INDIAN POINT UNIT NO. 2
INDIAN POINT UNIT NO. 3

NEAR-FIELD EFFECTS OF ONCE-THROUGH COOLING SYSTEM OPERATION ON HUDSON RIVER BIOTA

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CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
POWER AUTHORITY OF THE STATE OF NEW YORK

JULY 1977

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INTRODUCTION

Subject of This Report

This report examines the generating facilities at Indian Point, located at river mile (RM) 42, and the results of studies that have been performed to investigate the effects of plant operation on the near-field Hudson River biota. "Near-field" refers to the area extending approximately from Croton Point (RM 34) to Bear Mountain Bridge (RM 47). Most of the information contained in this report represents a condensation of material that has already been published, and submitted by Consolidated Edison Company of New York, Inc. (Con Ed) to various regulatory agencies. This material consists primarily of the annual progress reports of New York University Medical Center (NYU) and Texas Instruments Incorporated (TI), who have been under contract to Con Edison to study the ecological effects associated with the Indian Point plant operation.

In February 1977, Con Edison submitted a comprehensive report, entitled "Influence of Indian Point Unit 2 and Other Steam Electric Generating Plants on the Hudson River Estuary, With Emphasis on Striped Bass and Other Fish Populations," to the Nuclear Regulatory Commission (USNRC). This report addresses the multiplant impact of once-through cooling systems on the Hudson River, an assessment that necessarily requires a long-river (RM 12-153) evaluation. Since the current proceeding is also concerned with multiplant impact, the comprehensive report has been submitted together with Supplement I to present the most recent information on the subject of power plant impact on Hudson River biota.

The near-field report differs fundamentally from the objectives of the comprehensive report in that it does not emphasize long-river impact. For certain groups of organisms (e.g. decomposers, benthic invertebrates), it is clearly more appropriate to examine the impact produced in the local (near-field) area. For groups possessing greater mobility and depending to a larger degree on river-wide physicochemical characteristics (e.g. fish), a long-river assessment is more suitable. However, not every trophic level falls exclusively into one or the other of these categories (e.g. phytoplankton). A long-river assessment of impact dealing with non-fish groups appears as a separate exhibit in this proceeding. Another difference between the two reports exists in their format; the near-field report is oriented towards summarization of study results. Many of the details normally found in a first-time presentation of study results are included here only by reference.

The main body of the report (there are two appendices containing technical data on plant operations) is divided into ten subject sections. Section 1 provides a brief description of the design and operating characteristics of the existing once-through cooling water systems at Units Nos. 2 and 3, as well as other types of information (location, commercial operation dates, planned outage schedule, etc.). Section 2 examines the physical and chemical aspects of the Hudson River in the Indian Point area, including summarized results of thermal, hydrological, geological and water quality studies. The effects of plant discharges are also discussed in this section. Sections 3 through 10 present information on each of the following groups: detritus, decomposers, benthos, producers, microzooplankton, macrozooplankton, ichthyoplankton and fish.

At the beginning of each section, a summary of the items discussed, including study results, is presented. Producers, microzooplankton, macrozooplankton, ichthyoplankton and fish (Sections 6 through 10) are discussed in terms of their occurrence in the near-field and plant impact on them. Except in the case of fish (Section 10), the plant studies consisted primarily of intake and discharge canal comparisons of survival to determine the effect of pumped entrainment on these groups of organisms. The results of pertinent laboratory investigations are introduced wherever possible to complement the intake/discharge findings. Plume entrainment studies are also discussed. Data on the impingement of fish on cooling water intake screens are presented in Section 10.

Sections 9.2.1 and 9.2.2, dealing with ichthyoplankton entrainment survival, were prepared by Ecological Analysts, Incorporated (EAI). In these sections, the existing data base for ichthyoplankton survival at Indian Point is analyzed in a framework that permits previous net sampling efforts to be evaluated in view of a new and more efficient collection methodology. Utilizing information obtained from other Hudson River plants as well, a predictive assessment of entrainment survival is presented (the details of this predictive approach are contained in an exhibit in the proceeding).

