples used in the correlations, the 95% significance level of the coefficient was .444, while the 90% significance level of the coefficient was .378 (Downie & Heath, 1970). Under these conditions there were significant correlations at the 95% level for water temperature and river discharge, low air temperature vs. discharge, Julian day vs. discharge, and Julian day vs. water temperature. The high correlation with the dummy variable Julian Day indicates that river discharge and water temperature both decreased steadily throughout the study. Thus, river discharge vs. water temperature would indicate a high correlation while possibly having no direct cause/effect relationship. This same generalization can be made for the correlations with mean flux density which are significant at the 90% level. Since the mean flux density was correlated with Julian day, it should also have been correlated (at the same magnitude) with river discharge and water temperature (which it was). The data collected in 1986 could not be interpreted to draw definite conclusions as to a predictive correlation with environmental parameters.

Shad targets entering the forebay were concentrated in an area of water approximately 15-25m away from the transducer face. This band of fish movement coincided with a water velocity band of approximately 1.5 ft/s (Figure 4.1.2-1). Under varying operating regimes, the band of water with a velocity of approximately 1.5 ft/s was wider or narrower, and the band of fish targets seen on the sensor screen would be correspondingly wider or narrower.

The side scan monitoring of shad moving into the forebay was also used to determine directional movement of the fish. The transducer was aimed obliquely to the direction of flow and shad movement. Thus shad would enter the hydroacoustic beam farther from the transducer and leave the beam closer to the transducer if they were moving downstream and vice versa if they were moving upstream. Throughout the study the directional movement was visually monitored on the chromoscope of the hydroacoustic set-up. Fish movement always was found to be downstream, in the direction of the water movement. At no time were fish observed to be moving upstream out of the forebay. The side scan transducer was able to monitor a cross section all the way across the forebay to the trash racks for this purpose.

Some of the data collected in the daily side scan sample sets were biased by interference from the work barge pulling out of the forebay in the mornings and pulling into the forebay in the afternoons. Samples which seemed to be greatly interfered with (an unusually high MFD value) were removed from the data sets before continuing the analysis. To provide for enough samples for a statistical analysis, the sample days were divided into six time periods as follows. Afternoon samples were those data sets which were collected starting between 1:00 PM and 4:59 PM EDT (12:00 - 3:59 PM EST). Dusk samples were taken from 5:00 PM to 7:59 PM EDT. Evening samples were taken from 8:00 PM to 12:59 AM EDT. Late night samples were taken from 1:00 AM to 5:59 AM EDT. Dawn samples were taken from 6:00 AM to 8:59 AM EDT, and morning samples were taken from 9:00 AM to 12:59 PM EDT.

Mean flux densities for each time period and for each day in the study period are shown in Table 4.1.2-4. These results indicate that the shad move at all times of the day, with a slightly higher ratio occurring at night than during the day. The shad seem to be moving at the greatest rate at dusk and just before dawn, with the fewest shad moving in the morning, after dawn. Statistical significance of these differences was masked by the occurrence of certain days in which fish passage rates were much higher than average. These large peaks occurred on October 15-16, October 20-21, and November 2-3. Thus, two different cycles are shown in this data - one seasonal and one daily. Three seasonal peaks in movement are seen in the data - one at the beginning of the study, one in the middle, and one at the end. Figure 4.1.2-2 shows the mean flux density of the shad over the six daily time periods. Line A depicts the mean flux density averaged over the entire study period. Line B shows the average mean flux density after removing the seasonal cyclical high data values. With the seasonal variation removed, the data now indicate a slight peak of movement at dusk, while the rates of movement remain remarkably steady throughout the rest of the day. Also, during the seasonal high days of fish movement, the shad moved primarily at night with peaks at dusk and just before dawn.

4.1.3 Mobile Surveys

The mobile survey conducted on October 16, 1986 at 4:00 p.m. found very few fish targets in the upper forebay on either the west side or the east side of the forebay. No schools of fish were seen entering the powerhouse area. American shad were present in the forebay along the trash racks in front of units 1 and 2. In addition, shad were found near the west side of the forebay by the transformer house.

The second mobile survey was conducted on October 21, 1986 when many more American shad were in the York Haven forebay. Targets were seen throughout the length of the mobile survey transects upstream of the powerhouse. Higher concentrations of targets were observed along the east side of the upper forebay. The east side of the forebay is generally deeper than the west side of the forebay. However, most of the targets were observed in the upper half of the water column.

The survey observations showed that when fish density was higher, the fish generally tended to move toward the western side of the forebay as they entered the powerhouse area. Here fish were observed along a line about 15-20 meters in front of the transformer house, both during the mobile survey and by the forebay monitor.

4.1.4 Spill Test

The mean flux density of shad moving through the sluice gate was 10.3 targets/m^2/hr. Values ranged from 35.4 target/m^2/hr to .2 targets/m^2/hr. This variation may have been due to a schooling effect (the shad passed through in schools) or to differences in plant operation, time of day, or length of time the sluice gate had been opened.

A total of eight tests were run, generating from 4 to 7 data sets per test (Table 4.1.4-1). Variables which were tested included time of day (dusk or dawn), length of time the sluice gate had been opened (first hour or second hour) and operating regime (units 1-3 on or units 1-3 off). Statistical comparisons were made by calculating three two-way ANOVA's comparing each variable with the others. The results (Table 4.1.4-2) show that, although there are slight differences between the variables, they are not statistically significant differences ($p \leq .05$). Although differences were seen between having units 1-3 on or off, the analyses were not conclusive in that area. In general, flux density was higher at dusk than at dawn, was higher during the second hour after opening the trash sluice, and showed no difference whether units 1-3 were on or off.

Several other observations were made during the spill test concerning fish congregation and distribution. With units 1-3 on, only a few fish could actually be seen passing through the sluice gate, while many fish could still be seen hovering in front of the trash racks at unit 1. These fish could be seen both by eye and on the sensor screen present at unit 1. At this same time, very few fish could be seen hovering in front of the trash racks at unit 5, either visually or by the sensor equipment. When units 1-3 were shut down, the schools of shad in front of the trash racks at unit 1 moved along the trash racks until they were in front of units 4 and 5, which were operating. At unit 1, not one fish could be seen hovering in front of the trash racks, and the sensor equipment did not detect any fish. At the same time, schools of shad could now be seen hovering in front of unit 5, both by sight and by the sensor unit. Figure 4.1.4-1 shows the mean flux density of shad at unit 5 for a 24 hour period during which a spill test was run. For the majority of the time, very few fish passed through the trash racks at unit 5. The large peak in flux density at unit 5 coincided exactly with the time when units 1-3 were turned off. As soon as units 1-3 were turned back on, the shad were seen moving along the trash racks back to unit 1, the flux density at the unit 5 sensor decreased, and the flux density at the unit 1 sensor increased.

4.2 Current Direction and Velocity Study

The drogue study provided information about the direction of water flow throughout the intake forebay. With units 1-3 operating, the drogues released traveled into the intake forebay staying evenly spaced until they made contact with the trash racks. The drogue closest to the east wall came into contact with the trash racks at unit 13 after following the outside of the turbulent flow at the end of the powerhouse. The other drogues landed at unit 8, unit 3, unit 1 and just past unit 1. The drogue closest to the west wall moved the slowest. It also became trapped in an eddy near the end dam (Figure 4.2-1).

The drogue study performed with units 1-3 off was similar in general patterns except that the drogues landed farther up the trash racks at units 13, 10, 7, 5, and 3 (Figure 4.2-2). One drogue, the second from the west wall, crossed over the paths of the closest one to the west wall and became trapped in the still water near the trash sluice.

Velocity measurements for the two study modes are presented in Tables 4.2-1 and 4.2-2. The current velocity, with units 1-3 operating, at the trash racks varied throughout the length of the trash racks. At unit 17 the velocity at the racks was 0.25 ft/sec and increased to 4.1 ft/sec at unit 1. When units 1-3 were shut down, the velocity ranged from a low of 0.5 ft/sec at unit 1 to a high of 2.3 ft/sec in front of units 5 and 17.

The velocity of water in the total forebay changed considerably, as would be expected, when units 1-3 were shut down. A much larger "still" water area became evident at the downstream end of the forebay. The current velocity for transect 1 ranged from a high of 0.5 ft/sec at the trash racks to 0 at the locations in the forebay. With units 1-3 operating the currents were much more pronounced in this region (Tables 4.2-1 and 4.2-2).

5. Discussion

5.1 Hydroacoustic Monitoring

5.1.1 Trash Racks

The monitoring of the fish behavior along the trash racks provides an integral part of the picture of juvenile American shad movement past the York Haven Power Station. As shown by the results of the sampling program the units farthest downstream had the greatest preponderance of juvenile American shad no matter what the operating scenario was. When units 1, 2, and 3 were operating, the fish would concentrate in this area of the trash racks. When these units were shut down, the shad would move up the trash racks to the operating units. During one of the transducer maintenance scuba diving operations when units 1 through 7 were shut down, the fish were observed by units 9-10. Visual observations of fish presence supported the hydroacoustic data. Water clarity during most of the study period allowed the field personnel to see as much as 5-6 feet below the surface of the water and juvenile American shad could be visually verified if large numbers were acoustically detected.

Although fish would concentrate at the farthest downstream units it does not appear that they followed the trash racks to this location. The side scan and mobile hydroacoustic information show that the majority of fish enter the forebay area in front of the plant along a path that leads them to the trash racks in front of units 1, 2, 3 and 4. The current study shows that the velocity along this path is about 1.5 ft. per second (Figure 4.1.2-1).

An analysis of the data shows that it can be expected that about 74% of the fish that enter the York Haven forebay arrive at the trash racks in front of units 1-4. Data from the 24 hour study conducted at unit 3 in 1985 confirms that the passage rate at unit 3 is as high as unit 1 was in 1985 (BWEC, 1986). The fish passage through units 1-9 could represent as much as 88% of all of the fish that enter the York Haven forebay. It is interesting and important to know that the fish behavior at York Haven is such that the fish move to the farthest downstream operating units. Future sampling programs and, more importantly, mitigation efforts at York Haven can be focused on this area of the power station.

The ability of the juvenile shad to hold position in front of unit #1 even though the measured velocity was about 4 ft/sec is important in understanding the limits of their swimming ability. This holding ability may have accounted for an overestimate of juvenile shad at the unit #1 location; however, the overall calculated estimate compares favorably with the forebay monitoring site indicating that the overall index is appropriate and within the limitations of the equipment.

5.1.2 Forebay

The forebay monitoring site was selected after careful evaluation of the available locations at York Haven. Construction activity on the west wall and water turbulence at the end of the power house precluded these sites from useage. The transformer house location was selected because it was possible to acoustically examine the entire width of the forebay.

Another reason for selecting this site was the apparent path of the influx of juvenile American shad. As stated in the results, side scan hydroacoustic samples were collected over 24 hour periods from October 15 through November 3, 1986. Over 30 samples per day were collected resulting in over 600 total samples. It is estimated that an average index of 10,600 targets (fish) per day passed into the forebay near the power house. The hydroacoustic data provides an index of American shad passage and not absolute numbers because of several factors. The hydroacoustic beam does not sample the entire water cross section and the data must be extrapolated for the entire cross section. The degree of precision of the hydroacoustic equipment is dependent on several variables such as orientation of the targets to the beam and/or location of targets in the beam, and the grouping of targets as they pass through the hydroacoustic beam. However, as an index of fish passage the results are useful and should be reproducible. The fish monitoring program at York Haven consisted of 2 separate, but related programs; the forebay monitoring site and the trash rack monitoring sites. The results of the trash rack monitoring sites compare very well with the forebay monitoring site. At the trash racks it was estimated that a shad passage index of 12,000 fish per day existed throughout the study period, while an index of 10,600 fish per day was estimated for the side scan. It should be possible to repeat this experiment in the future and get an index that will allow the comparison of fish emigration from year to year.

Another important finding of the forebay monitoring program was the location and direction of the shad emigration route through the forebay. This information, coupled with the flow direction and velocity measurement study and substantiated by the mobile hydroacoustic surveys, shows that juvenile American shad are very specific in their path through the forebay near the power house. The mobile survey also showed that there was no specific path for the juvenile shad in the upper forebay. It appears that the juvenile shad move to the western side of the forebay as they enter the region near the power house and continue on a path that leads them to the farthest downstream operating units. The current velocity along this path is 1.5 ± feet per second until the trash racks are reached. Also, the side scan forebay monitoring showed that the directional movement of juvenile shad was always downstream during the study in the lower forebay area. This finding shows that the shad do not exit the forebay by moving back upstream and that they do not circle in the forebay. Any upstream or circling movement would be easily detected hydroacoustically. Any planning to pass fish around the hydro station without having them go through the units should be designed around these findings and the location of fish at the trash racks.

Fish emigration over the period of study as represented by Figure 5.1.2-1 shows that the beginning of the study was marked by a high flux density value which dropped off rapidly. The remainder of the time the flux density remained around .6 targets/m^2/hour with two peaks of around 1.0 to 1.2 targets/m^2/hour.

The initial high value was coincident with the only flow event of the study period. Heavy rains resulted in significantly higher flows for the preceding week. However, our data collection caught only the tail end of this event so no conclusions can be drawn at this time. For other species of clupeids emigration of juveniles may be initiated by the combination of a flow event and a coincident decrease in temperature (BWEC, 1987). This could be a factor for the American shad on the Susquehanna River also. Discharge, water temperature, and study day are all shown to be correlated to the mean flux density at the 90% confidence interval. However, both water discharge and temperature decreased over the study period. Aside from two small peaks, it appears that the fish continued emigrating at a relatively constant rate throughout the study.

The movement of the work barge into and out of the forebay caused some problems with the analyses of the diel movement of American shad at York Haven.

The examination of the side scan data for 24 hour periods throughout the study show that no statistical differences occurred during the daily time periods examined. However, on days when abnormally high numbers of shad are removed from the data set a peak in shad movement occurs at dusk. This corresponds to the trash rack monitoring site (unit #1) which also had a peak at dusk. The trash rack site had an additional smaller peak at dawn.

5.1.3 Mobile Surveys

The mobile surveys were used to supplement the hydroacoustic data collected at the fixed locations. With the mobile surveys it was possible to examine the forebay area for fish concentrations while the fixed transducers were collecting data on fish concentrations at many locations along the trash racks and within the forebay near the power house. The results of these efforts did not show any large concentrations of shad in the upper forebay during the survey on October 16, 1986. In fact, fish were observed throughout the forebay and not concentrated in any area except near the units 1-2 trash racks and along the west side of the forebay near the transformer house.

The mobile survey conducted on October 21, 1986 again showed fish distributed throughout the forebay; however, they were seen in greater numbers than on October 16, 1986. On the 21st, the concentration of fish seen at the trash racks was nearly twice that seen on October 16. The downstream movement in the upper forebay during these periods of higher American shad emigration appears to be greater on the east side but swings to the west side in the forebay area in front of the power house. The current study information and side scan hydroacoustic data from the location near the transformer house all support these findings. These data show that the shad move into the forebay along a narrow band near the west wall. Cast net samples taken in this area confirmed the presence of shad in the exact area scanned hydroacoustically.

5.1.4 Spill Test

The overall mean flux density of shad moving through the trash sluice was generally higher than the mean flux density at the trash racks. Under the present circumstances, the mean flux density at the trash sluice was not high enough to consider the sluice as an efficient way of passing juvenile shad around the power plant. Individual data set values, however, indicated that the trash sluice has the potential to pass many more shad.

The shad were seen to congregate in front of the trash racks at the units which were in operation at the time. Seemingly, the fish prefer a somewhat high water velocity to be in, since they are attempting to migrate downstream to the ocean. The opening to unit 1 is approximately 20 feet from the trash sluice, and also at a 90° angle to it. This distance was wide enough to create a pocket of "quiet" water (0 - .5 ft/sec), where the water velocity was much less than that in front of an operating unit (2.3 - 4 ft/sec) or immediately in front of the open sluice gate (3 - 3.5 ft/sec). Apparently, the shad schools in front of the trash rack units were not motivated to move through the "quiet" water and hover in front of the sluice gate opening before continuing downstream with the flow. A possible solution to this problem may be to somehow crowd the shad into the open trash sluice.

5.2 Current Direction and Velocity Study

The current study adds a valuable part to the puzzle of fish behavior at the York Haven Power Station. During normal operation of the power station units 1-3 are usually running. American shad will concentrate in this same area, with very few found upstream beyond unit 5. When the first 3 units are shut down the shad concentrated between units 4 and 10.

Hydroacoustic studies of the forebay also show that the shad move into the forebay along a line similar to the path of the second drogue from the west bank with units 1-3 operating. When units 1-3 are shut down the shad followed a path similar to drogues 3 and 4. An examination of the data shows that the velocities in these areas are in the 1 to 1.9 ft/sec range; with most of the measurements occurring near the middle of that range. At the face of the trash racks, however, the fish concentrate in the area of highest velocity, around units 1-3.

On the 28th of October fish were observed concentrated in a narrow band along the face of the trash racks throughout most of the length of the powerhouse from units 17 to 3. Trash had accumulated for several feet below the surface, clogging the racks and providing shelter. A longitudial current flowing the length of the powerhouse was observed and the velocity was measured. The velocity in this current was 1.3 ft/sec. It appears that the emigrating shad have a velocity preference. They avoid the higher and lower velocities as they approach the power station. However, at the trash racks the highest concentrations were found at the first 3 units where the velocities were the highest.

6. References

Barnes-Williams Environmental Consultants. 1987. Juvenile Blueback Herring Study. Downstream Migration, 1986. For Little Falls Hydroelectric Associates, Little Falls, NY. BWEC. Binghamton, NY.

Barnes-Williams Environmental Consultants. 1986. Hydroacoustic Evaluations of Juvenile Shad Movement and Passage at the York Haven Power Station; Susquehanna River, Pennsylvania. October-November 1985. In Annual Progress Report. Restoration of American Shad to the Susquehanna River, Susquehanna River Anadromous Fish Restoration Committee, January 1986. BWEC. Binghamton, NY.

Downie, N. M. and R. W. Heath. 1970. Basic Statistical Methods. Fourth Edition. New York. Harper & Row. 355 p.

Lozow, J. B. 1979. Transducer Directivity: A Simple Calculation of its Spatial Averages in: Diember, Ferdinand, et. al. (eds.) "Advanced Concepts in Ocean Measurement for Marine Biology." The Belle W. Baruch Library in Marine Science, Number 10, University of South Carolina Press, Columbia, South Carolina.

Madigan, S. and V. Lawrence. 1982. Stats Plus: A General Statistics Package for the Apple II/IIe/IIc. Northridge, CA. Human Systems Dynamics.

Suomala, J. B., Jr. and J. B. Lozow. 1979. Hydroacoustics and Fisheries Biomass Estimations. In: Diemer, Ferdinand, et. al. (eds.) "Advanced Concepts in Ocean Measurements for Marine Biology." The Belle W. Baruch Library in Marine Science, Number 10, University of South Carolina Press.

EDITOR'S NOTE:

Tables 4.1.1-2, 4.1.1-3, 4.1.1-4, 4.1.1-5, and 4.1.2-1 in this report show mean flux density hourly for a single representative date of data collection at the four trashrack monitors and at the forebay monitor. An additional 69 tables of similar data for each day of operation at each site are available for review in Appendix form. Interested parties should contact the Coordinator at 717-657-4547.

TABLE 3.1-1

ANOVA COMBINATIONS USED FOR

SLUICE GATE SPILL TEST

DATE	TEST #	TIME OF DAY	HOUR AFTER OPENING	OPERATING REGIME
10/21	1	DUSK	1ST	UNITS 1-3 ON
10/21	2	DUSK	2ND	UNITS 1-3 OFF
10/22	3	DUSK	1ST	UNITS 1-3 OFF
10/22	4	DUSK	2ND	UNITS 1-3 ON
10/23	5	DAWN	1ST	UNITS 1-3 ON
10/23	6	DAWN	2ND	UNITS 1-3 OFF
10/24	7	DAWN	1ST	UNITS 1-3 OFF
10/24	8	DAWN	2ND	UNITS 1-3 ON

Table 3.1.2-1
ANOVA for Detection of Statistical
Differences Between Sites

Source	Variation SS	df	Mean SS	F-ratio	P value
Between Sites	289.55	2	144.78	14.81	<.001
Between Machines	49.63	2	24.82	2.54	.0903
Total	381.16	39			

Table 4.1.1-1
Calculated Mean Flux Densities (Target/m^2 /hour)
Trash Rack Monitoring Program

Date	Forebay Monitoring Site	Trash Rack Site #1	Trash Rack Site #5	Trash Rack Site #10	Trash Rack Site #17
10/13			2.427	.213	
14				.016	.155
15	2.323			.003	.009
16	1.224	1.379	.103	.051	
17	.510		1.408	.155	
18	.518		1.492	.196	
19	.496			.115	
20	.714		.517		.582
21	.934	2.103	.572	.250	
22	.540	7.965	.028		.051
23	.581		.085	.085	.042
24	.403	1.641	.068	.078	
25	.475	.661	.053	.074	
26	.339	.547	.032	.143	
27	.550	.107	.035	.078	
28	.474	1.218	.038	.045	
29	.553		.035	.853	.095
30	.529	2.229	.126		.204
31	.431	3.529	.028	.019	
11/1	.352	3.217	.022	.024	
11/2	1.109	3.104	.147	.039	
11/3	.675	2.661	.021	.018	
Mean:	.687	2.335	.381	.129	.162

Table 4.1.1-2

Raw Data
and
Calculated Mean Flux Density
Trash Rack #1

OCT 22 HOUR	MVB (*1E-6)	# AT/ ABOVE	# BELOW	MFD
3	4.66	1000	0	9.7021
4	5.02	1000	0	10.452
4	5.14	1000	0	10.701
5	5.49	1000	0	11.430
5	5.14	970	6	10.381
6	9.16	357	259	6.8534
6	2.25	599	132	2.8290
7	5.14	1000	0	10.701
7	5.21	1000	0	10.847
8	4.92	1000	0	10.243
8	4.48	997	3	9.2999
9	4.63	1000	0	9.6397
9	4.7	1000	0	9.7854
10	4.8	1000	0	9.9936
10	4.55	1000	0	9.4731
11	4.49	1000	0	9.3482
11	4.65	1000	0	9.6813
12	4.58	1000	0	9.5356
12	4.57	1000	0	9.5147
13	4.58	1000	0	9.5356
13	4.63	1000	0	9.6397
14	4.2	1000	0	8.7444
14	4.1	1000	0	8.5362
15	4.01	1000	0	8.3488
15	4.07	1000	0	8.4737
16	3.8	1000	0	7.9116
16	3.63	1000	0	7.5577
17	3.71	1000	0	7.7242
17	3.6	1000	0	7.4952
18	3.51	1000	0	7.3078
18	2.39	221	136	1.1233
19	.507	27	89	.04397
19	1.62	73	189	.27907
20	.655	179	354	.30565
20	4.15	802	35	6.9356
21	4.08	1000	0	8.4946
21	3.42	1000	0	7.1204
22	3.21	1000	0	6.6832
MEANS:	4.1435	874.34	31.658	7.9651

NOTE: This table shows mean flux density per hour on October 21 at the Unit 1 trash rack. A similar table is available for each of the 13 days of data collection at this site.

