INDIAN POINT GENERATING STATION
ENTRAINMENT SURVIVAL AND RELATED STUDIES

1980 ANNUAL REPORT

Consolidated Edison Company of New York, Inc.

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NEW YORK, NEW YORK 10003

and

Power Authority of the State of New York

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NEW YORK, NEW YORK 10019

ECOLOGICAL
ANALYSTS
INC.

EA Report CON04K2

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Prepared for

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1. INTRODUCTION

1.1 PERSPECTIVE

The Indian Point Generating Station uses a once-through cooling system to dissipate waste heat. In the process, cooling water from the Hudson River is pumped through condensers where heat from steam leaving the turbine is transferred to the cooling water, which is returned to the river. The two electric power generating units in operation at the Indian Point Generating Station withdraw up to 6,360 m^3/min* (1.68 x 10^6 gpm) of water from the Hudson River for cooling purposes. Aquatic organisms small enough to pass through the 9.5-mm bar mesh intake screens may be carried through the cooling water system (entrained) where they are exposed to abrupt changes in temperature and hydrostatic pressure, mechanical buffeting, and velocity shear forces. Determining the survival of these organisms following entrainment is an important step in assessing potential effects of power plant operation on the aquatic environment.

Studies to examine survival of ichthyoplankton entrained through the condenser cooling water system of the Indian Point plant have been conducted throughout most of the past decade. Over the course of these studies, various sampling gear have been used and tested to assess biases associated with collection procedures, and to further minimize stresses associated with sampling. The results of entrainment studies at Indian Point have been instrumental in supporting and promoting state-of-the-art developments in entrainment survival sampling and assessment.

The use of stationary nets at the Indian Point plant to assess survival of entrained organisms was based on the assumptions that sampling stress for organisms captured by nets was the same in the discharge canal as in the lower velocity intake (control) stations, and that mortality caused by the sampling nets was not significant (NYU 1976). However, net entrainment sampling conducted at Indian Point in 1972 revealed that differences in the velocity of water at intake and discharge sampling stations may have an effect on ichthyoplankton survival (NYU 1973). To examine the relationship between water velocity and survival of ichthyoplankton captured in plankton nets of the type used at Indian Point, tests were conducted using early life stages of hatchery-reared striped bass from Hudson River brood stock (NYU 1976; O'Connor and Schaffer 1977). These studies demonstrated that survival for the striped bass eggs and larvae was velocity-dependent. Survival for these life stages was considerably higher at 0.15 m/sec than at 0.46 m/sec. Water velocities of 0.91 m/sec (3.0 fps) caused virtually complete mortality to all life stages. Yolk-sac larvae were found to be most sensitive to net

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

capture, followed by post yolk-sac larvae and eggs, in order of decreasing sensitivity. It was concluded that entrainment survival estimates for ichthyoplankton collected with standard net capture techniques may be profoundly affected by differences in water velocities and that failure to account for net-induced mortality may result in excessively high impact assessments (NYU 1976; O'Connor and Schaffer 1977).

Entrainment survival studies at the Indian Point plant were expanded in 1977 and 1978 to include sampling gear specifically designed to eliminate the effects of intake and discharge velocity differences on survival. These studies, conducted by Ecological Analysts, Inc. (EA), used pumps to transport water from sampling locations into a flume (pump/larval table) that reduced the velocity of water and concentrated the sample. The effects of entrainment on ichthyoplankton were estimated by comparing survival at discharge stations with survival at intake stations which served as controls on sampling and holding effects. This sampling gear and technique generally resulted in higher entrainment survival estimates for most taxa and life stages than were obtained using nets (EA 1978a; 1979a).

In spite of the refinements in entrainment survival estimates achieved using pump/larval table collection systems, the pumps can cause sampling mortality to eggs and juveniles. Of the eggs collected in the pump/larval tables in 1977 and 1978, none survived. Experiments have demonstrated that up to 20 percent of striped bass juveniles are killed by passage through 10- to 15-cm diameter pumps during normal sampling operation, and mortality may be as high as from 30 to 70 percent for clupeid juveniles (EA 1979b).

During the 1979 sampling season, raft-mounted collection systems designed to eliminate stresses associated with pump sampling were used at the Indian Point plant (EA 1981). The new collection systems utilized pressure-induced flow rather than pumps for sample delivery, but retained the velocity reduction aspects of a flume system. The discharge collection system, referred to as the pumpless plankton sampling flume, used the pressure created by the difference in water level between the discharge canal and the river to deliver the sample. A pressure differential was created within the flume system at the intake station by pumping water from behind the angled diversion screens in the partially submersed flume. This gear is referred to as a rear-draw plankton sampling flume. The floating support structures associated with the pumpless and rear-draw flumes offered additional advantages over the land-based pump/larval tables because the new systems could be placed near the point of sample withdrawal. Flotation of the discharge collection system provided a practical solution to sampling at the submerged discharge ports, which allows for evaluation of the effects of the entire entrainment process.

Results obtained with the pumpless and rear-draw plankton sampling flumes in 1979 (EA 1981) provided valuable new information on entrainment survival. Estimated survival of striped bass eggs was 74 percent, in contrast to previous years when there was no egg survival. For most larval groups discharge survival proportions were higher than for the pump/larval table collection systems used in 1978. However, unanticipated differences in sampling stress between the rear-draw and pumpless plankton sampling flumes resulted in a greater sampling effect at the intake (control) station for most larvae. Sampling the rear-draw flume at the intake was apparently more stressful to most larvae than the combined effects of entrainment and sampling experienced by fish collected in the pumpless flume at the discharge. This differential gear effect was found to be length-related, based on the results of collection system calibration experiments (EA 1981). The calibration experiments indicated that the rear-draw flume caused higher sampling mortality for striped bass larvae from approximately 4 to 10 mm in length than did the pumpless flume; differences in sampling mortality declined as larvae approached 11 mm and were not apparent for striped bass eggs. These findings precluded the use of intake survival to adjust for sampling effects in estimating entrainment survival (S_e) of larval stages collected in 1979.

Differences in sampling stress between the two collection systems in 1979 were likely caused by differences in water flow through the flume diversion screens during sampling or draining. The proximity of the pump intake manifolds to the diversion screens in the intake flume may have resulted in localized areas of high velocity flow through the screens, thus increasing the potential for impingement. No pump was required to induce water flow through the discharge flume; consequently, flow through the diversion screens of this sampler was more likely to be uniform. Additionally, the drain rate was typically faster at the intake station because the rear-draw (intake) flume could be raised to facilitate draining but the pumpless (discharge) flume could not. This situation may have resulted in higher water velocities through the diversion screens of the rear-draw flume and an increased likelihood of physical damage during the draining process.

1.2 1980 ENTRAINMENT SURVIVAL STUDIES

To correct probable sources of differential gear effects, the rear-draw and pumpless plankton sampling flumes used in 1980 were modified with flow diffusion panels and slotted standpipes installed behind the angled diversion screens. These refinements were designed to more evenly distribute water flow across the surface of the screens and eliminate localized areas of high velocity flow that may cause impingement on the screens. In addition, the gravity drain procedures applied in 1979 were discontinued in favor of a pump drainage system which allowed for control and standardization of the drain rates between the intake and discharge collection flumes.

1.3 SCOPE OF REPORT

This report presents the results of the 1980 entrainment survival and gear calibration studies conducted at the Indian Point Generating Station. The target taxa collected were striped bass (*Morone saxatilis*), white perch (*Morone americana*), herring (Clupeidae), and anchovies (Engraulidae). Analysis of juvenile Atlantic tomcod (*Microgadus tomcod*) was also undertaken because unusually large numbers of this species and life stage were collected during 1980 sampling. Entrainment survival was estimated for these taxa for several discharge temperature ranges. The results of the 1980 studies are also discussed with regard to the significance of organism size on entrainment survival. In addition, potential biases to entrainment survival estimates were evaluated by comparing sampling stress at the intake and discharge flumes.

Supplemental information is contained in the Appendixes. Estimated circulating water flow is presented in Appendix A. Design specifications of the sampling gear are provided in Appendix B. Length-frequency data in Appendix C are provided for the five major taxa analyzed.

2. SUMMARY

2.1 ENTRAINMENT SURVIVAL STUDY

Entrainment survival sampling was conducted at the Indian Point Generating Station from 30 April to 10 July 1980. Sampling focused on entrainable life stages of striped bass (Morone saxatilis), white perch (M. americana), herrings (Clupeidae), and anchovies (Engraulidae). In addition, juvenile Atlantic tomcod (Microgadus tomcod), were also collected in sufficient numbers for analysis.

(2) 1985

Raft-mounted collection flumes were positioned at the Unit 3 intake (Station I3) and at the first discharge port (Station DP). The flume systems were designed to reduce sampling stress by eliminating passage of the organisms through sampling pumps. At the intake station, water was drawn into the flume by pumping water from behind the diversion screens. At the discharge station, the difference in water level between the discharge canal and the river was used to deliver the sample. Although the basic design of the flumes was similar to the systems used in 1979, modifications were made to eliminate differences in collection stress between the flumes. These modifications included (1) installation of baffles and slotted standpipes at the primary water outlets to uniformly distribute water flow through the diversion screens and (2) use of pump drainage systems at both flumes so that drain rates could be controlled.

Except for intermittent shutdowns, Units 2 and 3 operated consistently throughout the sampling season. Cooling water flow was somewhat lower than in previous years as only five circulating pumps per unit were generally operated. The lower flow resulted in higher than normal discharge temperatures and provided the opportunity to collect statistically meaningful numbers of organisms at temperatures in excess of 33 C.

Striped bass were the most abundant ichthyoplankton taxon collected in the 1980 entrainment survival study at the Indian Point Generating Station, followed by anchovies, white perch, Atlantic tomcod, and herrings (Section 4.3.1). Unusually low precipitation in winter and spring 1980 resulted in higher than normal salinities during the sampling season, which may have caused the higher abundance of juvenile tomcod and lower abundance of herring compared to previous years. Post yolk-sac larvae were again the most frequent life stage collected, although striped bass eggs and yolk-sac larvae and juvenile Atlantic tomcod were also collected in numbers sufficient for survival analysis.

Initial survival proportions at the intake station were the highest yet achieved for all taxa (Section 4.3.2). Survival ranged from 0.323 for anchovy post yolk-sac larvae to 1.000 for juvenile Atlantic tomcod. White perch post yolk-sac survival was 0.929 while striped bass survival ranged from 0.816 for eggs to 0.953 and 0.951 for yolk-sac and post yolk-sac larvae, respectively. These extremely high survival proportions suggest that the gear modifications made before the 1980 season were extremely successful in reducing sampling stress.

Initial survival at the discharge station also compared favorably with previous data, particularly when examined over the established temperature ranges (Section 4.3.2). Survival in 1980 was the highest yet observed for eight of ten life stage-temperature groups studied. Notably high survival proportions were: 0.877 for Atlantic tomcod juveniles collected at temperatures ≤26 C, 0.469 for striped bass eggs (all temperatures combined), 0.550 for striped bass post yolk-sac larvae (≥33 C), and 0.898 and 0.496 for white perch post yolk-sac larvae collected at temperatures ≤29 C and ≥33 C, respectively. The extremely high survival proportions achieved for discharge temperatures ≤32 C indicate that survival of entrained organisms can be quite high if thermal stress is not severe.

The extended survival in 1980 was higher than in previous years (Section 4.3.3). Survival at the two sampling stations was generally similar, so latent effects of entrainment were not detectable for striped bass, white perch, herrings, and anchovy. Survival of organisms sampled at intake and discharge stations was significantly different ($\alpha = 0.05$) only for juvenile tomcod. The significant difference for these larger organisms (generally >25 mm TL) may be due to increased physical stress during pump or condenser passage.

Entrainment survival estimates for the 1980 study were extremely valuable in examining the effects of thermal stress (Section 4.3.4). Survival estimates for organisms entrained at temperatures below where thermal stress should occur, ≤32 C, ranged from 12 percent for anchovy post yolk-sac larve to 91 percent for white perch post yolk-sac larvae. Entrainment survival at temperatures below 33 C for striped bass varied from 58 percent for eggs to 65 percent for yolk-sac larvae and 80 percent for post yolk-sac larvae. Entrainment survival of juvenile Atlantic tomcod below thermal stress conditions (≤26 C) was 88 percent based on initial survial proportions, or 66 percent based on 24-hour survival since latent effects were observed. At high discharge temperatures, ≥33 C, entrainment survival was 58 percent for striped bass and 53 percent for white perch post yolk-sac larvae. These survival values are higher than would be expected from laboratory thermal tolerance studies. Entrainment survival of white perch and striped bass increased with size of the larvae (Section 4.3.5). Survival estimates at low discharge temperatures approached 100 percent when larval length exceeded 12 mm for both species. The survival of smaller larvae was extremely variable, but generally less than 60 percent. Above discharge temperatures of 33 C, survival also increased with length, but reached a maximum near 60 percent.

The success at reducing sampling stress in 1980 was important in dismissing potential biases in entrainment survival (S_e) estimates (Section 4.4.1). Greater sampling stress at Station I3 would cause an overestimate of entrainment survival and greater sampling stress at Station DP would cause an underestimate of entrainment survival. Previous S_e estimates were subject to station differences in sampling stress, which could introduce a bias. For example, in 1979 sampling bias was clearly more stressful at the intake station, which prevented adjustment for sampling stress of data collected at the discharge station. In 1980, however, sampling stress at the intake station was reduced to such a low level that overestimating entrainment survival was not possible. The entrainment survival values in 1980 are likely to be conservative and underestimate the actual survival, if any bias exists.

2.2 SAMPLING FLUME CALIBRATION STUDY

Sampling flume calibration experiments to assess sampling stress on entrainable life stages of striped bass were conducted in conjunction with the entrainment survival study. Calibration experiments used hatchery-reared eggs and larvae to estimate the probability of surviving sampling at each station.

Statistically significant gear effects were found for eggs in both flumes and for yolk-sac and post yolk-sac larvae at the discharge flume. Large sample sizes (generally $\geq$300 organisms) allowed extremely powerful statistical tests which detected small, but significant, gear effects for eggs at Stations I3 and DP, and yolk-sac larvae and post yolk-sac larvae at Station DP. Gear effect ratios indicate a maximum underestimate (bias) of about 16 percent for the entrainment survival of yolk-sac larvae. The potential bias for striped bass eggs and post yolk-sac larvae entrainment survival was small, only a 4 percent overestimate and a 2 percent underestimate, respectively. As in 1979, the potential sampling bias was greatest for small larvae. For larvae <10 mm, gear effects were detectable at Station DP. Sampling stress was undetectable for larvae of any size at Station I3.

3. SITE DESCRIPTION

3.1 THE HUDSON RIVER

The Hudson River, located in southeastern New York state, is a 496-km long river and tidal estuary, originating at Lake Tear of the Clouds and terminating at New York City. The non-tidal portion of the river extends 246 km from its origin to the Green Island Dam at Troy and drains an area of 11,000 km^2. The tidal estuary extends 250 km from Troy to New York City and drains an additional 14,000 km^2 (Figure 3-1).

Near the Indian Point Generating Station, located 69 km north of the Battery at Buchanan, New York, the Hudson River is approximately 1,500 m wide and has a cross-sectional area of 15,000 m^3. River depths range from 3 to 12 m within 60 m of the plant.

Water movement in this section of the river is primarily tidal. Mean tidal flows are approximately 4,000 m^3/sec and mean monthly freshwater flows range from 160 m^3/sec in August to 900 m^3/sec in April (Con Edison 1977a, p. 2-1). Seasonal trends in salinity vary with freshwater flow. During March, April, and May when freshwater flow generally exceeds 500 m^3/sec, the salt front (defined as 0.1 ppt salinity) usually remains downriver from the Indian Point Generating Station. During periods of low freshwater flow, generally from July through October (Con Edison 1977a, Table 2-2), salinity may fluctuate rapidly as the salt front moves upriver into the vicinity of Indian Point. Mean ambient river temperatures in the Indian Point area range from 0.7 to 25.0 C throughout the year (Con Edison 1977a, Table 2-3).

3.2 THE INDIAN POINT GENERATING STATION

The Indian Point Generating Station consists of three nuclear-fueled electric generating units. Unit 1 is owned by Con Edison and has not operated for commercial production since October 1974, although its circulating water and service water pumps are operated occasionally. Unit 2, owned and operated by Con Edison, has been in operation since 28 September 1973 and has a net rated capacity of 873 MWe. Unit 3 is owned and operated by the Power Authority of the State of New York and has been in operation since 30 August 1976. It has a net rated capacity of 965 MWe. All three units use Hudson River water for once-through cooling.

Each unit has a separate shoreline intake structure for withdrawal of water from the Hudson River (Figure 3-2). The intake structure for Unit 1 has four rectangular ports extending 8 m below mean low water. The intake structures for Units 2 and 3 each have six intake ports, also extending 8 m below mean low water. Units 1 and 2 are equipped with fixed screens at the entrance to the intake bays and vertical traveling screens behind the fixed screens. The Unit 3 intake only has vertical traveling screens at the entrance to the intake bays. All screens are 9.5-mm bar mesh, with the exception of an experimental fine mesh (2.5 mm) traveling screen located at the Unit 1 intake.

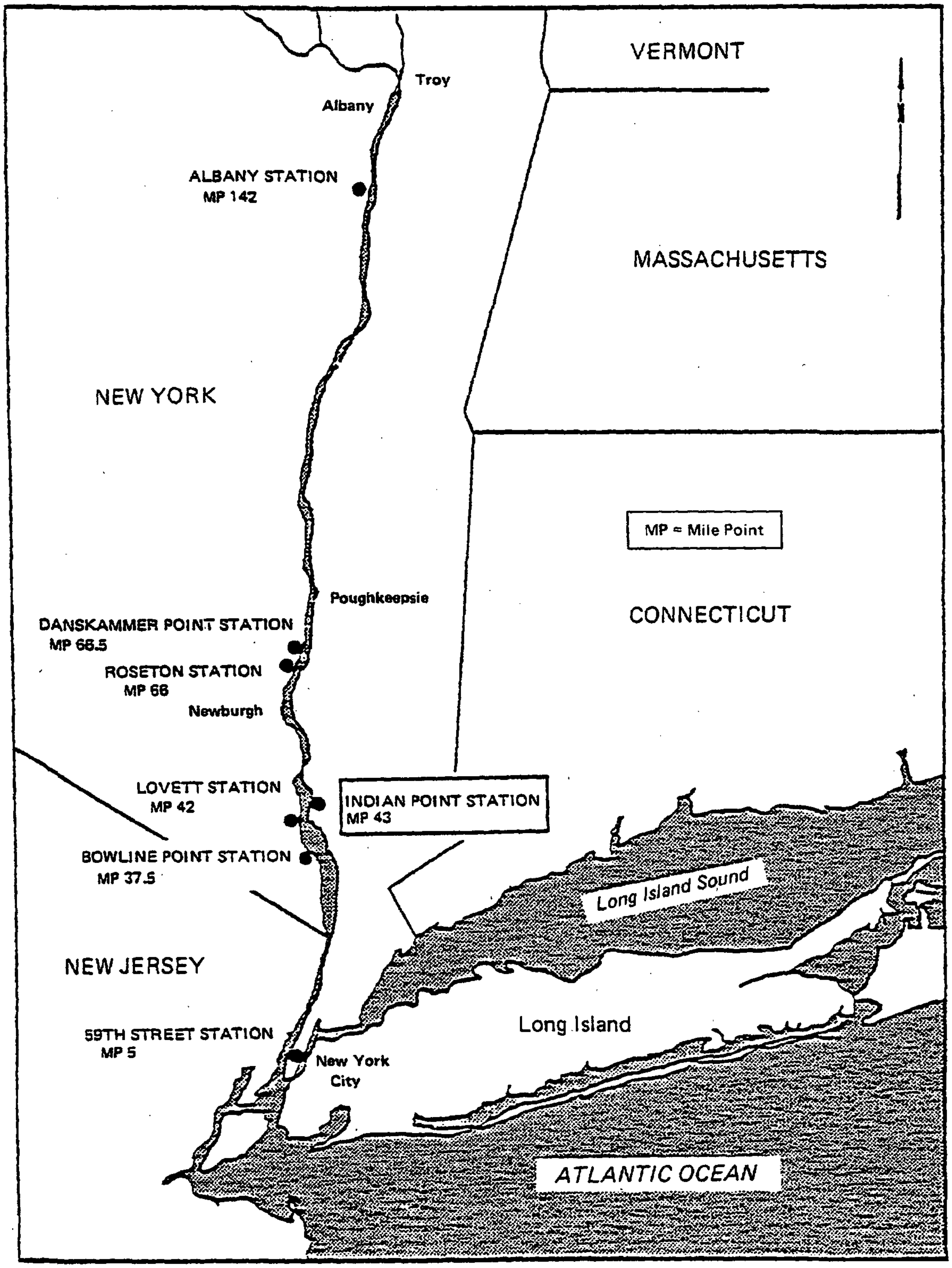


Figure 3-1. Location of the Indian Point Generating Station relative to other generating stations on the Hudson River Estuary (Scale – 1:1,267,200).

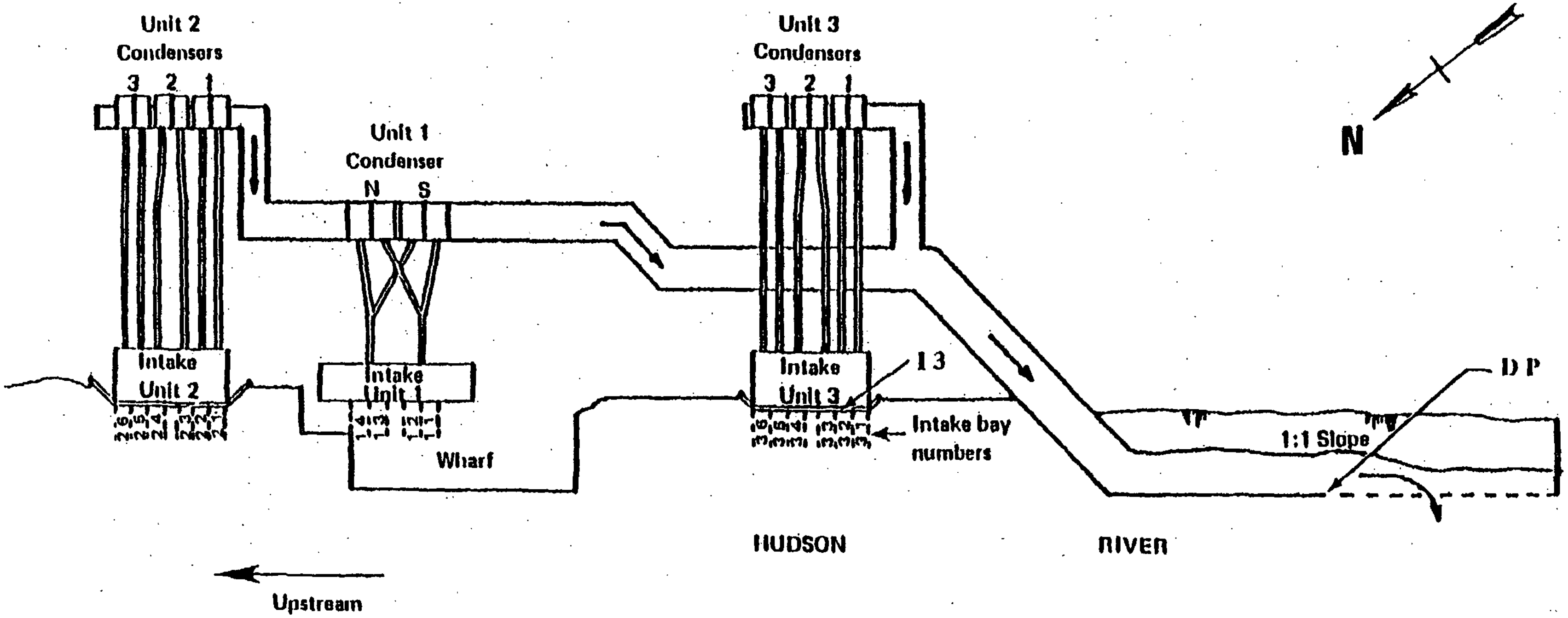


Figure 3-2. Diagram of the Indian Point Generating Station circulating water system showing location of sampling stations (from Con Edison 1977b).

Circulating water pumps with rated capacities of 530 m^3/min are used to pump Hudson River water through the condenser cooling system of each unit. Unit 1 has two circulating water pumps capable of pumping a total of 1,060 m^3/min, and two service water pumps with a combined rated capacity of 144 m^3/min. Units 2 and 3 each have six circulating water pumps, one for each intake bay (Figure 3-2). The circulating water systems for Units 2 and 3 are designed to operate at either 100 or 60 percent of maximum flow. When the ambient water temperature is above 4.4 C (spring through fall), the cooling water flow for each unit is approximately 3,200 m^3/min. During the winter, 40 percent of the cooling water is returned to the circulating pumps without passing through the condensers, thus reducing the water withdrawal to 1,900 m^3/min. Service water for Units 2 and 3 is drawn through a separate intake forebay at the center of each intake structure; the maximum total service water flow for Units 2 and 3 is 114 m^3/min.

The cooling water and service water from all three units flow into a common discharge canal. The combined discharge is returned to the Hudson River via a discharge structure (Figure 3-3) located at the shoreline downstream of Unit 3. The discharge structure is a steel-walled reservoir with 12 submerged ports. The center of each port is 3.7 m below the river surface at mean low water.

Calculated transit times of cooling water traveling from intake to river outfall when Units 2 and 3 are operating at full pumping capacity is 9.7 minutes for Unit 2 and 5.6 minutes for Unit 3 (Table 3-1). Passage from the intake to the condensers is about 1.5 minutes and calculated time through the condensers is 0.14 minutes for both units. Thus, much of the total transit time through the cooling-water systems occurs in the discharge canal. Because the discharge canal receives cooling water from all three units, transit times through the canal depend on the total circulating water flow through all units.

The temperature rise (delta-T) encountered by organisms passing through the condenser cooling systems of the Indian Point Generating Station depends on the cooling water flow and level of power generation (Tables 3-2 and 3-3). At Unit 2, with six pumps operating at full flow and the unit at 100 percent generating capacity, the calculated condenser temperature rise ranges from 8.8 to 8.9 C, depending on river temperature. At Unit 3, the calculated condenser temperature rise ranges from 9.5 to 9.7 C for 100 percent capacity generation with six pumps operating at full flow. The higher calculated delta-T at Unit 3 is due to the higher rated generation capacity.

Both units were operating during the 1980 sampling season (late April through mid-July), except from 4 to 11 June, when Unit 2 was offline, and isolated days for Units 2 and 3 (Section 4.2.1). Cooling water flow was generally maintained during the unit outages. Only service water pumps were operating at Unit 1. Summaries of the total calculated water flow (service and cooling water) for each unit during the 1980 sampling season are presented in Appendix A.

