EVALUATION OF THE EFFECTIVENESS OF A CONTINUOUSLY OPERATING FINE MESH TRAVELING SCREEN FOR REDUCING ICHTHYOPLANKTON ENTRAINMENT AT THE INDIAN POINT GENERATING STATION

Prepared for:

Central Hudson Gas & Electric Corporation
Consolidated Edison Company of New York, Inc.
Orange and Rockland Utilities, Inc.
Power Authority of the State of New York

ECOLOGICAL ANALYSTS, INC.

EA Report CON84G

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CHAPTER 1: INTRODUCTION

The Indian Point Generating Station, located on the east shore of the Hudson River estuary 42 miles (67.6 km) north of the Battery in New York City (Figure 1-1), employs a once through (open cycle) condenser cooling water system. Large quantities of river water are used in this cooling process; at full capacity, Indian Point Units 2 and 3* pump approximately 6,360 m^3 (1.68 million gallons) of water per minute from the Hudson River through the condensers. Small aquatic organisms are entrained with the river water through the condenser cooling system where they may be exposed to abrupt temperature changes, changes in hydrostatic pressure, mechanical buffeting, and velocity shear force.

Consolidated Edison Company of New York, Inc. (Con Edison) has installed an experimental continuously operating fine mesh traveling screen (2.5 mm mesh) at the Indian Point Unit 1 intake to examine the potential application of this screen design in reducing ichthyoplankton entrainment. Preliminary investigations to determine the effectiveness of this gear in screening out icthyoplankton that would otherwise be entrained, and to evaluate the survival of organisms impinged on the screen, were conducted in 1977 and are described in a previous report (Ecological Analysts, Inc. [EA] 1977).

This report presents the results of continued studies into the use of the fine mesh traveling screen conducted during the 1978 ichthyoplankton entrainment season (June-July), and discusses these findings in context with those obtained in 1977. The primary objectives of these studies were to (1) further define the collection efficiency of this screen design through the direct release of known numbers of hatchery-reared striped bass larvae and juveniles in front of the screen; and (2) examine the survival of early developmental stages of wild striped bass and other Hudson River fish species impinged on the screen.

* Indian Point Unit 1 has not operated for commercial production since 1974. Unit 2 is owned and operated by Consolidated Edison Company of New York, Inc. (Con Edison), whereas Unit 3 is owned and operated by the Power Authority of the State of New York.

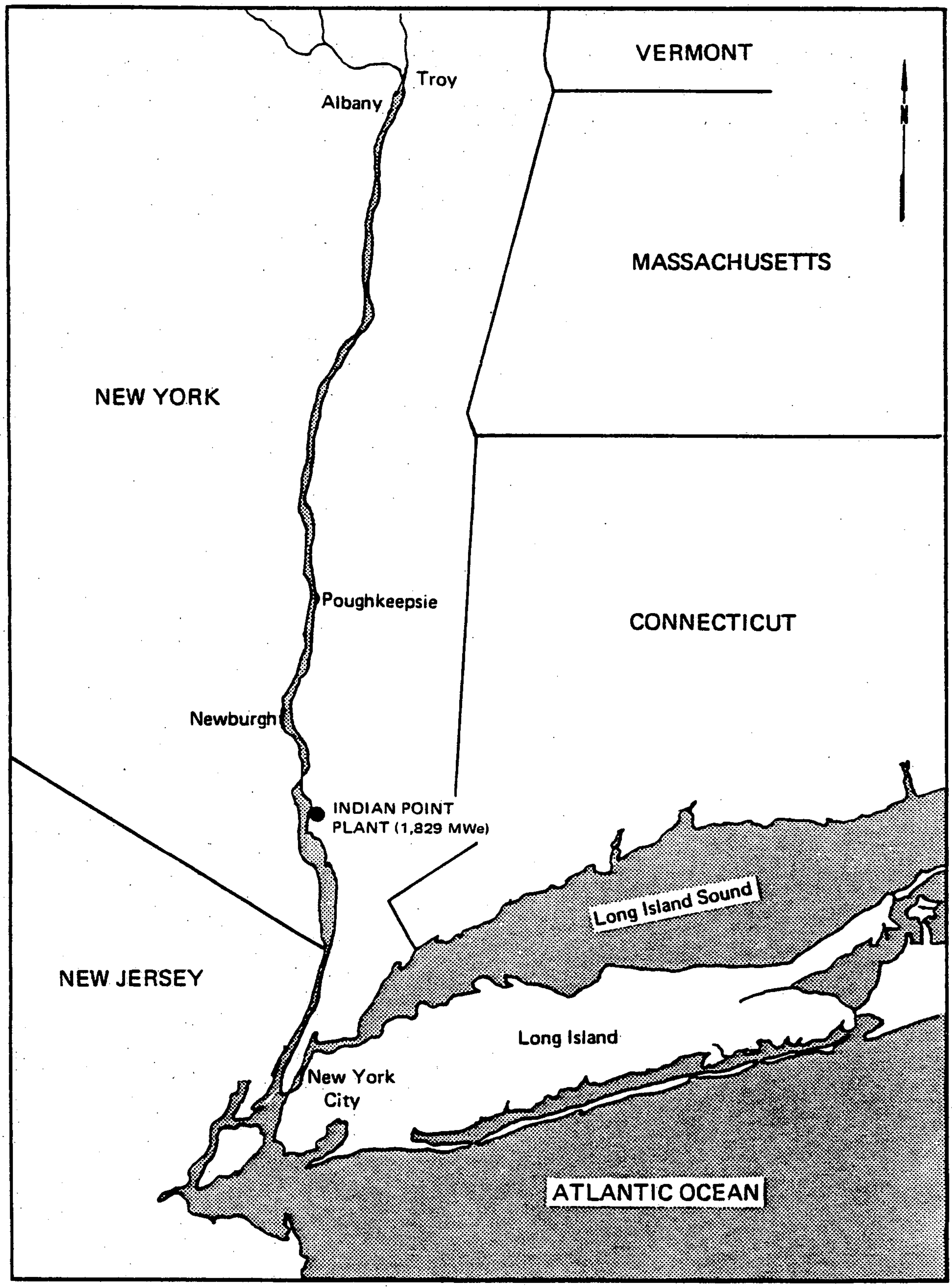

Figure 1-1. Location of the Indian Point Generating Station on the Hudson River Estuary (Scale: 1:1, 267, 200).

CHAPTER 2: SUMMARY

Results of studies conducted during 1977 and 1978 indicate that a continuously operating fine mesh traveling screen (2.5 mm mesh) of the design tested at the Indian Point Generating Station does not effectively reduce entrainment of striped bass yolk-sac and early post yolk-sac larvae (5 to 9 mm mean length); recovery of such larvae released directly in front of the screen ranged from 0.2 to 4.1 percent. Direct releases of striped bass juveniles averaging 25 mm in length resulted in 44 percent recovery in the screen collection system.

A comparison of the length-frequency distribution of striped bass collected at the Indian Point plant intakes using pumps versus the fine mesh traveling screen (EA 1977), as well as the results of other studies (Tomljanovich et al. 1977), indicate that selective retention (i.e., the point at which the proportion impinged exceeds the proportion entrained) of young striped bass on the 2.5 mm mesh screen begins at a length of approximately 15 mm. The minimum size at which 100 percent retention is expected to occur is 22 mm in length. The primary factor causing reduced effectiveness of the screen system in diverting life stages that are selectively retained (≥15 mm in length) appears to be a low efficiency of transfer between the screen fish buckets and the collection trough sluiceway. Collection efficiency for fish that are selectively retained could be substantially improved through minor refinements in the screen collection system (Section 5.1).

Survival estimates for early developmental stages of wild striped bass collected on the fine mesh traveling screen during 1977 and 1978 indicate that as the young fish continue to grow and become more susceptible to retention on the screen, their survival increases. Those life stages impinged infrequently on the 2.5 mm mesh screening (i.e., eggs through early post yolk-sac larvae) were not able to withstand the stresses imposed by impingement and collection. However, for larvae that had attained the size at which selective retention on the fine mesh screen is expected to begin (15 mm mean length), survival was estimated to be 60 percent. For juveniles averaging 19 mm or more, retention on the screen will approach 100 percent, and survival is expected to exceed 75 percent.

Potential application of the fine mesh traveling screen for reducing entrainment of striped bass through the Indian Point plant cooling water system was evaluated by comparing survival on the screen with survival during entrainment through the plant. Based on the results of entrainment studies conducted at Indian Point during 1977, entrainment survival of striped bass was estimated to be 38 to 67 percent for yolk-sac larvae, 75 to 85 percent for post yolk-sac larvae, and 83 percent for juveniles. Thus, in view of the low retention and survival of smaller larvae on the fine mesh traveling screen, this device would not be effective for reducing entrainment of those life stages most susceptible to cooling system effects. Moreover, since the survival of larger young following entrainment is comparable to that following impingement on the fine mesh screen, selectively diverting these fish at the intakes would not appreciably affect their survival.

