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Entrainment Survival Studies – 1979, 1980, 1988

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INDIAN POINT GENERATING STATION ENTRAINMENT SURVIVAL AND RELATED STUDIES

1979 ANNUAL REPORT

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and

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EA Report CON94D

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1979 ANNUAL REPORT

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 cooling process, water from the Hudson River is pumped through condensers where heat is transferred from the exhaust steam to the cooling water; the warmed water is then returned to the river. The two electrical power generating units in operation at the Indian Point plant* withdraw up to 6,360 m^3/minute (1.68 million gallons per minute) of water from the Hudson River for cooling purposes. Aquatic organisms small enough to pass through the intake screens (9.5 mm bar mesh) may be carried through the cooling water system (entrainment) where they are exposed to abrupt temperature changes, changes in hydrostatic pressure, mechanical buffeting, and velocity shear forces. Determination of the survival of these organisms following entrainment is an important step in realistically assessing the potential ecological effects of power plant operation on the aquatic environment.

Studies to examine the 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 applied collection procedures, and to further minimize stresses associated with sampling. The results of entrainment studies at Indian Point have thus been instrumental in supporting and promoting state-of-the-art developments in entrainment survival sampling and assessment.

Initial studies to evaluate the survival of selected ichthyoplankton species entrained at the Indian Point plant were conducted by the New York University Medical Center (NYU) in 1972. These studies used conical plankton nets mounted to stationary frames at plant intake and discharge stations to determine initial and extended survival of entrained organisms. This sampling approach, which was subsequently incorporated into the regulatory technical specifications for the Indian Point plant (NRC 1975), was continued by NYU through 1977 (NYU 1973, 1974, 1976a, 1976b, 1976c, 1977, 1978). In 1978, the administration of this sampling program was transferred to Ecological Analysts, Inc. (EA 1980a).

The use of stationary nets at the Indian Point plant to assess the survival of entrained organisms was originally based on the assumption that survival of organisms captured by nets was the same in the discharge canal as at the lower velocity intake (control) stations (NYU 1976b). In this regard, estimated cross-sectional flow velocities in the Indian Point plant's discharge canal typically exceed 0.61 m per second (2.0 fps), reaching approximately 3.0 m per second (10.0 fps) at the point where cooling water exits the discharge ports, whereas estimated velocities at the intakes are less than

* 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.

0.30 m per second (1.0 fps) (NYU 1978). However, initial net entrainment sampling at Indian Point conducted in 1972 revealed that differences in the velocity of water flow at intake versus discharge sampling stations may have an effect on ichthyoplankton survival in the collection nets (NYU 1973). To examine the relationship between water velocity and the survival of ichthyoplankton captured in plankton nets of the type used at Indian Point, tests were conducted at Con Edison's water flume (Alden Research Laboratories, Holden, Massachusetts) using early life stages of hatchery-reared striped bass from Hudson River brood stock (NYU 1976b; O'Connor and Schaffer 1977). These studies demonstrated that survival of all striped bass life stages tested (egg, yolk-sac larva, and post yolk-sac larva) was, in fact, velocity dependent. Survival for all life stages was considerably higher at 0.15 m per second (0.5 fps) than at 0.46 m per second (1.5 fps), and water velocities of 0.91 m per second (3.0 fps) caused virtually complete mortality to all life stages. Yolk-sac larvae were found to be most sensitive to net capture, followed by post yolk-sac larvae and eggs, in decreasing order of sensitivity. Based on these studies, it was concluded that entrainment survival estimates for ichthyoplankton collected using standard net capture techniques may be affected profoundly by differences in water velocities at power plant intakes and discharges, and that failure to account for net-induced mortality may result in excessively high impact assessments (NYU 1976b; O'Connor and Schaffer 1977).

In light of these findings, entrainment survival studies at the Indian Point plant were expanded in 1977 and 1978 to include sampling gear specifically designed to eliminate the effect of intake and dicharge velocity differences on survival. These studies, conducted by Ecological Analysts, Inc., used pumps to transport water from intake and discharge sampling locations into a flume (larval table) that reduced the velocity of water and concentrated the organisms collected. 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 technique, referred to as the pump/larval table collection system, generally resulted in higher entrainment survival estimates, for most taxa and life stages, than were determined using nets (EA 1978a, 1979a).

In spite of the refinements in entrainment survival estimates achieved through the use of pump/larval table collection systems, pumps nonetheless cause sampling mortality which can be pronounced in the case of more fragile species or life stages. Controlled experiments, for example, have demonstrated that only about 20 percent or less of striped bass juveniles are killed by passage through 10 to 15 cm (4 to 6 in.) diameter pumps during normal sampling operation, whereas mortality may be as high as 30 to 70 percent for clupeid juveniles (EA 1979b). Moreover, a comparison of striped bass survival data from collections taken at Indian Point intake and discharge stations in 1978 indicated higher entrainment survival for larvae and juveniles, but lower survival for eggs, in pump/larval table versus stationary plankton net collections (EA 1980a). Complete mortality was, in fact, observed for striped bass eggs collected at intake (control) as well as discharge stations using the pump/larval table systems, thus preventing a realistic assessment of entrainment survival for this life stage.

1.2 1979 ENTRAINMENT SURVIVAL STUDIES

In an attempt to reduce sampling stress on more sensitive ichthyoplankton taxa and life stages, entrainment survival studies conducted at the Indian Point plant during the 1979 spring-summer spawning and nursery season employed new raft-mounted sampling gear adapted from a collection system design that was used successfully by Ecological Analysts in 1978 to sample at an offshore diffuser discharge (EA 1979c). The new collection systems utilized head-induced flow, rather than pumps, for sample delivery but retained the velocity reduction aspects of a flume receiving system. The discharge collection system, referred to as the pumpless plankton sampling flume, used dynamic head created by the water velocity exiting the discharge ports (about 3 m per second [10 fps]) to deliver the sample into a floating collection flume. At the intake (control) station, where velocities are less, a head differential was created by pumping water from behind angled diversion screens in a partially submersed flume to induce sample flow into the collection system; this gear is referred to as the rear-draw plankton sampling flume.

Although the pumpless and rear-draw plankton sampling flumes were primarily designed to eliminate pump-induced sampling stresses, the floating support structures associated with these samplers offer additional advantages over the land-based pump/larval table collection systems. Because they are raft-mounted, the new systems can be moved without disassembly and can be placed near the point of sample withdrawal, thus, minimizing the length and elevation of the intake hose that delivers the sample to the collection flume. Moreover, flotation of the discharge collection system provides a practical solution to sampling at the Indian Point plant's submerged discharge ports, thereby permitting assessment of organism survival at the terminus of the cooling water system.

Entrainment survival studies at the Indian Point plant in 1979 were also expanded to include sampling for larvae of the winter-spawning Atlantic tomcod. This sampling effort was conducted in late winter using land-based pump/larval table collection systems. The raft-mounted samplers were not installed for this study because of their susceptibility to damage from ice floes that typically occur during this period.

1.3 SCOPE OF REPORT

This report addresses the results of the 1979 entrainment survival studies conducted at the Indian Point plant using pump/larval table collection systems (late winter), as well as the pumpless and rear-draw plankton sampling flumes (spring-summer). The late winter study effort was directed toward assessing the entrainment survival of Atlantic tomcod (Microgadus tomcod), whereas the spring-summer survival study focused on striped bass (Morone saxatilis), white perch, (M. americana), herrings (Clupeidae), and anchovies (Engraulidae). Entrainment abundance of ichthyoplankton species and life stages collected at the Indian Point plant during late spring 1979 using an automated pumped abundance sampling system is also presented. Ancillary experiments designed to evaluate the recovery and survival of hatchery-reared striped bass released directly into the cooling water system of the plant (direct release studies), and to compare sampling effects associated with the pumpless and rear-draw plankton sampling flumes (collection system calibration study), are described in Appendixes A and B, respectively. In addition, supplemental information on sampling gear and associated sampling conditions are contained in Appendix C. Appendix D presents length-frequency data for the major ichthyoplankton taxa. Included in Appendix E are procedures for the life stage apportionment of Atlantic tomcod larvae.

2. SUMMARY

2.1 ENTRAINMENT SURVIVAL

Entrainment survival studies at the Indian Point Generating Station in 1979 were conducted during two separate sampling periods; the late winter season (12 to 22 March) directed toward Atlantic tomcod (Microgadus tomcod) larvae, and the spring-summer season (30 April to 14 August) directed toward early life stages of striped bass (Morone saxatilis), white perch (M. americana), herrings (Clupeidae), and anchovies (Engraulidae). During the winter season, sampling with pump/larval table collection systems was conducted at the intakes to Units 2 and 3 (Stations I2 and I3), in the Unit 3 effluent before it enters the common discharge canal (Station D3), and in portions of the discharge canal containing effluent water from both units (Stations D2 and DP). Shutdown of Unit 3 from 20 to 22 March permitted examination of survival of Atlantic tomcod larvae under one- and two-unit generation.

New raft-mounted flume collection systems were used for the first time at the Indian Point plant during the spring-summer entrainment season. The flume systems were designed to reduce sampling stress by eliminating passage of the organisms through sampling pumps. In the pumpless plankton sampling flume used at the discharge port (Station DP), the difference in water levels of the river and discharge canal creates a head, or pressure difference, which causes water to flow into the flume. At the intake flume (Station I3) a head is created by pumping water out of the partially submersed flume from behind the diversion screens. As in the winter season, unit outages (Unit 2 after June 16) provided the opportunity to assess survival during both one- and two-unit generation.

2.1.1 Atlantic Tomcod Survival

Initial survival proportions over the winter season for Atlantic tomcod larvae were 0.624 at intake stations and 0.283 at discharge stations (Section 4.3.1.2.1). Survival proportions at intake stations were found to be independent of life stage (yolk-sac or post yolk-sac larvae) and plant operational mode (one- or two-unit generation). At discharge stations survival was also independent of life stage, but plant operation did have a significant effect on survival. The plant operation effect could be explained through differences in discharge water temperatures. Survival proportions at discharge stations declined sequentially from 0.398 at temperatures <16 C to 0.071 at temperatures between 20 and 22 C.

Extended survival proportions for Atlantic tomcod larvae, through 96 hours after collections, differed significantly between yolk-sac and post yolk-sac larvae collected at intake stations (0.347 and 0.667, respectively). However, extended survival proportions for both life stages collected in discharge samples, pooled over both operating conditions (0.214 for yolk-sac and 0.556 for post yolk-sac), were not significantly different from intake proportions (Section 4.3.1.2.2).

Entrainment survival of Atlantic tomcod measured over the entire 12 to 22 March sampling season was 45 percent (Section 4.3.1.2.3) for yolk-sac and post yolk-sac larvae combined. For the four discharge temperature categories examined, entrainment survival was 64 percent from 12 to 15.9 C, 52 percent from 16 to 17.9 C, 29 percent from 18 to 19.9 C, and 11 percent from 20 to 21.9 C. The substantial decline in survival with increasing discharge temperatures suggests that manipulation of cooling water flow to maximize entrainment survival could result in reduced entrainment cropping of Atlantic tomcod.

2.1.2 Striped Bass, White Perch, Herring, and Anchovy Entrainment Survival Study

The most abundant ichthyoplankton taxon collected at the Indian Point plant during the 1979 spring-summer entrainment survival study was the anchovy family (Engraulidae), followed by striped bass, herrings (Clupeidae), and white perch (Section 4.3.2.1). These four taxa comprised 94 percent of the ichthyoplankton collected with the new head-induced flow flume systems, compared to 96 percent and 91 percent in entrainment survival samples collected during 1977 and 1978 with the pump/larval table systems (EA 1978a, 1979a).

Consistent with entrainment survival studies at the Indian Point plant in 1977 and 1978, post yolk-sac larvae were collected in larger numbers than other life stages. Thus, although eggs, yolk-sac, and post yolk-sac larvae of striped bass were collected in sufficient numbers to determine entrainment survival, survival analysis for the other taxa was restricted to post yolk-sac larvae.

Survival proportions for striped bass eggs (proportion which hatch within 96 hours) were 0.444 for intake collections and 0.327 for discharge collections (Section 4.3.2.2.1). These survival proportions, were not significantly different at $\alpha = 0.05$, and represent substantial improvement over previous data from pump/larval table systems which generally produced 100 percent mortality for eggs.

Initial survival proportions for fish larvae collected at the discharge port station DP, which had experienced entrainment as well as sampling effects, were highest for striped bass (0.615 to 0.769), followed by white perch (0.236 to 0.700), herrings (0.285), and anchovies (0.058) (Section 4.3.2.2.2). When examined over the three discharge temperature ranges ($\leq$29.9 C, 30 to 32.9 C, $\geq$33 C), survival in 1979 was consistently higher than in 1977 or 1978 (Section 4.3.2.2.3). Thus, the pumpless plankton sampling flume represented a significant improvement in entrainment survival sampling methodology over the pump/larval table collection system since it not only reduced sampling stress but also permitted sampling entrained organisms at the terminus of the coolant system.

In contrast, initial survival proportions at intake station I3, which reflect sampling effects only, were unexpectedly lower than at the discharge port for larvae of most taxa. This indicated higher sampling stress in the rear-draw flume system, particularly for yolk-sac larvae and younger post yolk-sac larvae. (Further demonstration of the difference in sampling stress between the two flume systems, which declined with increasing size of the larvae, occurred in the collection system calibration study, Appendix B.) The reason for higher stress may have been localized areas of high through-screen velocity in the rear-draw flume which resulted in impingement of larvae on the diversion screens.

Differences in initial survival during periods of one-unit versus two-unit generation were seen only for white perch post yolk-sac larvae collected at Station DP. The higher survival during one-unit generation was probably due more to the larger size of the larvae collected during this operational mode than to any inherent difference in stress. The influence of larval size on survival was also seen for hatchery-reared striped bass in the collection system calibration study (Appendix B).

Survival proportions did not appear to decline with increasing temperature, however, striped bass, white perch, and herrings were not collected when discharge temperatures were $\geq$33 C. Anchovy post yolk-sac larvae, the only taxa collected over all three temperature ranges, exhibited lowest survival (0.028) at the intermediate temperature range (30 to 32.9 C). Again length of the larvae collected in the three temperature ranges provided an explanation for this apparent anomaly as larvae collected at the intermediate temperature range were generally the smallest.

Normalized extended survival (through 96 hours) for intake and discharge collections differed significantly (α = 0.05) only for striped bass yolk-sac larvae and herring post yolk-sac larvae (Section 4.3.2.2.4). For striped bass yolk-sac larvae, extended survival for discharge collections was consistently lower than for intake collections. For herring post yolk-sac larvae, discharge extended survival proportions consistently exceeded proportions for intake collections, however, statistical significance was found for only two observation periods, 12 and 96 hours. Although survival was low, anchovy larvae survived through 96 hours for the first time since the initiation of survival sampling, further demonstrating the improvements of the new flume sampling systems.

Entrainment survival, S_e, for striped bass eggs was 74 percent (Section 4.3.2.2.5), nearly identical to the 73 percent estimate of S_e from direct release experiments (Appendix A). Since no difference in sampling stress was found for the two flume systems (Appendix B), these S_e estimates are the first valid measures of egg entrainment survival for the Indian Point Generating Station. Previous estimates based on net collections were biased by differential sampling stress due to different water velocities at intake and discharge stations. Because of the difference in sampling stress between flumes for the larval life stages, S_e estimates for these stages could not be calculated according to standard methods. Nonetheless, the discharge station initial survival values indicate that entrainment survival for most taxa in 1979 was likely to be at least as high as most previous S_e estimates. Minimal entrainment survival estimates (i.e., discharge initial survival proportions) for all temperatures combined in 1979 were 59 percent for striped bass yolk-sac larvae, 63 percent for striped bass post yolk-sac larvae, 30 percent for white perch post yolk-sac larvae, 29 percent for herring post yolk-sac larvae, and 6 percent for anchovy post yolk-sac larvae.

Overall, the rear-draw and pumpless plankton sampling flumes used in 1979 appear to be effective collection systems for entrainment survival assessment. The reduction of sampling stress achieved with these samplers was demonstrated not only in the successful collection of reliable striped bass egg survival data (Section 4.3.2.3.1), but also in the generally higher survival of larvae in discharge collections, as compared to previous years (Section 4.3.2.2.3). Moreover, sensitive anchovy larvae were, for the first time, maintained throughout the entire 96-hour latent effects observation period (Section 4.3.2.2.4). With minor refinements to reduce differential gear effects on larval stages, these flume systems should yield survival data superior to that obtained with previous collection methods.

2.2 ENTRAINMENT ABUNDANCE

Abundance of ichthyoplankton in cooling water at the Indian Point Generating Station was examined using a portable automated abundance sampling system (AUTOSAM) at Station D1 from 2 May through 14 June. On one sampling date each week, seven 2-hour composite samples were collected over a 14-hour period. The midpoint of the fourth sample during each collection effort corresponded to dusk.

Herrings, striped bass, and white perch dominated the collections, as in previous years, comprising 44, 18, and 17 percent, respectively, of the 3,523 ichthyoplankton collected (Section 5.3.1). An additional 8 percent of the total were Morone that were not identifiable to species. The remaining 13 percent consisted of 12 other taxa and unidentifiable specimens (2.7 percent).

Post yolk-sac larvae (79 percent) were the most abundant life stage, followed by yolk-sac larvae (12 percent), eggs (2 percent), and juveniles (1 percent). The remaining 6 percent were unidentified organisms. The relatively high incidence of post yolk-sac larvae as compared to eggs and yolk-sac larvae probably resulted from their more extensive movements throughout the water column and, particularly for herrings and white perch, their higher relative abundance in the Indian Point vicinity.

Seasonal abundance of striped bass indicated a short period of abundance (two sampling dates) for striped bass eggs but longer entrainment seasons for larvae (Section 5.3.2). Yolk-sac larvae were present on the last five collection dates, however, abundance was clearly declining when sampling ceased. Post yolk-sac larvae were caught only on the last four collection dates and the peak in abundance occurred on the final date. An outage at Unit 2 precluded further abundance sampling after 14 June.

White perch life stages were slightly more dispersed temporally than striped bass. Eggs were present on four of the seven collection dates, yolk-sac larvae on six, post yolk-sac larvae on five collection dates. Both larval life stages were abundant when sampling terminated on 14 June, thus their temporal distribution in power plant coolant flows cannot be completely assessed from the 1979 sampling.

Post yolk-sac larvae were the only herring life stage caught in abundance. Although some post yolk-sac larvae were caught on each sampling date, abundance clearly peaked on 30 May and remained relatively high until sampling ended on 14 June.

Diel patterns in abundance were not statistically significant for post yolk-sac larvae of striped bass, white perch, or herrings or yolk-sac larvae of striped bass (Section 5.3.3). Although statistical significance was lacking, all four groups appeared to have bimodal diel distributions, with one peak in abundance just prior to or at dusk and a second peak in either the sixth or seventh collection period (i.e., 3 to 7 hours after dusk).

3. SITE DESCRIPTION

3.1 THE RIVER

The Indian Point Generating Station is located on the east bank of the Hudson River, between Peekskill and Haverstraw Bays, near the town of Buchanan, New York. The plant is 69 river kilometers (43 mi) north of the Battery in New York City (Figure 3-1). In the vicinity of the Indian Point plant the Hudson River has a surface width of approximately 1,524 m and a cross-sectional area of approximately 14,865 m^2. Within 60 m of the plant, river depths range from about 3 to 12 m.

Flow rates in this section of the river are controlled predominately by tides. Mean tidal flows are on the order of 3,964 m^3/second (140,000 cfs) and the freshwater flows range from 156 m^3/second (5,500 cfs) in August to 905 m^3/second (32,000 cfs) in April (Con Edison 1977a, p. 2-1). Seasonal trends in salinity vary primarily with freshwater flow. During the months of March, April, and May when freshwater flow normally exceeds 566 m^3/second (20,000 cfs), the salt front (defined as 0.1 ppt salinity) generally remains downriver of the Indian Point plant. However, during periods when lower freshwater flows predominate (typically July through October [Con Edison 1977a, Table 2-2]), the salt front extends upriver into the Indian Point area. At such times, salinity in the vicinity of the plant may fluctuate rapidly as a function of tidal stage and height. Ambient river temperatures typically range from 0 to 27.2 C throughout the year in the Indian Point area (Con Edison 1977a, Table 2-3).

3.2 THE PLANT

The Indian Point Generating Station consists of three nuclear-fueled electric generating units. Unit 1, owned by Con Edison, has not been 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 the withdrawal of water from the Hudson River (Figure 3-2). The intake structure for Unit 1 has four rectangular openings that extend 8.0 m (26.2 ft) below mean low water. The intake structures for Units 2 and 3 each have six intake openings extending 8.2 m (26.9 ft) below mean low water. The intakes to Units 1 and 2 are equipped with fixed screens at the entrance to the intake bays and vertical traveling screens located behind the fixed screens, whereas the intake to Unit 3 has only 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.

Circulating water pumps with rated capacities of 530 m^3/minute (140,000 gpm) 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

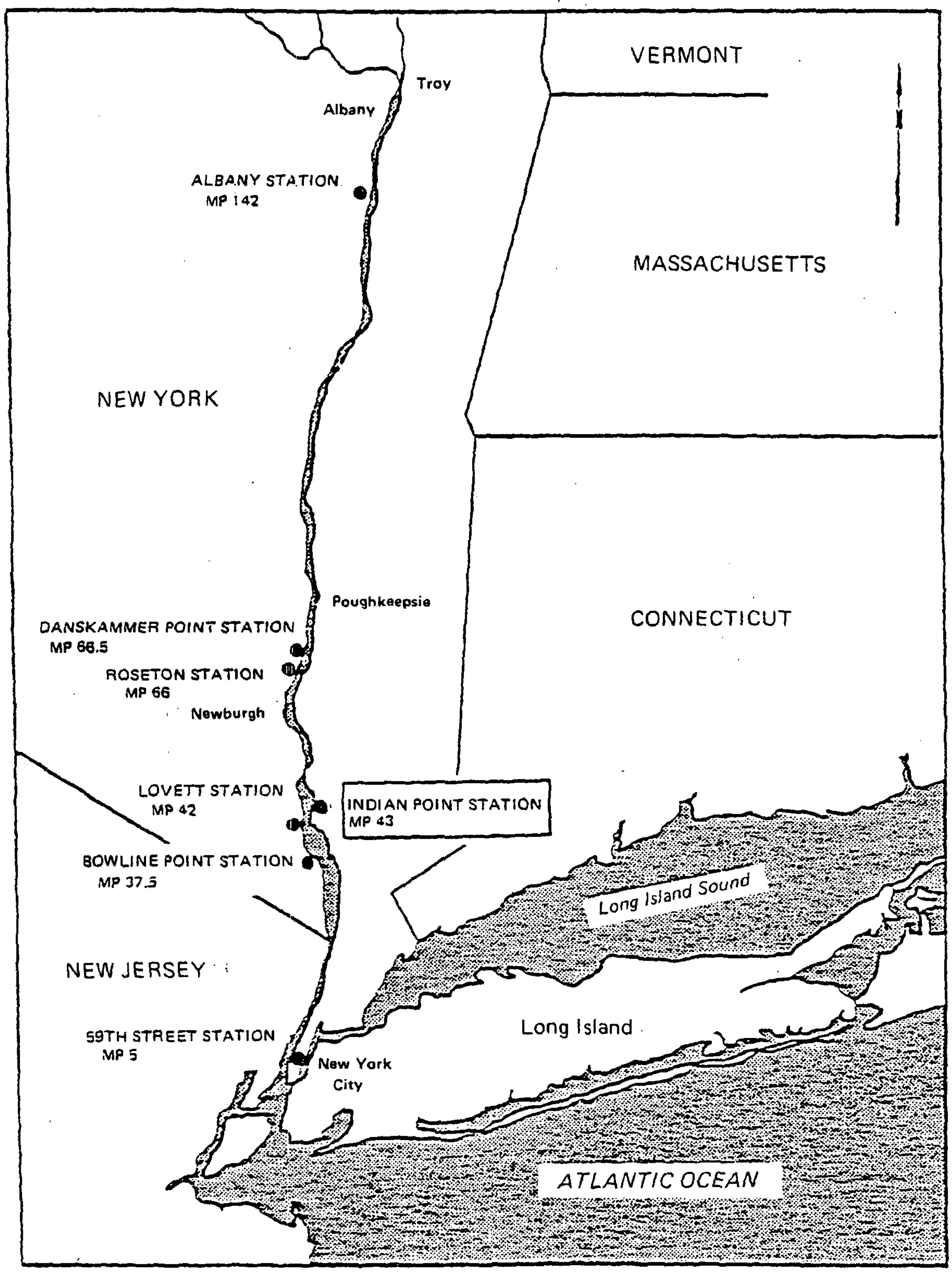


Figure 3-1. Location of the Indian Point Generating Station relative to other generating stations on the Hudson River Estuary (Scale – 1:1,267,200).

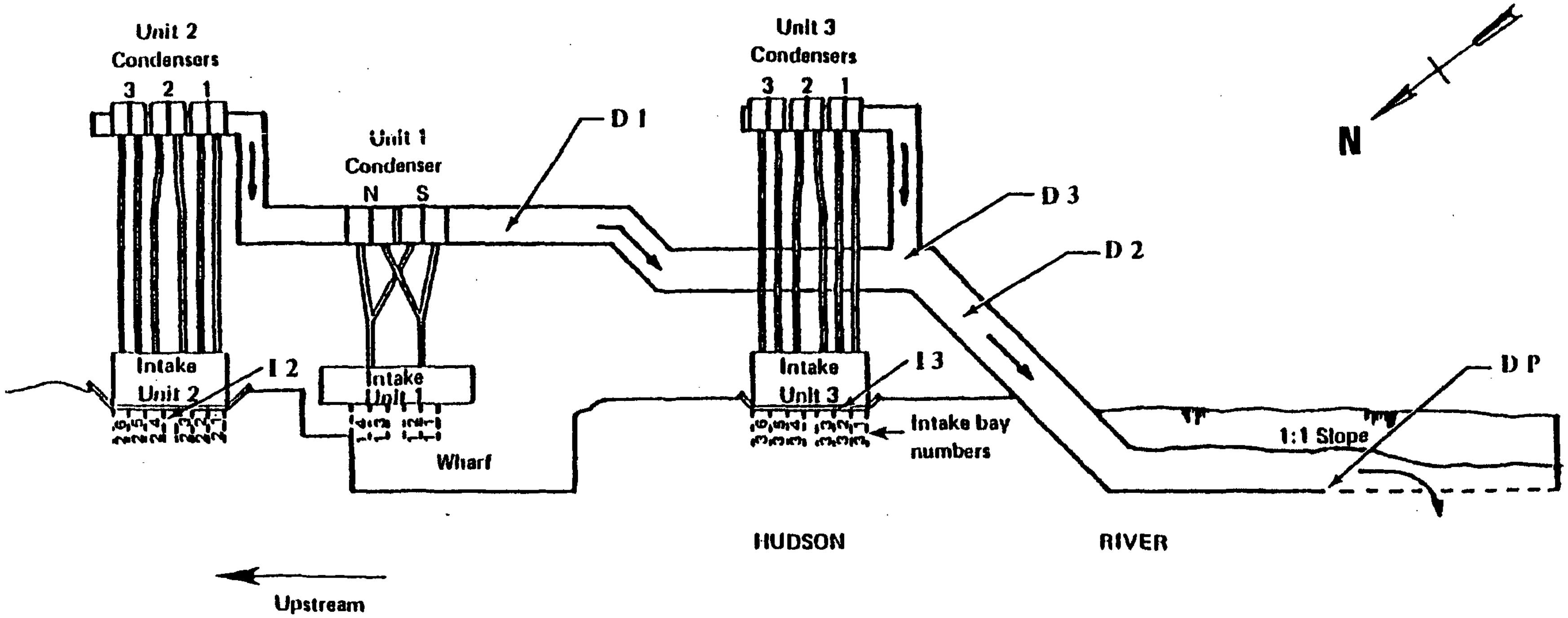


Figure 3-2. Diagram of the Indian Point Generating Station circulating water system showing location of sampling stations (from Con Edison 1977b).

of 1,060 m^3/minute (280,000 gpm), and two service water pumps with a combined rated capacity of 144 m^3/minute (38,000 gpm). Units 2 and 3 each have six circulating water pumps that withdraw water from separate intake bays (Figure 3-2). The circulating water systems for Units 2 and 3 are designed to operate at either 100 or 60 percent flow. When the ambient water temperature is above 4.4 C (spring through fall), the circulating pumps are operated so that the maximum cooling water flow for each unit is 3,178 m^3/minute (840,000 gpm). During the winter, 40 percent of the cooling water is returned to the circulating pumps without passing through the condenser, reducing the maximum intake flow for each unit to 1,908 m^3/minute (504,000 gpm). Service water for Units 2 and 3 is drawn through a separate intake forebay located at the center of each intake stucture; the maximum total service water flow for Units 2 and 3 is 114 m^3/minute (30,000 gpm).

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 downstream of Unit 3. The discharge structure consists of 12 ports submerged to a depth of 3.7 m (12 ft from center of port to water surface) at mean low water.

Calculated transit times of cooling water traveling from intake to river outfall for Units 2 and 3, when both units are operating at full pumping capacity, range from 8.5 to 9.7 minutes for Unit 2, and from 5.2 to 5.6 minutes for Unit 3, depending upon the number of pumps operating at Unit 1 (Table 3-1). The calculated transit time from the intake to the condensers is about 1.5 minutes, and the calculated transit time through the condensers is 0.14 minute for both units. Thus, much of the total transit time through the cooling water systems of Unit 2 and Unit 3 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 plant depends on the cooling water flow rates and level of power generation (Con Edison 1977a, Tables 1-13 and 1-14). At Unit 2, with six pumps operating at full flow and the unit at 100 percent capacity, the calculated condenser temperature rise ranges from 8.8 to 8.9 C, depending on river temperature. During full-capacity winter operation, with Unit 2 circulating pumps operating at 60 percent flow capacity (i.e., 40 percent recirculation), the calculated condenser temperature rise is approximately 14.7 C. At Unit 3, the calculated condenser temperature rise ranges from 9.5 to 9.7 C for 100 percent capacity with six pumps operating at full flow; during winter operation, the calculated temperature rise is approximately 16.1 C. The higher calculated delta-T at Unit 3 is due to the higher rated capacity using the same volume of water.

During the 1979 sampling season (March through August), Unit 2 was in operation until 17 June, and Unit 3 was in operation throughout the sampling season except from 20 to 26 March. Although Unit 1 is no longer operated commercially, one circulating pump was operated during late June and early July. Summaries of the total calculated water flow (service and cooling water) through each unit during the 1979 sampling season are presented in Tables 3-2 to 3-4.

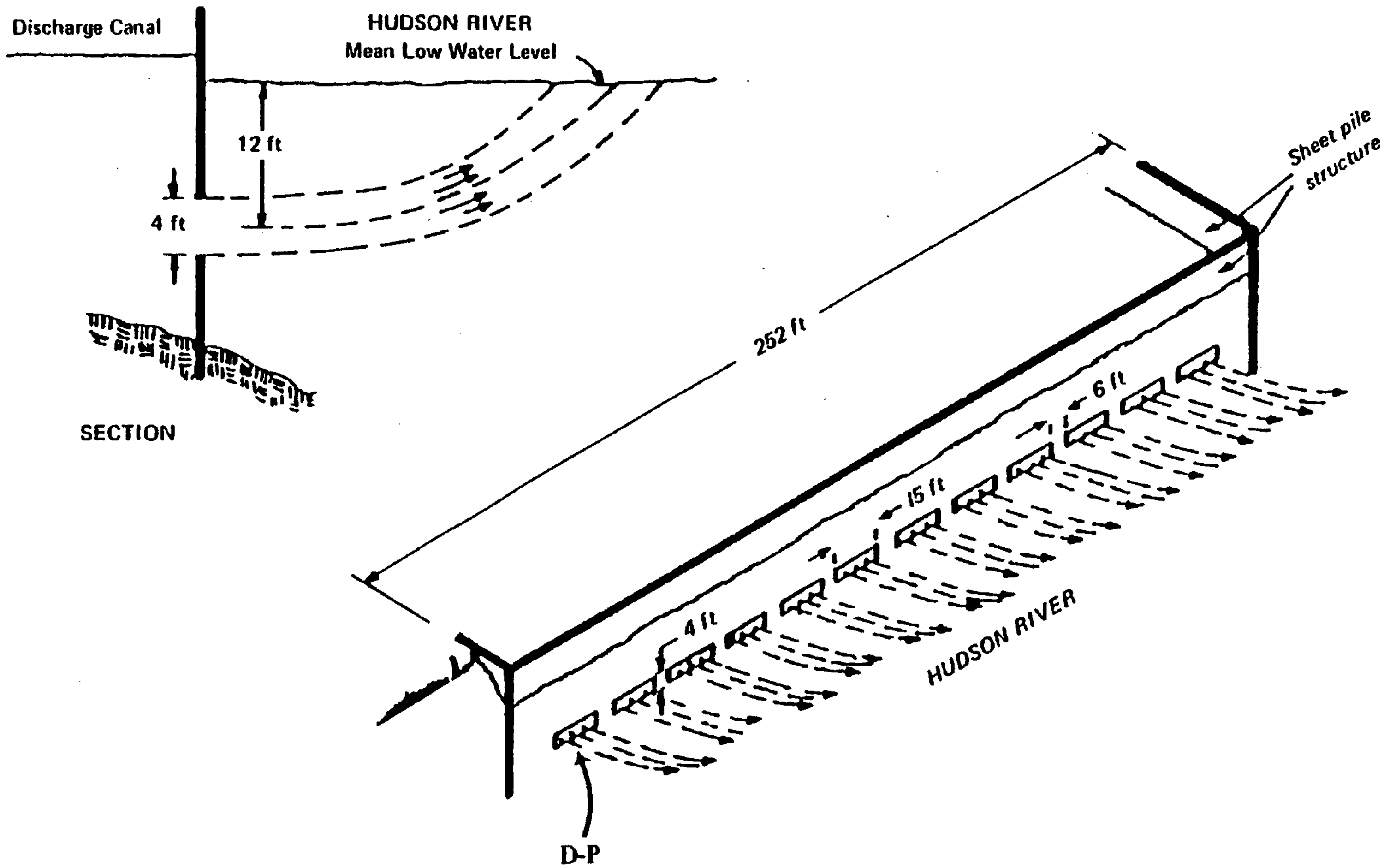


Figure 3-3. Diagrammatic sketch of Indian Point Generating Station discharge structure (from Con Edison 1974).

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)

Circulating Pumps Operating at Unit 3	Unit 2 Intake to Common Discharge Ports (time in minutes) — 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

Circulating Pumps Operating at Unit 3	Unit 3 Intake to Common Discharge Ports (time in minutes) — 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 3-4 ESTIMATED CIRCULATING WATER FLOW (INCLUDING SERVICE WATER) AT UNIT 3, INDIAN POINT GENERATING STATION, DURING ENTRAINMENT SURVIVAL STUDIES MARCH - AUGUST 1979 (millions of gallons per day)

	Month					
Day	MAR	APR	MAY	JUN	JUL	AUG
1	641	655	1,246	1,199	1,253	1,253
2	641	655	1,246	1,044	1,253	1,258
3	641	588	1,246	1,044	1,253	1,250
4	641	760	1,246	1,044	1,253	1,246
5	641	948	1,246	1,044	1,253	1,246
6	641	1,217	1,246	1,047	1,253	1,246
7	641	1,253	1,246	1,044	1,253	1,246
8	641	1,253	1,246	1,159	1,253	1,246
9	641	1,253	1,246	1,246	1,253	1,130
10	641	1,253	1,246	1,246	1,253	1,239
11	641	1,253	1,247	1,246	1,253	1,239
12	641	1,253	1,248	1,246	1,253	1,239
13	641	1,253	1,246	1,246	1,253	1,239
14	641	1,253	1,246	1,246	1,253	1,239
15	641	1,253	1,246	1,246	1,253	1,239
16	641	1,253	1,246	1,246	1,253	1,239
17	641	1,253	1,246	1,251	1,253	1,239
18	641	1,253	1,246	1,253	1,253	1,239
19	641	1,249	1,246	1,253	1,253	1,239
20	420	1,246	1,246	1,253	1,253	1,132
21	246	1,246	1,246	1,253	1,253	992
22	292	1,246	1,246	1,253	1,124	988
23	292	1,246	1,246	1,253	1,079	1,037
24	292	1,246	1,246	1,253	1,168	1,054
25	292	1,246	1,246	1,253	1,065	842
26	287	1,246	1,246	1,253	1,253	844
27	622	1,246	1,246	1,253	1,253	842
28	648	1,246	1,169	1,253	1,253	842
29	648	1,246	1,070	1,253	1,253	861
30	626	1,246	1,246	1,253	1,253	762
31	582	--	1,246	--	1,253	883

Source: Con Edison 1979.

4. ENTRAINMENT SURVIVAL STUDIES

4.1 INTRODUCTION

The 1979 entrainment survival studies were designed to determine the survival of ichthyoplankton that passed through the condenser cooling systems of the Indian Point Generating Station, and represent a continuation of studies conducted by Ecological Analysts in 1977 and 1978 (EA 1978a, 1979a). The 1979 studies consisted of two principal sampling efforts: (1) a late winter sampling effort directed towards assessing the entrainment survival of Atlantic tomcod (*Microgadus tomcod*), a winter spawning species; and (2) a spring-summer sampling effort that focused on determining entrainment survival of striped bass (*Morone saxatilis*), white perch (*M. americana*), herrings (Clupeidae), and anchovies (Engraulidae), which utilize the Hudson River estuary as a spawning and nursery area during spring and summer months.

Although pump/larval table collection systems were used for the 1977 and 1978 survival studies, as well as the late winter (Atlantic tomcod) study effort in 1979, a new gear design was applied during the 1979 spring-summer sampling effort to reduce sampling stress on more sensitive taxa and life stages. These collection systems, referred to as the pumpless (discharge) and rear-draw (intake) plankton sampling flumes, utilize head-induced flow to deliver samples into raft-mounted flumes, thus eliminating the passage of organisms through a sampling pump. Flotation of the samplers additionally permitted closer access to the point of sample withdrawal, and facilitated sampling at the discharge ports located along a steel bulkhead at the extreme end of the discharge canal. The new, raft-mounted collection systems were not installed during the late winter sampling effort in 1979 because of the hazards of ice floes which are prevalent during this time of year.

The effects of entrainment on ichthyoplankton collected during the study efforts were examined by comparing survival at discharge sampling stations with survival at intake stations, which served as controls on the effects of sampling and holding. Initial survival was determined from the number of live and dead ichthyoplankton collected, and extended survival of live organisms was monitored for 96 hours to evaluate latent effects of entrainment.

4.2 METHODS AND MATERIALS

4.2.1 Sampling Procedures

4.2.1.1 Atlantic Tomcod Entrainment Survival Study

4.2.1.1.1 Sampling Schedule and Station Locations

Entrainment survival sampling for Atlantic tomcod was conducted from 12 to 22 March 1979. Scheduling of sampling was coordinated with entrainment abundance monitoring conducted by Ecological Analysts at the nearby Bowline Point Generating Station (river mile 39), and was initiated upon notification of the first occurrence of tomcod larvae. Entrainment survival sampling at the Indian Point plant was then conducted on four consecutive nights per week over the 2-week sampling period (a total of 8 sampling days). Sampling occurred between 1700 and 0200 hours to coincide with the diel period of peak abundance of Atlantic tomcod larvae (EA 1979c). Although this sampling effort was originally anticipated to encompass a period during which both Unit 2 and Unit 3 were operational, an unscheduled maintenance shutdown of Unit 3 occurred on 20 March and the unit remained down through the completion of sampling on 22 March. During this shutdown, Unit 3 did not generate power, but two circulating pumps were operated (Table 4-1).