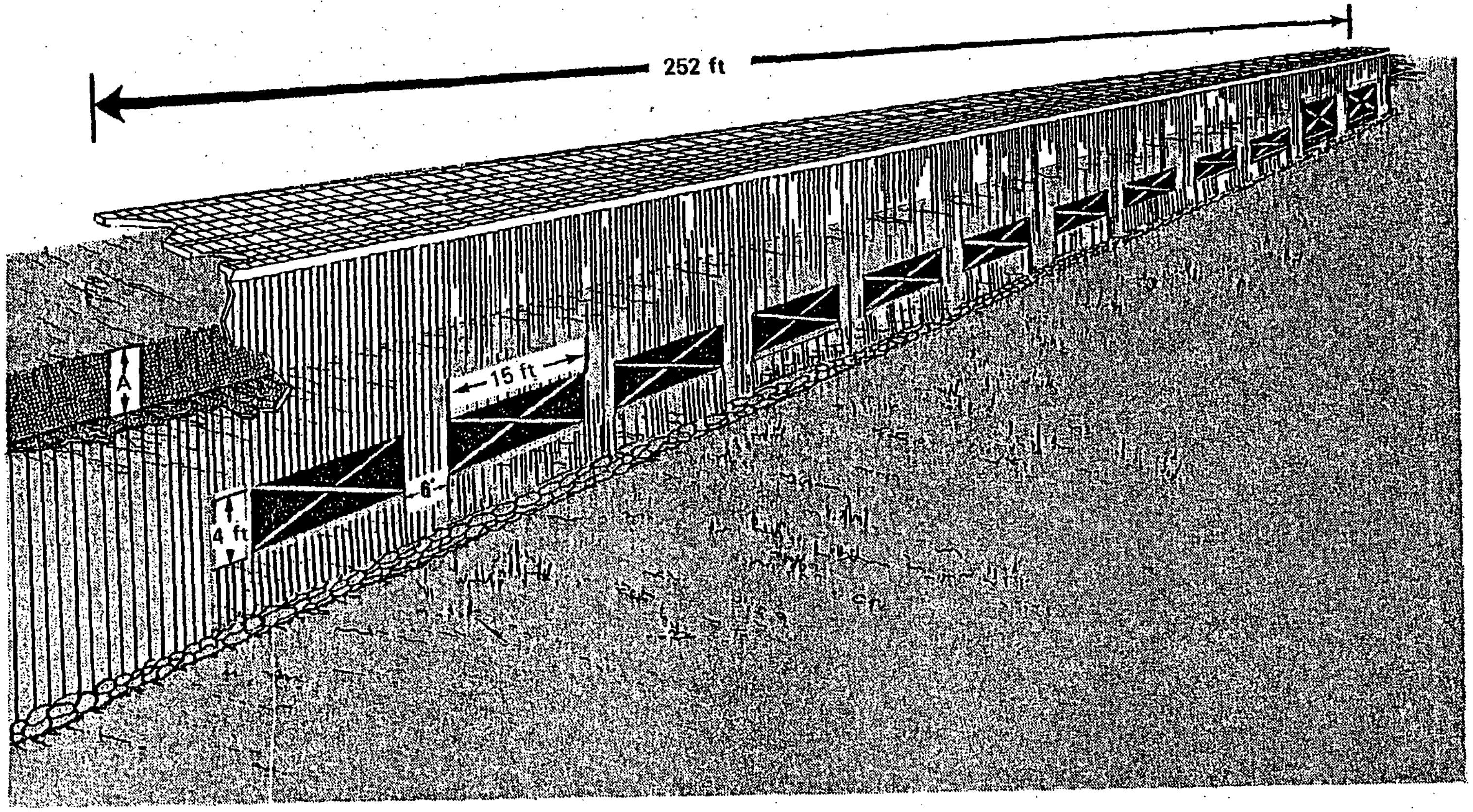


Figure 3-3. Indian Point Generating Station discharge structure (A = discharge canal water level relative to river surface).

TABLE 3-1 AVERAGE CALCULATED TRANSIT TIMES FOR COOLING WATER DURING FULL FLOW OPERATION OF INDIAN POINT GENERATING STATION--UNITS 1, 2, AND 3 OPERATING INDIVIDUALLY AND SIMULTANEOUSLY

Individual Operation (time in minutes)(a)

	Unit 1	Unit 2	Unit 3
Intake to Common Discharge Ports	33.23	12.85	8.77

Simultaneous Operation of Units 2 and 3(b)
(Unit 1 not operating)

Unit 2 Intake to Common Discharge Ports (time in minutes)

Circulating Pumps Operating at Unit 3	Circulating Pumps Operating at Unit 2			
	3	4	5	6
3	17.7	14.4	12.3	10.8
4	16.8	13.7	11.7	10.3
5	16.2	13.2	11.3	10.0
6	15.6	12.8	11.0	9.7

Unit 3 Intake to Common Discharge Ports (time in minutes)

Circulating Pumps Operating at Unit 3	Circulating Pumps Operating at Unit 2			
	3	4	5	6
3	9.6	8.3	7.4	6.7
4	8.7	7.6	6.8	6.3
5	8.0	7.1	6.4	5.9
6	7.5	6.7	6.1	5.6

(a) Source: NYU 1978, Table 1-1.

(b) Source: Personal Communication; Consolidated Edison Company of New York, Inc., 10 January 1980.

Note: Calculated transit times are based on pumps operating at 100 percent flow (312 cfs); calculated transit time through condenser: 0.14 minutes.

TABLE 3-2 PREDICTED TEMPERATURE RISE (C) OF CONDENSER COOLING WATER AT UNIT 2, INDIAN POINT GENERATING STATION

Plant Capacity (MWe)	River Temperature (C)	Pumps Operated With No Recirculation				Pumps Operated With 40% Recirculation			
		6 Pumps	5 Pumps	4 Pumps	3 Pumps	6 Pumps	5 Pumps	4 Pumps	3 Pumps
906 (100% load)	4.4	--	--	--	--	14.6	17.6	22.6	*
	10.0	8.8	10.4	13.1	17.9	14.7	17.7	22.7	*
	15.6	8.8	10.5	13.1	18.1	--	--	--	--
	21.1	8.9	10.6	13.2	*	--	--	--	--
	26.7	8.9	10.7	13.5	*	--	--	--	--
766 (75% load)	4.4	--	--	--	--	12.6	15.2	19.1	24.4
	10.0	7.5	9.1	11.4	15.3	12.7	15.3	19.2	24.4
	15.6	7.6	9.1	11.5	15.4	--	--	--	--
	21.1	7.6	9.2	11.6	15.7	--	--	--	--
	26.7	7.7	9.2	11.7	*	--	--	--	--
510 (50% load)	4.4	--	--	--	--	8.8	10.7	13.4	17.2
	10.0	5.2	6.4	8.1	10.8	8.9	10.8	13.5	17.2
	15.6	5.3	6.4	8.1	10.8	--	--	--	--
	21.1	5.3	6.5	8.2	11.0	--	--	--	--
	26.7	5.4	6.6	8.2	11.2	--	--	--	--

*Turbine backpressure higher than 3.5-in. Hg.

Dash (--) indicates operating mode not appropriate at these temperatures.

Source: Con Edison 1977a.

TABLE 3-3 PREDICTED TEMPERATURE RISE (C) OF CONDENSER COOLING WATER AT UNIT 3, INDIAN POINT GENERATING STATION

Plant Capacity (MWe)	River Temperature (C)	Pumps Operated With No Recirculation				Pumps Operated With 40% Recirculation			
		6 Pumps	5 Pumps	4 Pumps	3 Pumps	6 Pumps	5 Pumps	4 Pumps	3 Pumps
1,000 (100% load)	4.4	--	--	--	--	16.0	19.3	24.7	*
	10.0	9.5	11.5	14.3	19.6	16.2	19.4	24.8	*
	15.6	9.6	11.6	14.4	19.8	--	--	--	--
	21.1	9.6	11.6	14.5	*	--	--	--	--
	26.7	9.7	11.7	14.8	*	--	--	--	--
766 (75% load)	4.4	--	--	--	--	12.6	15.2	19.1	25.6
	10.0	7.5	9.1	11.4	15.3	12.7	15.3	19.2	25.6
	15.6	7.6	9.1	11.5	15.4	--	--	--	--
	21.1	7.6	9.2	11.6	15.7	--	--	--	--
	26.7	7.7	9.2	11.7	*	--	--	--	--
510 (50% load)	4.4	--	--	--	--	8.8	10.7	13.4	18.3
	10.0	5.2	6.4	8.1	10.8	8.9	10.8	13.5	18.3
	15.6	5.3	6.4	8.1	10.8	--	--	--	--
	21.1	5.3	6.5	8.2	11.0	--	--	--	--
	26.7	5.4	6.6	8.2	11.2	--	--	--	--

*Turbine backpressure higher than 3.5-in. Hg.

Dash (--) indicates operating mode not appropriate at these temperatures.

Source: Con Edison 1977a.

4. ENTRAINMENT SURVIVAL STUDIES

4.1 INTRODUCTION

The 1980 entrainment survival study was designed to determine the survival of ichthyoplankton passing through the condenser cooling systems of the Indian Point Generating Station. This study represents a continuation of studies conducted by Ecological Analysts in 1977, 1978, and 1979 and 80 (EA 1978a, 1979a, and 1981). The 1980 study focused on the entrainment survival of striped bass (*Morone saxatilis*), white perch (*M. americana*), herrings (Clupeidae), and anchovies (Engraulidae) which use the Hudson River estuary as a spawning and nursery area during spring and summer months. Unusually large collections of juvenile Atlantic tomcod (*Microgadus tomcod*) also allowed for an analysis of entrainment survival for this winter spawning taxon.

Although pump/larval table collection systems were used for the 1977 and 1978 survival studies and the late winter Atlantic tomcod study in 1979, a new gear design was implemented during the 1979 spring-summer sampling effort to further reduce sampling stress on more sensitive taxa and life stages. These new collection systems, the pumpless (discharge) and rear-draw (intake) plankton sampling flumes, strained organisms from the water without first passing them through a pump. Flotation of the samplers permitted closer access to the point of sample withdrawal and facilitated sampling at the ports of the discharge canal.

In 1980, additional modifications were incorporated in the flume sampling systems to eliminate the differences in sampling stress between flumes observed in 1979 (EA 1981). These modifications included altering water flow patterns across the diversion screens and standardizing the drain rates. The success of these modifications in controlling sampling stress was apparent in the 1980 data. Potential bias from sampling-related mortality has been practically eliminated and entrainment survival estimates were thus superior to any of the previous estimates. The increased quality of the data allowed a reexamination of previous ideas concerning the effect of entrainment at the Indian Point Generating Station on aquatic organisms.

4.2 METHODS AND MATERIALS

4.2.1 Sampling Procedures

4.2.1.1 Sampling Schedule and Station Locations

Entrainment survival sampling for striped bass, white perch, herrings, and anchovies was conducted from 30 April through 10 July 1980, coincident with the primary spawning and nursery seasons of these taxa. Samples were collected on four consecutive nights each week (a total of 44 sampling days) between 1600 and 0200 hours. Throughout the entrainment survival study, sampling was conducted at discharge port number one (Station DP) using a pumpless plankton sampling flume and at the Unit 3 intake (Station I3) (Figure 3-2) using a rear-draw plankton sampling flume. During the sampling period, Units 2 and 3 operated almost continuously and Unit 1 did not operate (Table 4-1).

4.2.1.2 Gear Description

The pumpless and rear-draw plankton sampling flumes used in 1980 were mounted on rafts and both systems collected organisms without first passing them through pumps. This design reduced sampling stresses on sensitive ichthyoplankton by eliminating mechanical and pressure effects associated with pump collection. Internal aspects of both flumes (e.g., length and width, orientation of the water inlet, flow expansion panels, diversion screens, ambient water injection systems, and collection box) were designed in the same manner (Figure 4-1) to minimize potential differential gear effects on organism survival.

The pumpless flume at Station DP used the pressure created by the difference in water level between the discharge canal and the river to deliver sample water. The flume was positioned along the outside of the discharge canal bulkhead adjacent to the northernmost discharge port (Figure 4-2). The sampler was secured to a raft so that the flume was maintained at the river surface. Water and organisms exiting the discharge port entered a 15-cm diameter curved steel pipe (Figure 4-2). The sample water then passed through a flexible hose to the inlet of the flume. The water velocity at the discharge port (about 3 m/sec) was sufficient to deliver sample water to the collection flume. The temperature of the sample was reduced gradually in the discharge flume by an ambient water injection system that supplied a fine stream of ambient temperature river water along the sides of the flow expansion panels, diversion screens, and collection box. Temperatures in the collection box were typically 2 to 3 C below the temperature of water entering during sampling. Water flow through the sampler was primarily by gravity since the water level in the flume was above the river surface. The flow of water across the diversion screens was diffused by baffle plates mounted behind the screens and slotted standpipes at the primary outlets from the flume. Flexible hoses attached to the primary outlets were raised or lowered to adjust water flow through the system and to alter the water depth within the sampler. Organisms and detritus filtered by the two vertical 505-μm mesh screens were diverted into the collection box. Filtered sample water was pumped at a constant rate (generally 0.15 m^3/min) from the collection system through the secondary outlet beneath the collection box. The volume of water sampled, which varied with the difference in water levels between the river and the discharge canal, was measured with a Signet inline flowmeter attached to the flume inlet. Sample volume averaged 16.9 m^3 (standard deviation = 3.2 m^3) and ranged from 8.6 to 25.8 m^3 per sample over the sampling season.

The rear-draw plankton sampling flume (Figure 4-3) was mounted on a raft in front of the Unit 3 intake structure. The design of the flume and collection box components of this sampler was consistent with the pumpless plankton sampling flume, and sample delivery was also achieved without passing the organisms through pumps. However, because the water velocity at this station (approximately 0.3 m/sec) was insufficient to supply an adequate sample flow, a water level difference was created within the flume by submerging the bottom of the flume below the river

TABLE 4-1 CIRCULATING PUMP OPERATION AND ELECTRICAL OUTPUT BY UNIT DURING ENTRAINMENT SURVIVAL SAMPLING AT THE INDIAN POINT GENERATING STATION, 1980

Sampling Date	Unit 2(a) Circulating Pumps Operating	Unit 2(a) Average Daily Kilowatt Generation (x10^3)	Unit 3(a) Circulating Pumps Operating	Unit 3(a) Average Daily Kilowatt Generation (x10^3)
30 APR	5	852	4	603
1 MAY	5	845	4	606
5 MAY	6	852	4	607
6 MAY	6	851	5	645
7 MAY	6	850	5	790
8 MAY	5	845	5	789
12 MAY	5	839	5	880
13 MAY	5	845	5	882
14 MAY	6	847	5	880
15 MAY	5	848	5	879
19 MAY	5	627	3	311(b)
20 MAY	5	839	5	435
21 MAY (0001-1952 hours)	5		5	
21 MAY (1952-2400 hours)	5	835	4	882
22 MAY	5	839	4	878
27 MAY	5	836	4	855
28 MAY	5	842	4	853
29 MAY (0001-2145 hours)	5		4	
29 MAY (2145-2400 hours)	5	836	5	854
30 MAY	5	837	5	588(b)
2 JUN (0001-1900 hours)	5		5	
2 JUN (1900-2400 hours)	4	820	5	809
3 JUN	0	500(b)	5	574
4 JUN	3	0	5	822

(a) Only Units 2 and 3 generated electricity and had circulating pumps operating during entrainment survival sampling.

(b) Electricity was not being generated during entrainment survival sampling on this day.

(c) Electricity was not being generated during the first two samples collected on this day.

(d) Electricity was not being generated during the last four samples collected on this day.

TABLE 4-1 (CONT.)

	Unit 2(a)		Unit 3(a)	
Sampling Date	Circulating Pumps Operating	Average Daily Kilowatt Generation (x10^3)	Circulating Pumps Operating	Average Daily Kilowatt Generation (x10^3)
5 JUN	3	0	5	874
9 JUN	0	0	5	880
10 JUN	0	0	5	880
11 JUN	5	0	3	339(b)
12 JUN	5	82	5	73(c)
16 JUN	5	841	5	877
17 JUN	5	839	5	877
18 JUN	5	839	5	879
19 JUN	5	838	5	878
23 JUN	5	837	5	875
24 JUN	5	833	5	871
25 JUN	5	834	5	870
26 JUN	5	832	5	866
30 JUN	5	830	5	683(d)
1 JUL	5	834	5	682
2 JUL	5	486(b)	5	534(c)
3 JUL	5	479	5	449
7 JUL (0001-1815 hours)	5		5	
7 JUL (1815-2400 hours)	6	830	5	860
8 JUL	6	834	5	862
9 JUL	6	838	5	857
10 JUL	6	835	5	854

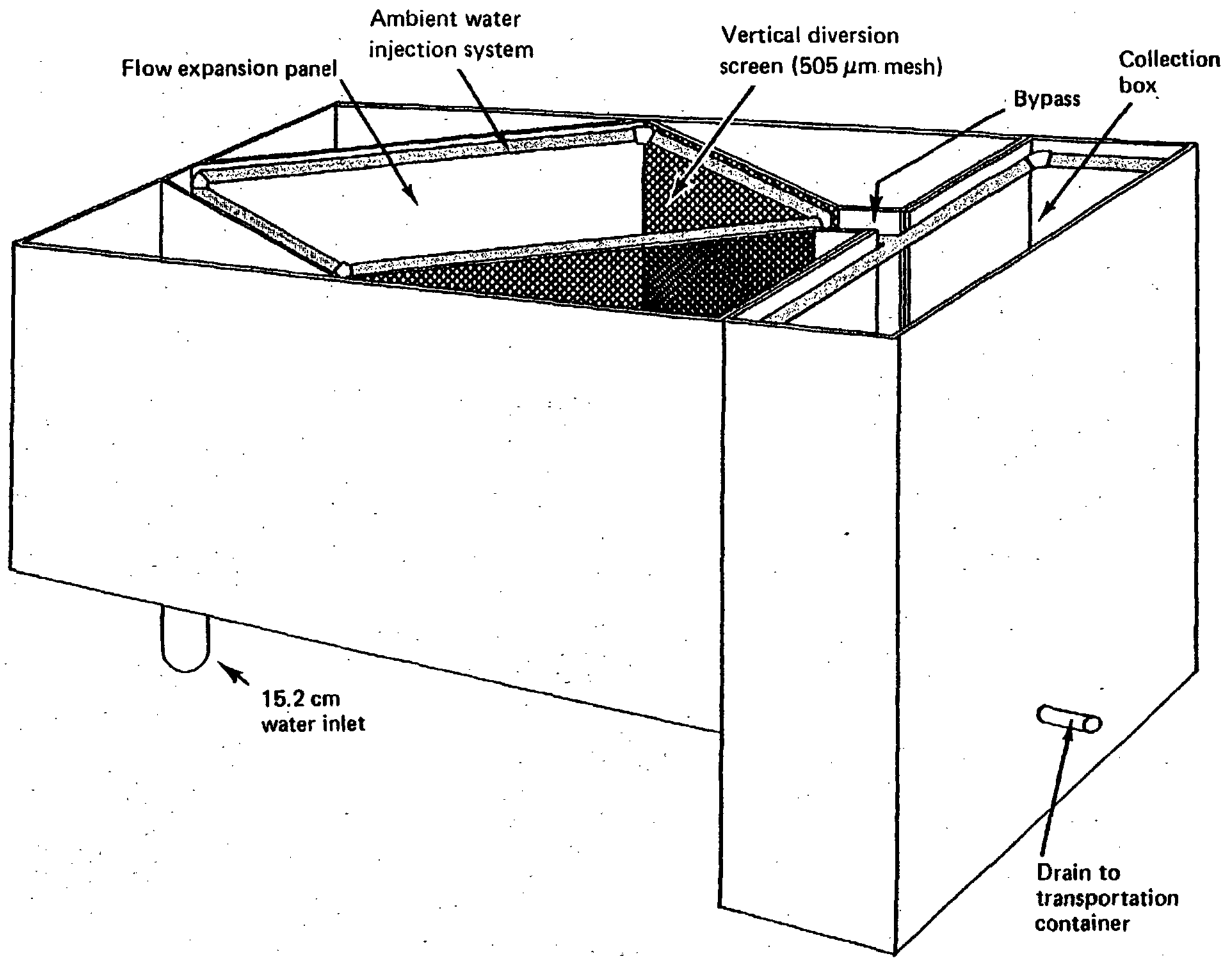


Figure 4-1. Design of the collection flume used in the pumpless and rear-draw samplers during the entrainment survival study, Indian Point Generating Station, 1980.

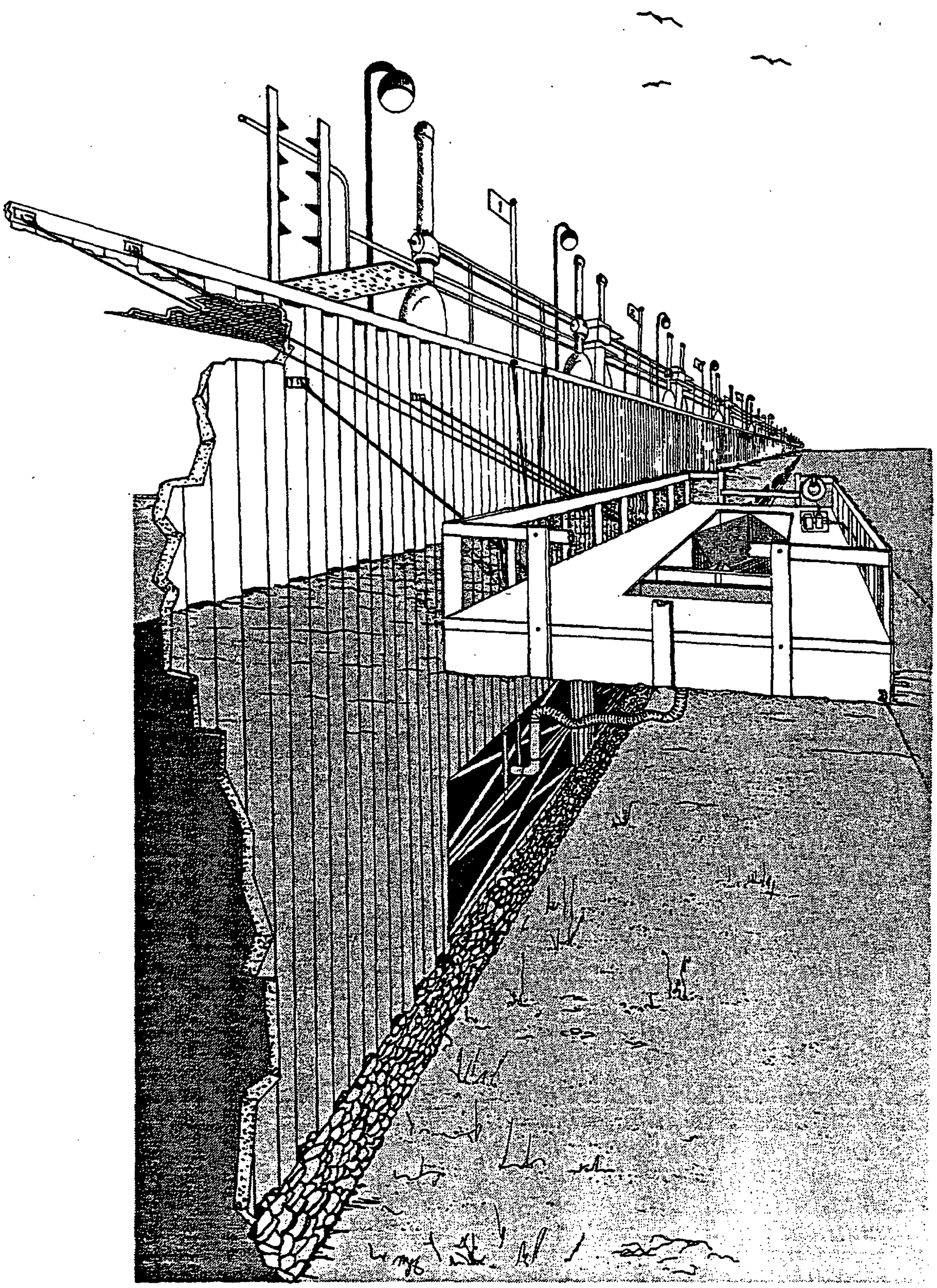


Figure 4-2. Basic configuration of the pumpless plankton sampling flume system used at the discharge port (Station DP) during the entrainment survival study, Indian Point Generating Station, 1980.

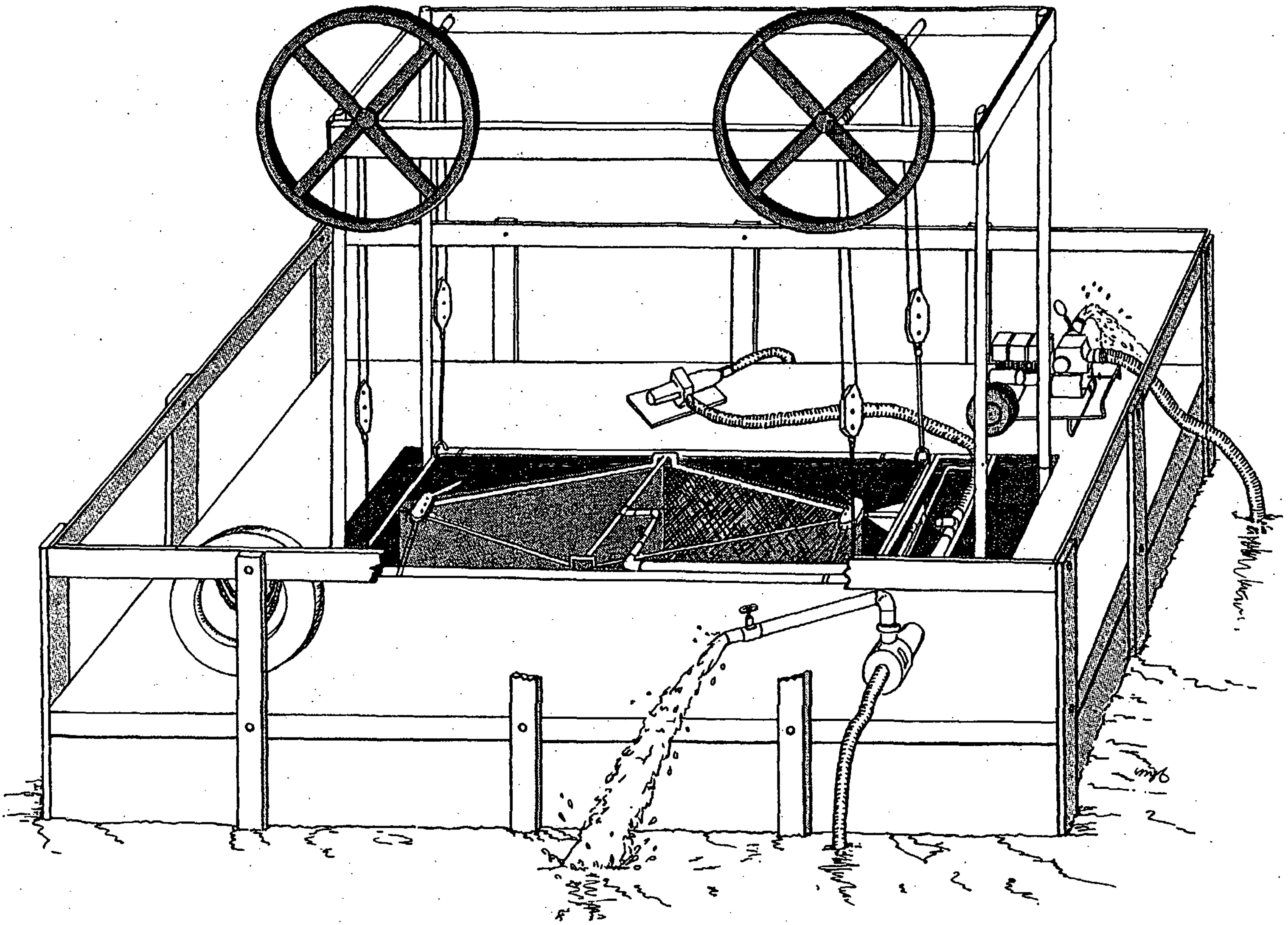


Figure 4-3. Rear-draw plankton sampling flume system used at the Unit 3 intake (Station 13) during the entrainment survival study, Indian Point Generating Station, 1980.

surface and using a 10-cm (4-in.) Homelite pump to pump water from behind the diversion screens. The flow of water across the diversion screens was diffused with baffle plates and slotted standpipes similar to those in the pumpless sampling flume. Water was pumped from the collection box at the same rate as at the discharge sampler (0.15 m^3/min). A separate pump supplied filtered river water to the ambient water injection system. Sample water entered the collection flume through a 15-cm diameter flexible hose attached to the flume inlet. The mouth of the hose, which faced into the Unit 3 intake flow, was suspended at a 3.4-m depth to match the depth of withdrawal at the discharge station. Volume sampled was measured with an inline Sparling "Masterflo" flowmeter attached to the Homelite pump. Sample volume averaged 15.5 m^3 (standard deviation = 2.0 m^3) and ranged from 11.0 to 21.0 m^3. Drain time ranged from 15 to 37 minutes per sample. (Specific information relative to sampling gear and associated sampling conditions at each station are presented in Appendix B, Table B-1).