Table 4.1.1-3

Raw Data
and
Calculated Mean Flux Density
Trash Rack #5

OCT 21 HOUR	MVB (*10-6)	# AT/ ABOVE	# BELOW	MFD
3	1.16	25	62	.07350
3	1.07	3	34	.01540
4	1.01	13	22	.03165
4	.787	3	35	.01401
5	1	20	39	.04968
5	.737	10	71	.03347
6	.703	2	47	.01535
6	5.49	869	11	9.3633
7	6.38	873	11	10.931
8	7.57	2	26	.03667
8	.817	2	31	.01151
9	1.58	1	27	.01033
9	1.76	8	41	.03861
10	.997	17	30	.04129
10	0	0	52	.01393
11	7.54	1	36	.02443
11	.965	5	48	.02232
12	.943	2	57	.01897
12	8.31	2	70	.05136
13	1.04	18	50	.05012
13	8.72	3	64	.06847
14	.954	9	79	.03800
14	.963	12	93	.04758
15	.98	8	94	.04056
15	.978	6	120	.04365
16	.831	16	124	.05930
17	.787	24	111	.06679
17	.733	4	71	.02477
18	.853	11	83	.04064
18	.894	103	275	.25431
19	1.15	365	356	.91889
19	1.61	451	217	1.4827
20	1.23	127	163	.35014
20	1.06	44	119	.12338
21	1.16	21	87	.07109
21	.961	17	101	.05910
22	1.04	17	101	.06174
22	1.21	17	132	.07571
23	1	21	125	.07468
0	1.15	25	136	.09283
0	1.23	25	111	.09006
1	1.11	29	100	.08994
1	1.12	17	102	.06467
2	1.16	19	188	.09359
MEAN:	1.8805	74.25	89.818	.57226

NOTE: This table shows mean flux density per hour on October 21 at the Unit 5 trash rack. A similar table is available for each of the 19 days of data collection at this site.

NOTE: This table shows mean flux density per hour on October 21 at the Unit 10 trash rack. A similar table is available for each of the 19 days of data collection at this site.

Table 4.1.1-4

Raw Data and Calculated Mean Flux Density Trash Rack #10

OCT 21 HOUR	MVB (*1E-6)	# AT/ ABOVE	# BELOW	MFD
8	1.83	3	7	.01440
8	3.77	4	9	.03553
9	2.03	3	6	.01528
9	2	1	2	.00503
10	2.48	4	10	.02497
11	1.3	3	6	.01063
11	2.97	7	7	.04685
12	2.24	8	2	.03880
12	3.07	1	2	.00730
13	1.7	2	9	.01075
13	3.56	2	4	.01668
14	8.67	1	6	.02075
14	2.3	7	8	.03730
15	2.17	10	9	.04957
16	1.95	13	12	.05849
17	.808	1	4	.00329
17	1.59	17	10	.06127
18	1.89	20	20	.08804
18	2.3	63	61	.33133
19	3.37	538	257	3.9466
20	2.56	54	40	.30894
20	2.36	48	42	.25679
21	2.67	39	25	.23070
22	2.76	41	18	.24709
22	2.55	40	26	.22657
23	2.45	28	20	.15337
0	2.5	53	29	.29244
0	2.4	67	63	.36584
1	2.23	52	34	.25933
1	1.83	63	64	.26971
2	2.01	66	46	.29947
MEANS:	2.5264	40.613	27.677	.24946

Table 4.1.1-5

Raw Data
and
Calculated Mean Flux Density
Trash Rack #17

NOTE: This table shows mean flux density per hour on October 22 at the Unit 17 trash rack. A similar table is available for each of the 7 days of data collection at this site.

OCT 22 HOUR	MVB (*1E-6)	# AT/ ABOVE	# BELOW	MFD
3	.852	2	33	.01660
3	.942	5	49	.02927
4	1.28	6	31	.02849
4	1.17	10	116	.07046
5	1.03	5	35	.02469
8	1.45	13	102	.08011
8	1.67	9	80	.06335
9	1.67	11	108	.08145
9	1.45	17	109	.09517
10	1.78	23	175	.15569
10	1.44	26	172	.14708
11	1.32	3	70	.03594
12	1.8	10	93	.07477
12	1.87	12	103	.08812
13	1.44	3	32	.02175
13	.904	4	67	.03403
14	1.18	2	12	.00973
14	0	0	6	.00236
15	0	0	22	.00866
15	1.52	2	18	.01353
16	0	0	12	.00472
16	1.57	4	61	.03732
MEANS:	1.1972	7.5909	68.455	.05106

Table 4.1.1-6
MFD's for Daily Time Periods
Trash Rack #1

	AFTERNOON	DUSK	EVENING	LATE NIGHT	DAWN	MORNING
10/21	1.435	2.532	2.594	.557	1.701	2.982
22	3.985	8.774	9.901	8.780	3.996	5.908
23						
24	3.193	1.608	1.254	1.108	1.020	1.610
25	1.272	.423	.737	.286	.275	.885
26	.805	.266	.430	.619	.498	.589
27	.150	.054	.155	.111	.053	.092
28	2.867	1.851	.962	.543	.390	.818
29						
30	7.923	5.293	.347	.482	.467	
31	2.018	2.287	3.964	3.956	4.352	2.872
11/1	2.174	1.926	3.991	3.732	3.991	3.008
2	4.309	2.048	3.407	3.129	2.499	2.615
3	3.147	1.949	2.612	2.875	2.693	
MEAN:	2.778	2.418	2.530	2.182	1.828	2.138

Table 4.1.1-7
MFD's for Daily Time Periods
Trash Rack #5

	AFTERNOON	DUSK	EVENING	LATE NIGHT	DAWN	MORNING
10/17	1.220	1.377	1.354	1.420	1.458	1.628
18	1.734	1.178	1.354	1.350	1.513	1.549
19						
20		2.816	.005	.003	.060	.018
21	.044	.029	.025	.046	.097	.078
22	.076	.031	.012	.003	.072	.044
23	.086	.288	.009	.015	.020	.185
24	.039	.082	.023	.093	.093	.081
25	.025	.037	.027	.067	.149	.045
26	.035	.074	.063	.006	.008	.010
27	.027	.060	.059	.011	.021	.029
28	.051	.036	.023	.022	.078	.037
29	.070	.065	.009	.012	.060	.060
30	.188	.308	.066	.017	.188	
31	.002	.037	.026	.019	.050	.018
11/1	.004	.022	.031	.020	.045	.014
2	.177	.508	.149	.045	.079	.025
3	.010	.028	.035	.008	.029	
MEAN:	.237	.410	.192	.186	.236	.255

Analysis of Variance:
(Without 10/17 - 10/20 data)

Source	Var. SS	df	Mean SS	F-ratio	95% Sig. level
Between	.0704	5	.0141	2.74	2.33
Within	.4103	80	.0051		
Total	.4807	85			

TABLE 4.1.2-1
RAW DATA AND MEAN FLUX DENSITY
FOREBAY MONITORING SITE

OCT 21 HOUR	# AT/ ABOVE	# BELOW	DENSITY	MFD
3	293	707	.186	.865444
4	64	919	.133	.398213
4	305	694	.166	.816114
5	669	331	.18	1.51178
6	941	59	.253	2.79512
6	676	251	.275	2.24925
7	1	938	.121	.306555
7	6	880	.139	.296001
8	196	728	.156	.593345
9	185	744	.164	.595798
9	183	704	.155	.559757
10	276	649	.163	.735689
10	399	559	.181	1.02392
11	309	610	.185	.864985
12	121	706	.168	.466696
12	124	694	.158	.454211
13	196	691	.181	.638442
13	591	406	.186	1.41381
14	560	431	.224	1.60284
15	615	376	.23	1.77163
15	695	302	.229	1.95399
16	803	189	.233	2.24306
16	665	322	.212	1.74858
17	534	444	.235	1.60765
18	677	321	.209	1.75423
18	257	721	.225	.908791
19	353	569	.287	1.36639
19	16	900	.157	.322073
20	24	969	.136	.353288
21	104	885	.186	.513454
21	10	952	.125	.324274
22	0	962	0	.312952
22	0	765	0	.248865
0	3	923	.114	.304253
0	1	926	.114	.302570
1	1	917	.131	.299840
1	38	957	.129	.368483
2	277	723	.143	.697066
2	312	685	.164	.819459
MEANS:	294.359	654.077	.170077	.933561

NOTE: This forebay monitoring was done from October 15 through November 3. This shows hourly mean flux density on October 21. Similar tables for all remaining days are available.

Table 4.1.2-2
Environmental Data Collected
During Study Period

Date	MFD Side Scan	Discharge	Water Temp.	High Air Temp.	Low Air Temp.	% Sunlight	Julian Day
10/15	2.323	13500	59	62	40	78	289
16	1.224	13800	58	60	42	70	290
17	.510	13600	59	55	48	9	291
18	.518	14600	59	58	48	88	292
19	.496	14300	57	61	36	100	293
20	.714	13500	57	63	36	100	294
21	.934	12500	56	68	38	81	295
22	.540	11700	55	75	52	100	296
23	.581	11000	55	74	52	53	297
24	.403	11000	55	66	52	71	298
25	.475	10200	50	58	46	0	299
26	.339	10000	50	59	53	0	300
27	.550	10000	50	63	55	16	301
28	.474	10000	49	68	54	78	302
29	.553	9700	49	74	44	100	303
30	.529	10400	49	66	50	97	304
31	.431	10500	49	56	42	100	305
11/1	.352	10800	49	60	41	0	306
2	1.109	11500	49	64	54	0	307
3	.675	11400	49	56	38	88	308

Table 4.1.2-3
Pearson's Correlation Matrix - Environmental Data and Mean Flux Density - Forebay Monitoring Site

Sample	n	Mean	SD
MFD	20	.687	.451
River Discharge	20	11680	1638.2
Water Temperature	20	53.15	4.133
High Air Temp.	20	63.3	6.088
Low Air Temp.	20	46.05	6.549
% Sunlight	20	61.45	40.517
Julian Day	20	29.85	5.916

	River Discharge	Water Temp.	High Air Temp.	Low Air Temp.	% Sunlight	Julia Day
MFD	.419	.402	-.007	-.281	.110	-.41
Discharge		.867	-.300	-.503	.290	-.76
Water Temp.			-.054	-.295	.253	-.94
High Air Temp.				.312	.319	.03
Low Air Temp.					-.410	.22
% Sunlight						-.18

Table 4.1.2-4
Mean Flux Densities for Daily Time Periods
Forebay Monitoring Site

	AFTERNOON	DUSK	EVENING	LATE NIGHT	DAWN	MORNING
10/15*		2.047	2.908	3.448	1.083	.286
16*	.543	1.474	1.537	1.951	.601	1.051
17	.584	.555	.529	.517	.411	.411
18	.483	.459	.526	.669	.517	.359
19	.426	.402	.526	.634	.325	
20*		1.787	.479	.441	.938	
21*	.865	1.554	.622	1.366	1.192	.310
22	.465	.901	.390	.531	.506	.497
23	.354	.429			.600	.492
24	.570	.486	.372	.336	.412	.434
25	.366	.797	.281	.574	.590	.267
26	.267	.351	.315	.422	.373	.232
27	.312	.754	.852			.290
28	.438	.731	.518	.299	.268	.358
29	.443	.786	.330	.297	.338	1.02
30	.418	.757	.432	.450	.383	.730
31	.469	.716	.324	.322	.626	.305
11/1	.262	.481	.330	.344	.405	.346
2*	1.133	.814	1.315	1.393	1.10	.424
3*	.675					
MEAN(A):	.504	.857	.699	.823	.593	.460
MEAN(B): (Without seasonal peaks)	.435	.615	.440	.441	.443	.442

*Seasonal peaks

Table 4.1.4-1
Mean Flux Densities - Spill Test

Date	Test #		Mean Flux Density Individual Data Sets		
10/21	1	Dusk, Hour 1, Units 1-3 on	17.7	9.03	23.95
			10.15	18.45	
			6.30	11.78	
10/21	2	Dusk, Hour 2, Units 1-3 off	13.98	5.98	
			1.53	14.95	
			14.18	2.25	
10/22	3	Dusk, Hour 1, Units 1-3 off	3.93	2.78	3.28
			14.13	.20	
			.90	.70	
10/22	4	Dusk, Hour 2, Units 1-3 on	17.80	35.35	
			22.15	26.80	
			24.93		
10/23	5	Dawn, Hour 1, Units 1-3 on	15.75	8.63	
			11.45		
			11.03		
10/23	6	Dawn, Hour 2, Units 1-3 off	11.25	1.03	
			6.00		
			8.30		
10/24	7	Dawn, Hour 1, Units 1-3 off	9.43	6.98	5.35
			3.80	1.88	
			4.25	2.38	
10/24	8	Dawn, Hour 2, Units 1-3 on	.30	23.20	.30
			16.45	30.93	
			1.70	1.50	

Table 4.1.4-2
Analysis of Variance - Spill Test

A) Time of day vs Hour

	n	Mean	SD	Source	SS	DF	MS	F	P
Dusk/Hour 1	14	8.81	7.54	Time of day	216.14	1	216.14	2.98	.088
Dusk/Hour 2	11	16.35	10.57	Hour	255.09	1	255.09	3.51	.064
				Error	3122.06	43	72.61		
Dawn/Hour 1	"	7.36	4.33						
Dawn/Hour 2	"	9.18	10.38						

B) Time of Day vs Operation

	n	Mean	SD	Source	SS	DF	MS	F	P
Dusk/on	13	11.56	6.57	Time of day	152.51	1	152.51	1.89	.173
Dusk/off	12	12.75	12.37	Operation	.17	1	.17	.00	----
				Error	3472.03	43	80.74		
Dawn/on	8	9.18	4.37						
Dawn/off	14	7.75	9.36						

C) Hour vs Operation

	n	Mean	SD	Source	SS	DF	MS	F	P
Hour 1/on	11	13.11	5.24	Hour	155.57	1	155.57	2.66	.106
Hour 1/off	14	4.29	3.78	Operation	.00	1	.00	.00	----
				Error	2512.23	43	58.42		
Hour 2/on	10	7.95	5.42						
Hour 2/off	12	16.78	12.75						

Table 4.2-1
Current Velocity Measurements
York Haven Power Station
October 29, 1986

UNITS 1 - 3 RUNNING

Location \ Transect	Unit 1	Unit 5	Unit 10	Unit 1[illegible]
A	4.1	2.4	2.3	0.25
B	S 3.2	2.9	2.2	0.5
	B 3.8	2.8	1.8	1.2
C	S ND	2.3	2.5	2.2
	B ND	2.4	2.2	2.5
D	S ND	1.1	2.3	1.5
	B ND	1.6	2.6	2.0
E	S ND	1.4	1.8	1.3
	B ND	1.6	1.8	1.6
F	S ND	1.0	1.2	1.0
	B ND	1.3	1.4	1.1

S = 18" below surface
B = 8' below surface
ND = Not Detectable

All measurements in ft/sec

Table 4.2-2
Current Velocity Measurements
York Haven Power Station
October 29, 1986

UNITS 1-3 SHUT DOWN

Location \ Transect	Unit 1	Unit 5	Unit 10	Unit 17
A	S 0.5	2.3	1.6	2.3
B	S 0.5 ----- B 0.4	2.0 --- 2.0	1.3 --- 1.9	2.4 --- 2.7
C	S ND ---- B ND	1.5 --- 1.4	1.3 --- 1.6	2.1 --- 2.3
D	S ND ---- B ND	1.0 --- 1.2	1.0 --- 1.0	1.3 --- 1.9
E	S ND ---- B ND	1.0 --- 1.1	1.9 --- 1.0	1.0 --- 1.2
F	S ND ---- B ND	ND -- ND	1.0 --- 0.8	0.8 --- 0.8

S = 18" below surface
B = 8' below surface
ND = Not Detectable

All measurements in ft/sec

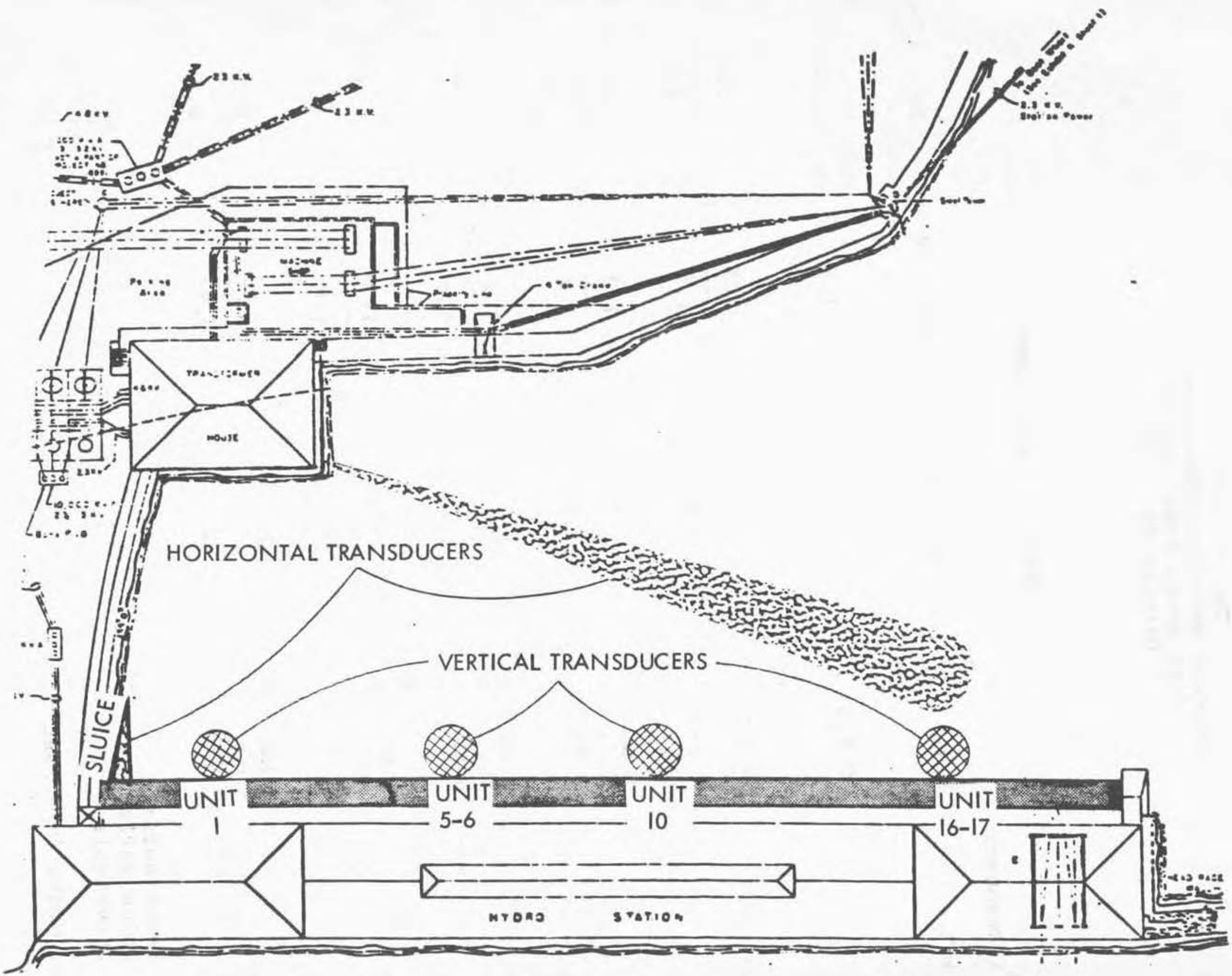


FIGURE 3.1–1	**YORK HAVEN PROJECT** YORK HAVEN POWER COMPANY	BARNES — WILLIAMS ENVIRONMENTAL CONSULTANTS	TRANSDUCER LOCATIONS FOR HYDROACOUSTIC STUDY

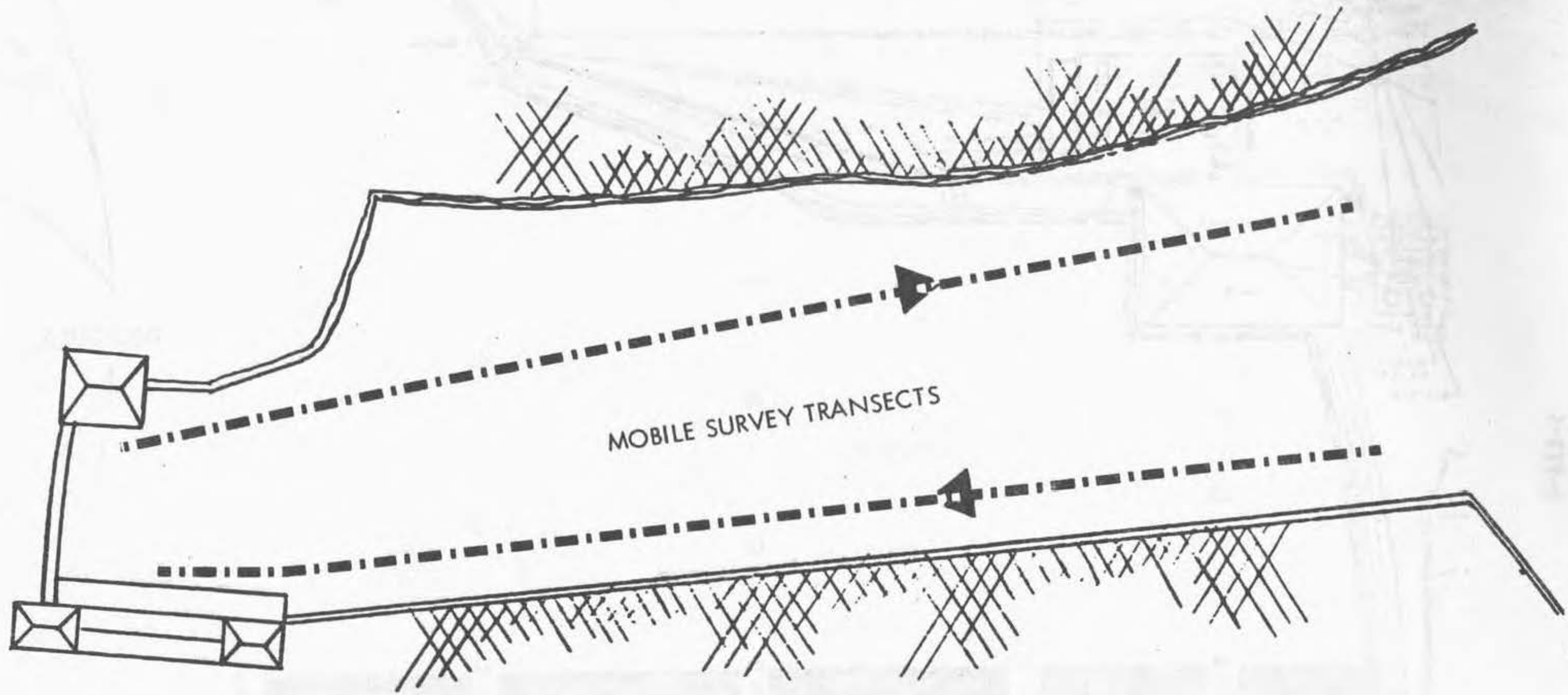


FIGURE 3.1-2	YORK HAVEN PROJECT YORK HAVEN POWER COMPANY	BARNES — WILLIAMS ENVIRONMENTAL CONSULTANTS	MOBILE SURVEY TRANSECTS