The pump/larval table collection systems used for Atlantic tomcod sampling were initially positioned at two stations along the discharge canal (Stations D3 and DP), and at the Unit 2 and Unit 3 intakes (Stations I2 and I3) which served as controls (Figure 3-2 and Table 4-1). The Station D3 collection system was located at the point where cooling water from Unit 3 enters the discharge canal, and sampled only discharge water from Unit 3. The collection system at Station DP was located near the end of the discharge canal, and sampled a mixture of discharge water from all operating units. As a result of the unscheduled maintenance shutdown of Unit 3, samples were not collected at Station I3 or Station D3 from 20 to 22 March. To maximize discharge sampling following this shutdown, the collection system at Station D3 was moved approximately 50 m downstream to Station D2, located along that portion of the discharge canal which receives cooling water from all operational units.

Each pump/larval table collection system was equipped with two pumps to simultaneously collect samples from two locations per station. At each discharge station the 10 cm (4 in.) diameter pump intake hoses were positioned approximately 2 m apart and sampled water from 1 to 5 m below the surface of the discharge canal. The intake hoses at Stations D3 and DP were oriented horizontally into the water flow, whereas at Station D2, the intake hoses were perpendicular to the current. At intake Station I2, samples were collected at middepth from intake bays 22 and 25, and at Station I3, samples were collected at middepth from intake bays 33 and 35.

4.2.1.1.2 Gear Description

The pump/larval table collection system used for Atlantic tomcod sampling consisted of a modular two-screen collection flume (Figure 4-1), modified from the design of McGroddy and Wyman (1977). Sample water was delivered to the table by two 10 cm (4 in.) diameter Homelite centrifugal pumps (two-vane open impeller) capable of passing solids up to about 5 cm in diameter. The flow rates and volumes of water pumped into each collection system were monitored with inline Sparling "Masterflo" flowmeters. The total volume of water sampled at each system during the standard 15 minute sampling interval ranged from 7 to 24 m^3.

Samples were collected and concentrated in the larval tables which are approximately 8.2 m long, 1.2 m wide, and 0.6 m deep (Figure 4-1). The front of each table expanded from the two 10 cm (4 in.) hose openings to full table width, thus reducing the velocity and turbulence of the pumped water. At the end of the expansion section, two directional screens (505 μm mesh) diverted organisms, debris, and a small portion of the water into a collection box. A valve (Q2 valve) controlled the flow of water through the collection box during sampling and was also used to drain the collection box at the end of the sampling interval. The remaining water exited through the overflow weirs behind the two directional screens. Valves located adjacent to the overflow

TABLE 4-1 SUMMARY OF CIRCULATING PUMP OPERATION AND STATIONS SAMPLED DURING THE LATE WINTER (ATLANTIC TOMCOD) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

		Number of Circulating Pumps Operating by Unit[a]	
Sampling Date	Sampling Station	Unit 2	Unit 3
12 MAR	I2, I3, D3, DP	6	5
13 MAR	I2, I3, I3, DP	6	5
14 MAR	I2, I3, D3, DP	6	5
15 MAR	I2, I3, D3, DP	6	5
19 MAR	I2, I3, D3, DP	6	5
20 MAR	I2, D2, DP	6	2
21 MAR	I2, D2, DP	6	2
22 MAR	I2, D2, DP	6	2

(a) Circulating water pumps for Units 2 and 3 were run at 60 percent rated capacity during late winter entrainment survival sampling; Unit 1 circulating pumps were not operated.

Source: Con Edison 1979.

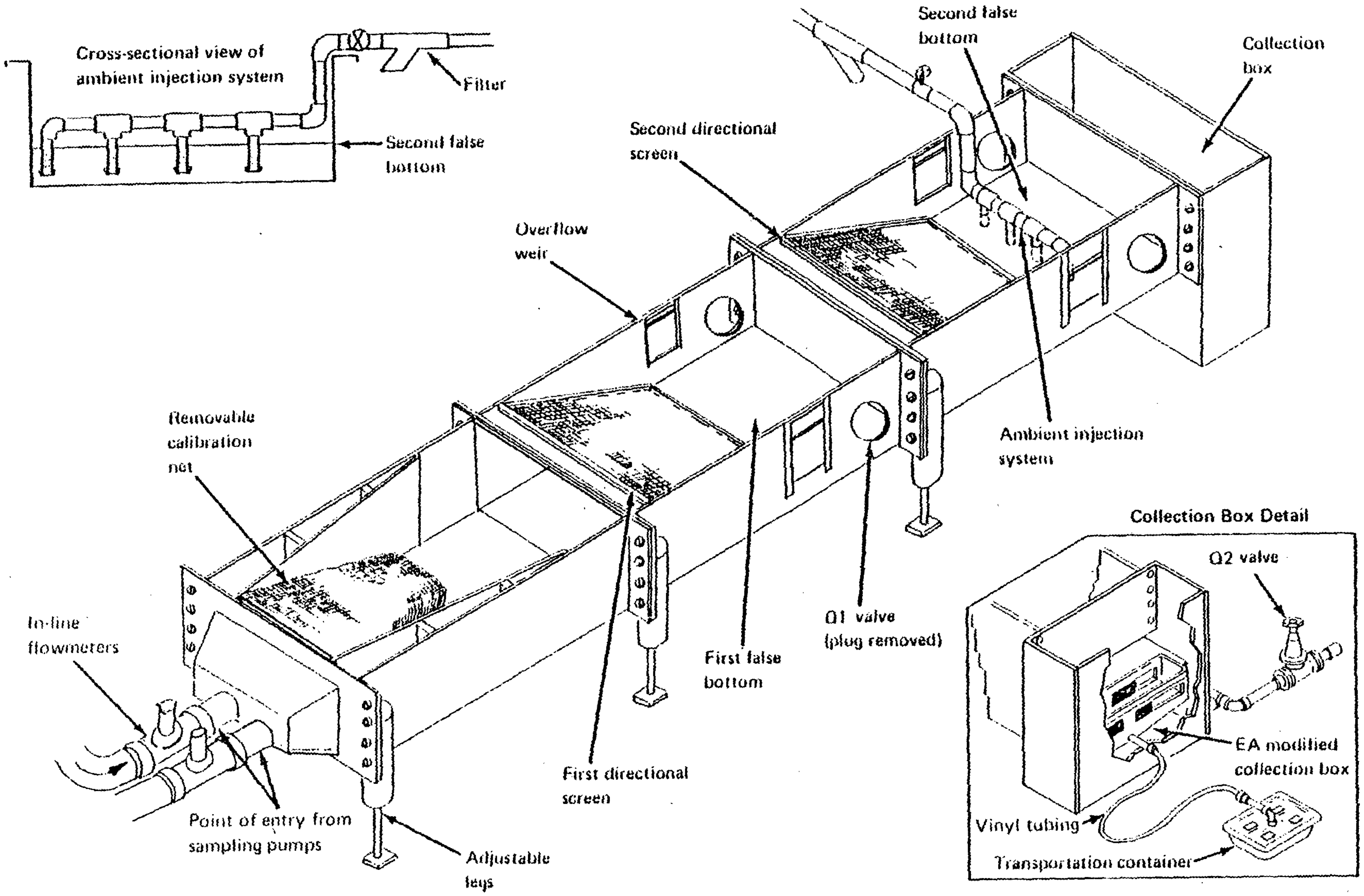


Figure 4-1. Design of the larval table collection system used during the late winter entrainment survival study, Indian Point Generating Station, 1979.

weirs (Q1 valves) were used to drain the table at the end of the sampling interval. The time required to rinse and drain the collection systems was approximately 25 minutes.

An ambient water injection system was used to reduce the exposure of organisms to elevated discharge temperatures during collection (Figure 4-1). This system injects filtered ambient river water into the larval table below the second false bottom at a rate of about 75 liters per minute, reducing the delta-T in the collection system by approximately 35 to 50 percent at the discharge stations. Limiting the thermal exposure during collection was necessary because normal through-plant transit times are about 5 to 10 minutes as compared to a 40 minute exposure in the larval table (sampling time plus table draining time). The ambient injection system was also used at the intake stations to maintain comparable methods at intake (control) and discharge (experimental) stations.

Specific information relative to the sampling gear and associated sampling conditions at each station are presented in Appendix C, Tables C-1 and C-2.

4.2.1.1.3 Collection Procedures

Each sample taken with the pump/larval table during the Atlantic tomcod sampling season was collected by pumping water through the system for 15 minutes. Before sampling, the pumps were started and the table was filled with water. The speed of the pumps was adjusted to 1,800-2,000 rpm and maintained at this speed throughout sample collection. A removable calibration net (505 μm mesh) inserted near the front of each table prevented contamination of the sample with organisms that may have been collected during the start-up period. The ambient injection system was also started prior to sampling.

Sampling was initiated simultaneously at intake and discharge stations by removing the calibration net from each larval table. At the end of the 15-minute sampling interval, the pumps at each station were turned off and the table was drained. The ambient injection system remained on until the water in the table reached the false bottom level. The table was continuously rinsed with a gentle flow of filtered ambient temperature river water during draining. After the sample was concentrated into the collection box, organisms and detritus were drained through a 3 cm vinyl tube into a detachable transportation container, and transferred to the onsite laboratory for sorting. The larval tables were thoroughly rinsed between samples with a high pressure spray wash to prevent contamination of subsequent samples by detritus and/or organisms adhering to the sides of the table and screens.

4.2.1.2 Striped Bass, White Perch, Herring, and Anchovy Entrainment Survival Study

4.2.1.2.1 Sampling Schedule and Station Locations

Entrainment survival sampling for striped bass, white perch, herrings, and anchovies was conducted from 30 April through 14 August 1979, coincident with the primary spawning and nursery seasons of these species. Samples were collected on two consecutive nights each week (a total of 32 sampling days) between 1800 and 0200 hours to coincide with the increased nocturnal abundance of ichthyoplankton that has been observed in the Indian Point region (EA 1980a). Throughout the spring-summer entrainment survival study, sampling was conducted at the outflow of a discharge port (Station DP) using a pumpless plankton sampling flume, and at the Unit 3 intake (Station I3) using a rear-draw plankton sampling flume (Figure 3-2). During the sampling period, Unit 3 operated continuously, Unit 2 operated only through 15 June, and Unit 1 did not generate power but ran one circulating pump during late June and early July (Table 4-2).

4.2.1.2.2 Gear Description

In contrast to the land-based pump/larval table collection systems used during the 1979 Atlantic tomcod sampling effort (Section 4.2.1.1), and during entrainment survival studies in 1977 and 1978 (EA 1978a, 1979a), the pumpless and rear-draw plankton sampling flumes were raft-mounted and utilized head-induced flow rather than pumps for sample delivery. This design was developed to reduce sampling stresses on more sensitive ichthyoplankton taxa and life stages by eliminating potential mechanical and pressure effects associated with pump collection. Internal aspects of the intake and discharge flumes (e.g., length and width dimensions, orientation of the water inlet, flow expansion panels, diversion screens, ambient injection systems, and collection box) were designed in the same manner (Figure 4-2) to minimize the potential of differential gear effects on organism survival.

The pumpless plankton sampling flume (2.4 x 1.2 x 0.6 m) was positioned along the outside (river) face of the discharge canal bulkhead adjacent to the northernmost discharge port (Figure 4-3). The sampler was secured in a raft support structure such that the bottom of the flume was maintained at the river surface. Water and organisms exiting the discharge port entered a 15.2 cm (6 in.) curved steel pipe, mounted near the center and flush with the mouth of the port. The sample then passed, via a length of flexible hose, to the inlet of the collection flume. Dynamic head created by the water flow exiting the discharge port (about 10 fps) was sufficient to deliver sample water to the collection flume from a depth of 3.7 m below the river surface at mean low water. Upon entering the collection flume, the temperature of the discharge sample was reduced approximately 2-3 C using an ambient injection system that supplied a fine spray of ambient river water along the sides of the flow expansion panels, diversion screens, and collection box. By the time the entire sample has been concentrated into the transportation container, the sample temperature approaches ambient temperature because the ambient injection system remains on throughout the draining of the flume and, therefore, flushes most of the discharge water from the transportation container.

Organisms and detritus filtered by the two vertical 505 μm mesh screens were diverted into the collection box. Water passage through the sampler, as well as drainage and sample concentration, were achieved by gravity flow since the water level in the flume was above the river surface. Filtered sample water exited the collection system through a Q2 valve located beneath the collection box and through Q1 outlets located behind the vertical screens. Flexible hoses, attached to the Q1 outlets, could be raised or lowered to increase or reduce water flow through the system. Volume of sampled water was measured with a Signet inline flowmeter attached to the flume inlet. Volume filtered during each sample ranged from 3.7 to 19.8 m^3, and varied according to head differences between the water level in the discharge canal and river as

TABLE 4-2 SUMMARY OF CIRCULATING PUMP OPERATION DURING THE SPRING-SUMMER (STRIPED BASS, WHITE PERCH, HERRING, AND BAY ANCHOVY) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

Sampling Date	Number of Circulating Pumps Operating by Unit[a]		
	Unit 1	Unit 2	Unit 3
30 APR	0	6	6
3 MAY	0	6	6
4 MAY	0	6	6
7 MAY	0	6	6
8 MAY	0	6	6
10 MAY	0	6	6
11 MAY	0	6	6
15 MAY	0	6	6
17 MAY	0	6	6
24 MAY	0	6	6
25 MAY	0	6	6
26 MAY	0	6	6
31 MAY	0	6	6
1 JUN	0	6	6
7 JUN	0	6	5
8 JUN	0	5	6
14 JUN	0	6	6
15 JUN	0	6	6
18 JUN	1	0	6
19 JUN	1	0	6
25 JUN	1	0	6
26 JUN	1	0	6
5 JUL	1	0	6
6 JUL	1	0	6
7 JUL	1	0	6
9 JUL	1	0	6
10 JUL	0	0	6
16 JUL	0	0	6
17 JUL	0	0	6
18 JUL	0	0	5
23 JUL (0001-2038 hours)	0	0	5
23 JUL (2038-2400 hours)	0	0	6
24 JUL	0	0	5
30 JUL	0	0	6
31 JUL	0	0	6

(a) Circulating water pumps were run at full capacity during spring-summer entrainment survival sampling.

Source: Con Edison 1979.

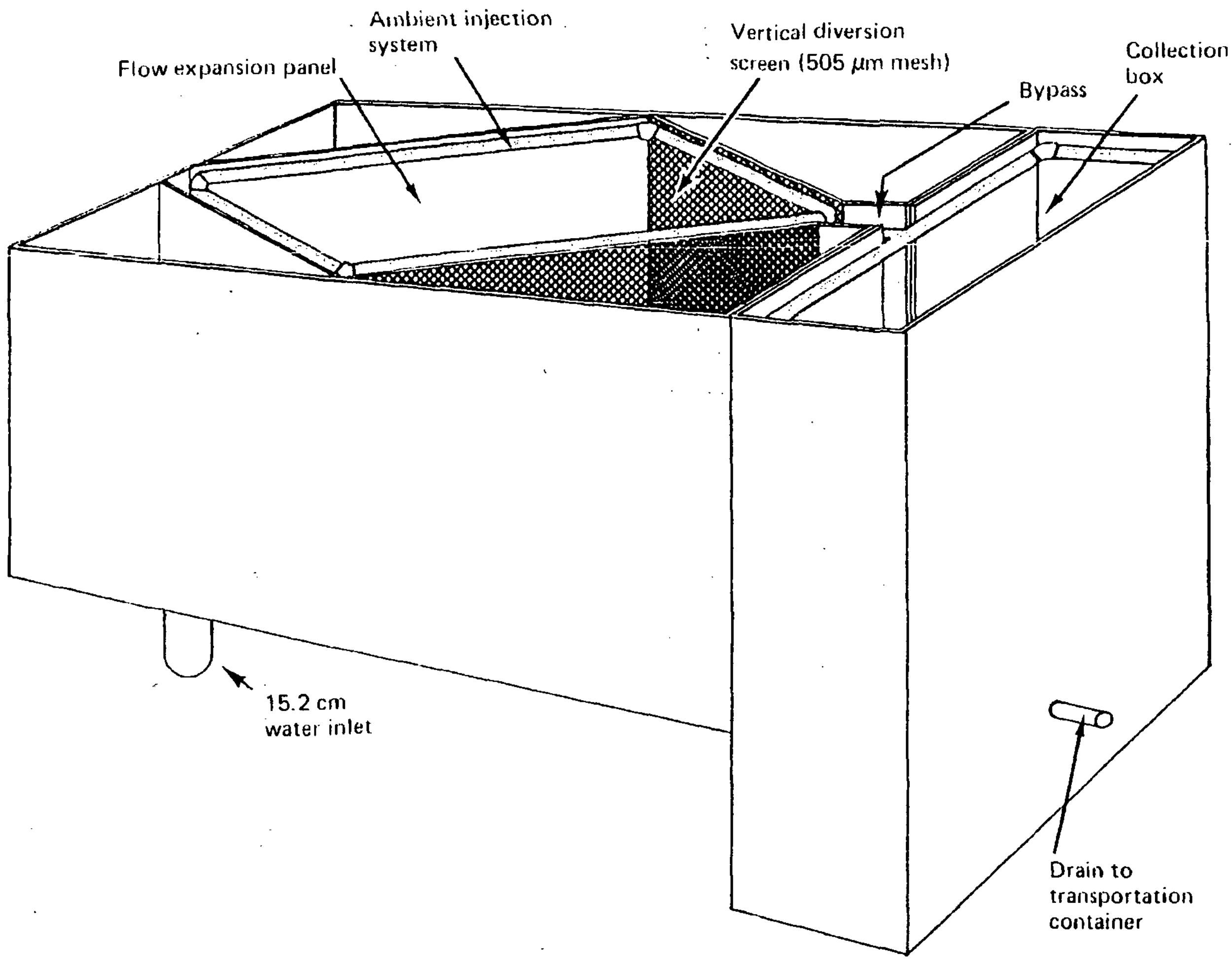


Figure 4-2. Design of the collection flume used in the pumpless and rear-draw samplers during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

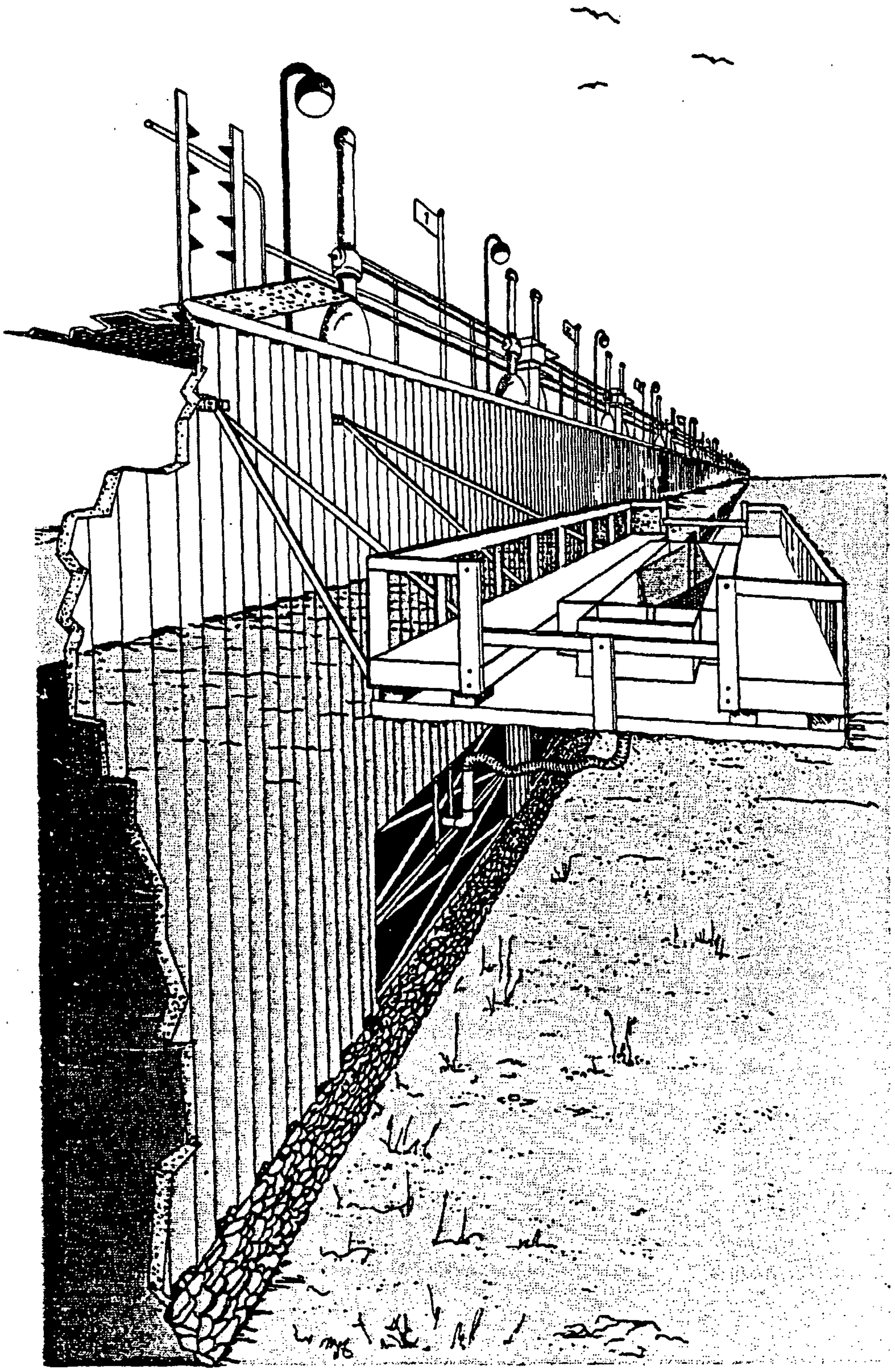


Figure 4-3. Basic configuration of the pumpless plankton sampling flume system used at the discharge port (Station DP) during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

affected by tide and plant operation. The time required to drain the sampler ranged from 12 to 15 minutes.

The rear-draw plankton sampling flume (Figure 4-4), which measured 2.4 x 1.2 x 1.2 m, 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 were consistent with those of the pumpless plankton sampling flume, and sample delivery was similarly implemented by head-induced flow. However, because the water velocities at this station (approximately 1.0 fps) were insufficient to supply an adequate sample flow to the collection device, a head differential was created by submersing the bottom of the flume about 0.6 m below the river surface and pumping water from behind the angled 505 μm mesh diversion screens using a 10 cm (4 in.) Homelite pump. Water was also withdrawn through a Q2 valve beneath the collection box using a 1 hp Goulds pump which recirculated water to the ambient injection system. Sample water entered the collection flume through a length of 15.2 cm (6 in.) diameter flexible hose attached to the flume inlet. The mouth of the hose, which faced into the intake flow, was initially suspended at a depth of 2 m (30 April to 11 May), but was subsequently adjusted to a depth of 3.7 m for the remainder of the sampling period (15 May to 14 August) 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, and ranged from 8.4 to 17.9 m^3 per sample. Gravity-induced drainage was achieved by raising the collection flume above the river surface with a hoist attached to a frame on the raft, and allowing water to pass out of the collection system through Q1 outlets located behind the diversion screens. Drain time ranged from 8 to 10 minutes per sample.

Specific information relative to sampling gear and associated sampling conditions at each station are presented in Appendix C, Table C-3.

4.2.1.2.3 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 injection systems were activated to fill the collection flumes with 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, if necessary, to conform with the sampling flow at the discharge station.

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 sampler. To facilitate draining, the Q1 hoses on the pumpless (discharge) flume were lowered their full extent. The rear-draw (intake) flume was raised and the plugs were removed from the Q1 outlets. The ambient injection systems remained on until the samplers were nearly drained to rinse the contact surfaces of the flow expansion panels, divergence screens, and collection boxes. Rinsing of the interior of the samplers was also supplemented with a gentle flow of filtered ambient river water from a garden hose. Once the samples were concentrated in the collection boxes, the Q2 valves were closed, and the Q2 pump at the rear-draw sampler (Figure 4-4) was turned off. Organisms and detritus were then drained through 3 cm tubes at the bottom of the collection boxes into detachable transportation containers, and the samples were transferred to

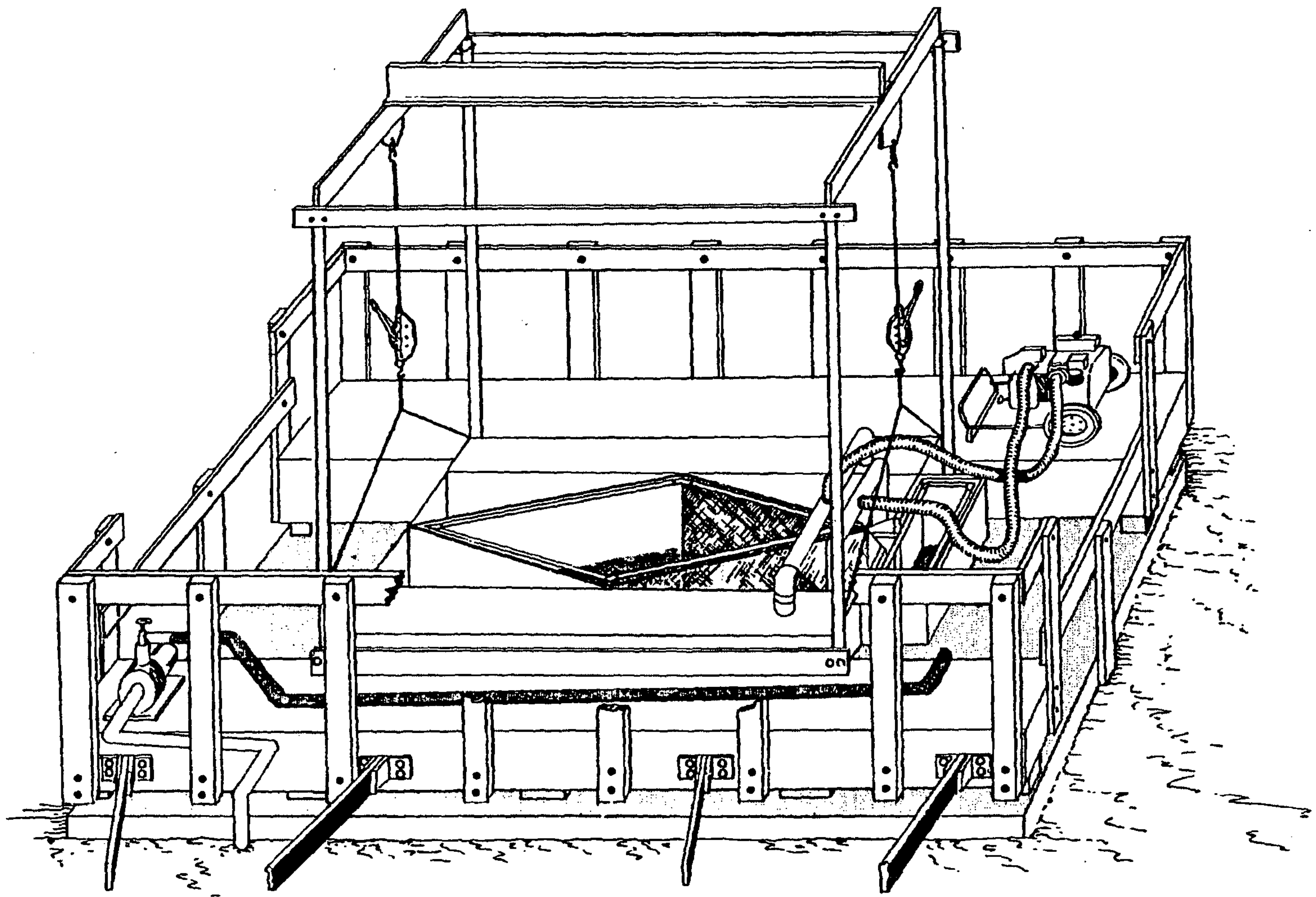


Figure 4-4. Rear-draw plankton sampling flume system used at the Unit 3 intake (Station 13) during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

the onsite laboratory for sorting. The flumes and collection boxes were thoroughly rinsed between samples with a high pressure spray wash to prevent contamination of subsequent samples from detritus and/or organisms adhering to the surface of the sampler.

4.2.1.3 Water Quality Measurements

Measurements of water temperature, conductivity, dissolved oxygen, and pH were taken during each sampling effort for both the late winter and spring-summer entrainment survival studies. Water temperature was recorded at each station during each sample collection. Conductivity, dissolved oxygen, and pH were measured at one of the intake stations only during the first, middle, and last collections on each sampling night. Water quality data collected at the intake stations during the late winter and spring-summer entrainment survival studies are presented in Tables 4-3 and 4-4, respectively.

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 were processed as indicated in Figure 4-5. 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 life 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. Using a large bore pipette, live and stunned larvae were carefully transferred 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 cannabalism. The holding jars were aerated and maintained in an ambient water bath for 96 hours after collection. Live eggs were carefully transferred from the sorting trays to egg holding cups with an inverted, dropping pipette. 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,

TABLE 4-3 AVERAGE TEMPERATURE, DISSOLVED OXYGEN, pH, AND CONDUCTIVITY RECORDED AT THE INTAKE STATIONS DURING THE LATE WINTER (ATLANTIC TOMCOD) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Date	Temp (C)	DO (ppm)	Cond (µmho)	pH
12 MAR	3.2	16.3	47	7.8
13 MAR	3.2	15.3	40	7.7
14 MAR	2.2	14.6	40	7.8
15 MAR	1.6	15.7	30	8.0
19 MAR	3.8	14.2	55	7.9
20 MAR	4.3	13.0	67	8.1
21 MAR	4.6	12.4	67	8.1
22 MAR	4.7	13.4	67	8.1

TABLE 4-4 AVERAGE TEMPERATURE, DISSOLVED OXYGEN, PH, AND CONDUCTIVITY RECORDED AT STATION I3 DURING THE SPRING-SUMMER (STRIPED BASS, WHITE PERCH, HERRING, AND BAY ANCHOVY) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

Date	Temp (C)	DO (ppm)	Cond (µmho)	pH
30 APR	11.7	7.8	100	8.3
3 MAY	12.9	8.6	100	8.2
4 MAY	12.8	9.8	130	7.8
7 MAY	14.8	8.0	175	7.9
8 MAY	14.2	8.2	160	7.6
10 MAY	16.7	7.3	340	8.0
11 MAY	17.3	7.9	890	7.7
15 MAY	16.8	12.2	188	7.6
17 MAY	18.0	8.7	123	7.5
24 MAY	20.1	--	--	--
25 MAY	17.3	9.2	160	7.5
31 MAY	18.5	7.3	395	7.8
1 JUN	19.0	8.2	345	7.7
7 JUN	20.8	8.5	1,106	7.7
8 JUN	20.9	8.7	1,467	7.5
14 JUN	20.8	12.7	514	7.6
15 JUN	21.5	11.2	349	7.4
18 JUN	23.2	9.5	311	7.3
19 JUN	22.7	8.8	254	7.4
25 JUN	22.0	8.0	250	7.3
26 JUN	22.1	8.6	540	7.1
5 JUL	22.6	10.1	2,110	7.6
6 JUL	22.7	7.5	2,898	7.8
9 JUL	22.6	7.2	3,510	7.8
10 JUL	22.7	7.2	2,931	7.9
16 JUL	24.7	6.5	4,270	7.6
17 JUL	25.2	6.4	3,892	7.6
23 JUL	25.7	6.4	3,133	7.4
24 JUL	26.2	6.5	3,443	7.4
30 JUL	27.3	6.4	3,640	7.5
31 JUL	27.4	6.3	4,137	7.5
7 AUG	28.2	6.2	5,110	7.3
8 AUG	27.3	6.1	4,125	7.3
13 AUG	25.9	7.0	4,107	7.5
14 AUG	26.2	6.5	4,676	7.5

Note: Dashes (--) indicate data were not available.

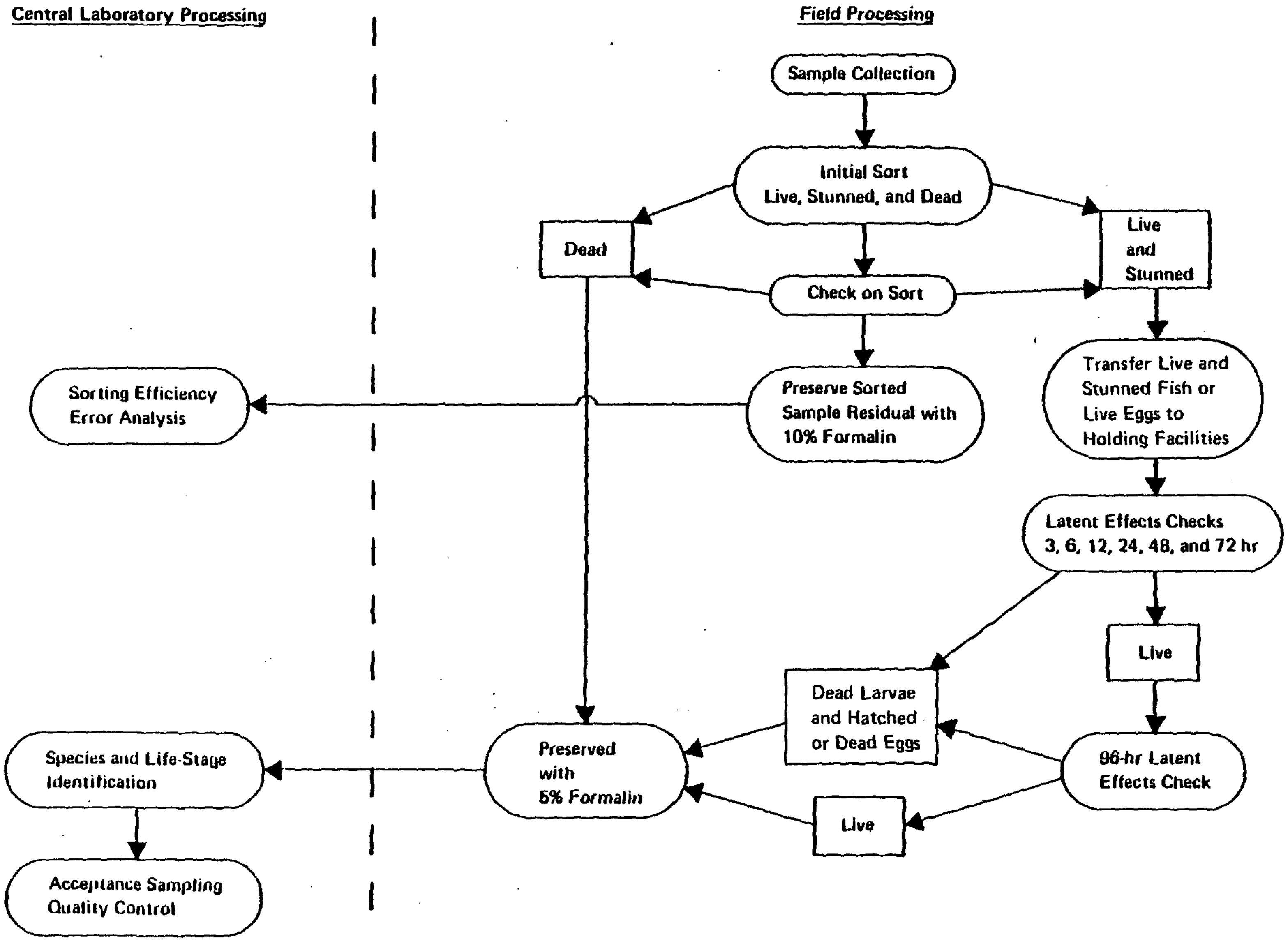


Figure 4-5. Work-flow chart for ichthyoplankton survival determinations.

New York, for identification and classification according to taxon and life stage. The total length of each specimen was determined to the nearest millimeter.

4.2.2.2 Extended Survival Observation Procedures

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

4.2.2.3 Quality Assurance and Control

Quality assurance and control procedures were employed 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 conducted 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 strict adherence to standard operating procedures. Quality control procedures established at the Central Laboratory included resorting of randomly selected preserved samples to document the sorting efficiency at the onsite laboratory, and the application of statistical quality control procedures (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, as shown in the equation below:

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

where

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

This method, which takes into account both initial and latent effects, was used because of the difficulty of visually determining live versus dead condition for the egg stage. The standard error of the survival proportion was calculated as:

$$\text{Standard error} = \sqrt{\frac{P\ (1-P)}{n}}$$

where

P = proportion of eggs surviving
n = total number of eggs collected.

To determine if differences in survival proportions between the intake (control) and discharge stations were statistically significant ($\alpha = 0.05$), the Fisher's exact test was used (Sokal and Rohlf 1969).

4.2.3.1.2 Initial Survival of Larvae and Juveniles

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

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

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 categorization. The standard error of the survival proportion was calculated in the same manner as described for eggs (Section 4.2.3.1.1).

Differences in survival proportions between intake (control) and discharge stations were tested with either Fisher's exact test or multidimensional contingency tables (Sokal and Rohlf 1969), depending upon the number of factors involved in a particular comparison. The probability of a Type I error (α level) was maintained at 0.05 throughout all comparisons.

Initial survival proportions for ichthyoplankton collected at the intake stations were pooled by life stage and species for all collections. Discharge survival proportions were based on data for specific discharge temperature categories. Temperature categories for Atlantic tomcod were: (1) <15.9 C, (2) from 16.0 to 17.9 C, (3) from 18.0 to 19.9 C, and (4) from 20.0 to 21.9 C. Temperature categories for striped bass, white perch, herrings (clupeids), and anchovies (engraulids) were: (1) <30.0 C, (2) from 30.0 to 32.9 C, and (3) $\geq$33.0 C.

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 potential latent effects from 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:

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

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.

The standard error of the normalized survival proportions was calculated according to the following equation:

$$\text{Standard error} = \sqrt{\frac{P_i\ (1-P_i)}{n}}$$

where

P_i = normalized survival proportion at time i

n = total number of initially alive or stunned fish.

Fisher's exact test (Sokal and Rohlf 1969) was used to determine if differences between the intake and discharge normalized extended survival proportions were significant ($\alpha = 0.05$) at each latent effects observation period. Because of the multiple tests and subsequent increased probability of α error on an experiment-wide basis, the only cases considered to be biologically significant were those where survival proportions were significantly different in the same direction for three consecutive latent effects observation periods.

4.2.3.2 Entrainment Survival Estimates

Entrainment survival estimates for eggs were determined by comparing proportions which hatched within 96 hours for intake and discharge samples. For larval and juvenile life stages, entrainment survival estimates were based on the initial survival proportions for the intake and discharge stations. Survival at the discharge stations is the product of the conditional probabilities of surviving entrainment and sampling. Assuming there is no interaction between the two stresses:

$$P_D = P_s \times P_e$$

where

P_D = probability of surviving at the discharge
P_s = probability of surviving sampling
P_e = probability of surviving entrainment.

The intake survival proportion (P_I) was used as an estimate of P_s, and entrainment survival was quantified using the equation:

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

where

S_e = entrainment survival.

The value S_e thus represents the percentage of organisms that survive passage through the plant cooling water system. Entrainment survival estimates were calculated only when the total number of a particular species and life stage were collected per station or temperature category was 10 or greater.

4.3 RESULTS AND DISCUSSION

4.3.1 Atlantic Tomcod Entrainment Survival Study

During the late winter Atlantic tomcod entrainment survival study (12 to 22 March 1979), Unit 2 of the Indian Point plant operated continuously, whereas an unscheduled maintenance shutdown of Unit 3 occurred on 20 March and extended through the remainder of the study period. Although Unit 3 did not generate power during this shutdown, two circulating water pumps were maintained in operation. Pump/larval table collection systems were used to sample at intake Stations I2 and I3, and discharge Stations D3 and DP during the period when Units 2 and 3 operated simultaneously (12 to 19 March). After the Unit 3 outage (20 to 22 March), sampling at Stations I3 and D3 (specific to Unit 3), was discontinued, and the D3 collection system was relocated to a site (Station D2) along the common discharge canal which receives cooling water from all operational units.