Relationship of the Cooling Water Intake Structures to Best Technology Available

As previously indicated, this report places major emphasis on the evaluation of near-field biological data obtained in the vicinity of Indian Point. This is appropriate in the evaluation of the impact of the operation of the once-through cooling systems on the Hudson River biota. Part of that evaluation, however, must include consideration of the design and operation of the intake structures and, for that reason, relevant design and operating information is presented in Sections 1 and 2. This complements the biological information to assist in the evaluation of the current cooling water intake structure technology in use at Indian Point.

Decision criteria for evaluating best cooling water intake technology are provided in the April 1976, U.S. Environmental Protection Agency, "Development Document for Best Technology Available for the Location, Design, Construction and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact" (EPA 440/1-76/015-a), hereinafter referred to as the "Development Document."

With respect to what constitutes best technology available (BTA), the Development Document indicates (pages 176-177) that, "Owing to the highly site specific characteristics of available technology for the location, design, construction and capacity of cooling water intake structures for minimizing adverse environmental impact, no technology can be presently generally identified as the best technology available, even within broad categories of possible application." Consideration must be given on a plant-by-plant basis, and the economic practicability of any modification must be included in the analysis.

The Development Document indicates (pages 12, 13, 177, 178) that, as an important first step for determining best technology, studies should be conducted sufficient for developing an assessment of the biological community in the environs of existing or proposed intake system. These studies should permit: (1) identification of major aquatic and other species in the water source, including estimates of population densities for each major species, preferably over several generations; (2) evaluation of temporal and spatial distribution of the major species with particular emphasis on the location of spawning grounds, migratory passageways, nursery areas, and shellfish beds; (3) data on source water temperatures for the full year; (4) documentation of fish swimming capabilities for the identified major species for the temperature range anticipated at the intake; (5) and data relating to the location of the intake with concern for the seasonal and diurnal spatial distribution of identified major aquatic species.

Extensive biological, water quality, thermal, and hydrological studies of the Hudson River have been conducted prior to and following operation of the Indian Point cooling water systems that provide data on items (1), (2), (3), and (5) above. Information on fish swimming capabilities has been acquired from available reports and published articles. In addition, extensive information from studies of impingement and entrainment abundance and survival through the Indian Point Unit No. 2 cooling water system, and on organism tolerance to time-temperature exposures are provided in other sections of this report and in related documents.

With respect to guidance on intake location provided in the Development Document, the Indian Point cooling water intakes are located in an area subject to intrusion of salt water during periods of low fresh water flow, which usually occurs from mid to late summer and in late winter of most years. Consequently, generalizations about salinity-induced stratification and associated organism distributions of estuarine sites contained in the Development Document (page 19) do apply to Indian Point at those times.

Utility companies, particularly Consolidated Edison, with power plants sited on the lower Hudson River, were in the forefront of efforts in the late 1960's and early 1970's to compile available information on design and configuration of cooling water intakes systems that minimize damage to aquatic life. The design and configuration of the Indian Point Units No. 2 and No. 3 cooling water systems are similar to the design portrayed in the Development Document. (See Development Document, pages 121-123, 126, and 131, and Section 1 of this report.)

The location of the Indian Point cooling water discharge port structure, and the dilution induced by the submerged discharge ports help to minimize recirculation of heated water into the station.

The cooling water system design results in exposure of entrained organisms to moderately elevated temperatures in the cooling system for approximately 9 minutes at Indian Point Unit No. 2 and approximately 5 minutes at Unit No. 3 when both plants are operating fully, in conformance with Development Document guidance (page 24) that short term-stress exposure conditions result in less damage to entrained organisms.

The Indian Point cooling water intakes are equipped with conventional vertical traveling water screens, described by the Development Document (page 180) as the only generally viable screen available at the present time. The three-eighths-inch screen mesh used is consistent with general practice (Development Document, page 182).

Calculated approach velocities to the traveling screen are approximately 1.0 foot per second at full operation, which compares favorably with the range of 0.8 to 1.1 feet per second described by the Development Document (page 28) as typical.

Conventional intake screen-wash and fish handling facilities are employed at Indian Point. As related in this report and other testimony, fish impingement abundance and survival are being studied to evaluate possible methods for reducing impingement losses of fish, consistent with characterization of best technology available on pages 183 and 184 of the Development Document.