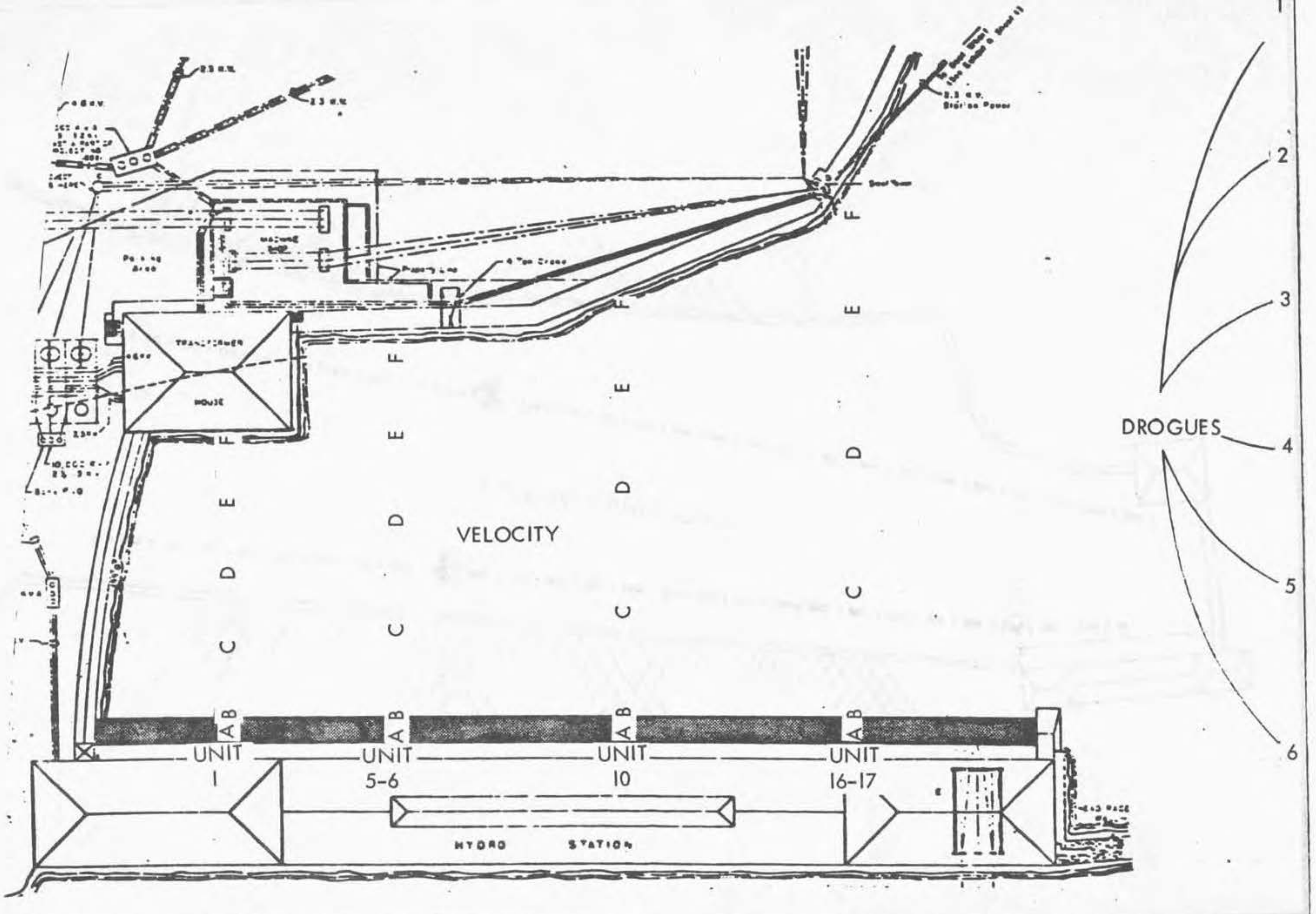


FIGURE 3.2-1	YORK HAVEN PROJECT YORK HAVEN POWER COMPANY	BARNES — WILLIAMS ENVIRONMENTAL CONSULTANTS 132 WASHINGTON STREET (607) 723-3113 BINGHAMTON NEW YORK 13901	CURRENT VELOCITY AND DROGUE SAMPLING LOCATIONS

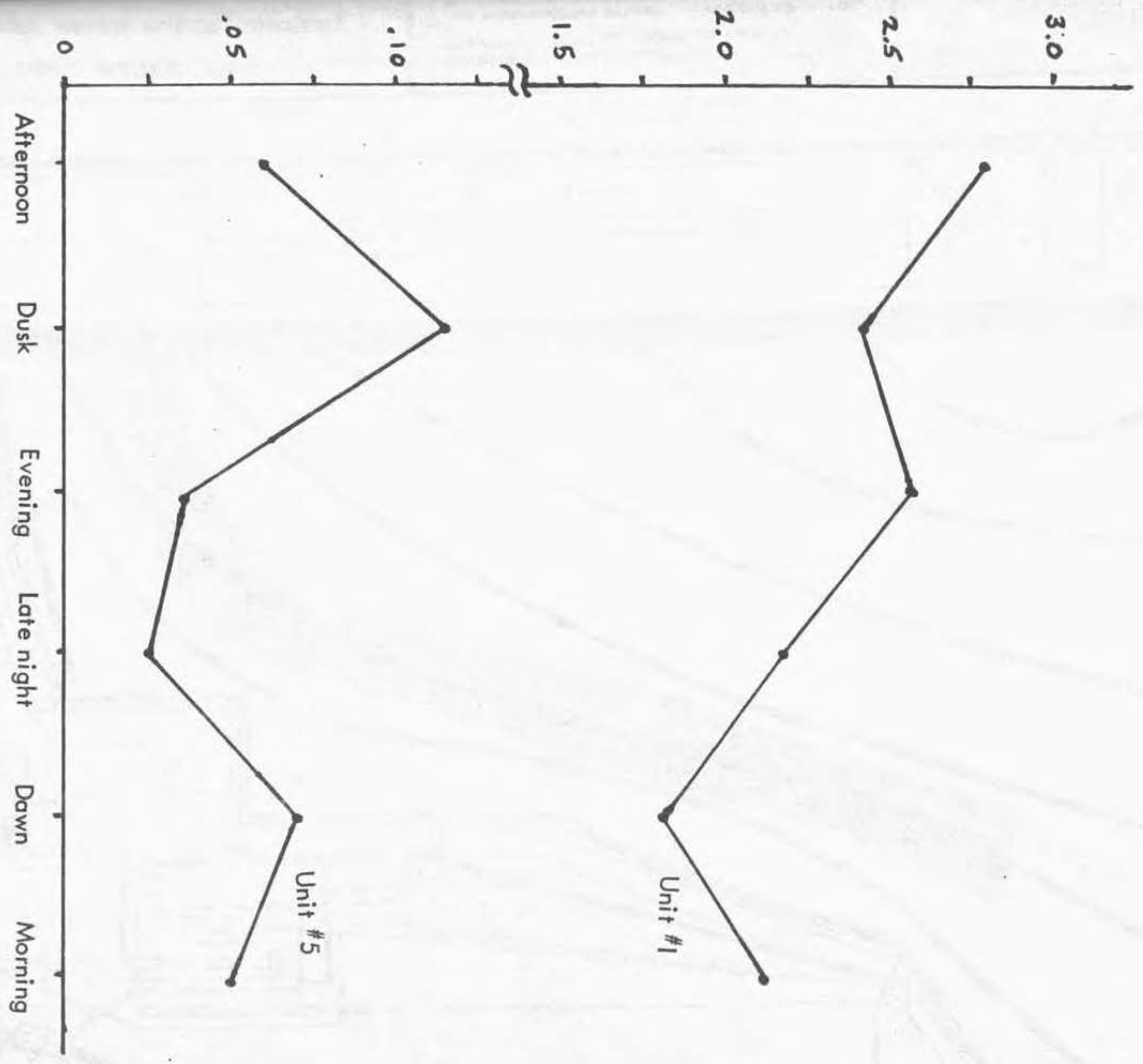


FIGURE 4.1.1-1	YORK HAVEN PROJECT YORK HAVEN POWER COMPANY	BARNES — WILLIAMS ENVIRONMENTAL CONSULTANTS 132 WASHINGTON STREET (607) 723-3113 BINGHAMTON, NEW YORK 13901	DIEL CHARACTERISTICS AT TWO TRASH RACK LOCATIONS

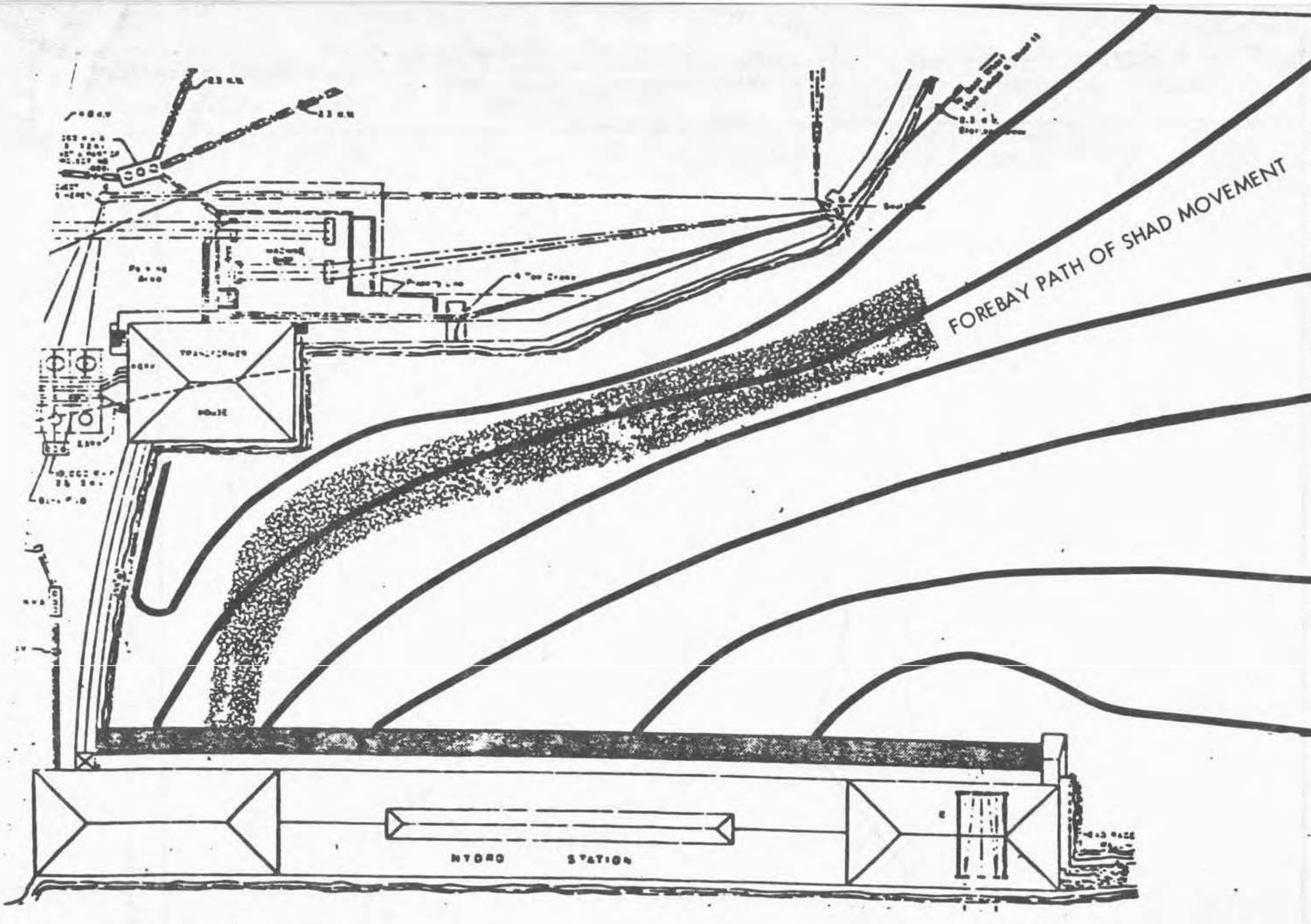
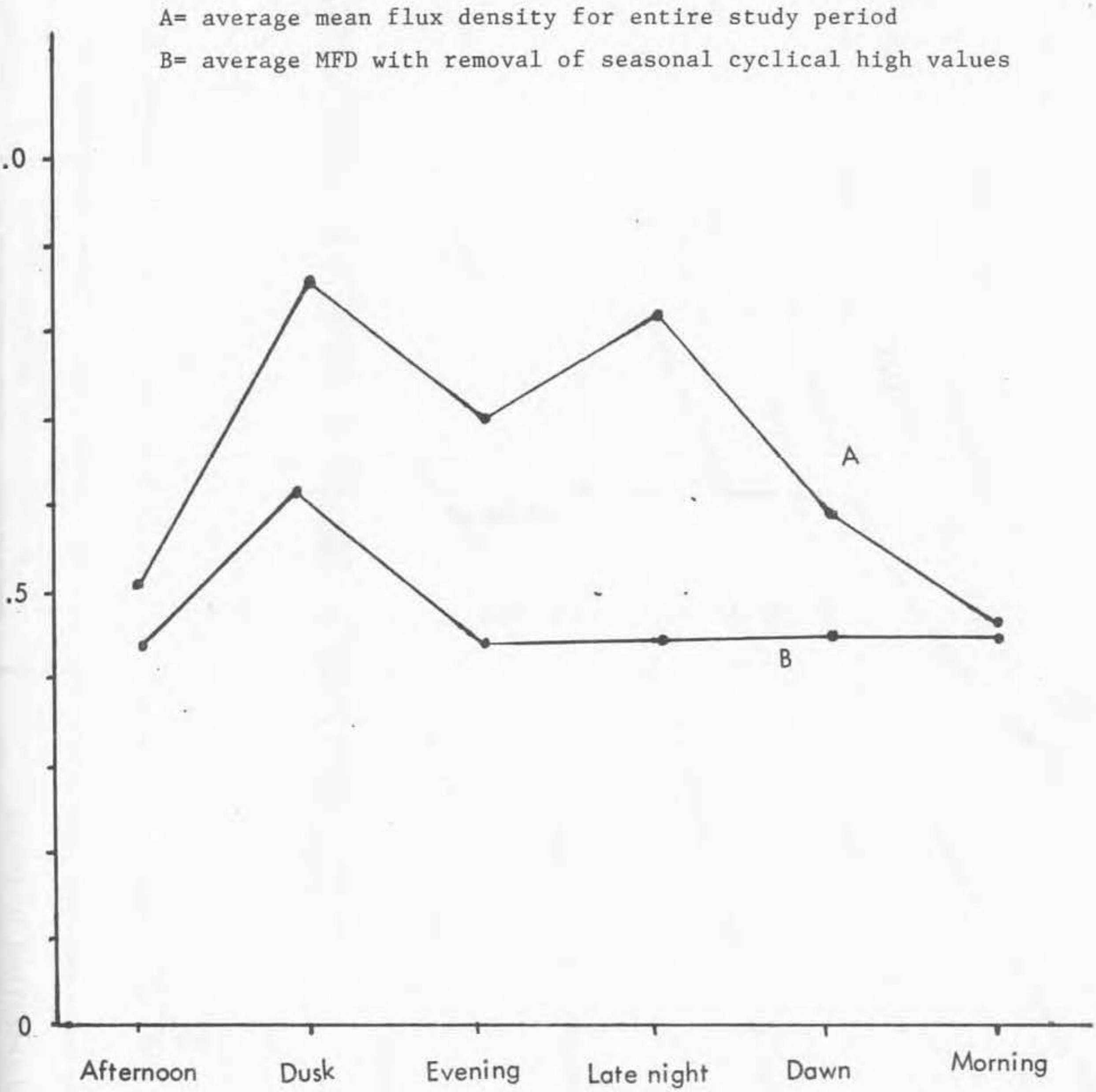


FIGURE 4.1.2-1	YORK HAVEN PROJECT YORK HAVEN POWER COMPANY	BARNES — WILLIAMS ENVIRONMENTAL CONSULTANTS 132 WASHINGTON STREET (607) 723-3115 BINGHAMTON, NEW YORK 13901	PATH OF SHAD MOVEMENT



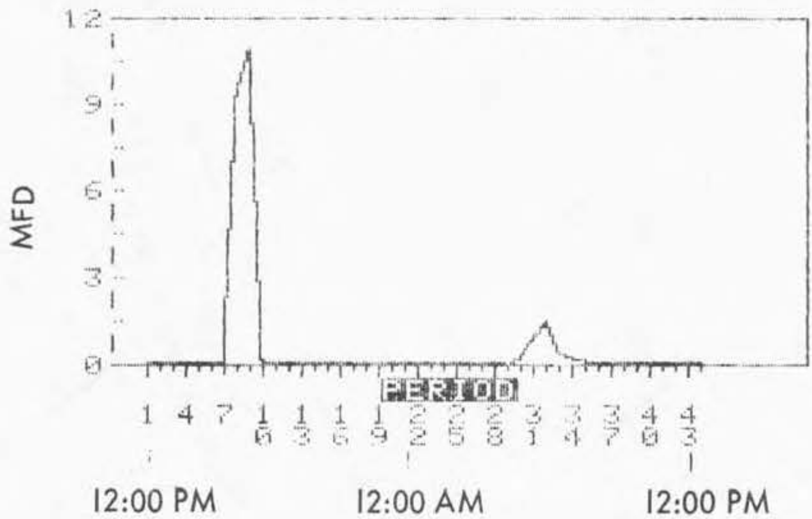
DIEL CHARACTERISTICS
FOREBAY MONITORING

BARNES — WILLIAMS
ENVIRONMENTAL CONSULTANTS
132 WASHINGTON STREET (607) 723-3113
BINGHAMTON, NEW YORK 13901

YORK HAVEN PROJECT
YORK HAVEN POWER COMPANY

FIGURE
4.1.2-2

Figure 4.1.4-1
Mean Flux Density during the 24-hour Period 12:00 noon Oct. 21 to 12:00 noon Oct. 22
Unit #5



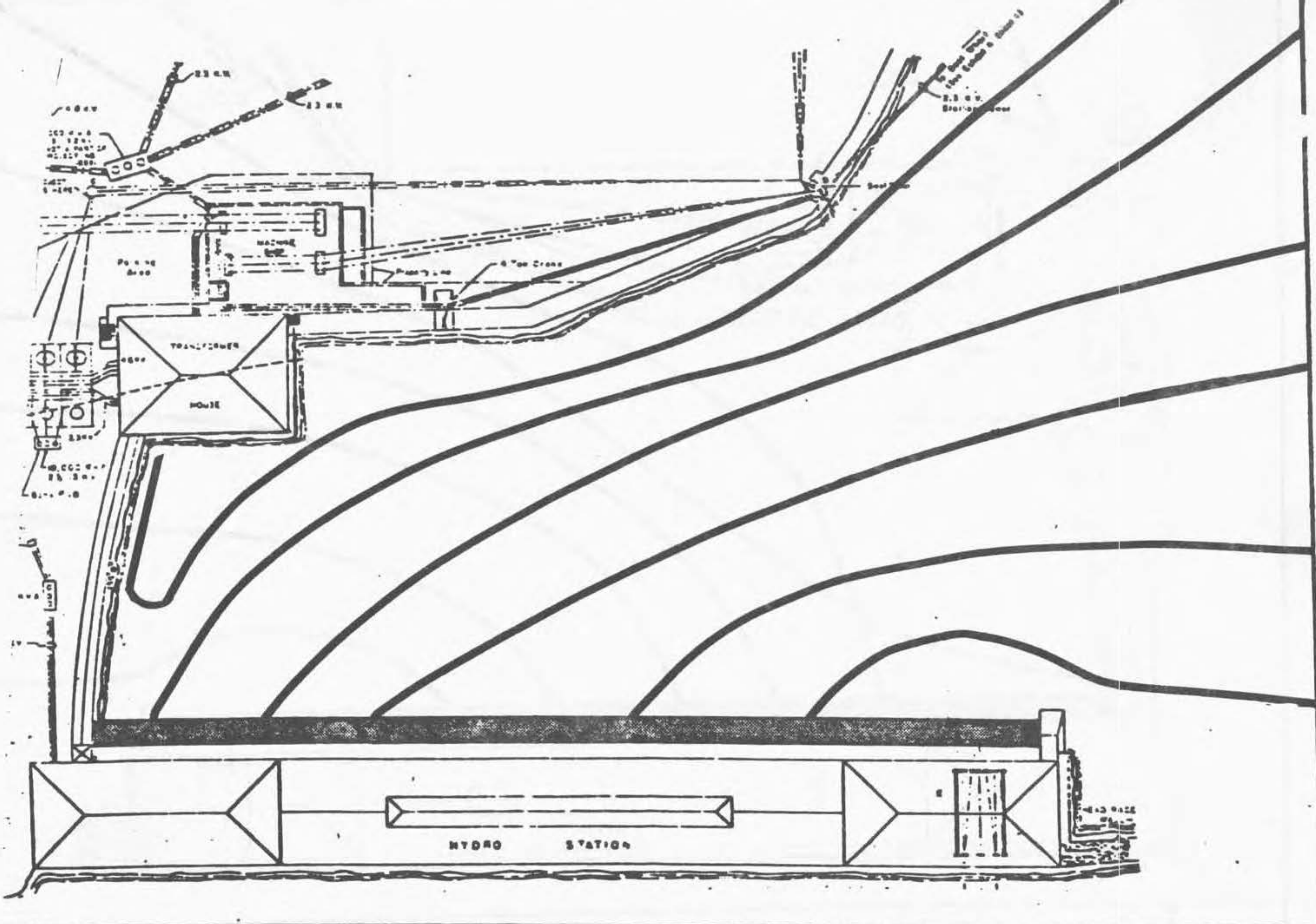


FIGURE 4.2-1	YORK HAVEN PROJECT YORK HAVEN POWER COMPANY	BARNES—WILLIAMS ENVIRONMENTAL CONSULTANTS 132 WASHINGTON STREET (607) 723-3112	CURRENT PATTERNS UNITS 1-3 OPERATING