Survival of Atlantic tomcod collected during the 2-week study period was analyzed to determine possible effects of plant operation (i.e., one-unit versus two-unit generation), sampling station, and discharge temperature. Data were examined with respect to four discharge temperature categories, <16.0 C, 16.0 to 17.9 C, 18.0 to 19.9 C, and ≥20.0 C. These categories were chosen to evaluate survival at temperatures for which no thermal mortality would be expected (<16.0 C), for which mortality would be expected (≥20.0 C) (EA 1978b), and at two intermediate temperature ranges.

As a result of the cold ambient water temperatures which prevail during the Atlantic tomcod spawning and nursery period, the early development of this species is slower than that of other Hudson River species that spawn during the spring and summer. Because of the extended developmental process, life stage identification, particularly among tomcod larvae, is sometimes problematic due to the occurrence of overlapping life stage characteristics and the similarity in size between yolk-sac and post yolk-sac larvae. In cases where specific life stage determination was not certain based on morphological characteristics, life stage was assigned according to the procedures described in Appendix E. Analyses presented throughout this section were conducted on all tomcod larvae, including those for which life stage was assigned.

4.3.1.1 Collection of Atlantic Tomcod for Survival Determinations

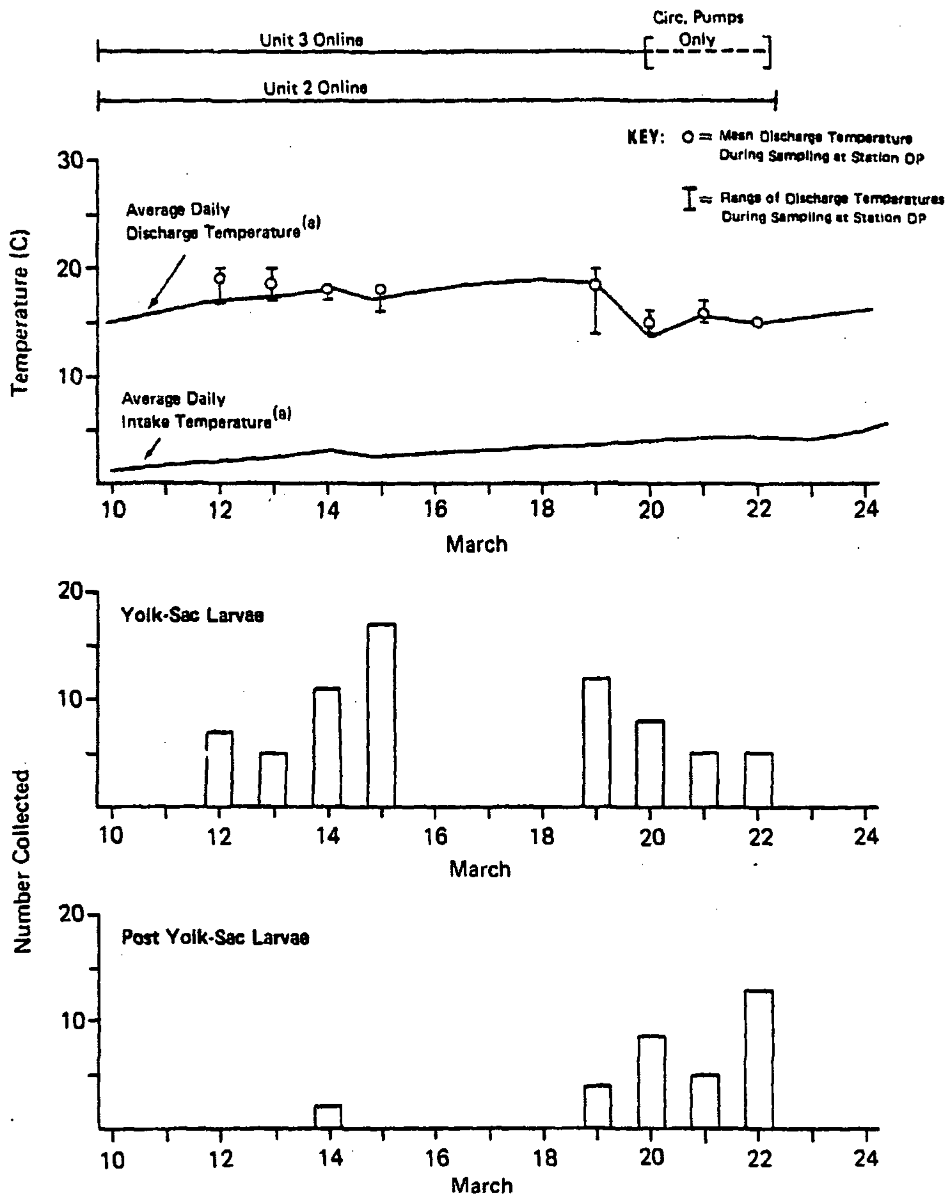
Only larval stages of Atlantic tomcod were collected during the late winter study effort. Yolk-sac larvae were collected throughout the 2-week study period, at average daily intake temperatures (which are representative of ambient conditions) ranging from 2 to 5 C (Figure 4-6). Post yolk-sac larvae occurred primarily during the second week of sampling when average daily intake temperatures varied from 4 to 5 C. Because the Atlantic tomcod is the only fish species that spawns in the Hudson River during winter, ichthyoplankton of other fish taxa were not collected.

Average daily discharge temperatures ranged from 15 to 19 C during the 2-week study period (Figure 4-6). However, discharge temperatures were higher during the period 12 to 19 March (18 to 19 C), when both Unit 2 and Unit 3 were operational, than during 20 to 22 March (15 to 16 C) when only Unit 2 was operational but two of the Unit 3 circulating pumps were discharging unheated water. The majority of Atlantic tomcod yolk-sac larvae (68 percent) were collected during the period of two-unit operation, whereas the majority of post yolk-sac larvae (65 percent) were collected after the shutdown of Unit 3. All Atlantic tomcod larvae sampled during the study period were of similar size, ranging from approximately 6 to 8 mm in length (Appendix Table D-1).

4.3.1.2 Survival Proportions

4.3.1.2.1 Initial Survival

Initial survival proportions for Atlantic tomcod larvae collected at intake stations throughout the study period ranged from 0.596 to 0.679 for yolk-sac larvae, and from 0.429 to 0.647 for post yolk-sac larvae (Table 4-5). For both life stages, initial survival at discharge stations was lower when Units 2 and 3 were both operating (12 to 19 March), than after the Unit 3 outage (20 to 22 March) when only Unit 2 was generating but two Unit 3 circulating pumps were discharging unheated water. During simultaneous operation of Units 2 and 3, initial survival proportions for discharge collections ranged from 0.135 to 0.277 for yolk-sac larvae, and from 0.167 to 0.250 for post yolk-sac larvae. Following the Unit 3 outage, however, initial survival at discharge stations ranged from 0.421 to 0.424 for yolk-sac larvae, and from 0.312 to 0.333 for post yolk-sac larvae. Initial survival proportions for yolk-sac and post yolk-sac larvae were not significantly different (Fisher's exact test, $\alpha = 0.05$) between intake Stations I2 versus I3, or between discharge Stations D3 versus DP when both units were operating (Table 4-5). Similarly, no significant differences ($\alpha = 0.05$) were found between initial survival proportions for either yolk-sac or post yolk-sac larvae collected at discharge Stations D2 versus DP after the Unit 3 outage. The similarity in survival proportions thus permitted pooling of data across stations to increase the power for detecting differences in survival among life stages and operating conditions.



(a) Source for average daily intake and discharge temperatures was Con Edison 1979.

Figure 4-6. Temporal distribution and thermal exposure of Atlantic tomcod collected at the discharge port station (DP) during the late winter entrainment survival study, Indian Point Generating Station, 12–22 March 1979.

TABLE 4-5 INITIAL SURVIVAL PROPORTIONS FOR ATLANTIC TOMCOD YOLK-SAC AND POST YOLK-SAC LARVAE COLLECTED DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

				Yolk-Sac Larvae				Post Yolk-Sac Larvae			
Station	Unit Operation[a]	March Sampling Dates	Temp. Range (C)	Number Collected	Survival Proportion	Standard Error	P[b]	Number Collected	Survival Proportion	Standard Error	P[b]
I2	2 unit	12-19	1.0-5.7	78	0.679	0.05	0.215	17	0.647	0.12	0.197
I3	2 unit	12-19	2.0-5.0	52	0.596	0.07		14	0.429	0.13	
D3	2 unit	12-19	12.0-21.0	48	0.271	0.06	0.073	11	0.273	0.13	0.555
DP	2 unit	12-19	14.0-20.0	52	0.135	0.05		6	0.167	0.15	
I2	1 unit	20-22	3.8-5.3	56	0.607	0.07		49	0.633	0.07	
D2	1 unit	20-22	13.0-17.0	35	0.457	0.08	0.582	16	0.312	0.12	0.548
DP	1 unit	20-22	15.0-17.0	18	0.444	0.12		26	0.346	0.09	

(a) Two unit operation refers to the simultaneous operation of Unit 2 and Unit 3; one unit operation refers to the operating condition when only Unit 2 was generating but two Unit 3 circulating pumps were discharging unheated water.
(b) Fisher's exact probability ($\alpha = 0.05$) of obtaining the observed or more dissimilar survival proportions under $H_0:P_1=P_2$ where P_1 and P_2 were determined from samples collected at I2 and I3, D3 and DP, and D2 and DP, respectively, in the separate test comparisons.

To determine the effects of unit operation (i.e., one- or two-unit generation) and life stage on initial survival proportions for Atlantic tomcod collected at intake and discharge stations, a three-way contingency analysis was used (Sokal and Rohlf 1969). For the intake stations, this analysis demonstrated that initial survival was independent of unit operation and life stage (Table 4-6), thus indicating that data from intake stations could validly be combined across life stages and plant operating conditions to produce a single estimate of intake survival. The three-way contingency analysis for the intake collections also demonstrated a significant ($\alpha = 0.05$) relationship between unit operation and life stage caused by the non-random occurrence of yolk-sac and post yolk-sac larvae over the sampling period; i.e., under both operating conditions, yolk-sac larvae were more abundant in collections than post yolk-sac larvae. This relationship was primarily responsible for the significant lack of independence ($\alpha = 0.05$) reflected in the combined test results (Table 4-6).

Based on the three-way contingency analysis, initial survival of Atlantic tomcod larvae collected at the discharge stations was also independent of life stage, and a relationship between unit operation and life stage was again demonstrated (Table 4-6). However, for the discharge stations, a significant lack of independence ($\alpha = 0.05$) was observed between initial survival and unit operation indicating that plant operation affected survival. The most obvious factor that could cause a difference in survival under the two operating conditions was discharge temperature; since maximum temperatures at the discharge stations were 3 to 4 C cooler during single unit generation (Table 4-5).

To examine the effect of temperature on the survival of Atlantic tomcod, life stages were pooled (since life stage and survival were found to be independent) and data collected during both one- and two-unit generation were separated into the four discharge temperature categories (<16.0 C, 16.0 to 17.9 C, 18.0 to 19.9 C, and ≥20.0 C). Resultant survival proportions determined for these categories indicated that initial survival decreased progressively as discharge temperatures increased (Table 4-7). The highest discharge station survival proportion for yolk-sac and post yolk-sac larvae combined (0.398) occurred at temperatures <16.0 C, whereas the lowest survival proportion (0.071) occurred at temperatures ≥20.0 C. Survival proportions at the two intermediate discharge temperature ranges, 16.0 to 17.9 C and 18.0 to 19.9 C, were 0.323 and 0.183, respectively. For all discharge collection temperatures (12.0 to 21.0 C), the overall initial survival proportion was 0.283. In contrast, the overall initial survival proportion for Atlantic tomcod larvae collected at all intake collection temperatures (1.0 to 5.7 C) was 0.624, as determined from data pooled over sampling station, life stage, and plant operating condition.

4.3.1.2.2 Extended Survival

Mortality of Atlantic tomcod during extended survival observations occurred almost entirely within the first 12 hours for yolk-sac larvae and within the first 6 hours for post yolk-sac larvae (Table 4-8; Figure 4-7). This trend was observed for intake as well as discharge collections during periods of both one- and two-unit generation. The difference in normalized extended survival between life stages at intake stations was statistically significant (Fisher's exact test, $\alpha = 0.05$) (Table 4-9). As a result of this difference,

TABLE 4-6 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG PLANT OPERATING CONDITION (O), LIFE STAGE (L), AND INITIAL SURVIVAL (S) FOR ATLANTIC TOMCOD LARVAE COLLECTED AT INTAKE AND DISCHARGE STATIONS DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

	Intake Stations		Discharge Stations	
Hypothesis Tested	Degrees of Freedom	G[a]	Degrees of Freedom	G[a]
O x L independence	1	22.48[b]	1	23.34[b]
O x S independence	1	0.02	1	9.64[b]
L x S independence	1	0.28	1	0.06
O x L x S interaction	1	0.80	1	1.44
O x L x S independence	4	23.58[b]	4	34.48[b]

(a) Test statistic; critical value is equal to χ^2 value with appropriate degrees of freedom and α level.

(b) Significant at $\alpha = 0.05$.

Note: Plant operating condition denotes either one unit generation (when only Unit 2 was generating power but two Unit 3 circulating pumps were discharging unheated water), or two unit generation (when Unit 2 and Unit 3 operated simultaneously).

TABLE 4-7 INITIAL SURVIVAL PROPORTIONS FOR ATLANTIC TOMCOD LARVAE COLLECTED AT DISCHARGE STATIONS[a] OVER FOUR DISCHARGE TEMPERATURE RANGES DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Discharge Temperature Range (C)	Number Collected	Initial Survival Proportion	Standard Error
12.0-15.9	93	0.398	0.05
16.0-17.9	31	0.323	0.08
18.0-19.9	63	0.183	0.05
20.0-21.9	25	0.071	0.05
12.0-21.9	212	0.283	

(a) Survival proportions pooled for stations (D2, D3, and DP), life stage (yolk-sac and post yolk-sac larvae), and operating condition (one- and two-unit generation).

TABLE 4-8 NORMALIZED EXTENDED SURVIVAL PROPORTIONS FOR ATLANTIC TOMCOD YOLK-SAC AND POST YOLK-SAC LARVAE COLLECTED DURING THE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Life Stage	Station	Unit Operation[a]	Initial Number Alive	Survival Proportions ±1 Standard Error — Time After Collection (hours): 3	6	12	24	48	72	96
Yolk-sac larvae	I2 + I3	1 + 2 unit (combined)	118	0.754±0.04	0.585±0.05	0.390±0.04	0.373±0.04	0.347±0.04	0.347±0.04	0.347±0.04
	D3 + DP	2 unit	20	0.650±0.11	0.450±0.11	0.200±0.09	0.150±0.08	0.150±0.08	0.150±0.08	0.150±0.08
	D2 + DP	1 unit	24	0.833±0.08	0.625±0.10	0.375±0.10	0.292±0.09	0.292±0.09	0.292±0.09	0.292±0.09
Post yolk-sac larvae	I2 + I3	1 + 2 unit (combined)	48	0.854±0.05	0.750±0.06	0.729±0.06	0.729±0.06	0.688±0.07	0.667±0.07	0.667±0.07
	D3 + DP	2 unit	4	0.750±0.22	0.750±0.22	0.750±0.22	0.750±0.22	0.750±0.22	0.750±0.22	0.750±0.22
	D2 + DP	1 unit	14	0.786±0.11	0.714±0.12	0.643±0.13	0.571±0.13	0.500±0.13	0.500±0.13	0.500±0.13

(a) Two unit operation refers to the simultaneous operation of Unit 2 and Unit 3; one unit operation refers to the operating condition when only Unit 2 was generating but two Unit 3 circulating pumps were discharging unheated water.

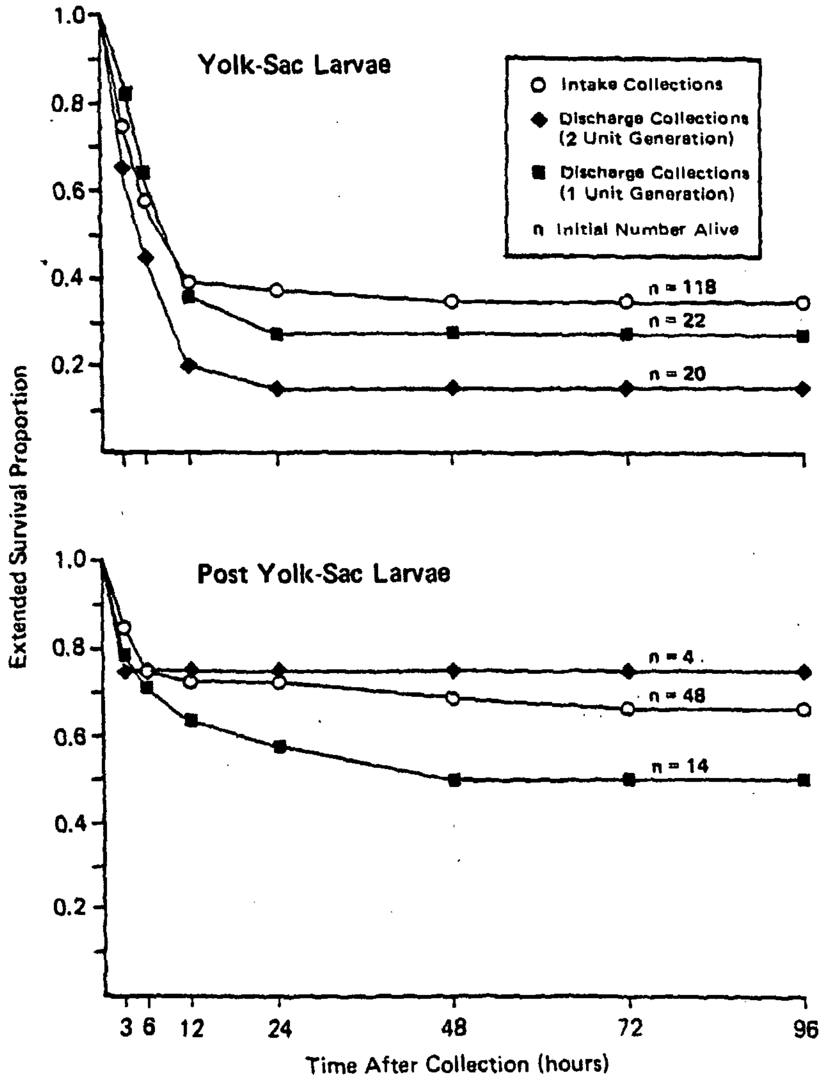


Figure 4-7. Normalized extended survival of Atlantic tomcod yolk-sac and post yolk-sac larvae collected during the late winter entrainment survival study, Indian Point Generating Station, 12–22 March 1979.

TABLE 4-9 RESULTS OF FISHER'S EXACT TEST FOR DIFFERENCES IN NORMALIZED EXTENDED SURVIVAL AMONG ATLANTIC TOMCOD YOLK-SAC AND POST YOLK-SAC LARVAE COLLECTED DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Comparison				Fisher's Exact Probability Level at Time After Collection (hours)						
Stations	Life Stage	Unit Operation[a]	Null Hypothesis	3	6	12	24	48	72	96
I2 + I3	YSL vs. PYSL	1 unit + 2 unit (combined)	$P_{YSL} = P_{PYSL}$[b]	0.111	0.032	<0.001[c]	<0.001[c]	<0.001[c]	<0.001[c]	(d)
D2 + D3 + DP	YSL	1 unit vs. 2 unit	$P_1 \leq P_2$[e]	0.104	0.184	0.204	0.279	(d)	(d)	(d)
I2 + I3 vs. D2 + D3 + DP	YSL	1 unit + 2 unit (combined)	$P_I \leq P_D$[e]	0.550	0.405	0.154	0.044[c]	0.078	(d)	(d)
I2 + I3 vs. D2 + D3 + DP	PYSL	1 unit + 2 unit (combined)	$P_I \leq P_D$[e]	0.344	0.525	0.415	0.262	0.237	0.289	(d)

(a) Two unit operation refers to the simultaneous operation of Unit 2 and Unit 3; one unit operation refers to the operating condition when only Unit 2 was generating but two Unit 3 circulating pumps were discharging unheated water.
(b) For the two-tailed test the critical probability is 0.025.
(c) Significant at $\alpha = 0.05$.
(d) Survival proportions and probability level identical to previous interval.
(e) For the one-tailed test the critical probability is 0.05.

Note: YSL = Yolk-sac larvae
PYSL = Post yolk-sac larvae
P_{YSL} = Survival proportion for yolk-sac larvae
P_{PYSL} = Survival proportion for post yolk-sac larvae
P_1 = Survival proportion when only one unit is generating
P_2 = Survival proportion when two units are generating
P_I = Survival proportion for larvae collected at intake stations
P_D = Survival proportion for larvae collected at discharge stations

extended survival comparisons between intake and discharge stations were performed separately for each life stage. For yolk-sac larvae, there was no detectable difference in extended survival at discharge stations for the two operating conditions, i.e., one- or two-unit generation, and only one significant difference between intake samples and pooled discharge samples (Table 4-9). For post yolk-sac larvae, sample size was too small to test for differences in survival at discharge stations between operating conditions (Table 4-8), but pooled discharge survival for both operating conditions combined was not significantly different ($\alpha = 0.05$) from that of intake stations (Table 4-9). Although differences were not significant, extended survival at discharge stations was lower for yolk-sac larvae during simultaneous operation of Units 2 and 3, similar to the effects seen in initial survival. Only four post yolk-sac larvae were initially alive in discharge collections during two-unit operation, thus precluding meaningful comparisons.

Although extended survival differed for yolk-sac and post yolk-sac larvae, no consistent increase in mortality was observed in discharge collections over that of control (intake) collections. Consequently, the effects of entrainment could be estimated from initial survival data.

4.3.1.3 Entrainment Survival Estimates

As with initial survival proportions, variations in entrainment survival of Atlantic tomcod larvae collected during different plant operating modes were associated with discharge temperature. The highest entrainment survival estimate, 61 percent, was determined for larvae collected after the Unit 3 outage (20 to 22 March) when average discharge temperatures were lowest (Table 4-10); during this period, discharge temperatures from Unit 2 were moderated by unheated flow from two circulating pumps at Unit 3. In contrast, lowest entrainment survival (33 percent) occurred during the simultaneous operation of Unit 2 and Unit 3 (12 to 19 March) when discharge temperatures were 3 to 4 C warmer.

During the study period, the effect of supplemental, unheated flow on the entrainment survival of Atlantic tomcod was observed for different operating conditions involving a single unit. Collections taken at the Unit 3 intake and discharge (Stations I3 and D3, respectively) permitted estimation of entrainment survival for Unit 3 alone during the period of two-unit generation. This estimate, 48 percent (Table 4-10), reflects survival during a period when all circulating pumps were discharging heated water, and the plant was operated at the 60 percent flow regime characteristic of winter operation. By comparison, entrainment survival was 13 percent higher (i.e., 61 percent) when only Unit 2 was generating power, but unheated flow was provided from two circulating pumps at Unit 3.

Entrainment survival estimates for Atlantic tomcod larvae collected at various discharge temperature categories similarly decreased with increasing temperature (Table 4-11). Highest survival (64 percent) was encountered at discharge temperatures <16 C (Table 4-11). Survival decreased successively at progressively higher temperature increments, with lowest survival (11 percent) occurring at temperatures >20 C, the highest discharge temperature category. Entrainment survival over all plant operating conditions and discharge temperatures was 45.4 percent (Tables 4-10 and 4-11).

TABLE 4-10 ENTRAINMENT SURVIVAL ESTIMATES OF ATLANTIC TOMCOD LARVAE FOR VARYING PLANT OPERATING CONDITIONS DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Stations	Unit Operation	March Sampling Dates	Intake Station(s) N_I	Intake Station(s) P_I	Discharge Station(s) N_D	Discharge Station(s) P_D	S_e(%)
I2 + I3 vs. D3 + DP	Unit 2 and Unit 3 (combined)	12-19	161	0.627	117	0.205	32.7
I3 vs. D3	Unit 3 (only)	12-19	66	0.561	59	0.271	48.3
I2 vs. D2 + DP	Unit 2 plus two circs. at Unit 3[a]	20-22	105	0.619	95	0.379	61.2
I2 + I3 vs. D2 + D3 + DP	All operating conditions	12-22	266	0.624	212	0.283	45.4

(a) The two circulating pumps for Unit 3 were discharging unheated water.

Note:
N_I = number of fish in intake collections
P_I = proportion of fish surviving at intake station(s)
N_D = number of fish in discharge collections
P_D = proportion of fish surviving at discharge station(s)
Se(%) = entrainment survival (percent)

TABLE 4-11 ENTRAINMENT SURVIVAL ESTIMATES FOR ATLANTIC TOMCOD LARVAE COLLECTED AT FOUR DISCHARGE TEMPERATURE RANGES DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

Discharge Temperature Range (C)	Discharge Survival Proportion	Entrainment Survival Se(%)[a]
12.0-15.9	0.398	63.8%
16.0-17.9	0.323	51.8%
18.0-19.9	0.183	29.3%
20.0-21.9	0.071	11.4%
12.0-21.9	0.283	45.4%

(a) Based on an intake station initial survival proportion of 0.624 (266 organisms), as determined by pooling data over sampling station, life stage, and plant operating condition.

Based on the relationship between entrainment survival and discharge temperature, it is likely that the survival of Atlantic tomcod entrained through the Indian Point plant could be increased by manipulating plant flows to reduce the condenser temperature rise. Thus, although maintenance of full flow conditions during winter operation may draw more larvae through the plant, the increased entrainment survival resulting from lower discharge temperatures could affect a net reduction in mortality. It should be emphasized, however, that the survival estimates presented were based on a relatively short sampling period during which all larvae collected were distributed within a relatively narrow size range (6.0 to 8.9 mm in length). Consideration of plant operating conditions which would optimize survival would require the evaluation of data for the entire Atlantic tomcod entrainment period to adequately assess the effects of seasonal changes in larval size, abundance, thermal tolerance, and discharge temperature conditions.

4.3.2 Striped Bass, White Perch, Herring, and Anchovy Entrainment Survival Study

During the spring-summer entrainment survival study (30 April to 14 August 1979), which examined the survival of early life stages of striped bass, white perch, herrings (Clupeidae), and anchovies (Engraulidae) entrained through the Indian Point plant, Unit 3 operated continuously, whereas Unit 2 operated only through 15 June. A scheduled maintenance shutdown of Unit 2 occurred after 15 June. Unit 1 did not generate power but one circulating pump for this unit was run from 18 June through 9 July. Throughout the study period sampling was conducted at the outflow of a discharge port (Station DP) using a pumpless plankton sampling flume, and at the Unit 3 intake (Station I3) using a rear-draw plankton sampling flume. These collection systems, which were raft-mounted and utilized head-induced flow rather than pumps for sample delivery (Section 4.2.1.2.2), were specifically designed to minimize sampling stress on more sensitive taxa and life stages.

Survival of ichthyoplankton collected in entrainment samples during the spring-summer study period was analyzed with respect to plant operating condition (i.e., one-unit versus two-unit generation), sampling station, and discharge temperature. The three discharge temperature categories for which survival was determined were <30.0 C; 30.0 to 32.9 C, and ≥33.0 C. These temperature categories were selected on the basis of laboratory and field thermal tolerance studies (EA 1978b, 1978c), and are consistent with temperature categories examined during entrainment survival studies at the Indian Point plant during 1977 and 1978 using pump/larval table collection systems (EA 1978a, 1979a).

4.3.2.1 Collection of Ichthyoplankton for Survival Determination

The most abundant ichthyoplankton taxon collected at the Indian Point plant during the 1979 spring-summer entrainment survival study was the anchovy family (Engraulidae), followed by (in order of decreasing abundance), striped bass, herrings (Clupeidae), and white perch (Table 4-12). These four taxa comprised 94 percent of the ichthyoplankton collected, compared with 96 percent and 91 percent, respectively, in entrainment survival samples collected during 1977 and 1978 (EA 1978a, 1979a).

TABLE 4-12 TOTAL NUMBER OF EACH ICHTHYOPLANKTON TAXON AND LIFE STAGE COLLECTED FOR SURVIVAL DETERMINATIONS DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

Taxon						
Common Name	Scientific Name	Eggs	Yolk-Sac Larvae	Post Yolk-Sac Larvae	Juveniles	Percent of Total
Anchovies[a]	Engraulidae	(b)	0	942	2	39.97
Striped bass	*Morone saxatilis*	179	107	178	0	19.64
Herrings	Clupeidae	0	5	446	1	19.14
White perch	*Morone americana*	0	15	342	3	15.24
Rainbow smelt	*Osmerus mordax*	0	4	61	4	2.92
Tessellated darter	*Etheostoma olmstedi*	0	9	17	1	1.14
Atlantic tomcod	*Microgadus tomcod*	0	0	0	10	0.42
Minnows	Cyprinidae	0	0	10	0	0.42
American eel	*Anguilla rostrata*	0	0	0	6	0.25
Yellow perch	*Perca flavescens*	0	6	0	0	0.25
Weakfish	*Cynoscion regalis*	0	0	2	4	0.25
Silversides	*Menidia* spp.	0	1	4	0	0.21
Sunfish	Centrarchidae	0	0	1	0	0.04
Northern pipefish	*Syngnathus fuscus*	0	0	0	1	0.04
Hogchoker	*Trinectes maculatus*	0	0	1	0	0.04

(a) Bay anchovies (*Anchoa mitchilli*) are the only engraulids occurring to any appreciable extent in the Hudson River estuary.
(b) Survival determinations were not made for anchovy eggs.

The majority of ichthyoplankton were collected during June when the average daily intake temperature was approximately 19 to 20 C (Figures 4-8 through 4-11). Striped bass eggs and herring larvae were the principal ichthyoplankton collected in entrainment survival samples during May, whereas striped bass, white perch, and herring larvae were predominant in June collections. Anchovy post yolk-sac larvae were the most abundant ichthyoplankton collected during July.

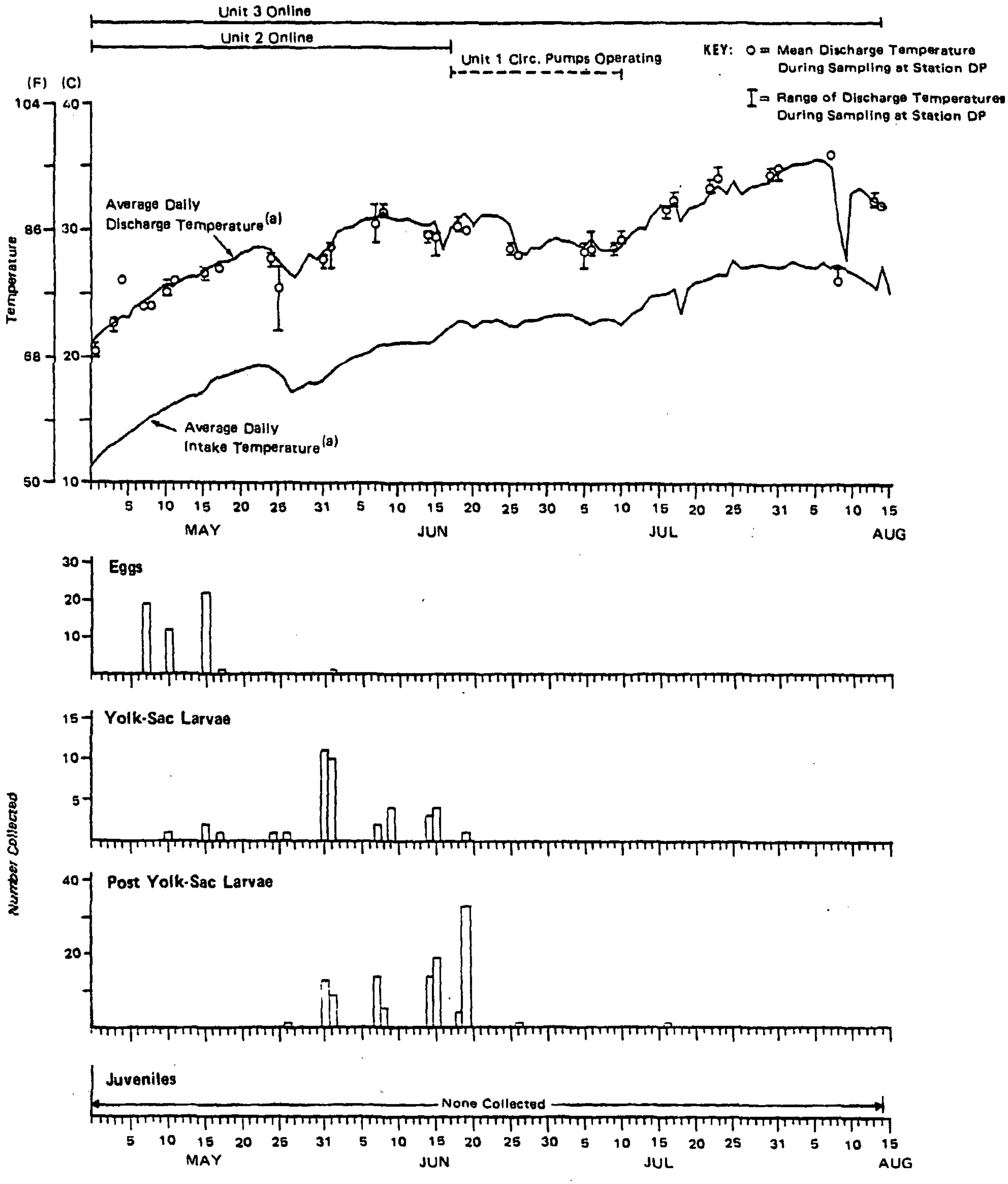
Consistent with previous entrainment survival studies at the Indian Point plant (EA 1978a, 1979a), post yolk-sac larvae were collected in larger numbers than other life stages (Table 4-12). Thus, although eggs, yolk-sac larvae, and post yolk-sac larvae of striped bass were collected in sufficient numbers for entrainment survival determination, survival analysis for the other taxa was restricted to post yolk-sac larvae. Entrainment survival was not determined for anchovy eggs because their small size and refractive index in water would make them difficult to detect and would have greatly increased the time required to sort samples, thus potentially having an adverse effect on the survival of other taxa. No juvenile striped bass were collected, and juveniles of other taxa were collected too infrequently to permit survival analysis. Weekly length-frequency distributions for the major ichthyoplankton taxa collected are presented in Appendix Tables D-2 through D-5.

Average daily discharge temperatures at the Indian Point plant during the spring-summer entrainment survival study ranged from 21 to 36 C (Figures 4-8 through 4-11); however, the majority of ichthyoplankton were collected at discharge temperatures ranging from 27 to 32 C. Based on laboratory thermal tolerance studies (EA 1978b), thermal effects of entrainment were expected to be negligible for most ichthyoplankton collected at discharge temperatures less than 30 C. The percentages of organisms collected at the discharge port station (DP) when discharge temperatures exceeded 30 C were 67 percent for striped bass larvae, 76 percent for white perch larvae, 26 percent for herring larvae, and 86 percent for anchovy larvae. Anchovy post yolk-sac larvae and juveniles were the only ichthyoplankton taxa collected at discharge temperatures above 33 C.

4.3.2.2 <u>Survival Proportions</u>

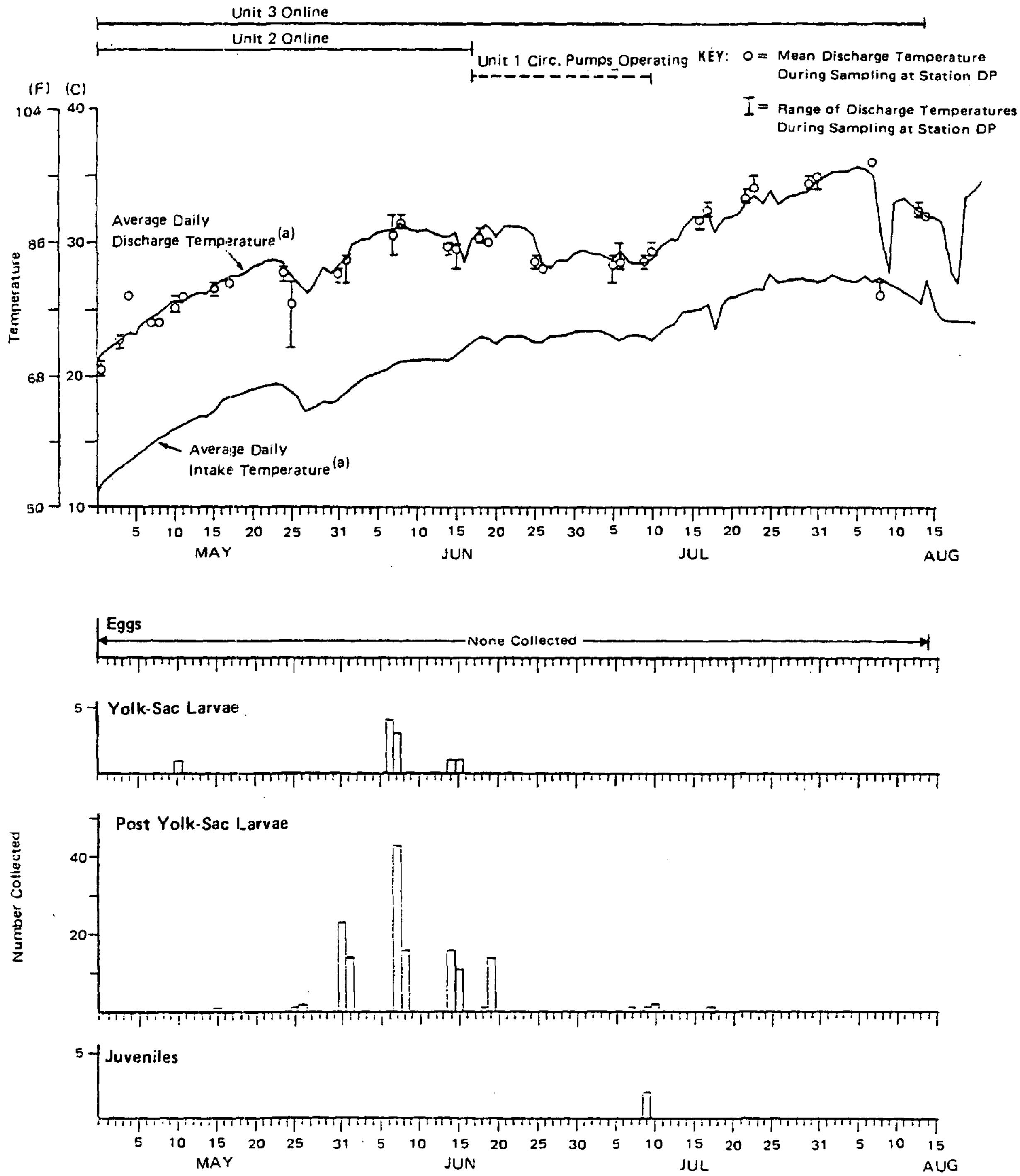
4.3.2.2.1 Survival of Striped Bass Eggs

All striped bass eggs were collected at the Indian Point plant from 7 May to 7 June when both Unit 2 and Unit 3 were operational. The proportion of eggs which hatched within 96 hours was 0.444 (based on 124 organisms) at the Unit 3 intake, Station I3, versus 0.327 (based on 55 organisms) at the discharge port, Station DP (Table 4-13). Survival proportions were not significantly different between the intake and discharge stations at $\alpha = 0.05$ (Fisher's exact test). Since discharge temperatures during collection (24 to 28 C) were below lethal levels determined from laboratory thermal tolerance experiments (EA 1978b), temperatures at the discharge station were expected to have minimal effect on hatching success. The majority of eggs collected at the intake and discharge stations (71 and 78 percent, respectively) hatched from 24 to 48 hours following collection.