4.2.1.3 Collection Procedures

Each sample collected with the pumpless or rear-draw plankton sampling flumes was taken by allowing water to flow through the gear for 15 minutes. Prior to sampling, the ambient water injection systems were activated to fill the collection flumes with filtered water, and the Homelite pump was started at the rear-draw sampler (Station I3). Sampling was initiated simultaneously at the intake and discharge stations by removing the plugs from the flume inlets. The pumping rate at the intake station was adjusted to conform to the flow (±100 ℓ/min) at the discharge station. Similar water depth within the samplers was maintained by adjusting the flexible hoses attached to the primary outlets of the pumpless flume, adjusting the pumping rate at the rear-draw flume, or adjusting the depth of submersion of the rear-draw flume.

At the end of the sampling interval, plugs were placed in the flume inlets and the Homelite pump was turned off at the rear-draw flume. The ambient water injection systems remained on until the samplers were nearly drained to rinse the surfaces of the flow expansion panels, diversion screens, and collection boxes. Rinsing of the interior of the samplers was supplemented with a gentle flow of filtered ambient river water from a 19-mm diameter garden hose. Because the depths within the samplers were similar during sampling and the secondary outlet pumps removed water at the same rate, the time to drain each sampler was also similar. Once the samples were concentrated in the collection boxes, the pumps were stopped. Organisms and detritus were then drained into detachable transportation containers through 3-cm diameter tubing at the bottom of the collection boxes. The samples were transferred to the onsite laboratory for sorting. Between samples, flumes and collection boxes were thoroughly rinsed with a high pressure spray wash to prevent contamination of subsequent samples from detritus or organisms adhering to the surface of the sampler.

4.2.1.4 Water Quality Measurements

Water temperature, conductivity, dissolved oxygen, and pH were measured each night. Water temperature was recorded at both stations during each sample collection. Conductivity, dissolved oxygen, and pH were measured within the flume at Station I3 during the first, middle, and last collections on each sampling night. Water quality data collected at the intake station during the entrainment survival study is presented in Table 4-2.

4.2.2 Sample Processing

4.2.2.1 Sorting Procedures

Live and dead ichthyoplankton were sorted from the transportation containers immediately after sample collection and processed as indicated in Figure 4-4. Ichthyoplankton were classified as live, stunned, or dead according to the following criteria:

Live:	Fish	- swimming vigorously, no apparent orientation difficulty.
	Eggs	- translucent, chorion complete, not cloudy in any internal portion.
Stunned:	Fish only	- swimming abnormally, struggling, swimming on side or upside down; or nonmotile except when gently probed.
Dead:	Fish	- no vital signs, no body or opercular movement, no response to gentle probing.
	Eggs	- opaque, chorion ruptured or cloudy in any internal portion.

Dead eggs and larvae were removed from the sample and preserved in 5 percent buffered formalin. Live and stunned larvae were carefully transferred with a spoon from the sorting trays to 1-liter jars of filtered ambient river water. A maximum of five specimens were placed in each holding jar. Young larvae were separated from the older larvae and juveniles to reduce the possibility of cannibalism. The holding jars were aerated and maintained in an ambient temperature water bath for 96 hours after collection. Live eggs were carefully transferred from the sorting trays to egg holding cups. Holding cups were constructed of 10-cm diameter PVC pipe, 10 cm high, with a fine mesh screen bottom to permit ambient water circulation. Residual detritus and invertebrates from all the samples were preserved in 10 percent buffered formalin. Preserved specimens were transported to Ecological Analysts' Central Laboratory in Middletown, New York, for identification and classification according to taxon and life stage. The total length of each specimen was determined to the nearest millimeter.

TABLE 4-2 AVERAGE TEMPERATURE, DISSOLVED OXYGEN, pH, AND CONDUCTIVITY RECORDED AT STATION I3 DURING THE ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 10 JULY 1980

Date	Temp. (C)	DO (ppm)	Cond. (μmho)	pH
30 APR[a]	12.0	6.0	2,980	7.8
30 APR	11.3	9.5	1,819	7.7
1 MAY	12.0	10.4	774	7.7
5 MAY	13.2	10.0	536	7.6
6 MAY	13.6	9.8	248	7.6
7 MAY	13.8	9.6	184	7.3
8 MAY	13.8	9.3	150	7.5
12 MAY	15.1	--	--	--
13 MAY	15.7	8.4	136	--
14 MAY	15.6	8.9	136	7.9
15 MAY	15.5	7.7	161	7.4
19 MAY	16.5	7.2	232	7.4
20 MAY	16.9	7.7	249	7.4
21 MAY	17.1	7.9	181	7.4
22 MAY	17.6	7.9	1,116	7.4
27 MAY	18.5	7.4	6,592	7.4
28 MAY	18.7	7.5	6,028	7.4
29 MAY	19.0	6.2	6,926	7.4
30 MAY	18.3	6.1	6,897	7.3
2 JUN	19.2	6.1	6,332	7.4
3 JUN	19.7	6.2	5,930	7.3
4 JUN	19.6	8.1	6,375	7.1
5 JUN	20.3	7.8	5,056	7.0
9 JUN	20.0	8.1	5,391	7.4
10 JUN	19.9	7.9	3,863	7.3
11 JUN	19.7	7.6	3,335	7.3
12 JUN	19.9	7.6	2,995	7.2
16 JUN	21.5	7.6	2,873	7.4
17 JUN	21.7	7.8	2,686	7.5
18 JUN	22.3	7.6	3,155	7.4
19 JUN	22.7	7.8	3,360	7.5
23 JUN	23.2	7.6	4,688	7.5
24 JUN	23.0	8.1	4,517	7.6
25 JUN	23.5	7.9	4,605	7.6
26 JUN	23.3	7.7	5,147	7.5
30 JUN	23.4	6.9	4,890	7.4
1 JUL	23.6	6.8	4,923	7.4
2 JUL	23.6	6.8	4,925	7.4
3 JUL	23.8	6.7	5,211	7.1
7 JUL	25.1	6.6	5,480	7.1
8 JUL	24.7	6.2	4,457	7.2
9 JUL	25.0	6.5	4,057	7.2
10 JUL	24.9	6.5	3,956	7.2

Note: (a) indicates sample collection from the previous night;
Dash (--) indicates data were not available.

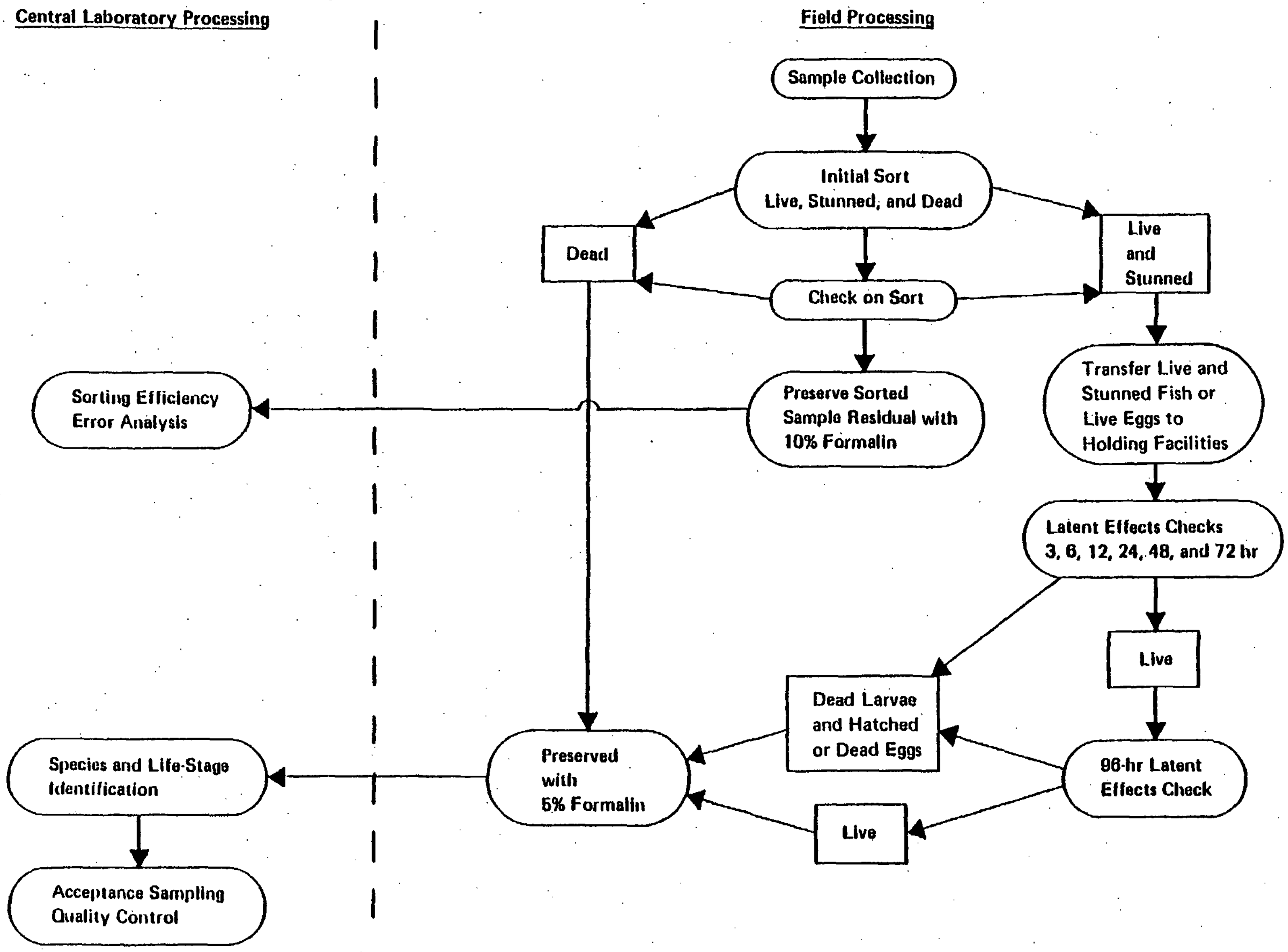


Figure 4-4. Work-flow chart for ichthyoplankton survival determinations.

4.2.2.2 Extended Survival Observation Procedures

The survival of live and stunned ichthyoplankton was monitored for 96 hours after collection (Figure 4-4). Interim survival assessments (latent effects checks) were made 3, 6, 12, 24, 48, and 72 hours after collection. At each check, dead organisms were removed from the holding containers and preserved in vials containing 5 percent buffered formalin. All organisms remaining alive at the 96-hour check were enumerated and preserved. Live eggs collected during survival sampling were monitored for 96 hours after collection to determine hatching success. Dead eggs were removed at each observation period. Larvae that had hatched were removed and preserved for later identification.

4.2.2.3 Quality Assurance and Control

Quality assurance and control procedures were used throughout the sampling effort to ensure the accuracy of the data. Quality control procedures established at the onsite laboratory consisted of: (1) sorting efficiency checks immediately after the initial sort and, when eggs were present, an additional check to determine whether all eggs had been removed; (2) a color-coded labeling system for holding containers and vials; and (3) records of the number of live and dead fish, or hatched eggs, observed at each extended survival observation.

In addition, periodic inspections of the field sampling program were conducted by Ecological Analysts' Documentation Control Office to ensure adherence to standard operating procedures. Quality control procedures established at the Central Laboratory included re-sorting of randomly selected preserved samples to document the sorting efficiency at the onsite laboratory, and the application of statistical quality control procedures for an average outgoing quality limit (AOQL) of 0.10 for a continuous sampling plan (Duncan 1974) to ensure the precision of ichthyoplankton identification.

4.2.3 Analytical Procedures

4.2.3.1 Survival Proportions

4.2.3.1.1 Egg Survival

The proportion of eggs that survived was determined on the basis of hatching success within 96 hours after collection:

$$P_I \text{ or } P_D = \frac{\text{No. of eggs which hatched within 96 hours}}{\text{Total no. of eggs collected}}$$

where

P_I = proportion surviving at the intake station
P_D = proportion surviving at the discharge station

This method accounts for initial and latent effects. To determine if differences in survival proportions between stations and among sampling weeks were statistically significant ($\alpha = 0.05$), a multi-way contingency analysis was used (Sokal and Rohlf 1969).

4.2.3.1.2 Initial Survival of Larvae and Juveniles

Initial survival proportions of larval and juvenile life stages collected at intake and discharge stations were calculated as the ratio of fish found alive and stunned immediately following collection to the total number of fish collected:

$$P_I \text{ or } P_D = \frac{\text{No. of live and stunned fish}}{\text{Total no. of fish collected}}$$

where

P_I = proportion surviving at the intake station
P_D = proportion surviving at the discharge station

Stunned fish were grouped with live fish in the analysis to avoid potential bias associated with the subjective stunned category. Differences in survival proportions between intake (control) and discharge stations were determined with the X^2 test (Sokal and Rohlf 1969).

Data were grouped for statistical comparisons according to sampling station and species. Ichthyoplankton collected at the intake station were pooled by life stage and species for all collections. Discharge station survival proportions were calculated for specific discharge temperature categories. Temperature categories for Atlantic tomcod were: $\leq$26 C and $\geq$27 C. Temperature categories for striped bass, white perch, herrings (clupeids), and anchovies (engraulids) were: $\leq$29 C, 30-32 C, and $\geq$33 C. In 1980, as in 1977-1979, discharge temperatures were measured to the nearest degree C. Thus, these categories correspond exactly with those reported previously as $\leq$29.9 C, 30.0-32.9 C, and $\geq$33 C (EA 1978a, 1979a, 1981).

4.2.3.1.3 Extended Survival of Larvae and Juveniles

Extended survival of larval and juvenile life stages collected at intake and discharge stations was compared to determine if mortality caused by entrainment was manifested beyond the initial survival observation. For these comparisons survival at each extended survival observation was calculated as a proportion of the initial number of live and stunned fish (i.e., normalized survival), as follows:

$$P_{I_i} \text{ or } P_{D_i} = \frac{\text{No. of fish live or stunned at time i}}{\text{Total no. of fish initially alive or stunned}}$$

where

P_{I_i} = normalized survival proportion at time i for fish collected at the intake
P_{D_i} = normalized survival proportion at time i for fish collected at the discharge

Gehan's nonparametric test (Gross and Clark 1975) was used to determine if differences between the intake and discharge normalized extended survival proportions were significant for a particular species and life stage.

4.2.3.2 Entrainment Survival Estimates

The calculation of an entrainment survival estimate differed depending on life stage. Entrainment survival estimates for eggs were determined by the ratio of proportions which hatched within 96 hours for intake and discharge samples. Larval and juvenile entrainment survival estimates were based on the ratio of initial survival proportions of the intake and discharge stations. Entrainment survival estimates were calculated according to the following assumptions: (1) survival at the intake station is the conditional probability of surviving sampling, (2) survival at the discharge station is the product of the conditional probabilities of surviving entrainment and sampling, (3) there is no interaction between the two stresses, and (4) each life stage consists of a homogeneous population in which all organisms have the same probability of surviving to the next life stage.

Entrainment survival was estimated by:

$$S_e = \frac{P_D}{P_I} \times 100\%$$

where

S_e = entrainment survival
P_D = survival proportion at the discharge station
P_I = survival proportion at the intake station

4.3 RESULTS AND DISCUSSION

The 1980 entrainment survival study (30 April - 10 July) examined the survival of early life stages of striped bass, white perch, herrings (Clupeidae), anchovies (Engraulidae), and Atlantic tomcod entrained through the Indian Point plant. During the study, Unit 2 and Unit 3 had brief outages. Unit 2 was offline from 3 to 12 June and both units did not operate for short periods during the sampling season (Table 4-1). Unit 1 did not generate power or operate any circulating pumps during the study. Throughout the study, sampling was conducted at the outflow of discharge port number one (Station DP) using a pumpless plankton sampling flume, and at the Unit 3 intake (Station I3) using a rear-draw plankton sampling flume. These floating collection systems were specifically designed to minimize sampling stress on sensitive taxa and life stages.

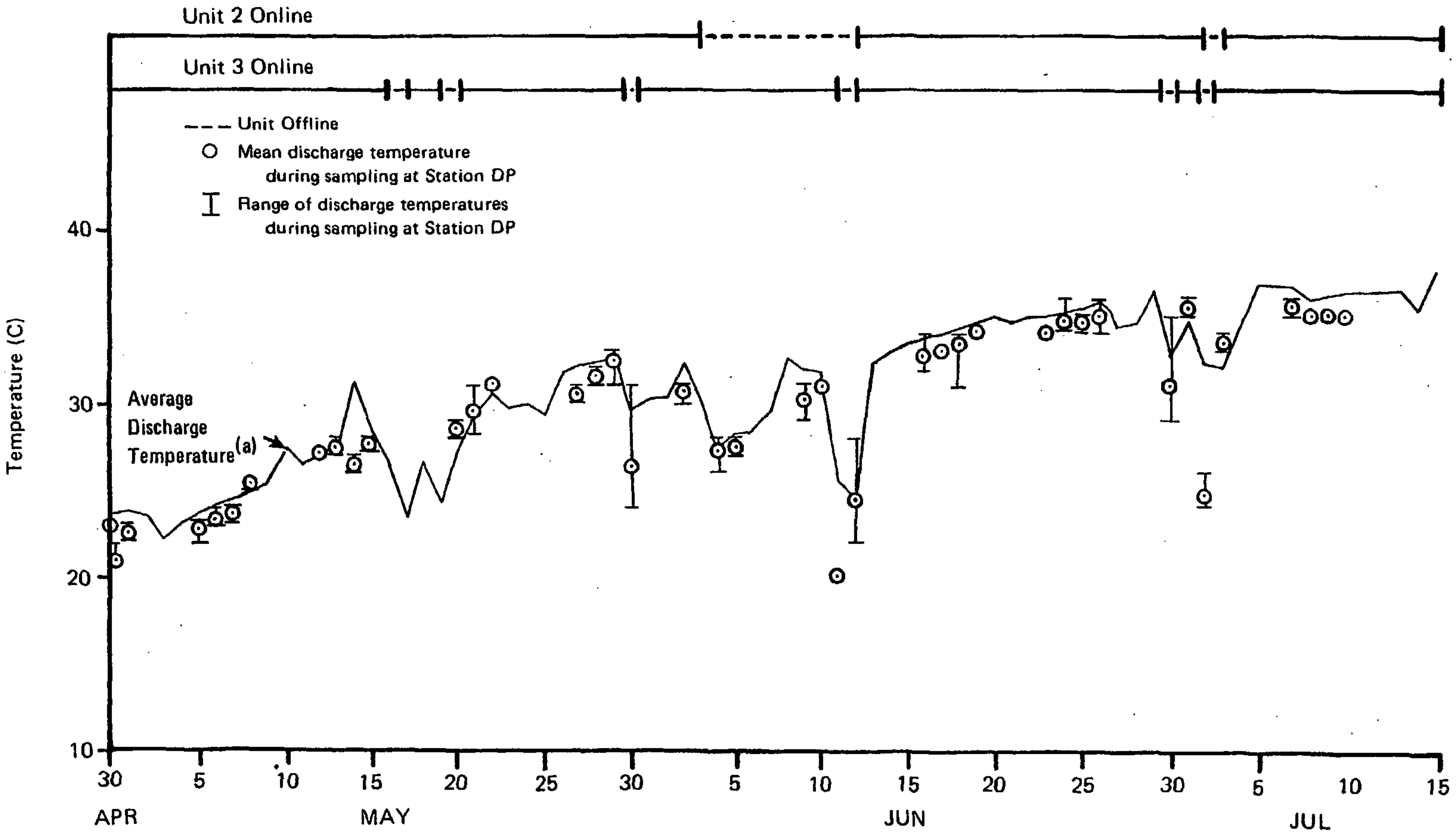
Survival of ichthyoplankton collected in entrainment samples during the study period was analyzed according to sampling station and discharge temperature. The three discharge temperature categories for which survival was determined were: ≤29 C, 30-32 C, and ≥33 C. These temperature categories were selected on the basis of laboratory and field thermal tolerance studies (EA 1978b and 1978c) and are consistent with temperature categories examined in entrainment survival studies at the Indian Point plant from 1977 to 1978. In addition, survival was analyzed by discharge temperature categories typical of May and June at the Indian Point plant (≤32 C).

Discharge temperatures for May, June, and July in the 1980 entrainment survival study were higher than normal (Figure 4-5) due to above average ambient temperatures and delta-T's. Average discharge temperatures exceeded 30 C in June and 33 C during July. Throughout the sampling season the plant operated generally with fewer than normal circulating pumps, which reduced the volume of cooling water which passed through the cooling system (Table 4-1). A reduction in one circulating water pump can increase the delta-T from 1 to 5 C depending on the generating load (Tables 3-2 and 3-3). The lower number of circulating pumps in operation during the 1980 sampling season and the relatively lower volume of cooling water passing through the plant may have contributed to the high delta-T's and maximum discharge temperatures.

4.3.1 Collection of Ichthyoplankton for Survival Determination

The most abundant ichthyoplankton taxon collected at the Indian Point plant during the 1980 entrainment survival study was striped bass (Morone saxatilis) followed in order of decreasing abundance by anchovies (Engraulidae), white perch (Morone americana), and Atlantic tomcod (Microgadus tomcod) (Table 4-3). These four taxa comprised 96 percent of the ichthyoplankton collected. For the first time since EA began entrainment survival studies at the Indian Point plant (1977), the herring family (Clupeidae) was not among the four major taxa collected.

Early season samples were dominated by Atlantic tomcod juveniles (Figure 4-6), which were more abundant in 1980 than in any previous sampling year. A review of conductivity measurements recorded in conjunction with entrainment survival sampling at the Indian Point plant over the 4-year period of 1977 through 1980 showed a distinct relationship between conductivity and the occurrence of juvenile Atlantic tomcod during May and early June. During 1978 and 1979 conductivities recorded during sampling were uniformly low (<400 µmhos) during May and did not begin to increase until the second week of June, reflecting an upstream movement of the salt front. The occurrence of juvenile tomcod in entrainment survival samples was low during both years; only 15 juveniles were collected in 1978 and 10 in 1979. In contrast, conductivity levels were relatively high during spring and early summer of 1977 (EA 1978a) and 1980 (Table 4-2), and juvenile tomcod were collected with greater frequency in entrainment survival samples. A total of 62 young-of-the-year Atlantic



(a) Source for average daily discharge temperatures was Con Edison 1980.

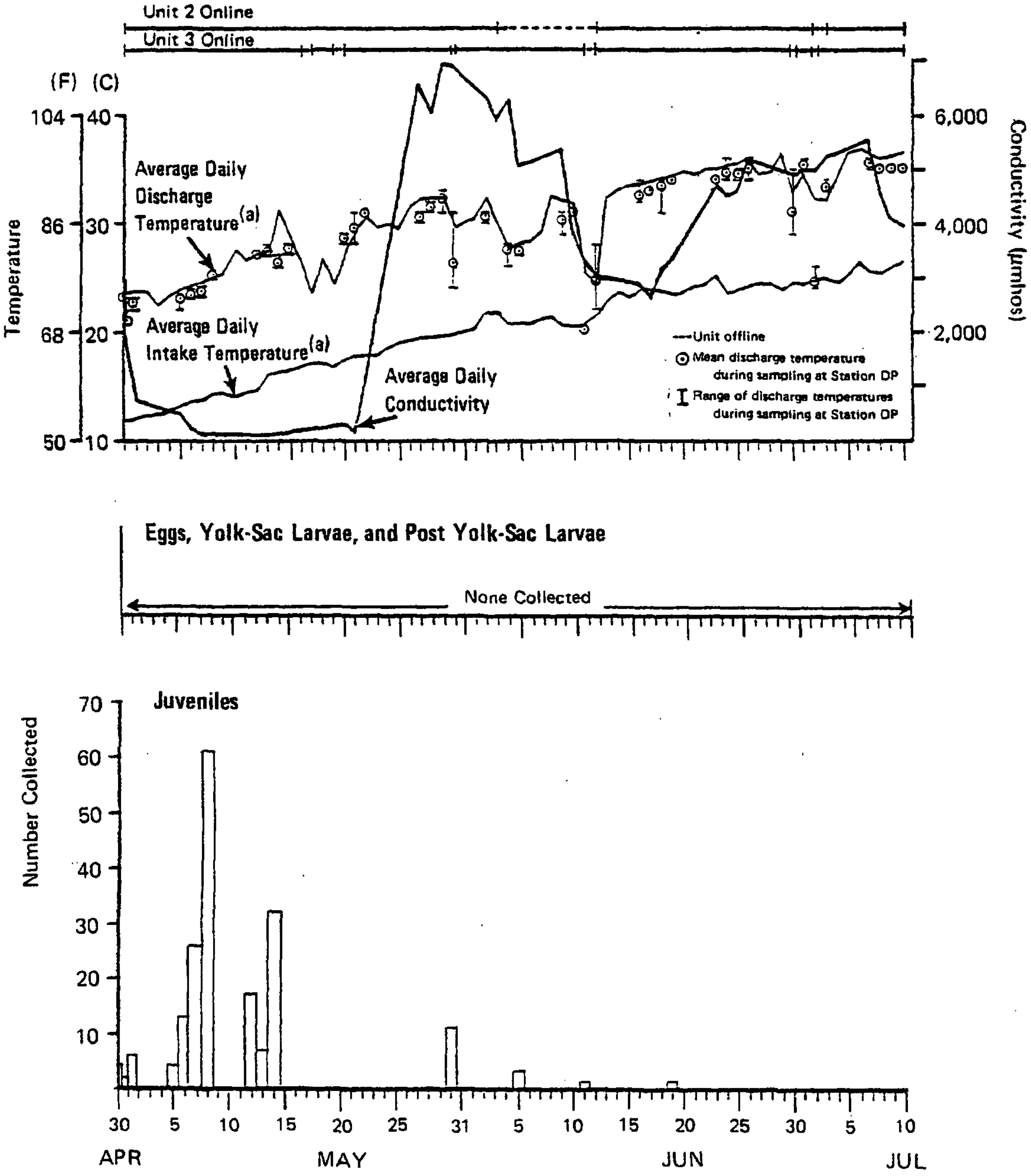
Figure 4-5. Discharge temperatures at the Indian Point Generating Station during 1980 entrainment sampling season.

TABLE 4-3 TOTAL NUMBER OF EACH ICHTHYOPLANKTON TAXON AND LIFE STAGE COLLECTED FOR SURVIVAL DETERMINATIONS DURING THE ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 10 JULY 1980

Taxon						
Common Name	Scientific Name	Eggs	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juveniles	Percent of Total
Striped bass	*Morone saxatilis*	419	126	349	9	38.3
Anchovies(a)	Engraulidae	(b)	8	840	0	36.0
White perch	*Morone americana*	0	1	288	3	12.4
Atlantic tomcod	*Microgadus tomcod*	0	0	2	210	9.0
Rainbow smelt	*Osmerus mordax*	0	4	27	5	1.5
Herrings	Clupeidae	0	3	26	3	1.4
Silversides	*Menidia* spp.	0	0	11	0	0.5
American eel	*Anguilla rostrata*	0	0	0	8	0.3
Tessellated darter	*Etheostoma olmstedi*	0	3	4	0	0.3
Yellow perch	*Perca flavescens*	0	5	0	0	0.2
Winter flounder	*Pseudopleuronectes americanus*	0	0	0	1	0.0

(a) Bay anchovy (*Anchoa mitchilli*) is the only engraulid occurring to any appreciable extent in the Hudson River estuary.

(b) Survival determinations were not made for anchovy eggs.



(a) Source for average daily intake and discharge temperatures was Con Edison 1980.

Figure 4-6. Temporal distribution and thermal exposure of Atlantic tomcod collected at the discharge port station (DP) during the spring–summer entrainment survival study, Indian Point Generating Station, 30 April – 10 July 1980.

tomcod were collected in 1977. In 1980 samples, 209 Atlantic tomcod juveniles and two post yolk-sac larvae were collected. The largest catches were recorded from 5 to 15 May when conductivity levels were low (Figure 4-6). These data suggest that juvenile tomcod were distributed in the proximity of the salt front, and were most subject to entrainment when the salt front moved past the Indian Point plant.