CHAPTER 3: METHODS AND MATERIALS

3.1 FINE MESH TRAVELING SCREEN

3.1.1 Location

The Indian Point Unit 1 intake structure (Figure 3-1) was selected for placement of the continuously operating fine mesh traveling screen because this unit is no longer operated commercially and, therefore, is well suited for the study of experimental screen designs. The Unit 1 intake system includes two circulating water pumps, each capable of pumping 530 m^3/minute (140,000 gpm) of water. Each pump draws water from two intake forebays; thus, at full capacity, 265 m^3/minute (70,000 gpm) of water enter Unit 1, Forebay 11 where the fine mesh traveling screen is located. The velocity of water at the Unit 1 intake forebays is approximately 0.9 fps during operation of the circulating water pumps at full capacity.*

3.1.2 Description

Conventionally, a fixed screen (9.5 mm [3/8 in.] mesh), a bar rack, and a traveling screen (9.5 mm [3/8 in.] mesh) have been used at the Unit 1 intake forebays to ensure that large fish, debris, and other objects were not pumped through the plant. However, to implement the fine mesh traveling screen design (Figure 3-2), the conventional traveling screen at Forebay 11 was modified by removing the wire mesh panels and replacing them with 2.5 mm nylon screening cloth. The screen was further modified to operate continuously at speeds from 2.5 to 20 ft/minute.

Fish buckets that span the width of the screen (10 ft) were added to enhance survival of impinged organisms. Low pressure spray washes, located at the top rear of the screen, remove impinged organisms from the screen. Fish are washed into a wooden collection trough where an auxiliary water system provides a water flow that transports them either to a collection device or back to the river. The auxiliary water flow is set such that a water depth of 2 in. is maintained in the collection trough to ensure that fish collected on the screen are not washed onto a dry surface. A high pressure spray wash, located below the fish trough, removes debris from the screen.

During all fine mesh traveling screen experiments, circulator pump number 11 was operated at 100 percent capacity (140,000 gpm). The screen was operated at a speed of 10 ft/minute for most of the June samples and 5 ft/minute for all of the July samples. This variation in screen speed was the result of operational restrictions imposed while mechanical difficulties associated with the screen were being corrected.

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* For a detailed description of the Indian Point Generating Station and the Hudson River environs, see Con Edison (1977).

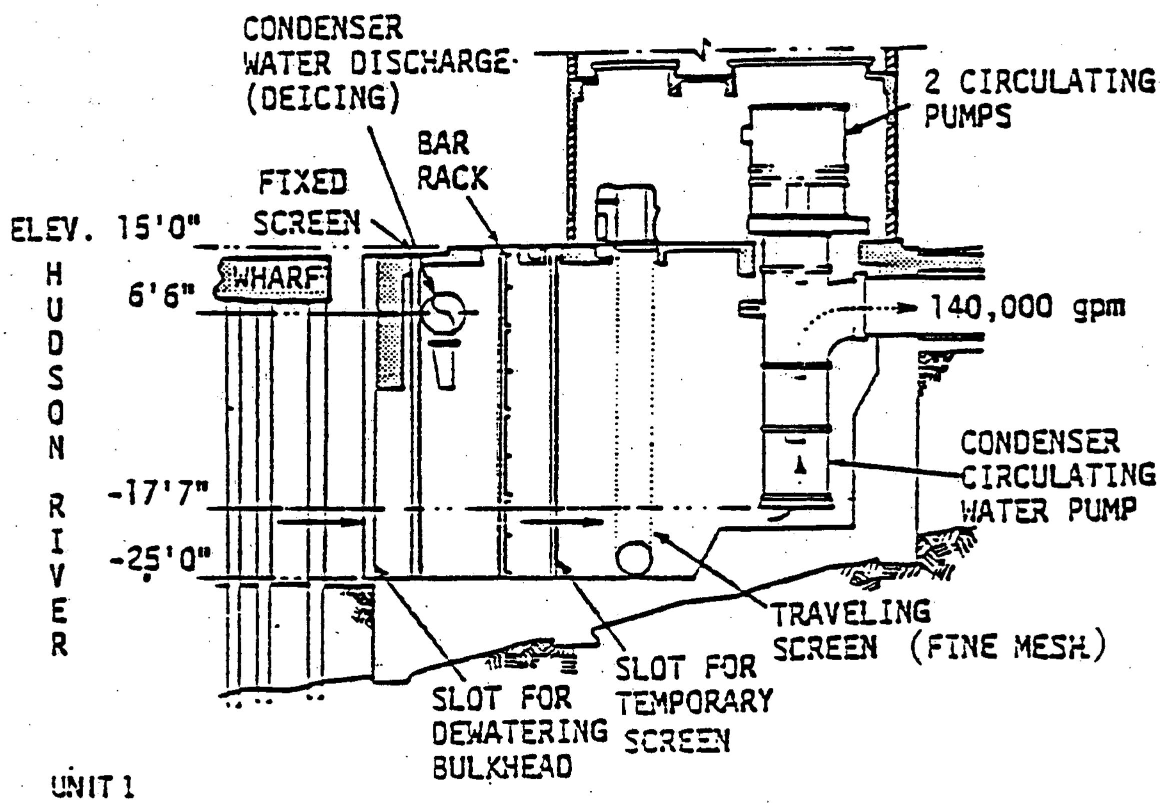


Figure 3-1. **Cross-sectional view of Indian Point Generating Station Unit 1 showing location of fine mesh traveling screen (Source: McFadden 1977; Figure 2.3-6).**

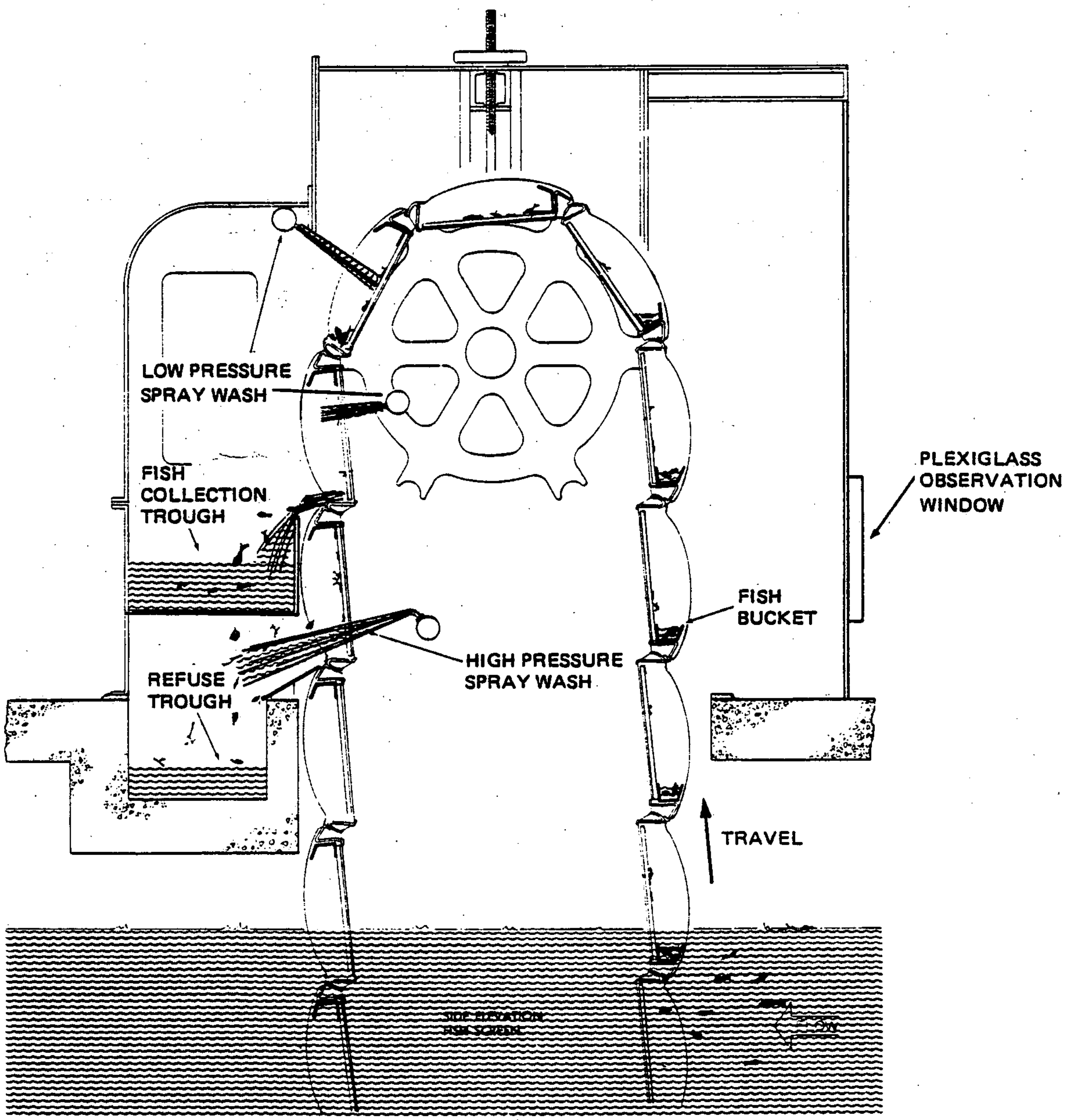


Figure 3-2. Cross-sectional view of experimental fine mesh traveling screen, Indian Point Generating Station, 1978.