A chlorination minimization program is practiced at Indian Point for control of biological fouling. During 1974 and 1975, an average of only 15 chlorinations per year were done. These were performed only after visual examination of condensers confirmed the need. This minimal use of chlorine is consistent with best technology available (Development Document, page 184). During 1976, no chlorinations were performed at Indian Point since a visual inspection of condenser tubing did not disclose a need for such chemical treatment to reduce biological fouling.

At full design cooling water pumping and generating capacity, the highest measured temperature rise in the Indian Point Unit No. 2 condensers has been about 8.3C.* Other combinations of cooling water pump and generating capacity operation produce somewhat different time-temperature conditions. Most entrained organisms can survive these rather moderate time-temperature exposures during most of the year.

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*Where possible, only degrees Centigrade (C) are used. However, in certain instances, degrees Fahrenheit (F), or both units, are indicated to avoid unnecessary confusion. For convenience, a Centigrade-Fahrenheit conversion table appears at the end of the report.

Conclusions

This report indicates that, in general, the present once-through cooling system at Indian Point has an insignificant effect on the area's biota. Specifically, it was found that:

1) under normal and extreme operating conditions, chemical discharge concentrations will not exceed established toxicity limits,

2) the plants exert a negligible effect on the river's organic detritus,

3) bacterial populations are not significantly altered by plant passage, even by thermal regimes more severe than those encountered during normal plant operation -- however, they will be temporarily reduced in numbers on those relatively few occasions when chlorination occurs,

4) detailed benthic studies have revealed no variations in community structure that are related to the effects of plant operation,

5) there was no significant effect on the abundance or productivity of phytoplankton susceptible to entrainment at Indian Point,

6) entrained microzooplankton showed insignificant reductions in survival throughout the year except during chlorination and during some mid-summer periods when ambient temperatures were high; overall the impact upon this group was negligible,

7) of the three major species of macrozooplankton, Gammarus spp. and Monoculodes edwardsii are negligibly affected by the plant; although the other major species, Neomysis americana suffered significant mortalities during certain summer periods, their river-wide population was not adversely affected,

8) ichthyoplankton entrainment survival is primarily determined by the final (ambient + ΔT) temperature; mechanical damage under normal operating conditions is of lesser importance; with respect to various life stages of striped bass, entrained larvae and juveniles survive better than do entrained eggs and yolk-sac larvae,

9) the fish species impinged in greatest numbers are young-of-the-year and yearling white perch, Atlantic tomcod and bay anchovy,

10) the intake structures at Indian Point generally conform with the guidelines in EPA's Development Document for the design and operation of intake structures in determining the best technology available.

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PLANT TECHNICAL DESCRIPTION

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1. PLANT TECHNICAL DESCRIPTION

1.0 SUMMARY

The Indian Point Generating Station is located on the east bank of the Hudson River in the Village of Buchanan, New York, about 25 miles north of the New York City limits. It consists of three nuclear power plants, Unit Nos. 1, 2, and 3. Unit No. 1, owned by Con Edison, has not operated since October 1, 1974. Unit No. 2, owned by Con Edison, has been operated since September 28, 1973 and has a rated capacity of 873 MWe. Unit No. 3, which is owned by the Power Authority of the State of New York, has been operated since August 30, 1976 and has a net rated capacity of 965 MWe. Unit No. 2 is the northern most (upstream) unit, followed in a southerly direction by Units Nos. 1 and 3.

The existing open-cycle cooling systems of the Indian Point Generating Station consist of intake screening systems, deicing systems, circulating water pumps, condensers, and a common outfall structure. Physical descriptions and modes of operation for each of the cooling components are presented in this section. The normal flow for Units Nos. 2 and 3 is 840,000 GPM each with all six circulating water pumps operating at each unit. The pumps are operated at a reduced flow of 504,000 GPM, when the ambient water temperature is 40F or less.

Hudson River cooling water passes through the intake structures where it is screened of debris and is then delivered by the circulating water pumps to the condensers. Unit No. 2 has trash racks and fixed fine screens (0.375 in. mesh) at the entrance of the intake structure and vertical traveling screens (also 0.375 in. mesh) behind the fixed screens. Unit No. 3 has traveling screens but no fixed screens. In addition to the screens, the intake bays at each unit have skimmer walls which prevent floating ice and debris from entering. Both the Unit No. 2 and No. 3 reinforced concrete intake structures have seven separate intake bays (one bay for each of six circulating water pumps and a partitioned bay for six service water pumps). The bays are 13'4" wide, the bottom of each opening being set at 27 feet below Mean Sea Level.