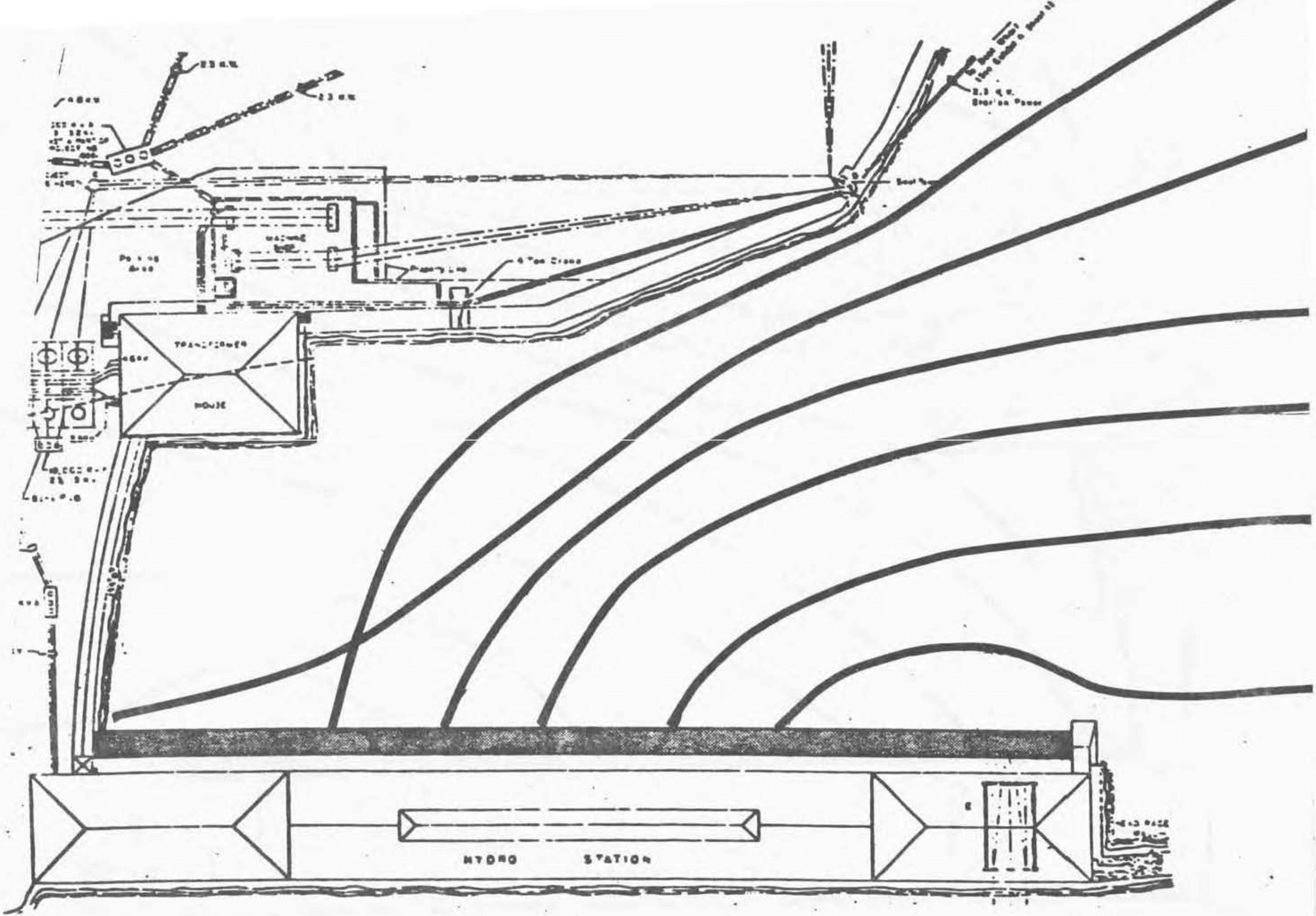


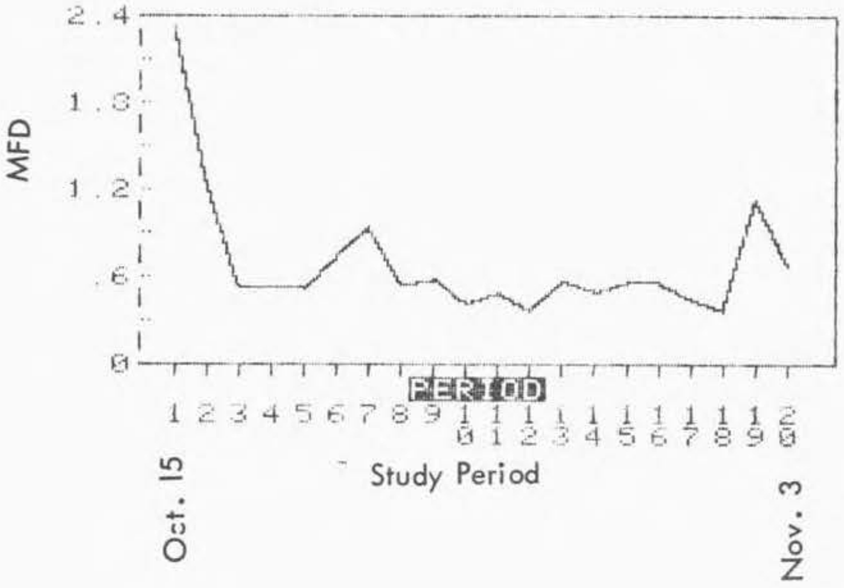
FIGURE 4.2-2

YORK HAVEN PROJECT
YORK HAVEN POWER COMPANY

BARNES — WILLIAMS
ENVIRONMENTAL CONSULTANTS
132 WASHINGTON STREET (607) 723-2113
BINGHAMTON, NEW YORK 13901

CURRENT PATTERNS UNITS I–3
NOT OPERATING

Figure 5.1.2-1
Daily Mean Flux Density
Oct. 15 - Nov. 3, 1986
Forebay Monitoring Site



JOB VI. SUMMARY OF OPERATION OF THE CONOWINGO DAM FISH PASSAGE FACILITY IN SPRING 1986

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

INTRODUCTION

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

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

Objectives of the 1986 operation were to (1) contribute to restoration efforts by the trap and transfer of prespawned American shad to upstream localities, (2) monitor relative abundance of Alosa species, (3) obtain life history information from selected migratory and resident fishes, (4) monitor species composition, and (5) assist Maryland Tidewater Administration in assessing the American shad population in the upper Chesapeake Bay.

METHODS

Prior to the operation of the Lift several surveys were conducted to detect the arrival of alosids into the lower river area. Alternate day herring checks at Deer Creek were initiated on 16 March. About 6 herrings were first observed in Deer Creek at the Baltimore City Pumping Station on 28 March at a water temperature of 56.3 F. Thereafter, the herring checks were terminated.

Preparations for the operation of the Lift began during the week of 23 March 1986 following the observation of herring in the lower river, and decreasing river flow. Weir gate and crowder motors were installed on 25 March. Adjustments to limit switches, calibration of weir gates, and all necessary maintenance were completed by 28 March. A test run of the facility was successfully completed on 31 March.

Lift operation commenced on 1 April 1986 and was scheduled to occur on an alternate half-day basis, as outlined in the 1986 Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) work plan (SRAFRC 1986).

However, operation on 1 April was terminated early due to the accumulation of debris in the holding channel that prevented the hopper from closing. Divers removed the debris on 2 April allowing the operation to resume on 3 April. Daily operation of the lift was initiated on 6 April as a result of the collection of 27 American shad on 5 April. Lift operation continued daily until 17 April when predicted river flows in excess of 120,000 cfs resulted in the termination of lift operation through 23 April. Operation resumed on an alternate day basis from 24 April through 28 April. Daily operation occurred from 29 April to 21 May, from 0700 hrs to approximately 1700 hrs. However, no operation occurred on 7 May due to mechanical problems in the late afternoon of 6 May that prevented the hopper from closing.

Increased river flows and the subsequent full peaking operation of the power station from 22 to 28 May resulted in an operation scheme that was based on the shad catch. Generally, the Lift was operated daily until 1300 hr and/or until no shad were collected in the last hour of operation on a given day. Extended operation resumed on 29 May and continued through 1 June. Operation of the Lift was reduced to a half day basis from 2 to 8 June and terminated on 12 June due to the advanced sexual condition of American shad collected.

Beginning in early April, PECO modified the normal pattern of station generation at Conowingo Dam to enhance Lift effectiveness when the natural river flows and electric demand permitted. Generally, Turbine Units No. 1 and/or 2 were kept off until all others had been placed into service and were taken out of service first when going to off peak generation. This modified generation scheme was maintained through 8 June and terminated when the catch of American shad in a post-spawned condition indicated the 1986 run of shad was over.

The mechanical aspect of Lift operation in 1986 was similar to that described in RMC (1983). Fishing time and/or lift frequency was determined by fish abundance and the time required to process the catch. However, due to large numbers of gizzard shad, and on occasion carp, two modifications implemented in 1985 to maximize collection of American shad were utilized (RMC 1986). Operation "Fast Fish", (RMC 1986) was employed on an as needed basis and resulted in increased fishing time during periods of heavy fish activity. On five occasions, as a result of changes in water levels in the tailrace, large numbers of gizzard shad were attracted to the lift. In an effort to maximize the collection of shad, either weir gate 1 or 2 was closed and fish that had accumulated were lifted rapidly utilizing operation "fast fish". After most fish had been removed, the operation of the Lift was changed back to the normal operational mode.

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

Since 1972 a continuous minimum flow of 5,000 cfs through Conowingo Dam has been maintained from 15 April through 15 June. Unit No. 5 was used in 1986 to release the continuous minimum flow, except on 1 June when Unit No. 7 was used. The minimum release from either Unit No. 5 or 7 was based on results of 1982 and experience at other fish passage facilities which showed that passage effectiveness increases when competition between the attraction flow from the passage devices and the flow releases from other sources is reduced.

Fishes were processed as reported earlier (RMC 1983). Fishes were either counted or estimated (when large numbers were present) and released back to the tailrace. Length, weight, sex, and scale samples were taken from blueback herring, hickory shad, alewife, striped bass, and striped bass x white bass hybrid. The use of scientific and common names of fishes collected (Table 6.1) followed Bailey et al. (1970). Initially, all healthy, active shad not transported were tagged with Floy anchor tags and released back to the tailrace. Length, weight, sex, and spawning condition of shad were determined prior to release as conditions permitted. Scale samples were taken from tagged shad (when possible), and those that died in handling and/or during transport.

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

Holding and Transport of Shad

Generally, transport occurs whenever 50 or more green or gravid shad are collected in a day, or at operator's discretion. However, some American shad were held for transport on an experimental basis (with the approval of the SRAFRC's Coordinator) in circular tanks continually supplied with river water. The aeration system utilized bottled oxygen and/or compressed air. Also, each tank was fitted with a cover to prevent escape of American shad.

Transportation of American shad was accomplished utilizing 800 and 1,100 gallon circular transfer units. Both transfer units were equipped similar to the system used in 1985 (RMC 1985). The holding and handling procedures employed during transport were similar to those used in previous years.

RESULTS

The relative abundance of fishes has fluctuated since 1972 (Table 6.2). Fluctuations have resulted primarily from changes in species abundance and modification to Lift and turbine operation. In the 1980-1986 period the catch was generally dominated by gizzard shad, white perch, and channel catfish. Prior to 1980 alosids (primarily blueback herring) and white perch dominated the catch.

In 59 days of Lift operation (1 April through 12 June, 1986) 1,830,641 fish of 43 taxa were caught (Table 6.2 and 6.3). Predominant species in order of numerical abundance were gizzard shad, white perch and channel catfish. Alosids (blueback herring, alewife, hickory shad and American shad) comprised less than 0.8% of the total catch.

The catch of gizzard shad (1,714,441) in 1986 was the second highest recorded for any species since 1972, and comprised over 93.5% of the total (Table 6.2). The daily catch (Table 6.3) was also dominated by gizzard shad and ranged from 835 (3 April) to 95,500 (16 May).

Operation "fast fish" in 1986 was a primary reason that over 1.8 million fish were collected. This mode of operation increased daily fishing time by reducing mechanical delays associated with normal lift operation. Total operating time was similar in 1985 and 1986 (542 hrs vs 546), however fishing time was increased by approximately 7% in 1986. Modifying normal weir gate openings, in combination with operation "fast fish" on five days when gizzard shad and/or carp numbers were excessive, resulted in an increased catch rate of American shad on 2 of those 5 days (Table 6.4).

River Herring and Hickory Shad

The combined catch of river herring (blueback and alewife) and hickory shad increased over that of 1985 (RMC 1986), but was much lower than historic levels (Table 6.2). The 1986 catch was several hundred times less than that in 1972 through 1975.

A total of 2,822 alewife was collected (Table 6.3) with the first capture on 1 April. Ninety-eight percent of the catch occurred from 28 April through 5 May at water temperature of 54.5 F to 63.5 F.

The age of 258 alewife was determined (Table 6.5). Males were III to VI year old; IV year olds dominated. Females were IV to VII year olds; IV year olds dominated. Most alewife (90%) were virgins.

A total of 6,327 blueback herring was collected, a slight decrease from 1985. Blueback herring typically arrive later than alewife and were first collected on 28 April, with 85% collected from 10 through 20 May. Water temperature ranged from 64.4 F to 69.8 F during this period.

The age was determined for 295 blueback herring (Table 6.6). Both males and females were IV to VII year olds; V years olds dominated. Comparison by sex indicated that females had a disproportionately higher rate of growth with increasing age. Repeat spawners accounted for 53% of the sample (48% single, 5% double repeat).

Hickory shad catches continued to be small, 45 were collected in 1986. Hickory shad first appeared in the catch on 6 April. Most (84%) were caught from 28 April through 5 May.

Twenty-eight hickory shad examined for age and spawning history varied in age from III to VII; V year olds dominated (Table 6.7). Fifty percent of samples examined were repeat spawners (36% single, 14% double repeat spawners).

American Shad

The 1986 catch of American shad (5,195) at the Lift was the highest recorded since Lift operation began in 1972 (Table 6.2). Over 87% of the shad collected were either transported or tagged. Three hundred ninety-five shad (unmarked) were released back to the tailrace. The remainder were comprised of RMC tag recaptures, resource agency recaptures (Maryland DNR, New Jersey Division of Fish, Game and Shell Fisheries), and handling mortalities.

A total of 115 American shad (2.2%) died at the Lift. Mortalities resulted from mechanical operation of the lift, handling, and holding. However, it is important to note that the low rate of mortality at the Conowingo Fish Lift is within the range of mortality (1-3%) observed at the Holyoke Fish Lift where handling procedures are generally non-existent; shad swim through a flume to gain access to the area upstream of the dam.

The daily catch of American shad exceeded 300 individuals on 6 days (Table 6.3 and Figure 6.2). Prior to 1986, the highest daily catch of American shad at the Lift occurred on 9 May 1982 when 276 were trapped. The largest catch occurred on 1 June when 861 shad were collected; on 10 and 11 May the daily catch was 813 and 765, respectively. All three of these dates were weekend days.

American shad were first observed at the Lift on 5 April (Table 6.3 and Figure 6.2). Most shad were collected from 28 April to 1 June. Examination of the daily catch during this period indicated that the shad catch varied daily but reflected three peak periods of abundance. The largest collection of shad (2,004) occurred from 8 to 11 May. Other periods of increased abundance occurred from 3 to 4 May, and 29 May to 1 June, when 409 and 1,514 shad were taken, respectively.

As in the past, the catch per effort (CPE) of American shad varied by station generation and time of day (Table 6.8). The CPE was over seven fold higher when one unit was in operation (Table 6.9). Also, the CPE was five times higher during weekend operation. Generally, the total CPE was similar during the week for all time periods, whereas, on weekends the catch was greatest during the afternoon and evening (1501-1900 hrs).

American shad were collected at water temperatures of 50.9 to 77.9 F and at natural river flows of 11,700 to 75,000 cfs (Table 6.3 and Figure 6.2). Approximately 56% of the shad were collected at water temperatures <65 F (Table 6.10). Water temperature during the period of peak shad abundance (28 April to 1 June) varied from 54.5 to 72.5 F.

Tag and Recapture

Of the 254 American shad tagged in 1986 (Table 6.11) 62 were recaptured. The Lift recaptured 52 (Table 6.12), a sport angler and Maryland DNR personnel accounted for two angler recaptures in the tailrace, and the remaining six (4 tagged in 1985) were captured outside the Susquehanna River by sport and commercial fishermen.

Of the 52 recaptures at the Lift, five were multiple 1986 recaptures and five were originally tagged in 1985 (Table 6.11). One shad tagged in 1985 was captured twice. The other multiple recaptures consisted of two fish twice, one fish three times, and one fish five times. The average free days for first time recaptures (38) was 18.9 and varied from 5 to 55 days. Average free days for multiple recaptures were 24, 6, and 9.8 for two fish captured twice, one fish captured three times, and one fish captured five times, respectively.

Approximately 15% (first time recaptures, 38) of all shad marked in 1986 were recaptured. However, examination of the tag information showed that none of the shad marked after 21 May (28) were recaptured. Therefore, assuming these shad were not subject to capture due to the effects of handling and/or tagging late in the season, the Lift captured 17% of the shad previously marked and released back to the tailrace.

A total of 91 shad was marked from 4 to 17 April and 163 were marked from 28 April to 18 May collection. Sixteen shad (18%) tagged prior to high flows were recaptured after an average of 33.8 freedays. Twenty-two shad tagged from 28 April to 18 May were recaptured and were free an average of 10.9 days. It is important to note the early tagged shad were not vulnerable to collection by the Lift due to high natural river flows that terminated the operation from 18 to 23 April. However, it is likely that the shad left the area coincident with high natural river flows. This conclusion is corroborated by a concurrent radio telemetry study of shad in the upstream areas. The radio tagged shad also left the Susquehanna River coincident with the high natural river flows.

Ninety American shad marked by resource agencies were captured at the lift; 89 were tagged by the Maryland DNR (see Job VII) and one was tagged by the New Jersey Division of Fish, and Game and Wildlife at Lambertville, NJ (Delaware River). Eighty-seven of the Maryland recaptures were tagged on the east side of the tailrace and two from in the lower river. Seventy-six (29%) of those marked in the tailrace were captured at the lift once. Nine shad were multiple recaptures; seven were collected twice and two were collected three times (Table 6.13).

Average free days for the first time recaptures was 14.8 days and varied from 3 to 29 days. Further examination of the tagging information showed that 40 shad were marked from 10 to 16 April, and 224 were marked from 30 April to 15 May. Eight shad (20.0%) tagged prior to 17 April were free an average of 25.3 days. Sixty-eight shad (30.4%) tagged from 30 April to 15 May were free an average of 13.5 days.

In general, the results of the Maryland DNR tag and recapture information were similar to, and support the results reported for shad marked and recaptured at the Lift. However, it is important to note that approximately 20% of the American shad marked in the tailrace prior to a period of flooding (river flows >188,000 cfs) were captured at the Lift after the river flows receded.

Sex and Age Composition of American Shad

Visual macroscopic inspection of shad was made to determine the daily and seasonal sex ratios. The age composition of American shad trapped at the Lift was determined for selected samples from tagging, mortalities from handling, and transport operations, and those scaled and released back to the tailrace. Therefore, this information is provided only to observe general trends.

The sex of 5,135 American shad was successfully determined, of which 4,224 were males and 911 were females (Table 6.14). The sex ratio of shad varied daily but was dominated by males. The daily sex ratios varied from the collection of all males on seven days to 2:1 (male to female) on 22 May. Generally, the overall observed sex ratio for shad collected at the lift (4.6:1) and those caught by hook and line (5.2:1) by the Maryland DNR in the tailrace were similar.

Five hundred thirty-one scale samples were taken, 507 (95%) were successfully aged (Table 6.15). Males were II to VI years old; IV and V year olds dominated. Females were III to VII years old; V and VI year olds dominated. Fifteen males (4.1%) and one female (0.7%) were repeat spawners. Because the sex ratio of mortalities (1:0.9) differed markedly from that observed for all shad collected (4.6:1) the data were analyzed to determine if the age composition of dead shad was different (Table 6.16). The age composition of females in the two samples was similar and dominated by V year olds. However, a slightly larger proportion of IV and V year old males was observed in the samples of handling and transport mortalities.

Transport of Adults

The trap and transport of prespawned American shad to upstream spawning areas is the primary objective of the fish lift operation and contributes to the American shad demonstration program. Efforts in 1986 afforded lift personnel the opportunity to gain valuable information related to the handling and transfer of large numbers of American shad. Prespawned American shad were transported from 6 April through 1 June. All transported shad were stocked above York Haven Dam at the public boat launch at City Island, Harrisburg. Originally, the PFC Fairview access was considered to be the prime stocking location. However, a preseason reconnaissance of the area revealed that heavy siltation had occurred at the access area (water depth ≤ 2 ft) and rendered this location unsuitable for stocking shad.

A total of 4,172 American shad was transported to potential upstream spawning areas with an overall stocking survival of 97.8% (Table 6.17). Transportation of shad occurred on 21 days and was accomplished in 39 trips.

Generally, individual trips averaged two hours. The number of trips per day varied from one to six; load size varied from 58 to 179 fish per trip. Trip survival varied from 86.3 to 100%. Shad were collected and transported at water temperatures between 58.1 to 71.6 F.

The upstream transport of a large number of shad afforded an opportunity to estimate the potential contribuiton of these fish. The potential egg deposition of female shad was calculated assuming an average fecundity of 200,000 eggs/female. Of the 853 females transported 94 died during handling and transport, resulting in 759 being stocked upstream. Although the estimated potential egg deposition of these 759 fish was 151 million eggs the fate of these eggs, survival to fry, and juvenile stages, is unknown. In contrast, the hatchery operated by PFC received 51 million eggs and released 15 million fry and 61 thousand juveniles.

In an effort to maximize the number of American shad transported, holding facilities were modified to allow shad collected on a given day to be held overnight and transported the following day. The first attempt was made on 5 May when 25 shad were held overnight and transported with the 47 shad collected on 6 May. Two mortalities occurred overnight but transport survival was 100%. Since initial results were positive, 100 shad collected on 10 May were held overnight and transported on 11 May. No mortality occurred overnight, and only four of the 113 shad (3.5%) transported died. Based on these experimental results shad were held overnight for transport when needed.

A total of 609 American shad was held overnight at the Lift on 10 days (Table 6.18). On 11 May an attempt was made to hold 264 shad because one of the transport units broke down (flat tire). A biologist remained on site and monitored fish behavior and DO conditions. Based on the observations of the biologist, the number of shad in each holding tank was reduced in order to maintain DO levels at or above 5.0 ppm. Thirty-seven shad were released back to the tailrace, 17 died overnight and 208 were successfully transported the following day. Some nine shad collected on 12 May were held two days before being transported.

Two loads of American shad were transported to controlled holding facilities (Table 6.18). Eighty-three prespawned shad, collected on 18 May, were transported on 19 May to the PFC Benner Springs Research Station. Only one female died even though shad were held overnight, and transit time was approximately three times longer than that for fish stocked at Harrisburg. The observation by PFC personnel of several hundred juveniles confirmed successful reproduction even though only six females were transported. On 4 June, 34 partially or post-spawned shad were transported to the Muddy Run Laboratory. Transport survival was 100% and spawning was confirmed by the collection of fertilized eggs.

DISCUSSION

As in earlier years, the catch of shad was much higher on weekends than on weekdays (Table 6.8 and Figure 6.3). A total of 3,517 shad was caught on 16 days of operation on weekends versus 1,678 shad on 43 weekdays of operation. The CPE (catch/hr) was 26.6 and 5.2 on weekends and weekdays, respectively. These differences occurred primarily due to the variations in station discharge (peak load vs reduced generation, natural river flows, and the nature of the shad run (changes in rate of immigration). The run of shad is primarily dictated by natural river flows and water temperature and occurs in waves. Station discharge is primarily dictated by natural river flows, peak power demand and minimum flow requirements. On weekends there is little peak power demand and if natural river flows are low the station either shuts down (up to 14 April) or discharges 5,000 cfs. If natural river flows are high the station must discharge higher flows. Three peaks in the shad catch occurred in May 1986 and were coincident with weekends (Figure 6.3).

The time of peak shad immigration into the tailrace also influenced the catch of shad. For example, in April when the station was shutdown or discharged 5,000 cfs the shad catch was low. In contrast during the peak of the run in

May under similar station operation conditions the catch of shad increased substantially (Figure 6.3).

Tables 6.19 and 6.23 list by year the catch and CPE of American shad as a function of temperature and natural river flows from 1982 through 1986. Differences between years were more evident with respect to water temperature. The effect of natural river flows on shad catch is masked by the station discharge. As noted earlier, the catch of shad increases substantially on weekends at reduced generation. Over 60% of the shad in 1986 were collected at water temperatures ≤65.0 F, in 1982 through 1985 most shad were collected at water temperatures ≥65 F.

The trap catch indicates an increased number of shad were available for capture in the tailrace in 1986 (Table 6.24). The total CPE from 1982 through 1986 was 8.1, 2.8, 2.4, 4.6, and 12.3, respectively. The CPE in 1986 was approximately 50% higher than that observed in 1982. It should be noted that in late May 1982, a period of peak shad abundance, due to high river flows (>200,000 cfs) the Lift could not be operated for a comparable number of days. The catch rates in 1983 and 1984 were similar and about half of the 1985 rates.

It is not clear whether there was a net increase in overall shad population in 1986, increased utilization of the tailrace, or greater escapement in the absence of commercial fishing activity. The upper Chesapeake Bay shad population estimates made by Maryland Department of Natural Resources ranged from approximately 33,000 in 1982 to 11,000 in 1985. The 1986 population estimate (see JOB VII) was approximately 21,000 shad. Based on these data it appears no increase in the shad population has occurred in the upper Chesapeake Bay in 1986.