3.2 COLLECTION APPARATUS

Ichthyoplankton impinged on the fine mesh traveling screen were collected by diverting the water flow from the collection trough sluiceway (Figure 3-3) into a "net-in-a-barrel" collection apparatus consisting of a 505 µ mesh, conical plankton net suspended in a cylindrical tank (Figure 3-4). The water within the tank was maintained at a level that covered the plankton net via a 3 in. (7.6 cm) drain pipe affixed with a standpipe and gate valve. The bottom (wide portion) of the conical plankton net was fastened to a modified funnel, the neck of which exited at the bottom of the tank. Tygon tubing (5 ft [1.52 m] long, 1.25 in. [3.2 cm] diameter) fastened to the neck of the funnel was connected at the opposite end to a 24 x 13 x 5 in. (61.0 x 33.0 x 12.7 cm) plastic collection container.

At the start of each sample, the collection trough gate to the river was closed and the sampling gate was opened (Figure 3-3) allowing the sluiceway flow containing organisms washed from the screen to enter the net-in-a-barrel collection apparatus. No flow was allowed through the Tygon tubing drain at the bottom of the net during sampling; thus, all water flowed through the net and out the 3 in. (7.6 cm) drain, thereby filtering out all organisms.

At the end of the sampling period, the collection trough sampling gate was closed and the river gate was opened to stop the flow into the collection apparatus. The tank was then drained and the net was thoroughly washed with a fine spray to rinse collected organisms into the funnel. Following wash-down procedures, collected organisms were drained into the collection container. Four screened openings (505 µ mesh) in the lid of the collection container enabled excess water to flow from the container, further concentrating the collected organisms. The collection container was then detached from the Tygon tubing drain and transported to the on-site laboratory.

3.3 DIRECT RELEASE EXPERIMENTS

To determine the collection efficiency of the fine mesh traveling screen, known numbers of Hudson River striped bass larvae and juveniles were obtained from the Con Edison hatchery facility at Verplanck, New York, operated by Texas Instruments Incorporated (TI), and were released approximately 10 ft (3.0 m) in front of the fine mesh traveling screen. Releases occurred at the location of the temporary screen shown in Figure 3-1. Prior to each release, the total number of specimens and the percent alive were determined by aliquoting. Ten aliquots (25 ml per aliquot for larvae and 450 ml per aliquot for juveniles) were removed from the holding container and the number of fish in each aliquot was counted. The total number of fish in the release batch was estimated on the basis of the average density of fish per aliquot and the total volume of water in the holding container. The specimens were then placed in 5 gallon containers and lowered into the intake water.

Time of travel experienced by organisms from release until retrieval in the net-in-a-barrel collection apparatus was estimated using styrofoam beads, which were released in the same manner as test specimens. Based on these estimates, sampling was initiated 2 minutes after the time of release by raising the collection trough sampling gate and lowering the river gate to divert the flow of water into the net-in-a-barrel collection apparatus.

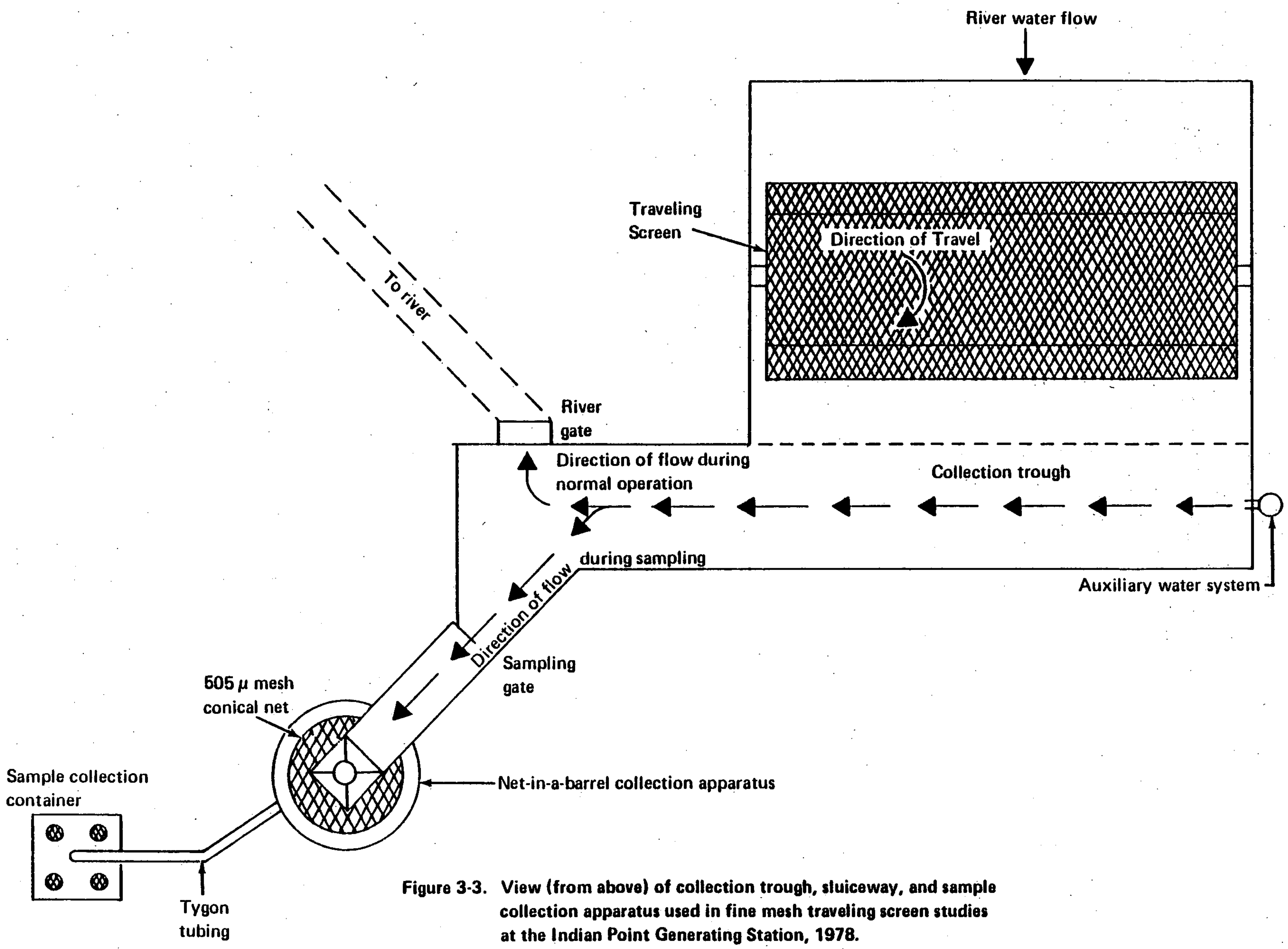


Figure 3-3. View (from above) of collection trough, sluiceway, and sample collection apparatus used in fine mesh traveling screen studies at the Indian Point Generating Station, 1978.