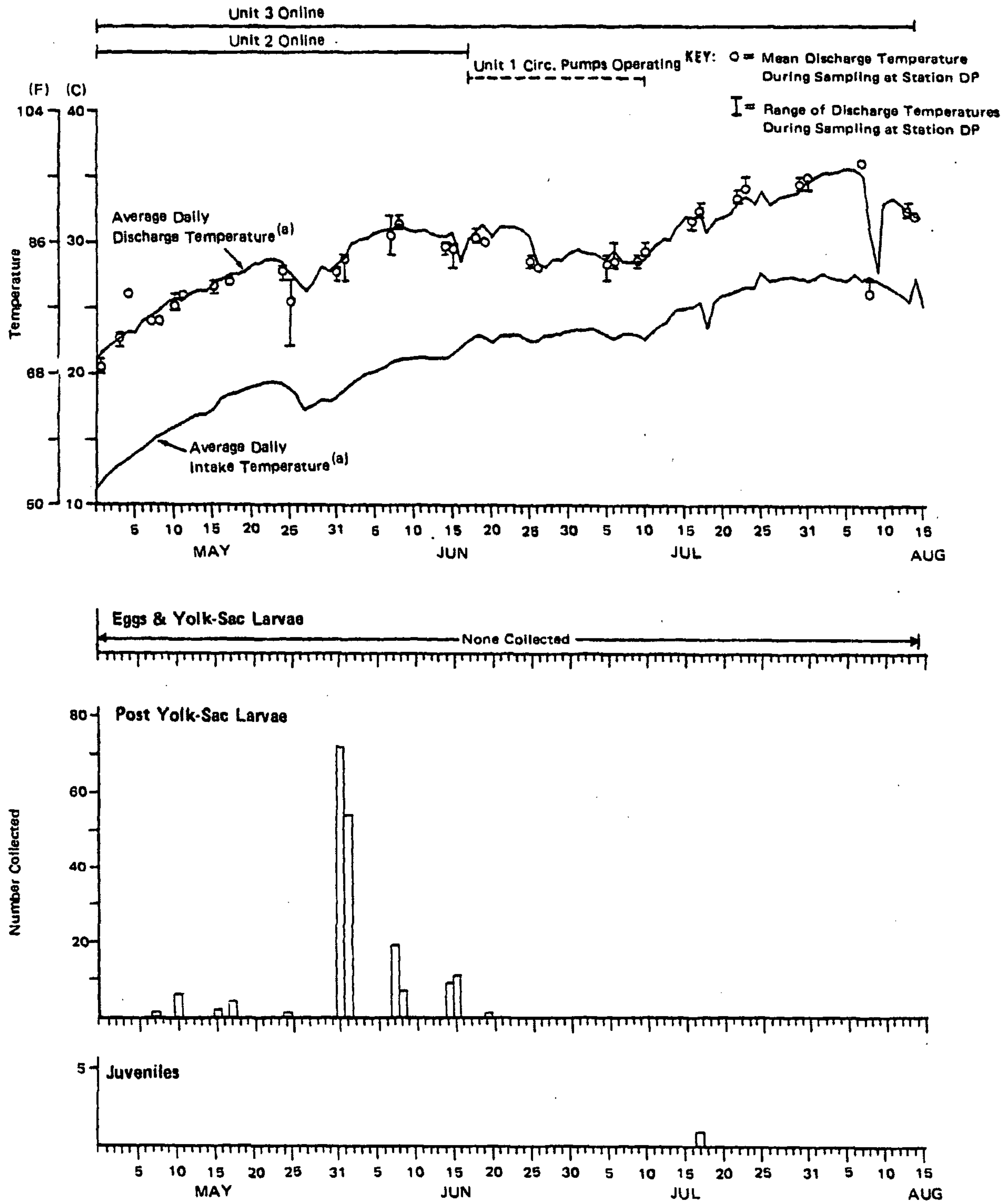
(a) Source for average daily intake and discharge temperatures was Con Edison 1979.

Figure 4-8. 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 – 14 August 1979.



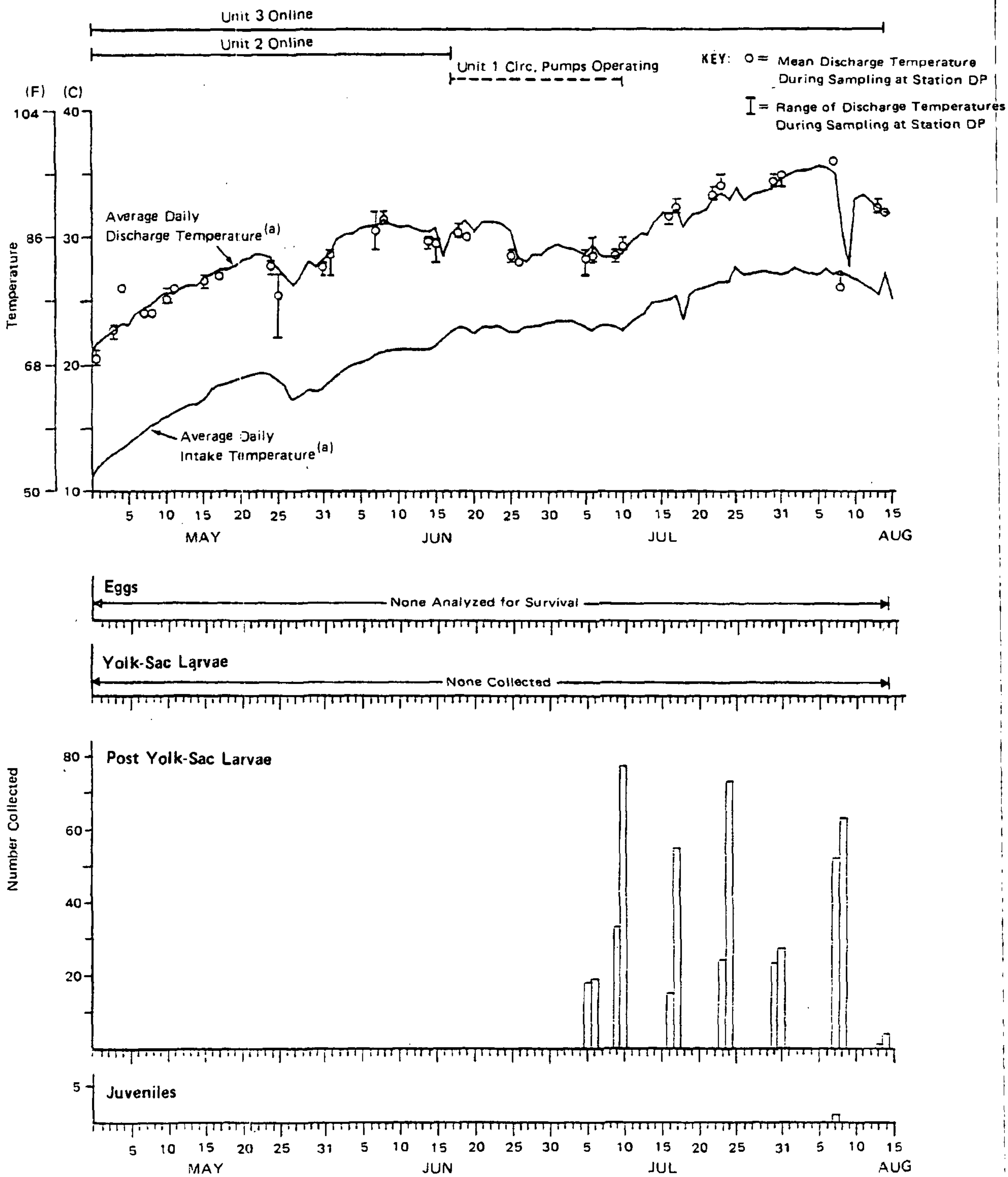
(a) Source for average daily intake and discharge temperatures was Con Edison 1979.

Figure 4-9. 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 – 14 August 1979.



(a) Source for average daily intake and discharge temperatures was Con Edison 1979.

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 – 14 August 1979.



(a) Source for average daily intake and discharge temperatures was Con Edison 1979.

Figure 4-11. 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 – 14 August 1979.

TABLE 4-13 SURVIVAL PROPORTIONS BASED ON HATCHING SUCCESS FOR STRIPED BASS EGGS COLLECTED DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

Station	Temperature Range (C)	Number Collected	Proportion Survival	Standard Error	p[a]
I3	14.0-21.1	124	0.444	0.045	0.045
DP	24.0-28.0	55	0.327	0.063	

(a) Fisher's exact probability of obtaining the observed or more dissimilar survival proportions under the null hypothesis that survival at the intake and discharge stations is equal, i.e., a two-tailed test. To achieve significance at $\alpha = 0.05$, the observed probability thus must be ≤ 0.025.

4.3.2.2.2 Initial Survival of Larvae

Initial survival proportions for larvae of the four major ichthyoplankton taxa collected at Station DP, which were exposed to entrainment as well as sampling effects, were highest for striped bass (0.615 to 0.769), followed by white perch (0.236 to 0.700), herrings (0.285), and anchovies (0.058) (Table 4-14). In contrast, initial survival proportions at Station I3, which reflect sampling effects only, were unexpectedly lower for larvae of most taxa. Evidence of this trend between the pumpless (discharge) and rear-draw (intake) plankton sampling flumes, based on their first combined application during this study, indicated the occurrence of differential sampling stresses between the two collection systems for yolk-sac and post yolk-sac larvae, thus precluding the use of the intake data as a representative measure of sampling (control) effects. Further examination and discussion of the observed station differences are presented later and in Appendix B (Collection System Calibration Study).

Over the spring-summer study period, only striped bass and white perch post yolk-sac larvae were collected in sufficient numbers to compare initial survival proportions for the two plant operating conditions, i.e., two-unit versus one-unit generation (Table 4-14). For these organisms, survival proportions at both the intake station (I3) and discharge port station (DP) were generally higher during the operation of Unit 3 alone (18 June to 14 August), than during the simultaneous operation of Units 2 and 3 (30 April to 15 June). The single exception occurred for white perch post yolk-sac larvae collected at Station I3 which showed higher survival during the period of two-unit generation. However, the difference in initial survival proportions between the two plant operating conditions, was significant only for white perch post yolk-sac larvae collected at the discharge port (Fisher's exact test, $\alpha = 0.05$); survival proportions for this larval stage varied from 0.236 (two-unit generation) to 0.700 (one-unit generation).

To compare the initial survival of striped bass and white perch post yolk-sac larvae collected at corresponding discharge temperature ranges during the different plant operating conditions, discharge collection data for one- and two-unit generation were separated into the three temperature categories <30.0 C; 30.0 to 32.9 C, and ≥33.0 C (Table 4-15). Although only the 30.0 to 32.9 C temperature category contained sufficient fish for testing, a significant difference between survival proportions for the two plant operational modes was again found for white perch post yolk-sac larvae (Fisher's exact test $\alpha = 0.05$). Within this discharge temperature category, initial survival of white perch post yolk-sac larvae varied from 0.203 during simultaneous operation of Units 2 and 3, to 0.667 during the operation of Unit 3 alone. For striped bass post yolk-sac larvae, the difference between survival proportions (0.653 for two-unit operation versus 0.763 for single-unit operation) was not significant.

The significant difference in initial survival proportions for white perch post yolk-sac larvae, as well as the general trend toward higher survival during the operation of Unit 3 alone, may be associated with increased survival as a function of length (size). The apparent greater ability of larger larvae to withstand entrainment and sampling stresses has been previously demonstrated for striped bass, white perch, and herrings (EA 1978d, 1980b), and was also observed for hatchery-reared striped bass during collection system calibration experiments in 1979 (Appendix B). Based on a comparison of

TABLE 4-14 INITIAL SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON COLLECTED DURING PERIODS OF ONE-UNIT AND TWO-UNIT OPERATION, SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

			Units 2 and 3 Operating 30 April - 15 June			Unit 3 Operating 18 June - 14 August			
Taxa	Life Stage	Station	Number Collected	Initial Survival[a]	Standard Error	Number Collected	Initial Survival[a]	Standard Error	P[b]
Striped bass	Yolk-sac larvae	I3	63	0.523	0.06	3			
		DP	39	0.615	0.08	2			
	Post yolk-sac larvae	I3	41	0.561	0.08	23	0.391	0.10	0.149
		DP	75	0.640	0.06	39	0.769	0.07	0.115
White perch	Post yolk-sac larvae	I3	180	0.133	0.03	15	0.330	0.12	0.052
		DP	127	0.236	0.04	20	0.700	0.10	<0.001[c]
Herrings	Post yolk-sac larvae	I3	254	0.228	0.03	5			
		DP	186	0.285	0.03	1			
Anchovies	Post yolk-sac larvae	I3	0			457	0.101	0.01	
		DP	0			485	0.058	0.01	

(a) Initial survival proportions were calculated only for sample sizes >10.
(b) Fisher's exact probability ($\alpha = 0.05$) of obtaining the observed or more dissimilar survival proportions under the null hypothesis that survival during one- and two-unit operation is equal.
(c) Significant at $\alpha = 0.05$.

TABLE 4-15 INITIAL SURVIVAL PROPORTIONS FOR STRIPED BASS AND WHITE PERCH POST YOLK-SAC LARVAE AS A FUNCTION OF COLLECTION TEMPERATURE EXPERIENCED DURING PERIODS OF ONE-UNIT AND TWO-UNIT OPERATION, SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

		Units 2 and 3 Operating 30 April - 15 June				Unit 3 Operating 18 June - 14 August				
Taxa/ Life Stage	Station	Temperature Range (C)	Number Collected	Initial Survival(a)	Standard Error	Temperature Range (C)	Number Collected	Initial Survival(a)	Standard Error	p(b)
Striped bass	I3	16.7-22.4(c)	41	0.561	0.08	22.1-23.6(c)	23	0.391	0.10	0.149
Post yolk-	DP	≤29.9	26	0.615	0.10	≤29.9	1			
sac larvae		30.0-32.9	49	0.653	0.07	30.0-32.9	38	0.763	0.07	0.191
		≥33.0	0			≥33.0	0			
White perch	I3	14.0-22.4(c)	180	0.133	0.03	22.4-26.5(c)	15	0.330	0.12	0.052
Post yolk-	DP	≤29.9	48	0.292	0.07	≤29.9	2			
sac larvae		30.0-32.9	79	0.203	0.05	30.0-32.9	18	0.667	0.11	<0.001(d)
		≥33.0	0			≥33.0	0			

(a) Initial survival proportions were calculated only for sample sizes >10.
(b) Fisher's exact probability (α = 0.05) of obtaining the observed or more dissimilar survival proportions under the null hypothesis that survival during one- and two-unit operation is equal.
(c) Entire range of temperatures at which each taxon was collected.
(d) Significant at α = 0.05.

the length-frequency distributions of striped bass and white perch larvae collected during periods of different plant operating conditions in 1979 (Figure 4-12), it can be seen that the difference between modal lengths (i.e., lengths occurring with greatest frequency) of fish collected during two-unit versus one-unit operation was most pronounced for white perch larvae at discharge port station DP. The greater separation of modal lengths in this case, and the tendency towards increased survival with size, may therefore explain the significant difference in initial survival observed for white perch post yolk-sac larvae at Station DP during the two different plant operational periods.

To further examine the possible effects of temperature on the initial survival of entrained larvae, data collected within each of the three discharge temperature categories were pooled over both plant operating conditions (Table 4-16). Identification of trends in survival with temperature, however, was limited by the absence of all larval groups, except anchovy post yolk-sac larvae, in samples collected in the highest discharge temperature category (≥33.0 C). For striped bass yolk-sac and post yolk-sac larvae, highest initial survival proportions at Station DP (0.750 and 0.701, respectively) occurred in the 30.0 to 32.9 C temperature category, whereas for white perch, herring, and anchovy post yolk-sac larvae, highest initial survival (0.320, 0.305, and 0.070, respectively) occurred at discharge temperatures <30.0 C. For anchovy post yolk-sac larvae, the only larval group collected over all temperature categories, the initial survival was lowest (0.028) at the intermediate discharge temperature category, 30.0-32.9 C, but relatively similar (0.063 versus 0.070) at the upper and lower temperature categories (i.e., ≥33.0 C and <30.0 C, respectively). This variation in anchovy survival was apparently influenced primarily by length rather than temperature (Figure 4-13). In contrast to the other taxonomic groups examined, the spawning season for anchovies is relatively long (McFadden et al. 1978), resulting in pronounced fluctuations in mean length, as opposed to a progressive increase in size during the entrainment period. Thus, consistent with the relationship between survival and size (length) discussed previously, variations in the initial survival proportions of anchovies entrained over the study period closely followed variations in mean length, with highest survival occurring during sampling weeks characterized by larger organism size.

Overall initial survival proportions at the discharge for combined temperature and plant operating conditions were again highest for striped bass larvae (0.634 and 0.684 for yolk-sac and post yolk-sac larvae, respectively), followed by post yolk-sac larvae of white perch (0.299), herrings (0.289), and anchovies (0.058) (Table 4-16). Initial survival at the discharge station, both for combined temperatures as well as individual temperature categories, was generally higher than pooled initial survival at the intake station. Under the null hypothesis that the proportion surviving at the intake is equal to the proportion surviving at the discharge ($\alpha = 0.05$), significant differences between intake and discharge survival (all temperatures) were observed for three of the five larval groups examined, i.e., striped bass, white perch, and anchovy post yolk-sac larvae (Table 4-16). Significant differences were additionally found in five cases when intake survival was compared to survival at specific discharge temperature categories. All comparisons resulting in significant station differences, with the exception of those for anchovy post yolk-sac larvae, were associated with higher survival at the discharge station than at the intake station.

TABLE 4-16 INITIAL SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON AS A FUNCTION OF COLLECTION TEMPERATURES EXPERIENCED DURING ONE-UNIT AND TWO-UNIT OPERATION COMBINED, SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

Taxa	Life Stage	Station	Temperature Range (C)	Number Collected	Initial Survival	Standard Error	p[b]
Striped bass	Yolk-sac	I3	16.7-23.6[a]	66	0.515	0.06	--
	larvae	DP	≤29.9	29	0.586	0.09	0.1452
			30.0-32.9	12	0.750	0.12	0.0850
			≥33.0	0			
			22.0-32.0[a]	41	0.634	0.08	0.0780
	Post yolk-sac	I3	16.7-23.6[a]	64	0.500	0.06	--
	larvae	DP	≤29.9	27	0.630	0.09	0.0977
			30.0-32.9	87	0.701	0.05	0.0059[c]
			≥33.0	0			
			22.0-32.0[a]	114	0.684	0.04	0.0070[c]
White perch	Post yolk-sac	I3	14.0-27.6[a]	195	0.149	0.03	--
	larvae	DP	≤29.9	50	0.320	0.07	0.0044[c]
			30.0-32.9	97	0.289	0.05	0.0025[c]
			≥33.0	0			
			22.0-32.0[a]	147	0.299	0.04	0.0004[c]
Herrings	Post yolk-sac	I3	12.6-24.8[a]	259	0.232	0.03	--
	larvae	DP	≤29.9	151	0.305	0.04	0.0249[c]
			30.0-32.9	36	0.222	0.07	0.1671
			≥33.0	0			
			24.0-32.0[a]	187	0.289	0.03	0.0346

(a) Entire range of temperatures at which each taxon was collected.
(b) Fisher's exact probability (α = 0.05) of obtaining the observed or more dissimilar survival proportions under the null hypothesis that survival at each discharge temperature range is equal to survival at the intake station; i.e., a two-tailed test.
(c) Significant at α = 0.05.

TABLE 4-16 (CONT.)

Taxa	Life Stage	Station	Temperature Range (C)	Number Collected	Initial Survival	Standard Error	p[b]
Anchovies	Post yolk-sac larvae	I3	21.9-29.2[a]	457	0.101	0.01	--
		DP	≤29.9	172	0.070	0.02	0.0632
			30.0-32.9	107	0.028	0.02	0.0063[c]
			≥33.0	206	0.063	0.02	0.0350
			27.0-36.0[a]	485	0.058	0.01	0.0049[c]

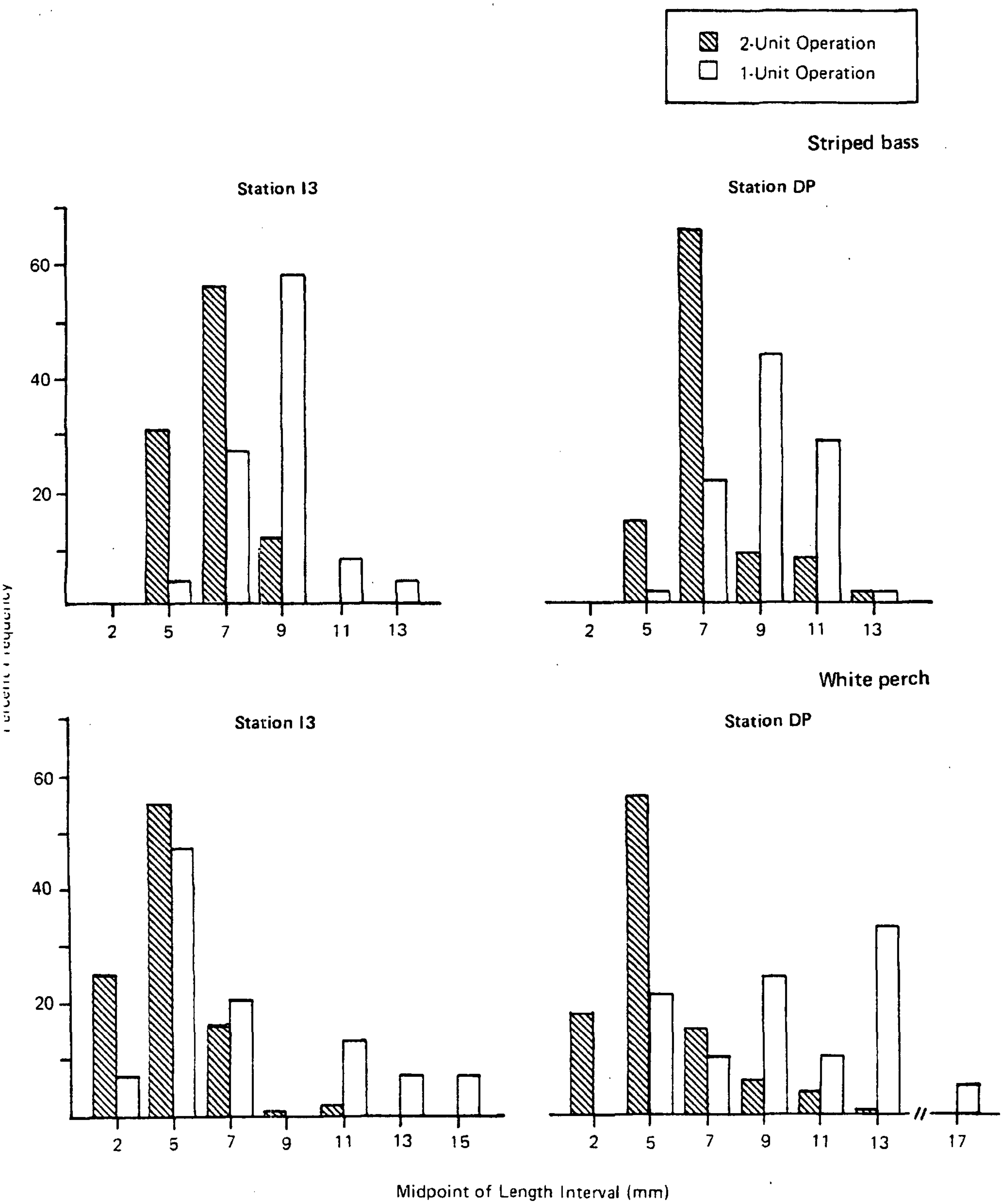


Figure 4-12. Length frequency distributions of striped bass and white perch larvae collected during periods of one-unit and two-unit operation, spring-summer entrainment survival study, Indian Point Generating Station, 30 April – 14 August 1979. (See Appendix Tables D-2 and D-3 for corresponding length frequency data.)

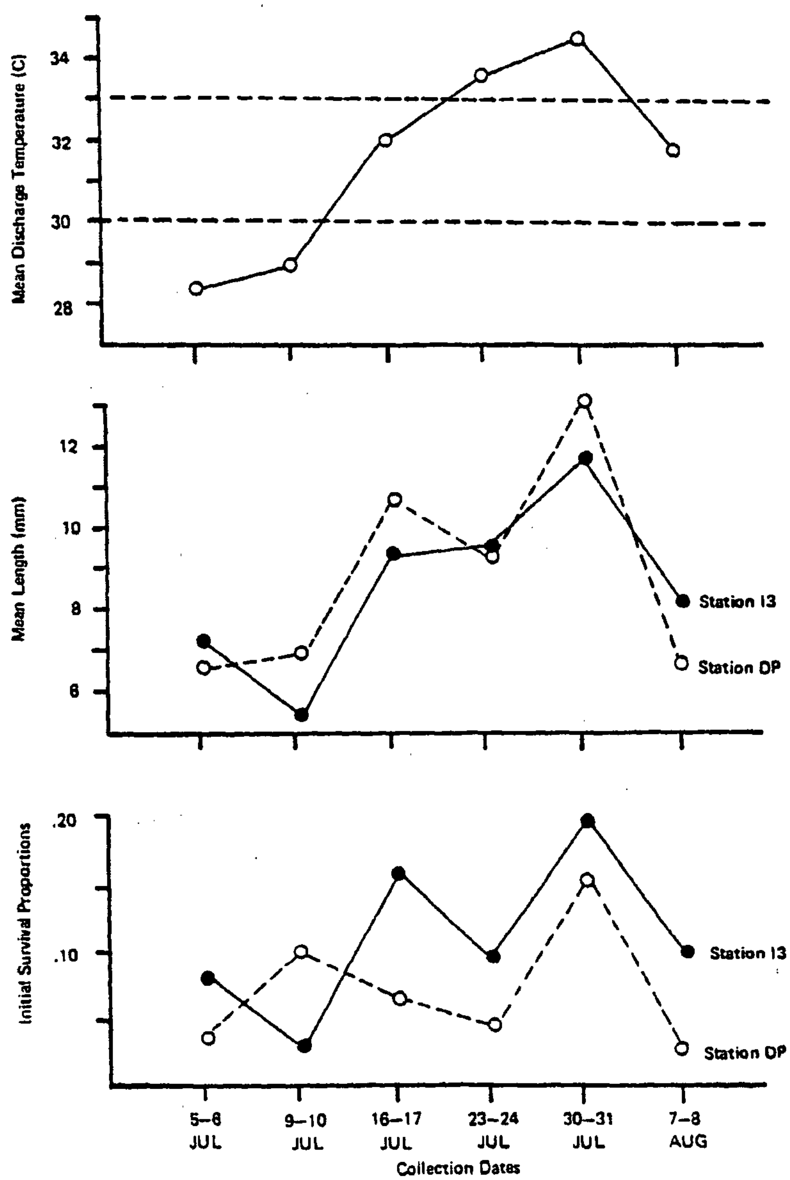


Figure 4-13. Initial survival proportions for anchovy (Engraulidae) post yolk-sac larvae collected during the spring-summer entrainment survival study versus mean length and discharge temperature, Indian Point Generating Station, 1979.

The reversal of expected differences in initial survival proportions between intake and discharge stations for most larval groups collected during the spring-summer entrainment survival study was indicative of differential sampling stress relative to the rear-draw and pumpless plankton sampling flumes used at Stations I3 and DP, respectively. Thus, in spite of efforts to achieve comparable design and operation between the two collection systems (Sections 4.2.1.2.2 and 4.2.1.2.3), sampling effects imposed by the rear-draw (intake) flume were apparently more stressful to most larvae than the combined effects of entrainment and sampling experienced by fish collected at the pumpless (discharge) flume. This conclusion is further supported by the results of collection system calibration experiments (Appendix B) designed to assess the comparability of sampling stresses between the rear-draw and pumpless plankton sampling flumes to early life stages of hatchery-reared striped bass. These experiments indicated that the rear-draw (intake) flume affected higher sampling mortality on striped bass larvae from approximately 4 to 10 mm in length, than did the pumpless (discharge) flume. However, differences in sampling mortality declined as larvae approached 11 mm, and were not apparent for striped bass eggs. That higher initial survival at the intake station for river ichthyoplankton occurred only in the case of anchovy post-yolk sac larvae, may be the result of a greater sensitivity of these larvae to entrainment stresses. Moreover, because anchovy larvae occurring in samples were generally larger than larvae of other taxa (Appendix Tables D-2 through D-5), differential gear effects on sampling mortality may have been less pronounced.

In retrospect, differences in sampling stresses between the two collection systems may have been caused by differences in water flow through the flume diversion screens during sampling or draining. To create head-induced flow through the intake flume, water was pumped from behind the diversion screens. The proximity of the pump intake manifolds to the diversion screens 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 and, consequently, flow through the diversion screens of this sampler was likely to be more uniform. Additionally, because the rear-draw flume (Station I3) could be raised to facilitate draining, whereas the pumpless flume (Station DP) could not, the drain time (and, therefore, the drain rate) was typically faster at the intake station. This factor, too, would have resulted in higher water velocities through the diversion screens of the rear-draw (intake) flume, and an increased likelihood of impingement stress during the draining process.

Assuming the occurrence of these through-screen flow conditions, it is also reasonable to expect the life-stage and size-specific differences in gear effects that were observed in the collection system calibration experiments (Appendix B). That is, the smaller, more fragile yolk-sac larvae would have greater susceptibility to potential impingement stress on the flume diversion screens, than larger, more robust post yolk-sac larvae. Moreover, eggs would be relatively resistant to such stresses. Because of their spherical shape, eggs would be more likely to roll along the face of the angled diversion screens than become impinged. Similar findings were reported by O'Connor and Schaffer (1977) who examined the survival of hatchery-reared striped bass life stages collected in plankton nets suspended in a test flume at various water velocities. These experiments indicated that yolk-sac larvae were most sensitive to net capture, followed by post yolk-sac larvae and eggs, in decreasing order of sensitivity.

4.3.2.2.3 Comparison of Initial Survival of Larvae Collected at Discharge Stations in 1979 (Pumpless Plankton Sampling Flume) versus 1977 and 1978 (Pump/Larval Table Collection System)

Initial survival proportions for most larval groups collected at the discharge (pumpless flume) in 1979 were considerably higher than in 1977 and 1978 (EA 1978a, 1979a) when pump/larval table collection systems were used (Table 4-17). Among the 29 comparisons that could be made between corresponding temperature categories (pooled over all plant operating conditions), the pumpless flume yielded higher survival than the pump/larval table in 25 (86 percent) of the cases. For the combined discharge temperature category, the 1979 initial survival proportions were highest for four of the five predominant larval groups collected during each of the three study years, e.g., striped bass yolk-sac and post yolk-sac larvae, and herring and anchovy post yolk-sac larvae. White perch post yolk-sac larvae, the only exception, exhibited highest initial survival (over all discharge temperatures) in 1977; however, discharge survival in 1979 was greater than in 1978 (Table 4-17).

The improved discharge survival proportions obtained in 1979 using the pumpless sampling flume are attributed primarily to reduced sampling stress associated with the elimination of pumps used to deliver the sample to the collected flume. The higher discharge survival for most larvae in 1979 is additionally noteworthy because the collection gear was located at the end of the discharge canal where water from the canal enters the river.

4.3.2.2.4 Extended Survival of Larvae

Normalized extended survival proportions for larvae collected at the intake station (I3) and discharge port (DP) were compared to determine possible latent effects caused by entrainment. To increase the sample size of the test groups, data were pooled across all collection temperatures for each station. Significant differences between intake and discharge stations (Fisher's exact test, $\alpha = 0.05$) were found only for striped bass yolk-sac larvae and herring post yolk-sac larvae (Table 4-18; Figures 4-14 and 4-15). Extended survival proportions for striped bass yolk-sac larvae were significantly lower at the discharge station than at the intake station for all observation periods, which was the reverse of initial survival data for this life stage (Section 4.3.2.2.2). Herring post yolk-sac larvae, on the other hand, exhibited significantly higher extended survival at the discharge versus intake station at the 12- and 96-hour observations; normalized extended survival proportions for the discharge station exceeded those at the intake station, however, during all but the 3-hour observation period.

For striped bass, white perch, and anchovy post yolk-sac larvae, no significant differences were found in extended survival proportions between intake and discharge stations (Table 4-18; Figures 4-14, 4-16, and 4-17), indicating that effects caused by the apparent greater sampling stress of the rear-draw (intake) flume were not manifested beyond the initial survival observation. Extended survival for anchovies (although low) was notable in that live organisms collected at both the intake and discharge stations were maintained for the entire 96-hour latent effects period. In contrast, during entrainment

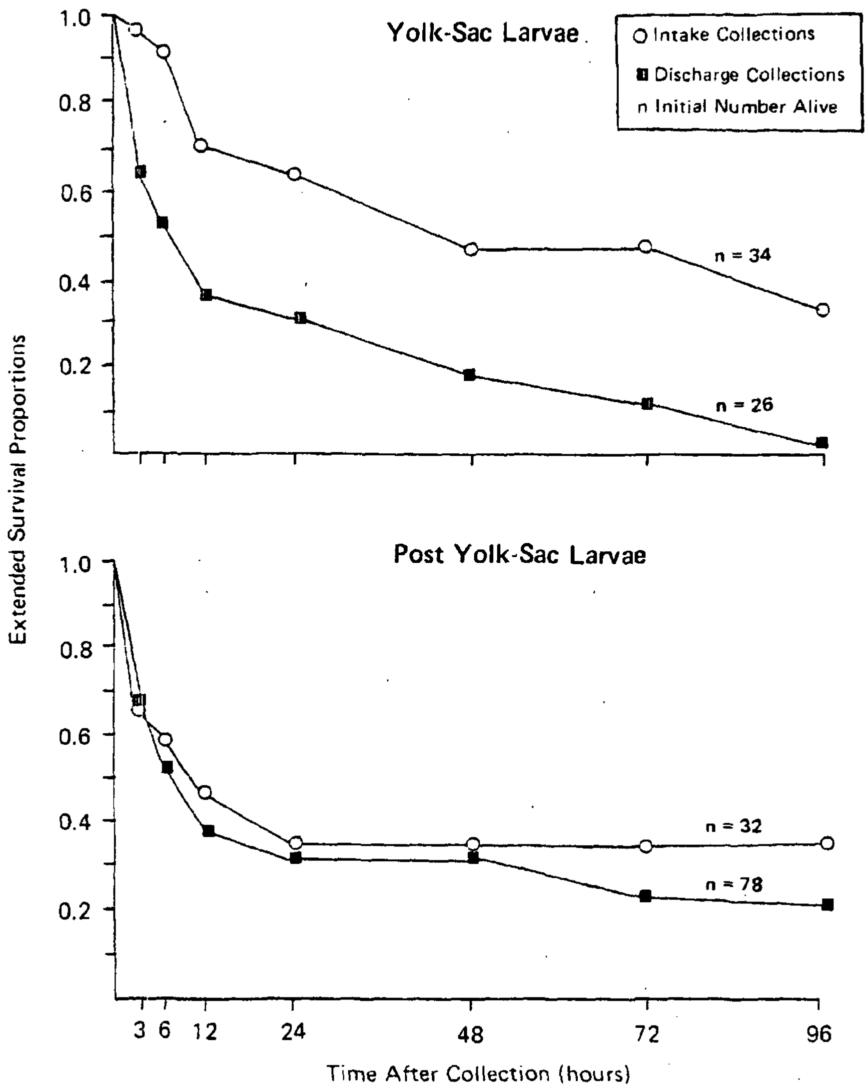


Figure 4-14. **Normalized extended survival of striped bass yolk-sac and post yolk-sac larvae collected during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.**

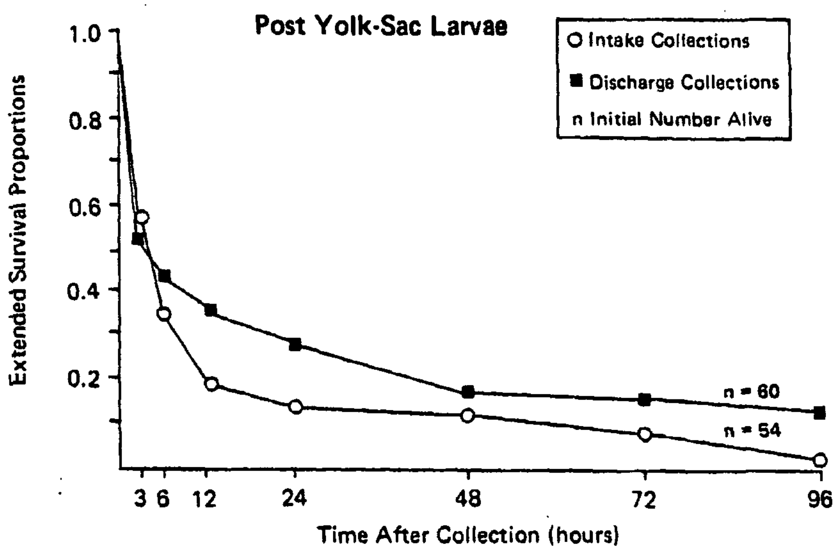


Figure 4-15. Normalized extended survival of herring post yolk-sac larvae collected during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

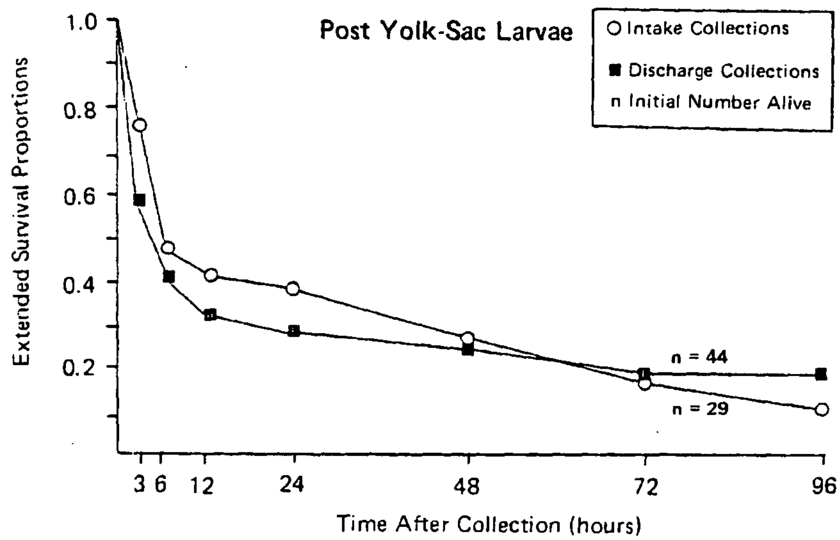


Figure 4-16. Normalized extended survival of white perch post yolk-sac larvae collected during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

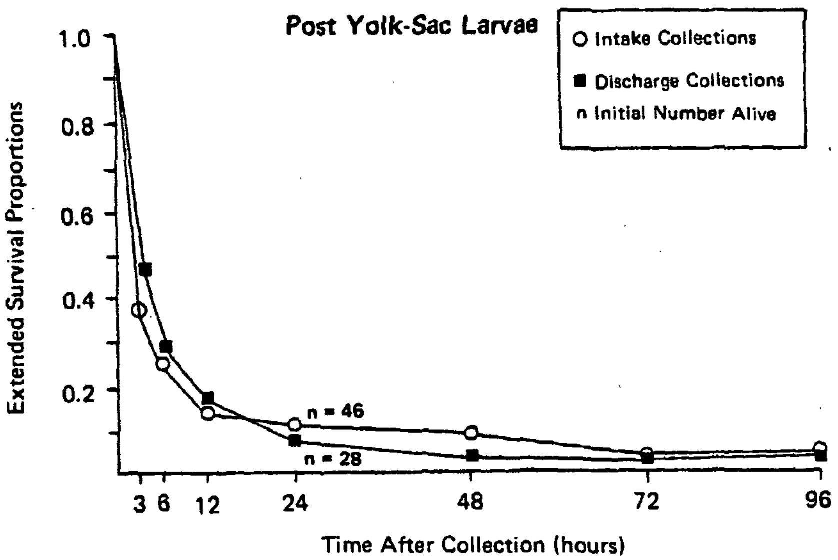


Figure 4-17. Normalized extended survival of anchovy post yolk-sac larvae collected during the spring-summer entrainment survival study, Indian Point Generating Station, 1979.