Recommendations for 1987

1. Release transported American shad in Lake Clarke. This recommendation is based on findings of radio telemetry study conducted in 1986 (see Job V) on shad transported from the Lift. If fish were released into Lake Clarke, the York Haven Dam would serve as a barrier to further upstream migration thus concentrating the shad and increasing the probability of the two sexes locating each other.

2. Discontinue the tag and release of small numbers of American shad to maximize the number of American shad transported from the Lift. Instead, hold all healthy pre-spawned shad until suitable number is reach for transport. Then the number of shad transported will be maximized and will also increase the probability of both sexes encountering each other.

3. Terminate lift operation when transportation of American shad ends for the season. The purpose of the Conowingo Fish Lift is to provide passage for migratory fishes to upstream spawning areas.

LITERATURE CITED

Bailey, R. M., J. F. Fitch, E. S. Herald, E. A. Lachner. C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. A list of common and scientific names of fishes from United States and Canada. Amer. Fish. Soc. Spec. Publ. No. 6. 150 pp.

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

Radiation Management Corporation (RMC). 1983. Summary of the operation of the Conowingo Dam Lift in spring 1982. 32 pp.

Radiation Management Corporation (RMC). 1986. Summary of the operation of Conowingo Dam Lift in spring 1985. 44 pp.

Susquehanna River Anadromous Fish Restoration Committee. 1986. Restoration of anadromous fishes to the Susquehanna River; Annual Work Plan 1986. Prepared for SRAFRC. 24 pp.

Weinrich, D. R., E. W. Franklin, S. P. Minkkenin, T. A. Jarzynski. 1986. Investigation of American shad in Upper Chesapeake Bay 1985. Fed. Air Project. F-37-R. Completion Rpt., U. S. Dept. Int., Fish and Wildl. Service. 73 pp.

TABLE 6.1.

List of scientific and common names of fishes collected at the Conowingo Dam Fish Lift, Spring 1980 through 1986 (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
Coregonus artedii	Lake herring
Salmo gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
S. fontinalis x S. namaycush	Splake
Family - Esocidae	Pikes
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
Esox niger	Chain pickerel
E. masquinongy x E. lucius	Tiger muskie
Family - Cyprinidae	Minnows and carps
Carassius auratus	Goldfish
Cyprinius carpio	Carp
Nocomis micropogon	River chub
Notemigonus crysoleucas	Golden shiner
Notropis amoenus	Comely shiner
Notropis hudsonius	Spottail shiner
Notropis procne	Swallowtail shiner
Notropis rubellus	Rosyface shiner
Notropis spilopterus	Spotfin shiner
Notropis spp.	Minnows
Pimephales notatus	Bluntnose minnow
Rhinichthys atratulus	Blacknose dace
Rhinichthys cataractae	Longnose dace

Continued

TABLE 6.1.

Continued.

Scientific Name	Common Name
Family - Catostomidae	Suckers
Carpiodes cyprinus	Quillback
Catostomus commersoni	White sucker
Erimyzon oblongus	Creek chubsucker
Hypentelium nigricans	Northern hog sucker
Moxostoma macrolepidotum	Shorthead redhorse
Family - Ictaluridae	Freshwater catfishes
Ictalurus catus	White catfish
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Noturus gyrinus	Tadpole madtom
Noturus insignus	Margined madtom
Noturus spp.	Madtoms
Family - Belonidae	Needlefishes
Strongylura marina	Atlantic needlefish
Family - Cyprinodontidae	Killifishes
Fundulus heteroclitus	Mummichog
Family - Percichthyidae	Temperate basses
Morone americana	White perch
Morone saxatilis	Striped bass
M. saxatilis x M. chrysops	Striped bass x white bass
Family - Centrarchidae	Sunfishes
Ambloplites rupestris	Rock bass
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Family - Percidae	Perches
Etheostoma olmstedi	Tessellated darter
Etheostoma zonale	Banded darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
Percina peltata	Shield darter
Stizostedion vitreum vitreum	Walleye

TABLE 6.2.

Comparison of annual catch of fishes at the Conowingo Dam Fish Lift, 1 April through 15 June, 1972 to 1986.

Year	1972	1973	1974	1975	1976	1977	1978
No. Days	54	62	58	55	63	61	35
Lifts	817	1527	819	514	684	707	358
Est. Oper. Time (Hr)	607	996	500	307	375	413	212
Fishing Time (Hr)	313	623	222	189	252	245	136
American eel	805	2050	91937	64375	60409	14601	5878
Blueback herring	58198	330341	340084	69916	35519	24395	13098
Hickory shad	429	739	219	20	-	1	-
Alewife	10345	144727	16675	4311	235	188	5
American shad	182	65	121	87	82	165	54
Gizzard shad	24849	45668	119672	139222	382275	742056	55104
Atlantic menhaden	-	-	112	-	506	1596	-
Trouts	1	-	-	-	-	-	-
Rainbow trout	34	67	20	24	54	291	70
Brown trout	172	286	483	219	427	700	261
Brook trout	1	3	4	1	-	2	23
Chain pickerel	-	1	10	-	-	1	-
Northern pike	-	2	2	-	-	2	2
Muskellunge	20	104	9	7	12	48	14
Minnows	264	3	-	-	-	-	-
Goldfish	-	27	1	9	4	1	-
Carp	4370	16362	34383	15114	6755	16256	11842
River chub	-	-	-	-	-	-	-
Golden shiner	165	430	437	751	1622	652	221
Comely shiner	5	252	3870	2079	740	769	1152
Spottail shiner	34	137	2036	268	1743	8107	8506
Swallowtail shiner	-	-	-	-	-	-	-
Rosyface shiner	1	-	-	1	-	-	-
Spotfin shiner	103	40	3011	1231	45879	7960	3751
Bluntnose minnow	-	-	-	-	-	-	4
Blacknose dace	-	-	-	-	-	-	-
Longnose dace	-	-	1	-	-	-	4
Shiners	-	-	-	-	-	-	-
Quillback	7119	27780	14565	8388	9882	6734	2361
White sucker	363	1034	286	152	444	282	189
Creek chubsucker	3	3	1	-	-	-	-
Northern hog sucker	-	2	-	1	5	-	3
Shorthead redhorse	1097	4420	434	445	1276	1724	697
White catfish	3070	6394	2200	6178	1451	3081	982
Yellow bullhead	7	45	1	32	2	47	25
Brown bullhead	510	5328	1612	740	451	2416	125
Channel catfish	61042	55084	75663	74042	41508	90442	48575
Margined madtom	-	-	-	-	-	-	-
Madtoms	-	-	-	-	-	-	-
Tadpole madtom	-	-	-	-	-	-	-
Mummichog	-	-	-	-	1	-	-
White perch	50991	647493	897113	511699	568018	224843	113164
Striped bass	3142	495	1150	174	13	1196	934
Rock bass	66	32	31	46	227	128	50
Redbreast sunfish	707	2056	1398	3040	3772	8377	4187
Green sunfish	3	-	4	39	81	168	25
Pumpkinseed	229	2578	2579	1000	878	1687	512
Bluegill	567	1423	927	3058	2712	5442	1361
Smallmouth bass	182	298	119	153	327	701	262
Largemouth bass	82	80	23	19	33	14	22
White crappie	4457	664	4371	9290	2987	1003	673
Black crappie	8	4	25	45	86	199	103
Tessellated darter	-	1	4	1	-	-	1
Yellow perch	5955	1090	682	494	2904	735	526
Logperch	-	-	-	-	-	-	27
Shield darter	-	-	-	-	-	-	-
Walleye	1840	2734	1613	369	2267	2140	967
Banded darter	-	-	-	-	-	-	1
Atlantic needlefish	1	-	-	1	-	-	-
Lampreys	-	-	-	-	-	-	-
Sea Lamprey	-	2	-	2	29	11	1
Lake herring	-	1	-	-	-	-	-
Striped bass x White bass	-	-	-	-	-	-	270
Tiger muskie	-	-	-	-	-	-	13
Brook trout x Lake trout	-	-	-	-	-	-	-
Striped bass x White perch	-	-	-	-	-	-	-
	241419	1300345	1617888	917043	1175616	1169161	276045

TABLE 6.2.

Continued.

Year	1979	1980	1981	1982	1983	1984	1985	1986
No. Days	29	30	37	44	29	34	55	59
Lifts	301	403	490	725	648	519	1118	831
Est. Oper. Time (Hr)	187	221	275	502	299	251	542	546
Fishing Time (Hr)	123	117	178	336	224	192	421	449
American eel	1602	377	11329	3961	1080	155	550	364
Blueback herring	2282	502	618	25249	517	311	6763	6327
Hickory shad	-	1	1	15	5	6	9	45
Alewife	9	9	129	3433	50	26	379	2822
American shad	50	139	328	2039	413	167	1546	5195
Gizzard shad	75553	275736	1156662	1226374	950252	912666	2182888	1714441
Atlantic menhaden	-	16	42	-	1	-	1	-
Trouts	-	-	2	-	-	-	-	-
Rainbow trout	15	23	219	20	2	5	70	9
Brown trout	324	258	207	219	225	141	175	65
Brook trout	-	4	3	5	2	-	1	-
Chain pickerel	-	-	1	-	-	-	-	-
Northern pike	4	3	-	5	1	-	-	2
Muskellunge	5	27	1	4	-	-	15	-
Minnows	-	-	-	1	-	-	-	-
Goldfish	-	-	1	-	-	-	-	-
Carp	14946	8879	18313	15362	16273	8012	6729	2930
River chub	-	1	-	-	-	-	-	-
Golden shiner	304	35	155	92	216	8	292	23
Comely shiner	1707	761	281	14214	3176	871	5141	582
Spottail shiner	1533	849	31	315	2132	-	3525	6247
Swallowtail shiner	-	-	3	-	-	-	-	1
Rosyface shiner	-	-	-	8	-	-	-	-
Spotfin shiner	41	314	524	622	501	-	2695	695
Bluntnose minnow	-	-	-	-	-	-	-	-
Blacknose dace	-	-	-	2	-	-	-	-
Longnose dace	-	-	-	-	-	-	-	-
Shiners	-	-	-	6	-	-	-	-
Quillback	5134	2929	3622	1617	4679	1942	957	2327
White sucker	906	1145	1394	582	412	109	776	853
Creek chubsucker	-	-	4	2	-	-	-	-
Northern hog sucker	6	13	1	-	-	-	-	2
Shorthead redhorse	2163	1394	6533	6974	7558	3467	3362	2057
White catfish	515	605	2199	565	224	77	1094	284
Yellow bullhead	13	18	36	61	10	7	21	35
Brown bullhead	284	675	531	338	179	69	461	134
Channel catfish	38251	38929	55528	40941	12559	20479	15200	18898
Margined madtom	-	-	-	6	-	-	-	3
Madtoms	-	-	-	1	-	-	-	-
Tadpole madtom	-	-	-	1	-	-	-	-
Mummichog	-	-	-	1	-	-	-	-
White perch	43103	26971	83363	53527	23151	6402	68344	56977
Striped bass	260	904	3277	60	23	181	213	194
Rock bass	46	88	381	138	269	158	122	200
Redbreast sunfish	3466	1524	1007	1335	401	465	3366	1433
Green sunfish	-	16	28	91	16	7	133	15
Pumpkinseed	323	446	306	848	228	104	1013	402
Bluegill	813	942	1299	1184	587	284	6048	1654
Smallmouth bass	374	455	881	1095	1003	608	1081	666
Largemouth bass	22	41	13	20	17	8	67	75
White crappie	384	100	231	303	450	59	345	199
Black crappie	53	15	20	39	46	6	45	51
Tessellated darter	-	-	2	-	-	-	1	-
Yellow perch	379	373	1007	724	387	487	2145	2267
Logperch	-	-	-	-	-	-	1	1
Shield darter	-	-	1	-	-	-	-	-
Walleye	2491	4153	2645	504	663	236	609	380
Banded darter	-	-	-	-	-	-	-	-
Atlantic needlefish	-	-	2	-	-	-	-	-
Lampreys	-	-	-	-	2	-	-	-
Sea lamprey	3	1	55	56	8	4	164	26
Lake herring	-	-	-	-	1	-	-	-
Striped bass x White bass	273	2674	39	160	355	282	1377	1713
Tiger muskie	132	34	53	56	16	10	73	35
Brook trout x Lake trout	-	-	-	-	-	2	-	2
Striped bass x White perch	-	-	-	-	-	-	-	10
	197769	372379	1353308	1403175	1028090	957821	2317797	1830641

TABLE 6.3

Daily summary of fishes collected at the Conowingo Dam Fish Lift in spring, 1986.

Date	1 Apr	3 Apr	5 Apr	6 Apr	7 Apr	8 Apr	9 Apr	10 Apr	11 Apr	12 Apr
No. Lifts	5	10	21	12	8	15	12	15	20	18
First Lift	710	705	700	713	705	705	700	715	705	705
Last Lift	937	1300	1831	1835	1800	1805	1804	1802	1813	1710
Operating Time	2.45	5.92	11.52	11.37	10.92	11.00	11.07	10.78	11.13	10.08
Fishing Time (Hr)	1.92	4.80	8.88	9.47	9.20	9.57	6.72	9.33	9.47	8.62
Ave. River Flow	43700	36000	33100	32700	30700	30100	32000	34300	35200	33600
Ave. Water Temp. (F)	53.6	57.2	59.0	59.8	59.0	59.0	58.1	58.3	54.5	54.5
American eel	4	3	11	5	2	-	2	1	3	2
Blueback herring	-	-	-	-	-	-	1	-	-	-
Hickory shad	-	-	-	1	-	-	-	-	-	-
Alewife	5	20	14	27	2	27	1	5	-	-
American shad	-	-	27	91	5	12	7	4	3	-
Gizzard shad	1885	835	28045	85300	57750	69175	53814	33015	14848	23625
Rainbow trout	-	-	-	1	-	-	-	-	-	-
Brown trout	-	-	3	-	1	1	1	2	1	-
Northern pike	-	-	-	-	-	1	-	-	-	-
Carp	-	-	7	2	10	50	129	28	21	8
Golden shiner	1	2	-	1	-	-	2	2	-	-
Comely shiner	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	4	-	-	-	11	10	-	-	-
Swallowtail shiner	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Quillback	-	-	3	-	3	-	-	-	-	-
White sucker	59	71	230	112	56	53	91	15	2	-
Northern hog sucker	-	-	-	-	-	1	-	-	-	-
Shorthead redhorse	9	36	41	9	7	23	10	6	4	2
White catfish	4	-	3	-	-	-	-	1	-	1
Yellow bullhead	-	-	-	-	1	1	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-	-	-	-
Channel catfish	56	25	269	124	79	22	170	57	23	9
Margined madtom	-	-	-	-	-	-	-	-	-	-
White perch	-	-	3	4	2	2	6	-	1	-
Striped bass	-	-	2	-	-	-	-	-	-	-
Rock bass	-	4	1	-	3	2	1	-	-	1
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-
Green sunfish	-	-	1	-	-	-	-	-	-	-
Pumpkinseed	-	1	1	-	-	2	-	-	-	-
Bluegill	-	4	6	-	1	16	-	1	3	6
Smallmouth bass	-	3	27	14	16	11	19	2	2	2
Largemouth bass	-	2	1	3	2	4	-	-	3	1
White crappie	-	6	3	1	3	4	2	1	1	1
Black crappie	-	16	7	-	3	4	1	-	-	-
Yellow perch	29	157	121	101	63	130	30	5	6	14
Logperch	-	-	-	-	-	-	-	-	-	-
Walleye	3	-	25	9	9	8	21	7	1	-
Sea lamprey	-	-	-	1	-	4	1	1	1	1
Striped bass x White bass	32	7	105	35	30	52	35	42	103	36
Tiger muskie	1	2	1	-	1	4	-	1	1	1
Brook trout x Lake trout	-	-	-	-	-	-	-	-	-	-
Striped bass x White perch	-	-	-	-	-	1	1	1	-	-
	2088	1198	28957	85841	58049	69621	54355	33197	15027	23710

TABLE 6.3

Continued.

Date	13 Apr	14 Apr	15 Apr	16 Apr	17 Apr	24 Apr	26 Apr	28 Apr	29 Apr	30 Apr
No. Lifts	18	12	19	13	13	6	9	20	13	19
First Lift	708	700	704	701	705	705	705	600	600	605
Last Lift	1740	1455	1751	1357	1241	1430	1300	1733	1715	1830
Operating Time	10.53	7.92	10.78	6.93	5.60	7.42	5.92	11.55	11.25	12.42
Fishing Time (Hr)	8.58	6.13	8.95	5.53	4.10	3.00	4.33	9.25	9.57	10.33
Ave. River Flow	32500	30700	32000	40400	75000	62900	52600	43600	37600	35300
Ave. Water Temp. (F)	54.4	53.6	52.7	51.8	50.0	50.9	53.6	54.5	55.4	58.1
American eel	2	1	-	1	1	1	-	-	1	3
Blueback herring	-	-	-	-	-	-	-	31	-	25
Hickory shad	-	-	-	-	-	-	-	6	-	8
Alewife	1	-	3	2	1	-	2	574	753	664
American shad	17	-	15	2	5	-	-	36	48	68
Gizzard shad	16825	24035	6083	5121	18675	52000	20975	17442	18950	18425
Rainbow trout	-	-	-	-	-	-	-	-	1	-
Brown trout	1	1	2	-	-	2	-	4	-	1
Northern pike	-	-	-	-	-	-	-	-	1	-
Carp	6	24	-	37	196	32	-	15	2	3
Golden shiner	-	-	-	-	-	-	-	1	1	-
Comely shiner	-	-	-	-	-	-	1	-	-	-
Spottail shiner	-	-	-	-	-	-	-	-	5	41
Swallowtail shiner	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Quillback	-	-	-	-	-	-	-	3	-	10
White sucker	4	5	4	7	5	6	4	4	10	14
Northern hog sucker	-	-	-	-	-	-	-	-	-	1
Shorthead redhorse	5	2	2	1	5	3	5	473	479	259
White catfish	-	-	-	1	-	-	-	-	-	-
Yellow bullhead	-	-	-	-	-	-	-	-	2	-
Brown bullhead	-	-	-	-	-	-	-	-	-	2
Channel catfish	2	11	22	13	19	56	2	63	73	70
Margined madtom	-	-	-	-	-	-	-	1	1	-
White perch	-	6	3	1	1	2	-	26	503	864
Striped bass	-	-	-	-	-	-	-	-	-	-
Rock bass	1	-	-	-	-	1	1	9	7	16
Redbreast sunfish	-	-	-	-	-	-	-	-	1	7
Green sunfish	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-	1	1
Bluegill	-	4	-	-	-	-	3	3	7	16
Smallmouth bass	2	10	-	-	-	3	2	12	21	61
Largemouth bass	-	2	1	-	-	-	-	1	3	8
White crappie	-	-	-	-	-	-	-	2	5	14
Black crappie	1	-	-	-	-	-	1	-	-	1
Yellow perch	24	18	14	18	2	-	1	9	13	42
Logperch	-	-	-	-	-	-	-	1	-	-
Walleye	1	-	4	2	2	1	-	13	12	12
Sea lamprey	-	1	-	-	2	1	-	1	-	2
Striped bass x White bass	269	71	113	26	35	18	41	134	85	83
Tiger muskie	-	-	-	-	-	-	-	1	1	1
Brook trout x Lake trout	-	-	-	-	-	-	-	-	-	-
Striped bass x White perch	1	-	-	-	1	1	-	1	-	1
	17162	24191	6266	5232	18950	52127	21038	18866	20986	20723

Continued.

TABLE 6.3

Continued.

Date	1 May	2 May	3 May	4 May	5 May	6 May	8 May	9 May	10 May	11 May
No. Lifts	21	11	22	21	22	10	19	16	15	9
First Lift	600	600	605	600	600	600	605	600	600	615
Last Lift	1815	1651	1755	1700	1800	1404	1847	1810	1700	1700
Operating Time	12.25	10.85	11.83	11.00	12.00	8.07	12.70	12.17	11.00	10.75
Fishing Time (Hr)	10.10	9.45	9.40	9.17	9.78	6.75	10.65	10.10	9.47	9.95
Ave. River Flow	30400	32600	28700	27300	24500	23600	21300	20000	19700	18900
Ave. Water Temp. (F)	59.0	60.8	63.5	61.7	63.5	62.6	63.2	64.3	64.4	64.4
American eel	1	3	3	1	3	9	3	7	2	12
Blueback herring	-	-	16	38	2	-	56	95	217	592
Hickory shad	6	1	11	3	3	-	2	-	2	-
Alewife	100	4	72	96	9	1	6	13	3	1
American shad	89	5	101	308	27	47	320	101	818	765
Gizzard shad	7285	34850	11410	32362	10549	2950	29875	59950	47000	51000
Rainbow trout	-	1	-	-	-	-	1	-	-	-
Brown trout	1	-	2	3	-	-	1	1	2	3
Northern pike	-	-	-	-	-	-	-	-	-	-
Carp	1	13	3	1	13	1	12	5	5	2
Golden shiner	-	-	-	-	-	1	-	4	-	-
Comely shiner	-	-	-	-	-	-	-	-	-	-
Spottail shiner	45	215	-	-	-	-	5	-	-	81
Swallowtail shiner	-	-	-	-	-	-	-	-	-	1
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Quillback	6	6	-	1	-	-	6	21	-	1
White sucker	13	12	7	-	3	1	3	-	1	3
Northern hog sucker	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	169	96	34	37	14	4	5	12	8	5
White catfish	-	-	-	-	-	-	-	-	-	-
Yellow bullhead	-	-	-	-	-	-	-	-	-	-
Brown bullhead	2	1	7	1	4	-	-	-	-	1
Channel catfish	178	342	143	136	176	123	148	152	118	114
Margined madtom	-	-	-	-	-	-	-	-	-	-
White perch	310	232	49	67	421	181	1590	1820	1405	1310
Striped bass	-	-	-	-	-	1	1	-	1	1
Rock bass	1	6	7	9	8	1	8	2	5	7
Redbreast sunfish	4	11	25	11	17	9	20	36	6	16
Green sunfish	-	-	-	-	-	-	-	1	1	-
Pumpkinseed	3	8	2	2	8	1	5	10	8	5
Bluegill	16	58	37	40	39	17	50	22	30	34
Smallmouth bass	50	130	22	70	16	1	7	4	26	15
Largemouth bass	4	15	10	2	1	1	1	-	2	-
White crappie	2	3	6	4	8	5	9	4	3	-
Black crappie	1	-	-	1	2	-	2	-	1	-
Yellow perch	11	38	23	14	72	15	47	28	48	57
Logperch	-	-	-	-	-	-	-	-	-	-
Walleye	21	7	8	6	9	2	3	5	7	5
Sea lamprey	-	1	-	1	2	-	-	1	-	-
Striped bass x White bass	98	27	15	7	5	3	8	15	4	10
Tiger muskie	1	1	-	3	1	1	1	2	1	-
Brook trout x Lake trout	-	-	-	-	-	-	-	-	-	-
Striped bass x White perch	-	-	-	-	-	-	-	-	-	-
	8418	36086	12013	33224	11412	3375	32195	62311	49724	54041

TABLE 6.3

Continued.