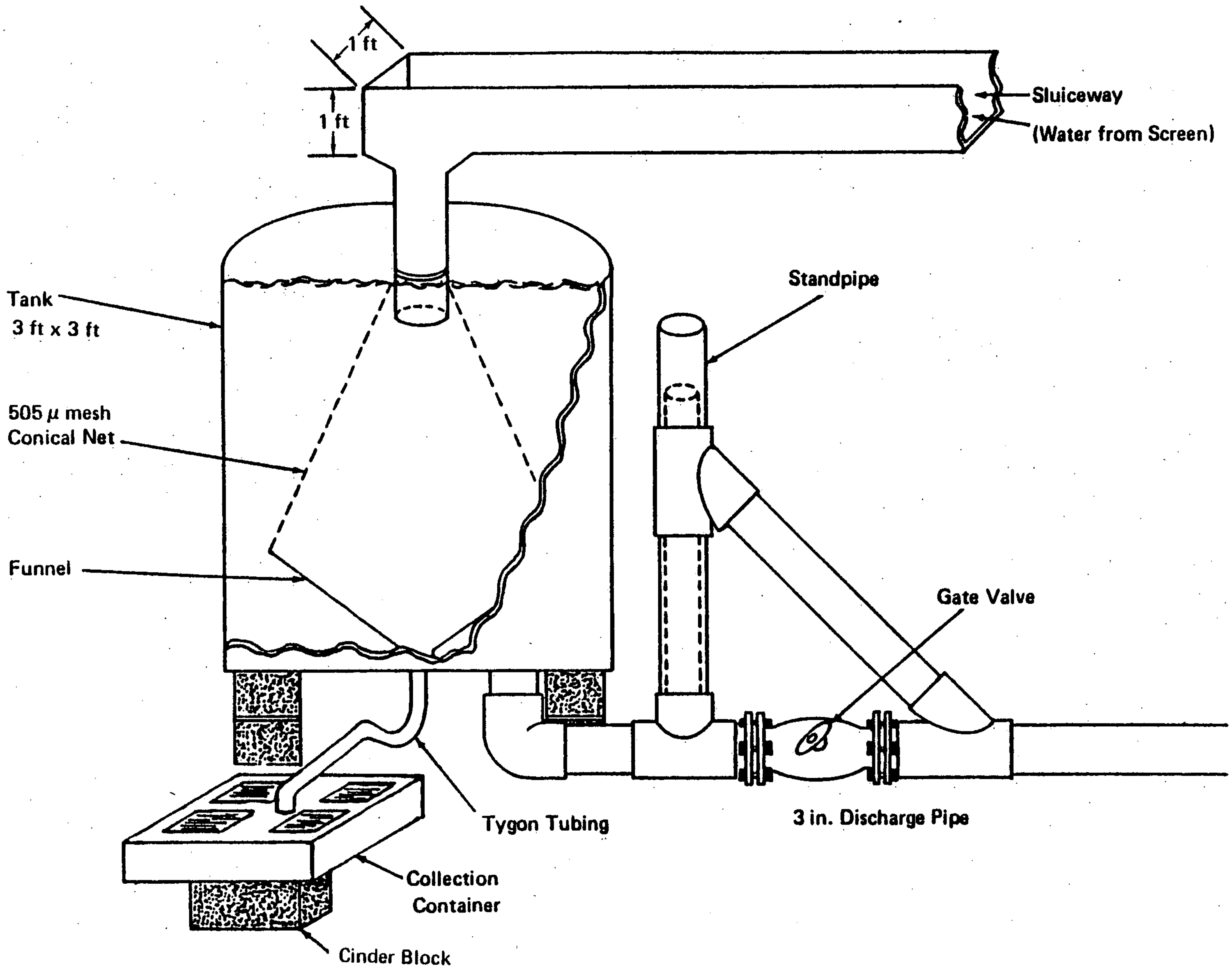


Figure 3-4. Collection apparatus used for fine mesh traveling screen studies at the Indian Point Generating Station, 1978.

Direct release experiments were conducted during the day between 0800 and 1700 hours; sampling duration was from 10 to 15 minutes. During these experiments, the low pressure screenwash was set at 5, 10, or 15 psi in an effort to define the optimum screenwash pressure for achieving maximum survival and collection efficiency. Before and after each direct release experiment, background samples were collected by diverting screen washwater into the collection apparatus for 10 minutes to determine the number of wild striped bass that could be expected to occur in the direct release sample.

3.4 IMPINGEMENT SURVIVAL

To determine the survival of larvae and juveniles of wild Hudson River fish species, particularly striped bass, impinged on the fine mesh traveling screen, collections of screen washwater were made during June and July when river densities of these life stages are characteristically high. Sampling was conducted between 1600 and 0100 hours at a low pressure screenwash of 10 psi. Screen washwater was diverted into the net-in-a-barrel collection apparatus for periods of from 2 to 15 minutes, depending on detrital load.

After collection, the samples were brought to the on-site laboratory and sorted immediately. Organisms were classified as to condition and held for latent effects observations. Larval and juvenile fish were classified as live, stunned, or dead, based upon the following criteria:

- Live: swimming vigorously with no apparent orientation problems
- Stunned: swimming abnormally, struggling, swimming on side or upside-down; non-motile except when gently prodded with a probe
- Dead: no vital life signs, no body or opercular movement, no response to gentle probing.

Live and stunned fish were transferred to separate holding containers (0.95 liter jars containing filtered, ambient river water) with a large-bore glass pipette. A maximum of five larvae were placed in each holding container, which was aerated and maintained in an ambient water trough. Dead specimens were preserved for later identification and length determination.

Fish initially classified as live or stunned were examined for latent effects 3, 6, 12, 24, 48, 72, and 96 hours after sample collection. Dead organisms observed during the latent effects check periods were counted, removed from the holding containers, and preserved in vials containing 5 percent formalin. Organisms remaining alive after 96 hours were likewise enumerated and preserved. Following completion of latent effects observations, all vials were transported to Ecological Analysts' Central Laboratory in Middletown, New York, where species and life stage identifications were made.

Because of the large number of live fish collected during sampling on 20 July, it was necessary to subsample live and stunned fish for latent effects observations. The subsamples included all but two of the striped bass collected on that date, and approximately 65 percent of the other species collected. The actual number of fish used for latent effects determinations are given in Appendix Table A-2.

3.5 CONTROL EXPERIMENTS

Three types of control experiments (designated as Control A, Control B, and Control C) were conducted during the study period to further evaluate collection efficiency and/or survival associated with various components of the fine mesh traveling screen collection system, and handling and holding procedures associated with sample processing and latent effects determination. Hatchery-reared Hudson River striped bass larvae and/or juveniles, served as the control specimens. During all control experiments, the low pressure screenwash was set at 10 psi.

Control A experiments were designed to evaluate the efficiency with which organisms were transferred from the fish buckets on the fine mesh traveling screen into the collection trough. In these experiments, approximately 50 hatchery-reared striped bass larvae or juveniles were placed directly into the fish buckets, and the screen washwater was diverted into the collection apparatus for 10 minutes. At the end of the collection period, the number of striped bass retrieved in the collection apparatus was recorded.

Control B experiments were conducted to determine the collection efficiency of the collection trough diversion system, as well as survival effects associated with collection methodology, handling, and holding. In these tests, approximately 50 control specimens were placed in the collection trough and the water flow within the trough was diverted into the net-in-a-barrel collection apparatus for 10 minutes. Collected organisms were subsequently enumerated and subjected to 96-hour latent effects handling and holding procedures identical to those used in impingement survival experiments (Section 3.4).

The third type of control experiment (Control C) was designed to evaluate survival associated with stresses imposed by post-sampling handling and holding procedures only. During these tests, approximately 25 control specimens were placed in the 24 x 13 x 5 in. collection container and subjected to 96-hour latent effects handling and holding procedures as described in Section 3.4.

3.6 DATA ANALYSIS

Survival estimates for early developmental stages of wild striped bass impinged on the fine mesh traveling screen were determined from the results of impingement survival experiments (Section 3.4). Initial survival is calculated as the ratio of organisms initially live or stunned to the total number collected:

$$P_T = \frac{\text{initial number alive (live + stunned)}}{\text{total number collected (live + stunned + dead)}}$$

where

P_T = total proportion surviving impingement and sampling procedures.

The proportion surviving latent effects is determined as the ratio of the number of live and stunned individuals surviving to a specified time after collection to the total number of live and stunned individuals held for latent effects.

The survival of test organisms is the product of the conditional probabilities of surviving impingement and the sampling process. Assuming there is no interaction between the two stresses:

$$P_t = P_i \times P_s$$

where

P_t = probability of surviving impingement and sampling
P_i = probability of surviving impingement
P_s = probability of surviving sampling procedures.

The survival of the control organisms (P_S) can be used as an estimate of P_s and the probability of surviving impingement (P_i) can be estimated by:

$$P_I = \frac{P_T}{P_S}$$

Impingement survival is calculated by the equation:

$$S_I\ (\%) = P_I \times 100 = \frac{P_T}{P_S} \times 100$$

where

S_I = the estimated percentage of organisms that survive impingement on the fine mesh traveling screen.

Significant differences between survival proportions for experimental and control organisms were tested using a z-test for comparisons between two proportions (Armore 1973:pp. 207-209). The standard error of the survival proportion was calculated according to the following equation:

$$\text{standard error} = \sqrt{\frac{P_I(1-P_I)}{n}}$$

CHAPTER 4: RESULTS

4.1 COLLECTION EFFICIENCY

Direct release experiments were originally scheduled from June through mid-July to test the efficiency of the fine mesh traveling screen for collecting progressively older and larger striped bass early life stages. However, because of mechanical problems associated with screen operation, direct releases were conducted only for yolk-sac larvae averaging 5 mm in length (6 June), and juveniles averaging 24 to 26 mm in length (18 and 20 July).