TABLE 4-17 COMPARISON OF INITIAL SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON LARVAE COLLECTED AT DISCHARGE STATIONS DURING 1977-1979, INDIAN POINT GENERATING STATION

		Initial Survival at Discharge Stations											
		Discharge Temp. <30.0 C			Discharge Temp. 30.0-32.9 C			Discharge Temp. >33.0 C			All Temp. Combined		
Taxa[a]	Life Stage	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]
Striped bass	YSL	0.400	0.158	0.586	--	0.030	0.750	--	0.0	--	0.369	0.052	0.634
	PYSL	0.491	0.091	0.630	0.440	0.282	0.701	0.467	0.038	--	0.482	0.263	0.684
White perch	PYSL	0.359	0.0	0.320	0.318	0.245	0.289	--	0.0	--	0.343	0.204	0.300
Herrings	PYSL	0.149	0.035	0.305	0.00	0.023	0.222	--	0.018	--	0.108	0.025	0.289
Anchovies	PYSL	--	--	0.070	0.039	0.0	0.028	0.028	0.0	0.063	0.031	0.0	0.058

(a) Includes larvae of all taxa for which sample sizes at discharge stations were >10 in at least one temperature category.
(b) Based on pooled data collected at discharge Stations D3 and DP using pump/larval table collection systems (EA 1978a, Table 4-8).
(c) Based on pooled data collected at discharge Stations D1, D3, and DP using pump/larval table collection systems (EA 1979a, Tables 4-5, 4-6, and 4-7).
(d) Based on data collected at discharge Station DP (discharge port outfall) using pumpless plankton sampling flume.

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

Dashes (--) indicate data not available.

TABLE 4-18 NORMALIZED EXTENDED SURVIVAL PROPORTIONS FOR ICHTHYOPLANKTON COLLECTED DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 30 APRIL - 14 AUGUST 1979

				Survival Proportions (±1 Standard Error)[a]						
				Time After Collection (Hours)						
Taxa	Life Stage	Station	Initial No. Alive	3	6	12	24	48	72	96
Striped bass	YSL	I3	34	0.971±0.03	0.912±0.05	0.706±0.08	0.647±0.08	0.471±0.09	0.471±0.09	0.324±0.08
		DP	26	0.654±0.09	0.538±0.10	0.385±0.10	0.308±0.09	0.192±0.08	0.115±0.06	0.038±0.04
				(0.0014*)	(0.0010*)	(0.0099*)	(0.0072*)	(0.0181*)	(0.0028*)	(0.0053*)
	PYSL	I3	32	0.656±0.08	0.594±0.09	0.469±0.09	0.344±0.08	0.344±0.08	0.344±0.08	0.344±0.08
		DP	78	0.680±0.05	0.526±0.06	0.385±0.06	0.308±0.05	0.308±0.05	0.231±0.05	0.205±0.05
				(0.1707)	(0.1361)	(0.1208)	(0.1646)	(0.1646)	(0.0885)	(0.0600)
White perch	PYSL	I3	29	0.759±0.08	0.483±0.09	0.414±0.09	0.379±0.09	0.276±0.08	0.172±0.07	0.138±0.06
		DP	44	0.591±0.07	0.409±0.07	0.341±0.07	0.295±0.07	0.250±0.06	0.182±0.06	0.182±0.06
				(0.0692)	(0.1572)	(0.1599)	(0.1516)	(0.2067)	(0.2439)	(0.2289)
Herrings	PYSL	I3	60	0.567±0.06	0.350±0.06	0.183±0.05	0.133±0.04	0.117±0.04	0.083±0.04	0.017±0.02
		DP	54	0.537±0.07	0.444±0.07	0.352±0.06	0.278±0.06	0.167±0.05	0.148±0.05	0.130±0.05
				(0.1422)	(0.0901)	(0.0217*)	(0.0304)	(0.1592)	(0.1311)	(0.0193*)
Anchovies	PYSL	I3	46	0.370±0.07	0.261±0.06	0.152±0.05	0.109±0.05	0.087±0.04	0.043±0.03	0.043±0.03
		DP	28	0.464±0.09	0.286±0.08	0.179±0.07	0.071±0.05	0.036±0.04	0.036±0.04	0.036±0.04
				(0.1396)	(0.2053)	(0.2397)	(0.2879)	(0.2836)	(0.4470)	(0.4470)

(a) The null hypothesis was that the proportion of live and dead larvae is independent of the sampling location (equal). The probability (p) of obtaining the observed case, *or a more extreme case*, under the null hypothesis is indicated in parentheses. Significant differences at $\alpha = 0.05$ are noted by an asterisk (*).

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

survival studies conducted at the Indian Point plant in 1977 and 1978 (EA 1978a, 1979a) using pump/larval table collection systems, complete mortality of anchovy larvae was generally observed within 12 hours of collection, and survival was never recorded for up to 96 hours. Thus, the rear-draw and pumpless plankton sampling flumes used in 1979 successfully reduced sampling stress on larvae of this taxonomic group to an extent that allowed a greater potential for examining and detecting latent effects.

4.3.2.3 Entrainment Survival Estimates

4.3.2.3.1 Striped Bass Eggs

Entrainment survival for striped bass eggs collected during the 1979 spring-summer entrainment survival study was 74 percent, based on the proportions of eggs from intake and discharge samples that hatched within 96 hours of collection (Section 4.3.2.2.1). In light of the comparable intake and discharge gear effects determined for this life stage (Appendix B), this estimate represents the first valid assessment of the survival of striped bass eggs entrained through the condenser cooling water system of the Indian Point plant. Collection gear used in previous study years was not effective for evaluating egg survival because of differential sampling stress between the intake and discharge stations caused by variations in water velocity (stationary nets), or because of virtually complete mortality effected by sampling (pump/larval table collection systems).

4.3.2.3.2 Fish Larvae

Although direct estimates of entrainment survival, S_e, could not be calculated for larval life stages due to differential sampling stress for the rear-draw and pumpless plankton sampling flumes (Section 4.3.2.2.2 and Appendix B), initial survival proportions for larvae collected at the discharge station (DP) provided a minimum estimate of entrainment survival. That is, if entrainment survival was calculated as the ratio of the proportion surviving at the discharge to the proportion surviving at the intake (Section 4.2.3.2), the lower initial survival which typically occurred at the intake station (I3) would result in survival estimates of over 100 percent. However, if no correction is made to remove sampling-induced mortality, discharge survival represents a conservative estimate of entrainment survival, i.e., entrainment survival must be greater than or equal to discharge survival.

Comparison of initial survival for larvae collected at the discharge port (pumpless flume) in 1979, with entrainment survival (S_e) estimates for larvae collected in pump/larval tables in 1977 and 1978 (EA 1978a, 1979a) indicated generally higher results than in 1978 but lower results than in 1977 (Table 4-19). For all discharge temperatures, the 1979 estimate for striped bass yolk-sac larvae (63 percent), uncorrected for sampling mortality, was similar to the survival estimate determined in 1977 (67 percent), and considerably higher than that observed in 1978 (0 percent). Discharge survival for striped bass post yolk-sac larvae in 1979 (68 percent) was intermediate to the survival estimates determined in 1977 and 1978 (85 and 55 percent, respectively).

For white perch, herring, and anchovy post yolk-sac larvae, seasonal survival over the 3-year period ranged from 30 to 77 percent, 16 to 34 percent, and 0 to 36 percent, respectively (Table 4-19). In all cases, highest survival was

TABLE 4-19 COMPARISON OF 1979 DISCHARGE SURVIVAL WITH 1977 AND 1978 ENTRAINMENT SURVIVAL ESTIMATES (S_e) FOR DOMINANT ICHTHYOPLANKTON LARVAE COLLECTED AT THE INDIAN POINT GENERATING STATION

		Survival Estimates (Percent)											
		Discharge Temperatures Less Than 30.0 C			Discharge Temperatures 30.0 to 32.9 C			Discharge Temperatures Greater Than 32.9 C			All Discharge Temperatures Combined		
Taxa[a]	Life Stage	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]	1977[b]	1978[c]	1979[d]
Striped bass	YSL	63	--	58.6	--	0.0	75.0	--	--	--	67	0.0	63.4
	PYSL	85	0.0	63.0	87	66.2	70.1	--	--	--	85	55.4	68.4
White perch	PYSL	73	--	32.0	89	60.1	28.9	--	--	--	77	53.4	30.0
Herrings	PYSL	40	22.3	30.5	--	14.0	22.2	--	--	--	34	15.9	28.9
Anchovies	PYSL	--	--	7.0	36	0.0	2.8	18	0.0	6.3	36	0.0	5.8

(a) Includes all taxa and life stages for which sample sizes were greater than 10 for at least one discharge temperature category.
(b) Entrainment survival estimates (S_e) based on samples collected at Stations I2, I3, and DP using pump/larval table collection systems (from EA 1978a, Table 4-10). These estimates were calculated to the nearest whole number.
(c) Entrainment survival estimates (S_e) based on samples collected at Stations I2, I3, and DP (30 May - 7 June) and I2 and DP (12 June - 12 July) using pump/larval table collection systems (EA 1979a, Tables 4-6 and 4-7).
(d) Survival percent is based on initial survival proportions at the discharge port (Station DP) multiplied by 100. These survival values are unadjusted for intake (control) mortality.

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

observed in 1977. The 1979 discharge survival values unadjusted for intake (control) mortality, represented the lowest survival estimates for white perch post yolk-sac larvae (30 percent) but were intermediate for post yolk-sac larvae of herrings (29 percent) and anchovies (6 percent). For these three taxa, the 1979 estimates based on discharge survival alone are expected to be more severely biased low than for striped bass larvae. Because these taxa characteristically exhibit lower intake survival (i.e., greater sensitivity to sampling effects) than striped bass, the bias in the use of discharge survival as an unadjusted estimate of entrainment survival is, therefore, increased.

Overall, the results obtained with the rear-draw and pumpless plankton sampling flumes in 1979 appear very favorable insofar as the application and effectiveness of these collection systems in entrainment survival assessment. The reduction of sampling stress achieved through the use of these samplers was demonstrated not only in the successful collection of reliable striped bass egg survival data (Section 4.3.2.3.1), but also in the generally higher survival of larvae in discharge collections, as compared to previous years (Section 4.3.2.2.3). Moreover, extended survival of sensitive anchovy larvae was, for the first time, maintained throughout the entire 96-hour latent effects observation period (Section 4.3.2.2.4). With minor refinements to equilibrate gear effects on larval stages, it is, therefore, expected that these flume systems will yield survival data superior to that obtained through application of other collection methods that have been used previously.

5. ENTRAINMENT ABUNDANCE STUDY

5.1 INTRODUCTION

Entrainment abundance samples were collected at a location along the Indian Point Generating Station discharge canal in 1979 to monitor densities of ichthyoplankton entrained through the plant's cooling water system. Sampling was conducted using Ecological Analysts portable automated abundance sampling system (AUTOSAM*) concurrently with stationary plankton net collections. Data were analyzed to determine ichthyoplankton species and life stage composition, as well as seasonal and diel distribution.

The study results presented in this report pertain to the AUTOSAM entrainment abundance sampling effort. Findings and analyses relative to stationary net collections will be presented and compared with the AUTOSAM sampling results in the forthcoming report, "Indian Point Generating Station Entrainment and Near Field River Studies, 1979 Annual Report."

5.2 METHODS AND MATERIALS

5.2.1 Collection Procedures

The AUTOSAM was used to sample ichthyoplankton entrained by the Indian Point plant from 2 May through 14 June 1979 at discharge Station D1 (Figure 3-2), located along a portion of the discharge canal which transports cooling water from Units 1 and 2 (when Unit 1 circulating pumps are operating). The inlet of the intake hose connected to the AUTOSAM sampling pump was positioned at middepth (approximately 3.0 m below the water surface of the canal) and oriented into the discharge water flow. The sampling schedule consisted of one 14-hour sampling effort per week for six weeks. Each 14-hour sampling effort was composed of seven consecutive 2-hour collection periods scheduled such that the midpoint of the fourth collection period occurred approximately at dusk. Five-minute samples collected using conical plankton nets (0.5-m diameter net mouth, and 571-µm mesh) secured to a stationary frame at Station D1 were initiated to coincide with the midpoint of each 2-hour collection period. Sampling was discontinued after 14 June 1979 because of a scheduled maintenance shutdown of Unit 2.

The AUTOSAM is designed to collect ichthyoplankton samples automatically over any preselected time interval. The basic components of the system include a 7.6-cm (3-in.) electric pump, a cylindrical collection tank (1 m in diameter and 1.2 m in height) containing a 505 µm-mesh plankton net, and a microcomputer control module. All components are housed in an enclosed trailer (Figures 5-1 and 5-2).

Operational sequences of the AUTOSAM are controlled by the microcomputer module. During sampling, water is pumped into the net in the collection tank where primary concentration of the sampled organisms and detritus occurs. Filtered water passes out of the collection tank through a discharge drain

*AUTOSAM was developed and patented by Ecological Analysts, Inc. (U.S. Patent No. 4, 145, 928).

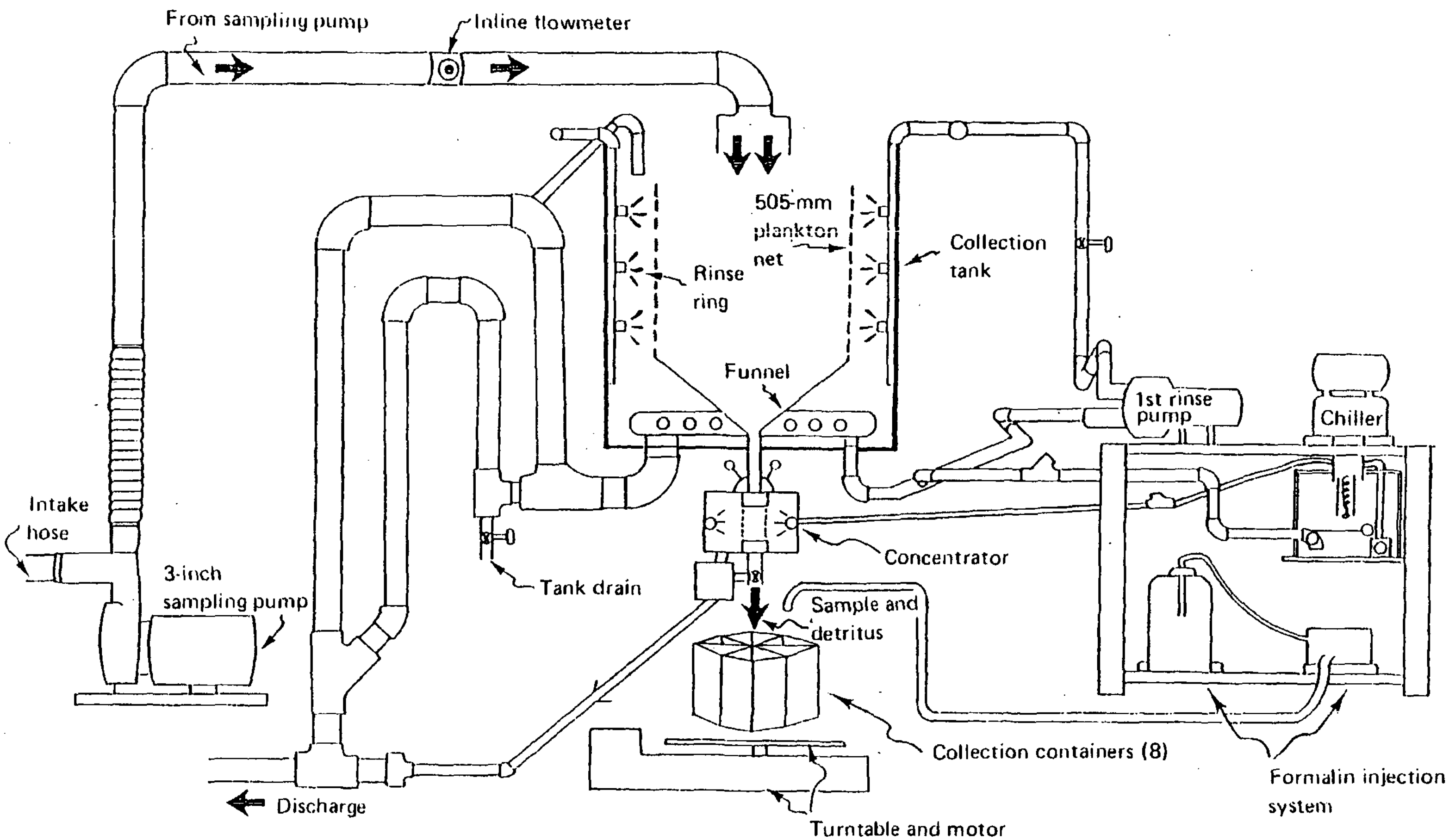


Figure 5-1. Schematic diagram of sampling components of Ecological Analysts' automated abundance sampling system – AUTOSAM (U.S. Patent No. 4, 145, 928).

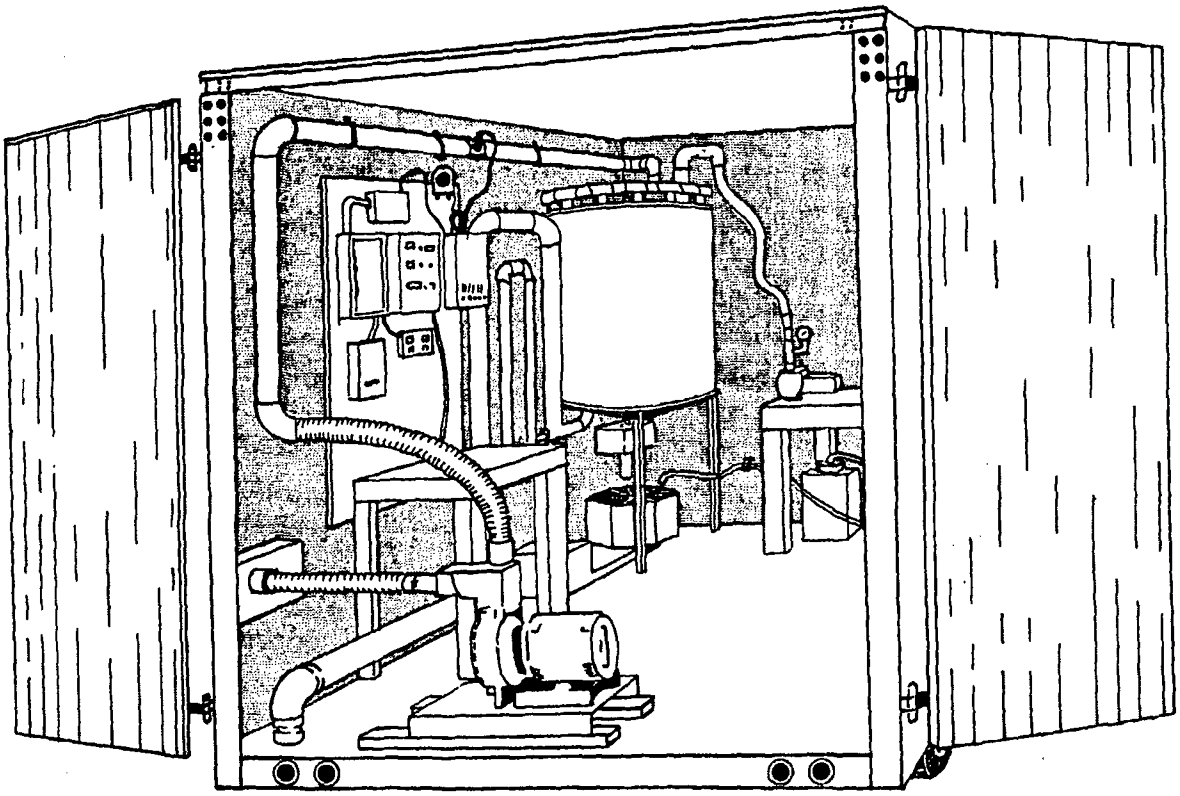


Figure 5-2. Representation of Ecological Analysts' automated abundance sampling system (AUTOSAM) showing orientation of components within trailer housing (U.S. Patent No. 4, 145, 928).

pipe. At the end of the programmed sampling interval, the following automated operations occur: (1) the pump shuts off and the collection tank drains; (2) the collection net is rinsed, concentrating the sample into the bottom of the collection net; (3) the sample is washed into the secondary concentrator and then into a collection container using chilled water (4.4 C) to reduce organism decomposition; and (4) formalin is automatically injected into the collection container to achieve a 10 percent formalin to water solution. After each sample is collected, the turntable holding the collection containers rotates to an empty container, and the sampling sequence automatically begins again.

Four 27-minute samples were composited to make up each of the seven 2-hour abundance samples collected during a 14-hour sampling effort. Water volumes filtered for each 2-hour sample generally ranged from 81 to 106 m^3, as measured by a Signet inline flowmeter mounted to the pipe that transports water from the AUTOSAM sampling pump to the collection tank (Figure 5-1).

Water quality parameters, including water temperature, conductivity, dissolved oxygen, and pH, were recorded from the surface of the discharge canal at Station D1 during the midpoint of each 2-hour collection period. The same parameters were measured concurrently at the Unit 2 intake in conjunction with stationary net sampling at that location. All water quality measurements were obtained using a Martek VI water quality analyzer.

Preserved entrainment abundance samples were transported to Ecological Analysts Central Laboratory in Middletown, New York, for ichthyoplankton identification and life stage determination.

5.2.2 Analytical Procedures

Icthyoplankton collected in each entrainment abundance sample were enumerated to determine species and life stage composition. Mean density for each sampling date and collection period was calculated for life stages of the three major taxa, striped bass (Morone saxatilis), white perch (M. americanus), and herring (Clupeidae), as follows:

$$\text{Mean daily density} = \bar{Y}_i = \frac{\sum_{j=i}^{m} Y_{ij}}{m}$$

$$\text{Mean collection period density} = \bar{Y}_j = \frac{\sum_{i=1}^{n} Y_{ij}}{n}$$

where

Y_{ij} = density of the sample collected on day i in collection period j
n = number of sampling dates = 7
m = number of collection periods per sampling date = 7

Diel trends in abundance were tested statistically with the Friedman rank sum test (Hollander and Wolfe 1973) for only the most abundant taxa-life stage combinations. To avoid loss of power for the test, sampling dates on which the organism was present in the sample in less than five of the collection periods were omitted from the test. The null hypothesis that densities in all collection periods are equal was tested against the alternative hypothesis that densities in all collection periods are not equal.

5.3 RESULTS AND DISCUSSION

5.3.1 Species and Life Stage Composition

The most abundant taxa occurring in AUTOSAM entrainment abundance samples during the 2 May through 14 June sampling season were herrings, striped bass, and white perch. Life stages of these species accounted for 44, 18, and 17 percent, respectively, of the 3,523 ichthyoplankton collected (Table 5-1). An additional 8 percent of the total catch was composed of ichthyoplankton identifiable to the genus *Morone* spp., which includes striped bass and white perch. Thus, of the total fish collected, the majority (87 percent) were representatives of the taxonomic categories Clupeidae (herrings) or *Morone* spp. The remaining 13 percent of the catch was composed of 12 other taxa (Table 5-1), as well as a category that included unidentifiable specimens (i.e., specimens damaged during collection to the extent that reliable identification could not be made).

Among the ichthyoplankton life stages occurring in AUTOSAM entrainment abundance samples, post yolk-sac larvae were predominant, accounting for 79 percent of all organisms collected, followed by yolk-sac larvae (12 percent) (Table 5-1). These life stages were collected in greatest abundance during the 30 May sampling effort, but densities remained relatively high through the termination of sampling on 14 June (Figure 5-3). The majority of larvae collected during the early May through mid-June sampling season were the young of anadromous or migratory estuarine taxa (i.e., herrings, striped bass, and white perch) which spawn during spring and early summer (Table 5-1).

In contrast to yolk-sac and post yolk-sac larvae, egg and juvenile life stages were entrained in relatively low abundance during the sampling season (Figure 5-3). Eggs accounted for only 2 percent of the ichthyoplankton collected, and juveniles for only 1 percent (Table 5-1). Most of the eggs were those of either white perch (62 percent) or striped bass (24 percent), whereas young of the winter-spawning Atlantic tomcod and catadromous (ocean-spawning) American eel were predominant among the juveniles (accounting for 67 and 24 percent, respectively, of all juveniles collected). Juveniles of herrings, striped bass, and white perch were absent from entrainment abundance samples (Table 5-1); sampling was terminated before young of these spring-summer spawners would have developed to the juvenile stage.

5.3.2 Seasonal Distribution

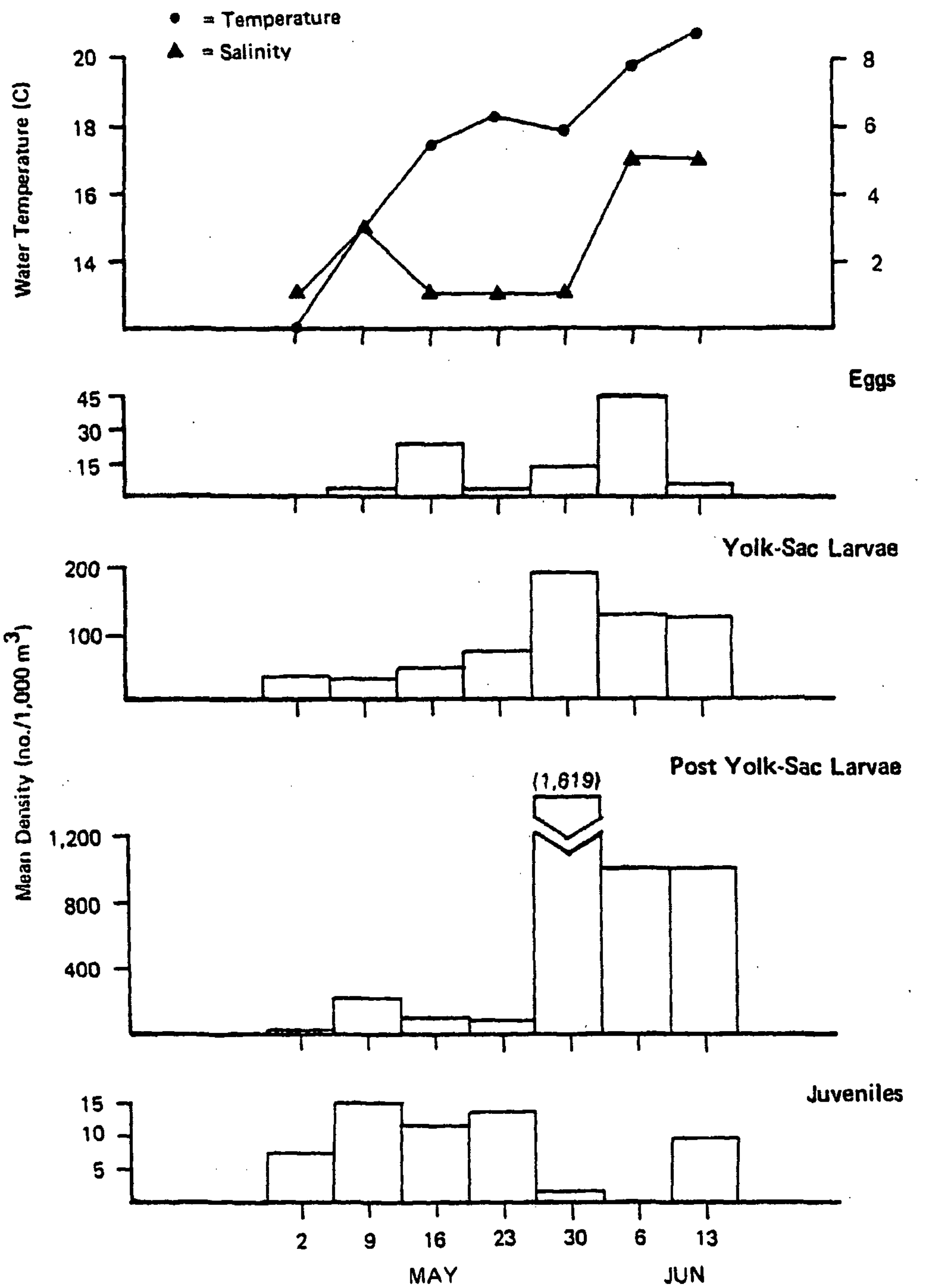
5.3.2.1 Striped Bass

Striped bass eggs were caught only on 9 and 16 May (Figure 5-4), which is consistent with their generally short spawning season (McFadden et al. 1978). Mean water temperatures on these dates (15.0 and 17.5 C) were within the

TABLE 5-1 TOTAL NUMBER AND PERCENT COMPOSITION OF ICHTHYOPLANKTON TAXA AND LIFE STAGES COLLECTED IN THE INDIAN POINT GENERATING STATION DISCHARGE CANAL (Station D1) USING AN AUTOMATED ABUNDANCE SAMPLER, 2 MAY - 14 JUNE 1979

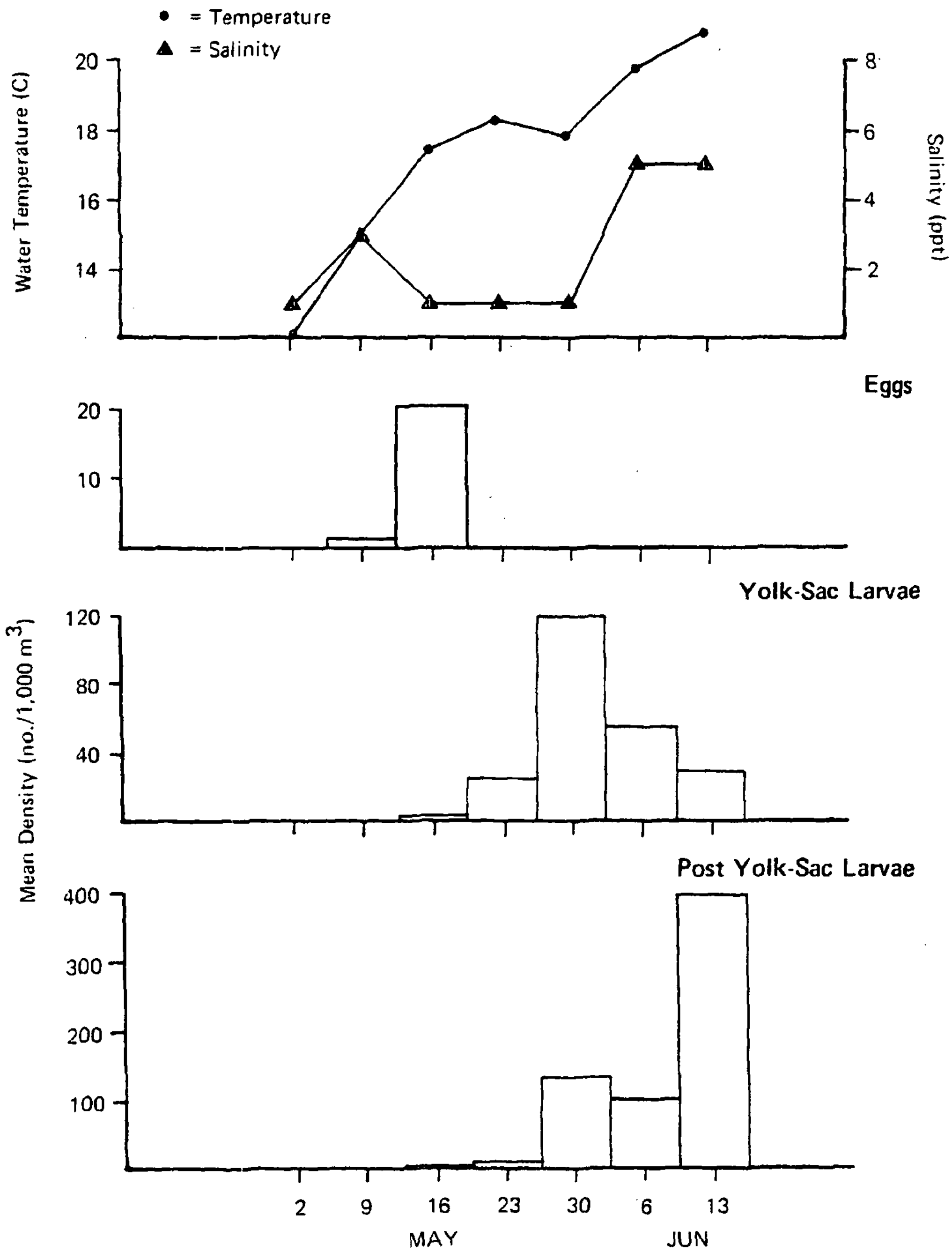
Taxon		Egg	YSL	PYSL	JUV	UID	Total	%
Herrings	Clupeidae	1	3	1,550			1,554	44.1
Striped bass	*Morone saxatilis*	15	160	448			623	17.7
White perch	*Morone americana*	39	107	453			599	17.0
Temperate bass	*Morone* spp.		10	122		134	266	7.6
Rainbow smelt	*Osmerus mordax*	3	30	131			164	4.7
Tessellated darter	*Etheostoma olmstedi*		87	29	2		118	3.3
Minnows	Cyprinidae	1	21	14			36	1.0
Atlantic tomcod	*Microgadus tomcod*				23		23	0.7
American shad	*Alosa sapidissima*			20			20	0.6
American eel	*Anguilla rostrata*				8		8	0.2
Yellow perch	*Perca flavescens*		5	2			7	0.2
Sunfish	Centrarchidae		3	1			4	0.1
Bay anchovy	*Anchoa mitchilli*	1		1			2	0.1
Killifish	*Fundulus* sp.		1				1	0.1
Herring order	Clupeiformes			1			1	0.1
Hogchoker	*Trinectes maculatus*				1		1	0.1
Unidentifiable specimens		3		2		91	96	2.7
Total		63	427	2,774	34	225	3,523	
Percentage of total		(1.8%)	(12.1%)	(78.7%)	(1.0%)	(6.4%)		

Note: YSL = yolk-sac larvae
PYSL = post yolk-sac larvae
JUV = juvenile
UID = unidentified life stage



Note: Water temperature and salinity graphs reflect mean ambient values recorded at the Unit 2 intake during the 14-hour sampling efforts.

Figure 5-3. Mean densities per 14-hour sampling effort for all ichthyoplankton identifiable to life stage collected in the Indian Point Generating Station discharge canal (Station D1) using an automated abundance sampler, 2 May – 14 June 1979.



Note: Water temperature and salinity graphs reflect mean ambient values recorded at the Unit 2 intake during the 14-hour sampling efforts.

Figure 5-4. Mean densities per 14-hour sampling effort for early life stages of striped bass collected in the Indian Point Generating Station discharge canal (Station D1) using an automated abundance sampler, 2 May – 14 June 1979.

temperature range for peak spawning activity, from 15.4 to 19.6 C (Talbot 1966). Initial occurrence for both yolk-sac and post yolk-sac larvae was on 16 May. Peak abundance of yolk-sac larvae occurred on 30 May, but post yolk-sac larvae abundance was highest on 13 June, the final sampling date.

The relative abundance of striped bass early life stages collected in the discharge canal of the Indian Point plant may be associated with the duration of these life stages within the river. Because of the longer duration of successive developmental stages (i.e., 36-48 hours for eggs, 8-13 days for yolk-sac larvae, and 35-40 days for post yolk-sac larvae [Mansueti 1958]), the entrainment period for post yolk-sac larvae is also considerably more extended than for eggs and yolk-sac larvae.

5.3.2.2 White Perch

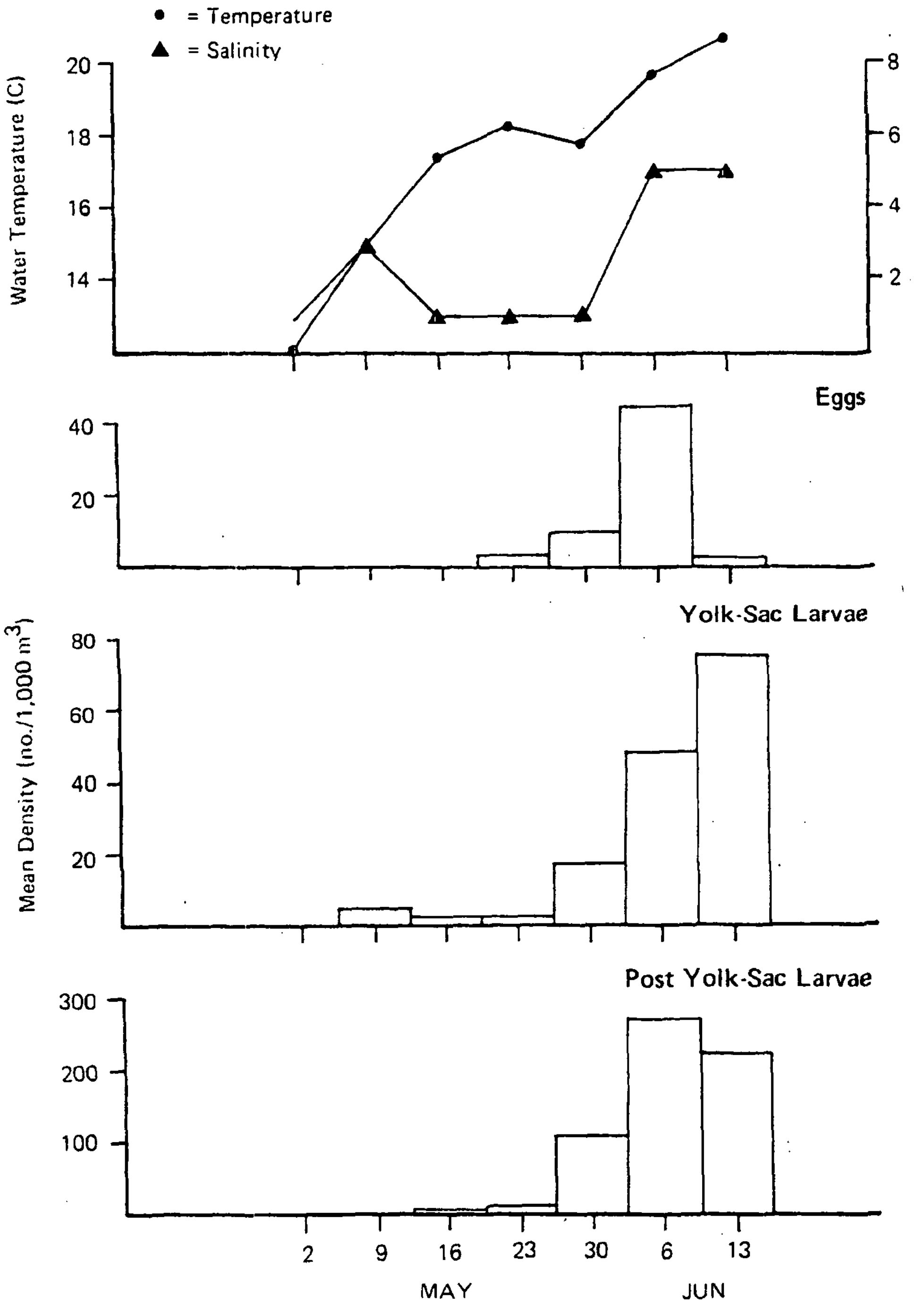
White perch eggs first appeared in samples on 23 May after the earliest collections of yolk-sac and post yolk-sac larvae on 9 and 16 May, respectively (Figure 5-5). The occurrence of larvae before eggs was likely a result of early spawning activity, which can begin at temperatures as low as 10 or 11 C (Mansueti 1964). Highest densities of eggs, however, occurred on 6 June at a mean ambient river temperature of 19.8 C, which is in the temperature range for peak spawning in the Hudson River (16 to 22 C) reported by McFadden et al. (1978). Yolk-sac and post yolk-sac larvae were collected in relatively low abundance until 30 May when densities of both life stages increased markedly in the discharge samples. Densities of both larval stages showed further increase in early June and remained high through 13 June when sampling was terminated.