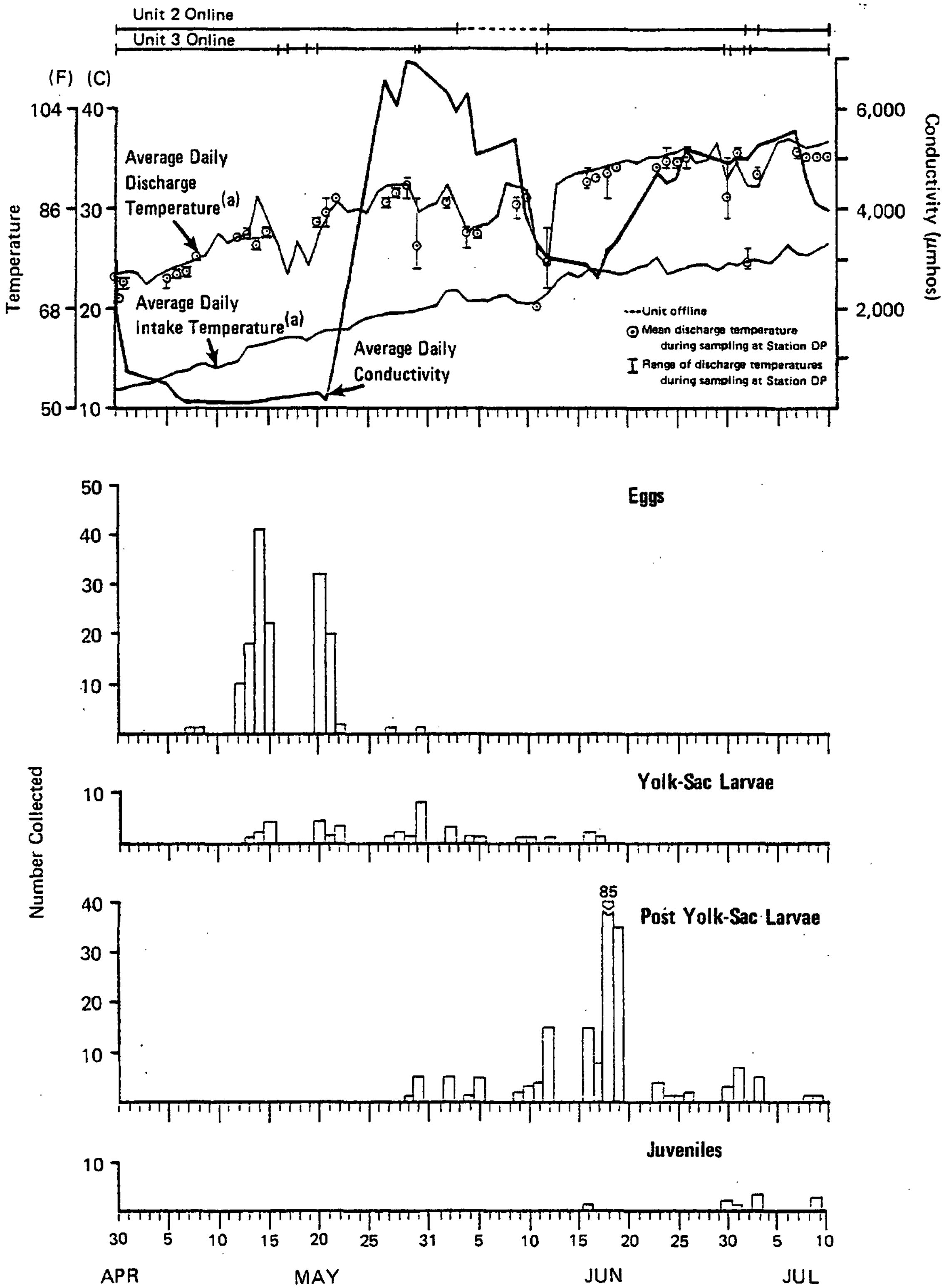
Similar patterns in abundance of striped bass during the sampling season have occurred since 1977. As in previous years, striped bass were first seen in samples as eggs in early May. Peak egg catches occurred between 12 and 21 May (Figure 4-7) when average temperature ranged from 15.1 to 17.1 C (Table 4-2). Yolk-sac larvae were caught from 13 May through 17 June, but never in large numbers. Post yolk-sac larvae were present from 29 May through 9 July, but peak occurrence was from 16 to 19 June. Juveniles were encountered infrequently from mid-June through the end of the sampling season.

White perch were the next major taxon to appear in entrainment collections (Figure 4-8). Post yolk-sac larvae occurred initally on 27 May but did not become abundant until after mid-June. As in previous years, egg, yolk-sac larvae, and juvenile white perch were seen only infrequently, if at all (Table 4-3).

Anchovies were the second most abundant taxa over the sampling season, but were not collected in large numbers until 23 June (Figure 4-9). Post yolk-sac larvae were the most frequently collected life stage. Eggs were not enumerated and yolk-sac larvae were collected on only one date. As in previous years, anchovy post yolk-sac larvae occurred during the high salinity periods of late June and early July when water temperatures are also relatively high.

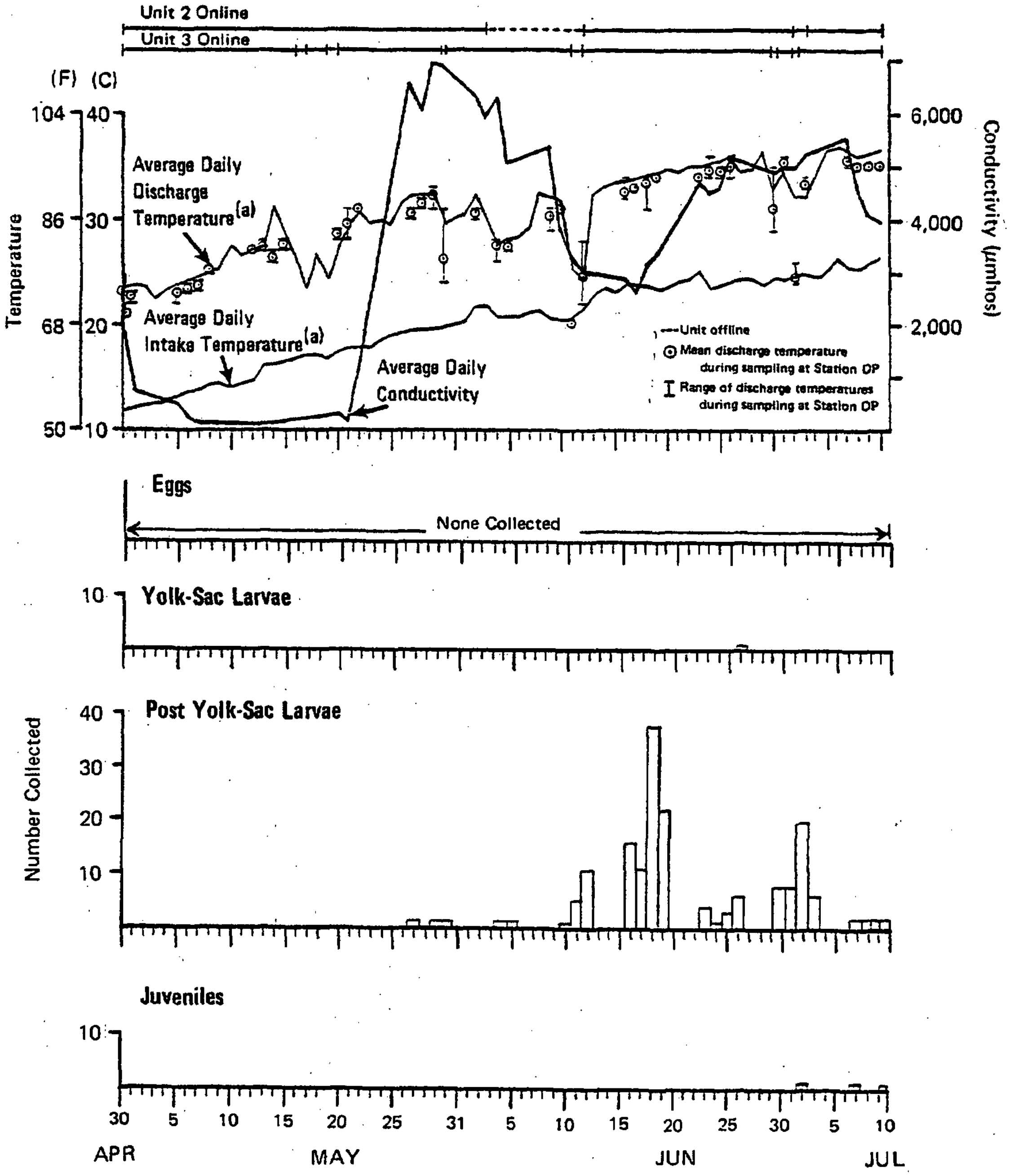
The number of herring collected at the Indian Point plant during 1980 was the lowest of any year since 1977. The low occurrence of herring during the sampling season (Figure 4-10) may be due to their preference for fresh water for spawning and only slightly brackish waters for nursery areas (McFadden 1978, TI 1980). The sampling season in 1980 was preceded by a mild winter and dry conditions in the early spring. With the movement of the salt front further upstream than normal during the 1980 sampling season, herring were probably distributed further upstream during the months of April and May and not subject to entrainment at Indian Point.

Consistent with previous entrainment survival studies at the Indian Point plant (EA 1978a, 1979a, 1981), post yolk-sac larvae were collected in larger numbers than other life stages (Table 4-3). Eggs, yolk-sac larvae, and post yolk-sac larvae of striped bass were collected in sufficient numbers for entrainment survival determination. Survival analysis for other taxa was restricted to post yolk-sac larvae, except for Atlantic tomcod juveniles. Entrainment survival was not determined for anchovy eggs because their small size and refractive index make live eggs difficult to detect in water. Weekly length frequency distributions for the major ichthyoplankton taxa collected are presented in Appendix Tables C-1 through C-4.



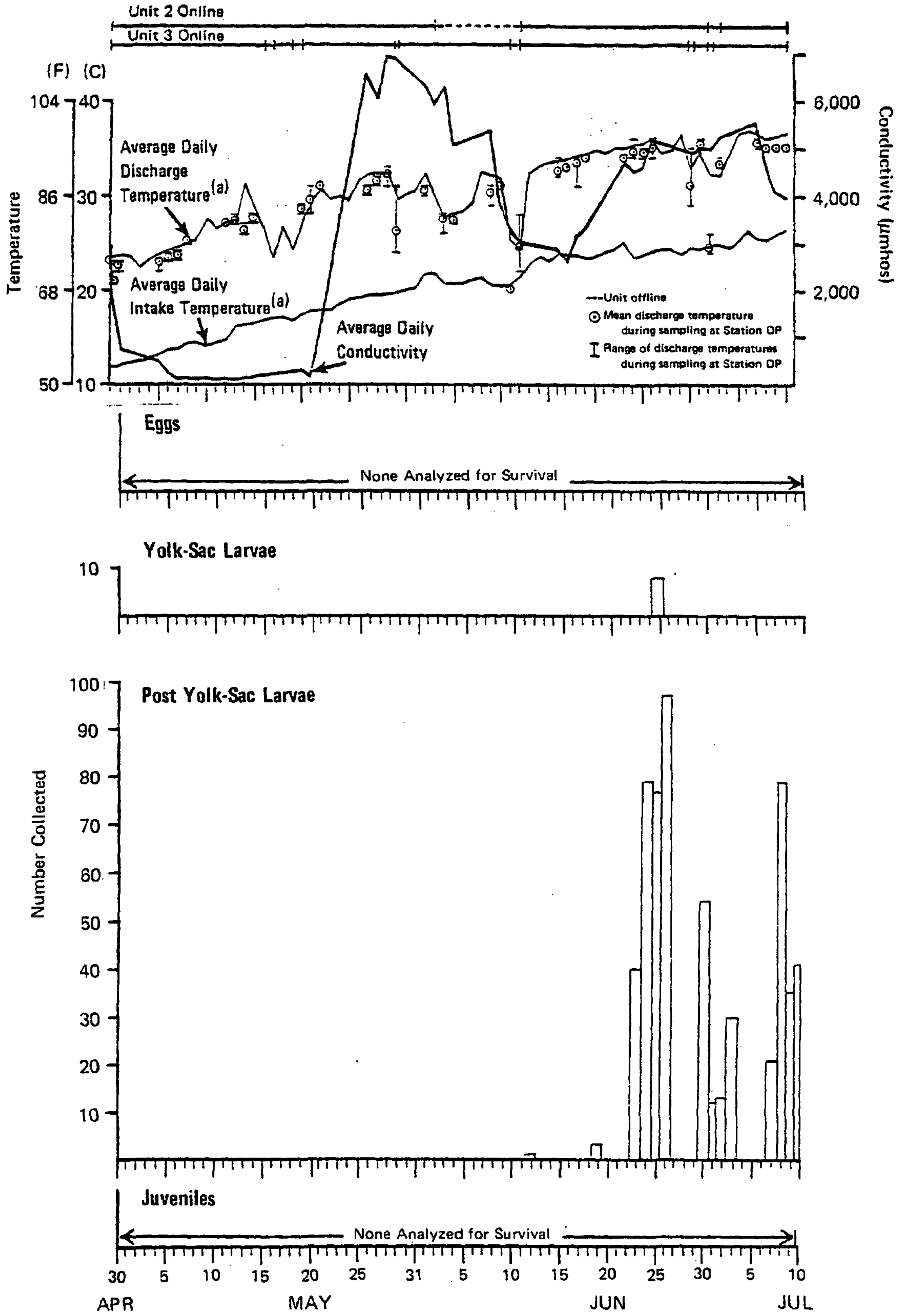
(a) Source for average daily intake and discharge temperatures was Con Edison 1980.

Figure 4-7. Temporal distribution and thermal exposure of striped bass collected at the discharge port station (DP) during the spring–summer entrainment survival study, Indian Point Generating Station, 30 April – 10 July 1980.



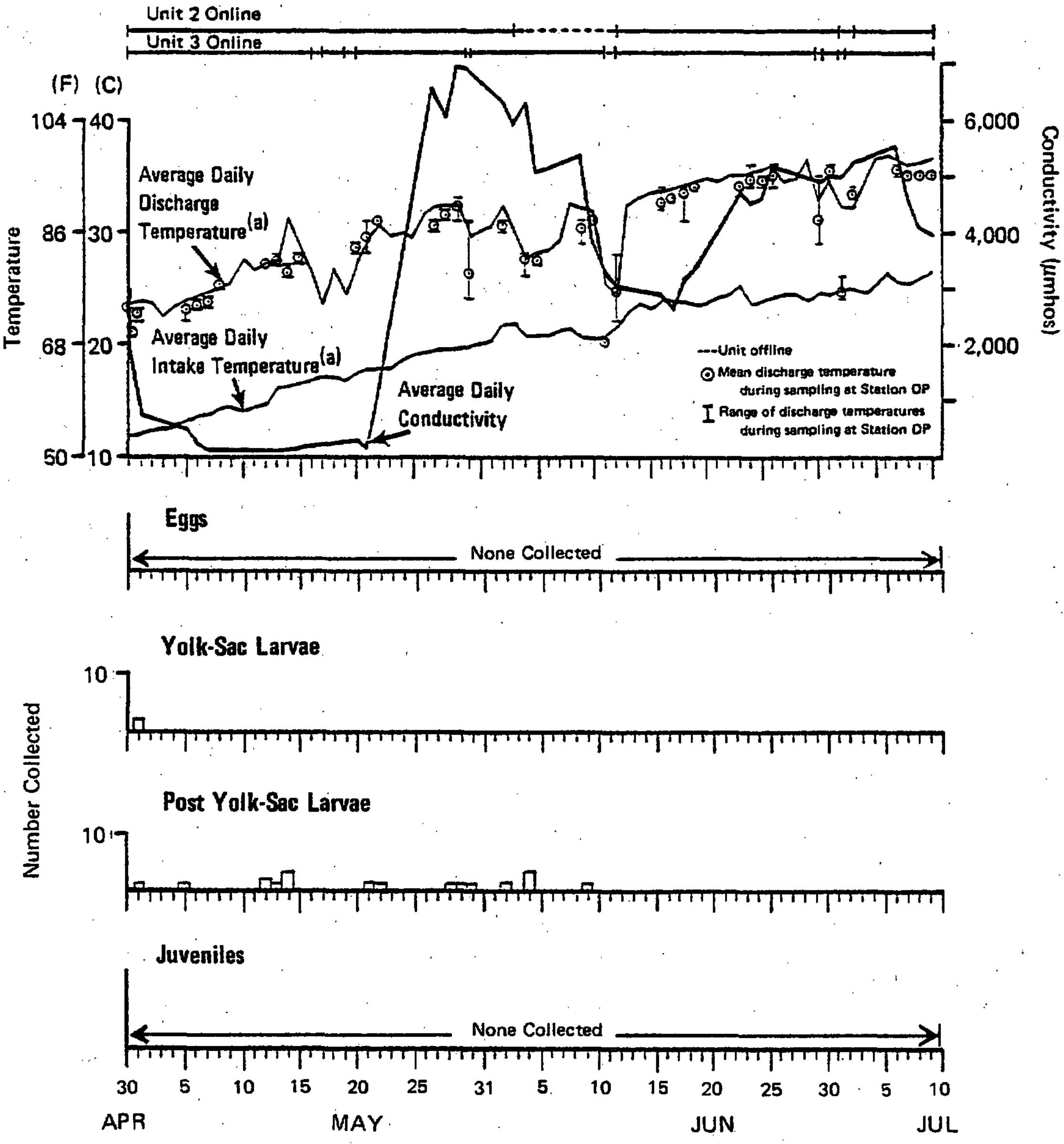
(a) Source for average daily intake and discharge temperatures was Con Edison 1980.

Figure 4-8. Temporal distribution and thermal exposure of white perch collected at the discharge port station (DP) during the spring–summer entrainment survival study, Indian Point Generating Station, 30 April – 10 July 1980.



(a) Source for average daily intake and discharge temperatures was Con Edison 1980.

Figure 4-9. Temporal distribution and thermal exposure of anchovies (Engraulidae) collected at the discharge port station (DP) during the spring-summer entrainment survival study, Indian Point Generating Station, 30 April – 10 July 1980.



(a) Source for average daily intake and discharge temperatures was Con Edison 1980.

Figure 4-10. Temporal distribution and thermal exposure of herrings (Clupeidae) collected at the discharge port station (DP) during the spring-summer entrainment survival study, Indian Point Generating Station, 30 April – 10 July 1980.

Average daily discharge temperatures at the Indian Point plant during the entrainment survival study ranged from 20 to 36 C (Figure 4-5). The majority of ichthyoplankton were collected at discharge temperatures ranging from 21 to 35 C. Based on laboratory thermal tolerance studies, thermal effects of entrainment were expected to be negligible for most ichthyoplankton collected at discharge temperatures less than 30 C (EA 1978b). The percentages of organisms collected at Station DP when discharge temperatures equaled or exceeded 30 C were 79 percent for striped bass larvae and 72 percent for white perch larvae. When temperatures at Station DP exceeded 32 C, the percentages of organisms collected were 66 percent for striped bass larvae, 67 percent for white perch larvae, and over 97 percent for anchovy larvae. Only one Atlantic tomcod was collected at Station DP at discharge temperatures above 30 C.

4.3.2 Survival Proportions

4.3.2.1 Survival of Striped Bass Eggs

The hatching proportion of striped bass eggs collected at the discharge (Station DP) was 0.469, while the control (Station I3) hatching success was 0.816 (Table 4-4). Intake temperatures associated with the collection of striped bass eggs ranged from 11.8 to 18.4 C and discharge temperatures varied from 23 to 31 C. These discharge temperatures were below those expected to cause significant thermal mortality as determined by thermal laboratory studies. The temperature of the 30-minute TL50 for striped bass eggs 11-49 hours old ranged from 31.5 to 35.2 C (EA 1978b).

Factors influencing the survival of striped bass eggs in 1980 were assessed by using a three-way contingency analysis (Sokal and Rohlf 1969). The three variables examined were survival (Su), station (St), and sampling week (W) (Table 4-5). Because over 96 percent of all eggs were collected during the weeks of 12 May and 19 May, only data from these two sampling weeks were considered for the analysis. This analysis demonstrated that there was a significant difference ($\alpha = 0.05$) in survival between the intake station and the discharge station (St x Su) which indicates that entrainment did have an effect on striped bass survival. The fraction of eggs collected at each station was also significantly different between the two weeks (St x W). Fewer eggs were collected at Station DP during the second week than during the first week (53 vs. 93, respectively) thereby giving the survival at the discharge station less weight during the second week. Pooled survival proportions indicated no significant difference in survival by week. However, nonsignificance may be due to sample sizes. The test for interaction among the variables (St x Su x W) was also significant, which indicated that entrainment survival estimates would differ for the two weeks. The significant interaction could be the result of increasing discharge temperatures even though the discharge temperatures were below those expected to cause thermal mortality. Discharge temperatures ranged from 26 to 28 C during the week of 12 May and from 28 to 31 C during the week of 19 May. However, when the survival at the control station (Station I3) is considered, it is evident that there was an almost identical drop in survival for striped bass eggs that had not experienced entrainment (Figure 4-11). This strongly suggests that the difference in egg survival over the two week period was caused by factors other than discharge temperatures. Variablity in

TABLE 4-4 SURVIVAL PROPORTIONS BASED ON HATCHING SUCCESS FOR STRIPED BASS EGGS COLLECTED DURING ENTRAINMENT SURVIVAL SAMPLING, INDIAN POINT GENERATING STATION, 1980

Station	Temperature Range (C)	Number Collected	Proportion Surviving(a)
I3	11.8-18.4(b)	272	0.816
DP	23-31(b)	147	0.469

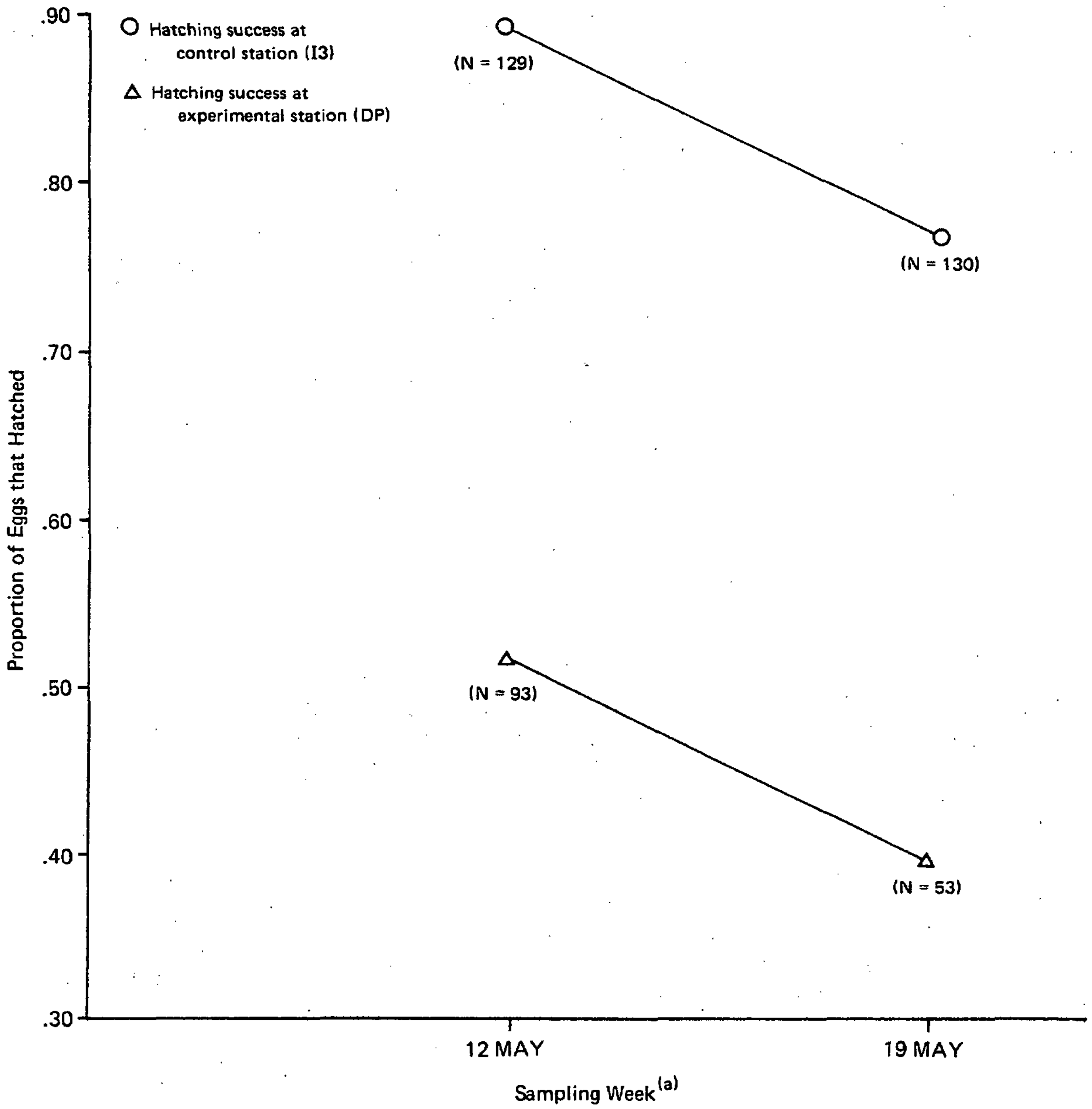
(a) Based on the proportion that hatched within 96 hours following collection.

(b) Entire range of temperatures at which striped bass eggs were collected.

TABLE 4-5 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG STATIONS (St), SURVIVAL (Su), AND SAMPLING WEEKS (W) FOR STRIPED BASS EGGS COLLECTED AT THE INTAKE AND DISCHARGE STATIONS DURING ENTRAINMENT SURVIVAL SAMPLING AT THE INDIAN POINT GENERATING STATION, 12-26 MAY 1980

Hypothesis Tested	Degree of Freedom	G(a)
St x Su indpendence	1	55.932(b)
St x W independence	1	7.342(b)
Su x W independence	1	2.546
St x W x Su interaction	1	6.414(b)
St x W x Su independence	4	72.234(b)

(a) Test statistic; critical value is equal to X^2 value with appropriate degrees of freedom and α level.
(b) Significant at $\alpha = 0.05$.



(a) Includes sampling weeks in which ten or more striped bass eggs were collected at either station.

Figure 4-11. Striped bass egg survival by sampling week at the Indian Point Generating Station, 1980.

striped bass egg survival may be the result of egg size, salinity, and the age of the egg (Albrecht 1964; Bayless 1972; Lal et al. 1977). Lauer et al. (1974) found that striped bass eggs 4-18 hours old were more sensitive to thermal stress than eggs that were approximately 48 hours old. Ecological Analysts, Inc. (1978b) also found that younger eggs had lower 30-minute TL50s than older eggs. A large number of striped bass eggs normally die 12 to 18 hours after spawning as a result of nonfertilization (Bayless 1972). Any, or all, of these factors could contribute to the weekly differences observed in hatching success.

4.3.2.2 Initial Survival at the Intake Station

The initial survival proportions for five major taxa and life stages at the Indian Point Unit 3 intake (Station I3) during 1980 far exceed values obtained at the intake stations during the previous years of 1977-1979 (Table 4-6). Survival proportions for sample sizes of ten or more ranged from 0.323 for anchovy post yolk-sac larvae to 1.000 for juvenile Atlantic tomcod.

The survival proportion for juvenile Atlantic tomcod in 1980 is the first value reported for this life stage at the Indian Point Generating Station. During past study years, late post yolk-sac larvae and juvenile Atlantic tomcod were generally collected infrequently during the entrainment sampling season and their entrainment survival was not estimated. Survival proportions calculated from previous data are 0.500 or lower (Table 4-6).

The uniformly high intake survival for all life stages of striped bass in 1980 illustrates substantial improvement in survival at the intake station(s) when compared to previous years. The proportion of eggs that hatched was nearly twice that obtained in 1979, the only other year in which successful hatching occurred after collection. Yolk-sac larvae and post yolk-sac larvae survival was very high, 0.953 and 0.951, respectively, which indicates that negligible sampling mortality occurred for these life stages.