The three direct releases on 6 June indicated a low efficiency of the fine mesh traveling screen for collecting striped bass yolk-sac larvae (5 mm mean length). Of the 38,700 larvae released during these tests (Table 4-1), only 835 (2.2 percent) were recovered. A positive relationship was indicated between screenwash pressure and the percentage of larvae recovered, with lowest recovery (1.1 percent) occurring at a screenwash pressure of 5 psi, intermediate recovery (2.3 percent) occurring at 10 psi, and highest recovery (4.1 percent) occurring at 15 psi. None of the larvae collected at the three screenwash pressures were alive when recaptured.

The collection efficiency of the fine mesh traveling screen was substantially higher for juveniles. Of the 17,000 juveniles (24-26 mm mean length) released during six experiments on 18 and 20 July, 7,407 (43.6 percent) were retrieved in the collection apparatus (Table 4-1). Tests conducted at low pressure screenwashes of 5, 10, and 15 psi showed no apparent relationship between screenwash pressure and the percentage of juveniles recovered or their initial survival. At the time of testing, 90.0 to 96.8 percent of the hatchery-reared striped bass juveniles used in the direct release experiments were estimated to be alive; however, many appeared to be stressed due to pre-sampling handling and holding procedures. Although these fish were held for latent effects observations, the high variability of both initial survival (Table 4-1) and latent survival (Appendix Table A-1) gave further indication of the influence of stresses other than those associated with testing. For this reason, results of direct release experiments using hatchery-reared striped bass were not used for survival estimates. Similar problems associated with estimating long term survival of wild striped bass and other species, based on experiments using hatchery-reared fish, were experienced by Tomljanovich et al. (1977) in laboratory fine mesh screen experiments. They, too, reported that reliable survival estimates were difficult owing to non-test-induced stresses associated with the pre-sampling handling and holding requirements for hatchery fish.

Control experiments using hatchery-reared striped bass larvae and juveniles indicated a high recovery by the collection system after fish enter the collection trough (Control B), but a poor efficiency of transfer between the screen fish buckets and the collection trough (Control A). Of the 50 juveniles (24 mm mean length) placed directly into the collection trough during the Control B experiment conducted on 18 July, 37 specimens (74.0 percent) were recovered in the net-in-a-barrel collection apparatus (Table 4-1). During a similar control experiment conducted in 1977 using larvae averaging 7 mm in length, 23 (92 percent) of the 25 larvae released into the collection trough were recovered in the collection apparatus (EA 1977). Observations of

TABLE 4-1 RESULTS OF EXPERIMENTS TO DETERMINE STRIPED BASS COLLECTION EFFICIENCY OF THE INDIAN POINT GENERATING STATION FINE MESH TRAVELING SCREEN, 6 JUNE - 20 JULY 1978

Release Number	Release Date	Number Released	Mean Length (mm)	Percent of Released Alive	Screenwash Pressure(PSI)	Number Recovered Live	Stunned	Dead	Total	Percent Recovered	Initial[a] Survival (%)
1[b]	6 JUN	19,200	5	98.6	5	0	0	208	208	1.1	0.0
2[b]	6 JUN	9,500	5	79.2	10	0	0	219	219	2.3	0.0
3[b]	6 JUN	10,000	5	88.9	15	0	0	408	408	4.1	0.0
4[c]	18 JUL	3,000	25	96.8	5	1,105	60	530	1,695	56.5	71.0
5[c]	18 JUL	3,000	24	91.0	10	395	37	766	1,198	39.9	39.6
6[c]	18 JUL	3,000	26	96.2	15	653	21	853	1,527	50.9	45.9
7[c]	20 JUL	2,000	24	90.0	5	80	63	242	385	19.3	41.3
8[c]	20 JUL	3,000	25	90.0	10	336	106	822	1,264	42.1	38.9
9[c]	20 JUL	3,000	24	90.0	15	836	43	459	1,338	44.6	73.0
Control A[c]	6 JUN	53	5	100.0	10	0	0	7	7	13.2	0.0
Control A[c]	18 JUL	50	26	100.0	10	3	0	0	3	6.0	100.0
Control A[c]	18 JUL	50	24	100.0	10	4	0	2	6	12.0	66.7
Control A[c]	20 JUL	50	26	100.0	10	6	2	1	9	18.0	88.9
Control B[c]	18 JUL	50	24	100.0	10	34	1	2	37	74.0	94.6
Control B[c,d]	20 JUL	51	25	--	10	11	20	32	63	--	49.2

(a) Initial Survival (%) = $\frac{\text{Proportion alive when recovered}}{\text{Proportion alive when released}} \times 100.$

(b) Yolk-sac larvae and larvae.

(c) Juveniles.

(d) The fact that the recorded number of fish released (51) during this control experiment is less than the actual number of fish recovered (63) indicates that the test specimens may have been incorrectly counted or recorded at the time of release. Consequently, the percentage recovered is not presented for this experiment. Initial Survival (%) is based on the proportion alive when recovered.

Note: Control A = Control specimens were placed directly into the fine mesh traveling screen fish buckets and retrieved in the net-in-a-barrel collection apparatus.

Control B = Control specimens were placed into the collection trough behind the fine mesh traveling screen and retrieved in the net-in-a-barrel collection apparatus.

the collection trough and sluiceway during sampling indicated that some organisms are able to avoid collection by remaining in an area of reduced current at the corner of the sluiceway to the immediate left of the river gate (Figure 3-3).

Of the 53 Control A larvae (5 mm mean length) placed into the fish buckets on the fine mesh traveling screen, 7 specimens (13.2 percent) were retrieved in the net-in-a-barrel collection apparatus (Table 4-1). Similarly, in the three Control A experiments using juveniles (24-26 mm mean length), only 18 (12.0 percent) of the 150 fish placed in the screen fish buckets were recovered in the collection gear. Although an explanation of the lower recovery of juveniles in Control A versus direct release experiments was not apparent, the control experiments do demonstrate that a considerable number of organisms collected in the fish buckets are not successfully transferred to the collection trough. This is probably due to the fact that there is a gap of approximately 5 in. between the fish buckets and collection trough that results in some fish falling between the trough and the screen when the buckets overturn. Additionally, some organisms have been observed to remain on the horizontal ledge created by the bottom side of the fish buckets when traveling downward.

4.2 SURVIVAL ESTIMATES

Experiments to evaluate the survival of early developmental stages of wild striped bass and other Hudson River fish species impinged on the fine mesh traveling screen were conducted from early June through mid-July. A total of 35 survival experiments using wild fish was made over this study period: 6 on 6 June, 4 on 15 June, 10 on 6 July, 2 on 18 July, and 13 on 20 July.

The taxa, life stage, and numbers of Hudson River fishes impinged on the fine mesh traveling screen are presented in Table 4-2. Of the 49 striped bass collected, 6 were yolk-sac larvae (5 mm mean length), 9 were post yolk-sac larvae (7 mm mean length), and 34 were juveniles (35 mm mean length). In addition, 11 striped bass eggs were collected, all of which were classified as dead upon initial observation.

Of the fish larvae impinged on the fine mesh traveling screen, bay anchovy were the most numerous and accounted for 65 (38 percent) of the 172 larvae collected. Other larvae collected frequently included herrings (*Alosa* spp.) and white perch, represented by 62 and 13 specimens (36 and 8 percent of the total), respectively.

Blueback herring were predominant among the juveniles impinged on the screen and accounted for 234 (51 percent) of the 463 juveniles collected; other clupeid juveniles included American shad (23 specimens) and alewife (7 specimens). Juvenile rainbow smelt were collected frequently and accounted for 120 specimens (26 percent of the juvenile catch). White perch were represented by 14 juveniles.