Like striped bass, white perch post yolk-sac larvae were more abundant in entrainment samples than eggs or yolk-sac larvae, as is consistent with life history and distributional characteristics. White perch spawn primarily in shallow areas and tributaries of the estuary, mostly upriver from Indian Point (McFadden et al. 1978). The demersal eggs and less motile yolk-sac larvae are, therefore, expected to be less vulnerable to entrainment at the Indian Point plant. Distributional data for ichthyoplankton within the Hudson River from 1974 through 1977 also indicate that white perch post yolk-sac larvae are relatively more abundant in the Indian Point region than eggs or yolk-sac larvae (TI 1980).

5.3.2.3 Herrings

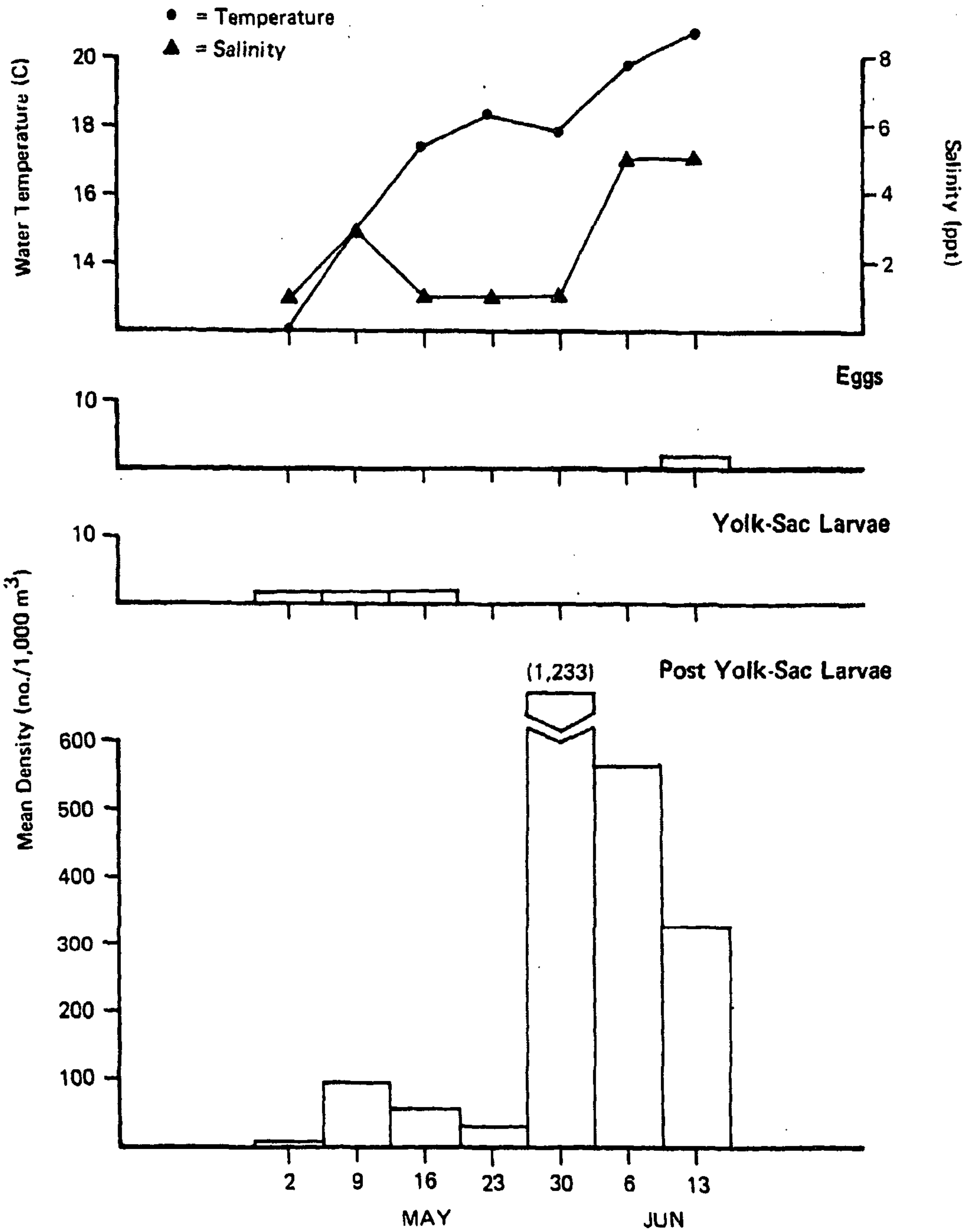
Herring post yolk-sac larvae were abundant in AUTOSAM collections on the last three sampling dates (Figure 5-6). Peak density (1,233 larvae/1000 m^3) occurred on 30 May, whereas mean density was less than 100/1000 m^3 during prior sampling dates. In contrast, eggs and yolk-sac larvae were never abundant during the sampling season; only one egg and three yolk-sac larvae were collected (Table 5-1).

The predominance of post yolk-sac larvae among the life stages of herrings entrained at the Indian Point plant is again reflective of life history and distribution. The principal members of the herring family (Clupeidae) which occur in the Hudson River are the American shad (*Alosa sapidissima*), blueback herring (*A. aestivalis*); and alewife (*A. pseudoharengus*). American shad spawn primarily in the upper estuary, thus eggs and yolk-sac larvae seldom



Note: Water temperature and salinity graphs reflect mean ambient values recorded at the Unit 2 intake during the 14-hour sampling efforts.

Figure 5-5. Mean densities per 14-hour sampling effort for early life stages of white perch collected in the Indian Point Generating Station discharge canal (Station D1) using an automated abundance sampler, 2 May – 14 June 1979.



Note: Water temperature and salinity graphs reflect mean ambient values recorded at the Unit 2 intake during the 14-hour sampling efforts.

Figure 5-6. Mean densities per 14-hour sampling effort for early life stages of herrings collected in the Indian Point Generating Station discharge canal (Station D1) using an automated abundance sampler, 2 May – 14 June 1979.

occur in the Indian Point vicinity (McFadden et al. 1978). Blueback herring and alewife typically spawn in tributary streams. Consequently, earliest life stages of these species (i.e., eggs and yolk-sac larvae) are expected to be less abundant in the river proper during the spring-summer spawning and nursery season, than the more highly motile post yolk-sac larvae.

5.3.3 Diel Distribution

Mean densities per 2-hour collection periods varied widely for the three dominant taxa, particularly with regard to post yolk-sac larvae (Table 5-2). The skewed temporal distribution (Figures 5-4, 5-5, and 5-6) thus precluded statistical analysis based on assumptions of normal distribution of sample densities over the entire sampling season.

No significant differences in density among collection periods ($\alpha = 0.05$) were found for striped bass, white perch, and herrings based on the application of the Friedman rank sum test (Table 5-3), although the power of this test may have been limited by the small number of sampling dates available for the analysis, particularly for striped bass and white perch. The mean daily rank for each collection period suggested bimodal peaks in abundance for all three taxa (Figure 5-7). Peaks occurred for striped bass in collection periods 3 and 6, for white perch in collection periods 3 and 7, and for herring in collection periods 4 and 7. Thus, all three taxa showed peaks in abundance just prior to, or at, dusk (collection period 4) and 4-6 hours after dusk. Again, it should be emphasized that although these trends may be real, they were not statistically significant.

TABLE 5-2 MEAN DENSITY (No./1,000 m^3) BY COLLECTION PERIOD FOR EARLY LIFE STAGES OF STRIPED BASS, WHITE PERCH, AND HERRINGS COLLECTED IN THE INDIAN POINT GENERATING STATION DISCHARGE CANAL (Station D1) USING AN AUTOMATED ABUNDANCE SAMPLER, 2 MAY - 14 JUNE 1979

Taxon	Life Stage	1	2	3	4	5	6	7
Striped bass	Egg	2.9	3.2	8.9	1.5	0.0	0.0	5.7
	YSL	43.5	57.8	30.4	17.3	25.7	42.5	11.4
	PYSL	67.6	115.3	93.9	46.6	23.1	166.8	125.8
White perch	Egg	3.0	1.5	0.0	6.0	3.0	14.6	30.0
	YSL	10.2	12.4	21.9	19.7	1.3	26.1	60.7
	PYSL	54.2	63.6	132.0	71.2	63.1	119.3	147.3
Herrings	Egg	0.0	0.0	0.0	0.0	1.5	0.0	0.0
	YSL	0.0	0.0	1.7	0.0	3.3	0.0	0.0
	PYSL	138.3	141.6	265.3	749.2	321.3	238.1	385.2

Note: YSL = yolk-sac larvae
PYSL = post yolk-sac larvae

TABLE 5-3 RESULTS OF FRIEDMAN RANK SUM TEST FOR DIFFERENCES IN DENSITIES ACROSS COLLECTION PERIODS RELATIVE TO EARLY LIFE STAGES OF STRIPED BASS, WHITE PERCH, AND HERRINGS COLLECTED IN THE INDIAN POINT GENERATING STATION DISCHARGE CANAL (Station D1) USING AN AUTOMATED ABUNDANCE SAMPLER, 2 MAY - 14 JUNE 1979

Taxon	Life Stage	n[a]	Rank Sums For Each Collection Period 1	2	3	4 (dusk)	5	6	7	S[b]	p
Striped bass	PYSL	3	9	11	16	13	5	16	14	6.86	>0.05
	YSL	4	11	22	18.5	16	12.5	20	12	6.03[c]	>0.05
White Perch	PYSL	3	8	8	17	10	11	14	16	5.86	>0.05
Herrings	PYSL	6	18	17	26	31.5	23	20.5	32	7.97[c]	>0.05

(a) Number of sampling dates when organisms were collected in at least 5 of the 7 collection periods.
(b) Test statistic (S) has an approximate chi-square (χ^2) distribution under the null hypothesis that densities during all collection periods are equal; critical value at $\alpha = 0.05$ is 12.6.
(c) Correction for ties (i.e., cases where the same rank occurred for one or more collection period) required calculation of S' instead of S (Hollander and Wolfe 1973).

Note: YSL = yolk-sac larvae
PYSL = post yolk-sac larvae

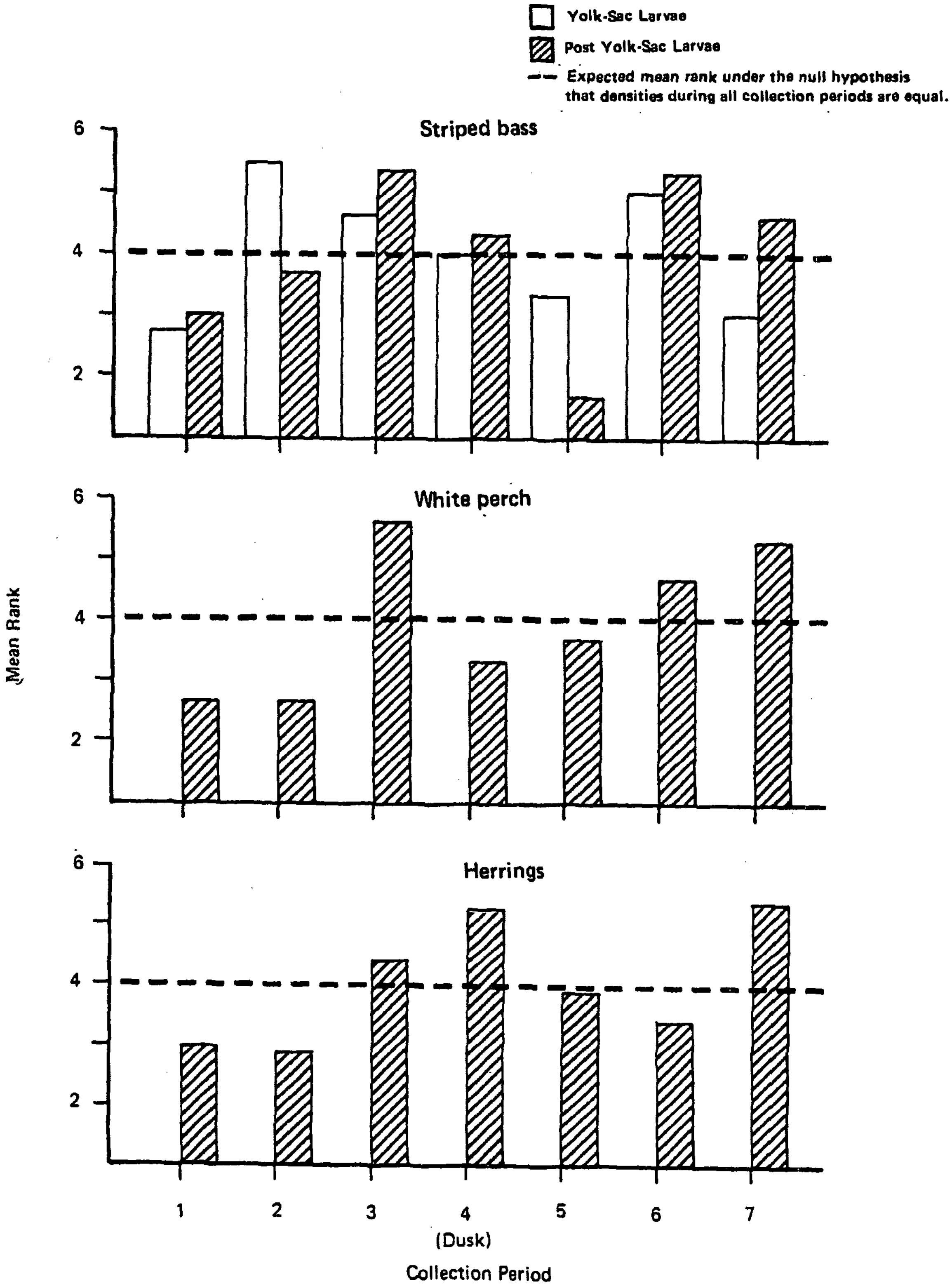


Figure 5-7. Mean rank per 2-hour collection period for early life stages of striped bass, white perch, and herrings, as determined from densities collected in the Indian Point Generating Station discharge canal (Station D1) using an automated abundance sampler, 2 May – 14 June 1979.

REFERENCES

Consolidated Edison Company of New York, Inc. 1974. Economic and Environmental Impacts of Alternative Closed Cycle Cooling Systems for Indian Point Unit No. 2.

Consolidated Edison Company of New York, Inc. 1977a. Indian Point Unit No. 2, Indian Point Unit No. 3. Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota. Consolidated Edison Company of New York, Inc., Power Authority of the State of New York. July.

Consolidated Edison Company of New York, Inc. 1977b. Routine monthly thermal monitoring report. October 1976.

Consolidated Edison Company of New York, Inc. 1979. Monthly Section 401 Certification Data, January-December 1979. Prepared for the Commissioner, New York State Department of Environmental Conservation. Buchanan, N.Y.

Duncan, A.J. 1974. Quality Control and Industrial Statistics. 4th Ed. Richard D. Irwin, Inc. Homewood, Illinois. 1,047 pp.

Ecological Analysts, Inc. 1978a. Indian Point Generating Station Entrainment Survival and Related Studies. 1977 Annual Report. Prepared for Consolidated Edison Company of New York, Inc.

Ecological Analysts, Inc. 1978b. Hudson River Thermal Effects Studies for Representative Species--Final Report. Prepared for Central Hudson Gas and Electric Corp., Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978c. Field Studies of the Effects of Thermal Discharges from Roseton and Danskammer Point Generating Stations on Hudson River Fishes. Prepared for Central Hudson Gas and Electric Corp.

Ecological Analysts, Inc. 1978d. Roseton Generating Station Entrainment Survival Studies, 1977 Annual Report. Prepared for Central Hudson Gas and Electric Corp.

Ecological Analysts, Inc. 1979a. Indian Point Generating Station Entrainment Survival and Related Studies. 1978 Annual Report. Prepared for Consolidated Edison Company of New York, Inc., and Power Authority of the State of New York.

Ecological Analysts, Inc. 1979b. Ichthyoplankton Entrainment Survival and Abundance Sampling Study Research and Development of Gear and Methods. Prepared for Empire State Electric Energy Research Corporation.

Ecological Analysts, Inc. 1979c. Bowline Point Generating Station Entrainment Abundance and Survival Studies. 1978 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1980a. Indian Point Generating Station Entrainment and Near Field River Studies. 1978 Annual Report. Prepared for Consolidated Edison Company of New York, Inc., and Power Authority of the State of New York.

Ecological Analysts, Inc. 1980b. Danskammer Point Generating Station Entrainment Survival Studies. 1978 Annual Report. Prepared for Central Hudson Gas and Electric Corp.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York.

Mansueti, R. J. 1958. Eggs, larvae and young of the year striped bass, Roccus saxatilis. Md. Dept. Res. and Ed., Ches. Biol. Lab. Contr. 112. 35 pp.

Mansueti, R. J. 1964. Eggs, larvae and young of the year white perch, Roccus americanus with comments on its ecology in the estuary. Ches. Sci. 5(1-2):3-45.

McFadden, J. T., Texas Instruments Incorporated, and Lawler, Matusky & Skelly Engineers. 1978. Influence of the Proposed Cornwall Pumped Storage Project and Steam Electric Generating Plants on the Hudson River Estuary with Emphasis on Striped Bass and Other Fish Populations (revised). Prepared for Consolidated Edison Company of New York, Inc.

McGroddy, P. N. and R. L. Wyman. 1977. Efficiency of nets and a new device for sampling living fish larvae. J. Fish. Res. Board Can. 34:4.

New York University Medical Center. 1973. Effects of Entrainment by the Indian Point Power Plant on Hudson River Biota. Progress Report for 1971 and 1972. Prepared for Consolidated Edison Co. of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1974. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1973. Prepared for Consolidated Edison Company of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1976a. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1974. Prepared for Consolidated Edison Company of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1976b. Mortality of Striped Bass Eggs and Larvae in Nets. A special report to Consolidated Edison Company of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1976c. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Addenda to the 1973 Report. Prepared for Consolidated Edison Company of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1977. Hudson River Ecosystem Studies. Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1975. Prepared for Consolidated Edison Company of New York, Inc., by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

New York University Medical Center. 1978. The Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary. Progress Report for 1976. Prepared by NYU Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

O'Connor, J. M. and S. A. Schaffer. 1977. The effects of sampling gear on the survival of striped bass ichthyoplankton. Chesapeake Sci. 18(3).

Sokal, R. R. and F. J. Rohlf. 1969. Biometry--The Principles and Practice of Statistics in Biological Research. W. H. Freeman and Company, San Francisco.

Talbot, G. B. 1966. Estuarine environmental requirements and limiting factors for striped bass, in A Symposium on Estuarine Fishes. Am. Fish. Soc. Spec. Publ. No. 3. 1966. Pp. 37-49.

U.S. Nuclear Regulatory Commission. 1975. Appendix B to Facility Operating License for Consolidated Edison Company of New York, Incorporated. Indian Point Nuclear Generating Units Numbers 1, 2, and 3 (Docket Numbers 50-3, 50-247, 50-286) Environmental Technical Specification Requirements for Once-Through Cooling.

Texas Instruments Incorporated. 1980. 1977 Year Class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

APPENDIX A

DIRECT RELEASE STUDIES

APPENDIX A: DIRECT RELEASE STUDIES

A.1 INTRODUCTION

In 1979, hatchery-reared striped bass were released at the Indian Point plant Unit 2 and Unit 3 intakes and collected in the discharge canal, and/or at the discharge port, to provide additional information on entrainment survival and to assess recovery efficiency of organisms known to have entered the cooling water systems. For direct release experiments designed to determine survival, samples were recovered at the discharge port (Station DP) using the pumpless plankton flume. Survival was compared to that of control organisms exposed to sampling effects only in the rear-draw plankton sampling flume at the Unit 3 intake (Station I3). The release of large numbers of organisms facilitated collection of more fish at the discharge than normally collected during sampling of wild ichthyoplankton, thus providing larger sample sizes for estimating entrainment survival. Evaluation of test results, however, must take into account additional stresses associated with pre-test, or hatchery-induced, handling and holding that are not experienced by wild organisms.

Striped bass life stages released during recovery efficiency experiments at Unit 2 and Unit 3 were sampled at the discharge port (Station DP) using the pumpless plankton sampling flume. For the Unit 2 experiments, additional samples were collected using stationary plankton nets at a location along the discharge canal which contains cooling water from Unit 2 only (Station D1). Recovery efficiency was examined by comparing the number of released fish recovered at the discharge stations with predicted recovery based on the number released, the volume of discharge water sampled, and the volume of cooling water pumped at the time of the test. Results were compared with findings of similar tests conducted in 1977 and 1978 (EA 1978a, 1979a).

A.2 METHODS

A.2.1 Direct Release Survival Experiments

To obtain supplemental information on the survival of striped bass early life stages entrained through the cooling water systems of the Indian Point plant, test groups of hatchery-reared striped bass eggs, yolk-sac larvae, and post yolk-sac larvae were released at the Unit 2 and Unit 3 intake bays and recaptured at the discharge port (Station DP) using the pumpless plankton sampling flume. One release per unit was conducted for eggs, yolk-sac larvae, 14-day old post yolk-sac larvae, and 20-day old post yolk-sac larvae. An additional release of 32- to 33-day old post yolk-sac larvae was conducted only at Unit 3 due to the limited availability of organisms within this age group. For eggs and yolk-sac larvae, approximately 300,000 organisms were released during each test, whereas approximately 150,000 organisms were released per test for each of the post yolk-sac larvae age groups. It was not possible to test juvenile striped bass because of the difficulty in rearing large numbers of hatchery fish to this life stage.

Striped bass used in the direct release experiments were obtained from the Con Edison hatchery facility at Verplanck, New York, operated by Texas

Instruments Incorporated. Organisms were transported from the hatchery to the Indian Point site in insulated containers and transferred immediately into 500-liter holding tanks. Eggs were acclimated to ambient river water over a 10-minute period. All other life stages were acclimated for 2 to 5 hours before release. Holding tanks were supplied with oxygen and a constant flow of river water during acclimation. Following acclimation, test organisms (150,000 or 300,000 per unit) were released between the trash racks and the circulating pumps at the Unit 2 and Unit 3 intakes through a 10-cm diameter hose attached to the bottom of the holding tank. Striped bass were recovered at the discharge port station (DP) with the pumpless plankton sampling flume according to standard collection procedures (Section 4.2.1.2.3). Sampling was initiated 2 to 5 minutes after each release, depending on the predicted through-plant transit time, and was continued for 15 minutes.

Sampling and handling control tests were conducted in conjunction with each direct release experiment to determine mortality due to various stress components including sampling, handling, and pre-test holding. These tests were conducted within 1 to 6 hours of releases at both units. Control organisms were of similar age to the released organisms and experienced the same acclimation procedures. In sampling control tests, approximately 70 to 100 eggs or larvae were released into the front of the rear-draw plankton sampling flume at Station I3. Sampling was then conducted according to standard procedures (Section 4.2.1.2.3). These organisms experienced transport from the hatchery, acclimation, handling, and sampling, but not entrainment. For handling control tests, approximately 50 to 100 organisms of each life stage were placed in sample transport containers after experiencing transport from the hatchery, acclimation, and handling. These organisms thus experienced all stresses other than entrainment and sampling stress.

At the completion of each direct release experiment, test and control samples were taken to the onsite laboratory for sorting. All striped bass larvae within the size range of the released fish were considered to be recoveries from the experimental group. Live and stunned organisms were maintained for 96 hours to assess latent effects. Eggs were held until hatching or mortality occurred. All specimens were preserved at death or at the end of latent effects observations.

Survival proportions and entrainment survival estimates, were determined as described in Section 4.2.3. Survival proportion for hatchery-reared striped bass recovered at the discharge port station (DP) were additionally compared to survival proportions for intake control fish (exposed to sampling, handling, and holding stresses) using three-way contingency analysis (Sokal and Rohlf 1969) to examine possible differences in survival associated with station and life stage.

A.2.2 Direct Release Recovery Efficiency Experiments

Experiments to determine recovery efficiency were conducted by releasing dyed hatchery-reared striped bass between the trash racks and the circulating pumps at Units 2 and 3 and collecting them after they had passed through the cooling water system of the power plant. Releases were made at Bay 25 for Unit 2 and at Bay 36 for Unit 3. For both Unit 2 and Unit 3 releases, organisms were recovered at the discharge port station (DP) using the pumpless plankton sampling flume. For experiments conducted at Unit 2, additional samples were collected at Station D1 (located upstream of the point where discharge water from Unit 3 enters the common discharge canal) using paired, 571 μm mesh conical plankton nets (0.5 m diameter mouth opening, 1.8 m in length) positioned at the surface, middepth, and bottom (Figure A-1). Sampling duration was 30 minutes at Station DP (pumpless flume), and 15 minutes at Station D1 (nets), beginning simultaneously with release of the organisms.

Prior to each experiment, the total number of organisms to be released was estimated and organisms were dyed to distinguish the hatchery-reared from wild striped bass. The total number released was estimated by counting the number of eggs or larvae in 5 or 6 aliquots (5 ml each for eggs and young larvae, 17 ml each for older post yolk-sac larvae) and extrapolating the mean density to the total volume of concentrated eggs or larvae. Because these experiments were conducted with dead organisms, only a minimum amount of water was retained with the organisms during sample size estimation.

During initial efforts at dyeing the hatchery-reared organisms, trypan blue (eggs) or a combination of rose bengal and neutral red dyes (yolk-sac and early post yolk-sac larvae) were used. These dyes were not effective, however, and the hatchery-reared organisms could not be easily distinguished from river organisms. For older groups of post yolk-sac larvae (20 to 33 days), the preservative isopropyl alcohol was added to the rose bengal-neutral red dye. For these larvae, dye retention was sufficient to distinguish wild and hatchery-reared larvae. Poor dye retention for eggs and early post yolk-sac larvae was recognized immediately upon collection, and a 5-minute sample was subsequently collected with the plankton nets at Station D1 to estimate the background density of wild striped bass.

The expected number of fish in discharge collections, $E(N_C)$, was calculated as follows:

$$E(N_C) = (\hat{NR}) \frac{V_s}{V_p}$$

where

$E(N_C)$ = expected number of fish recovered

$\hat{NR}$ = estimated total number of fish released

V_s = volume of discharge water sampled

V_p = volume of water pumped through the plant during sampling

Approximate 95 percent confidence limits for the expected number of fish recovered were similarly calculated from the upper and lower 95 percent confidence limits for the total number released.

95 percent confidence limits for $\hat{NR}$:

$$\hat{NR} \pm t_{(.05,\ n-1)} \cdot \frac{\text{standard deviation of aliquot densities} \cdot \text{total volume of organisms}}{n}$$

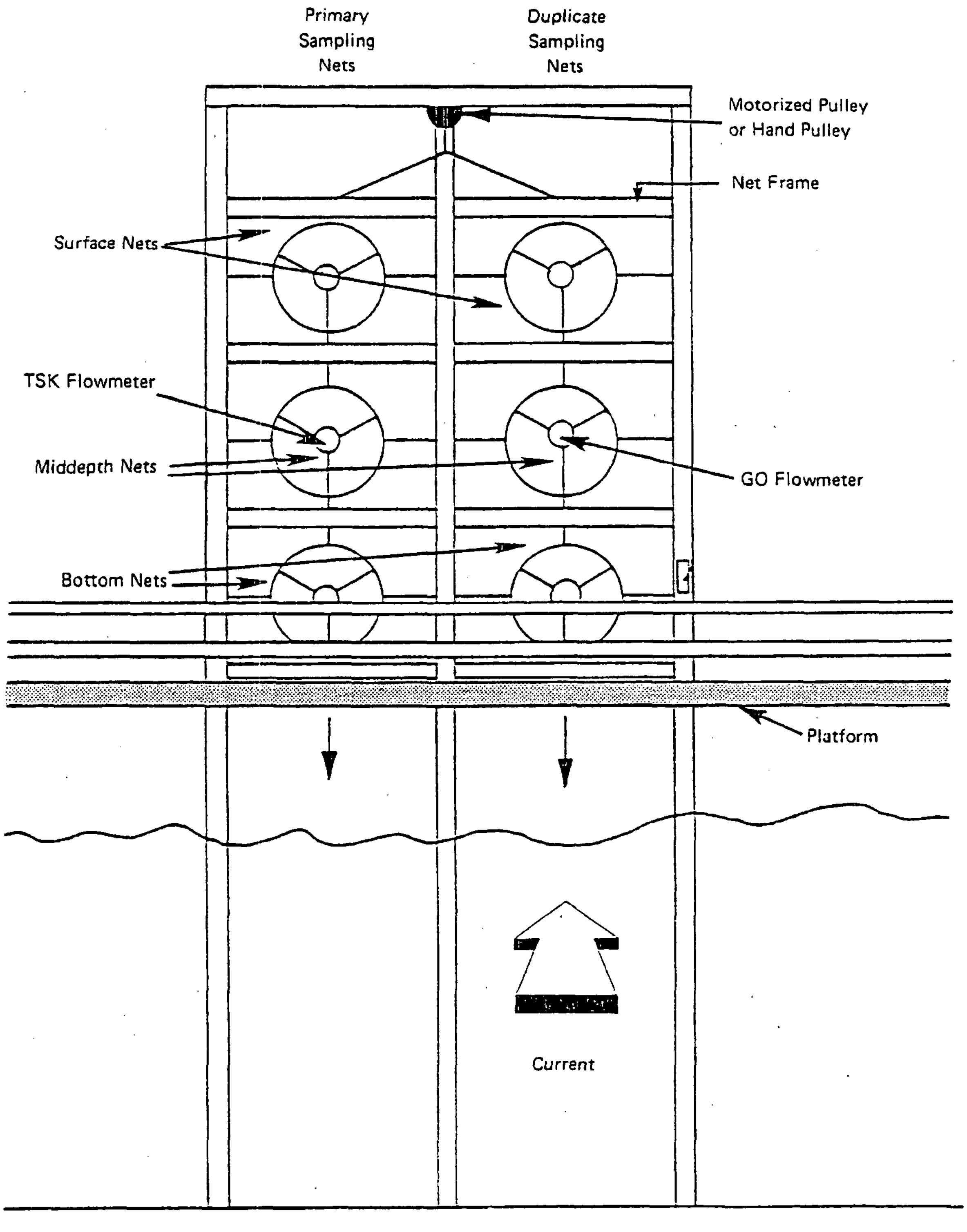


Figure A-1. Stationary net sampling apparatus at Station D1 used during direct release recovery efficiency experiments, Indian Point Generating Station, 1979.

where

t = Student's t value for $\alpha = 0.05$ and (n-1) degrees of freedom
n = number of aliquots

Recovery efficiency at the two discharge stations was determined as the number of organisms recovered at each station divided by the number of organisms that were expected to be recovered. To provide unbiased estimates for recovery experiments in which background density was measured (eggs and early post yolk-sac larvae), the density of fish recovered at each discharge station was adjusted. Adjustments were based on the average density of wild striped bass in the background samples.

A.3 RESULTS AND DISCUSSION

A.3.1 Direct Release Survival Experiments

A.3.1.1 Survival Proportions

A.3.1.1.1 Egg Survival and Initial Survival of Larvae

Survival proportions for striped bass eggs tested in direct release and associated control experiments varied from 0.500 to 0.960 (Table A-1). Survival proportions for eggs recovered at the discharge port (Station DP) during both the Unit 2 and Unit 3 tests (0.500 and 0.651, respectively), were lower than those for sampling controls at Station I3 (0.838), whereas highest survival was observed in the handling controls (0.960 for the Unit 2 tests and 0.930 for the Unit 3 tests).

Striped bass yolk-sac larvae, 2 to 3 days old were apparently more sensitive to stresses associated with entrainment, sampling, and holding, since initial survival proportions for all test groups were lower than those for eggs (Table A-1). Again, highest survival proportions occurred for the handling controls (0.921 and 0.777 for the Unit 2 and Unit 3 tests, respectively). In contrast to eggs, however, the survival proportion for yolk-sac larvae tested in the sampling control (I3) was lower (0.064) than survival proportion for entrained larvae recovered at the discharge port (DP) following the Unit 2 and Unit 3 releases (0.111 and 0.308, respectively).

Initial survival proportions for post yolk-sac larvae were substantially higher than for yolk-sac larvae. Handling controls for all test groups exhibited 100 percent survival (Table A-1). Initial survival for sampling controls increased progressively from 0.763 to 0.980 as the larvae increased in age and size. Survival of entrained larvae was 0.938 (Unit 3) and 0.455 (Unit 2) for the first test on 4 June, and 0.786 (Unit 3) and 0.571 (Unit 2) for the second test on 11 June. The final test on 22 June was conducted only at Unit 3 and only one initially alive larva was recovered.

Differences in survival proportions among tests (and thus among life stages) and sampling stations were examined using three-way contingency analysis (Sokal and Rohlf 1969) for the first four tests at each station. The final test, conducted at Unit 3 only, was omitted because of low recovery (one larva) at Station DP. The overall test of independence among test group (life stage), station, and survival was highly significant, G = 277.1, with

TABLE A-1 INITIAL SURVIVAL PROPORTIONS FOR HATCHERY-REARED STRIPED BASS EGGS AND LARVAE RECOVERED IN DIRECT RELEASE SURVIVAL EXPERIMENTS, INDIAN POINT GENERATING STATION, 1979

						Unit 2 Experiments				Unit 3 Experiments			
Date	Life Stage	Age[a] (Days)	Total Length (mm)	Estimated No. Released/ Unit	Station/ Control	Temp. (C)	N	Survival[c] Proportion	SE	Temp. (C)	N	Survival[c] Proportion	SE
18 MAY	Egg	2	--	300,000	HC	18	100	0.960	0.02	18	100	0.930	0.03
					I3-SC[b]	18	105	0.838	0.04	18	105	0.838	0.04
					DP	27	24	0.500	0.01	27	63	0.651	0.06
22 MAY	YSL	2-3	4-6	300,000	HC	18	89	0.921	0.03	18	130	0.777	0.04
					I3-SC[b]	17	93	0.064	0.03	17	93	0.064	0.03
					DP	29	9	0.111	0.10	27	13	0.308	0.11
4 JUN	PYSL	14	5-8	150,000	HC	19	96	1.000	0.00	20	101	1.000	0.00
					I3-SC[b]	20	97	0.763	0.04	20	97	0.763	0.04
					DP	29	11	0.455	0.15	29	16	0.938	0.06
11 JUN	PYSL	20	6-10	150,000	HC	20	100	1.000	0.00	20	100	1.000	0.00
					I3-SC[b]	21	74	0.959	0.02	21	74	0.959	0.02
					DP	30	7	0.571	0.19	30	14	0.786	0.11
22 JUN	PYSL	33	10-13	150,000	HC					23	54	1.000	0.00
					I3-SC					23	99	0.980	0.01
					DP					30	1	1.000	0.00

(a) Age of eggs is from time of spawning. Age of larvae is from time of hatching.
(b) Intake control samples (Station I3) were used for both Unit 2 and Unit 3 experiments.
(c) Survival proportions for eggs = No. of eggs that hatched within 96 hours / Total no. of eggs recovered

Survival proportions for larvae = No. of alive + stunned larvae observed immediately after collection or testing / Total no. of larvae recovered

NOTE: HC = handling control group
I3-SC = sampling control group conducted at Station I3
DP = experimental group sampled at Station DP
N = number collected
SE = standard error

17 degrees of freedom (Table A-2). All three main factors were related, i.e., test group X station, test group X survival, and station X survival were all significant ($\alpha = 0.05$). The interaction among the three factors was also significant.

The significant interaction among factors (G = 29.4 with 6 degrees of freedom, Table A-2) occurred due to the extremely low survival of yolk-sac larvae at the Unit 3 intake station (I3) (Figure A-2). For this life stage, sampling stress in the rear-draw (intake) flume was apparently greater than the combined effects of entrainment and sampling stress of the pumpless (discharge) flume. Similar low survival for yolk-sac larvae at Station I3 was observed for wild striped bass (Section 4.3.2.2.2) and for hatchery-reared organisms tested in collection system calibration experiments (Appendix B). The higher sampling stress associated with the rear-draw flume (Station I3) apparently declined for older larvae since survival at Station I3 was intermediate between the discharge samples for Unit 2 and Unit 3 for 14-day old larvae, and higher than both discharge samples for 20-day old larvae. No interaction occurred between the discharge samples for Units 2 and 3 (Figure A-2).

The lack of independence between test group and station, although highly significant, G = 36.9 with 6 degrees of freedom, indicated only that organisms were not randomly distributed among the test group X station combinations (Table A-2). Station I3, the sampling control, always had approximately 100 organisms, whereas the discharge port collections (Station DP) always contained fewer organisms. Since this lack of indpendence was, thus, artificially induced and the distribution of organisms among tests and stations was not of interest, the G value was not partitioned to examine specific differences.

Lack of independence between test groups, or life stages, and survival accounted for most of the total significance. The G value for the test group X survival was 201.3 with 3 degrees of freedom out of the total G value of 277.1 (Table A-2). Since 3 degrees of freedom were available, the G value could, therefore, be partitioned. Since all three stations, i.e., DP for Unit 2 tests, DP for Unit 3 tests, and the intake control (I3), exhibited similar low survival for yolk-sac larvae (Figure A-2), survival of this life stage was compared to that of the other three test groups. This comparison was highly significant and accounted for most of the significant G value (188.4 with 1 degree of freedom, Table A-2) for the test group X survival effect. Further partitioning was not conducted due to the three-way interaction and the inequality of sample sizes among stations.