White perch post yolk-sac larvae historically have survived collection at intake stations to a lesser extent than striped bass post yolk-sac larvae. This suggests that white perch larvae may be more susceptible to sampling effects than striped bass larvae. However, in 1980 intake survival of white perch post yolk-sac larvae, 0.929, was similar to that of striped bass post yolk-sac larvae.

The high initial survival of the few herring post yolk-sac larvae collected (0.889) suggests that collection stress was also low for this species. The highest previous intake survival proportion for herring post yolk-sac larvae was 0.290 in 1977. Such low survival made past entrainment survival estimates for herring questionable.

Anchovies were the only species collected at the intake station that demonstrated a relatively poor ability to survive sampling. Initial survival has improved over the past 3 years (Table 4-6), but this species appears more sensitive to stresses of sampling than the four other taxa examined.

TABLE 4-6 INITIAL SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON COLLECTED AT THE INTAKES OF THE INDIAN POINT GENERATING STATION, 1977-1980

Taxa	Life Stage[a]	1977[b] Proportion Surviving	1977[b] N	1978[b] Proportion Surviving	1978[b] N	1979[c] Proportion Surviving	1979[c] N	1980[d] Proportion Surviving	1980[d] N
Atlantic tomcod	Late PYSL and JUV	0.130	46	0.500	8	--	0	1.000	25
Striped bass	Eggs[e]	--	0	0.000	62	0.444	124	0.816	272
	YSL	0.719	32	0.302	63	0.515	66	0.953	85
	PYSL	0.610	806	0.447	423	0.500	64	0.951	142
White perch	PYSL	0.563	158	0.344	180	0.149	195	0.929	113
Herrings	YSL	--	0	--	0	0.000	5	0.000	1
	PYSL	0.290	100	0.152	809	0.232	259	0.889	9
	JUV	0.333	3	0.286	14	1.000	1	1.000	2
Anchovies	PYSL	0.109	1,254	0.020	500	0.101	457	0.323	260

(a) Only life stages collected during the 1980 study are included for comparison.
(b) Based on pooled data collected at intake Stations I2 and I3 using pump/larval table collection systems.
(c) Based on data collected at intake Station I3 using rear-draw plankton sampling flume with gravity drainage system.
(d) Based on data collected at intake Station I3 using rear-draw plankton sampling flume with pump drainage system and modifications to evenly distribute water flow across flume diversion screens.
(e) Hatching success data is presented for striped bass eggs.

Note: N = number collected; YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juveniles.

The high intake survival proportions obtained at the Indian Point Generating Station in 1980 indicate the success of continued modifications of gear and refinements in minimizing sampling stress on entrainable ichthyoplankton. Survival proportions for Atlantic tomcod, striped bass, white perch, and herring indicate that most ichthyoplankton of these species were alive when entering the sampling gear.

4.3.2.3 Initial Survival at the Discharge Station

Survival of juvenile Atlantic tomcod at the discharge station appears to be temperature related. Survival was uniformly high at discharge temperatures from 20 to 26 C, ranging from 0.846 to 1.000 (Table 4-7). However, at discharge temperatures of 27 and 28 C, initial survival was 0.500, and at 34 C the single specimen collected was dead. The consistently high survival proportions at discharge temperatures ≤26 C suggests that thermal stress does not affect entrainment survival at these temperatures. However, the reduced survival at temperatures above 26 C is supported by laboratory thermal studies which indicate that the ultimate upper incipient lethal temperature for juvenile Atlantic tomcod during summer ambient water temperature conditions was approximately 27 C (EA 1978b). The ultimate upper incipient lethal temperature is the temperature at which a rapid increase in mortality rate would begin to occur for a species that has fully extended its ability to acclimate to higher temperatures. This parameter is an estimate of the temperature below which no reduction in survival occurs, regardless of exposure time or acclimation temperature (Con Edison 1978).

Initial survival proportions for Atlantic tomcod juveniles at the discharge station are also the estimate of entrainment survival because the intake (control) survival was 100 percent (Table 4-7). The entrainment survival estimates for Atlantic tomcod juveniles were 87.7 percent at discharge temperatures ≤26 C and 48.0 percent at discharge temperatures ≥27 C.

The discharge survival proportions obtained in 1980 for Atlantic tomcod are quite similar to the initial survival of the few juveniles collected during 1979. For 1979, discharge survival proportions were 0.833 at temperatures ≤26 C and 0.500 at temperatures ≥27 C (Table 4-8). The sampling device used in 1979 was essentially the same as that used in 1980 and, because gear effects were not evident at the discharge station in 1979 (EA 1981), survival should be similar between the two years. Low survival of Atlantic tomcod late post yolk-sac larvae and juveniles during 1977 and 1978 was probably due to damage caused by the pump/larval table collection system. Ebey and Beauchamp (1977) indicated that the probability of a fish being killed by a propeller blade during pump passage is directly proportional to fish length. Although most species of ichthyoplankton collected during entrainment survival sampling are less than 20 mm long, Atlantic tomcod collected during late spring and early summer over the past 4 years ranged from 14 to 62 mm with the majority of specimens between 25 and 40 mm long. The likelihood of Atlantic tomcod incurring damage from pumps is greater than for most ichthyoplankton commonly collected at the Indian Point Generating Station during this time period.

TABLE 4-7 INITIAL DISCHARGE STATION SURVIVAL (DP Station) AND ENTRAINMENT SURVIVAL ESTIMATES FOR ATLANTIC TOMCOD JUVENILES, AS A FUNCTION OF DISCHARGE WATER TEMPERATURE, INDIAN POINT GENERATING STATION, 1980

Discharge Temperature (C)	N	Proportion Surviving	S_e(%)[a]
20	1	1.000	87.7
21			
22	3	1.000	
23	29	0.862	
24	26	0.846	
25	72	0.861	
26	31	0.935	

Thermal Effects Expected[b]

27	22	0.500	48.0
28	2	0.500	
29			
30			
31			
32			
33			
34	1	0.000	

(a) Because the initial survival proportion at the intake station was 1.000, S_e(%) = proportion surviving at the discharge x 100.

(b) Mortalities due to thermal stress are expected at water temperatures greater than 26 C for Atlantic tomcod juveniles, according to laboratory thermal tolerance data (EA 1978b).

N = number collected.

TABLE 4-8 INITIAL SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON AS A FUNCTION OF DISCHARGE WATER TEMPERATURE, INDIAN POINT GENERATING STATION, 1977-1980

Taxa	Life Stage[a]	Temperature Range (C)	1977[b] Proportion Surviving	1977[b] N	1978[c] Proportion Surviving	1978[c] N	1979[d] Proportion Surviving	1979[d] N	1980[e] Proportion Surviving	1980[e] N
Atlantic tomcod	Late PYSL and JUV	≤26	--	0	0.083	12	0.833	6	0.877	162
		≥27	0.000	16	0.000	1	0.500	4	0.480	25
Striped bass	Egg[f]	All	--	0	0.000	113	0.327	55	0.469	147
	YSL	≤29	0.400	30	0.158	19	0.586	29	0.667	21
		30-32	0.333	6	0.030	67	0.750	12	0.562	16
		≥33	--	0	0.000	11	--	0	0.500	4
	PYSL	≤29	0.491	428	0.091	22	0.630	27	0.742	31
		30-32	0.440	75	0.282	503	0.701	87	0.812	16
		≥33	0.467	15	0.038	26	--	0	0.550	160
	JUV	≤29	1.000	1	--	0	--	0	1.000	2
		30-32	1.000	2	0.625	8	--	0	--	0
		≥33	0.000	3	0.500	2	--	0	0.429	7

(a) Only life stages collected during the 1980 study are included for comparison.

(b) Based on pooled data collected at discharge Stations D3 and DP using pump/larval table collection systems.

(c) Based on pooled data collected at discharge Stations D1, D3, and DP using pump/larval table collection systems.

(d) Based on data collected at discharge Station DP (discharge port outfall) using pumpless plankton sampling flume with gravity drainage system.

(e) Based on data collected at discharge Station DP (discharge port outfall) using pumpless plankton sampling flume with pump drainage system and modifications to evenly distribute water flow across the flume diversion screens.

(f) Hatching success data are presented for striped bass eggs.

Note: N = number collected; YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juveniles.

TABLE 4-8 (CONT.)

Taxa	Life(a) Stage	Temperature Range (C)	1977(b) Proportion Surviving	N	1978(c) Proportion Surviving	N	1979(d) Proportion Surviving	N	1980(e) Proportion Surviving	N
White perch	YSL	≤29	--	0	0.000	1	0.000	1	--	0
		30-32	0.000	2	0.000	1	0.000	9	--	0
		≥33	--	0	0.000	1	--	0	0.000	1
	PYSL	≤29	0.359	39	0.000	22	0.320	50	0.898	49
		30-32	0.318	22	0.245	163	0.289	97	0.556	9
		≥33	0.333	6	0.000	11	--	0	0.496	117
	JUV	≤29	--	0	--	0	1.000	2	1.000	1
		30-32	1.000	2	1.000	3	--	0	--	0
		≥33	1.000	3	--	0	--	0	1.000	2
Herrings	YSL	≤29	--	0	--	0	--	0	0.000	1
		30-32	--	0	--	0	--	0	--	0
		≥33	--	0	--	0	--	0	--	0
	PYSL	≤29	0.149	47	0.035	142	0.305	151	0.615	13
		30-32	0.000	13	0.023	398	0.222	36	0.500	4
		≥33	0.000	5	0.018	57	--	0	--	0
Anchovies	YSL	≤29	--	0	--	0	--	0	--	0
		30-32	--	0	--	0	--	0	--	0
		≥33	0.000	3	0.000	2	--	0	0.000	8
	PYSL	≤29	--	0	0.000	4	0.070	172	0.040	24
		30-32	0.039	233	0.000	25	0.028	107	--	0
		≥33	0.028	471	0.000	382	0.063	206	0.016	556

When high salinity conditions bring entrainable-sized tomcod juveniles into the vicinity of the Indian Point plant, the majority are likely to be entrained at discharge temperatures ≤26 C (Table 4-8), and entrainment survival should approach 90 percent. Growth of juvenile tomcod throughout the spring reduces their susceptibility to entrainment during high discharge temperature conditions (≥27 C).

Initial survival proportions for striped bass larvae collected at Station DP in 1980 were, with one exception, the highest values yet achieved (Table 4-8). Survival of yolk-sac larvae ranged from 0.667 at temperatures ≤29 C to 0.500 at temperatures ≥33 C. Post yolk-sac larval survival was highest at 30 to 32 C (0.812) and lowest at ≥33 C (0.550). The survival proportions for larvae collected at high temperatures are particularly important since they were based on far greater sample sizes (164 larvae) than in any previous year (EA 1978a, 1979a, and 1981).

The increase in survival proportions in 1980 was even more striking for white perch than for striped bass. Survival proportions for post yolk-sac larvae ranged from 0.898 at ≤29 C to 0.496 at temperatures ≥33 C (Table 4-8). At the high temperature range, survival was above all previous survival values at any temperature category. The substantial improvement in survival demonstrates the value of minimizing sampling stress in entrainment survival programs.

Initial survival proportions of herring post yolk-sac larvae increased in 1980 from estimates obtained in previous years for the same temperature categories (Table 4-8). As indicated in Section 4.3.1, the number of herrings collected in 1980 was considerably less than in earlier studies and this low sample size may reduce precision of the survival proportions. However, improved survival of other taxa in 1980 suggests that the improvement in survival proportions for herrings is probably real.

Anchovies were the only taxa collected in 1980 that did not show a dramatic improvement in the initial proportion surviving at Station DP (Table 4-8). At discharge temperatures ≤29 C the proportion of post yolk-sac larvae surviving in 1980 was 0.040 compared to 0.070 in 1979. Most anchovies were collected at temperatures ≥33 C. At those higher discharge temperatures, the initial survival proportion of post yolk-sac larvae at the discharge station was 0.016. In 1977 and 1979, when slightly higher survival proportions were obtained, most of the larvae were collected at temperatures of 33 and 34 C. In 1980 only 17 percent of the anchovy post yolk-sac larvae were collected at these relatively lower temperatures (Table 4-9). Most of the anchovies collected in the temperature range ≥33 C were collected at temperatures ≥35 C, and therefore experienced greater thermal stress than those collected previously.

4.3.3 Extended Survival Proportions

Normalized extended survival proportions were compared for organisms collected at the intake (Station I3) and discharge (Station DP) to determine whether latent effects caused by entrainment were present. To increase the sample size for initial statistical testing, data were pooled across

TABLE 4-9 INITIAL SURVIVAL FOR ANCHOVY POST YOLK-SAC LARVAE COLLECTED AT DISCHARGE TEMPERATURES ≥33 C AT THE INDIAN POINT GENERATING STATION, 1977-1980

Discharge Temperature (C)	1977(a)		1978(b)		1979(c)		1980(d)	
	Proportion Surviving	N(e)	Proportion Surviving	N(e)	Proportion Surviving	N(e)	Proportion Surviving	N(e)
33	0.036	165 (35.0%)	0.000	25 (6.5%)	0.214	14 (6.8%)	0.000	28 (5.0%)
34	0.022	275 (58.4%)	0.000	37 (9.7%)	0.041	98 (47.6%)	0.045	66 (11.9%)
35	0.000	31 (6.6%)	0.000	279 (73.0%)	0.119	42 (20.4%)	0.014	362 (65.1%)
36	--	0 (0.0%)	0.000	41 (10.7%)	0.000	52 (25.2%)	0.010	100 (18.0%)
Total	0.028	471	0.000	382	0.063	206	0.016	556

(a) Based on pooled data collected at discharge Stations D3 and DP using pump/larval table collection systems.
(b) Based on pooled data collected at discharge Stations D1 and DP using pump/larval table collection systems.
(c) Based on data collected at discharge Station DP (discharge port outfall) using pumpless plankton sampling flume with gravity drainage system.
(d) Based on data collected at discharge Station DP (discharge port outfall) using pumpless plankton sampling flume with pump drainage system and modifications to evenly distribute water flow across the flume diversion screens.
(e) Numbers in parentheses represent the percentage of the total number of post yolk-sac larvae collected at discharge temperatures ≥33 C that were collected at each of the designated temperatures.

Note: N = number collected.

all collection temperatures for each station. Gehan's nonparametric test (Gross and Clark 1975) was used to examine the null hypothesis that the survival distributions are the same at both stations.

Extended survival through the 96-hour observation period was higher than in previous years. Normalized survival proportions at 96 hours for striped bass were about 60 percent for yolk-sac larvae and greater than 70 percent for post yolk-sac larvae (Table 4-10). Survival proportions for white perch post yolk-sac larvae were similar to those for striped bass. Survival of Atlantic tomcod juveniles was also high, 80 percent at Station I3 and 56 percent at Station DP. Herrings and anchovies also exhibited high extended survival compared to previous years, although values for these taxa were lower than for the striped bass, white perch, and tomcod. Herring 96-hour survival was 0.375 at Station I3 and 0.600 at Station DP. However, these proportions were based on very small samples. For anchovies, post yolk-sac larvae survival was 0.048 at Station I3 and 0.0 at Station DP.

Only Atlantic tomcod exhibited significantly different ($\alpha = 0.05$) survival patterns between intake and discharge stations (Table 4-10). When juvenile tomcod collected at Station DP were separated into two groups based on collection temperature, both groups exhibited poorer survival than fish collected at Station I3 (Figure 4-12). Juveniles collected at ≤26 C sustained 28 percent mortality through 24 hours. Survival after 24 hours was relatively stable. At temperatures ≥27 C survival declined rapidly to 58 percent after 12 hours and by the end of the 96-hour observation period survival was only 20 perent. However, survival proportions for this group were based on only 12 fish initially alive.

The similarity of survival distributions between organisms collected at intake and discharge stations for most taxa indicates that latent effects of entrainment are minimal and that entrainment survival can be estimated adequately from initial survival proportions. The only exception appears to be Atlantic tomcod juveniles; extended survival was significantly lower at the discharge station than for control (Station I3) fish. This could be due to the larger size of juvenile tomcod (from 14 to 60 mm) compared to larvae of other taxa (5 to 15 mm), which may subject them to more physical damage during passage through the power plant. These physical stresses may not be severe enough to cause immediate death, but may instead cause mortality within 24 to 48 hours.

4.3.4 Entrainment Survival Estimates

4.3.4.1 Atlantic Tomcod Juveniles

Entrainment survival estimates for Atlantic tomcod juveniles, based on initial survival proportions, require no adjustment for sampling mortality since all tomcod captured at Station I3 were initially alive. Entrainment survival thus was 87.7 percent at discharge temperatures ≤26 C and 48.0 percent at temperatures ≥27 C (Table 4-11). However, as demonstrated in Section 4.3.3, significant differences in extended survival existed between fish captured at intake and discharge stations. Therefore, survival proportions at some other time interval may be preferrable for calculating entrainment survival rates. If survival

TABLE 4-10 NORMALIZED EXTENDED SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON COLLECTED DURING ENTRAINMENT SURVIVAL SAMPLING, INDIAN POINT GENERATING STATION, 1980

				Survival Proportions Time After Collection (Hours)							
Taxa	Life Stage	Station	Initial No. Alive	3	6	12	24	48	72	96	Z(a)
Striped bass	YSL	I3	81	1.000	0.963	0.926	0.815	0.728	0.679	0.580	-0.42
		DP	25	0.960	0.880	0.800	0.720	0.680	0.600	0.600	
	PYSL	I3	135	0.978	0.941	0.941	0.911	0.911	0.837	0.748	-0.62
		DP	124	0.944	0.911	0.879	0.879	0.863	0.839	0.718	
White perch	PYSL	I3	105	0.981	0.943	0.914	0.886	0.857	0.771	0.619	1.37
		DP	107	0.953	0.944	0.888	0.879	0.869	0.804	0.729	
Herrings	PYSL	I3	8	0.625	0.625	0.625	0.500	0.500	0.375	0.375	1.10
		DP	10	1.000	1.000	0.700	0.600	0.600	0.600	0.600	
Anchovies	PYSL	I3	84	0.417	0.202	0.095	0.071	0.060	0.060	0.048	-1.70
		DP	10	0.100	0.100	0.100	0.100	0.100	0.000	--	
Atlantic tomcod	Late PYSL(b) and JUV	I3	25	1.000	1.000	0.960	0.960	0.960	0.920	0.800	-2.66(c)
		DP	154	0.968	0.896	0.812	0.714	0.662	0.604	0.558	

(a) Test statistic for differences in survival distributions based on Gehan's nonparametric test (Gross and Clark 1975).

(b) Two late post yolk-sac Atlantic tomcod larvae were included in the normalized extended survival at Station I3.

(c) Indicates significance at $\alpha=0.05$ under the null hypothesis that the survival distributions are similar. Critical value of Z is $|Z| \geq 1.96$.

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juveniles.

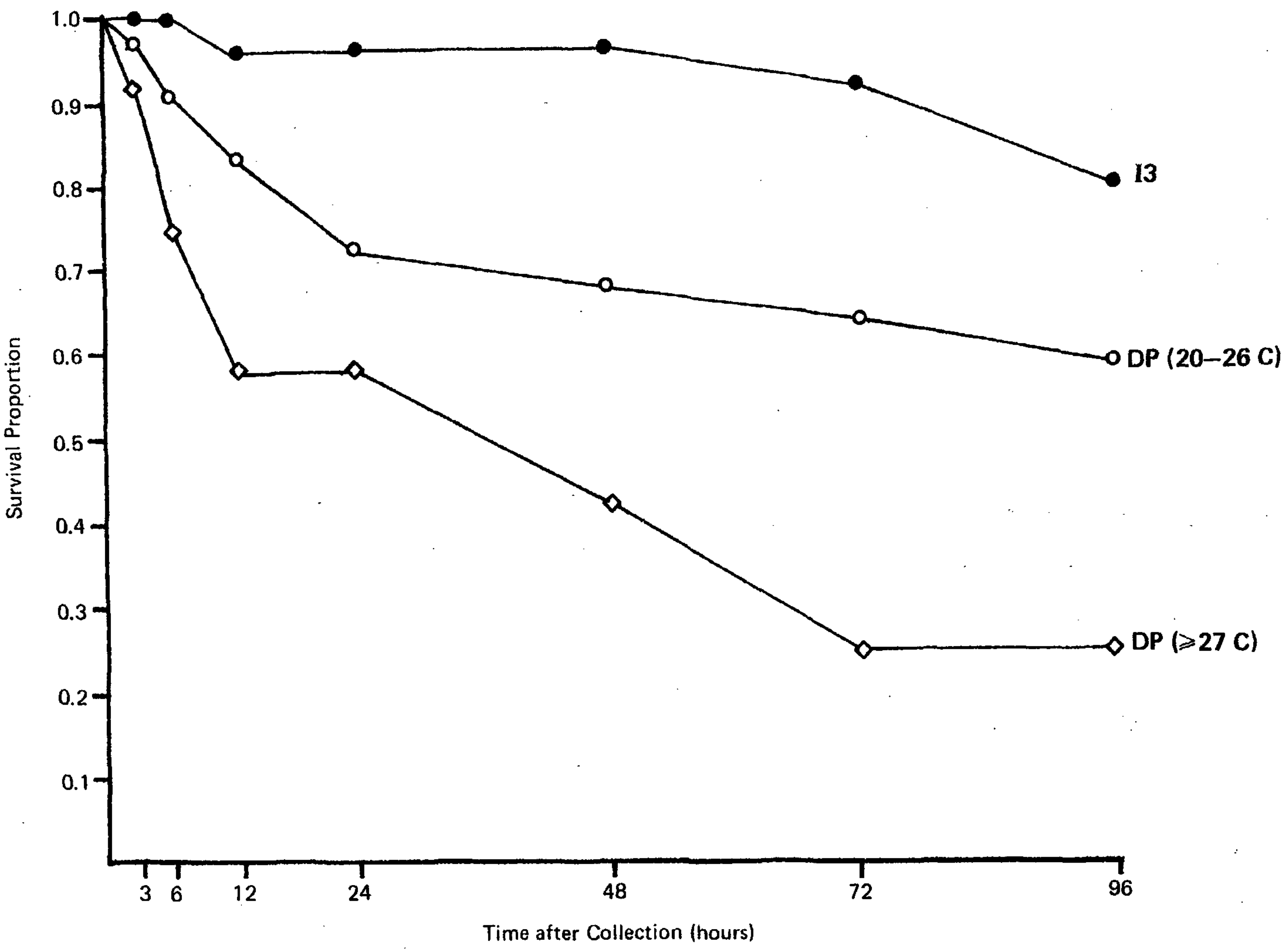


Figure 4-12. Extended survival of Atlantic tomcod juveniles collected at Station I3 and at Station DP at discharge temperatures ≤26 C and ≥27 C, Indian Point Generating Station, 1980.

TABLE 4-11 ENTRAINMENT SURVIVAL ESTIMATES (S_e) FOR DOMINANT ICHTHYOPLANKTON COLLECTED AT THE INDIAN POINT GENERATING STATION, 1980

Taxa[(a)]	Life Stage	Discharge Temperature Range (C)	N_d[(b)]	S_e(%)[(c)]	X^2[(d)]	P
Atlantic tomcod	Late PYSL and JUV	≤ 26	162	87.7 (66.2)[(e)]	3.456	>0.050[(f)]
		≥ 27	25	48.0 (29.2)[(e)]	17.568	<0.001
Striped bass	Eggs	24-31[(g)]	147	57.5	54.076	<0.001
	YSL	≤ 29	21	70.0	14.839	<0.001
		30-32	16	59.0	21.151	<0.001
	PYSL	≤ 29	31	78.0	14.005	<0.001
		30-32	16	85.4	4.633	<0.050
		≥ 33	160	57.8	62.536	<0.001
White perch	PYSL	≤ 29	49	96.7	0.452	>0.050[(f)]
		≥ 33	117	53.4	52.319	<0.001
Herrings	PYSL	≤ 29	13	69.2[(g)]	2.006	>0.050[(f)]
Anchovies	PYSL	≤ 29	24	12.4	8.297	<0.005
		≥ 33	556	5.0	165.227	<0.001

(a) Includes all taxa and life stages for which sample sizes were ≥ 10 for at least one discharge temperature category.

(b) Number collected at the discharge station (Station DP) at the indicated temperature range.

(c) S_e's were calculated for temperature categories for which sample sizes were ≥ 10, at the intake (over all temperatures) and discharge stations, except where indicated.

(d) The null hypothesis (H_0) tested by X^2 is that discharge survival is equal to survival of organisms at the intake ($\alpha = 0.05$).

(e) Numbers in parentheses represent S_e(%) based on proportions surviving 24 hours from collection. This alternative S_e (%) is presented because of a significant difference between intake and discharge extended-survival proportions for Atlantic tomcod.

(f) Indicates acceptance of H_0, which is that the survival of organisms collected at the discharge was not significantly lower than that of those collected at the intake ($\alpha = 0.05$). The critical X^2 value is 3.84.

(g) Only nine herring post yolk-sac larvae were collected at the intake station, but because of the importance of this taxa, the S_e is presented.

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juveniles.

proportions through 24 hours after collection are used as the basis for S_e estimates, entrainment survival for Atlantic tomcod would be 66.2 percent at temperatures $\leq$26 C and 29.2 percent at $\geq$27 C.

4.3.4.2 Striped Bass

Entrainment survival for striped bass eggs collected during the 1980 study was 57.5 percent (Table 4-11). The gear effects ratio for artificially spawned striped bass eggs was 0.959 from collection system calibration data (Section 5) indicating that the intake sampling gear appears to be slightly more stressful than the discharge gear for eggs. The small deviation from unity indicates that bias due to differences in sampling stress was minimal and no adjustment to the entrainment survival estimate was made.

Intake (control) survival of striped bass larvae was uniformly high in 1980 (Table 4-6), so the S_e estimates closely reflect discharge survival (Table 4-8). Entrainment survival for yolk-sac larvae was lower than for post yolk-sac larvae for two temperature categories in which comparisons were possible (Table 4-11) confirming results obtained by Lauer et al. (1974) which indicated that younger striped bass larvae were more susceptible than older larvae to stresses encountered during entrainment. The majority of striped bass post yolk-sac larvae were collected at discharge temperatures $\geq$33 C. Since the mean TL50 (based on 30-minute exposures) for striped bass larvae was 33 C (EA 1978b) the survival of larvae collected in this temperature range, 57.8 percent, is at least as high as that which would be expected if larvae had been exposed only to thermal stress. This fact, along with the high S_e estimates for the lower temperature ranges, suggests that entrainment mortality of post yolk-sac larvae is caused primarily by thermal stress and that synergistic effects between mechanical and thermal stress, if they occur at all, are small.

4.3.4.3 White Perch

Discharge temperatures had an even greater effect on entrainment survival for white perch post yolk-sac larvae than for striped bass. At discharge temperatures for which no thermal effects would be expected, $\leq$29 C (EA 1978b), the S_e estimate was 96.7 percent (Table 4-11). In fact, the reduction in survival at the discharge station was not statistically significant at $\alpha = 0.05$. However, entrainment survival for white perch post yolk-sac larvae collected at discharge temperatures $\geq$33 C was 53.4 percent, similar to the value obtained for the congeneric striped bass at the same temperatures. The extreme difference in S_e estimates between the two discharge temperature ranges again suggests that mechanical stress during entrainment has only a small effect on white perch and striped bass larvae.

4.3.4.4 Herrings

Entrainment survival for herring post yolk-sac larvae was high (69.2 percent) at temperatures $\leq$29 C. However, herrings appear slightly more susceptible to mechanical stress than the white perch and striped bass because thermal stress should not occur at temperatures $\leq$29 C. The survival of herring at the discharge station was not significantly lower

(α = 0.05) than that at the intake station (Table 4-11), although small sample size may have prevented the detection of an actual difference in survival.

4.3.4.5 Anchovies

Anchovies survive the entrainment experience less frequently than any of the other major taxa studied. The relatively low S_e estimates for this species, regardless of temperature, suggest that thermal effects were not the major contributor to their low entrainment survival. Anchovies are highly vulnerable to mechanical stress, as indicated by the low survival at Station I3 (Table 4-6). This extreme sensitivity to physical stress makes it difficult to precisely estimate entrainment survival for this species, although it must certainly be low when compared to the other taxa.