TABLE 4-2 TOTAL NUMBER, MEAN LENGTH, AND LENGTH RANGE OF EACH TAXON AND LIFE STAGE COLLECTED FOR SURVIVAL DETERMINATIONS AT THE INDIAN POINT GENERATING STATION FINE MESH TRAVELING SCREEN, 6 JUNE - 20 JULY 1978

	Yolk-Sac Larvae		Post Yolk-Sac Larvae		Juveniles		Adults	
Taxon	Number Collected	Mean Length and Range (mm)	Number Collected	Mean Length and Range (mm)	Number Collected	Mean Length and Range (mm)	Number Collected	Mean Length and Range (mm)
White perch (*Morone americana*)			13	8 (4-16)	14	30 (21-42)	1	--
Striped bass[(a)] (*M. saxatilis*)	6	5 (5-6)	9	7 (6-11)	34	35 (18-57)		
Unidentified *Morone* (*Morone* spp.)			8	6[(b)]				
Conger eel (*Conger oceanicus*)			1	99				
Blueback herring (*Alosa aestivalis*)					234	48 (40-59)		
Alewife (*A. pseudoharengus*)					7	60 (57-62)		
American shad (*A. sapidissima*)					23	55 (44-65)		
Unidentified *Alosa* (*Alosa* spp.)			62	8 (4-18)				
Herrings (Clupeidae)					2	--		
Bay anchovy (*Anchoa mitchilli*)			65	18 (6-27)			39[(c)]	73 (62-92)
Rainbow smelt (*Osmerus mordax*)			4	34 (32-36)	120	42 (35-51)	1	97
White catfish (*Ictalurus catus*)					1	22		
Atlantic tomcod (*Microgadus tomcod*)					10	66 (56-80)		
Northern pipefish (*Syngnathus fuscus*)					2	36 (32-40)		
Tessellated darter (*Etheostoma olmstedi*)					7	23 (16-30)		
Weakfish (*Cynoscion regalis*)					9	67 (61-75)		
Unidentified			4	--				

(a) 11 dead eggs collected.
(b) It was possible to determine total length for only 1 of the 8 unidentified *Morone*; therefore, the value presented (6 mm) represents the length of a single specimen.
(c) Includes young of the year.

Note: Dashes (--) indicate no length recorded.

4.2.1 Proportion Surviving Impingement and Collection

Initial and 96-hour survival of Hudson River fish larvae and juveniles collected on the fine mesh traveling screen are presented in Table 4-3; latent survival results are given in Appendix Table A-2. With the exception of a conger eel larva, no larvae impinged on the screen survived initially. Initial and 96-hour survival of wild striped bass juveniles after experiencing impingement, collection, handling and holding were 77 percent and 60 percent, respectively. Initial and 96-hour survival of control striped bass subjected to collection, handling and holding procedures (Control B) were lower (66 percent and 20 percent, respectively) than for experimental fish. Lower survival of Control B versus experimental juveniles, both initially and over the 96-hour latent effects period (Figure 4-1; Appendix Table A-3), probably reflects the adverse effects of pre-sampling handling and holding stresses on the hatchery-reared control specimens. The test group of hatchery-reared striped bass juveniles subjected to handling and holding procedures only (Control C) appeared to be less stressed and showed a 96-hour latent survival of 60 percent. Survival of Control C fish was not significantly different ($\alpha = 0.05$) from that of experimental fish during the latent effects observation period (Figure 4-1; Appendix Table A-3).

4.2.2 Estimates of Impingement Survival

As determined by initial survival observations, striped bass eggs, yolk-sac and early post yolk-sac larvae are not able to withstand the stresses caused by impingement on the fine mesh traveling screen and subsequent collection. Although the effects of impingement alone on the survival of striped bass juveniles could not be determined because of the low initial and latent survival of Control B specimens, survival was determined for impingement and collection using the results of the wild and Control C experiments. Since latent survival was not statistically different for Control C and wild fish, impingement and collection survival was estimated to be 77 percent based on initial survival data.

TABLE 4-3 INITIAL AND 96-HOUR SURVIVAL OF EACH TAXON AND LIFE STAGE COLLECTED DURING FINE MESH TRAVELING SCREEN IMPINGEMENT SURVIVAL AND CONTROL EXPERIMENTS, INDIAN POINT GENERATING STATION, 6 JUNE - 20 JULY 1978

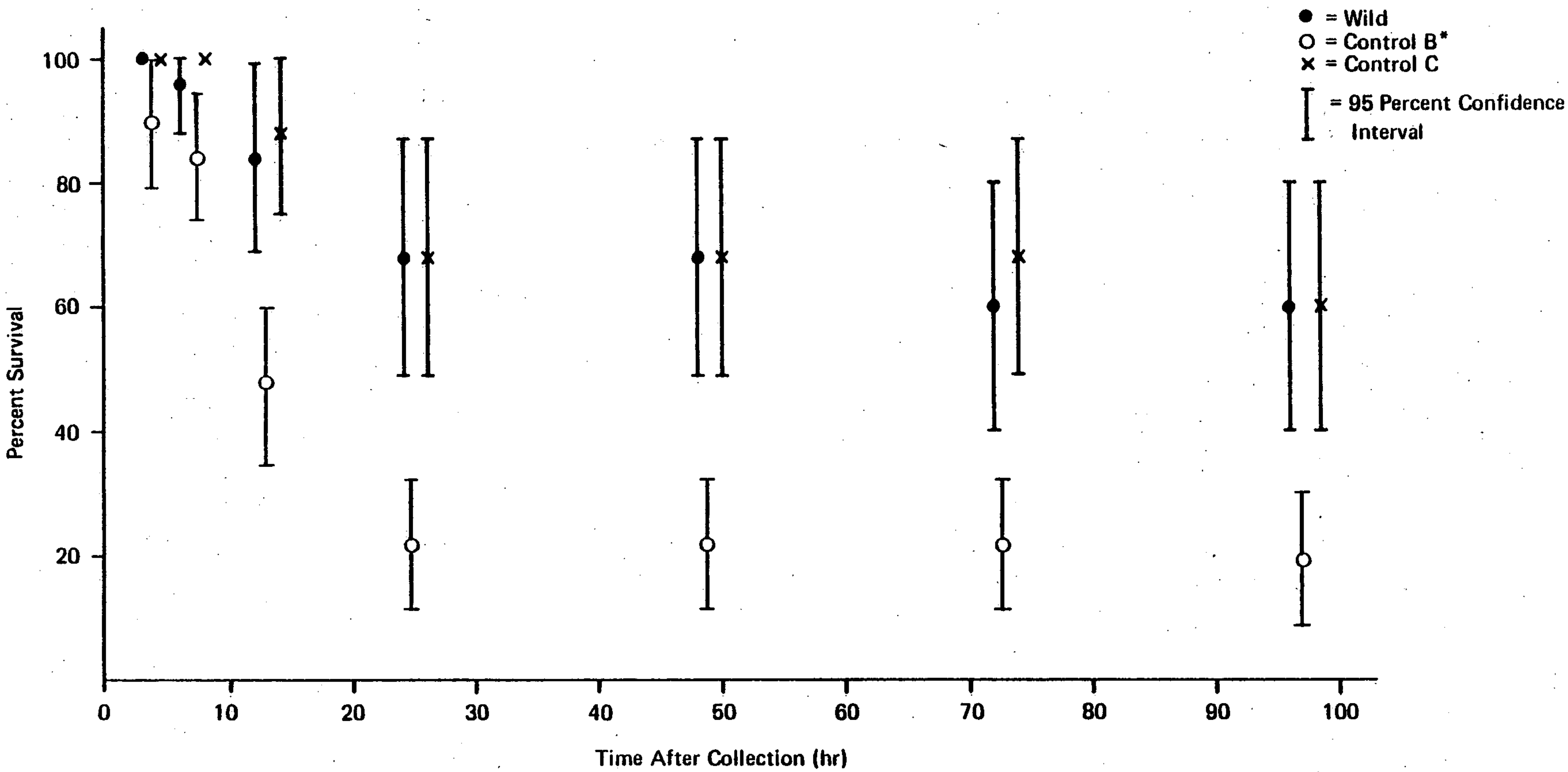
Taxa	Yolk-Sac Larvae			Post Yolk-Sac Larvae			Juveniles		
	Number Collected	Proportion Surviving[a][b] Initial	Proportion Surviving[a][b] 96-Hour	Number Collected	Proportion Surviving Initial	Proportion Surviving 96-Hour	Number Collected	Proportion Surviving Initial	Proportion Surviving 96-Hour
Morone americana	0	--	--	13	0	0	14	0.79 (±0.11)	0.71 (±0.17)
M. saxatilis	6	0	0	9	0	0	35	0.77 (±0.07)	0.60 (±0.10)
Morone spp.	0	--	--	8	0	0	0	--	--
Alosa aestivalis	0	--	--	0	--	--	234	0.77 (±0.03)	0.01 (±0.01)
A. sapidissima	0	--	--	0	--	--	23	0.87 (±0.07)	0
A. pseudoharengus	0	--	--	0	--	--	7	0.86 (±0.13)	0
Alosa spp.	0	--	--	62	0	0	0	--	--
Clupeidae	0	--	--	0	--	--	2	0	0
Anchoa mitchilli	0	--	--	65	0	0	0	--	--
Conger oceanicus	0	--	--	1	1.00	0	0	--	--
Microgadus tomcod	0	--	--	0	--	--	10	0.90 (±0.09)	0
Ictalurus catus	0	--	--	0	--	--	1	1.00	1.00
Osmerus mordax	0	--	--	4	0	0	120	0.28 (±0.04)	0
Etheostoma olmstedi	0	--	--	0	--	--	7	1.00	1.00
Cynoscion regalis	0	--	--	0	--	--	9	0.89 (±0.10)	0
Syngnathus fuscus	0	--	--	0	--	--	2	0	0
Unidentified	0	--	--	4	0	0	0	--	--
Control B[c]	0	--	--	0	--	--	100	0.66 (±0.05)	0.20 (±0.05)
Control C	0	--	--	0	--	--	25	1.00	0.60 (±0.10)

(a) Proportion surviving calculated using live plus stunned organisms.