Differences in survival across stations were significant (G = 9.52 with 2 degrees of freedom) but did not account for a large part of the overall lack of independence (Table A-2). Since differences in survival across stations provide the basis for entrainment survival estimates, the G value was partitioned further. The interaction among sampling controls (Station I3) and the discharge samples (Station DP) (Figure A-2) precluded any comparisons which included the I3 samples. However, since there was no interaction between DP samples for Unit 2 and Unit 3 tests, this comparison could be made. Differences in survival between DP collections for Units 2 and 3 were significant (G = 8.0 with 1 degree of freedom) and thus accounted for most of the station X survival effect. The significant difference in discharge survival between Unit 2 and 3 tests may have been caused by different thermal exposure at the

TABLE A-2 RESULTS OF THREE-WAY CONTINGENCY ANALYSIS FOR INDEPENDENCE AMONG TEST GROUP, STATION, AND SURVIVAL FOR HATCHERY-REARED STRIPED BASS RECOVERED IN DIRECT RELEASE SURVIVAL EXPERIMENTS AT THE INDIAN POINT GENERATING STATION, 1979

Source	dF	G
Test group X station independence	6	36.7**
Test group X survival independence	3	201.0**
2 vs. (1 + 3 + 4)	1	188.4**
Station X survival independence	2	9.5*
DP2 vs. DP3	1	8.0**
Test group X station X survival interaction	6	29.4**
Test group X station X survival independence	17	276.5**

NOTE: Test group 1 = eggs (18 May)
2 = yolk-sac larvae (22 May)
3 = post yolk-sac larvae (4 June)
4 = post yolk-sac larvae (11 June)

Station DP2 = discharge port sample for Unit 2 test
DP3 = discharge port sample for Unit 3 test

df = degrees of freedom
G = test statistic
* denotes $p \leq 0.05$
** denotes $p \leq 0.005$

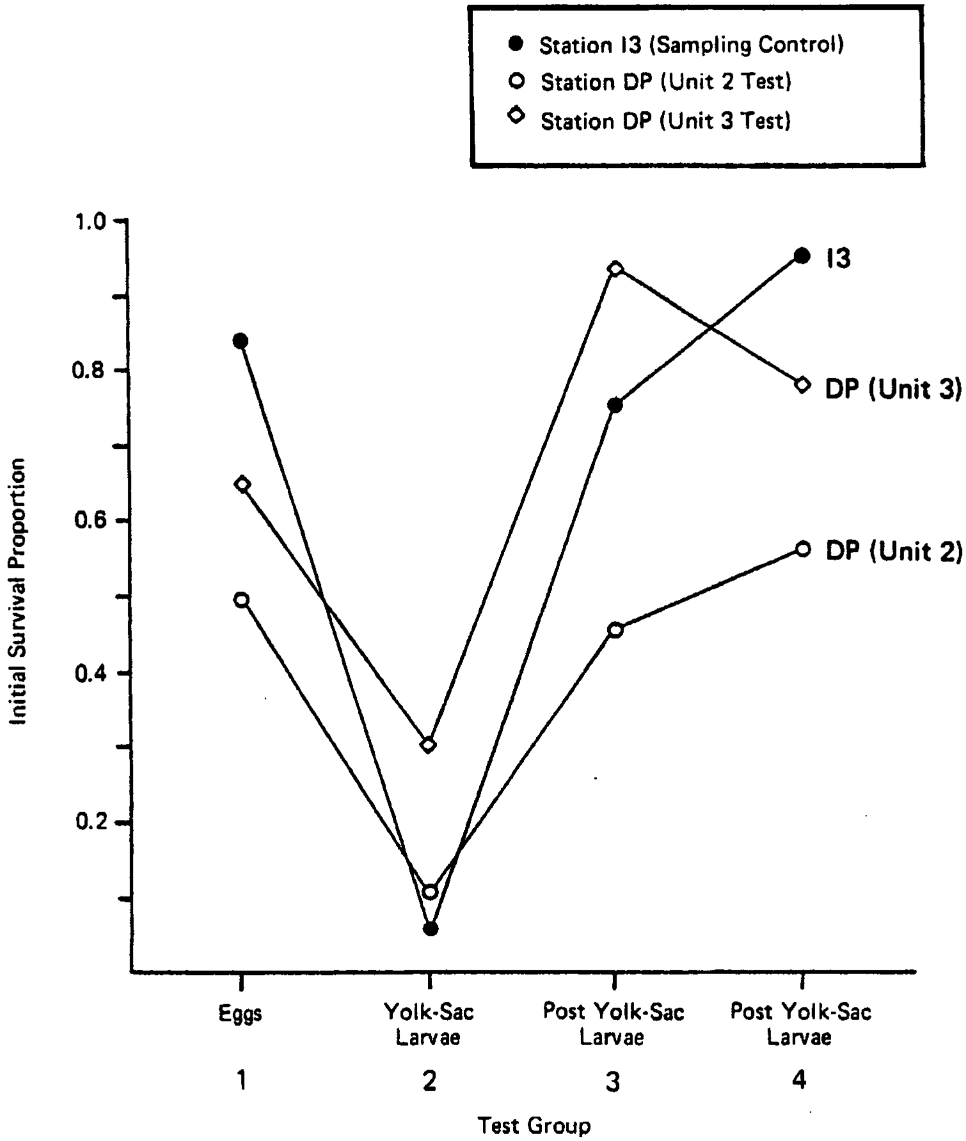


Figure A-2. Initial survival proportions for hatchery-reared striped bass eggs and larvae recovered in direct release survival experiments, Indian Point Generating Station, 1979.

two units, resulting from varying generating levels, circulating pump operation, and longer transit time for Unit 2.

A.3.1.1.2 Comparison of Survival Proportion for Hatchery-Reared and Wild Striped Bass

Direct release survival proportions for hatchery-reared striped bass were compared to survival proportions for appropriate groups of wild striped bass collected during the spring-summer entrainment survival study (Section 4.3.2.2.2) to determine whether survival was similar for hatchery and wild fish. Egg survival was significantly higher ($\alpha = 0.05$) for hatchery-reared eggs than for wild eggs for both intake and discharge collections (Table A-3). Hatchery-reared egg survial proportions were 0.838 at the intake and 0.609 at Station DP for pooled Unit 2 and Unit 3 tests. Even though discharge temperatures were similar, wild egg survival was only 0.455 at Station I3 and 0.333 at DP.

Initial survival proportions for hatchery-reared striped bass yolk-sac larvae recovered in the direct release samples were significantly lower ($\alpha = 0.05$) than for their wild counterparts (Table A-3). Hatchery-reared yolk-sac larvae exhibited survival proportions of only 0.064 and 0.227 at intake Station I3 and discharge Station DP, respectively, whereas initial survival proportions for wild yolk-sac larvae at these same stations were 0.515 and 0.586. The lower initial survival for this life stage in direct release experiments may have been due to the small size and narrow size range (4-6 mm) of the test specimens. That is, in view of the direct relationship between survival and size (Appendix B and EA 1978d, 1980b), this result would be expected since wild larvae collected in entrainment survival samples exhibited a greater progression of sizes (Appendix D, Table D-2). The occurrence of larger, more stress resistant yolk-sac larvae in the river samples would tend to affect higher initial survival proportions for these organisms.

In contrast, post yolk-sac larvae tested in direct release experiments survived better than wild post yolk-sac larvae. The initial survival proportion for hatchery-reared fish was 0.897 at the intake (all temperatures), compared to 0.741 for discharge temperatures of 29 C, and 0.773 for discharge temperatures of 30 C (Table A-3). For wild striped bass post yolk-sac larvae, initial survival was 0.500 at intake Station I3, versus 0.630 and 0.701 at discharge Station DP for temperatures less than 30 C, and between 30 and 32.9 C, respectively. The lower survival for wild fish was significant ($\alpha = 0.05$) only at the intake station, where, for these organisms, sampling stress imposed by the rear-draw (intake) flume was apparently more severe than the combined effects of entrainment and sample collection in the pumpless (intake) flume.

A.3.1.1.2 Extended Survival Proportions

Survival of hatchery-reared striped bass determined initially to be alive or stunned was monitored for 96 hours following sample collection to test for the presence of latent effects due to entrainment. Low sample sizes ($n \leq 10$ organisms) at the discharge port station (DP) precluded statistical analyses for the majority of the direct release extended survival data (Tables A-4 and A-5). In cases where sample size was sufficient for analysis ($n > 10$), extended survival for handling controls and collection controls was similar. Only 14- and 20-day old post yolk-sac larvae released at Unit 3 were collected

TABLE A-3 COMPARISON OF INITIAL SURVIVAL PROPORTIONS FOR EARLY LIFE STAGES OF WILD STRIPED BASS COLLECTED DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY AND HATCHERY-REARED STRIPED BASS RECOVERED DURING DIRECT RELEASE SURVIVAL EXPERIMENTS, INDIAN POINT GENERATING STATION, 1979

		WILD[a]			HATCHERY[a]			
Life Stage	Station	Temperature Range (C)	Number Collected	Survival Proportion[b]	Temperature Range (C)	Number Collected	Survival Proportion[b]	p[c]
Egg	I3	14-18	121	0.455	18	105	0.838	<0.0001[d]
	DP	24-27	54	0.333	27	87	0.609	0.0012[d]
Yolk-sac larvae	I3	17-24	66	0.515	17	93	0.064	<0.0001[d]
	DP	≤29.9	29	0.586	≤29	22	0.227	0.0106[d]
Post yolk-sac larvae	I3	17-24	64	0.500	20-23	271	0.897	<0.0001[d]
	DP	≤29.9	27	0.630	29	27	0.741	0.2793
		≥30-32.9	87	0.701	30	22	0.773	0.3523

(a) Data and/or collections for Unit 2 and Unit 3 pooled.

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

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

(c) Fisher's exact probability of obtaining the observed or more dissimilar survival proportions under the null hypothesis that survival for wild and hatchery-reared fish is equal.

(d) Significant at $\alpha = 0.05$.

TABLE A-4 NORMALIZED EXTENDED SURVIVAL OF HATCHERY-REARED STRIPED BASS LARVAE RELEASED AT THE UNIT 2 INTAKE, INDIAN POINT GENERATING STATION, 1979

Life Stage	Age (Days)	Station/ Control	Initial No. Alive	Survival Proportions ±1 Standard Error — Time After Collection (Hours) 3	6	12	24	48	72	96
Yolk-sac larvae	2-3	HC	82	1.000±0.00	1.000±0.00	0.988±.01	0.939±0.03	0.354±0.05	0.012±0.01	0.012±0.01
		I3-SC	6[a]	0.500±0.21	0.333±0.19	0.333±0.19	0.333±0.19	0.000±0.00	0.000±0.00	0.000±0.00
		DP	1[a]	0.000±0.00	0.000±0.00	0.000±0.00	0.000±0.00	0.000±0.00	0.000±0.00	0.000±0.00
Post yolk-sac larvae	14	HC	96	1.000±0.00	1.000±0.00	0.969±0.02	0.917±0.03	0.792±0.04	0.646±0.05	0.542±0.05
		I3-SC	74	0.986±0.14	0.932±0.03	0.838±0.04	0.811±0.05	0.797±0.05	0.757±0.05	0.676±0.05
		DP	5[a]	1.000±0.00	1.000±0.00	1.000±0.00	1.000±0.00	0.800±0.18	0.600±0.22	0.600±0.22
Post yolk-sac larvae	20	HC	100	1.000±0.00	1.000±0.00	0.990±0.01	0.970±0.02	0.930±0.03	0.790±0.04	0.550±0.05
		I3-SC	71	0.972±0.02	0.944±0.03	0.930±0.03	0.930±0.03	0.930±0.03	0.845±0.04	0.648±0.06
		DP	4[a]	0.750±0.02	0.750±0.22	0.750±0.22	0.750±0.22	0.500±0.25	0.500±0.25	0.250±0.22

(a) Too few organisms (≤10) were recovered alive to statistically compare extended survival at the discharge with extended survival at the intake.

NOTE: HC = Handling Control
I3-SC = Sampling Control at Station I3
DP = Discharge Port Collection.

TABLE A-5 NORMALIZED EXTENDED SURVIVAL OF HATCHERY-REARED STRIPED BASS LARVAE RELEASED AT THE UNIT 3 INTAKE, INDIAN POINT GENERATING STATION, 1979

Life Stage	Age (Days)	Station/ Control	Initial No. Alive	Survival Proportions ±1 Standard Error[a] Time After Collection (Hours) 3	6	12	24	48	72	96
Yolk-Sac Larvae	2-3	HC	101	1.000±0.00	0.960±0.02	0.951±0.02	0.931±0.03	0.802±0.04	0.119±0.04	0.030±0.02
		I3-SC	6[b]	0.500±0.21	0.333±0.19	0.333±0.19	0.333±0.19	0.000±0.00	0.000±0.00	0.000±0.00
		DP	4[b]	0.500±0.25	0.500±0.25	0.500±0.25	0.500±0.25	0.500±0.25	0.250±0.22	0.025±0.22
Post Yolk-Sac Larvae	14	HC	101	1.000±0.00	1.000±0.00	0.802±0.04	0.713±0.05	0.693±0.05	0.663±0.05	0.594±0.05
		I3-SC	74	0.986±0.14	0.932±0.03	0.838±0.04	0.811±0.05	0.797±0.05	0.757±0.05	0.676±0.05
		DP	15	1.867±0.09 (.0684)	0.867±0.09 (.3241)	0.800±0.10 (.2616)	0.733±0.11 (.2053)	0.733±0.11 (.2197)	0.667±0.12 (.1860)	0.467±0.13 (.0728)
Post Yolk-Sac Larvae	20	HC	100	1.000±0.00	1.000±0.00	1.000±0.00	0.990±0.01	0.940±0.02	0.860±0.03	0.520±0.05
		I3-SC	71	0.972±0.02	0.944±0.03	0.930±0.03	0.930±0.03	0.930±0.03	0.845±0.04	0.648±0.06
		DP	11	1.000±0.00 (.7482)	0.910±0.09 (.3917)	0.910±0.09 (.4090)	0.910±0.09 (.4090)	0.818±0.12 (.1883)	0.545±0.15 (.0283)	0.273±0.13 (.0218*)
Post Yolk-Sac Larvae	33	HC	54	1.000±0.00	1.000±0.00	1.000±0.00	1.000±0.00	0.907±0.04	0.741±0.06	0.426±0.07
		I3-SC	97	0.979±0.01	0.969±0.02	0.969±0.02	0.969±0.02	0.948±0.02	0.825±0.04	0.619±0.05
		DP	1[b]	1.000±0.0	1.000±0.00	1.000±0.00	1.000±0.00	1.000±0.00	1.000±0.00	1.000±0.00

(a) Fishers exact test probability, indicated in parentheses, of obtaining the observed or more dissimilar survival proportions under the null hypothesis that the proportions of live and dead larvae are independent of the sampling location (i.e., a two-tailed test). Significant differences at $\alpha = 0.05$ are noted by an asterisk (*).

(b) Too few organisms ($\leq$10) were recovered alive to statistically compare the discharge extended survival with the intake extended survival.

NOTE: HC = Handling Control
I3-SC = Sampling Control at Station I3
DP = Discharge Port Collection

in sufficient numbers to warrant statistical analysis between intake and discharge extended survival proportions. Significant differences (α = 0.05) were detected in only 1 out of 14 comparisons, indicating comparable extended survival among sampling control and experimental organisms.

A.3.1.2 Entrainment Survival Estimates

Unit-specific entrainment survival estimates were calculated for direct release organisms only when initial survival proportions for the sampling controls (Station I3) exceeded survival proportions for entrained organisms collected at the discharge port (Station DP), and when sample size at each station exceeded 10 organisms. These conditions occurred for tests involving eggs at both units, 14-day old post yolk-sac larvae at Unit 2 only, and 20-day old post yolk-sac larvae at Unit 3 only (Table A-6). Based on these criteria, entrainment survival estimates for pooled data from both units were calculated for all test groups except yolk-sac larvae.

Entrainment survival estimates for eggs recovered at the discharge port during direct release experiments were 59.7 percent for the Unit 2 tests, 77.7 percent for the Unit 3 tests, and 72.7 percent based on pooled data from direct release at both units (Table A-6). The pooled estimate is nearly identical to the estimate of entrainment survival for wild eggs during two-unit operation (74 percent, Section 4.3.2.3.1), although initial survival proportions were much lower for wild eggs (Table A-3). These estimates of entrainment survival should be accurate since differential sampling stress in the two collection systems was not observed for eggs in the collection system calibration experiments (Appendix B).

Entrainment survival was not estimated for hatchery-reared yolk-sac larvae used in the direct release experiments because survival for organisms exposed to sampling effects only at intake Station I3 (rear-draw flume) was lower than for organisms recovered at discharge station DP (pumpless flume) following entrainment. Differences in survival between intake (control) and discharge stations, caused by differential gear effects on this life stage for the two collection systems (Appendix A), were similarly observed for wild yolk-sac larvae (Section 4.3.2.2.2). However, based on the apparent greater sensitivity of yolk-sac larvae to various stresses, as demonstrated in both the direct release and wild experiments, it is likely that entrainment survival for these larvae is lower than for other striped bass early life stages.

Entrainment survival estimates for 14-day old post yolk-sac larvae were 59.5 percent for the Unit 2 release, and 96.9 percent for release data pooled for both units (Table A-6). These estimates, however, are likely to be biased high as indicated by the high initial survival proportion for Unit 3 discharge port samples (0.938) when compared to the sampling control survival proportion (0.765). More reliable estimates of entrainment survival can be calculated if true sampling survival is assumed to be between 0.938 (the observed initial survival proportion at DP for the Unit 3 test) and 1.0. Then entrainment survival for Unit 2 would be estimated to be between 45.5 and 48.5 percent, Unit 3 entrainment survival would be between 93.8 and 100 percent, and entrainment survival pooled for both units would be between 74.1 and 79.0 percent.

TABLE A-6 ENTRAINMENT SURVIVAL ESTIMATES FOR STRIPED BASS EGGS AND LARVAE RECOVERED IN DIRECT RELEASE SURVIVAL EXPERIMENTS, INDIAN POINT GENERATING STATION, 1979

Life Stage	Age[(a)] (Days)	Sampling Control N_I	Sampling Control P_I	Unit 2 N_D	Unit 2 P_D	Unit 2 S_e(%)	Unit 3 N_D	Unit 3 P_D	Unit 3 S_e(%)	Units Combined N_D	Units Combined P_D	Units Combined S_e(%)
Eggs	2	105	0.838	24	0.500	59.7	63	0.651	77.7	87	0.609	72.7
Yolk-sac larvae	2-3	93	0.064	9	0.111	(b)	13	0.308	(b)	22	0.227	(b)
Post yolk-sac larvae	14	98	0.765	11	0.455	59.5	16	0.938	(b)	27	0.741	96.9
Post yolk-sac larvae	20	74	0.959	7	0.571	(c)	14	0.786	82.0	21	0.714	74.5

NOTE: N_I = number of organisms collected at intake station I3; P_I = initial survival proportion at intake station I3,
N_D = number of organisms collected at discharge station DP; P_D = initial survival proportion at discharge station DP,
S_e = entrainment survival (percent).

(a) Age of eggs is from day of spawning. Age of larvae is from day of hatching.
(b) S_e could not be calculated because $P_D > P_I$.
(c) S_e not calculated because $N_D < 10$.

For 20-day old post yolk-sac larvae, entrainment survival estimates based on direct release experiments were 82.0 percent for Unit 3 and 74.5 percent for both units combined (Table A-6). The high initial survival proportion of the sampling control at Station I3 (0.959) indicated that sampling stress at the intake station was not severe, thus bias in entrainment survival, if present, was expected to be minimal. However, these larvae were within the size range found to be affected by sampling stress at the intake station, i.e., less than 11 mm (Appendix B). The likely range for entrainment survival at Unit 3 could thus be considered to be between 78.6 percent (assuming $P_I = 1.0$) and 82.0 percent (assuming $P_I = 0.959$, the observed survival proportion at Station I3). Similarly, entrainment survival for both units combined would be between 71.4 and 74.5 percent.

A.3.2 Direct Release Recovery Experiments

Recovery efficiency based on direct release of hatchery-reared organisms in 1979 ranged from 0 to 106 percent (Table A-7). Recovery of eggs ranged from 31 to 84 percent of the expected number, yolk-sac larvae from 19 to 62 percent, and post yolk-sac larvae from 0 to 106 percent. As in similar experiments conducted in 1977 and 1978 (EA 1978a, 1979a), estimates of recovery efficiency were highly variable, although extremely high values did not occur in 1979.

For the Unit 2 experiments, which employed stationary nets (Station D1), as well as the plankton sampling flume (Station DP), for organism recovery, recovery efficiency was higher in the net samples than in the flume samples (Table A-7). Efficiency values for nets ranged from 49 to 84 percent whereas efficiency values for flume samples ranged from 0 to 53 percent.

Recovery efficiency for the pumpless flume was generally similar for the Unit 2 and Unit 3 releases (Table A-7). The largest difference between tests at the two units was 42 percent (yolk-sac larvae). Recovery efficiencies for eggs released at Unit 2 and Unit 3 differed by only 5 percent. For post yolk-sac larvae, recovery efficiencies between the two units differed by 33 percent for 13- to 15-day old larvae, and 3 percent for 20-day old larvae, based on collections made with the pumpless flume. Recovery efficiencies for the two tests conducted at Unit 3 using 32- to 33-day old post yolk-sac larvae varied by 18 percent.

The extremely large variation in recovery efficiency estimates both within and between years (1977 to 1979) makes statistical analyses and interpretation of these data difficult. That is, real differences in recovery efficiency which may exist between life stages or units are masked by variations inherent in the sampling methods and procedures. Thus, any mathematical attempt to relate recovery efficiency to some other variable would probably explain only a small amount of the total variation.

The high variability in recovery efficiency may be caused by the interaction between non-uniform distribution of organisms and the volume of water sampled. If organisms are distributed uniformly within the effluent water each sample will collect organisms in direct proportion to the volume strained. In this situation, a large sample is no more accurate, or precise, than a small sample. However, if organisms are randomly distributed, variation will occur in sample densities. If samples are small, i.e., the expected number of

TABLE A-7 RECOVERY OF DYED STRIPED BASS IN DIRECT RELEASE RECOVERY EXPERIMENTS, INDIAN POINT GENERATING STATION, 1979

Date	Life Stage	Age[a] (Days)	Total Length (mm)	Unit	Gear	V_s/V_p [b]	Estimated Number Released (NR) (x 10^3) [95% conf. limits]	Expected Number Recovered $E(N_C)$	Actual Number Recovered	Adjusted[c] Number Recovered	Percent of Expected Number
21 MAY	Egg	2	--	2	Nets	1.63×10^{-2}	246 [220-272]	4,000	3,503	3,343.5	84
				2	Flume	1.12×10^{-4}	246 [220-272]	28	13	8.6	31
				3	Flume	1.37×10^{-4}	316 [278-354]	43	21	15.6	36
22 MAY	Yolk-sac Larvae	2-3	3.5	2	Nets	1.53×10^{-2}	256 [218-294]	3,900	1,912	1,912[d]	49
				2	Flume	2.21×10^{-4}	256 [218-294]	57	11	11[d]	19
				3	Flume	2.21×10^{-4}	228 [211-245]	50	31	31[d]	62
5 JUN	Post Yolk-sac Larvae	13-15	6-8	2	Nets	1.55×10^{-2}	124 [121-172]	1,900	1,384	1,151.9	61
				2	Flume	4.75×10^{-5}	124 [121-127]	6	2	0	0
				3	Flume	1.10×10^{-4}	160 [144-176]	18	6	6	33
12 JUN	Post Yolk-sac Larvae	20	8-10	2	Nets	1.50×10^{-2}	123 [110-136]	1,800	1,403	1,403[e]	78
				2	Flume	1.56×10^{-4}	123 [110-136]	19	10	10[e]	53
				3	Flume	1.20×10^{-4}	120 [99-141]	14	7	7[e]	50
26 JUN	Post Yolk-sac Larvae	32-33	9-14	3	Flume	1.62×10^{-4}	113 [98-128]	18	19	19[e]	106[f]
		32-33	10-15	3	Flume	1.77×10^{-4}	137 [132-142]	24	21	21[e]	88

(a) Age of eggs is from day of spawning. Age of larvae is from day of hatching.
(b) Volume sampled per volume pumped past sampling station during sampling (based on Con Edison 1979).
(c) Adjustment based on background density of wild organisms.
(d) Background densities not available for adjustment.
(e) Based on dyed fish only. Adjustment for background density not necessary.
(f) Within 95 percent confidence limits.

organisms to be captured is small based on the true mean density and the volume sampled, variation in density estimates will be high. If organisms are patchily distributed, however, as is often the case for ichthyoplankton, then small samples, which have small expected numbers of recaptures, will be even more variable and in a high proportion of the time will result in an underestimate of the true mean density.

Although a great deal of mixing occurs after water passes through the condensers, it is unlikely that it would be sufficient to randomize the distributions of organisms that were extremely patchy upon entering the intake. Mixing could, however, be sufficient to eliminate stratification, i.e., systematic non-randomness, thus providing unbiased sampling at any point within the discharge canal if samples are large enough to effectively average densities over dense and sparse patches. Consequently, large samples which have high expected numbers of recoveries, will have relatively less variation than small samples which have small expected values.

Results of recovery efficiency experiments over the last three years illustrate the affect of expected recoveries on variability. The set of estimates with the smallest mean expected number of recoveries, 17.5 (DP samples for Unit 3 in 1978) had the highest standard error of the recovery efficiency estimate, 36.4 percent (Table A-8). Conversely, the set with the highest expected recoveries, 2900 for D1 net collections for Unit 2 in 1979, had the smallest standard error, 7.9 percent.

The 1979 test results were improved over those obtained in 1977 and 1978 insofar as reducing inherent variation in recovery efficiency estimates. The nets allowed a much larger volume to be sampled, which increased the number of expected recoveries approximately two orders of magnitude above the flume samples. Estimates based on flume samples were also less variable (Table A-8) than in previous years due to the higher expected number of recoveries than in previous years.

The consistently low (i.e., less than 100 percent) recovery efficiency estimates produced from the net samples in 1979 could be the result of a systematic bias in the net data. One factor which could cause such a bias is extrusion of organisms through the mesh of the sampling nets. O'Connor and Schaffer (1977) reported net retention for early life stages of striped bass in nets of the same mesh size to be between 89 and 98 percent. The retention of each life stage indicated by these authors is similar to the trend in recovery efficiency seen in this study (Figure A-3). Although net retention reported by O'Connor and Schaffer (1977) was higher than recovery efficiency observed in the 1979 direct release experiments, several reasons exist for possible increased extrusion in this study. First, O'Connor and Schaffer used a variety of velocity reduction cones whereas none were used in this study. Thus, even though water velocities for the two studies may have been comparable, through-net velocities could have been higher for the 1979 direct release recovery experiments. Second, the organisms used in the present study were dead for several hours before testing, whereas O'Connor and Schaffer tested predominantly live organisms. Fish eggs and larvae decompose rapidly after death if not preserved, thus, extrusion through the mesh may be higher than for live organisms. This could also explain the generally lower recovery efficiency estimates for 1979 tests compared to those conducted in 1977 and 1978 which used live organisms. Moreover, the

TABLE A-8 SUMMARY OF DIRECT RELEASE RECOVERY EFFICIENCY EXPERIMENTS AT THE INDIAN POINT GENERATING STATION, 1977-1979

Year	Unit	Station	Number of Estimates	Mean Expected Number of Recoveries (Range)	Mean Recovery Efficiency % (Range)	Standard Error of Recovery Efficiency
1977	3	D3 + DP	6	27.3 (11-63)	128.2 (80-222)	23.5
1978	2	D1	4	20 (5-45)	199.8 (170-250)	19.1
	2	DP	4	20.2 (7-25)	94.8 (65-177)	13.0
	3	D3	4	34.5 (16-44)	42.2 (0-84)	17.2
	3	DP	4	17.5 (9-21)	61.8 (10-168)	36.4
1979	2	D1	4	2,900 (1,800-4,000)	68.2 (49-84)	7.9
	2	DP	4	27.2 (6-57)	26.0 (0-53)	11.1
	3	DP	6	27.8 (14-50)	62.2 (33-105)	11.8

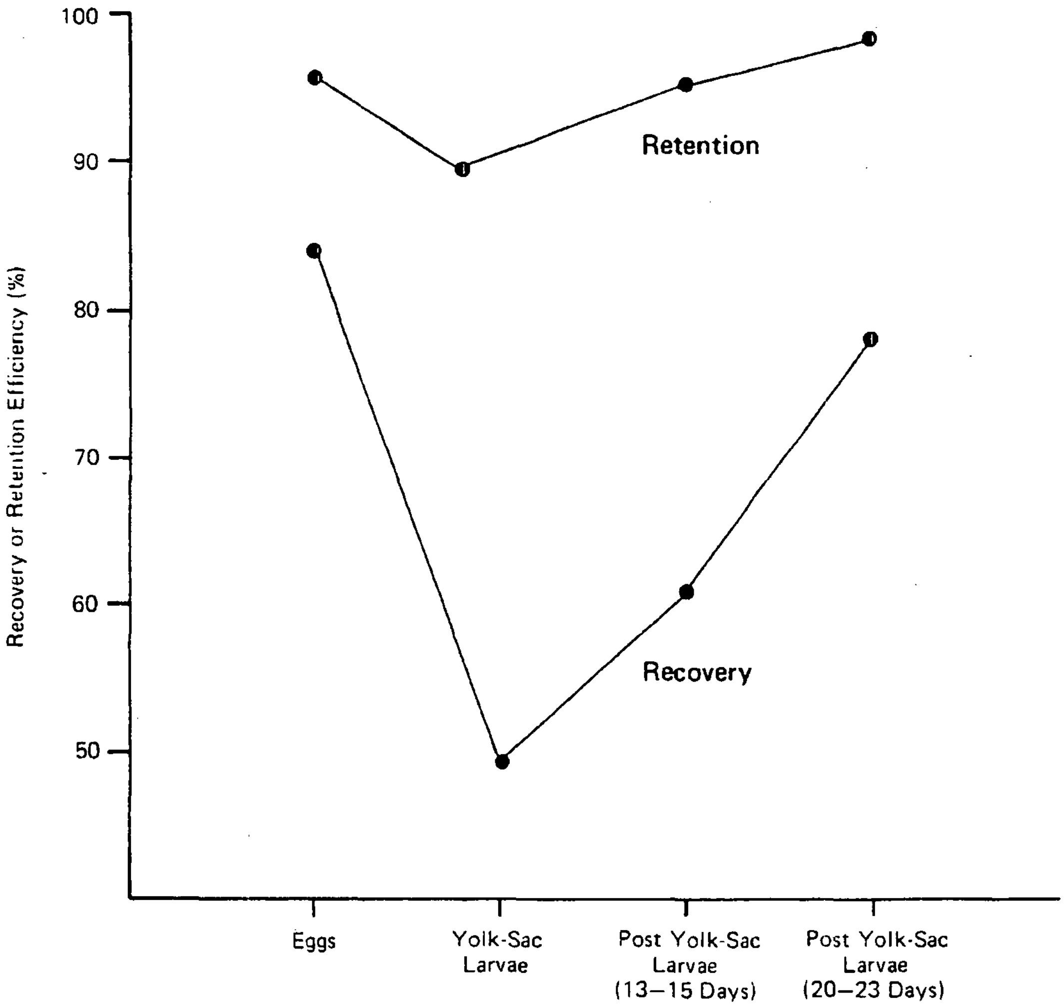


Figure A-3. Net retention (O'Connor and Schaffer 1977) and recovery efficiency in net samples of early life stages of hatchery-reared striped bass, Indian Point Generating Station, 1979.

highest recovery efficiencies in 1979 (106 and 88 percent) both occurred for the final experiment. These organisms were larger than for any other experiment (9 to 15 mm) and additionally were preserved before the test. Both of these factors would decrease the possibility of net extrusion or damage during passage through the plant.

To obtain precise estimates of recovery efficiency, inherent variability of the sampling methods and procedures must be reduced as much as possible. Large numbers of hatchery-reared organisms should be used so that expected numbers of recoveries are as large as possible. As a further step toward high expected recoveries, only high volume sampling gear (e.g., nets) should be used. Flume samples are too small to sufficiently average over the patchy distribution of test organisms. Finally, to eliminate variation due to background density of wild organisms and extrusion of decaying organisms through the net mesh, only dyed preserved organisms should be used.

APPENDIX B

COLLECTION SYSTEM
CALIBRATION STUDY

APPENDIX B: COLLECTION SYSTEM CALIBRATION STUDY

B.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 sampling stations (Section 4.2.3.2). A critical assumption of this method is that mortality due to sampling, i.e., gear-induced, is identical for the intake and discharge collection systems. This study was designed to test this assumption relative to 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 1979 spring-summer entrainment survival study. Hatchery-reared striped bass were used in these experiments to allow greater control of factors (e.g., organism age and size) which may affect susceptibility to sampling stress.

B.2 METHODS

B.2.1 Field and Laboratory Procedures

Collection system calibration tests utilized striped bass eggs and larvae obtained from the Con Edison hatchery facility at Verplanck, New York, operated by Texas Instruments Incorporated. After arrival from the hatchery, the test organisms were acclimated to ambient river water. Eggs were acclimated over a 10-minute period, whereas larvae were acclimated for 2-5 hours. 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 test period. Two tests were conducted for each flume with eggs, three with yolk-sac larvae, and four with post yolk-sac larvae.

Gear operating procedures applied during the collection system calibration tests were the same as those for entrainment survival sampling (Section 4.2.1.2), except that organisms were introduced just above the inlets of the sampling flumes at the beginning of each test period. After retrieving the test organisms from the flume, the number of live and dead striped bass recovered was determined to assess initial survival. All striped bass ichthyoplankton recovered alive were maintained at the onsite laboratory for 96 hours to assess extended survival. For eggs, the proportion surviving to hatch (up to 96 hours) was determined.

Controls were conducted concurrently with each release to assess handling and thermal effects. At the beginning of each calibration test, approximately 100 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 were transported with the experimental fish to the onsite laboratory at the end of the test. Survival of control organisms was observed immediately after testing and was monitored for up to 96 hours in the same manner as experimental organisms.

B.2.2 Analytical Procedures

Analyses were designed to detect differences in initial and extended survival for striped bass collected in the rear-draw and pumpless sampling flumes. Additionally, survival data were used to quantitatively estimate the magnitude of gear-induced mortality for the two systems.

B.2.2.1 Survival Proportions

Consistent with entrainment survival analyses for river ichthyoplankton (Section 4.2.3.1), the survival of striped bass eggs released into the intake and discharge collection systems during calibration experiments was based on the proportion of eggs that hatched within 96 hours. That is,

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

where:

P_I = proportion surviving at the intake (Station I3)
P_D = proportion surviving at the discharge (Station DP)

This proportion takes both initial and latent effects into account, and is appropriate for eggs because of the difficulty in visually determining the live versus dead condition.

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

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

Extended survival data were examined to determine if mortality occurred beyond the initial survival observation and to detect differences between experimental and control tests. Survival was normalized by calculating survival proportions for each extended survival observation on the basis of the initial number of live and stunned fish. Fisher's exact test (Sokal and Rohlf 1969) was used to test for differences ($\alpha = .05$) between extended survival proportions at each observation period for gear used at the intake and discharge. Because of the multiple tests and subsequent increased probability of Type I error on an experiment-wide basis, the only cases considered to be biologically significant were those where survival proportions were significantly different in the same direction for three consecutive latent effects observation periods.

B.2.2.2 Determination of Gear Effects

To isolate gear effects at each station, mortality caused by handling and thermal effects was factored out of the egg survival proportions and initial survival proportions for larvae according to the following equations:

Entrainment survival (S_e) can be estimated as

$$S_e(\%) = \frac{P_D}{P_I} \times 100 \qquad (1)$$

However, P_D and P_I can be factored into the following components:

$$P_D = (P_{SD} \cdot P_e) \qquad (2)$$

$$P_I = P_{SI} \qquad (3)$$

where:

P_{SD} = proportion of organisms surviving sampling at the discharge
P_{SI} = proportion of organisms surviving sampling at the intake
P_e = proportion of organisms surviving entrainment

Substituting Equations (2) and (3) into (1) gives:

$$\frac{S_e(\%)}{100} = \frac{P_D}{P_I} = \frac{(P_{SD} \cdot P_e)}{P_{SI}} \qquad (4)$$

Thus, $S_e = (P_e \times 100\%)$ only if $P_{SD} = P_{SI}$

The individual components of $(P_{SD} \cdot P_e)$ cannot be estimated from standard sampling; therefore, hatchery-reared fish were used to estimate P_{SD} and P_{SI} directly and to test the hypothesis that $P_{SI} = P_{SD}$. However, because handling of the test organisms, as well as elevated water temperatures at the discharge station, induces additional stress, P_{SD} and P_{SI} must be further divided into components:

$$P_{SI} = P\{g_i\} \cdot P_h \qquad (5)$$

$$P_{SD} = P\{g_d\} \cdot P_h \cdot P_t \qquad (6)$$

where:

$P\{g\}$ = probability of surviving the stress of the sampling gear; "i" denotes the gear at the intake and "d" denotes the gear at the discharge

P_h = proportion of organisms that survive handling

P_t = proportion of organisms that survive thermal stress associated with sampling

Then

$$P\{g_i\} = \frac{P_{SI}}{P_h} \qquad (7)$$

and $$P\{g_d\} = \frac{P_{SD}}{P_h \cdot P_t} \qquad (8)$$

To incorporate these gear effects into entrainment survival estimates:

$$\frac{S_{e(\%)}}{100} = \frac{(P_{SD} \cdot P_e)}{P_{SI}} \cdot \frac{P_{SI}}{P_{SD}} = \frac{(P_{SD} \cdot P_e)}{P_{SI}} \cdot \frac{P\{g_i\} \cdot P_h}{P\{g_d\} \cdot P_h \cdot P_t} \tag{9}$$

If the thermal stress associated with sampling at the discharge station can be assumed to be similar to that experienced by unsampled entrained organisms, i.e., stress within the thermal plume, then P_t can be considered a component of S_e and Equation (9) reduces to:

$$S_e(\%) = \frac{P_D}{P_I} \cdot \frac{P\{g_i\}}{P\{g_d\}} \cdot 100 \tag{10}$$

Gear effects, once isolated as in Equations (7) and (8), were tested for significance using a chi-square (χ^2) test (Sokal and Rohlf 1969). The ratio of gear effects, as presented in Equation (10), served as an indicator of the comparability, or difference, in sampling stresses between the rear-draw (intake) and pumpless (discharge) flume systems. If sampling stresses for the two gears are approximately equal for a given life stage, the ratio $P\{g_i\}/P\{g_d\}$ will be near 1.0. However, if sampling stress is greater in the rear-draw flume (Station I3), the ratio will be less than 1.0.

Conversely, if sampling stress is greater in the pumpless flume (Station DP), the ratio will be greater than unity.

B.3 RESULTS

B.3.1 Initial Survival

Calibration tests for striped bass eggs indicated high survival proportions ($\geq$0.810) for both the control and experimental groups, based on hatching success (Table B-1). Survival of eggs exposed to the pumpless sampling flume at the discharge port (Station DP) ranged from 0.810 to 0.907, whereas the survival of eggs in the rear-draw sampling flume at the Unit 3 intake (Station I3) varied from 0.838 to 0.934. Pooled striped bass egg survival exceeded 85 percent for both intake and discharge gear (Table B-2). The intake and discharge gear effects ($P\{g\}$) on eggs were small but highly significant (Table B-2). However, gear effects on striped bass eggs were almost identical for the rear-draw and pumpless flumes ($P\{g_i\}/P\{g_d\}$ = 1.036), indicating essentially no difference in sampling stresses between intake and discharge stations.

Initial survival of 2- to 3-day-old striped bass yolk-sac larvae for the intake and discharge gear was variable and generally lower than survival for eggs (Table B-1). Probability of surviving sampling was only 0.236 at the intake flume and 0.539 at the discharge flume (Table B-2). These probabilities represent statistically significant gear effects and the resultant ratio of gear effects was 0.438. Since equal gear effects would produce a ratio of 1.0, these results indicate greater sampling stress in the rear-draw (intake) flume than in the pumpless (discharge) flume for this life stage.