After passing through the plant the circulating water from the Indian Point Station enters a discharge canal and is released to the Hudson River via an outfall structure consisting of 12 submerged ports located south of Unit No. 3. The length of the total port section is about 252 feet.

The amount of heat rejected to the Units Nos. 2 and 3 condensers is primarily dependent upon the electrical output of the power plant. The condenser temperature rise is dependent upon the rate of condenser cooling water flow and the amount of waste heat rejection to the condenser.

1.1 INTRODUCTION

The purpose of this chapter is to provide a concise description of the design and operating characteristics of the existing once-through cooling water systems at Indian Point Units Nos. 2 and 3.

1.1.1 General Information

1.1.1.1 Geographic Location

The Indian Point Generating Station is located on the east bank of the Hudson River in the Village of Buchanan in northern Westchester County, New York. The plant is situated about 25 miles north of the New York City limits and some 42 river miles above the Battery at 41°16'20" latitude and 73°57'10" longitude (discharge coordinates). Significant points of reference include the City of Peekskill (2.5 miles to the northeast), the West Point Military Academy (8.3 miles to the north) and the Lovett and Bowline Point generating stations located across the river about 0.5 and 4.6 miles to the south, respectively. Fig. 1-1 shows the location of the station relative to other plants along the river, and Fig. 1-2 shows the local area within five miles of the plant.

At Indian Point, the Hudson River winds through the Hudson Highlands, the station being situated on a point of land comprising the beginning of a large bend in the river. The station consists of three generating units, numbers 1, 2, and 3, which are situated on a site with an area of about 239 acres. The nuclear reactors and turbine generator buildings for Units Nos. 1, 2, and 3 occupy only 35 acres of the site. The Indian Point site is zoned for medium density (M-D) industrial use. Unit 2 is the northernmost (upstream) unit followed by Units 1 and 3 going south (downstream).