(b) $96\text{-Hr survival } (\%) = \frac{\text{Number live + stunned at the end of 96 hours}}{\text{Initial number live + stunned tested for latent effects}}$

(c) Data presented for Control B are based on pooled test results (see Appendix Table A-3).

Note: Numbers in parentheses indicate ± 1 standard error.
Dashes (--) indicate no data.
Control B = Control striped bass were placed into the collection trough behind the fine mesh traveling screen, retrieved in the net-in-a-barrel collection apparatus, and subjected to 96-hour latent effects handling and holding procedures.
Control C = Control striped bass were placed directly into the 24 x 13 x 5 in. collection container and subjected to 96-hour latent effects handling and holding procedures.



*Plotted values for Control B are based on pooled test results (see Appendix Table A-3).

Figure 4-1. Latent effects survival for striped bass juveniles impinged on the fine mesh traveling screen, Indian Point Generating Station, 1978.

CHAPTER 5: DISCUSSION

5.1 COLLECTION EFFICIENCY

Results of direct release experiments conducted in 1977 (EA 1977) and 1978, as shown in the table below, indicate that the experimental fine mesh traveling screen (2.5 mm mesh) installed at Indian Point Generating Station Unit 1 is not effective for preventing entrainment of striped bass yolk-sac or post yolk-sac larvae averaging 5 to 9 mm in length, and is at least 44 percent effective for preventing entrainment of juveniles averaging 25 mm in length.

EFFICIENCY OF THE INDIAN POINT FINE MESH TRAVELING SCREEN FOR COLLECTING STRIPED BASS EARLY LIFE STAGES, 1977 AND 1978

Study Year	Life Stage	Mean Length	Number Released	Number Recovered	Percent Recovery
1978	Yolk-sac larvae	5 mm	38,700	835	2.2
1977	Post yolk-sac larvae	7 mm	20,000	34	0.2*
1977	Post yolk-sac larvae	9 mm	78,750	3,229	4.1
1978	Juveniles	25 mm	17,000	7,407	43.6

*The higher percentage of 5 mm larvae collected in 1978 versus 7 mm larvae collected in 1977 is attributed to a greater detrital accumulation on the screen in 1978, resulting from heavy rainfall during May and early June. Detrital loading on the screen effectively blocks or reduces the screen openings, thereby increasing collection efficiency for smaller organisms.

Direct release experiments conducted during 1978 at low pressure screenwash settings of 5, 10, and 15 psi resulted in progressively higher recovery (1.1, 2.3, and 4.1 percent, respectively) of 5 mm striped bass larvae with increased spray pressure. No relationship was apparent between these same screenwash pressures and the percentage of 25 mm juveniles recovered.

A comparison of the length-frequency distribution of striped bass larvae collected by pumps versus the fine mesh traveling screen over the same time period (16 - 21 June 1977) has shown that 60 percent of the larvae collected on the screen were over 15 mm in length, whereas only 17 percent of those collected by pump exceeded 15 mm (EA 1977). Assuming that the length-frequency distribution of larvae collected by pumps was representative of the length distribution of larvae in the river, the implication is that the 2.5 mm mesh screen selectively retains larvae over 15 mm, but allows entrainment of smaller larvae. In other words, impingement of young striped bass on the fine mesh traveling screen begins to exceed entrainment through the screen at a length of approximately 15 mm.

Tomljanovich et al. (1977) conducted laboratory (flume) experiments to determine the retention of certain fish species, including striped bass, on fine mesh screening of various mesh sizes. Results of those experiments indicated that for mesh openings larger than 0.5 mm, average retention of all species combined (at test velocities of 0.5, 1.0, and 1.5 fps) appeared to be largely dependent on average body depth. The 2.5 mm mesh test screen showed average retentions ranging from 30.6 to 72.7 percent for fish whose average body depth ranged from 2.9 to 3.3 mm. Thus, as body depth approaches 3.3 mm, selective retention on the 2.5 mm screen begins to occur, i.e., the proportion of organisms impinged on the screen begins to exceed the proportion of organisms entrained through the screen. The minimum body depth which would result in essentially 100 percent retention on the 2.5 mm screen was determined to be greater than 4.6 mm.

Based on the average body length and depth measurements of Mansueti (1958), as shown in Table 5-1, the average body depth at which selective retention on the 2.5 mm screen is expected to occur (i.e., approximately 3.3 mm) corresponds to an average total length of 15 mm for young striped bass. The findings of Tomljanovich et al. are, therefore, consistent with those cited previously for length frequency comparisons of striped bass collected at Indian Point using pumps versus the fine mesh traveling screen. The minimum body depth at which 100 percent retention on the 2.5 mm screen is expected to occur (i.e., greater than 4.6 mm), corresponds to an average total length for striped bass of approximately 22 mm (Table 5-1).

Observations of the Indian Point fine mesh traveling screen indicated that fish are not impinged in such a way as to prevent them from being washed from the screen by the low pressure spray wash. However, control experiments (Section 4.1) did show that the effectiveness of the screen is reduced by low efficiency of transfer between the screen fish buckets and the collection trough. The principal factor limiting transfer efficiency appears to be a gap between the fish buckets and the collection trough that allows some fish to fall between the trough and screen as the buckets rotate. Also, some fish have been observed to remain on the bottom side of the fish buckets when traveling downward and thus are not transferred to the collection trough. Transfer efficiency could, therefore, be improved by installing a neoprene flap along the edge of the collection trough to prevent the loss of organisms between the trough and screen. Moreover, the attachment of deflectors to the underside of the fish buckets, set such that the surface of the deflectors are angled downward away from the screen when the buckets overturn, would increase the efficiency of fish removal from the screen system.

Control experiments conducted during 1977 and 1978 demonstrated high recovery by the collection system following introduction of striped bass early life stages into the collection trough; 92 percent of the 7 mm larvae released into the collection trough in 1977 were recovered in the net-in-a-barrel collection apparatus (EA 1977), whereas the percent recovery for 24 mm juveniles tested in 1978 was 74 percent. Higher efficiency of the collection system could be gained by eliminating corners and obstructions in the sluiceway (Figure 3-3) that create areas of reduced flow where fish (particularly larger life stages such as juveniles) can congregate and avoid diversion into the collection gear. Such a design could be implemented by replacing the existing sluiceway system with a U-shaped fiberglass trough fitted with a Y-shaped section, containing a flop gate, that would divert the entire washwater volume from the river bypass to the collection apparatus.

TABLE 5-1 AVERAGE BODY LENGTH AND DEPTH (mm) MEASUREMENTS FOR STRIPED BASS LARVAE AND JUVENILES WITHIN VARYING 1 mm SIZE INTERVALS[a]

Size Interval (Total Length)	Average Total Length	Average Body Depth
10-11	10.38	2.17
11-12	11.63	2.45
12-13	12.62	2.52
13-14	13.25	2.65
14-15	14.50	3.26
15-16[b]	15.12[b]	3.35[b]
16-17	16.50	3.50
17-18	17.71	3.76
18-19	18.69	3.99
19-20	--	--
20-21	20.17	4.35
21-22[c]	21.66[c]	4.90[c]
22-23	22.82	5.27
23-24	23.95	5.65

(a) From Mansueti (1958).
(b) Size at which retention on 2.5 mm screen exceeds entrainment.
(c) Minimum size for which retention on 2.5 mm screen is approximately 100%.

5.2 IMPINGEMENT SURVIVAL

Survival estimates for wild striped bass impinged on the Indian Point fine mesh traveling screen during 1977 (EA 1977) and 1978, as shown in the table below, indicate that the most sensitive early developmental stages (eggs through early post yolk-sac larvae) are not able to survive collection on the screen system. However, as discussed previously, few of these smaller life stages are expected to be retained on the 2.5 mm mesh screening.

STRIPED BASS IMPINGEMENT SURVIVAL
ON THE INDIAN POINT
FINE MESH TRAVELING SCREEN, 1977-1978

Study Year	Life Stage	Mean Length	Survival Estimate(%)
1978	Eggs	--	0
1978	YSL	5 mm	0
1978	Early PYSL	7 mm	0
1977	Late PYSL	15 mm	60
1977	Juveniles	19 mm	100
1978	Juveniles	35 mm	77[(a)]

(a) Estimate includes impingement as well as collection survival, and is, therefore, considered to be a conservative estimate for impingement survival alone.