4.3.4.6 Comparison of 1980 Entrainment Survival Data With 1977, 1978, and 1979 Results

Plant operational mode was atypical during the 1980 entrainment survival sampling season. In contrast to previous years, maximum, or nearly maximum, cooling water flow was not maintained for the Indian Point Generating Station during May, June, and July of 1980 when striped bass, white perch, herrings, and anchovies were entrained. At least two circulating pumps, one pump each for Units 2 and 3, were not operating during most of the 1980 entrainment sampling season (Table 4-1). In addition, the discharge flow was not supplemented by the Unit 1 circulating water pumps as it was in the past. The reduced cooling flow increased magnitude of delta-Ts which allowed discharge temperatures to rise above 33 C during the period of peak occurrence for larvae of important species (Figure 4-5). Discharge temperatures recorded during the entrainment season in 1980 were generally higher than during all previous study years (1977-1979).

Discharge temperatures at the Indian Point plant do not normally exceed 33 C during periods of high ichthyoplankton abundance, with the exception of anchovy larvae. This is confirmed by the maximum discharge temperature profile for the Indian Point plant (Figure 4-5), determined by adding the calculated maximum delta-T to the seasonal plot of maximum ambient temperatures (Con Edison 1978). The maximum discharge temperature profile indicates that temperatures above 33 C should occur only in mid-summer (mid-July to mid-August) after the primary period of abundance of entrainable fish life stages. Ichthyoplankton of striped bass, white perch, and most other species would usually be exposed to discharge temperatures below 33 C during early summer if maximum cooling water flow is maintained.

The uniqueness of the 1980 data is highlighted by the fact that the majority of striped bass and white perch post yolk-sac larvae (77 and 67 percent, respectively) were collected at discharge temperatures of $\geq$33 C. In previous years the percentage of post yolk-sac larvae collected at temperatures $\geq$33 C has ranged from 0 to 5 percent for striped bass and from 0 to 9 percent for white perch (Table 4-12). Atlantic tomcod late post yolk-sac larvae and juveniles, striped bass eggs and yolk-sac

TABLE 4-12 TOTAL NUMBER OF IMPORTANT ICHTHYOPLANKTON SPECIES COLLECTED AT DISCHARGE STATIONS OF THE INDIAN POINT GENERATING STATION DURING SPRING-SUMMER ENTRAINMENT SURVIVAL SAMPLING, 1977-1980

			Discharge Temp. Category				
			<33 C		>33 C		
Taxa	Life(a) Stage	Year	N	%	N	%	Total
Atlantic tomcod	Late PYSL and JUV	1977	15	93.8	1	6.2	16
		1978	13	100.0	0	0.0	13
		1979	10	100.0	0	0.0	10
		1980	186	99.5	1	0.5	187
Striped bass	EGG	1977	0	--	0	--	0
		1978	113	100.0	0	0.0	113
		1979	55	100.0	0	0.0	55
		1980	147	100.0	0	0.0	147
	YSL	1977	36	100.0	0	0.0	36
		1978	86	88.7	11	11.3	97
		1979	41	100.0	0	0.0	41
		1980	37	90.2	4	9.8	41
	PYSL	1977	503	97.1	15	2.9	518
		1978	525	95.3	26	4.7	551
		1979	114	100.0	0	0.0	114
		1980	47	22.7	160	77.3	207
White perch	PYSL	1977	61	91.0	6	9.0	67
		1978	185	94.0	11	5.6	196
		1979	147	100.0	0	0.0	147
		1980	58	33.1	117	66.9	175
Herrings	PYSL	1977	60	92.3	5	7.7	65
		1978	540	90.5	57	9.5	597
		1979	187	100.0	0	0.0	187
		1980	17	100.0	0	0.0	17
Anchovies	PYSL	1977	233	33.1	471	66.9	704
		1978	29	7.1	382	92.9	411
		1979	279	57.5	206	42.5	485
		1980	24	4.1	556	95.9	580

(a) Includes all life stages for which S_e's were calculated in 1980.

Note: N = number collected.
Survival sampling during each year was conducted over the following sampling periods:
1977: 1 June to 18 July
1978: 1 May to 12 July
1979: 30 April to 14 August
1980: 30 April to 10 July

larvae, and herring larvae occur predominantly before discharge temperatures exceed 33 C, even during an atypical year such as 1980. Anchovy larvae are the only major taxa frequently collected at discharge temperatures ≥33 C and a greater percentage, 96 percent, were collected at this high temperature range in 1980 than in any previous year.

The occurrence of discharge temperatures ≥33 C during primary abundance periods for entrainable life stages of spring and summer spawning species has important consequences for entrainment survival. Based on laboratory thermal effects studies for larval Hudson River fishes, temperatures ≥33 are within the critical range at which thermally induced mortality would be expected (EA 1978b). Mean TL50s (temperature lethal to 50 percent of the test organisms) determined for important taxa were 32.4-33.3 C for alewife, 33.5 C for blueback herring, 33.1 C for American shad, 33.4 C for bay anchovy, and 33.0 C for striped bass. Upper incipient lethal temperatures, the temperatures at which increased mortality occurs regardless of acclimation temperature, were 33.5 C for striped bass post yolk-sac larvae and 33.8 C for early juvenile white perch. Thus, for most species of interest in the Hudson River, temperatures typically found during their period of abundance in entrainment samples should not represent extreme thermal hazards. However, if temperatures are allowed to exceed 33 C, substantial mortality due to thermal stress would be expected.

To aid in comparing 1980 results to previous years, discharge temperature categories were combined to produce S_e estimates representative of typical conditions (≤32 C) and atypical conditions (≥33 C). The 1980 entrainment survival values for temperatures ≤32 C exceeded previous estimates obtained for all species commonly found in the vicinity of the Indian Point Generating Station, except for striped bass eggs and anchovy post yolk-sac larvae (Table 4-13). Survival for striped bass eggs at the intake and discharge stations was higher in 1980 than in 1979, but the relative improvement in survival at the intake station was greater than at the discharge, resulting in the lower S_e estimate. Survival of striped bass eggs is variable and may be related to such factors as the age (EA 1978a) and size of the egg (Albrecht 1964). The lower S_e for anchovy post yolk-sac larvae in 1980 compared to 1977 appears to be due to the lower survival at the intake in 1977, when compared to 1980 (Table 4-6), rather than a difference in survival at the discharge station (Table 4-8).

Entrainment survival estimates in 1980 at discharge temperatures ≥33 C exceeded the only previous value for white perch post yolk-sac larvae, but were below values obtained previously for striped bass and anchovy post yolk-sac larvae. The higher value for striped bass post yolk-sac larvae in 1977, however, was based on a much smaller sample, 15 versus 160, than in 1980. The majority of anchovies collected during 1977 and 1979 were collected at discharge temperatures of 33-34 C, while the majority of anchovies were collected at discharge temperatures of 35-36 C in 1980 (Table 4-9). The 1980 S_e estimates represent the most reliable values obtained to date for the high temperature range. The high intake

TABLE 4-13 ENTRAINMENT SURVIVAL ESTIMATES (S_e) FOR ICHTHYOPLANKTON OCCURRING AT AND ABOVE TYPICAL SUMMER DISCHARGE EXPOSURE CONDITIONS, INDIAN POINT GENERATING STATION, 1977-1980

		Survival (S_e%) at Typical[a] May-July Discharge Temp. Conditions (<32 C)				Survival (S_e%) at High[a] Discharge Temp. Conditions (>33 C)			
Taxa[b]	Life Stage	1977[c]	1978[d]	1979[e]	1980[f]	1977[c]	1978[d]	1979[e]	1980[f]
Atlantic tomcod	Late PYSL and JUV	0.0	--	70.0	82.8	--	--	--	--
Striped bass	Egg	--	0.0	73.6	57.5	--	--	--	--
	YSL	54.1	19.2	63.4	65.3	--	0.0	--	--
	PYSL	79.2	61.3	68.4	80.5	76.6	8.5	--	57.8
White perch	PYSL	61.	62.8	29.9	91.0	--	0.0	--	53.4
Herrings	PYSL	40.3	17.1	28.9	66.1[g]	--	11.8	--	--
Anchovies	PYSL	35.8	0.0	5.4	12.4	25.7	0.0	6.3	5.0

(a) S_e's were calculated for temperature categories for which sample sizes were ≥ 10, except where indicated.

(b) Includes all taxa and life stages for which S_e's were calculated in 1980.

(c) Entrainment survival estimates (S_e) based on pooled data collected at Stations I2, I3, D3, and DP using pump/larval table collection systems.

(d) Entrainment survival estimates (S_e) based on pooled data collected at Stations I2, I3, D1, D3, and DP using pump/larval table collection systems.

(e) Due to the higher gear effect determined for the rear-draw (intake) plankton sampling flume than for the pumpless (discharge) plankton sampling flume in 1979, the survival percentages for larvae collected during this year are based on the initial survival proportions at Station DP (discharge port outfall) multiplied by 100. That is, these survival values are unadjusted for intake (control mortality).

(f) Entrainment survival estimates (S_e) based on samples collected at Station I3 using the rear-draw plankton sampling flume, and at Station DP (discharge port outfall) using the pumpless plankton sampling flume. In contrast to 1979, both flume samplers were equipped with pump, as opposed to gravity drainage systems, as well as modifications to evenly distribute water flow across the flume diversion screens.

(g) Only nine herring post yolk-sac larvae were collected at the intake station in 1980, but because of the importance of this taxa, the S_e is presented.

Note: YSL = yolk-sac larvae; PYSL = post yolk-sac larvae, JUV = juveniles.
Dash (--) indicates insufficient sample size for S_e calculations.

station survival, which reduces the likelihood of any bias in the S_e estimate (see Section 4.4), and the large sample sizes, particularly for striped bass and white perch post yolk-sac larvae, allow a great deal of confidence in these estimates.

4.3.5 Entrainment Survival as a Function of Size

As larval fish grow, their natural mortality rate generally declines (Farris 1960, Dahlberg 1979). This decline occurs partly because larger larvae are available as prey for fewer predators. Large larvae can also ingest larger zooplankton as food, deriving more energy per plankter and increasing possible food items. Avoidance capabilities increase with size, further reducing vulnerability to predation. Physiological changes also occur which increase their ability to withstand extremes of temperature, salinity, dissolved oxygen, or physical stress (Lauer et al. 1974).

The change in population size with changing length has been modeled mathematically by Hackney and Webb (1978):

$$\frac{dN}{dL} = -\frac{ZN}{GL}$$

where

dN = change in population size
dL = change in length
Z = instantaneous mortality rate
G = instantaneous growth rate
N = population size
L = length

The rate of change of the population size, dN/N, with changing length is an inverse function of length:

$$\frac{dN/N}{dL} = -\frac{Z}{GL}$$

This model and similar length-related models of mortality have been used to describe early life stage population dynamics for crappie, *Pomoxis* sp. (Hackney and Webb 1978); Pacific sardine, *Sardinops caerulea* (Farris 1960); Atlantic mackerel, *Scomber scombrus* (Sette 1943); winter flounder, *Pseudopleuronectes americanus* (Pearcy 1962); and striped bass, *Morone saxatilis* (TI 1980).

The relationship between size and mortality rate indicates that as a fish grows the probability that it will live to reproduce increases rapidly. Loss of small larvae at power plants therefore results in a smaller reduction in the population than losing the same number of larger larvae or juveniles. However, S_e estimates (Section 4.3.4) are calculated under the assumption that each life stage consists of a homogeneous population in which all organisms have the same fixed probability of surviving to the next life stage. Violation of this assumption can lead to overestimates or underestimates of entrainment survival, depending on the size distribution of the entrained larvae.

The errors caused by violating the assumption of a homogeneous population can be eliminated by calculating entrainment mortality as a function of size. The relationship between entrainment survival and size was estimated by separating all larvae collected and measured into 2-mm size intervals. The initial survival proportions within each interval were calculated for Station I3 and for Station DP at discharge temperatures $\leq$32 C and $\geq$33 C. Only striped bass and white perch had sufficient numbers collected and/or initial survival high enough to permit analysis. Length specific S_e estimates were calculated according to standard analytical procedures (Section 4.2). Curves were fitted to the S_e estimates by inspection.

Initial survival proportions at the intake station increased rapidly with increasing size for both striped bass and white perch (Figures 4-13 and 4-14). Both species' initial survival was 1.0 for the 6-7 mm size interval. Striped bass survival dropped slightly between 10 and 13 mm, but white perch survival remained at 1.0 for all larger size groups.

Survival at the discharge station generally increased with increasing size, although larvae collected at temperatures $\geq$33 C exhibited relatively lower survival for a given size than larvae collected at $\leq$32 C (Figures 4-13 and 4-14). Large striped bass larvae ($\geq$10 mm) had lower survival than smaller larvae for striped bass and white perch larvae at the higher temperature range.

Estimates of entrainment survival for each length interval generally increased with size and were very similar for striped bass and white perch (Figure 4-15). Striped bass S_e estimates ranged from 47 percent to 111 percent at the low temperature range, $\leq$32 C. White perch estimated entrainment survival at $\leq$32 C ranged from 67 percent to 119 percent. At discharge temperatures of $\leq$32 C most larvae larger than 10 mm survive entrainment. This size corresponds to that at which sampling mortality became undetectable in 1979 (EA 1980a) and 1980 (Chapter 5). At the high temperature range, $\geq$33 C, entrainment survival did not consistently increase with increasing size (Figure 4-15). This may be due to the tendency for larger larvae to occur later in the season when discharge temperatures are higher. The rate of survival declines rapidly at exposure temperatures above 33 C (EA 1978a) and the survival of any larvae would be very sensitive to the actual discharge temperature encountered. These analyses of 1980 entrainment survival at the Indian Point Generating Station demonstrate that entrainment survival varies with size for striped bass and white perch larvae. For both species very high survival is expected for larvae larger than 10 mm, if discharge temperatures are maintained below 33 C. At higher discharge temperatures, the

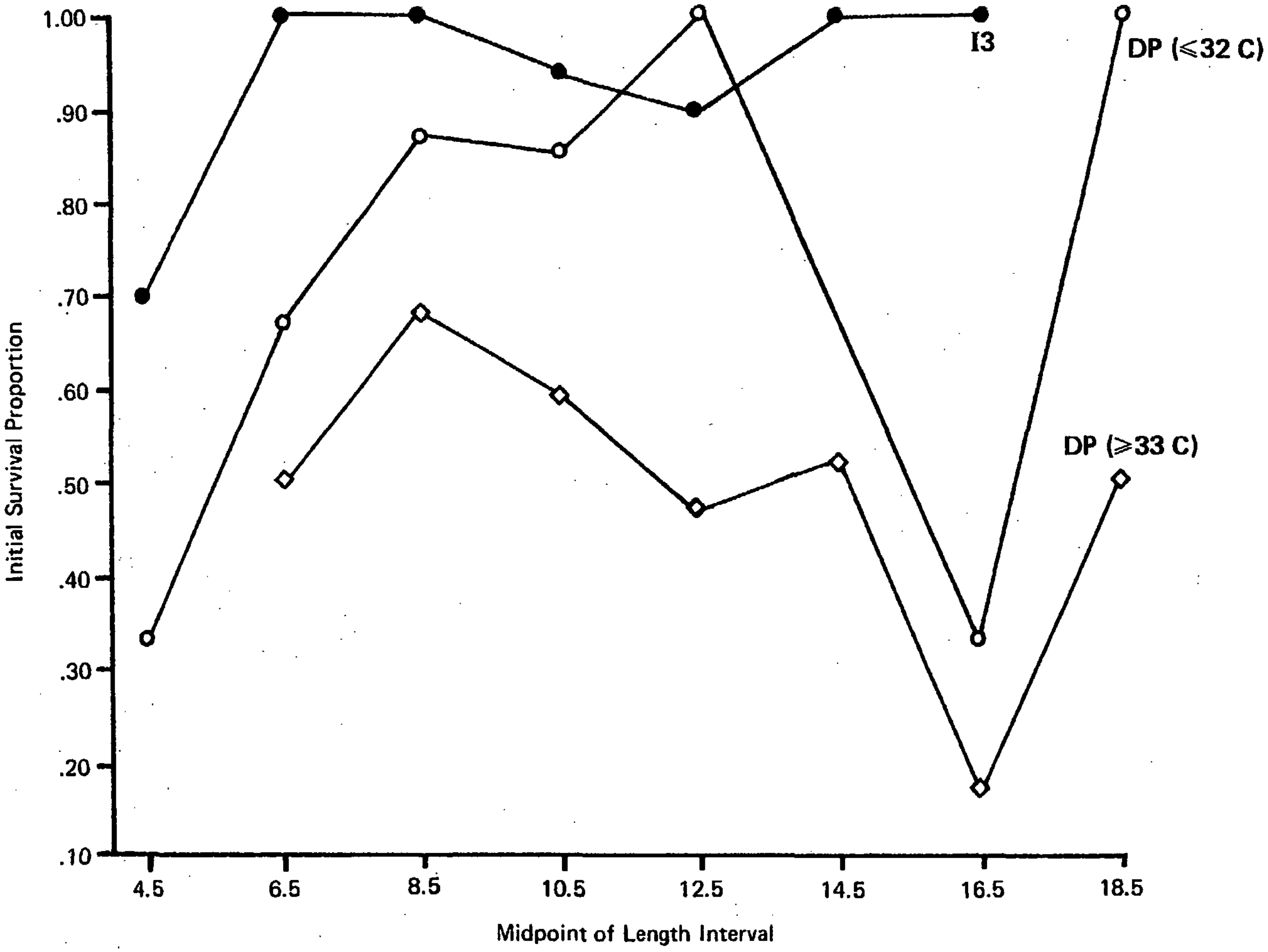


Figure 4-13. Initial survival as a function of size for striped bass larvae at the Indian Point Generating Station, 1980.

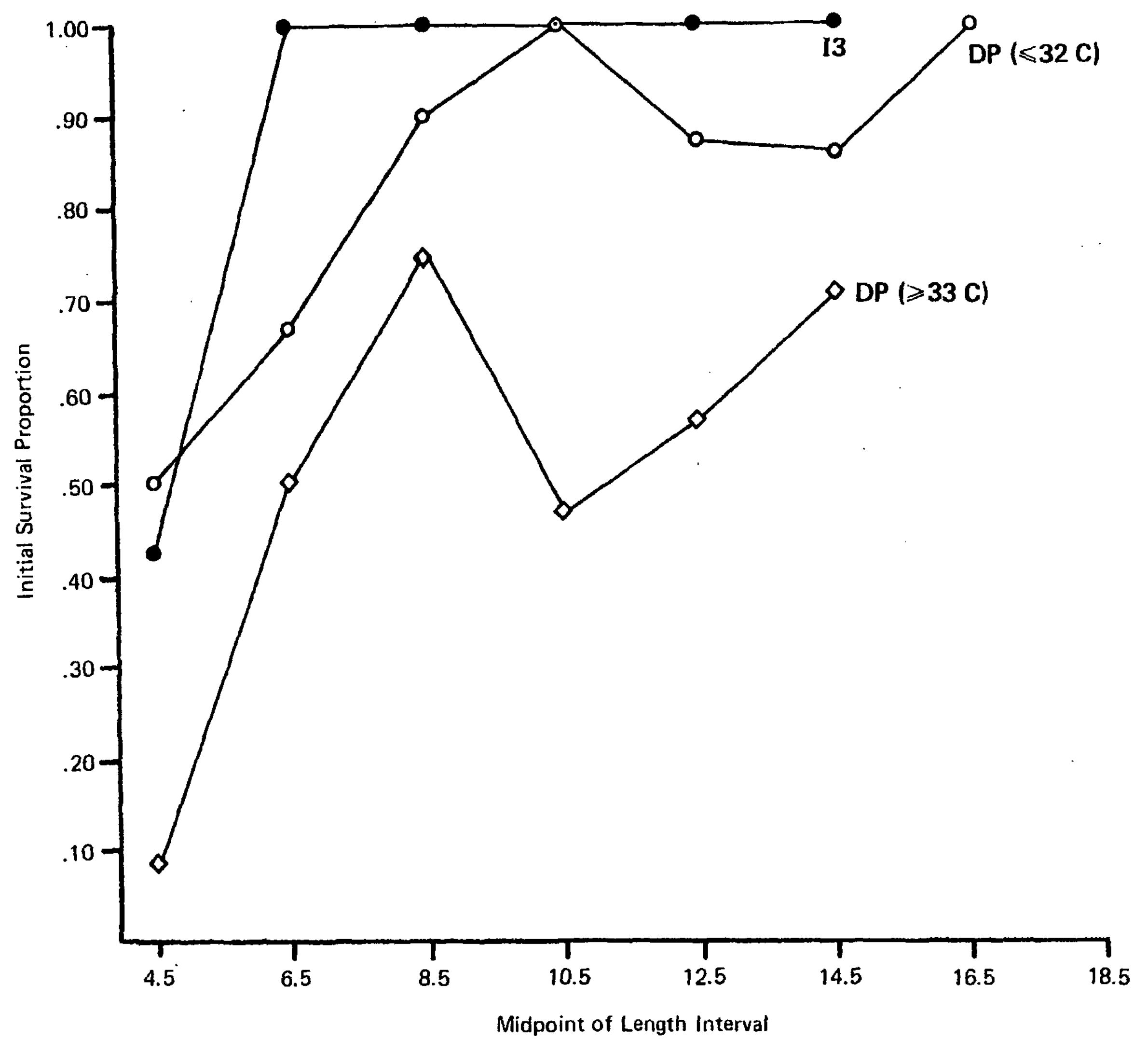


Figure 4-14. Initial survival as a function of size for white perch larvae at the Indian Point Generating Station, 1980.

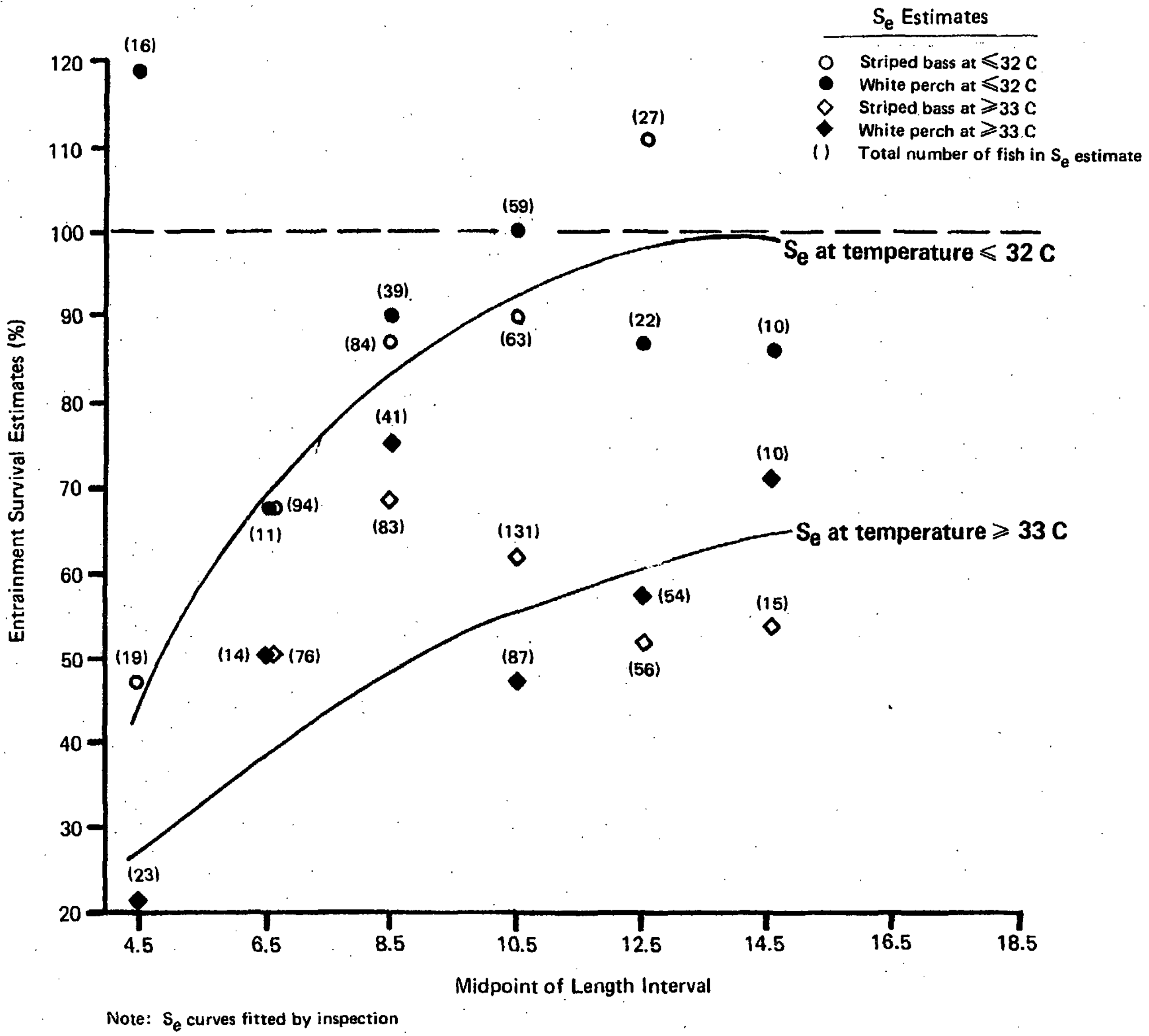


Figure 4-15. Estimates of initial entrainment survival as a function of size for white perch and striped bass larvae at the Indian Point Generating Station, 1980.

actual temperature and size of larvae must be considered to predict entrainment survival. Analysis of entrainment survival by length and estimates of size-related natural mortality can provide increased accuracy in predicting conditional entrainment mortality rates.

4.4 IMPLICATIONS OF THE 1980 ENTRAINMENT SURVIVAL RESULTS ON POTENTIAL BIASES TO ENTRAINMENT SURVIVAL ESTIMATES

The high intake survival obtained through application of gear refinements at the Indian Point plant in 1980 (Table 4-6) indicates that most larvae, with the possible exception of anchovies, were alive when they entered the sampling gear. This provides new insight on factors which may affect positive or negative biases in entrainment survival estimates (Boreman and Goodyear 1980). The degree to which sampling stress was minimized in 1980 and the resultant high intake (control) survival observed for nearly all species and life stages examined is a strong indication of the conservative nature of the survival estimates presented in Tables 4-7, 4-11, and 4-13. High intake survival proportions would cause either a true estimate or an underestimate of entrainment survival. Greater selectivity of the intake sampling gear for dead organisms, which could cause an overestimation of entrainment survival, clearly did not occur.

High intake survival could reflect either the actual proportions of live and dead organisms at the intake station, i.e., a true predominance of live organisms or gear selectivity for live organisms. This latter situation could be caused by either of the following factors: dead organisms are so fragile that most are destroyed during sampling, or dead organisms are stratified in the water column at the intake and rarely occur at the depth of sample withdrawal (3.4 m below the surface). If dead organisms are being damaged beyond recognition by the pumpless plankton sampling flume at the intake station, then it is reasonable to expect that the greater physical stresses associated with entrainment would also destroy dead organisms when they enter the cooling water system and preclude their identification and enumeration in discharge samples. This would nullify any bias in survival between the two sampling stations. Alternatively, if dead organisms are stratified and do not generally occur at the depth of sample withdrawal, then underestimation of entrainment survival should occur because the proportion surviving at the intake station would be inflated. Dead organisms which are stratified at the intake station would be expected to be more evenly distributed within the discharge water due to the mixing of water within the canal system, and be more susceptible to collection in the discharge sampling gear.