Date	12 May	13 May	14 May	15 May	16 May	17 May	18 May	19 May	20 May	21 May
No. Lifts	19	16	20	17	14	8	19	18	21	20
First Lift	615	600	600	600	600	600	600	600	600	600
Last Lift	1731	1700	1815	1623	1800	1715	1856	1655	1702	1705
Operating Time	11.27	11.00	12.25	10.38	12.00	11.25	12.93	10.92	11.03	11.08
Fishing Time (Hr)	9.57	9.57	9.97	8.68	9.92	10.50	10.75	9.12	9.52	9.58
Ave. River Flow	16900	15400	14700	14400	11700	15400	14800	12600	14100	19300
Ave. Water Temp. (F)	64.4	65.3	66.2	67.1	68.0	67.1	67.7	68.0	69.8	70.7
American eel	6	11	42	22	11	23	13	14	4	12
Blueback herring	205	143	1565	140	25	17	123	1160	1248	21
Hickory shad	-	-	-	-	-	-	-	-	1	-
Alewife	210	-	190	10	-	-	-	-	-	-
American shad	10	12	45	21	156	191	136	6	13	12
Gizzard shad	35750	58100	56150	47750	96500	87550	31650	17247	67050	35550
Rainbow trout	-	-	-	-	-	-	-	1	-	1
Brown trout	1	-	4	2	1	2	1	1	-	4
Northern pike	-	-	-	-	-	-	-	-	-	-
Carp	347	33	37	112	148	27	157	93	91	238
Golden shiner	-	-	-	-	-	1	-	1	-	1
Comely shiner	-	-	-	-	-	75	-	1	-	-
Spottail shiner	2200	15	-	-	-	-	3000	-	-	-
Swallowtail shiner	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	-
Quillback	32	15	15	56	190	89	18	125	24	801
White sucker	-	3	3	1	14	1	1	-	2	6
Northern hog sucker	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	24	19	13	22	53	25	6	10	20	42
White catfish	-	-	1	-	1	-	-	-	-	1
Yellow bullhead	-	-	1	-	-	-	-	-	-	-
Brown bullhead	1	1	1	-	-	1	1	1	-	1
Channel catfish	220	68	33	84	79	93	207	85	151	108
Margined madtom	-	-	-	-	-	-	-	-	-	-
White perch	6150	2305	8750	2790	2295	1676	2645	1400	8563	2560
Striped bass	-	-	-	2	-	-	1	-	1	5
Rock bass	3	10	7	5	8	4	2	3	2	5
Redbreast sunfish	34	48	20	21	33	17	43	43	68	59
Green sunfish	-	1	-	-	-	1	1	-	-	2
Pumpkinseed	14	16	7	8	9	4	2	27	13	15
Bluegill	36	57	20	25	46	48	30	48	100	68
Smallmouth bass	19	7	13	14	2	3	3	4	7	9
Largemouth bass	1	-	1	-	1	-	1	-	-	-
White crappie	5	2	10	2	3	1	1	4	7	7
Black crappie	-	-	1	1	1	-	-	1	1	1
Yellow perch	44	64	28	18	29	17	46	57	81	55
Logperch	-	-	-	-	-	-	-	-	-	-
Walleye	2	7	4	1	4	1	1	4	5	9
Sea lamprey	-	1	-	-	1	2	-	-	-	1
Striped bass x White bass	7	8	7	6	16	10	7	10	9	12
Tiger muskie	-	-	1	2	-	-	-	-	-	-
Brook trout x Lake trout	-	-	1	1	-	-	-	-	-	-
Striped bass x White perch	-	-	1	-	-	-	-	-	-	-
	45321	60946	66971	51116	99526	89879	38096	20346	77461	39606

Continued

TABLE 6.3

Continued.

Date	22 May	23 May	25 May	26 May	27 May	28 May	29 May	30 May	31 May	1 Jun
No. Lifts	9	9	13	13	12	10	20	13	18	9
First Lift	605	600	557	555	600	600	610	600	600	600
Last Lift	1200	1150	1330	1223	1243	1302	1740	1610	1650	1540
Operating Time	5.92	5.83	7.55	6.47	6.72	7.03	11.50	10.17	10.83	9.67
Fishing Time (Hr)	4.98	5.05	6.50	5.35	5.30	5.87	9.72	8.98	9.33	9.00
Ave. River Flow	33000	52800	54500	46800	37700	31400	27600	23500	22400	20800
Ave. Water Temp. (F)	72.5	71.6	70.7	71.6	69.9	69.9	71.6	71.6	71.6	71.6
American eel	2	7	8	15	6	6	4	5	3	12
Blueback herring	6	2	26	55	12	9	35	218	79	43
Hickory shad	-	-	-	-	-	-	-	-	-	1
Alewife	-	-	1	-	1	2	-	1	-	-
American shad	12	4	48	10	12	50	354	102	147	861
Gizzard shad	30500	37500	12225	20550	3405	33550	17300	38150	33000	13600
Rainbow trout	-	-	1	-	-	-	1	-	-	-
Brown trout	1	-	2	-	-	-	1	2	5	4
Northern pike	-	-	-	-	-	-	-	-	-	-
Carp	78	117	26	11	3	50	11	37	155	76
Golden shiner	1	-	-	-	-	1	-	-	1	-
Comely shiner	210	-	-	-	-	-	-	-	40	220
Spottail shiner	-	-	-	5	300	-	-	-	10	10
Swallowtail shiner	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	375	-	-	-	-	25
Quillback	346	80	16	2	2	11	1	9	9	70
White sucker	-	4	4	2	1	1	4	3	1	3
Northern hog sucker	-	-	-	-	-	-	-	-	-	-
Shorthead redhorse	22	8	7	1	3	2	2	5	1	-
White catfish	2	-	2	2	21	7	2	8	4	3
Yellow bullhead	-	-	-	-	-	1	-	-	-	-
Borwn bullhead	1	-	2	1	11	4	2	7	2	4
Channel catfish	496	366	755	248	297	395	121	238	315	170
Margined madtom	-	-	-	-	-	-	-	1	-	-
White perch	782	754	700	265	820	555	1665	386	925	347
Striped bass	2	-	2	5	6	8	7	9	5	9
Rock bass	4	1	13	3	-	2	3	1	4	4
Redbreast sunfish	37	67	93	27	34	35	41	24	23	10
Green sunfish	-	-	1	-	-	-	-	1	-	-
Pumpkinseed	11	27	27	7	6	8	5	5	9	5
Bluegill	64	25	47	50	18	55	14	50	53	48
Smallmouth bass	5	5	4	-	-	3	1	-	3	1
Largemouth bass	1	-	1	-	-	-	2	-	-	-
White crappie	4	4	2	4	4	1	6	2	8	1
Black crappie	-	-	-	1	-	1	-	-	-	-
Yellow perch	37	71	71	39	37	27	16	44	40	30
Logperch	-	-	-	-	-	-	-	-	-	-
Walleye	7	5	4	3	-	8	1	12	6	14
Sea lamprey	-	-	-	-	-	-	-	-	-	-
Striped bass x White bass	8	5	2	-	-	2	1	-	-	2
Tiger muskie	1	-	1	-	1	-	1	-	-	-
Brook trout x Lake trout	-	-	-	-	-	-	-	-	-	-
Striped bass x White perch	-	-	-	-	-	-	-	-	-	-
	32640	39052	14091	21306	5375	34794	19601	39320	34849	15573

TABLE 6. 3

Continued.

Date	2 Jun	3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	8 Jun	10 Jun	12 Jun	TOTALS
No. Lifts	12	11	9	11	11	10	7	9	9	
First Lift	600	600	615	600	600	605	605	910	610	
Last Lift	1250	1152	1200	1200	1147	1150	1150	1320	1118	546.01
Operating Time	6.83	5.87	5.75	6.00	5.78	5.75	5.75	4.17	5.13	448.61
Fishing Time (Hr)	5.55	3.60	5.07	5.08	4.62	4.50	3.00	3.25	4.12	
Ave. River Flow	18500	15800	15300	12300	16200	19500	43100	45400	35900	
Ave. Water Temp. (F)	73.4	74.3	71.6	74.3	75.2	75.2	77.9	77.0	73.4	
American eel	5	3	8	3	6	6	12	4	4	364
Blueback herring	39	4	20	16	36	2	1	-	4	6,327
Hickory shad	-	-	-	-	-	-	-	-	-	45
Alewife	-	-	-	1	-	-	-	-	-	2,822
American shad	7	1	113	18	25	5	2	-	1	5,195
Gizzard shad	8050	21350	5895	9350	6010	12600	9780	11550	2725	1,714,441
Rainbow trout	1	-	-	-	-	-	-	-	-	9
Brown trout	1	-	-	-	-	-	-	-	-	65
Northern pike	-	-	-	-	-	-	-	-	-	2
Carp	69	41	80	54	37	129	12	17	18	2,930
Golden shiner	-	-	1	-	-	-	-	-	1	23
Comely shiner	10	-	20	5	-	-	-	-	-	582
Spottail shiner	210	-	55	20	-	5	-	-	-	6,247
Swallowtail shiner	-	-	-	-	-	-	-	-	-	1
Spotfin shiner	250	25	-	15	-	5	-	-	-	695
Quillback	253	42	14	11	10	22	-	2	2	2,327
White sucker	-	-	-	-	-	1	1	1	1	853
Northern hog sucker	-	-	-	-	-	-	-	-	-	2
Shorthead redhorse	-	1	-	-	-	-	1	3	2	2,057
White catfish	3	40	23	14	17	2	15	78	28	284
Yellow bullhead	-	-	11	10	3	-	-	-	5	35
Brown bullhead	5	8	18	12	3	1	5	15	8	134
Channel catfish	347	723	841	1215	898	375	575	5000	1600	18,898
Margined madtom	-	-	-	-	-	-	-	-	-	3
White perch	625	505	106	181	194	40	60	83	41	56,977
Striped bass	5	-	3	26	30	22	24	2	14	194
Rock bass	1	3	1	-	-	1	5	2	2	200
Redbreast sunfish	26	43	144	38	38	25	101	48	30	1,433
Green sunfish	1	2	-	1	-	1	-	-	-	15
Pumpkinseed	21	21	4	8	4	7	26	18	10	402
Bluegill	25	37	30	39	57	35	70	4	42	1,654
Smallmouth bass	1	2	3	-	3	3	1	1	1	666
Largemouth bass	-	-	-	-	-	-	-	-	-	75
White crappie	6	2	1	3	5	3	8	3	3	199
Black crappie	-	-	-	-	-	1	-	-	1	51
Yellow perch	27	33	20	22	18	21	80	19	26	2,267
Logperch	-	-	-	-	-	-	-	-	-	1
Walleye	6	12	7	8	11	9	13	10	3	380
Sea lamprey	-	-	-	-	-	-	-	-	-	26
Striped bass x White bass	8	1	7	8	12	9	6	5	1	1,713
Tiger muskie	1	1	-	-	-	-	-	-	-	35
Brook trout x Lake trout	-	-	-	-	-	-	-	-	-	2
Striped bass x White perch	-	-	-	-	-	-	-	-	-	10
	10003	22900	7425	11078	7417	13330	10798	16865	4573	1,830,641

TABLE 6.4.

Total and catch per hour of American shad by date and weir gate setting during modified lift operation at Conowingo Dam Fish Lift, 1986.

Date		No. One Weir Gate Open	No. Two Weir Gate Open	Both Weir Gates Open	Daily Total
6 Apr	No. Shad	-	9	82	91
	Hrs. Fishing	0.0	1.3	8.1	9.5
	Catch/Hr Fishing	-	6.92	10.12	9.58
4 May	No. Shad	-	10	298	308
	Hrs. Fishing	0.0	0.7	8.5	9.2
	Catch/Hr Fishing	-	14.29	35.06	33.48
13 May	No. Shad	-	-	12	12
	Hrs. Fishing	0.0	1.6	7.9	9.6
	Catch/Hr Fishing	-	-	1.52	1.25
14 May	No. Shad	-	14	30	44
	Hrs. Fishing	0.0	2.7	7.3	10.0
	Catch/Hr Fishing	-	5.19	4.11	4.40
5 Jun	No. Shad	4	-	13	17
	Hrs. Fishing	0.5	0.0	4.6	5.1
	Catch/Hr Fishing	8.00	-	2.83	3.33
Total No. Shad		4	33	435	472
Total Fishing Time (Hr)		0.5	6.3	36.4	43.4
Catch/Hr		8.00	5.23	11.95	10.87

TABLE 6.5.

Mean, minimum, and maximum fork length (mm) ; age ; and spawning history of alewife collected at Conowingo Dam Fish Lift in 1986.

Sex	Age	N	Spawning History No. Virgins	No. Repeats (Single)	Mean (FL)	Minimum (FL)	Maximum (FL)
Male	3	2	2	-	228	225	230
	4	75	73	2	241	221	254
	5	28	20	8	247	233	259
	6	2	-	2	265	254	275
Total		107	95	12	243	221	275
Female	4	107	104	3	252	227	266
	5	37	33	4	258	240	271
	6	6	2	4	276	260	289
	7	1	1	-	275	275	275
Total		151	140	11	254	227	289

TABLE 6.6.

Mean, minimum, and maximum for length (mm) ; age ; and spawning history of blueback herring collected at Conowingo Dam Fish Lift in 1986.

Sex	Age	N	Spawning History No. Virgins	No. Repeats Single	Double	Mean (FL)	Min. (FL)	Max. (FL)
Male	4	66	65	1	-	231	212	251
	5	135	40	93	2	247	221	267
	6	37	8	21	8	253	234	269
	7	2	-	1	1	255	254	256
Total		240	113	116	11	243	212	269
Female	4	10	10	-	-	235	221	245
	5	23	11	12	-	255	235	274
	6	21	5	12	4	265	252	278
	7	1	-	1	-	281	281	281
Total		55	26	25	4	256	221	281

TABLE 6.7.

Mean, minimum, and maximum fork length (mm) ; age ; and spawning history of hickory shad collected at the Conowingo Dam Fish Lift in 1986.

Sex	Age	N	Spawning History No. Virgins	No. Repeats Single	Double	Mean (FL)	Min. (FL)	Max. (FL)
Male	4	2	2	-	-	292	281	302
	5	9	3	6	-	335	317	355
	6	2	1	-	1	368	348	388
	7	1	-	-	1	360	360	360
Total		14	6	6	2	335	281	388
Female	3	1	1	-	-	273	273	273
	4	3	3	-	-	315	310	318
	5	7	3	4	-	341	328	353
	6	1	-	-	1	390	390	390
	7	2	1	-	1	398	389	406
Total		14	8	4	2	342	273	406

TABLE 6.8.

Comparison of catch per effort (Hr) of American shad on weekdays vs weekend days and generation (cfs) at the Conowingo Dam Fish Lift, 1 April through 12 June 1986.

	Lift Time	5000 cfs Catch/Hr	10-20000 cfs Catch/Hr	25-40000 cfs Catch/Hr	45000+ cfs Catch/Hr	Total Catch/Hr
Weekdays	Morning 5-9	9.3	0.0	3.4	5.8	5.3
	Mid-AM 9-11	-	1.8	4.9	6.0	5.4
	Mid-Day 11-3	-	0.0	4.3	5.2	4.7
	Late PM 3-12	16.5	1.9	3.1	4.9	5.6
Mean Weekday		10.5	1.3	3.9	5.4	5.2
Weekend	Morning 5-9	28.1	36.0	3.5	2.4	24.3
	Mid-AM 9-11	61.0	26.8	2.1	4.9	21.8
	Mid-Day 11-3	47.5	6.0	7.7	0.6	15.8
	Late PM 3-12	72.1	1.9	4.5	-	46.8
Mean Weekend		52.6	12.1	5.4	2.4	26.6
Grand Mean		42.0	7.7	4.3	5.1	11.5

TABLE 6.9.

Comparison of the American shad catch, catch per effort, and effort between low (one or less unit generation) and high discharges (two or more unit generation) at the Conowingo Dam Fish Lift, 1 April to 12 June 1986.

Generation Status	No. Shad Caught	Total Time Fished (min)	Number of Lifts	Catch Per Hour
Low	3056	4364	106	42.0
High	2139	22551	784	5.6
Total	5195	26915	890	11.5

TABLE 6.10.

Catch per hour and percent of American shad collected in the Conowingo Dam Fish Lift by water temperature, 1 April through 12 June 1986.

Water Temp. (F)	Hours Fishing	Catch		
		No.	Catch/effort	Percent
≤ 65	252.12	2931	11.63	56.4
≥ 65	196.47	2264	11.52	43.6
Total	448.58	5195	11.58	100.0

TABLE 6.11.

Daily number by sex of American shad floy tagged at the Conowingo Dam Fish Lift, 1986.

Date	Female	Male	Total
5 April	8	19	27
7 April	-	4	4
8 April	2	9	11
9 April	1	5	6
10 April	-	4	4
11 April	-	2	2
13 April	2	15	17
15 April	-	15	15
16 April	-	1	1
17 April	1	3	4
28 April	3	26	29
29 April	-	32	32
2 May	1	4	5
9 May	-	1	1
10 May	6	55	61
18 May	7	-	7
21 May	1	9	10
6 June	5	12	17
8 June	-	1	1
Total	37	217	254

TABLE 6.12.

Data for tagged American shad recaptured at the Conowingo Dam Fish Lift, 1986.

Date of Recapture	Date Tagged	Number of Days Free
29 April 1986	11 April 1986	18
1 May 1986	8 April 1986	23
3 May 1986	28 April 1986	5
4 May 1986	5 May 1986	29
4 May 1986	13 April 1986	21
4 May 1986	29 April 1986	5
8 May 1986	7 April 1986	31
8 May 1986	15 April 1986	23
8 May 1986	28 April 1986	10
8 May 1986	29 April 1986	9
9 May 1986	16 April 1986	23
10 May 1986	28 April 1986	12
10 May 1986	5 April 1986	35
10 May 1986	9 April 1986	31
10 May 1986	13 April 1986	27
10 May 1986	28 April 1986	12
10 May 1986	28 April 1986	12
10 May 1986	29 April 1986	11
10 May 1986	29 April 1986	11
11 May 1986	8 May 1985	368
11 May 1986	16 May 1985	360
11 May 1986	28 April 1986	13
11 May 1986	28 April 1986	13
11 May 1986	22 April 1985	384
11 May 1986	5 April 1986	36
11 May 1986	5 April 1986	36
11 May 1986	8 April 1986	33
11 May 1986	29 April 1986	12
14 May 1986	5 April 1986	39
15 May 1986	29 April 1986	16
16 May 1986	8 May 1985	373
17 May 1986	5 April 1986	42
17 May 1986	13 April 1986	34
17 May 1986	29 April 1986	18
18 May 1986	29 April 1986	19
18 May 1986	2 May 1986	16
26 May 1986	5 April 1986	51
29 May 1986	25 May 1985	369
29 May 1986	5 April 1986	54
29 May 1986	13 April 1986	46
29 May 1986	10 May 1986	19
30 May 1986	5 April 1986	55
30 May 1986	10 May 1986	20
1 June 1986	18 May 1986	14
1 June 1986	18 May 1986	14
1 June 1986	14 May 1985	383
1 June 1986	13 April 1986	49
1 June 1986	10 May 1986	22
1 June 1986	10 May 1986	22
1 June 1986	10 May 1986	22
4 June 1986	10 May 1986	25
4 June 1986	10 May 1986	25

TABLE 6.13.

Data for American shad tagged by Maryland Department of Natural Resources in the Conowingo tailrace and captured at the Conowingo Dam Fish Lift, 1986.

Recapture Date	Tag Date	Days Free
4 May	10 April	24
4 May	15 April	19
20 May	15 April	35
5 May	11 April	24
5 May	15 April	20
8 May	11 April	27
8 May	30 April	8
8 May	2 May	6
9 May	10 April	29
9 May	1 May	8
1 June	1 May	31
10 May	10 April	30
10 May	15 April	25
18 May	15 April	33
30 May	15 April	45
10 May	30 April	10
1 June	30 April	32
10 May	30 April	10
10 May	30 April	10
10 May	1 May	9
10 May	2 May	8
17 May	2 May	15
25 May	2 May	23
10 May	2 May	8
29 May	2 May	27
10 May	2 May	8
10 May	2 May	8
10 May	6 May	4
14 May	6 May	8
10 May	6 May	4
10 May	7 May	3
10 May	8 May	2
11 May	30 April	11
11 May	1 May	10
11 May	1 May	10
11 May	2 May	9
11 May	6 May	5
11 May	7 May	4
11 May	7 May	4
11 May	7 May	4
11 May	8 May	3
16 May	6 May	10
16 May	8 May	8
16 May	8 May	8
17 May	6 May	11
17 May	6 May	11
17 May	6 May	11

Continued

TABLE 6.13.

Continued.

Recapture Date	Tag Date	Days Free
17 May	7 May	10
17 May	8 May	9
17 May	12 May	5
17 May	13 May	4
18 May	2 May	16
29 May	2 May	27
18 May	8 May	10
18 May	8 May	10
18 May	13 May	5
25 May	30 April	25
25 May	8 May	17
28 May	7 May	21
28 May	14 May	14
29 May	30 April	29
29 May	2 May	27
29 May	6 May	23
29 May	8 May	21
29 May	12 May	17
29 May	13 May	16
29 May	15 May	14
29 May	15 May	14
30 May	6 May	24
30 May	14 May	16
30 May	15 May	15
31 May	13 May	18
1 June	1 May	31
1 June	6 May	26
1 June	7 May	25
1 June	8 May	24
1 June	9 May	23
1 June	13 May	19
4 June	13 May	22
1 June	14 May	18
1 June	15 May	17
2 June	14 May	19
4 June	6 May	29
4 June	7 May	28
4 June	12 May	23
4 June	13 May	22
4 June	14 May	21

transport in 1986.