Note: YSL = Yolk-sac larvae
PSYL = Post yolk-sac larvae

Survival of young striped bass averaging 15 mm in length, the size at which selective retention on the fine mesh traveling screen is expected to begin, was estimated to be 60 percent. As the young fish continue to grow and become more susceptible to impingement on the 2.5 mm mesh screen, their ability to withstand the stresses imposed by retention on the screen is expected to increase. Upon attaining lengths of 19 mm or more, retention on the fine mesh traveling screen will approach 100 percent and survival is expected to exceed 75 percent.

An evaluation of the potential application of the fine mesh traveling screen in reducing entrainment losses can be made by comparing survival associated with entrainment through the condenser cooling water system. Based on the results of entrainment studies conducted at the Indian Point plant during 1977, entrainment survival of striped bass was estimated to be 38 to 67 percent for yolk-sac larvae, 75 to 85 percent for post yolk-sac larvae, and 83 percent for juveniles (EA 1978). Thus, in view of the low retention and survival of smaller larvae on the fine mesh traveling screen, this device would not be effective for mitigating entrainment mortality among those life stages most susceptible to cooling system effects. Retention of larger larvae and juveniles on the 2.5 mm mesh screen is high, and increased collection efficiency could be facilitated by minor modifications in the collection system design (Section 5.1). Since the survival of larger young following plant entrainment is comparable to that following impingement on the fine mesh screen, no appreciable increase in survival would be gained by diverting these fish at the intake.

Although early developmental stages of striped bass and other fish species are generally not subjected to lethal time/temperature exposures during entrainment through the cooling water systems of Hudson River power plants, applications of the screen system evaluated herein could be effective at plants where larger young are entrained in high numbers during periods when lethal time/temperature exposures occur. Moreover, this screen design can be practically retrofitted to conventional traveling screens to effectively increase impingement survival (White and Brehmer 1976). In such situations, however, the screen mechanism must be designed specifically for continuous service, since conventional traveling screen operation is on an intermittent basis and components are not subjected to as much wear. In discussing present engineering limitations to the protection of fish at water intakes, Richards (1977) cautions that the continuous operation requirement of this vertical screen system has resulted in undesirable maintenance problems to date, even though conventional screen components have been refined over many years.

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APPENDIX A

STRIPED BASS LATENT SURVIVAL RESULTS FOR DIRECT RELEASE, IMPINGEMENT SURVIVAL, AND CONTROL EXPERIMENTS

TABLE A-1 NUMBERS OF RELEASED STRIPED BASS SURVIVING TO 96 HOURS AFTER IMPINGEMENT ON A CONTINUOUSLY OPERATING FINE MESH TRAVELING SCREEN INCLUDING EFFECTS ASSOCIATED WITH SAMPLE COLLECTION AND HOLDING, INDIAN POINT GENERATING STATION, 6 JUNE - 20 JULY 1978

Release Number	Release Date	Mean Length (mm)	Initial No. Tested		Number of Specimens Alive After Indicated Time Period														96-Hr Survival[a] (%)
					3 Hr		6 Hr		12 Hr		24 Hr		48 Hr		72 Hr		96 Hr		
			L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	
1[b]	6 JUN	5	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
2[b]	6 JUN	5	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
3[b]	6 JUN	5	0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0
4[c]	18 JUL	25	49	10	47	10	47	10	41	9	17	2	14	2	12	2	12	2	23.7
5[c]	18 JUL	24	49	20	49	20	49	19	47	17	44	13	36	13	34	13	32	13	65.2
6[c]	18 JUL	26	49	11	49	10	49	10	47	7	42	6	40	6	40	6	38	5	71.7
7[c]	20 JUL	24	49	10	47	10	47	10	46	7	40	3	32	3	21	3	10	1	18.6
8[c]	20 JUL	25	50	10	50	9	49	9	49	7	43	4	38	4	28	2	9[d]	0[d]	15.0
9[c]	20 JUL	24	56	10	56	5	51	5	51	4	45	4	38	4	25	2	11	1	18.2

(a) $\text{96-Hr Survival (\%)} = \frac{\text{Number live + stunned at the end of 96 hours}}{\text{Initial number live + stunned tested for latent effects}}$

(b) Yolk-sac larvae and larvae.

(c) Juveniles.

(d) Actual elapsed time was 100 hours, 55 minutes.

Note: Dashes (--) indicate no data.

TABLE A-2 NUMBER AND CONDITION OF WILD FISH LARVAE AND JUVENILES COLLECTED, AND SURVIVAL TO 96 HOURS AFTER IMPINGEMENT, ON A CONTINUOUSLY OPERATING FINE MESH TRAVELING SCREEN, INCLUDING EFFECTS ASSOCIATED WITH SAMPLE COLLECTION AND HOLDING, INDIAN POINT GENERATING STATION, 6 JUNE - 20 JULY 1978

	Initial Survival[a]			Number of Specimens Alive After Indicated Time Period													
				3 Hr		6 Hr		12 Hr		24 Hr		48 Hr		72 Hr		96 Hr	
	L	S	D	L[b]	S[c]	L	S	L	S	L	S	L	S	L	S	L	S
Larvae																	
Morone americana	0	0	13	--	--	--	--	--	--	--	--	--	--	--	--	--	--
M. saxatilis	0	0	15	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Morone spp.	0	0	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Alosa spp.	0	0	62	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anchoa mitchilli	0	0	65	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Conger oceanicus	1	0	0	1	--	1	--	1	--	0	--	0	--	0	--	0	--
Osmerus mordax	0	0	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentified	0	0	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Juveniles																	
Morone americana	9(5)	2(2)	3	5	2	5	2	5	1	5	1	4	1	4	1	4	1
M. saxatilis	24(23)	3(2)	8	23	2	22	2	19	2	17	0	17	0	15	0	15	0
Alosa aestivalis	167(126)	13(9)	54	60	2	33	1	15	1	3	0	2	0	1	0	1	0
A. sapidissima	16(10)	4(3)	3	3	1	2	0	1	0	0	0	0	0	0	0	0	0
A. pseudoharengus	5(3)	1(0)	1	2	--	1	--	0	--	0	--	0	--	0	--	0	--
Clupeid spp.	0	0	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Microgadus tomcod	6(6)	3(3)	1	6	2	4	2	3	1	1	0	0	0	0	0	0	0
Ictalurus catus	1(1)	0	0	1	--	1	--	1	--	1	--	1	--	1	--	1	--
Osmerus mordax	2(2)	31(25)	87	1	5	0	1	0	0	0	0	0	0	0	0	0	0
Etheostoma olmstedi	7(7)	0	0	7	--	7	--	7	--	7	--	7	--	7	--	7	--
Cynoscion regalis	6(4)	2(2)	1	4	2	3	0	0	0	0	0	0	0	0	0	0	0
Sygnathus fuscus	0	0	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--

(a) Numbers in parentheses indicate the number of specimens used for latent effects determinations.
(b) Data are for specimens that were initially alive.
(c) Data are for specimens that were initially stunned.

Note: Dashes (--) indicate no data.

TABLE A-3 NUMBER OF CONTROL STRIPED BASS JUVENILES SURVIVING TO 96 HOURS AFTER EXPERIENCING COLLECTION AND/OR HANDLING AND HOLDING PROCEDURES ASSOCIATED WITH FINE MESH TRAVELING SCREEN EXPERIMENTS, INDIAN POINT GENERATING STATION, 18-20 JULY 1978

Control Methodology	Release Date	Mean Length (mm)	Number Recovered	Initial Survival			Number of Specimens Alive After Indicated Time Period: 3 Hr		6 Hr		12 Hr		24 Hr		48 Hr		72 Hr		96 Hr	
				L	S	D	L[a]	S[b]	L	S	L	S	L	S	L	S	L	S	L	S
Control B	18 JUL	24	37	34	1	2	34	1	34	1	21	1	8	1	8	1	8	1	8	1
Control B	20 JUL	25	63	11	20	32	11	11	11	6	8	0	6	0	5	0	5	0	4	0
Control B[c]	18-20 JUL	24-25	100	45	21	34	45	12	45	7	29	1	14	1	13	1	13	1	12	1
Control C	18 July	25	25	25	0	0	25	--	25	--	22	--	17	--	17	--	17	--	15	--

(a) Data are for specimens that were initially alive.
(b) Data are for specimens that were initially stunned.
(c) Data presented are pooled test results for Control B experiments conducted on 18 and 20 July.

Note: Control B = Control specimens were placed into the collection trough behind the fine mesh traveling screen, retrieved in the net-in-a-barrel collection apparatus, and subjected to 96-hour latent effects handling and holding procedures.
Control C = Control specimens were placed directly into the 24 x 13 x 5 in. collection container and subjected to 96-hour latent effects handling and holding procedures.
Dashes (--) indicate no data.