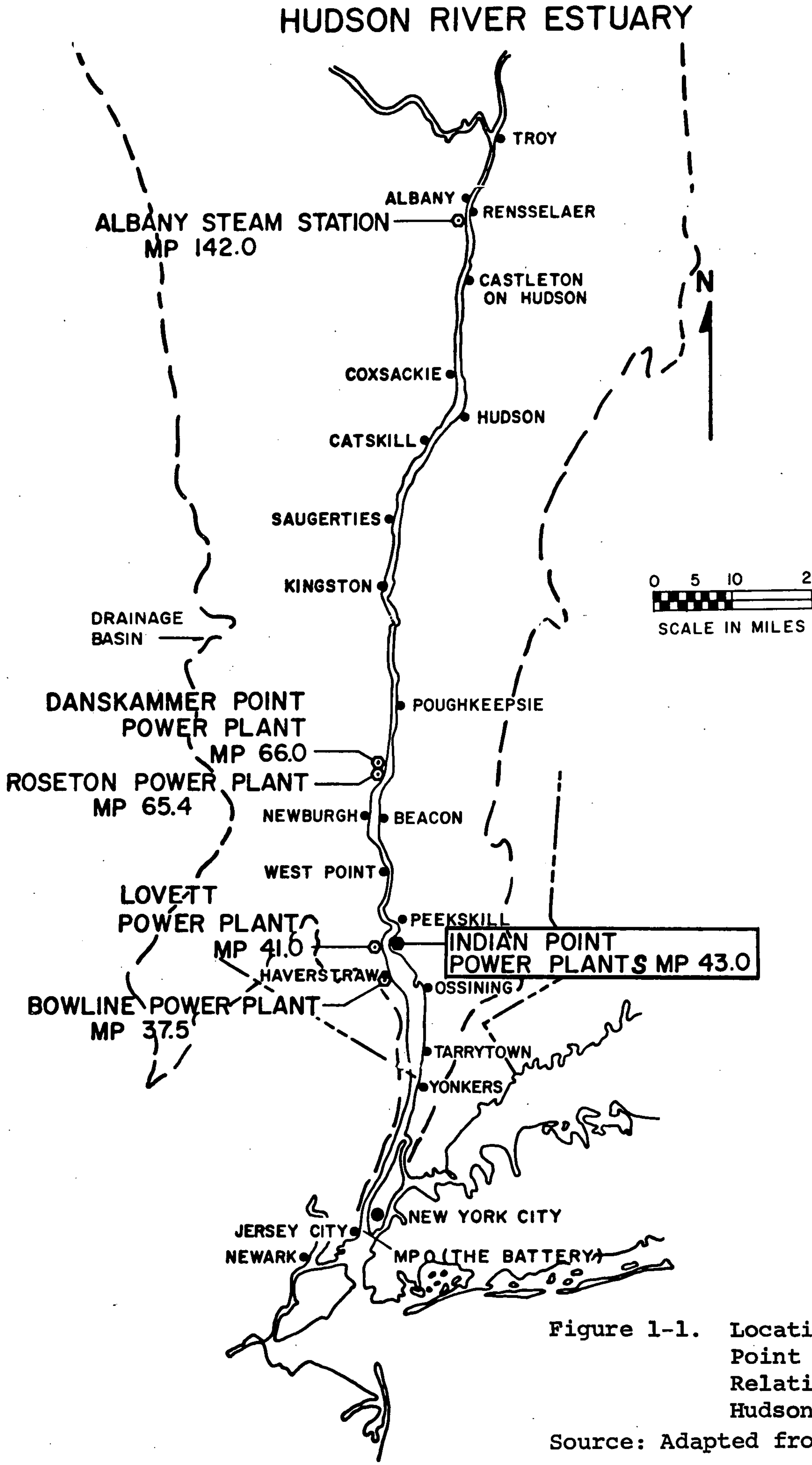


Figure 1-1. Location of Indian Point Station Relative to other Hudson River Stations.
Source: Adapted from QLM 1970