Date	No. Males	No. Females	Sex Undetermined	Total Caught	No. of Mortalities at Lift				No. of Transport Mortalities			
					Males	Females	Undetermined	Total	Males	Females	Undetermined	Total
1 Apr	0	0	0	0	0	0	0	0	0	0	0	0
3 Apr	0	0	0	0	0	0	0	0	0	0	0	0
5 Apr	19	8	0	27	0	0	0	0	0	0	0	0
6 Apr	71	20	0	91	1	0	0	1	1	0	1	2
7 Apr	5	0	0	5	0	0	0	0	0	0	0	0
8 Apr	9	3	0	12	0	1	0	1	0	0	0	0
9 Apr	6	1	0	7	1	0	0	1	0	0	0	0
10 Apr	4	0	0	4	0	0	0	0	0	0	0	0
11 Apr	2	0	1	3	0	0	0	0	0	0	0	0
12 Apr	0	0	0	0	0	0	0	0	0	0	0	0
13 Apr	15	2	0	17	0	0	0	0	0	0	0	0
14 Apr	0	0	0	0	0	0	0	0	0	0	0	0
15 Apr	15	0	0	15	0	0	0	0	0	0	0	0
16 Apr	1	0	1	2	0	0	0	0	0	0	0	0
17 Apr	3	1	1	5	0	0	0	0	0	0	0	0
24 Apr	0	0	0	0	0	0	0	0	0	0	0	0
26 Apr	0	0	0	0	0	0	0	0	0	0	0	0
28 Apr	30	3	3	36	0	0	0	0	0	0	0	0
29 Apr	42	2	4	48	4	2	0	6	0	0	0	0
30 Apr	63	5	0	68	0	0	0	0	1	0	0	1
1 May	81	7	1	89	0	0	0	0	0	0	0	0
2 May	4	1	0	5	0	0	0	0	0	0	0	0
3 May	81	17	3	101	0	2	0	2	0	1	0	1
4 May	217	90	0	308	2	2	0	4	0	2	1	3
5 May	24	3	0	27	3	1	0	4	0	0	0	0
6 May	42	5	0	47	0	0	0	0	0	0	0	0
8 May	276	43	1	320	0	0	0	0	1	0	0	1
9 May	89	12	0	101	3	1	0	4	0	2	0	2
10 May	666	135	17	818	3	7	0	10	21	13	3	37
11 May	673	79	13	765	15	10	0	25	12	12	0	24
12 May	8	2	0	10	1	0	0	1	0	0	0	0
13 May	12	0	0	12	0	0	0	0	0	0	0	0
14 May	37	8	0	45	0	1	0	1	1	1	1	3
15 May	18	3	0	21	1	0	0	1	0	0	0	0
16 May	48	4	4	56	2	0	0	2	0	1	0	1
17 May	150	41	0	191	9	3	0	12	0	1	0	1
18 May	120	14	2	136	0	0	0	0	0	1	0	1
19 May	6	0	0	6	0	0	0	0	0	0	0	0
20 May	12	1	0	13	0	1	0	1	0	0	0	0
21 May	11	1	0	12	2	0	0	2	0	0	0	0
22 May	8	4	0	12	0	3	0	3	0	0	0	0
23 May	3	1	0	4	0	1	0	1	0	0	0	0
25 May	42	6	0	48	0	0	0	0	0	0	0	0
26 May	8	2	0	10	0	0	0	0	0	0	0	0
27 May	10	2	0	12	0	0	0	0	0	0	0	0
28 May	35	15	0	50	0	0	0	0	0	0	0	0
29 May	291	61	2	354	5	7	0	12	1	0	0	1
30 May	85	17	0	102	0	2	0	2	0	0	0	0
31 May	117	30	0	147	2	1	0	3	0	0	0	0
1 Jun	633	223	5	861	5	10	0	15	8	8	1	17
2 Jun	5	2	0	7	0	1	0	1	0	0	0	0
3 Jun	0	0	1	1	0	0	0	0	0	0	0	0
4 Jun	88	25	0	113	0	0	0	0	0	0	0	0
5 Jun	14	4	0	18	0	0	0	0	0	0	0	0
6 Jun	20	5	0	25	0	0	0	0	0	0	0	0
7 Jun	4	1	0	5	0	0	0	0	0	0	0	0
8 Jun	1	1	0	2	0	0	0	0	0	0	0	0
10 Jun	0	0	0	0	0	0	0	0	0	0	0	0
12 Jun	0	1	0	1	0	0	0	0	0	0	0	0
Totals	4224	912	59	5195	59	56	0	115	46	42	7	95

TABLE 6.15.

Mean, minimum, and maximum fork length (mm); age; and spawning history of American shad collected at the Conowingo Dam Fish Lift, 1986.

Sex	Age	N	Spawning History No. Virgins	Spawning History No. Repeats Single	Mean (FL)	Minimum (FL)	Maximum (FL)
Male	2	2	2	-	272	261	283
	3	81	81	-	324	263	378
	4	159	152	7	385	318	462
	5	112	105	7	426	361	484
	6	13	12	1	461	430	502
Total		367	352	15	386	261	502
Female	3	3	3	-	385	372	410
	4	23	23	-	440	401	475
	5	66	65	1	465	405	515
	6	40	40	-	502	462	545
	7	8	8	-	532	510	540
Total		140	139	1	474	372	545

[illegible]

Mean, minimum, and maximum fork length (mm); age; and spawning history of American shad by disposition collected at the Conowingo Dam Fish Lift, 1986.

Sex	Disposition Of Fish	Age	N	Spawning History: No. Virgins	Spawning History: No. Repeats Single	Mean (FL)	Minimum (FL)	Maximum (FL)
Male	Released	3	14	14	-	310	279	342
		4	27	25	2	397	342	436
		5	19	18	1	429	402	472
		6	1	-	1	484	484	484
	Total		61			388	279	484
	Died in Handling	3	5	5	-	324	263	366
		4	23	22	1	402	339	441
		5	26	25	1	427	361	484
		6	3	3	-	431	430	432
	Total		57			408	263	484
	Died in Transport	3	6	6	-	332	307	376
		4	16	14	2	396	318	436
		5	20	19	1	419	388	465
		6	3	3	-	490	482	502
	Total		45			404	307	502
	Tagged	2	2	2	-	272	261	283
		3	56	56	-	327	279	378
		4	93	91	2	375	327	462
		5	47	43	4	427	378	475
		6	6	6	-	458	436	478
	Total		204	352	15	375	261	478
Combined Total			367			386	261	502
Female	Released	3	1	1	-	372	372	372
		4	3	3	-	426	409	439
		5	4	4	-	475	465	500
		6	10	10	-	500	472	525
		7	1	1	-	510	510	510
	Total		19			477	372	525
	Died in Handling	4	8	8	-	449	426	465
		5	23	22	1	476	430	508
		6	14	14	-	508	462	545
		7	3	3	-	538	536	540
	Total		48			485	426	545
	Died in Transport	3	1	1	-	372	372	372
		4	7	7	-	441	410	475
		5	19	19	-	464	435	515
		6	9	9	-	501	480	536
		7	1	1	-	537	537	537
	Total		37			468	372	537
	Tagged	3	1	1	-	410	410	410
		4	5	5	-	433	401	460
		5	20	20	-	451	405	493
		6	7	7	-	496	476	515
		7	3	3	-	532	525	540
	Total		36	139	1	463	401	540
Combined Total			140			474	372	545

TABLE 6.17.

Summary of transportation of American shad from Conowingo Dam Fish Lift, 6 April through 4 June 1986.

Date	No. Collected	Water Temp. (F)	No. Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp. (F) at Stocking Location
6 Apr	91	59.8	86	City Island	2	97.8	14.4	14.2	50.6
30 Apr	68	58.1	68	City Island	1	98.5	11.0	11.0	62.3
1 May	89	59.0	88	City Island	0	100.0	16.6	14.6	64.4
3 May	101	63.5	94	City Island	1	99.0	11.0	9.0	55.4
4 May	308	61.7	89	City Island	0	100.0	16.0	17.5	59.0
		61.7	88		1	98.9	11.6	11.0	59.0
		61.7	112		2	98.2	12.4	12.8	59.0
6 May	47	62.6	70	City Island	0	100.0	15.0	12.0	66.2
8 May	320	63.2	145	City Island	1	99.3	14.0	13.0	71.6
		63.2	104		0	100.0	16.0	19.0	70.7
		63.2	58		0	100.0	15.0	16.0	70.7
9 May	101	64.3	92	City Island	2	97.8	14.4	18.0	68.0
10 May	818	64.4	88	City Island	1	98.9	12.2	15.5	70.7
		64.4	172		11	93.6	12.0	11.7	69.5
		64.4	173		4	97.7	19.0	14.0	71.6
		64.4	153		21*	86.3	14.9	6.8	-
11 May	765	64.4	113	City Island	4	96.5	13.4	12.6	68.0
		64.4	127		3	97.6	10.8	13.0	70.6
		64.4	179		10	94.4	13.8	13.2	71.6
		64.4	156		5	96.8	15.0	13.0	70.7
12 May	10	64.4	110	City Island	2	98.2	11.5	13.8	65.9
		64.4	100		0	100.0	16.4	14.4	64.8
14 May	45	66.2	63	City Island	3	95.2	17.5	14.0	63.5
16 May	56	68.0	64	City Island	1	98.4	14.0	8.8	68.0
17 May	191	67.1	132	City Island	1	99.2	11.5	15.3	73.4
18 May	136	67.7	70	City Island	0	100.0	16.0	16.2	67.1
19 May	6	68.0	83	Benner Springs	1	98.8	17.0	8.4	70.2
25 May	40	70.7	44	City Island	0	100.0	12.1	13.4	67.5
28 May	50	69.9	47	City Island	0	100.0	17.0	15.0	73.4
29 May	354	71.6	93	City Island	0	100.0	16.5	11.7	75.2
			123		0	100.0	11.0	15.0	76.7
30 May	102	71.6	115	City Island	1	99.1	12.5	13.8	76.1
			77		0	100.0	13.4	13.0	79.2
31 May	147	71.6	120	City Island	0	100.0	15.0	15.2	80.3
1 June	861	71.6	150	City Island	0	100.0	14.0	14.0	77.9
		71.6	144		0	100.0	10.1	13.2	78.6
		71.6	150		4	97.3	14.2	15.5	77.9
		71.6	130		11	91.5	12.5	13.7	79.7
		71.6	117		1	99.2	15.5	14.0	79.7
		71.6	68		1	98.5	-	-	79.7
4 June	113	71.6	34	Muddy Run	0	100.0	12.4	13.9	-
Totals			4,289		95	97.8			

* Oxygen ran out.

TABLE 6.18.

Summary of American shad held over at the Conowingo Dam Fish Lift for transport on the following day in 1986.

Date	No. Shad Held Over At Lift	No. Shad Mortalities From Being Held Over	No. Shad Transported	No. Shad Transport Mortalities
5 May	25	2	-	-
6 May	-	-	70	0
10 May	100	0	-	-
11 May	264	17	113	4
12 May*	10	1	210 (100) (110)	2
13 May	12	0	-	-
14 May	-	-	63	3
15 May	19	0	-	-
16 May	45	0	64	1
17 May	32	0	-	-
18 May	83	1	70	0
19 May	-	-	83	1
31 May	19	1	-	-
1 June	-	-	150	0
Total	609	22	823	11

* Biologist released 37 American shad back to tailrace during the night.

TABLE 6.19.

The catch and catch/hr of American shad by average daily water temperature (F) and river flow (Holtwood) at the Conowingo Dam Fish Lift, 15 April through 31 May 1982.

River Flow (x 1000 cfs)	≤50 No. Shad Time (Hr) Shad/Hr	50-54 No. Shad Time (Hr) Shad/Hr	55-59 No. Shad Time (Hr) Shad/Hr	60-64 No. Shad Time (Hr) Shad/Hr	65-70 No. Shad Time (Hr) Shad/Hr	71-74 No. Shad Time (Hr) Shad/Hr	≥75+ No. Shad Time (Hr) Shad/Hr
11-15						132 9.1 14.5	
16-20					788 52.4 15.0	223 47.7 4.7	
21-25				156 25.6 6.1	386 32.1 12.0		
26-30				187 23.1 8.1		3 4.8 0.6	
31-35				46 8.6 5.3		0 8.0 0.0	
36-40			0 6.0 0.0		47 19.8 2.4		
41-45			2 5.8 0.3		66 11.8 5.6		
46-50			0 5.8 0.0				
56-60			0 6.4 0.0				
66-70	0 10.2 0.0		0 6.0 0.0				
76-80			0 11.6 0.0				

TABLE 6.20.

The catch and catch/hr of American shad by average daily water temperature (F) and river flow (Holtwood) at the Conowingo Dam Fish Lift, 12 May through 5 June 1983.

River Flow (x 1000 cfs)	<50 No. Shad Time (Hr) Shad/Hr	50-54 No. Shad Time (Hr) Shad/Hr	55-59 No. Shad Time (Hr) Shad/Hr	60-64 No. Shad Time (Hr) Shad/Hr	65-70 No. Shad Time (Hr) Shad/Hr	71-74 No. Shad Time (Hr) Shad/Hr	≥75 No. Shad Time (Hr) Shad/Hr
31-35					3 21.4 0.1		
36-40				4 11.3 0.4	111 10.8 10.3		
41-45					8 13.9 0.6		
46-50				256 89.4 2.9			
51-55			5 9.0 0.6				
56-60			1 8.1 0.1	15 9.3 1.6			
66-70			0 8.0 0.0	7 9.8 0.7			
> 80				2 5.6 0.4			

TABLE 6.21.

The catch and catch/hr of American shad by average daily water temperature (F) and river flow (Holtwood) at the Conowingo Dam Fish Lift, 15 April through 29 May 1984.

River Flow (x 1000 cfs)	<50 No. Shad Time (Hr) Shad/Hr	50-54 No. Shad Time (Hr) Shad/Hr	55-59 No. Shad Time (Hr) Shad/Hr	60-64 No. Shad Time (Hr) Shad/Hr	65-70 No. Shad Time (Hr) Shad/Hr	71-74 No. Shad Time (Hr) Shad/Hr	≥75 No. Shad Time (Hr) Shad/Hr
46-50					2 10.1 0.2		
51-55			2 8.4 0.2	0 5.1 0.0	79 17.4 4.5		
56-60			3 22.8 0.1	6 6.6 0.9	23 10.7 2.1	15 7.5 2.0	
61-65			4 22.5 0.2	13 6.0 2.0			
71-75		0 9.7 0.0	0 5.0 0.0	0 2.6 0.0			
> 90		0 16.9 0.0	0 4.8 0.0				

TABLE 6.22.

The catch and catch/hour of American shad by average daily water temperature (F) and river flow (Holtwood) at the Conowingo Dam Fish Lift, 15 April through 31 May 1985.

River Flow (x 1000 cfs)	Water Temperature (F) <50 No. Shad Time (Hr) Shad/Hr	50-54 No. Shad Time (Hr) Shad/Hr	55-59 No. Shad Time (Hr) Shad/Hr	60-64 No. Shad Time (Hr) Shad/Hr	65-70 No. Shad Time (Hr) Shad/Hr	71-74 No. Shad Time (Hr) Shad/Hr	≥75 No. Shad Time (Hr) Shad/Hr
11-15					32 8.9 3.6		
16-20				5 8.3 0.6	531 85.9 6.2		
21-25				172 35.7 4.8	454 107.5 4.2		
26-30			19 10.1 1.9	70 21.6 3.2	9 9.8 0.9		
31-35				21 8.9 2.4			
36-40				35 9.4 3.7			
41-45					109 19.7 5.5		
46-50					74 9.8 7.6		

TABLE 6.23.

The catch and catch/hour of American shad by average daily water temperature (F) and river flow (Holtwood) at the Conowingo Dam Fish Lift, 5 April through 7 June 1986.

River Flow (x 1000 cfs)	Water Temperature (F) <50 No. Shad Time (Hr) Shad/Hr	50-54 No. Shad Time (Hr) Shad/Hr	55-59 No. Shad Time (Hr) Shad/Hr	60-64 No. Shad Time (Hr) Shad/Hr	65-70 No. Shad Time (Hr) Shad/Hr	71-74 No. Shad Time (Hr) Shad/Hr	≥75 No. Shad Time (Hr) Shad/Hr
11-15					410 49.0 8.4	31 14.6 2.1	
16-20				1593 29.0 54.9	57 19.6 2.9	133 23.8 5.6	30 9.1 3.3
21-25				468 27.5 17.0		1110 27.3 40.7	
26-30			5 9.2 0.5	436 28.4 15.4		354 9.7 36.5	
31-35		32 23.6 1.4	139 53.2 2.6	96 18.9 5.1		62 10.9 5.7	
36-40		2 5.5 0.4	119 29.4 4.0			12 5.3 2.3	
41-45			36 9.3 3.9				
46-50		0 4.3 0.0				10 5.3 1.9	
51-55						52 11.5 4.5	
61-65		0 3.0 0.0					
76-80		5 4.1 1.2					

TABLE 6.24.

Summary of American shad catch by generation during periods of peak abundance at the Conowingo Dam Fish Lift, 1 to 31 May 1982; 19 May to 6 June 1983; 23 to 29 May 1984; 21 April to 27 May 1985 and 5 April to 7 June 1986.

Total Discharge (x 1000 cfs)	Unit 1	Unit 2	1982 No. Lifts	1982 Time (Min.)	1982 Total Shad	1982 Shad/Hr	1983 No. Lifts	1983 Time (Min.)	1983 Total Shad	1983 Shad/Hr	1984 No. Lifts	1984 Time (Min.)	1984 Total Shad	1984 Shad/Hr
≤ 5	On	Off	1	15	1	4.0	-	-	-	-	-	-	-	-
≤ 5	Off	On	23	575	19	2.0	-	-	-	-	-	-	-	-
≤ 5	Off	Off	157	4571	1179	15.5	19	495	125	15.2	1	15	0	0.0
			181	5161	1199	13.9	19	495	125	15.2	1	15	0	0.0
10-40	On	On	5	171	1	0.4	4	120	4	2.0	16	155	6	2.3
10-40	On	Off	1	30	0	0.0	-	-	-	-	-	-	-	-
10-40	Off	On	46	1253	202	9.7	-	-	-	-	-	-	-	-
10-40	Off	Off	61	1937	138	4.3	33	930	70	4.5	8	165	54	19.6
			113	3391	341	6.0	37	1050	74	4.2	24	320	60	11.3
Change	On	On	7	190	4	1.3	2	45	0	0.0	6	90	1	0.7
Change	On	Off	4	120	19	9.5	-	-	-	-	-	-	-	-
Change	Off	On	15	405	35	5.2	-	-	-	-	-	-	-	-
Change	Off	Off	38	1194	204	10.3	24	690	68	5.9	2	50	7	8.4
			64	1909	262	8.2	26	735	68	5.6	8	140	8	3.4
>40	On	On	36	1181	3	0.2	225	5135	88	1.0	120	2729	58	1.3
>40	On	Off	12	350	12	2.1	-	-	-	-	-	-	-	-
>40	Off	On	30	898	21	1.4	1	30	1	2.0	5	150	8	3.2
>40	Off	Off	28	1006	46	2.7	21	600	19	1.9	-	-	-	-
			106	3435	82	1.4	247	5765	108	1.1	125	2879	66	1.4
Total			464	13896	1884	8.1	329	8045	375	2.8	158	3354	134	2.4

TABLE 6.24.

Continued.

Total Discharge (x 1000 cfs)	Unit 1	Unit 2	1985 No. Lifts	1985 Time (Min.)	1985 Total Shad	1985 Shad/Hr	1986 No. Lifts	1986 Time (Min.)	1986 Total Shad	1986 Shad/Hr	1982-1986 No. Lifts	1982-1986 Time (Min.)	1982-1986 Total Shad	1982-1986 Shad/Hr
≤ 5	On	Off	-	-	-	-	-	-	-	-	1	15	1	4.0
≤ 5	Off	On	-	-	-	-	-	-	-	-	23	575	19	2.0
≤ 5	Off	Off	205	4213	685	9.8	103	4287	3053	42.7	485	13581	5042	22.3
			205	4213	685	9.8	103	4287	3053	42.7	509	14171	5062	21.4
10-40	On	On	11	22	0	0.0	3	43	0	0.0	39	511	11	1.3
10-40	On	Off	-	-	-	-	-	-	-	-	1	30	0	0.0
10-40	Off	On	-	-	-	-	3	77	1	0.8	49	1330	203	9.2
10-40	Off	Off	150	2905	110	2.3	153	4717	433	5.5	405	10654	805	4.5
			161	2927	110	2.3	159	4837	434	5.4	494	12525	1019	4.9
Change	On	On	2	4	1	15.0	5	394	2	0.3	22	723	8	0.7
Change	On	Off	-	-	-	-	-	-	-	-	4	120	19	9.5
Change	Off	On	1	30	0	0.0	8	470	13	1.7	24	905	48	3.2
Change	Off	Off	164	4509	340	4.5	126	4686	651	8.3	354	1129	1270	6.8
			167	4543	341	4.5	139	5550	666	7.2	404	12877	1345	6.3
>40	On	On	15	45	1	1.3	58	2240	38	1.0	454	11330	188	1.0
>40	On	Off	-	-	-	-	7	175	0	0.0	19	525	12	1.4
>40	Off	On	8	241	4	1.0	69	2345	85	2.2	113	3664	119	1.9
>40	Off	Off	283	7747	377	2.9	166	5136	779	9.1	498	14489	1221	5.1
			306	8033	382	2.9	300	9896	902	5.5	1084	30008	1540	3.1
Total			839	19716	1518	4.6	701	24570	5055	12.3	2491	69581	8966	7.7

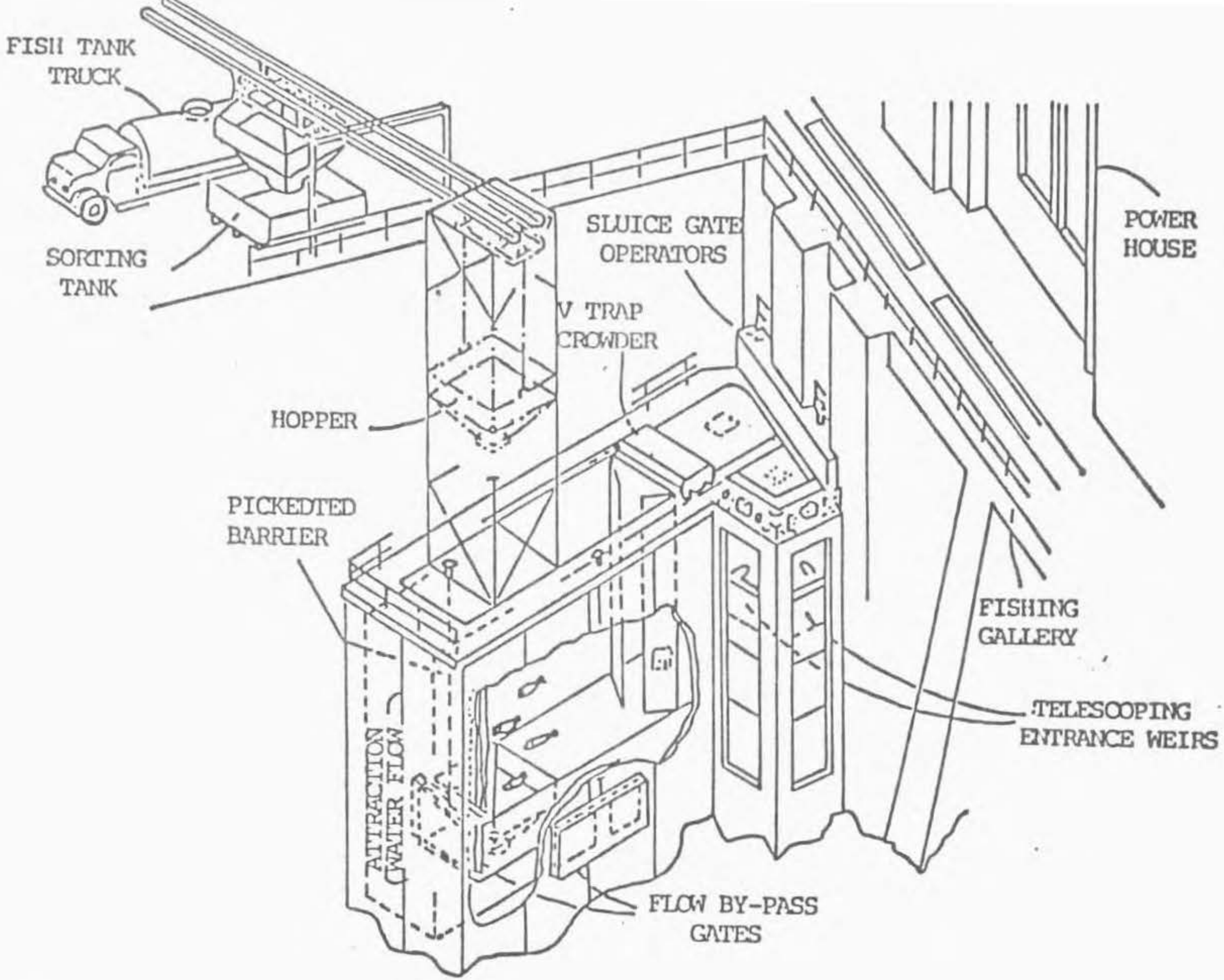


FIGURE 6-1.