Gear effects analyses for all striped bass post yolk-sac larvae tested (14-35 days old) indicated considerably higher probabilities of surviving sampling stresses associated with the rear-draw and pumpless sampling flumes (0.927

TABLE B-1 SURVIVAL PROPORTIONS FOR HATCHERY-REARED STRIPED BASS EGGS AND LARVAE TESTED DURING THE COLLECTION SYSTEM CALIBRATION STUDY, INDIAN POINT GENERATING STATION, 1979

Life Stage	Date	Age[a] (days)	Station	Temp. (C)	Number of Organisms	Survival Component Estimated: P_h	$P_h \cdot P_t$	$P_h \cdot P\{g_i\}$	$P_h \cdot P_t \cdot P\{g_d\}$
Egg	18 MAY	≈2	I3-HC	18	106	0.934			
			I3	18	105			0.838	
			DP-HC	17	104	0.962			
			DP	27	116				0.810
	21 MAY	≈2	I3-HC	18	100	0.970			
			I3	18	122			0.934	
			DP-HC	18	85	0.965			
			DP	28	86				0.907
Yolk-Sac Larvae	22 MAY	2-3	I3-HC	17	96	0.938			
			I3	17	93			0.064	
			DP-HC	21	90	0.875			
			DP-TC	27	113		0.575		
			DP	28	98				0.173

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

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

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

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 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 B-1 (CONT.)

Life Stage	Date	Age[(a)] (days)	Station	Temp. (C)	Number of Organisms	Survival Component Estimated P_h	$P_h \cdot P_t$	$P_h \cdot P\{g_i\}$	$P_h \cdot P_t \cdot P\{g_d\}$
	25 MAY	3	I3-HC	17	93	0.839			
			I3	17	106			0.283	
			DP-HC	17	94	1.000			
			DP-HC	17	90	0.867			
			DP	26	123				0.268
	25 MAY	3	I3-HC	17	62	0.968			
			I3	17	54			0.315	
			DP-TC	26	58		0.500		
			DP-TC	26	54		0.463		
			DP	25	29				0.690
Post Yolk-Sac Larvae	04 JUN	14	I3-HC	20	102	1.000			
			I3	20	97			0.763	
			DP-HC	20	100	1.000			
			DP-TC	30	101		0.950		
			DP	29	101				0.980
	11 JUN	20	I3-HC	21	99	0.980			
			I3	21	74			0.959	
			DP-HC	21	102	1.000			
			DP-TC	32	94		0.968		
			DP	31	107				0.981
	22 JUN	33	I3-HC	24	46	1.000			
			I3	23	99			0.980	
			DP-HC	24	51	1.000			
			DP-TC	28	96		0.979		
			DP	31	99				1.000

TABLE B-1 (CONT.)

Life Stage	Date	Age[a] (days)	Station	Temp. (C)	Number of Organisms	Survival Component Estimated P_h	$P_h \cdot P_t$	$P_h \cdot P\{g_i\}$	$P_h \cdot P_t \cdot P\{g_d\}$
	26 JUN	35	I3-HC	22	99	0.990			
			I3	22	99			0.990	
			DP-HC	23	100	0.990			
			DP-TC	29	99		0.970		
			DP	28	96				0.896

TABLE B-2 POOLED SURVIVAL PROPORTIONS AND ESTIMATES OF SAMPLING GEAR EFFECTS FOR HATCHERY-REARED STRIPED BASS EGGS AND LARVAE TESTED DURING THE TABLE CALIBRATION STUDY, INDIAN POINT GENERATING STATION, 1979

Life Stage	Age[a] (days)	Test	Temp. (C)	Number of Organisms	P_h	$P_h \cdot P_t$	$P_h \cdot P\{g_i\}$	$P_h \cdot P_t \cdot P\{g_d\}$	$P\{g_i\}$	$P\{g_d\}$	χ^2	$P\{g_i\}/P\{g_d\}$
Eggs	2	HC	17-18	395	0.954							
		I3	18	227			0.890		0.933		9.34[b]	
		DP	27-28	202				0.851		0.892[c]	19.16[b]	1.046
Yolk-sac larvae	2-3	HC	17-21	525	0.886							
		TC	26-27	225		0.519						
		I3	17	253			0.209		0.236		350.87[b]	
		DP	25-28	250				0.280		0.539	28.58[b]	0.438
All post yolk-sac larvae	14-35	HC	20-24	699	0.994							
		TC	28-32	390		0.967						
		I3	20-23	369			0.921		0.927		42.83[b]	
		DP	28-31	403				0.965		0.998	0.01	0.929
Early post yolk-sac larvae	14-20	HC	20-21	403	0.995							
		TC	30-32	195		0.959						
		I3	20-21	171			0.848		0.852		55.97[b]	
		DP	29-31	208				0.981		1.02	1.65	0.835
Late post yolk-sac larvae	33-35	HC	22-24	296	0.993							
		TC	28-29	195		0.974						
		I3	22-23	198			0.985		0.992		0.83	
		DP	28-31	195				0.949		0.974	0.01	1.018

(a) Age of eggs is from day of spawning; age of larvae is from day of hatching.
(b) Indicates rejection of H_0: there are no sampling effects, i.e., $P\{g\} = 1.0$, at $\alpha = 0.05$.
(c) Survival value from handling control (0.954) used to calculate $P\{g_d\}$.

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

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

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 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.

and 0.998, respectively) than were determined for yolk-sac larvae (Table B-2). In addition, the difference in sampling stress between the two gears was much less pronounced, as indicated by the $P\{g_i\}/P\{g_d\}$ ratio of 0.929. The gear effect for the rear-draw flume at intake Station I3 was statistically significant ($\alpha = 0.05$), whereas the gear effect for the pumpless flume at discharge Station DP was not.

In view of the apparent greater susceptibility of smaller larvae to sampling stresses, and the previously documented relationship between age (size) and survival (EA 1978d, 1980b), gear effects were also analyzed for post yolk-sac larvae grouped by age categories (Table B-2). Results of these analyses indicated gear effects for early post yolk-sac larvae (14 to 20 days old) of 0.852 at the intake flume (significant at $\alpha = 0.05$) and 1.02 at the discharge flume (not significant). The ratio of gear effects ($P\{g_i\}/P\{g_d\}$) for this age group was 0.835, indicating higher sampling stress associated with the rear-draw (intake) flume. For late post yolk-sac larvae (33 to 35 days old), the probability of surviving sampling stress in the intake and discharge flumes was estimated as 0.992 and 0.974, respectively. Neither value was significant at $\alpha = 0.05$, and the resultant ratio of gear effects was 1.018, indicating negligible, as well as comparable, sampling effects associated with the two collection systems. These results, therefore, demonstrate that gear effects for striped bass larvae are related to age (size), and that the greater susceptibility to sampling stresses of the rear-draw (intake) flume system decreases as age increases.

To further examine the relationship between gear effect and size, experimental and control survival associated with the intake and discharge stations were analyzed in terms of 1-mm length groups. The difference between gear effect for the intake and discharge flumes was greatest for the smallest larvae (5.0 to 6.9 mm) and decreased as larval size increased (Table B-3 and Figure B-1). Larvae larger than 11 mm showed little or no reduction in survival attributable to the sampling gear, and there was essentially no difference in gear effect for the intake and discharge flumes.

3.3.2 Extended Survival

Extended survival (up to 96 hours after collection) was generally similar for larvae collected in the intake and discharge sampling gears. Survival of yolk-sac larvae at 96 hours was 0.189 for those collected in the rear-draw (intake) flume and 0.271 for those collected at the pumpless (discharge) flume (Table B-4). None of the extended survival values were significantly different at $\alpha = 0.05$ (Table B-4) based on a two-tailed Fisher's exact test.

Extended survival of early post yolk-sac larvae was greater than for yolk-sac larvae. Again, 96-hour survival proportions were similar for fish tested in both sampling gear (0.662 and 0.637 for intake and discharge gear, respectively) (Table B-4). Proportions surviving at the discharge flume were significantly higher at 6 and 12 hours, but not for earlier or later time periods, therefore extended survival was considered comparable.

Extended survival of late post yolk-sac larvae was 0.692 and 0.578 at the intake and discharge sampling flumes, respectively, about equal to that of early post yolk-sac larvae (Table B-4). Significant differences in survival

TABLE B-3 ESTIMATED GEAR EFFECTS, P{g}, FOR 1-MM SIZE INTERVALS OF HATCHERY-REARED STRIPED BASS LARVAE TESTED DURING THE COLLECTION SYSTEM CALIBRATION STUDY, INDIAN POINT GENERATING STATION, 1979

Length Interval (mm)	Rear-Draw Sampling Flume Intake Station I3: Control		Experimental			Pumpless Sampling Flume Discharge Station DP: Control		Experimental			
	n	P_h	n	$P_h \cdot P\{g_i\}$	$P\{g_i\}$	n	$P_h \cdot P_t$	n	$P_h \cdot P_t \cdot P\{g_d\}$	$P\{g_d\}$	$P\{g_i\}/P\{g_d\}$
3.0-3.9	--	--	1	0.0	--	--	--	--	--	--	--
4.0-4.9	1	1.0	--	--	--	2	1.00	1	0.0	--	--
5.0-5.9	73	0.945	46	0.283	0.299	42	0.976	36	0.667	0.683	0.438
6.0-6.9	157	0.885	100	0.470	0.531	140	0.471	101	0.604	1.282	0.414
7.0-7.9	45	1.00	38	0.789	0.789	45	0.933	39	1.00	1.072	0.736
8.0-8.9	31	1.00	21	0.857	0.857	29	0.931	22	1.00	1.074	0.798
9.0-9.9	34	1.00	25	0.960	0.960	28	0.964	30	0.967	1.003	0.957
10.0-10.9	21	1.00	24	0.958	0.958	25	0.960	26	1.00	1.042	0.919
11.0-11.9	29	1.00	29	0.966	0.966	42	0.976	39	0.949	0.972	0.994
12.0-12.9	26	1.00	28	0.964	0.964	32	0.938	29	0.897	0.956	1.008
13.0-13.9	19	1.00	17	1.00	1.00	19	1.00	20	0.900	0.900	1.111
14.0-14.9	2	1.00	8	1.00	1.00	9	0.889	7	0.857	0.964	1.037
15.0-15.9	1	1.00	1	1.00	1.00	1	1.00	1	1.00	1.000	1.000
16.0-16.9	1	1.00	--	--	--	--	--	--	--	--	--

Note: n = number of organisms
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.

Dashes (--) indicate no organisms in this category.

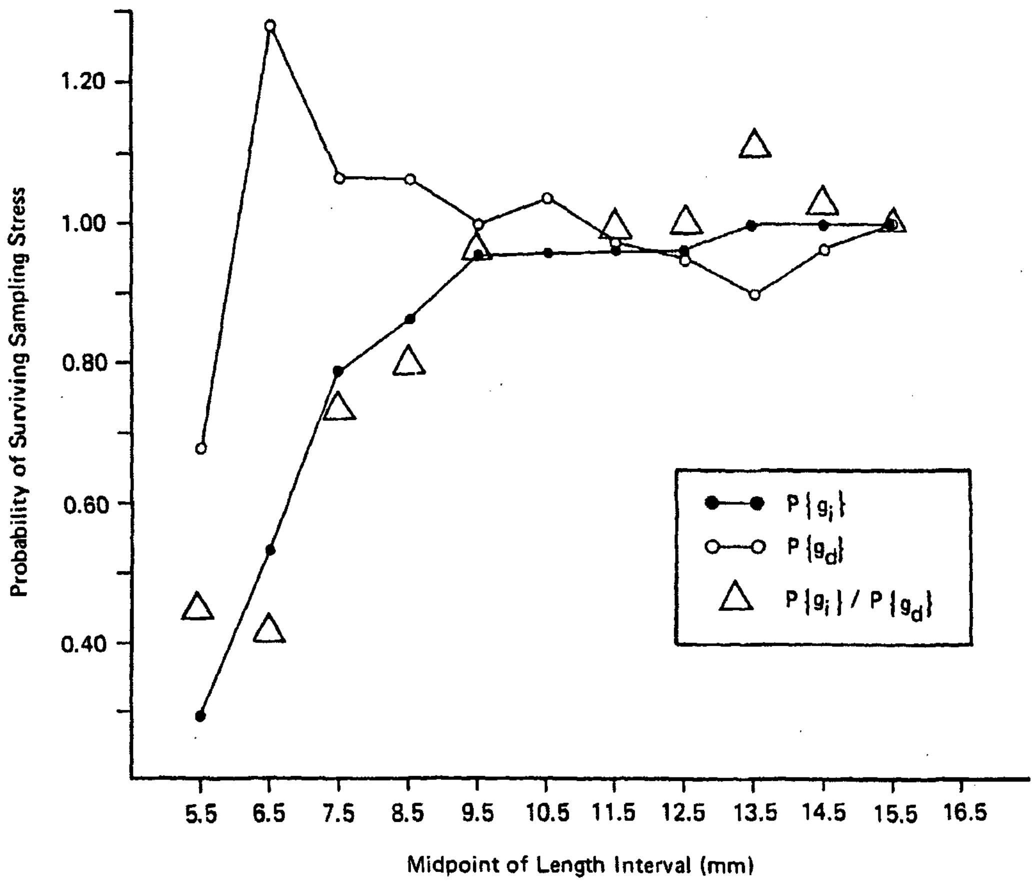


Figure B-1. Gear effects and ratio of gear effects for hatchery-reared striped bass larvae (5.0 to 16.9 mm total length) tested during the collection system calibration study, Indian Point Generating Station, 1979.

TABLE B-4 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, 1979

Life Stage	Station	Initial No. Alive	Survival Proportions ±1 Standard Error[(a)] Time After Collection (Hours) 3	6	12	24	48	72	96
Yolk-sac larvae	I3	53	0.943±0.03	0.830±0.05	0.755±0.06	0.660±0.07	0.264±0.06	0.208±0.06	0.189±0.05
	DP	70	0.929±0.03	0.857±0.04	0.743±0.05	0.586±0.06	0.443±0.06	0.357±0.06	0.271±0.05
			(0.522)	(0.434)	(0.525)	(0.256)	(0.032)	(0.053)	(0.197)
Early post yolk-sac larvae	I3	145	0.979±0.01	0.938±0.02	0.883±0.03	0.869±0.03	0.862±0.03	0.800±0.03	0.662±0.04
	DP	204	1.000±0.00	0.985±0.01	0.966±0.01	0.917±0.02	0.868±0.02	0.799±0.03	0.637±0.03
			(0.071)	(0.015*)	(0.002*)	(0.050)	(0.124)	(0.108)	(0.080)
Late post yolk-sac larvae	I3	195	0.990±0.01	0.979±0.01	0.974±0.01	0.974±0.01	0.954±0.02	0.877±0.02	0.692±0.03
	DP	185	0.995±0.01	0.995±0.01	0.968±0.01	0.962±0.01	0.904±0.02	0.762±0.03	0.578±0.04
			(0.386)	(0.168)	(0.226)	(0.184)	(0.035)	(0.002*)	(0.006*)

(a) Fishers exact test probability, indicated in parentheses, of obtaining the observed or more dissimilar survival proportions under the null hypothesis that the proportions of live and dead larvae are independent of the sampling location (i.e., a two-tailed test). Significant differences at $\alpha = 0.05$ are noted by an asterisk (*).

(α = 0.05) appeared at 72 and 96 hours when survival of larvae in intake samples exceeded that of discharge samples.

B.4 DISCUSSION

The collection system calibration study indicated that there is a definite reduction in survival of eggs and larvae associated with sampling stress. This gear effect, $P\{g\}$, was seen for both collection systems and was most severe for yolk-sac larvae. Eggs and early post yolk-sac larvae were less affected and no significant gear effect was apparent for late post yolk-sac larvae.

Differences in gear effect between the two collection systems were also apparent, with the rear-draw (intake) flume generally having a more severe effect than the pumpless (discharge) flume. Ratios of gear effects ($P\{g_i\}/P\{g_d\}$), were 1.036 for eggs, 0.438 for yolk-sac larvae, 0.835 for early post yolk-sac larvae (14 to 20 days old), and 1.018 for late post yolk-sac larvae (33 to 35 days old). The nearness to 1.0 of the ratios for eggs and late post yolk-sac larvae indicates that gear effects associated with the pumpless and rear-draw flumes were essentially equal for these life stages.

Analysis of gear effects as a function of larval size indicated that larvae 5 to 11 mm long are the most sensitive to sampling stress. At this size the rear-draw flume was noticeably more severe than the pumpless flume system. Larvae larger than 11 mm were apparently more resistant to sampling stress since neither flume system appeared to affect their survival.

The differential gear effects were primarily manifested in the initial survival values as extended survival was generally similar for both samplers. Four of 21 tests for differences in extended survival were significant at α = 0.05, but no consistent pattern was apparent. The two cases of significant differences for early post yolk-sac larvae indicated greater survival of fish collected in the pumpless sampling flume used at discharge Station DP. This could reflect a latent component of the more severe sampling stress for the rear-draw flume (Station I3). For late post yolk-sac larvae, significant differences occurred in the opposite direction; i.e., fish collected in the pumpless flume (discharge) exhibited higher mortality. This may have been caused by the disappearance of the gear effects, as noted with initial survival, and the influence of thermal stress which occurs at the discharge.

APPENDIX C

SAMPLING GEAR SPECIFICATIONS AND ASSOCIATED SAMPLING CONDITIONS, INDIAN POINT GENERATING STATION ENTRAINMENT SURVIVAL STUDIES, 1979

TABLE C-1 INTAKE SAMPLING GEAR SPECIFICATIONS AND ASSOCIATED SAMPLING CONDITIONS FOR THE LATE WINTER (ATLANTIC TOMCOD) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

	Station			
	I2		I3	
	Pump 1	Pump 2	Pump 1	Pump 2
Pump type	Two vane, open, nonrecessed impeller, 4-in. Homelite pump		Two vane, open, nonrecessed impeller, 4-in. Homelite pump	
Collection device	Pump/Larval Table Collection System		Pump/Larval Table Collection System	
Pump intake diameter	10.2 cm (4 in.)		10.2 cm (4 in.)	
Depth of removal[a]	4.6-5.8 m (15-19 ft)	4.6-5.8 m (15-19 ft)	3.7-4.9 m (12-16 ft)	2.7-4.0 m (9-13 ft)
Elevation of pump with respect to water surface	0.6-1.8 m (2-6 ft)	0.6-1.8 m (2-6 ft)	0.9-2.1 m (3-7 ft)	0.9-2.1 m (3-7 ft)
Elevation of collection device with respect to water surface	4.9-6.1 m (16-20 ft)		3.7-4.9 m (12-16 ft)	
Pump speed (rpm)[b]	1,700-2,000	1,800-2,000	1,800-1,900	1,800-1,900

(a) Depth of removal refers to the measurement from sample depth to the water surface.
(b) Standard operating procedures require that each pump be checked every 5 minutes and adjusted to 1,800-2,000 rpm. These procedures preclude extended operation outside this range.
(c) The normal sampling mode is to have two pumps operating simultaneously. Occasionally, samples were collected with only one pump operating.

TABLE C-1 (CONT.)

	Station I2		Station I3	
	Pump 1	Pump 2	Pump 1	Pump 2
Pumping rate	450-750 l/min (118-198 gpm)	325-750 l/min (85-198 gpm)	350-700 l/min (92-185 gpm)	350-750 l/min (92-198 gpm)
Duration of sample (min)	15		15	
Volume pumped per sample				
1 pump oper.[c]	7.3-9.5 m^3		Not applicable	
2 pump oper.	11.6-23.5 m^3		11.1-20.8 m^3	
Orientation of tubing relative to water flow	Vertically		Vertically	
Length of tubing from point of removal to the pump	7.6 m (25 ft)	7.6 m (25 ft)	9.1 m (30 ft)	7.6 m (25 ft)
Length of tubing from pump to collection device	22.9 m (75 ft)	49.7 m (163 ft)	10.7 m (35 ft)	7.6 m (25 ft)

TABLE C-2 DISCHARGE SAMPLING GEAR SPECIFICATIONS AND ASSOCIATED SAMPLING CONDITIONS FOR THE LATE WINTER (ATLANTIC TOMCOD) ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 12-22 MARCH 1979

	Station					
	D2		D3		DP	
	Pump 1	Pump 2	Pump 1	Pump 2	Pump 1	Pump 2
Pump type	Two vane, open, nonrecessed impeller, 4-in. Homelite pump		Two vane, open, nonrecessed impeller, 4-in. Homelite pump		Two vane, open, nonrecessed impeller, 4-in. Homelite pump	
Collection device	Pump/Larval Table Collection System		Pump/Larval Table Collection System		Pump/Larval Table Collection System	
Pump intake diameter	10.2 cm (4 in.)		10.2 cm (4 in.)		10.2 cm (4 in.)	
Depth of removal[a]	4.6-5.8 m (15-19 ft)	4.6-5.8 m (15-19 ft)	0.9-1.8 m (3-6 ft)	0.9-1.8 m (3-6 ft)	2.0-2.6 m (6.5-8.5 ft)	2.1-2.7 m (7-9 ft)
Elevation of pump with respect to water surface	0.9-1.8 m (3-6 ft)	0.9-1.8 m (3-6 ft)	0.9-1.8 m (3-6 ft)	0.9-1.8 m (3-6 ft)	1.2 m (4 ft)	1.2 m (4 ft)
Elevation of collection device with respect to water surface	3.4-4.6 m (11-15 ft)		3.4-4.6 m (11-15 ft)		4.9-6.1 m (16-20 ft)	
Pump speed (rpm)[b]	1,800-1,900	1,800-2,000	1,800-2,200[c]	1,800-2,200[c]	1,800-1,900	1,800-1,900
Pumping rate	450-800 l/min (118-211 gpm)	80-600 l/min (21-159 gpm)	200-750 l/min (53-198 gpm)	300-700 l/min (53-198 gpm)	300-700 l/min (79-185 gpm)	325-650 l/min (85-172 gpm)
Duration of sample (min)	15		15		15	
Volume pumped per sample						
1 pump oper.[d]	6.5-9.2 m^3		5.5-10.7 m^3		Not applicable	
2 pump oper.	11.0-17.8 m^3		6.6-19.5 m^3		10.8-20.8 m^3	
Orientation of tubing relative to water flow	Vertically		Horizontally, facing the current		Horizontally, facing the current	

(a) Depth of removal refers to the measurement from sample depth to the water surface.
(b) Standard operating procedures require that each pump be checked every 5 minutes and adjusted to 1,800-2,000 rpm. These procedures preclude extended operation outside this range.
(c) These pumps operated at 2,200 rpm throughout one sample because of an exceedingly low tide which increased the head and caused loss of suction in the intake hose at standard pump speeds.
(d) The normal sampling mode is to have two pumps operating simultaneously. Occasionally, samples were collected with only one pump operating.

TABLE C-2 (CONT.)

	D2		D3		DP	
	Pump 1	Pump 2	Pump 1	Pump 2	Pump 1	Pump 2
Length of tubing from point of removal to the pump	22.6 m (74 ft)	22.6 m (74 ft)	41.1 m (135 ft)	41.1 m (135 ft)	12.2 m (40 ft)	12.2 m (40 ft)
Length of tubing from pump to collection device	7.6 m (25 ft)	7.6 m (25 ft)	7.6 m (25 ft)	7.6 m (25 ft)	18.9 m (62 ft)	21.5 m (70.5 ft)

TABLE C-3 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 - 14 AUGUST 1979

	Station	
	I3	DP
Collection device	Floating, rear-draw plankton sampling flume	Floating, pumpless plankton sampling flume
Depth of removal[a]	2 m (6.6 ft) from 30 April-11 May; 3.7 m (12.0 ft) from 15 May-14 August	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 ft) Floating
Length of tubing from point of removal to collection device	14.3 m (47 ft)	10.7 m (35 ft)
Flow rate	550-1,250 l/min (145-330 gpm)	250-1,300 l/min[c] (66-344 gpm)
Duration of sample[d] (min)	13-17	15-16
Volume sampled per collection	8.4-17.9 m^3 (2,219-4,729 gal)	3.7-19.8 m^3 (980-5,231 gal)
Orientation of tubing relative to water flow	Horizontally, facing the current	Horizontally, facing the current

(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 height of the bottom of the collection device (flume) relative to the water surface.
(c) The Signet flowmeter used at Station DP measured total volume sampled. Flow rates were estimated by dividing the volume sampled by the elapsed time of the sample.
(d) Standard sampling duration was 15 minutes, however, equipment difficulties infrequently resulted in slightly shorter or longer sampling times. Samples were considered valid, according to standard operating procedures, if sampling duration did not exceed the range of 13 to 17 minutes.

APPENDIX D

LENGTH FREQUENCY DISTRIBUTIONS FOR ATLANTIC TOMCOD, STRIPED BASS, WHITE PERCH HERRINGS (CLUPEIDAE), AND ANCHOVIES (ENGRAULIDAE) COLLECTED DURING ENTRAINMENT SURVIVAL STUDIES, INDIAN POINT GENERATING STATION, 1979

TABLE D-1 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING DAY FOR ATLANTIC TOMCOD COLLECTED AT STATIONS I2, I3, D2, D3, AND DP DURING THE LATE WINTER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 1979

Date	No. of Fish	Mean Length (mm)	Standard Deviation (mm)	Length Intervals (mm) 0.0 - 3.9	4.0 - 4.9	5.0 - 5.9	6.0 - 6.9	7.0 - 7.9	8.0 - 8.9	9.0 - 9.9	10.0+	Range (mm)[a] MIN	MED	MAX
Station I2														
12 MAR 79	4	7.0	0.0	0	0	0	0	4	0	0	0	7.0	7.0	7.0
13 MAR 79	11	7.1	0.3	0	0	0	0	10	1	0	0	7.0	7.0	8.0
14 MAR 79	14	7.2	0.6	0	0	0	1	9	4	0	0	6.0	7.0	8.0
15 MAR 79	30	7.1	0.5	0	0	0	2	23	5	0	0	6.0	7.0	8.0
19 MAR 79	23	7.3	0.5	0	0	0	0	16	7	0	0	7.0	7.0	8.0
20 MAR 79	20	7.2	0.6	0	0	0	2	1	6	0	0	6.0	7.0	8.0
21 MAR 79	28	7.2	0.5	0	0	0	2	19	7	0	0	6.0	7.0	8.0
22 MAR 79	44	7.3	0.6	0	0	0	4	25	15	0	0	6.0	7.0	8.0
Station I3														
12 MAR 79	11	7.3	0.6	0	0	0	1	6	4	0	0	6.0	7.0	8.0
13 MAR 79	12	7.0	0.0	0	0	0	0	12	0	0	0	7.0	7.0	7.0
14 MAR 79	15	7.1	0.3	0	0	0	0	13	2	0	0	7.0	7.0	8.0
15 MAR 79	0	0.0	0.0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
19 MAR 79	13	7.2	0.4	0	0	0	0	10	3	0	0	7.0	7.0	8.0
Station D2														
20 MAR 79	4	7.0	0.0	0	0	0	0	4	0	0	0	7.0	7.0	7.0
21 MAR 79	12	7.2	0.6	0	0	0	1	8	3	0	0	6.0	7.0	8.0
22 MAR 79	22	7.1	0.6	0	0	0	3	13	6	0	0	6.0	7.0	8.0
Station D3														
12 MAR 79	3	7.0	0.0	0	0	0	0	3	0	0	0	7.0	7.0	7.0
13 MAR 79	9	6.9	0.6	0	0	0	2	6	1	0	0	6.0	7.0	8.0
14 MAR 79	16	6.9	0.4	0	0	0	2	13	1	0	0	6.0	7.0	8.0
15 MAR 79	2	7.5	0.5	0	0	0	0	1	1	0	0	7.0	7.5	8.0
19 MAR 79	11	7.2	0.4	0	0	0	0	9	2	0	0	7.0	7.0	8.0
Station DP														
12 MAR 79	5	7.2	0.4	0	0	0	0	4	1	0	0	7.0	7.0	8.0
13 MAR 79	5	7.0	0.6	0	0	0	1	3	1	0	0	6.0	7.0	8.0
14 MAR 79	8	7.3	0.4	0	0	0	0	6	2	0	0	7.0	7.0	8.0
15 MAR 79	6	7.3	0.7	0	0	0	1	2	3	0	0	6.0	7.5	8.0
19 MAR 79	10	7.4	0.5	0	0	0	0	6	4	0	0	7.0	7.0	8.0
20 MAR 79	13	6.9	0.3	0	0	0	1	12	0	0	0	6.0	7.0	7.0
21 MAR 79	8	7.1	0.3	0	0	0	0	7	1	0	0	7.0	7.0	8.0
22 MAR 79	13	7.1	0.3	0	0	0	0	12	1	0	0	7.0	7.0	8.0

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

Note: Only those days when sampling was conducted at a particular station are listed for that station.

TABLE D-2 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR STRIPED BASS COLLECTED AT STATIONS I-3 AND DP DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 1979

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	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	2	4.0	0.0	0	2	0	0	0	0	0	0	0	4.0	4.0	4.0
15 MAY	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
24 MAY	17	6.0	0.8	0	4	13	0	0	0	0	0	0	4.0	6.0	7.0
31 MAY	35	5.7	1.0	0	14	19	2	0	0	0	0	0	4.0	6.0	8.0
7 JUN	24	6.4	1.0	0	4	17	3	0	0	0	0	0	5.0	6.0	9.0
14 JUN	20	6.7	1.6	0	6	7	7	0	0	0	0	0	4.0	6.5	9.0
18 JUN	24	7.9	1.4	0	1	7	14	1	1	0	0	0	5.0	8.0	12.0
25 JUN	1	10.0	0.0	0	0	0	0	1	0	0	0	0	10.0	10.0	10.0
5 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUL	1	9.0	0.0	0	0	0	1	0	0	0	0	0	9.0	9.0	9.0
16 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
13 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Station DP															
30 APR	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	1	5.0	0.0	0	1	0	0	0	0	0	0	0	5.0	5.0	5.0
15 MAY	3	6.3	0.5	0	0	3	0	0	0	0	0	0	6.0	6.0	7.0
24 MAY	3	6.3	1.2	0	1	1	1	0	0	0	0	0	5.0	6.0	8.0
31 MAY	41	6.1	0.8	0	9	30	2	0	0	0	0	0	4.0	6.0	8.0
7 JUN	25	6.4	1.4	0	5	17	1	2	0	0	0	0	5.0	6.0	10.0
14 JUN	39	7.8	1.9	0	1	23	6	7	2	0	0	0	5.0	7.0	12.0
18 JUN	39	8.5	1.6	0	1	9	17	12	0	0	0	0	5.0	9.0	11.0
25 JUN	1	13.0	0.0	0	0	0	0	0	1	0	0	0	13.0	13.0	13.0
5 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUL	1	9.0	0.0	0	0	0	1	0	0	0	0	0	9.0	9.0	9.0
23 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
13 AUG	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 D-3 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR WHITE PERCH COLLECTED AT STATIONS I3 AND DP DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 1979

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	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
15 MAY	3	4.3	0.5	0	3	0	0	0	0	0	0	0	4.0	4.0	5.0
24 MAY	3	5.3	0.5	0	2	1	0	0	0	0	0	0	5.0	5.0	6.0
31 MAY	44	5.0	1.1	3	25	16	0	0	0	0	0	0	3.0	5.0	7.0
7 JUN	106	3.9	1.0	38	60	7	1	0	0	0	0	0	3.0	4.0	8.0
14 JUN	26	5.3	2.2	5	11	6	1	3	0	0	0	0	3.0	4.0	10.0
18 JUN	9	6.3	2.7	1	4	2	0	2	0	0	0	0	3.0	5.0	11.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	3	4.0	0.0	0	3	0	0	0	0	0	0	0	4.0	4.0	4.0
9 JUL	1	14.0	0.0	0	0	0	0	0	0	1	0	0	14.0	14.0	14.0
16 JUL	1	6.0	0.0	0	0	1	0	0	0	0	0	0	6.0	6.0	6.0
23 JUL	1	12.0	0.0	0	0	0	0	0	1	0	0	0	12.0	12.0	12.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	1	56.0	0.0	0	0	0	0	0	0	0	0	1	56.0	56.0	56.0
13 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Station DP															
30 APR	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	1	3.0	0.0	1	0	0	0	0	0	0	0	0	3.0	3.0	3.0
15 MAY	1	4.0	0.0	0	1	0	0	0	0	0	0	0	4.0	4.0	4.0
24 MAY	2	5.0	1.0	0	1	1	0	0	0	0	0	0	4.0	5.0	6.0
31 MAY	37	5.2	1.6	6	18	9	4	0	0	0	0	0	3.0	5.0	8.0
7 JUN	66	4.1	1.0	14	44	8	0	0	0	0	0	0	3.0	4.0	7.0
14 JUN	29	6.3	2.9	4	12	3	4	5	1	0	0	0	3.0	5.0	12.0
18 JUN	15	7.9	2.8	0	4	2	5	1	3	0	0	0	4.0	8.0	12.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	1	11.0	0.0	0	0	0	0	1	0	0	0	0	11.0	11.0	11.0
9 JUL	5	16.4	6.1	0	0	0	0	0	3	0	1	1	12.0	13.0	28.0
16 JUL	1	13.0	0.0	0	0	0	0	0	1	0	0	0	13.0	13.0	13.0
23 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
13 AUG	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 D-4 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR HERRINGS (CLUPEIDAE) COLLECTED AT STATIONS I3 AND DP DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 1979

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	4	6.2	0.4	0	0	4	0	0	0	0	0	0	6.0	6.0	7.0
7 MAY	26	6.0	0.8	0	6	20	0	0	0	0	0	0	4.0	6.0	7.0
15 MAY	10	5.5	0.8	0	3	7	0	0	0	0	0	0	4.0	6.0	6.0
24 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
31 MAY	116	6.8	1.8	0	29	58	16	11	2	0	0	0	4.0	6.0	12.0
7 JUN	64	7.6	2.2	0	8	28	22	2	2	1	1	0	4.0	7.0	17.0
14 JUN	20	11.9	3.1	0	1	0	4	5	3	5	2	0	5.0	12.0	17.0
18 JUN	5	13.6	3.1	0	0	0	1	0	1	2	1	0	8.0	15.0	17.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUL	1	28.0	0.0	0	0	0	0	0	0	0	0	1	28.0	28.0	28.0
23 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
13 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
Station DP															
30 APR	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	7	6.4	1.5	0	2	4	1	0	0	0	0	0	4.0	7.0	9.0
15 MAY	5	7.2	1.5	0	1	1	3	0	0	0	0	0	5.0	8.0	9.0
24 MAY	1	9.0	0.0	0	0	0	1	0	0	0	0	0	9.0	9.0	9.0
31 MAY	109	7.3	2.0	0	18	50	27	9	5	0	0	0	4.0	7.0	13.0
7 JUN	24	7.3	1.4	0	1	14	7	2	0	0	0	0	5.0	7.0	10.0
14 JUN	19	12.9	3.5	0	0	2	1	3	5	3	2	3	6.0	13.0	18.0
18 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
9 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
16 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
23 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
30 JUL	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 AUG	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
13 AUG	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 D-5 LENGTH FREQUENCY DISTRIBUTION BY SAMPLING WEEK FOR ANCHOVIES (ENGRAULIDAE) COLLECTED AT STATIONS I3 AND DP DURING THE SPRING-SUMMER ENTRAINMENT SURVIVAL STUDY, INDIAN POINT GENERATING STATION, 1979

				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	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
15 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
31 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
14 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
18 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	34	7.2	3.2	1	12	10	4	1	4	2	0	0	3.0	6.0	14.0
9 JUL	85	5.4	2.5	6	46	29	1	1	1	0	0	1	3.0	5.0	24.0
16 JUL	51	9.4	4.0	0	4	12	19	6	1	4	2	3	4.0	8.0	23.0
23 JUL	55	9.6	5.3	0	14	13	5	6	5	4	5	3	4.0	8.0	31.0
30 JUL	49	11.8	3.7	0	0	5	6	12	16	5	3	2	6.0	12.0	26.0
7 AUG	52	8.1	4.0	7	11	12	4	4	8	4	2	0	3.0	7.0	17.0
13 AUG	1	5.0	0.0	0	1	0	0	0	0	0	0	0	5.0	5.0	5.0
Station DP															
30 APR	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
15 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
24 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
31 MAY	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
7 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
14 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
18 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
25 JUN	0	0.0	0.0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
5 JUL	29	6.6	4.7	10	7	5	1	0	3	0	2	1	2.0	4.0	19.0
9 JUL	79	7.0	3.9	6	28	22	9	6	2	3	1	2	3.0	6.0	23.0
16 JUL	41	10.7	5.1	1	3	7	9	12	1	0	2	6	3.0	10.0	25.0
23 JUL	44	9.3	4.7	3	9	5	9	8	1	4	3	2	3.0	9.0	24.0
30 JUL	41	13.1	4.6	0	1	1	8	5	9	9	3	5	4.0	13.0	25.0
7 AUG	80	6.7	4.3	19	15	23	12	2	4	4	0	1	3.0	6.0	32.0
13 AUG	4	7.8	3.3	0	2	0	0	1	1	0	0	0	4.0	7.5	12.0

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

APPENDIX E

PROCEDURES FOR THE LIFE STAGE APPORTIONMENT OF ATLANTIC TOMCOD LARVAE

APPENDIX E: PROCEDURES FOR THE LIFE STAGE APPORTIONMENT OF ATLANTIC TOMCOD LARVAE

E.1 INTRODUCTION

The differentiation of larval fishes by life stage (e.g., yolk-sac and post yolk-sac larvae) provides a means by which larvae of varying sizes and ages can be distinguished. In reality, development is a continuous process and thus, during certain phases of development, life stage determination is difficult. That is, the change or transformation from one life stage to the next is gradual rather than abrupt. In spring and summer spawning fishes, early life stages occur at relatively warm temperatures and development is rapid; consequently, the period during which larvae are difficult to identify to life stage is short. However, in winter spawning species, development occurs more slowly and larvae take longer to transform from one life stage to the next. For these species (e.g., Atlantic tomcod), a larger proportion of the larvae will exhibit some characteristics of both the yolk-sac and post yolk-sac larval stages. In such cases, life stage cannot be determined with certainty by visual examination.

E.2 LIFE STAGE IDENTIFICATION AND APPORTIONMENT PROCEDURES

The criteria used to classify Atlantic tomcod larvae as yolk-sac larvae include the occurrence of (1) a distinct yolk-sac or an incomplete digestive tract with no food in the gut, and (2) a continuous, nondifferentiated median finfold. Post yolk-sac larvae, in contrast, are characterized by (1) presence of food in the gut, indicating a functional digestive tract, and (2) differentiation of the median finfold. Confusion as to life stage may occur when larvae have absorbed the yolk-sac, but contain no food in the gut and/or have a frayed or incomplete median finfold. When an overlap in morphological characteristics prevented conclusive identification of Atlantic tomcod larvae to life stage, larvae were assigned to either the yolk-sac or post yolk-sac larval category based on the relative frequencies of larvae that could be visually identified to life stage. Specific steps in this procedure were as follows:

Step 1: Array the fish collected at each station by life stage and by 1.0 mm length intervals.

Step 2: Establish frequency of occurrence (percent) of known yolk-sac and post yolk-sac larvae at each length interval.

Step 3: Apportion the measured Atlantic tomcod not identified to life stage in each length interval using the proportions of known yolk-sac and post yolk-sac larvae found in that length interval.

Step 4: Unmeasured Atlantic tomcod not identified to life stage may be apportioned by either of two procedures based on the length distribution of the measured Atlantic tomcod not identified to life stage.

Option A - If the measured Atlantic tomcod not identified to life stage show a clumped length distribution (i.e., 75 percent or more of the individuals collected at a station occur within one length interval), apportion the unmeasured Atlantic tomcod not identified to life stage according to the percentage of each known life stage within the particular length interval that is the focus of the clumping.

Option B - If the measured Atlantic tomcod not classified to life stage do not show a clumped length distribution, or too few were collected to determine the presence of a clumped length distribution, apportion according to the percentage of all Atlantic tomcod collected that are classified to each life stage. The apportioned number of measured Atlantic tomcod not identified to life stage should be added to each life stage for this calculation.

Step 5: Assign undifferentiated larvae to life stage. The first ocurring individuals at a station should be assigned as yolk-sac larvae and the later occurring individuals should be assigned as post yolk-sac larvae in accordance with the apportioned numbers determined in Steps 1-4.