A remaining assumption which could affect bias in the entrainment survival estimates is that a significant number of organisms which enter the cooling system alive are damaged beyond recognition during the entrainment process, thus preventing their identification and enumeration in discharge samples. This would cause an overestimate of entrainment survival. Physical stresses to entrained organisms may result from a number of factors, including stresses associated with pump passage (cavitation, turbulence, contact with impeller blades), mechanical abrasion in the pipes, abrupt pressure changes, and shear forces. Based on the results of tests conducted in simulated power plant condensers, various investigators have concluded that typical power plant condensers cause minimal mechanical damage (<5 percent mortality) to larvae of most species (Coutant and Kedl 1975; Marcy et al. 1978; O'Connor and Poje 1979). Circulating water pumps were suggested as the most likely source of physical damage to entrained organisms. However, recent power plant simulator studies conducted at the Oak Ridge National Laboratories (ORNL) refute this supposition (Cada et al. 1980). The ORNL power plant simulator was designed to reproduce the internal hydraulics of an open-cycle condenser cooling water system. In addition to imposing thermal, pressure, and fluid-induced shear stresses typical of power plant condensers, it included a pump selected for its similarity to circulating water pumps used at power plants. The results discounted previous speculation that substantial mutilation or destruction of live organisms occurs in the circulating water pumps. Therefore, it is unlikely that an overestimate of entrainment survival would occur due to physical damage from entrainment.

The uniformly high intake survival for Atlantic tomcod juveniles, striped bass eggs, and striped bass, white perch, and herring larvae obtained at the Indian Point Generating Station in 1980, and the recent power plant simulation studies (Cada et al. 1980), give credibility to the current entrainment survival estimates. The 1980 entrainment survival data, therefore, provide valid estimates of entrainment survival which are conservative because they are likely to underestimate true entrainment survival.

5. ENTRAINMENT SAMPLING GEAR CALIBRATION STUDY

5.1 INTRODUCTION

Survival estimates for ichthyoplankton entrained through the cooling water system of the Indian Point Generating Station are calculated from the proportions of organisms that survive collection at the intake (control) and discharge (experimental) sampling stations (Section 4.2.3.2). A critical assumption is that mortality due to sampling stress is identical for the intake and discharge collection systems. This study was designed to examine that assumption by estimating survival of organisms collected in the rear-draw plankton sampling flume used at the Unit 3 intake (Station I3) and the pumpless plankton sampling flume used at the discharge port (Station DP) during the 1980 entrainment survival study. Hatchery-reared striped bass were used in these experiments to allow greater control of factors which might affect susceptibility to sampling stress (e.g., organism age and size).

Contrary to expectations, larval survival at the Indian Point Generating Station in 1979 was often greater at the discharge station than at the intake station. In such cases, estimates of entrainment survival that corrected for intake control survival were not possible. This difference in gear effects was confirmed for hatchery-reared yolk-sac and early post yolk-sac striped bass larvae used in the flume calibration study conducted during the 1979 sampling season at Indian Point (EA 1981). To eliminate the difference in sampling stress, changes were made in the design and operation of the sampling flumes used in the 1980 sampling season. The sampling flumes were modified to distribute water flow evenly across the surface of the vertical diversion screens and to standardize flume drain rates. Flow diffusion panels (baffles) and slotted outlet standpipes were installed behind the vertical screens to eliminate areas of localized high velocity flow that could cause organisms to become impinged on the diversion screens. Identical pump drainage systems were installed to permit control and standardization of the drain rates.

5.2 METHODS

5.2.1 Field and Laboratory Procedures

Collection system calibration tests used striped bass eggs and larvae obtained from the Con Edison hatchery facility at Verplanck, New York. After arrival from the hatchery, eggs were supplied with air and larvae were supplied with a slow flow of oxygen. Larvae were acclimated with ambient Hudson River water for a minimum of two hours; eggs were not acclimated. Experiments were conducted by releasing approximately 100 striped bass eggs or larvae into each sampling flume and collecting them at the end of a 15-minute sampling period. Four tests were conducted at each flume with eggs, yolk-sac larvae, early post yolk-sac larvae, and late post yolk-sac larvae.

Gear operating procedures during the collection system calibration tests were the same as those for entrainment survival sampling (Section 4.2.1), except that organisms were introduced just above the inlets of the sampling flumes. Introduction of eggs and larvae in the first five tests was simultaneous with the start of sampling. For all tests after 27 May, larvae were introduced 30 seconds before each test to avoid the concentration of organisms in the turbulent water at the sample inlet. After retrieving the test organisms from the flume, the number of recovered live and dead striped bass was determined to assess initial survival. All striped bass ichthyoplankton recovered alive were maintained at the onsite laboratory for up to 96 hours to assess extended survival. The proportion of striped bass eggs surviving to hatch (up to 96 hours after collection) was used as the basis for egg survival.

Controls were conducted with each experimental release to assess the effects of handling and increased water temperatures in the discharge canal on the eggs and larvae. At the beginning of each calibration test, approximately 100 eggs or larvae were placed in transportation containers filled with ambient water from the intake flume (I3 handling control), ambient water from the discharge flume (DP handling control), and discharge water at the discharge flume (DP thermal control). Control organisms remained in these containers during the 15-minute test period and the period of flume drainage. They were then transported with the experimental fish to the onsite laboratory at the end of the calibration test. Approximately 100 eggs or larvae were placed directly in appropriate holding containers filled with ambient water (hatchery control) to assess the general health of each batch of hatchery-reared ichthyoplankton, the effects of transportation from the hatchery to the Indian Point site, and the effects of minimal handling. Survival of control organisms was determined immediately after testing and was monitored for up to 96 hours in the same manner as experimental organisms.

5.2.2 Analytical Procedures

Analyses were designed to detect differences in initial and extended survival proportions for hatchery-reared striped bass collected in the reardraw and pumpless plankton sampling flumes. This information was used to estimate the magnitude of gear-induced mortality for the two sampling gear.

5.2.2.1 Survival Proportions

The survival of striped bass eggs released into the sampling flumes was determined by the proportion of eggs that hatched within 96 hours. This procedure is consistent with that used for wild eggs (Section 4.2.3.1). Hatching success is calculated as follows:

$$P_I \text{ or } P_D = \frac{\text{Number of eggs that hatched within 96 hours}}{\text{Total number of eggs recovered}}$$

where,

P_I = proportion surviving at the intake (Station I3)

P_D = proportion surviving at the discharge (Station DP)

An egg is considered viable only if it survives to hatch. Within the 96-hour observation period, all the eggs collected should either hatch or die.

For yolk-sac and post yolk-sac larvae, the initial proportion of organisms surviving collection in the sampling gear was determined as:

$$P_I \text{ or } P_D = \frac{\text{No. of alive and stunned fish observed immediately after collection}}{\text{Total number of fish recovered}}$$

Extended survival data were examined to determine if mortality occurred beyond the initial survival observation and to detect differences between the experimental and control test data. Survival was normalized by calculating survival proportions for each extended survival observation on the basis of the initial number of live and stunned fish. Gehan's nonparametric test (Gross and Clark 1975) was used to detect differences in the survival distributions for the entire extended survival observation period.

5.2.2.2 Determination of Gear Effects

To isolate gear effects at each station, the mortality caused by handling and thermal effects was factored out of the egg hatching success and larval initial survival proportions according to the following equations.

Initial survival proportions at each of the stations can be considered estimates of the product of the probabilities of surviving the stresses encountered by the organisms at each station, if it is assumed that there is no interaction, or synergism, between the stresses. Thus,

$$P_I = (P[h] \hat{\cdot} P[g_i]) \tag{1}$$

and

$$P_D = (P[h] \cdot P[\hat{t}] \cdot P[g_d]) \tag{2}$$

where

$P[h]$ = probability of surviving handling stress
$P[t]$ = probability of surviving thermal stress
$P[g_i]$ = probability of surviving gear induced stress at the intake flume
$P[g_d]$ = probability of surviving gear induced stress at the discharge flume

Additionally, $P[h]$ and $P[h] \cdot P[t]$ can be estimated directly from the handling and thermal controls at the intake and discharge stations.

$$P_h = P[\hat{h}] \tag{3}$$

and

$$P_h \cdot P_t = (P[h] \,\hat{\cdot}\, P[t]) \qquad (4)$$

where

P_h = proportion of organisms that survive handling

$P_h \cdot P_t$ = proportion of organisms that survive handling and thermal stress

Equations (1)-(4) can be combined algebraically to produce estimates of P[t], $P[g_i]$, and $P[g_d]$ and to test whether the stresses were statistically significant.

$$\frac{P_h \cdot P_t}{P_h} = \frac{(P[h] \,\hat{\cdot}\, P[t]}{P[h]} = P[\hat{t}] \qquad (5)$$

$$\frac{P_I}{P_h} = \frac{(P[h] \,\hat{\cdot}\, P[g_i])}{P\hat{[}h]} = P[\hat{g}_i] \qquad (6)$$

$$\frac{P_D}{P_h \cdot P_t} = \frac{(P[h] \,.\, P\hat{[}t] \,.\, P[g_d])}{(P[h] \,.\, P[t])} = P[\hat{g}_d] \qquad (7)$$

Thermal and gear effects, once isolated as in Equations (5), (6), and (7), were tested for significance using a chi-square (x^2) test (Sokal and Rohlf 1969). The ratio of gear effects served as an indicator of the similarity or difference of sampling stresses between the rear-draw (intake) and pumpless (discharge) flume systems. If sampling stresses for the two gear are approximately equal for a given life stage, the ratio $P[g_i]/P[g_d]$ will approach unity. However, if sampling stress is greater in the rear-draw flume (Station I3), the ratio will be less than 1; conversely, if sampling stress is greater in the pumpless flume (Station DP), the ratio will be greater than 1.

5.3 RESULTS

5.3.1 Initial Survival

The flume calibration tests for striped bass eggs indicated generally good hatching success from both sampling gear and their controls. The first test using striped bass eggs had relatively lower hatching success, which varied from 0.743 for the intake station handling control to 0.523 for the eggs collected at Station DP (Table 5-1). Handling stress may have contributed to this low hatching success. Hatching success for both handling controls was relatively low, which suggests that handling stress may have affected the survival of the experimental and thermal control organisms. It is also possible that the hatchery eggs were not in good condition, since the hatching success was 0.535 for striped bass eggs in the hatchery control that were subjected to only minimal handling. Age

TABLE 5-1 HATCHING SUCCESS AND INITIAL SURVIVAL PROPORTIONS FOR HATCHERY-REARED STRIPED BASS EGGS AND LARVAE FROM THE FLUME CALIBRATION STUDY AT THE INDIAN POINT GENERATING STATION, 1980

						Initial Survival Proportions				
Life Stage	Date	Age(a) (days)	Station	Temp. (C)	Number of Organisms	P_H	P_h	$P_h \cdot P_t$	P_I	P_D
Egg(b)	12 MAY	1	H	16.0	99	0.535				
			I3-HC	15.0	70		0.743			
			DP-HC	15.0	73		0.575			
			DP-TC	28.0	69			0.594		
			I3	15.0	86				0.593	
			DP	28.0	65					0.523

(a) Age of eggs is from day of spawning; age of larvae is from day of hatching.
(b) Hatching success at 96 hours after collection is presented for eggs.

Note: H denotes "hatchery control;" HC denotes "handling control;" TC denotes "thermal control."

$$\text{Survival proportions for eggs} = \frac{\text{No. of eggs that hatched within 96 hours}}{\text{Total no. of eggs recovered}}$$

$$\text{Survival proportions for larvae} = \frac{\text{No. of alive + stunned larvae observed immediately after collection or testing}}{\text{Total no. of larvae recovered}}$$

P_H = proportion of organisms surviving from the hatchery

P_h = proportion of organisms surviving handling stress

P_t = proportion of organisms surviving thermal stress associated with sampling

$P[g_i]$ = probability of surviving stress of the sampling gear at Station I3

$P[g_d]$ = probability of surviving stress of the sampling gear at Station DP

TABLE 5-1 (CONT.)

Life Stage	Date	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Initial Survival Proportions P_H	P_h	$P_h \cdot P_t$	P_I	P_D
Egg (cont.)	13 MAY	2	H	16.0	97	0.990				
			I3-HC	15.0	102		0.980			
			DP-HC	16.0	92		0.989			
			DP-TC	27.0	107			0.981		
			I3	15.2	84				0.845	
			DP	27.0	93					0.957
	19 MAY	3	H	17.0	79	0.987				
			I3-HC	17.0	110		1.000			
			DP-HC	15.0	60		1.000			
			DP-TC	25.0	150			0.993		
			I3	16.8	95				0.979	
			DP	24.0	81					0.938
	22 MAY	1	H	17.0	66	0.985				
			I3-HC	19.0	109		0.991			
			DP-HC	18.0	105		0.990			
			DP-TC	31.0	77			0.961		
			I3	19.0	107				0.981	
			DP	31.0	63					1.000
Yolk-sac larvae	27 MAY	4	H	18.0	95	1.000				
			I3-HC	19.0	97		0.887			
			DP-HC	20.0	97		0.918			
			DP-TC	31.0	92			0.880		
			I3	18.9	92				0.978	
			DP	31.0	79					0.101

TABLE 5-1 (CONT.)

Life Stage	Date	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Initial Survival Proportions P_H	P_h	$P_h \cdot P_t$	P_I	P_D
Yolk-sac larvae (cont.)	28 MAY	4	H	18.0	94	1.000				
			I3-HC	19.0	95		0.674			
			DP-HC	19.0	104		0.644			
			DP-TC	32.0	95			0.884		
			I3	17.8	104				0.798	
			DP	32.0	89					0.607
	2 JUN	7	H	21.0	97	1.000				
			I3-HC	20.0	100		0.980			
			DP-HC	20.0	97		1.000			
			DP-TC	31.0	67			0.985		
			I3	19.4	93				1.000	
			DP	31.0	89					0.944
	5 JUN	10	H	21.0	101	1.000				
			I3-HC	21.0	100		1.000			
			DP-HC	21.0	100		1.000			
			DP-TC	28.0	97			0.990		
			I3	20.8	100				0.990	
			DP	28.0	100					1.000
Post yolk-sac larvae	9 JUN	23	H	20.0	100	1.000				
			I3-HC	22.0	100		0.990			
			DP-HC	22.0	102		1.000			
			DP-TC	31.0	95			1.000		
			I3	20.4	94				1.000	
			DP	31.0	98					1.000

TABLE 5-1 (CONT.)

Life Stage	Date	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Initial Survival Proportions				
						P_H	P_h	$P_h \cdot P_t$	P_I	P_D
Post yolk-sac larvae (cont.)	10 JUN	24	H	18.0	100	1.000				
			I3-HC	20.0	101		1.000			
			DP-HC	20.0	97		1.000			
			DP-TC	30.0	100			1.000		
			I3	20.4	100				0.990	
			DP	30.0	99					0.929
	16 JUN	30	H	20.0		1.000				
			I3-HC	21.0	102		0.980			
			DP-HC	21.0	100		1.000			
			DP-TC	32.0	98			0.990		
			I3	21.6	100				0.990	
			DP	33.0	99					0.990
	17 JUN	31	H	21.0	100	1.000				
			I3-HC	22.0	99		0.970			
			DP-HC	22.0	99		1.000			
			DP-TC	32.0	98			1.000		
			I3	22.0	98				0.980	
			DP	33.0	98					0.980
	23 JUN	37	H	22.0	100	1.000				
			I3-HC	24.0	100		1.000			
			DP-HC	24.0	100		1.000			
			DP-TC	34.0	100			1.000		
			I3	24.2	99				1.000	
			DP	34.0	100					0.950

TABLE 5-1 (CONT.)

Life Stage	Date	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Initial Survival Proportions P_H	P_h	$P_h \cdot P_t$	P_I	P_D
Post yolk-sac larvae (cont.)	24 JUN	38	H	23.0	100	1.000				
			I3-HC	24.0	100		1.000			
			DP-HC	24.0	100		1.000			
			DP-TC	34.0	100			0.970		
			I3	23.6	100				1.000	
			DP	34.0	99					0.919
	30 JUN	44	H	24.0	100	1.000				
			I3-HC	24.0	99		0.990			
			DP-HC	24.0	100		1.000			
			DP-TC	28.0	99			1.000		
			I3	23.8	101				0.990	
			DP	30.0	100					1.000
	1 JUL	45	H	24.0	100	1.000				
			I3-HC	24.0	100		1.000			
			DP-HC	24.0	100		0.990			
			DP-TC	35.0	99			0.960		
			I3	24.3	98				1.000	
			DP	36.0	99					0.949

of the eggs did not seem to be a major factor in the lower hatching success. Similarly aged eggs used as hatchery controls in the fourth test exhibited good hatching success (0.985). However, eggs are known to be very sensitive to stress within 24 hours of spawning (Lauer et al. 1974). The hatching success of eggs tested at Station DP ranged from 0.938 to 1.000, and for eggs sampled at Station I3 the range of hatching success was 0.845-0.981, excluding 12 May. Hatching success when pooled over all four tests was 0.860 for eggs collected at Station I3 and 0.868 at Station DP (Table 5-2). Pooled hatching success showed statistically significant gear effects at the intake and discharge stations. Differences in survival between the discharge handling and thermal controls were not statistically significant, indicating that temperature alone did not reduce survival at Station DP. The gear-effect ratio for striped bass eggs was 0.959, indicating that gear stress was slightly greater at the intake than the discharge station.

Four flume calibration tests were completed using hatchery-reared striped bass yolk-sac larvae. Two circumstances affected the recovery and survival of the fish collected in the pumpless plankton sampling flume at Station DP. A break in the seal between the vertical screens and the flume bottom was discovered and corrected on 2 June after the flume calibration test; the break may have affected the recovery of test organisms. The next test, on 5 June 1980, recovered 100 yolk-sac larvae as opposed to 79-89 yolk-sac larvae previously collected at Station DP (Table 5-1). Use of only one primary water outlet to moderate the flume water depth at Station DP on 27 May also may have affected the results. During sample collection the use of only one outlet would have increased the probability of contact of larvae with the vertical screen associated with the open outlet because of the greater water flow through that screen. Increased contact with the vertical screens may have been the cause of the very low survival of yolk-sac larvae (0.101) obtained from Station DP on 27 May 1980 (Table 5-1). The problem was corrected immediately and subsequent survival of striped bass yolk-sac larvae at Station DP increased markedly to 0.607 or greater.

The survival proportions of striped bass yolk-sac larvae generally improved with age and length for the tests on 28 May, 2 June, and 5 June. The survival for 4-day old larvae was 0.798 at Station I3 and increased for 10-day old larvae to 0.990 (Table 5-1). At Station DP, survival improved from 0.607 to 1.000 for 4- and 10-day old larvae, respectively. The pooled survival proportions for the yolk-sac larvae were 0.926 at Station I3 and 0.856 at Station DP (Table 5-2). These survival values for yolk-sac larvae at both experimental stations are very high compared to results from the 1979 sampling season (EA 1981). However, the ratio of gear effects indicates that for striped bass yolk-sac larvae the gear at the discharge had a greater effect on survival than the gear at Station I3 (Table 5-2). The effect of the gear at Station DP and the effect of temperature (as measured by the thermal control) on survival were statistically significant ($\alpha = 0.05$). The significant difference in survival between the discharge handling control and thermal control was contrary to expectations; survival was greater for the thermal control larvae than for the handling control larvae. The cause of the significant gear effects was expected to be a reduction in survival associated

TABLE 5-2 POOLED INITIAL SURVIVAL PROPORTIONS AND ESTIMATES OF SAMPLING GEAR EFFECTS FOR HATCHERY-REARED STRIPED BASS EGGS AND LARVAE FROM THE FLUME CALIBRATION STUDY AT INDIAN POINT GENERATING STATION, 1980

					Initial Survival Proportions				Estimated Probabilities of Survival				Gear Effect Ratio
Life Stage	Age[a] (days)	Station	Temp. (C)	Number of Organisms	P_h	$P_h \cdot P_t$	P_I	P_D	$P[t]$	$P[g_i]$	$P[g_d]$	χ^2(b)	$P[g_i]/P[g_d]$
Eggs[c]	1-3	I3-HC	15-19	391	0.946								
		DP-HC	15-18	330	0.900								
		DP-TC	25-31	403		0.916			1.018			0.534	
		I3	15-19	372			0.860			0.909		16.32*	0.959
		DP	24-31	302				0.868			0.948	4.248*	
Yolk-sac larvae[d]	4-10	I3-HC	19-21	295	0.888								
		DP-HC	19-21	301	0.877								
		DP-TC	28-32	259		0.950			1.083			9.056*	
		I3	17.8-20.8	297			0.926			1.043		2.508	
		DP	28-32	278				0.856			0.901	13.231*	1.158
All post yolk-sac larvae	23-45	I3-HC	20-24	801	0.991								
		DP-HC	20-24	798	0.999								
		DP-TC	28-35	789		0.982			0.983			11.524*	
		I3	20.4-24.3	790			0.995			1.004		0.783	1.021
		DP	30-36	792				0.965			0.983	4.740*	

(a) Age of eggs is from day of spawning; age of larvae is from day of hatching.

(b) Null hypotheses tested for each life stage are $P[t] = 1$, $P[g_i] = 1$, and $P[g_d] = 1$. X^2 values were obtained by comparing the proportions in columns denoted by P_h and $P_h \cdot P_t$, P_h and P_I, and $P_h \cdot P_t$ and P_D for the appropriate stations for the three null hypotheses. Rejection of a null hypothesis at $\alpha = 0.05$ is signified by *, and at $\alpha = 0.01$ by **.

(c) Hatching success data is presented for striped bass eggs.

(d) Data from 28 May, 2 June, and 5 June are pooled for this analysis.

(e) Due to the low number of deaths, probabilities of rejecting a true null hypothesis were also computed with Fisher's exact test (Sokal and Rohlf 1969) for these groups. The exact probabilities associated with these tests were 0.1196 for early post yolk-sac larvae and 0.00003 for late post yolk-sac larvae.

Note: HC denotes "handling control;" TC denotes "thermal control."

$$\text{Survival proportions for eggs} = \frac{\text{No. of eggs that hatched within 96 hours}}{\text{Total no. of eggs recovered}}$$

$$\text{Survival proportions for larvae} = \frac{\text{No. of alive + stunned larvae observed immediately after collection or testing}}{\text{Total no. of larvae recovered}}$$

P_h = proportion of organisms surviving handling stress
P_t = proportion of organisms survival thermal stress associated with sampling
$P[g_i]$ = probability of surviving stress of the sampling gear at Station I3
$P[g_d]$ = probability of surviving stress of the sampling gear at Station DP.

TABLE 5-2 (CONT.)

Life Stage	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Initial Survival Proportions P_h	$P_h \cdot P_t$	P_I	P_D	Estimated Probabilities of Survival P[t]	$P[g_i]$	$P[g_d]$	χ^2(b)	Gear Effect Ratio $P[g_i]/P[g_d]$
Early post yolk-sac larvae	23-31	I3-HC	20-22	402	0.985								
		DP-HC	20-22	398	1.000								
		DP-TC	30-32	391		0.990			0.990			4.092(e)	
		I3	20.4-22.0	392			0.992			1.007		0.937	1.022
		DP	31-33	394				0.975			0.985	2.572	
Late post yolk-sac larvae	37-45	I3-HC	24	399	0.997								
		DP-HC	24	400	0.998								
		DP-TC	28-35	398		0.975			0.977			7.512**(e)	
		I3	23.6-24.3	398			0.997			1.000		0.000	1.021
		DP	30-36	398				0.955			0.979	2.369	

with increased temperatures, but in this case, temperature appears to have had an opposite effect.

The initial survival proportions for all of the flume calibration tests using striped bass post yolk-sac larvae were consistently high. For the eight sampling dates the survival of striped bass post yolk-sac larvae at Station I3 varied from 0.980 to 1.000 (Table 5-1). For larvae collected at Station DP survival was also high, ranging from 0.919 to 1.000. The pooled survival data for all post yolk-sac larvae from 23 to 45 days old indicated that, in spite of the very high survival at both stations, a gear effect is present at Station DP (significant at $\alpha = 0.05$). However, the effect was so small ($P[g_d] = 0.983$) that when the fish were separated by age into groups of early (23-31 days old) and late (37-45 days old) post yolk-sac larvae, the gear effect was not statistically significant (Table 5-2). The gear-effect ratios for the two age groups were similar, 1.022 (early) and 1.021 (late), which indicated slightly greater effects of the pumpless plankton sampling flume at Station DP. The thermal effect was also statistically significant ($\alpha = 0.05$) for all post yolk-sac larvae combined and late post yolk-sac larvae, which indicated that discharge water temperatures as high as 35 C were responsible for mortality above that due to handling alone (Table 5-2), but temperatures up to 32 C did not significantly affect survival.

These gear effects for post yolk-sac larvae may be real, as determined by statistical tests, but they are quite small and possibly negligible for survival proportions based on smaller sample sizes (e.g., entrainment survival samples). Since the gear effect ratio is only slightly greater than unity (1.02), and entrainment survival samples are too small to distinguish survival differences of 2 percent, the bias to entrainment survival estimates (Section 4.3.4) is negligible.

Survival of hatchery-reared striped bass larvae varied with length at Station DP, but not at Station I3 (Figure 5-1). Regardless of length, the survival of fish in the intake station handling control, intake station experimental group, and the thermal control at Station DP was above 90 percent, except for 6-mm larvae (Table 5-3). The estimated probability of surviving the sampling stress at Station I3 ($P[g_i]$) was 0.998, or greater, as a result of the very high survival of the intake control and experimental larvae (Table 5-3). The high survival of fish in the thermal (DP) control group indicated that temperature and handling stresses combined were not directly size-selective for striped bass larvae. For those larvae collected in the pumpless plankton sampling flume at Station DP, however, length had a noticeable effect on survival--as length increased, survival increased (Figure 5-1). For larvae less than 10 mm, the high gear-effect ratios indicate the greater effect of the sampling flume at Station DP than at Station I3. The effects of both sampling flumes on larvae longer than 10 mm appear to be very small (Table 5-3 and Figure 5-1).

The probability of surviving sampling stress for the smaller larvae (5-7 mm) at Station DP decreased as the discharge temperature increased (Table 5-4). The temperature and handling stresses to which the thermal control organisms were subjected had only a slight effect on survival (Table 5-3). Interaction or synergism of sampling, thermal, and handling

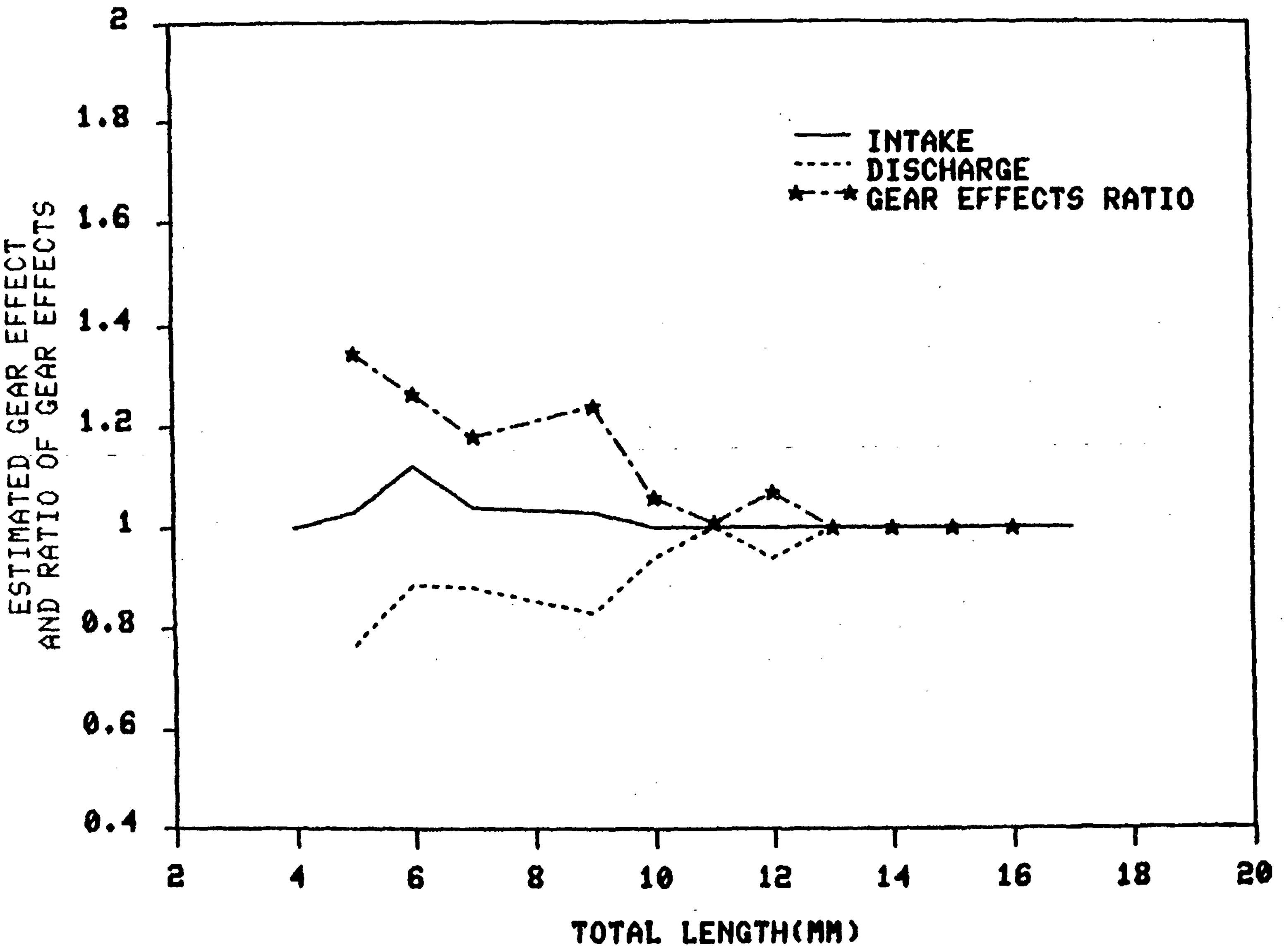


Figure 5-1. Intake and discharge station gear effects on the survival of hatchery-reared striped bass larvae as a function of length (mm) at the Indian Point Generating Station, 1980.