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

CONOWINGO FISH PASSAGE FACILITY – 1986

DAILY AMERICAN SHAD (CATCHX5), WITH RIVERFLOW(1000 CFS) AND TEMP(F)

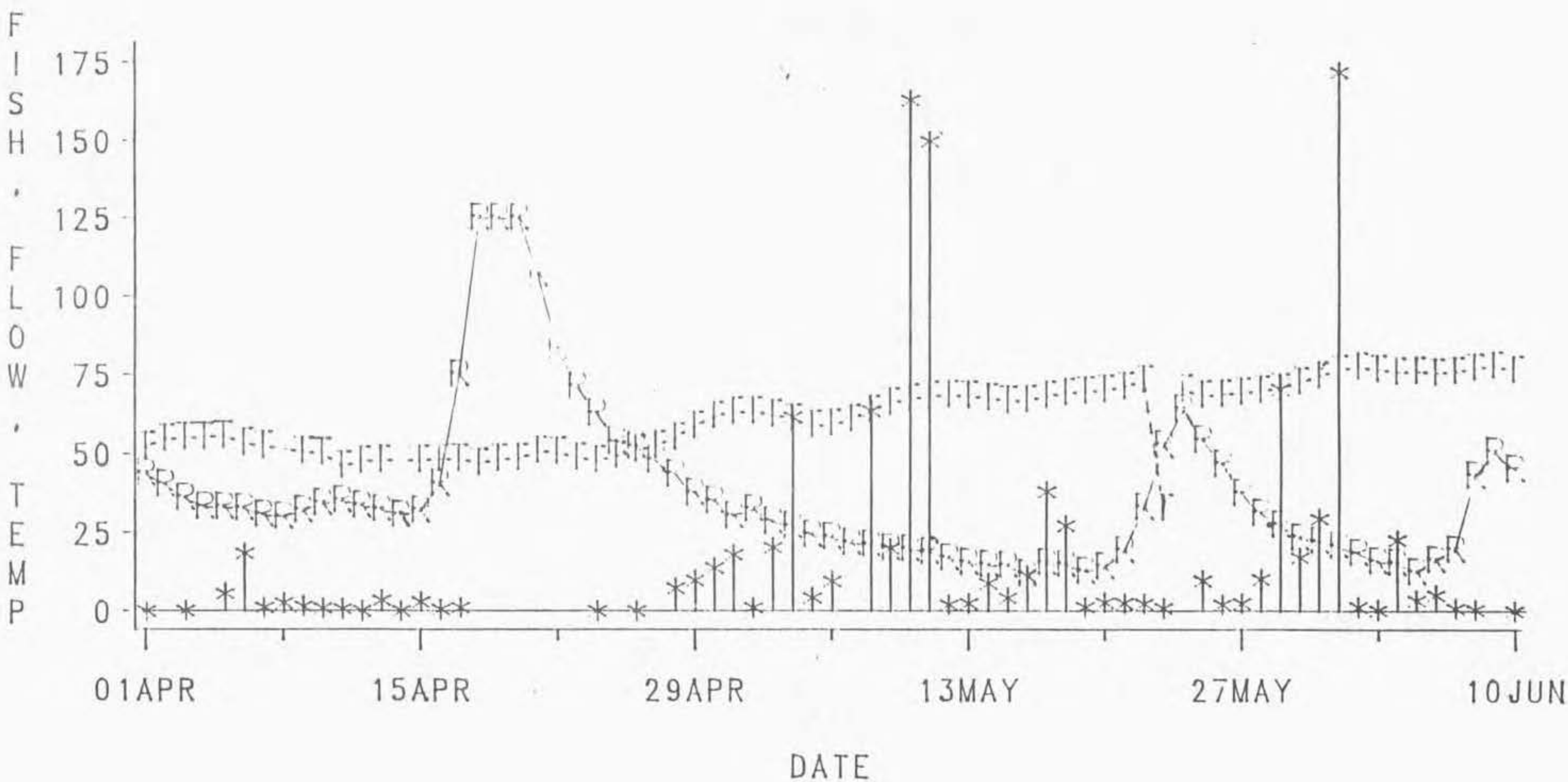
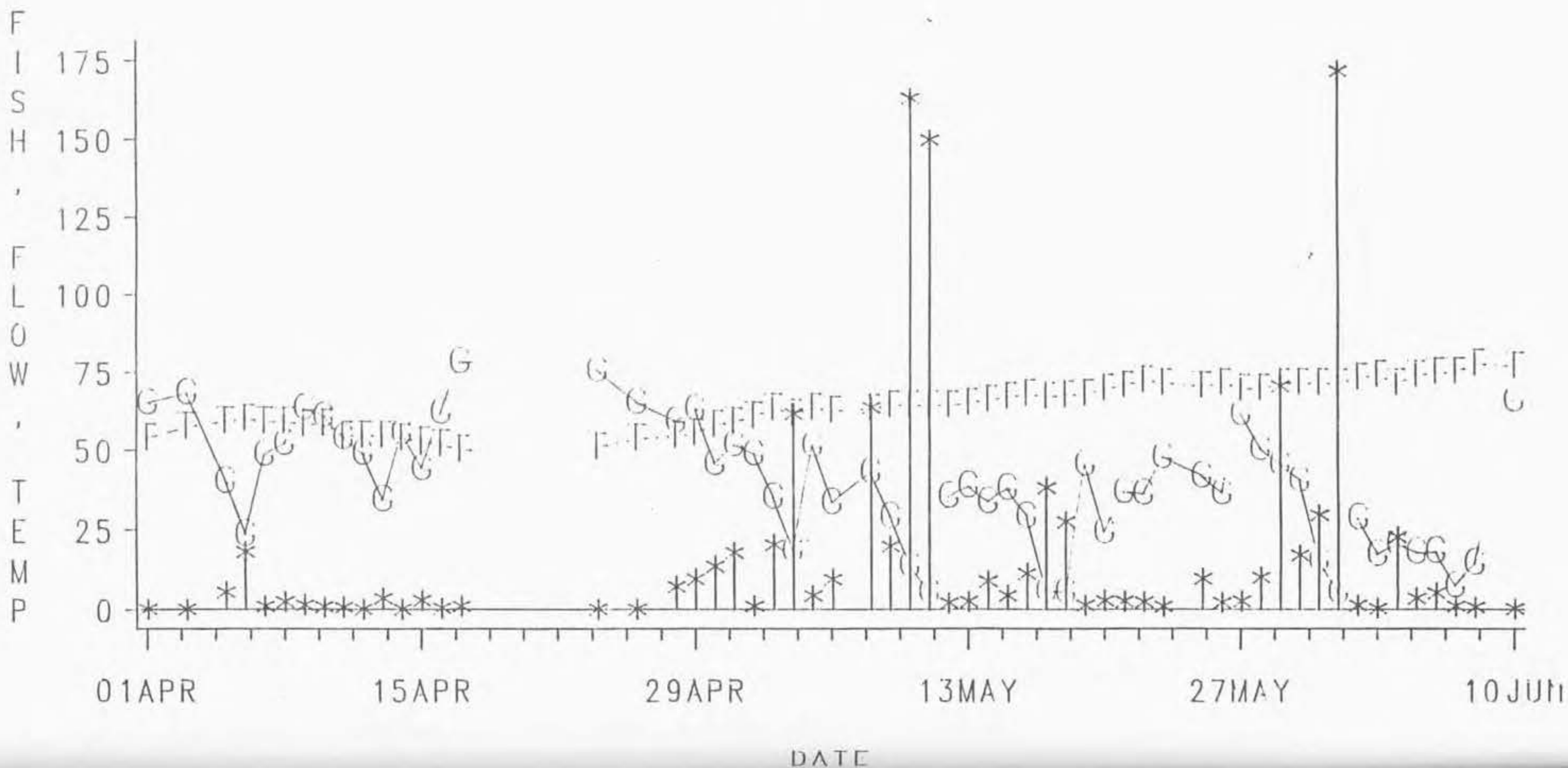


FIGURE 6.3.

CONOWINGO FISH PASSAGE FACILITY – 1986

DAILY AMERICAN SHAD (CATCH/5), WITH GENERATION (1000 CFS) AND TEMP(F)



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

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INTRODUCTION

In April 1980, the Secretary of Natural Resources banned commercial and sport fishing of American shad in all Maryland state waters except the Potomac and coastal waters. This decision was based on the continous decline of American shad landings from a reported 1,037,731 pounds in 1970 to 33,000 pounds in 1979. The serious status of American shad prompted the Tidewater Administration of Maryland's Department of Natural Resources to begin a long-term investigation in the upper Chesapeake Bay. The American shad stock assessment survey has been confined to the lower Susquehanna River, Susquehanna Flats, and the Northeast River. Historically, these areas have been the most productive for American shad (Mansuetti and Kolb 1953, Walburg and Nichols 1967).

The primary objective of the American shad investigation is to assess the status of the stock in the upper Chesapeake Bay. Stock assessment includes the following activities: adult population estimate based on mark-recapture data; adult population characterization using length, sex, age and spawning history; and a juvenile recruitment survey to assess reproductive success. The information obtained through these activities is used to formulate management policies and practices in order to restore American shad to stable, harvestable levels.

METHODS AND MATERIALS

Tagging procedures for 1986 followed the methodology established in previous years and are described in the SRAFRC 1982 and 1983 annual reports. Adult shad were captured using a 500' x 6' x 5 1/4" stretch mesh anchor gill net set off Spencer Island, Maryland, and by hook and line fished from a boat anchored in the tailrace of the Conowingo Dam. In previous years, adult shad were also caught by pound net set by local fishermen located in the Susquehanna Flats area. During 1986, the pound net was set too late in the season for DNR personnel to utilize this gear type in the mark-recapture survey. To avoid duplication of effort and allow more time to concentrate on hook and line tagging activities, the sport angling survey was dropped from the assessment survey.

RESULTS

The 1986 tagging effort encompassed 2 days of gill netting and 19 days of hook and line fishing. Of the 336 fish tagged, 69 were collected by gill net and 267 by hook and line (Table 1). During the fishing effort, 85 fish were recaptured. Recapture data is summarized as follows:

a) 78 fish recaptured by the Conowingo fish lift (does not include multiple recaptures)
   6 fish recaptured by hook and line
   1 fish recaptured by gill net

b) 79 fish originally tagged by hook and line
   6 fish originally tagged by gill net

c) 78 fish recaptured in the same area as initially tagged

6 fish recaptured upstream of their initial tagging

1 fish (tagged in 1985) recaptured downstream of initial tagging

d) Shortest period at large was 3 days

Longest period at large (1986 fish only) was 31 days

1 fish tagged in 1985 at large for 344 days

e) Mean number of days at large for double recaptures was 26 days and ranged from 8-35 days

Mean number of days to first recapture was 12 days

Mean number of days to second recapture was 14 days

The two triple recaptures were at large for 23 and 53 days.

The 1986 adult population estimate using the Petersen Index was 20,850 (Table 2). This estimate, including 95% confidence intervals, was compared to estimates from all years of the study (Fig.1). The Schaefer method computed a population estimate of 19,763 (Table 3a & 3b). Gill net efficiency increased during 1986 and was the highest since the study was initiated (Table 4). Hook and line effort and tagging success was the greatest to date (Table 5).

ADULT POPULATION CHARACTERIZATION

The techniques for characterizing adult shad according to length, sex, age and spawning history remained unchanged from previous years. The 1986 sex ratios were skewed towards males for all gear types with an overall sex ratio of 1: 0.30 males to females (Table 6). In previous years, the anchor gill net has been highly selective for larger, older females. During 1986, the anchor gill net still selected for older and larger fish but with a sex ratio of 1: 0.46 males to females. The percentage of repeat spawners varied with gear type. Female repeat spawners varied between 0 and 21.7% while males varied between 1.9 and 4.0%. Only 3.0% of all fish sampled in 1986 were repeat spawners (n=928). The 1986 value has decreased from the 1985 value of 13.4% (n=768).

The age of American shad ranged from 2 to 7 years; however, only in 1981 have other 2 yr.-old fish been collected. Mean fork lengths for age 3 fish slightly decreased for all gear types compared with 1985 values (Table 7). Other age groups showed no consistent change in mean fork lengths between years.

JUVENILE RECRUITMENT SURVEY

The bi-weekly sampling regime with replicate hauls at each site and supplemental survey, which was done in 1985, was replaced with a weekly sampling program without replicates. As in previous years, the sampling period began in July and continued through October. Detailed descriptions of gear and materials can be found in previous SRAFRC reports. Juvenile sampling during 1986 consisted of 144 seine hauls and 105 otter trawls. A total of 14 juvenile American shad were caught during the sampling period. They ranged in length from 72 mm to 119 mm. Catch composition for 5 important finfish species is presented in Table 8.

The 1986 catches of American shad, blueback herring, alewife herring, white perch, and striped bass increased from 1985. Numbers of young alosids were at record high levels (Table 9). Juvenile

American shad caught during 1986 were given to Pennsylvania Fish Commission personnel for otolith examination to determine whether they were hatchery or wild fish. Results from their examination will give some indication of hatchery-stocking success in comparison with wild shad reproductive success.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, April-May 1986

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Anchor Gill Net	Spencer Island Susquehanna River	107	69
Hook and Line	Conowingo Tailrace Susquehanna River	434	264*
Hook and Line	Spencer Is. Susquehanna River	3	3
Fish Lift	Conowingo Tailrace	5195**	
	TOTALS	5739	336

* 170 fish not tagged via hook and line capture were either below 350 mm minimum length or in poor condition
** fish lift catch excludes RMC recaptures of their tagged shad

Table 2. Population estimate of adult American shad in the Susquehanna River during 1986 using the Petersen Index.

Chapman's Modification to the Petersen Index-

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

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

For the 1986 survey-

C = 5258
R = 84
M = 336

Therefore-

$$N = \frac{(336 + 1)(5258 + 1)}{84 + 1}$$

$$= 20,850$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(336 + 1)(5258 + 1)}{67.99 + 1} = 25,741$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(336 + 1)(5258 + 1)}{103.99 + 1} = 16,880$$ @ .95 confidence limits

TABLE 3. Population estimate of adult American shad in the Susquehanna River during 1986 using the Schaefer method.

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

	Week of Tagging 1	2	3	4	5	6	7	Tagged Fish Recovery (Ri)	Total Fish Recovery (Ci)	Ci/Ri
Week of Recovery										
1								0	160	
2								0	48	
3	3	2						5	802	160.4
4	3	2	21	6				32	2050	64.1
5			6	9				15	488	32.5
6			9	13	4			26	1551	59.7
7			1	5				6	163	27.2
Tagged Fish Recovered (Ri)	6	4	37	33	4	0	0	84		
Total Fish Tagged (Mi)	21	19	151	131	14	0	0	336		
Mi/Ri	3.5	4.8	4.1	4.0	3.5	0	0			

Table 3B. Computed totals of American shad in the Susquehanna River during 1986 using the Shaefer Method.

Week of Recovery (j)	Week of Tagging (i) 1	2	3	4	5	6	7	Total
1								0
2								0
3	1684	1524						3208
4	673	609	5492	1527				8301
5			796	1161				1957
6			2192	3081	455			5728
7			29	540				569
Totals	2357	2133	8509	6309	455			19,763

Table 4. Catch, effort and catch per unit effort (CPUE) for adult American shad by anchor gill net during the 1980-1986 upper Chesapeake tagging programs.

YEAR	TOTAL CATCH	SQ.YD. HRS. OF NET FISHED	SQ.YD. HRS. NEEDED TO CATCH ONE SHAD
1980	115	31,600	275
1981	228	59,591	261
1982	277	93,200	336
1983	213	8,311	39
1984	125	7,822	63
1985	134	10,667	67
1986	107	4,000	37

Table 5. Catch, effort and catch per unit effort (CPUE) for adult American shad by hook and line during the 1982-1986 tagging program in the upper Chesapeake Bay.

YEAR	HOURS FISHED	TOTAL CATCH	CPUE	
			CPAH*	HTC**
1982	-***	88	-	-
1983	-***	11	-	-
1984	52.0	126	2.42	0.41
1985	85.0	182	2.14	0.47
1986	147.5	437	2.96	0.34

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

TABLE 6. Age frequency, number, and repeat spawners by gear type and sex for adult American shad collected during the 1986 upper Chesapeake Bay tagging program.

GEAR TYPE	SEX	SEX RATIO	II	III	IV	V	VI	VII	% REPEAT SPAWNERS	TOTALS
Anchor	M				18	30	2			50
Gill	Rpts.				0	0	2		4.0	2
Net		1: 0.46								
	F			1	3	13	6			23
	Rpts.			0	0	3	2		21.7	5
Hook	M			101	205	58				364
&	Rpts.			0	1	6			1.9	7
Line		1: 0.19								
	F			2	28	35	3			68
	Rpts.			0	0	0	0		0	0
Trap	M		2	81	159	112	13			367
	Rpts.		0	0	7	7	1		4.1	15
		1: 0.38								
	F			3	23	66	40	8		140
	Rpts.			0	0	1	0	0	0.7	1
TOTALS	M		2	182	382	200	15	-	3.1	781
	Rpts.		0	0	8	13	3			24
		1: 0.30								
	F		0	6	54	114	49	8	2.6	231
	Rpts.		0	0	0	4	2			6
								TOTALS	3.0	1012
										30

TABLE 7. Mean fork lengths (mm) and length ranges by sex and age groups for adult American shad collected by gear type during the 1986 Chesapeake Bay tagging operation.

AGE GROUP	SEX	N	MEAN	RANGE Min.	RANGE Max.
A. Anchor Gill Net					
IV	M	19	410	370	455
V		29	437	410	460
VI		2	440	420	460
III	F	1	380	-	-
IV		3	423	375	450
V		13	474	445	525
VI		6	495	485	525
B. Hook & Line					
III	M	101	323	270	375
IV		205	394	330	460
V		58	428	390	500
III	F	2	390	380	400
IV		28	429	385	475
V		35	468	390	530
VI		3	528	525	530
C. Trap					
II	M	2	272	261	283
III		81	324	263	378
IV		159	385	318	462
V		112	426	361	484
VI		13	461	430	502
III	F	3	385	372	410
IV		23	440	401	475
V		66	465	405	515
VI		40	502	462	545
VII		8	532	510	540

Table 8. Juvenile catch composition of five species taken during the 1986 juvenile recruitment survey.

SPECIES	GEAR TYPE	TOTAL NUMBER OF FISH	CPUE
American shad	HS *	8	0.056
	OT **	6	0.057
Blueback herring	HS	3484	24.194
	OT	1988	18.933
Alewife herring	HS	175	1.215
	OT	241	2.295
White perch	HS	1686	11.708
	OT	3028	28.838
Striped bass	HS	60	0.417
	OT	37	0.352

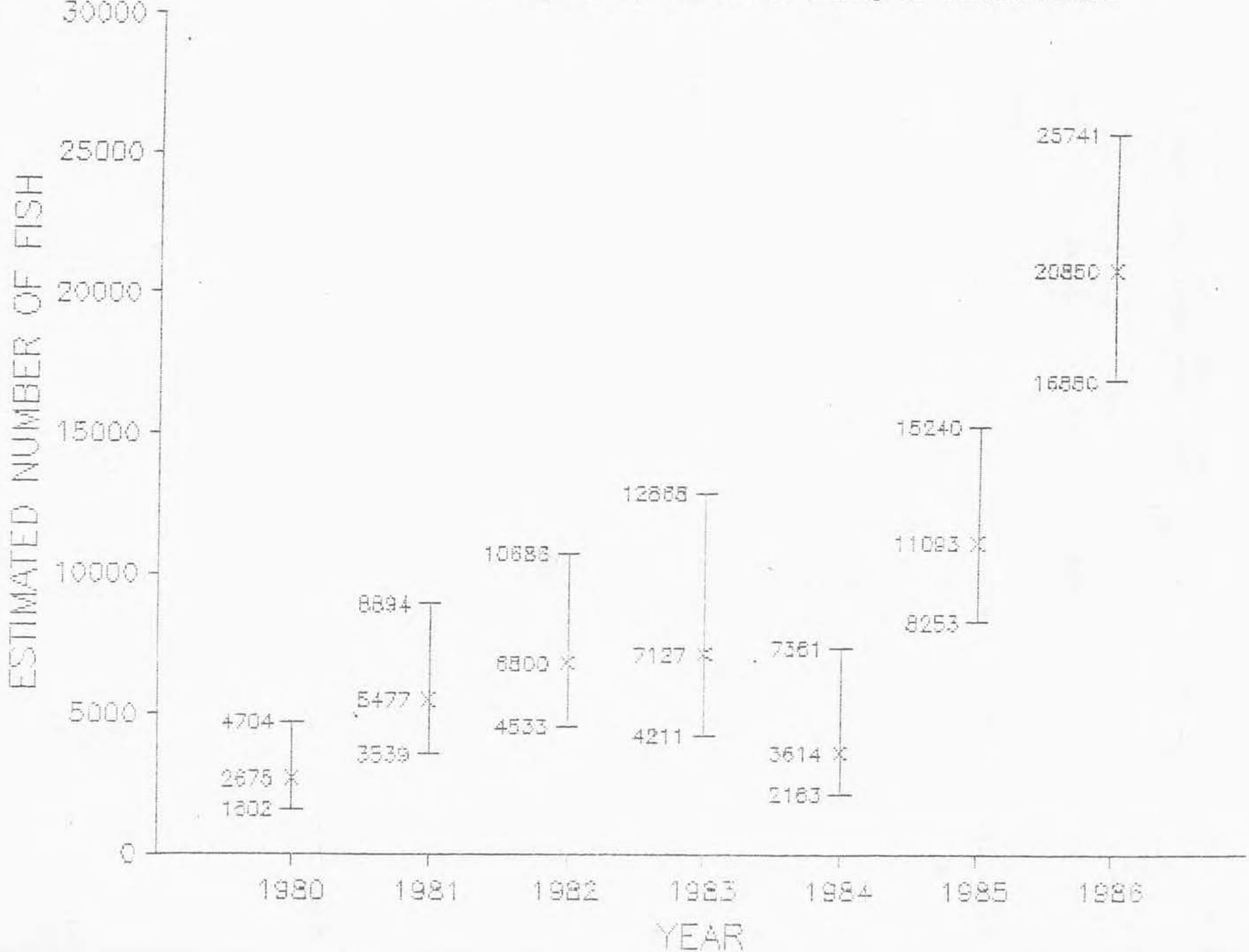
* haul seine
** otter trawl

able 9. Catch-per-unit-of-effort (CPUE) for juvenile alosids by gear type during the years 1980-1986 in the upper Chesapeake Bay juvenile recruitment survey.

SPECIES	YEAR	GEAR	TOTAL CATCH	CPUE
Alosa sapidissima	1980	HS *	0	0
		OT **	0	0
	1981	HS	0	0
		OT	0	0
	1982	HS	0	0
		OT	1	0.01
	1983	HS	0	0
		OT	0	0
	1984	HS	0	0
		OT	0	0
	1985	HS	0	0
		OT	1	0.02
	1986	HS	8	0.06
		OT	6	0.06
Alosa aestivalis	1980	HS	108	0.59
		OT	27	0.23
	1981	HS	2	0.02
		OT	0	0
	1982	HS	130	0.79
		OT	8	0.08
	1983	HS	1	0.01
		OT	2	0.02
	1984	HS	40	0.30
		OT	17	0.30
	1985	HS	96	0.67
		OT	16	0.16
	1986	HS	3484	24.19
		OT	1988	18.93
Alosa pseudoharangus	1980	HS	194	1.07
		OT	38	0.38
	1981	HS	108	0.78
		OT	35	0.38
	1982	HS	14	0.09
		OT	19	0.18
	1983	HS	4	0.03
		OT	6	0.06
	1984	HS	11	0.10
		OT	49	0.70
	1985	HS	99	0.69
		OT	171	1.71
	1986	HS	175	1.22
		OT	241	2.30

haul seine
otter trawl

FIGURE 1. Estimates of adult American shad in the upper Chesapeake Bay from 1980-1986 using the Petersen method.



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