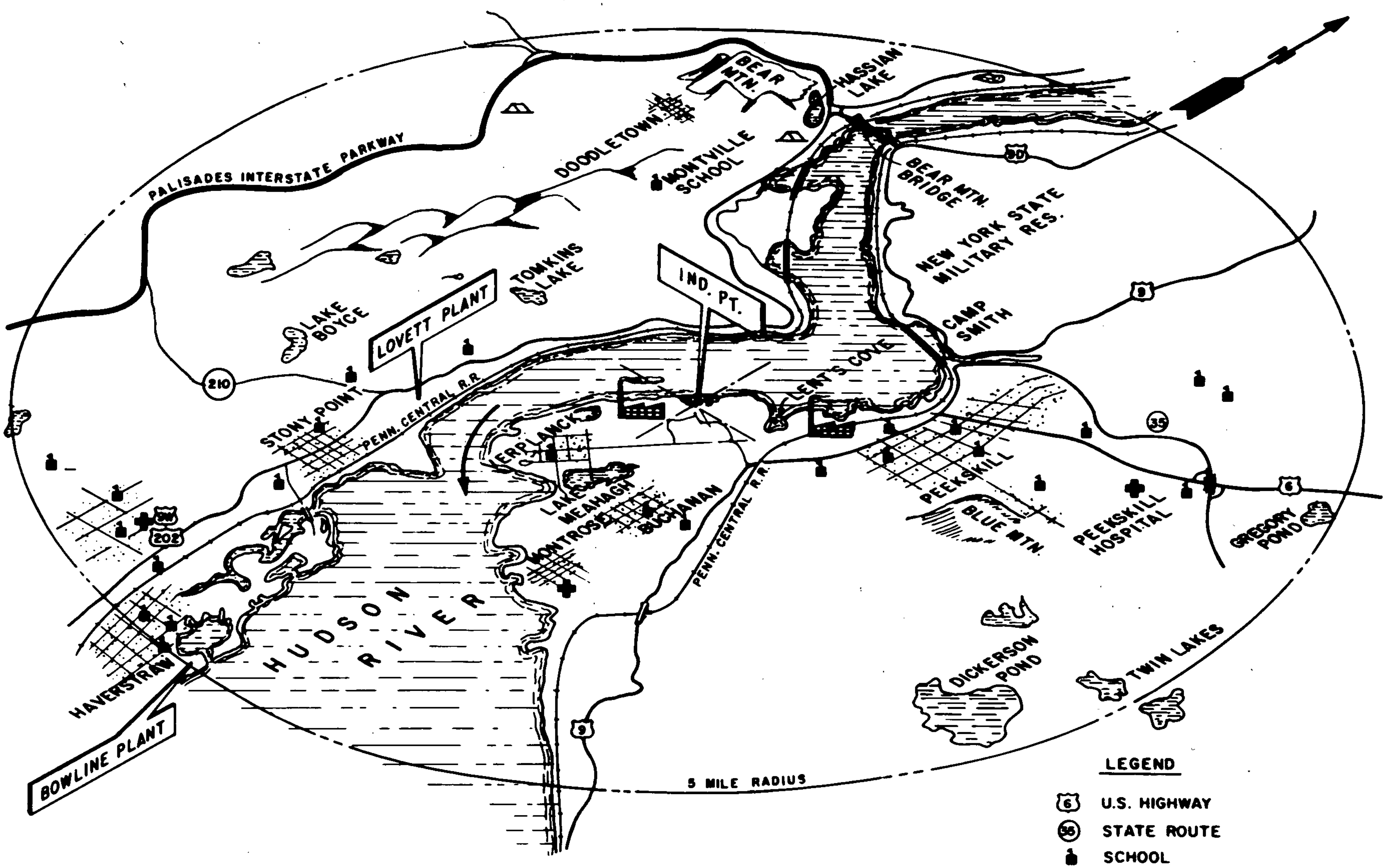


Figure 1-2. Indian Point 5-mile area.

Source: USAEC 1972

1.1.1.2 Ownership

137 acres of the site including Units Nos. 1 and 2 are owned by the Consolidated Edison Company of New York, Inc. (Con Edison), while the remaining 102 acres, including Unit No. 3 are owned by the Power Authority of the State of New York (the Authority). Unit No. 1 has not operated since October 1, 1974.

1.1.1.3 Plant Electrical Output

1.1.1.3.1 Unit Type

Both Indian Point Unit Nos. 2 and 3 are nuclear power plants. Each unit contains a nuclear steam supply system consisting of a pressurized water reactor, reactor coolant system, and associated auxiliary systems. The Unit Nos. 2 and 3 turbines are tandem-compound generating units which are driven by the steam produced in the supply systems and run at 1800 revolutions per minute. The turbine auxiliaries include deaerating surface condensers, steam jet air ejectors, turbine driven main feed pumps, motor driven condensate pumps, and six stages of feedwater heating. The principal components of the plants, including the pressurized water reactors, steam generators, and turbines were designed and manufactured by Westinghouse Electric Corporation.

1.1.1.3.2 Rated Output Capabilities

The Indian Point Units Nos. 2 and 3 turbines each have a guaranteed capability of 1,021,793 KW at 1.5 in. Hg absolute exhaust pressure with zero per cent make up and six stages of feedwater heating. The current net rated capacities of Indian Point Units Nos. 2 and 3 are 873 MWe and 965 MWe., respectively.

Unit No. 2 is licensed to operate a power output of 873 MWe. Unit No. 3 is currently licensed to operate at a 91% power level with an output of 873 MWe.

1.1.1.3.3 Commercial Operation Dates

On September 28, 1973, Con Edison received a Facility Operating License (DPR-26) from the Nuclear Regulatory Commission (NRC) (formerly, Atomic Energy Commission) authorizing the full-term, full-power operation of Indian Point Unit No. 2. Indian Point Unit No. 3 began commercial operation on August 30, 1976. The Facility Operating License (DPR-64) obtained from the NRC authorized 91% power operation.

1.1.1.3.4 Historical Summary of Net Generation

Indian Point Unit No. 2 is designed for base load operation at its rated capacity. Due to ecological considerations, the unit has been operated during the winter with the intake of condenser cooling water reduced by 40%. This reduced flow operation may affect the power output. However, there is no diurnal generation difference.

A summary of historical net generation data for Unit No. 2 for the months of April through August during the past several years is presented in Appendix 1-1. Historical net generation data for Unit No. 3 are not available since the unit only recently began commercial operation.