TABLE 5-3 INITIAL SURVIVAL AND ESTIMATED GEAR EFFECTS BY LENGTH CATEGORIES FOR HATCHERY-REARED STRIPED BASS LARVAE FROM THE FLUME CALIBRATION STUDY AT THE INDIAN POINT GENERATING STATION, 1980(a)

	Rear-Draw Plankton Sampling Flume Intake Station I3					Pumpless Plankton Sampling Flume Discharge Station DP					Gear-Effect Ratio
	Control		Experimental			Control		Experimental			
Total Length (mm)	n	P_h	n	$P_h \cdot P[g_i]$	$P[g_i]$	n	$P_h \cdot P_t$	n	$P_h \cdot P_t \cdot P[g_d]$	$P[g_d]$	$P[g_i]/P[g_d]$
4.0	16	1.000	7	1.000	1.000	0	--	0	--	--	--
5.0	22	0.909	32	0.938	1.032	34	0.941	18	0.722	0.767	1.346
6.0	87	0.724	101	0.842	1.163	107	0.897	98	0.796	0.887	1.311
7.0	26	0.962	19	1.000	1.040	14	1.000	26	0.885	0.885	1.175
8.0	9	1.000	0	--	--	4	1.000	0	--	--	--
9.0	30	0.967	11	1.000	1.034	29	1.000	18	0.833	0.833	1.241
10.0	100	1.000	62	1.000	1.000	105	0.990	77	0.935	0.944	1.059
11.0	167	0.982	169	0.982	1.000	139	0.971	182	0.962	0.991	1.009
12.0	155	0.994	130	0.992	0.998	139	0.993	127	0.929	0.936	1.066
13.0	61	1.000	74	1.000	1.000	89	0.978	80	0.975	0.997	1.003
14.0	33	1.000	43	1.000	1.000	37	0.973	40	0.975	1.002	0.998
15.0	6	1.000	24	1.000	1.000	11	1.000	13	1.000	1.000	1.000
16.0	1	1.000	6	1.000	1.000	3	1.000	1	1.000	1.000	1.000
17.0	1	1.000	3	1.000	1.000	0	-	0	--	--	--
18.0	0	--	1	1.000	--	0	--	0	--	--	--

(a) Data from 27 May 1980 are excluded.

Note: n = number of organisms

P_h = proportion of organisms surviving handling stress

P_t = proportion of organisms surviving thermal stress associated with sampling at Station DP

$P[g_i]$ = probability of surviving stress of the sampling gear at Station I3

$P[g_d]$ = probability of surviving stress of the sampling gear at Station DP.

TABLE 5-4 INITIAL SURVIVAL AND GEAR EFFECTS BY LENGTH FOR STRIPED BASS LARVAE AT THE INDIAN POINT GENERATING STATION, 1980

Length (mm)	Date	Station	Temp. at Station DP (C)	Survival		Gear Effects		Gear-Effect Ratio
				n	P_s	$P[g_i]$	$P[g_d]$	$P[g_i]/P[g_d]$
5	28 MAY	HC-I3		21	0.905			1.582
		I3		31	0.936	1.034		
		DP-TC		29	0.966			
		DP	32.0	17	0.632		0.654	
6	28 MAY	HC-I3		60	0.617			1.448
		I3		63	0.698	1.131		
		DP-TC		75	0.867			
		DP	32.0	62	0.677		0.781	
	2 JUN	HC-I3		17	0.941			1.063
		I3		29	1.000	1.063		
		DP-TC		28	1.000			
		DP	31.0	23	1.000		1.000	
	5 JUN	HC-I3		10	1.000			
		I3		9	1.000	1.000		0.933
		DP-TC		14	0.933			
		DP	28.0	13	1.000		1.072	

Note: n = number of organisms
P_s = proportion surviving
$P[g_i]$ = probability of organisms surviving the sampling gear stress at Station I3
$P[g_d]$ = probability of organisms surviving the sampling gear stress at Station DP
HC = handling control
TC = thermal control

TABLE 5-4 (CONT.)

Length (mm)	Date	Station	Temp. at Station DP (C)	Survival		Gear Effects		Gear-Effect Ratio
				n	P_s	$P[g_i]$	$P[g_d]$	$P[g_i]/P[g_d]$
7	2 JUN	HC-I3		11	0.909			1.467
		I3		3	1.000	1.100		
		DP-TC		10	1.000			
		DP	31.0	9	0.750		0.750	
	5 JUN	HC-I3		15	1.000			1.000
		I3		3	1.000	1.000		
		DP-TC		14	1.000			
		DP	28.0	14	1.000		1.000	

stresses may contribute to the discharge gear effects on survival of 5-7 mm larvae. These lengths correspond to the yolk-sac developmental stage, which is recognized as a more sensitive stage than older and larger larvae (Lauer et al. 1974 and EA 1978b). Possible synergism was also noticed for wild yolk-sac larvae (Section 4.4). The changes in the gear-effect ratio with discharge temperature are magnified in some cases because the intake station handling control survival was below that of the intake station experimental fish. However, the direct relation of discharge temperature to gear stress on survival still exists.

5.3.2 Extended Survival

The extended survival of yolk-sac larvae was very high at Stations I3 and DP. Normalized survival remained above 75 percent for both stations throughout the 96-hour observation period (Table 5-5). The survival distributions for yolk-sac larvae were not significantly different ($\alpha = 0.05$) for the two stations.

Survival of early post yolk-sac larvae collected at Station DP was slightly greater than at Station I3 for most of the extended survival observation period; however, these differences were not significant at $\alpha = 0.05$ (Table 5-5). Normalized survival of early post yolk-sac larvae remained near, or was greater than, 80 percent through the 72-hour observation, but decreased to 0.550 for Station I3 and 0.589 for Station DP by 96 hours. This sudden decline in survival after 72 hours at both stations may be the result of starvation as the remaining energy reserves are depleted and no food is available. Feeding has been demonstrated to be critical to the survival of striped bass larvae at this stage of development (Lewis and Heidinger 1981; Bonn et al. 1976).

The survival of late post yolk-sac larvae at the intake station was slightly greater than at the discharge station at most of the extended survival observations (Table 5-5). These differences were not significant at $\alpha = 0.05$. Despite normalized survival greater than 95 percent at both stations through 24 hours, late post yolk-sac larvae survival declined to less than 10 percent by 96 hours (Table 5-5). Since food requirements are greater for late post yolk-sac larvae than for early post yolk-sac larvae, the effects of starvation may occur earlier and cause the rapid decline in survival, especially at 72 and 96 hours.

5.4 DISCUSSION

The flume calibration study has shown that differences in survival between the intake and discharge station sampling gear are minimal. A gear-effect ratio of 1.0 would indicate that gear stresses are identical. In 1980 these ratios were all within 4 percent of 1.0 except for yolk-sac larvae. Of the life stages studied, striped bass post yolk-sac larvae were least affected by gear stress. The sampling gear at Station I3 was slightly more stressful for striped bass eggs than gear at Station DP. In contrast, the gear-related stress on yolk-sac larvae was greater at Station DP.

Alterations in the design and operation of the sampling flumes to reduce stress on organisms were successful as shown by the reduction in gear

TABLE 5-5 NORMALIZED EXTENDED SURVIVAL FOR HATCHERY-REARED STRIPED BASS YOLK-SAC AND POST YOLK-SAC LARVAE TESTED DURING THE COLLECTION SYSTEM CALIBRATION STUDY, INDIAN POINT GENERATING STATION, 1980

Life Stage	Station	Initial No. Live	Survival Proportions Time After Collection (Hours) 3	6	12	24	48	72	96	Z[a]
Yolk-sac larvae	I3	275	0.938	0.891	0.851	0.818	0.793	0.767	0.764	-0.50
	DP	238	0.895	0.832	0.815	0.794	0.790	0.782	0.756	
Early post yolk-sac larvae	I3	389	0.995	0.995	0.990	0.959	0.884	0.779	0.550	-1.18
	DP	384	1.000	1.000	0.990	0.969	0.922	0.797	0.589	
Late post yolk-sac larvae	I3	397	0.995	0.995	0.992	0.967	0.763	0.398	0.081	-1.67
	DP	380	0.995	0.984	0.979	0.953	0.758	0.326	0.055	

(a) Test statistic for differences in survival distributions based on Gehan's nonparametric test (Gross and Clark 1975). Critical value for Z is $|Z| \geq 1.96$. $\alpha = 0.05$ under the null hypothesis that the survival distributions are similar.

effects and improvements in gear-effect ratios from 1979 to 1980. Hatching success for eggs was high for both years, but the gear effects (sampling mortality) were further reduced in 1980. In 1980 the rear-draw sampling flume at Station I3 had a greater adverse effect on hatching success ($P[g_i]/P[g_d] = 0.959$), while in 1979 the gear at Station DP was more stressful. Initial survival of striped bass yolk-sac larvae improved substantially in 1980 and the stresses from both sampling flumes were reduced. The gear-effect ratio improved from 0.438 in 1979 to 1.158 in 1980. A small effect on survival of yolk-sac larvae still occurs due to sampling-associated stress at Station DP. Striped bass post yolk-sac larvae had very high initial survival in 1979 and 1980, and the differences between gear effects decreased in 1980 for the groups of all post yolk-sac larvae and early post yolk-sac larvae, so that the gear-effect ratio for the life stage improved from 0.929 to 1.021.

Extended survival observations revealed no significant effects of sampling gear on the survival of yolk-sac and early post yolk-sac striped bass larvae. However, late post yolk-sac larvae had poorer extended survival than either yolk-sac or early post yolk-sac larvae. The greater food requirements of older larvae may have caused starvation, since larvae were not fed throughout the observation period, which resulted in mortality in the last 48 hours. Similar results have been observed at other generating stations on the Hudson River (EA 1979d).

Analysis of larval survival and gear effects by length revealed that, for larvae less than 10 mm, survival at Station DP and the associated gear effect was related to length. This relation between length and survival was not found for larvae greater than 10 mm or for fish in control and Station I3 groups. Data for larvae from 5 to 7 mm suggested that the lower survival at Station DP may be due to an interaction between handling, thermal, and sampling stresses. Interaction between factors has been previously suggested from power plant simulation studies (Cada et al. 1980; Schubel et al. 1979), and was also noted for wild yolk-sac larvae in 1980 field studies (Section 4.4).

Sampling biases need to be minimized to accurately estimate entrainment survival. The bias of gear effects was statistically significant, but small, for striped bass eggs at Station I3, yolk-sac larvae at Station DP, and post yolk-sac larvae at Station DP. These gear effects, measured using large sample sizes, were so small that the biases may not be detectable for the smaller sample sizes obtained with standard entrainment survival sampling efforts. The gear-effect ratios greater than unity for striped bass larvae indicate that for this life stage any bias caused by the sampling gear would make corresponding entrainment survival estimates conservative when determined by sampling wild larvae (Section 4.4.1).

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APPENDIX A

ESTIMATED CIRCULATING WATER FLOW AT UNITS 1, 2, AND 3

TABLE A-1 ESTIMATED CIRCULATING WATER FLOW (including service water) AT UNIT 1, INDIAN POINT GENERATING STATION, DURING ENTRAINMENT SURVIVAL STUDIES, APRIL-JULY 1980 (million m^3/day)

	Month			
DAY	APR	MAY	JUN	JUL
1	0.101	0.104	0.104	0.104
2	0.104	0.104	0.104	0.104
3	0.104	0.104	0.104	0.104
4	0.104	0.104	0.104	0.104
5	0.104	0.104	0.104	0.104
6	0.104	0.104	0.104	0.104
7	0.104	0.104	0.104	0.104
8	0.104	0.104	0.104	0.104
9	0.104	0.104	0.104	0.104
10	0.104	0.104	0.104	0.104
11	0.104	0.104	0.104	0.104
12	0.104	0.104	0.104	0.104
13	0.104	0.104	0.104	0.104
14	0.104	0.104	0.104	0.104
15	0.104	0.104	0.104	0.432
16	0.104	0.104	0.104	0.142
17	0.104	0.104	0.104	0.104
18	0.104	0.104	0.104	0.104
19	0.104	0.104	0.104	0.104
20	0.104	0.104	0.104	0.104
21	0.104	0.104	0.104	0.104
22	0.104	0.104	0.104	0.104
23	0.104	0.104	0.104	0.104
24	0.104	0.104	0.104	0.104
25	0.104	0.104	0.104	0.104
26	0.104	0.104	0.104	0.104
27	0.100	0.104	0.104	0.104
28	0.104	0.104	0.104	0.104
29	0.104	0.104	0.104	0.104
30	0.104	0.104	0.104	0.104
31	---	0.104	---	0.294

Source: Con Edison 1980.

TABLE A-2 ESTIMATED CIRCULATING WATER FLOW (including service water) AT UNIT 2, INDIAN POINT GENERATING STATION, DURING ENTRAINMENT SURVIVAL STUDIES APRIL-JULY 1980 (million m^3/day)

	Month			
DAY	APR	MAY	JUN	JUL
1	2.845	3.924	3.924	3.924
2	2.828	3.772	3.672	3.924
3	2.829	3.459	2.463	3.924
4	2.669	4.512	2.848	3.924
5	2.732	4.687	2.398	3.927
6	2.856	4.687	2.398	3.952
7	2.856	4.687	1.917	4.137
8	2.706	4.230	0.124	4.715
9	2.669	3.925	0.136	4.731
10	2.597	3.924	0.111	4.715
11	3.627	3.924	1.142	4.715
12	4.086	3.734	3.937	4.333
13	4.077	3.840	3.936	4.715
14	4.039	4.153	3.952	4.509
15	4.687	4.283	3.952	3.746
16	4.687	3.924	3.934	4.516
17	4.184	3.924	3.924	4.715
18	4.550	3.924	3.924	4.715
19	4.245	3.924	3.924	4.715
20	3.924	3.924	3.924	4.722
21	3.176	3.924	3.924	4.742
22	2.421	3.924	3.924	4.742
23	3.421	3.924	3.924	4.742
24	3.611	3.912	3.924	4.742
25	3.665	3.897	3.924	4.742
26	3.924	3.897	3.924	4.742
27	3.767	3.923	3.924	4.742
28	3.924	3.924	3.924	4.742
29	3.924	3.924	3.924	4.742
30	3.925	3.924	3.924	4.742
31	---	3.924	---	4.742

Source: Con Edison 1980.

TABLE A-3 ESTIMATED CIRCULATING WATER FLOW (including service water) AT UNIT 3, INDIAN POINT GENERATING STATION, DURING ENTRAINMENT SURVIVAL STUDIES APRIL-JULY 1980 (million m^3/day)

	Month			
DAY	APR	MAY	JUN	JUL
1	2.462	3.188	3.829	3.952
2	2.439	3.188	3.952	3.952
3	2.375	3.188	3.944	3.952
4	2.007	3.188	3.952	3.952
5	1.862	3.196	3.952	3.952
6	1.367	3.570	3.952	3.952
7	0.804	3.952	3.952	3.952
8	0.636	3.952	3.952	3.952
9	0.621	3.952	3.952	3.952
10	0.356	3.952	3.952	3.952
11	0.652	3.952	3.433	3.952
12	0.928	3.950	2.929	3.952
13	0.904	3.947	3.952	3.952
14	1.393	3.952	3.952	3.952
15	1.663	3.952	3.952	3.952
16	1.659	3.952	3.952	1.868
17	1.662	3.188	3.952	1.567
18	1.662	3.303	3.952	0.927
19	1.861	3.311	3.952	0.927
20	2.425	3.311	3.952	0.927
21	2.425	3.822	3.952	0.927
22	2.425	3.532	3.952	0.927
23	2.425	3.509	3.952	0.927
24	2.082	3.952	3.952	0.927
25	1.701	3.196	3.952	0.927
26	2.425	3.188	3.952	0.927
27	2.344	3.188	3.952	0.927
28	2.525	3.188	3.952	0.927
29	3.188	3.257	3.952	2.247
30	3.188	3.669	3.952	2.849
31	—	3.417	—	3.807

Source: Con Edison 1980.

APPENDIX B

GEAR SPECIFICATIONS AND SAMPLING CONDITIONS

TABLE B-1 SAMPLING GEAR SPECIFICATIONS AND ASSOCIATED SAMPLING CONDITIONS FOR THE SPRING-SUMMER (striped bass, white perch, herring, and anchovy) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 10 JULY 1980

	Station	
	I3	DP
Collection device	Floating, rear-draw plankton sampling flume	Floating, pumpless plankton sampling flume
Depth of removal[(a)]	3.6 m (12.0 ft)	3.6 m (12.0 ft)
Collection device intake diameter	15.2 cm (6 in.)	15.2 cm (6 in.)
Elevation of collection device with respect to water surface[(b)]	0.6 m (2 ft) floating	0.0 m (0.0 ft) floating
Length of tubing from point of removal to collection device	10.4 m (34 ft)	10.4 m (34 ft)
Flow rate	600-1,450 ℓ/min (159-383 gpm)	687-1,720 ℓ/min (182-454 gpm)
Duration of sample	15 min	15-16 min
Volume sampled per collection	11.0-21.0 m^3 (2,906-5,548 gal)	8.6-25.8 m^3 (2,272-6,816 gal)
Orientation of tubing relative to water flow	Horizontally, facing the current	Horizontally, facing the current
Drain time	15-37 min	15-47 min
Sample water depth in collection device	25.4-73.7 cm (10-29 in.)	22.9-53.3 cm (9-21 in.)

(a) Depth of removal refers to the measurements from sample depth to the water surface at mean low water.

(b) Elevation of collection device refers to the level of the bottom of the collection device (flume) relative to the water surface.

APPENDIX C

LENGTH-FREQUENCY DISTRIBUTION DATA

TABLE C-1 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR ATLANTIC TOMCOD COLLECTED AT STATIONS I3 AND DP FOR ENTRAINMENT SAMPLING, INDIAN POINT GENERATING STATION, 1980

Week of	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	Length Intervals (mm)									Range (mm)[a]		
				00.0-19.9	20.0-24.9	25.0-29.9	30.0-34.9	35.0-39.9	40.0-44.9	45.0-49.9	50.0-54.9	55.0+	Min	Med	Max
Station I3															
30 APR 80	11	28.5	3.5	0	1	6	3	1	0	0	0	0	23.0	28.0	35.0
12 MAY 80	10	32.7	7.0	1	0	1	3	5	0	0	0	0	14.0	34.5	39.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUL 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Station DP															
30 APR 80	6	26.2	3.6	0	3	1	2	0	0	0	0	0	21.0	26.5	30.0
12 MAY 80	50	31.7	3.6	0	3	7	29	10	1	0	0	0	23.0	32.0	40.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	11	48.6	5.3	0	0	0	0	0	2	5	3	1	43.0	47.0	62.0
2 JUN 80	1	46.0	0.0	0	0	0	0	0	0	1	0	0	46.0	46.0	46.0
9 JUN 80	1	52.0	0.0	0	0	0	0	0	0	0	1	0	52.0	52.0	52.0
16 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUL 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

(a) Min = shortest length, Med = median length, Max = greatest length.

TABLE C-2 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR STRIPED BASS COLLECTED AT STATIONS I3 AND DP FOR ENTRAINMENT SAMPLING, INDIAN POINT GENERATING STATION, 1980

Week of	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	Length Intervals (mm) 0.0-3.9	4.0-5.9	6.0-7.9	8.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0+	Range (mm)[(a)] Min	Med	Max
Station I3															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	9	5.2	0.9	0	4	5	0	0	0	0	0	0	4.0	6.0	6.0
19 MAY 80	20	6.0	0.7	0	5	15	0	0	0	0	0	0	5.0	6.0	7.0
27 MAY 80	32	7.3	0.9	0	1	17	14	0	0	0	0	0	5.0	7.0	9.0
2 JUN 80	15	7.7	1.8	0	0	10	2	2	1	0	0	0	6.0	7.0	12.0
9 JUN 80	71	8.8	1.8	0	0	19	26	20	6	0	0	0	6.0	9.0	13.0
16 JUN 80	60	10.1	1.9	0	0	3	19	27	8	2	1	0	6.0	10.0	16.0
23 JUN 80	3	11.7	0.5	0	0	0	0	1	2	0	0	0	11.0	12.0	12.0
30 JUN 80	5	12.0	2.9	0	0	1	0	0	3	0	1	0	7.0	12.0	16.0
7 JUL 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Station DP															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	7	4.7	0.9	0	5	2	0	0	0	0	0	0	4.0	4.0	6.0
19 MAY 80	6	5.7	0.1	0	2	4	0	0	0	0	0	0	5.0	6.0	6.0
27 MAY 80	18	7.1	1.0	0	1	11	6	0	0	0	0	0	5.0	7.0	9.0
2 JUN 80	15	8.3	1.3	0	0	4	9	2	0	0	0	0	6.0	8.0	11.0
9 JUN 80	27	9.9	2.0	0	0	4	8	9	6	0	0	0	7.0	10.0	13.0
16 JUN 80	144	10.7	1.8	0	0	4	21	78	31	9	0	1	6.0	10.5	18.0
23 JUN 80	6	11.5	3.1	0	0	1	0	2	2	0	1	0	6.0	12.0	16.0
30 JUN 80	20	15.7	5.4	0	0	0	1	2	4	3	8	2	8.0	15.5	31.0
7 JUL 80	4	23.5	11.1	0	0	0	0	1	0	1	0	2	11.0	23.5	36.0

[(a)] Min = shortest length, Med = median length, Max = greatest length.

TABLE C-3 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR WHITE PERCH COLLECTED AT STATIONS I3 AND DP FOR ENTRAINMENT SAMPLING, INDIAN POINT GENERATING STATION, 1980

Week of	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	Length Intervals (mm)									Range (mm)[a]		
				0.0-3.9	4.0-5.9	6.0-7.9	8.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0+	Min	Med	Max
Station I3															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	3	6.0	0.8	0	1	2	0	0	0	0	0	0	5.0	6.0	7.0
2 JUN 80	4	8.5	2.2	0	1	0	2	1	0	0	0	0	5.0	9.0	11.0
9 JUN 80	15	9.7	1.9	0	1	0	4	8	2	0	0	0	4.0	10.0	12.0
16 JUN 80	46	10.1	1.7	0	1	1	13	24	7	0	0	0	4.0	10.0	13.0
23 JUN 80	14	6.6	2.4	0	6	3	3	2	0	0	0	0	4.0	6.0	11.0
30 JUN 80	20	10.5	2.7	0	1	2	4	5	5	3	0	0	5.0	11.0	14.0
7 JUL 80	9	9.9	2.8	0	1	0	3	2	3	0	0	0	4.0	11.0	13.0
Station DP															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	3	5.0	0.0	0	3	0	0	0	0	0	0	0	5.0	5.0	5.0
2 JUN 80	2	9.0	1.0	0	0	0	1	1	0	0	0	0	8.0	9.0	10.0
9 JUN 80	17	8.8	2.4	0	2	3	4	6	2	0	0	0	4.0	9.0	12.0
16 JUN 80	84	10.7	1.8	0	2	2	10	41	29	0	0	0	4.0	11.0	13.0
23 JUN 80	15	5.9	2.2	0	8	4	1	2	0	0	0	0	4.0	5.0	11.0
30 JUN 80	44	12.3	1.9	0	0	0	4	10	17	12	1	0	8.0	13.0	16.0
7 JUL 80	10	11.4	1.9	0	0	0	2	2	4	2	0	0	8.0	12.0	14.0

(a) Min = shortest length, Med = median length, Max = greatest length.

TABLE C-4 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR HERRING COLLECTED AT STATIONS I3 AND DP FOR ENTRAINMENT SAMPLING, INDIAN POINT GENERATING STATION, 1980

Week of	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	Length Intervals (mm) 0.0-3.9	4.0-5.9	6.0-7.9	8.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0+	Range (mm)(a) Min	Med	Max
Station I3															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	1	7.0	0.0	0	0	1	0	0	0	0	0	0	7.0	7.0	7.0
19 MAY 80	3	7.3	2.6	0	1	1	0	1	0	0	0	0	5.0	6.0	11.0
27 MAY 80	2	6.5	0.5	0	0	2	0	0	0	0	0	0	6.0	6.5	7.0
2 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUN 80	2	9.0	0.0	0	0	0	2	0	0	0	0	0	9.0	9.0	9.0
16 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUL 80	2	63.0	1.0	0	0	0	0	0	0	0	0	2	62.0	63.0	64.0
Station DP															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	5	6.4	0.5	0	0	5	0	0	0	0	0	0	6.0	6.0	7.0
19 MAY 80	2	7.5	0.5	0	0	1	1	0	0	0	0	0	7.0	7.5	8.0
27 MAY 80	2	8.0	1.0	0	0	1	1	0	0	0	0	0	7.0	8.0	9.0
2 JUN 80	4	11.0	0.7	0	0	0	0	3	1	0	0	0	10.0	11.0	12.0
9 JUN 80	1	17.0	0.0	0	0	0	0	0	0	0	1	0	17.0	17.0	17.0
16 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUL 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0

(a) Min = shortest length, Med = median length, Max = greatest length.

TABLE C-5 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR ANCHOVIES COLLECTED AT STATIONS I3 AND DP FOR ENTRAINMENT SAMPLING, INDIAN POINT GENERATING STATION, 1980

				Length Intervals (mm)									Range (mm)(a)		
Week of	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	0.0-3.9	4.0-5.9	6.0-7.9	8.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0+	Min	Med	Max
Station I3															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUN 80	1	11.0	0.0	0	0	0	0	1	0	0	0	0	11.0	11.0	11.0
23 JUN 80	112	10.4	4.0	0	15	26	5	13	19	28	4	2	4.0	11.0	20.0
30 JUN 80	66	7.1	2.5	0	17	27	18	2	0	0	1	1	4.0	7.0	19.0
7 JUL 80	44	10.0	3.2	0	0	9	18	6	2	5	4	0	6.0	9.0	17.0
Station DP															
30 APR 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
12 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
19 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
27 MAY 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
2 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUN 80	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUN 80	4	11.8	3.0	0	0	0	1	1	1	0	1	0	8.0	11.5	16.0
23 JUN 80	226	9.7	5.3	16	70	16	9	14	32	31	22	16	3.0	10.5	22.0
30 JUN 80	72	6.4	2.0	0	26	32	12	1	0	0	0	1	4.0	6.0	18.0
7 JUL 80	109	10.5	5.1	0	12	24	31	7	4	7	9	15	4.0	9.0	28.0

(a) Min = shortest length, Med = median length, Max = greatest length.