1.1.1.3.5 Planned Outage Schedule

Planning for future outages at Indian Point Units Nos. 2 and 3 is primarily governed by the refueling operation of the nuclear reactors and the power dispatch systems of Con Edison and PASNY. Table 1-1 shows a 38-year planned outage schedule for Indian Point Unit No. 2 while Table 1-2 presents a 40 year planned outage schedule for Unit No. 3. In general, the periods of time preferred for the 7-week annual planned outages are during the winter and spring so that the units will be available to meet the peak summer system demand. It should be emphasized that these outage schedules are two of many possible plant outage schedules.

1.2 COOLING WATER SYSTEM

1.2.1 General Plan

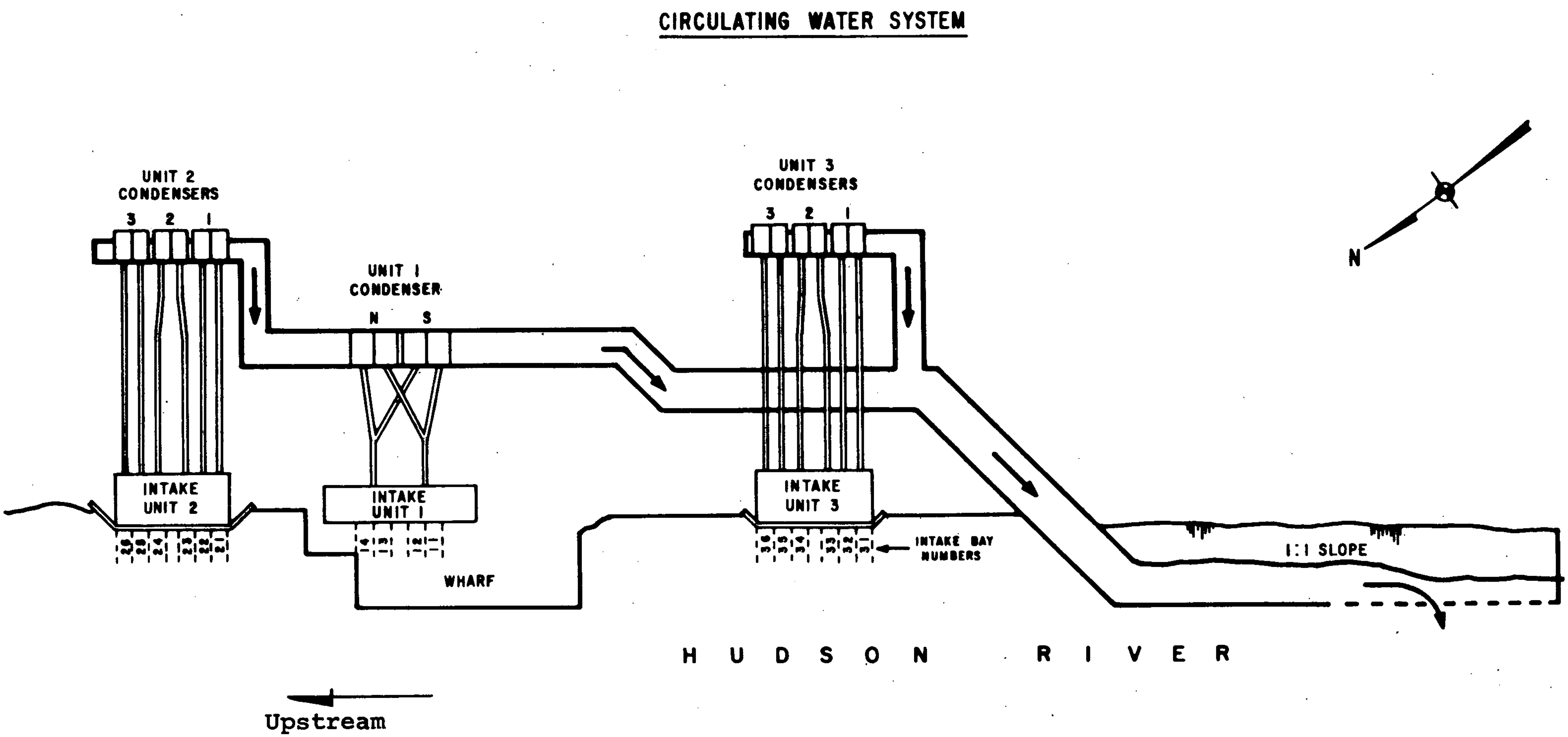
A plan view of the existing open-cycle cooling water systems is shown in Fig. 1-3. Cooling water from the river enters the station through the Units Nos. 2 and 3 intakes, is pumped through the condensers, and returns to the river via a common discharge canal located south of Unit No. 3. Normal flow for each Unit with all six circulating water pumps operating, is 840,000 GPM. During the winter, the intake of cooling water is reduced to 504,000 GPM, when the water temperature is 40F or less. Service water is drawn through a separate intake forebay in the center of each intake and, after utilization, is discharged into the common canal. The maximum total service water flow for each unit is 30,000 GPM.

Table 1-1. PLANNED OUTAGE SCHEDULE OF INDIAN POINT UNIT NO. 2 (WEEKS)

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1977	-	-	-	3	2	-	-	-	-	-	-	-
1978-86	-	-	-	-	-	-	-	-	-	3	4	-
1987	3	4	-	-	-	-	-	-	-	-	-	-
1988	-	-	4	3	-	-	-	-	-	-	-	-
1989	-	-	-	3	4	-	-	-	-	-	-	-
1990	-	2	4	1	-	-	-	-	-	-	-	-
1991	-	-	-	3	4	-	-	-	-	-	-	-
1992	3	4	-	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	4	3	-	-	-	-	-	-
1994	4	3	-	-	-	-	-	-	-	-	-	-
1995	-	-	4	3	-	-	-	-	-	-	-	-
1996	-	-	3	4	-	-	-	-	-	-	-	-
1997	-	-	-	-	4	3	-	-	-	-	-	-
1998	3	4	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	3	4
2000	-	-	-	-	-	-	-	-	-	-	4	3
2001	-	-	-	-	-	-	-	-	4	3	-	-
2002	-	-	-	-	3	4	-	-	-	-	-	-
2003	-	-	-	-	2	4	1	-	-	-	-	-
2004	-	-	-	-	3	4	-	-	-	-	-	-
2005	-	-	-	-	3	4	-	-	-	-	-	-
2006	-	-	2	4	1	-	-	-	-	-	-	-
2007-2013	-	-	-	-	3	4	-	-	-	-	-	-

TABLE 1-2 PLANNED OUTAGE SCHEDULE OF INDIAN POINT UNIT NO. 3 (WEEKS)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977	–	–	–	–	–	–	–	–	–	4	4	–
1978	–	–	–	–	4	4	–	–	–	–	–	–
1979	–	–	–	–	–	–	–	–	4	4	–	–
1980	–	–	–	–	–	–	–	–	–	–	–	–
1981	4	4	–	–	–	–	–	–	–	–	–	–
1982	–	–	–	–	4	4	–	–	–	–	–	–
1983	–	–	–	–	–	–	–	–	4	4	–	–
1984	–	–	–	–	–	–	–	–	–	–	–	–
1985	4	4	–	–	–	–	–	–	–	–	–	–
1986	–	–	–	–	4	4	–	–	–	–	–	–
1987	–	–	–	–	–	–	–	–	4	4	–	–
1988	–	–	–	–	–	–	–	–	–	–	–	–
1989	4	4	–	–	–	–	–	–	–	–	–	–
1990	–	–	–	–	4	4	–	–	–	–	–	–
1991	–	–	–	–	–	–	–	–	4	4	–	–
1992	–	–	–	–	–	–	–	–	–	–	–	–
1993	4	4	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	4	4	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	4	4	–	–
1996	–	–	–	–	–	–	–	–	–	–	–	–
1997	4	4	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	4	4	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	4	4	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–
2001	4	4	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	4	4	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	4	4	–	–
2004	–	–	–	–	–	–	–	–	–	–	–	–
2005	4	4	–	–	–	–	–	–	–	–	–	–
2006	–	–	–	–	4	4	–	–	–	–	–	–
2007	–	–	–	–	–	–	–	–	4	4	–	–
2008	–	–	–	–	–	–	–	–	–	–	–	–
2009	4	4	–	–	–	–	–	–	–	–	–	–
2010	–	–	–	–	4	4	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–	4	4	–	–
2012	–	–	–	–	–	–	–	–	–	–	–	–
2013	4	4	–	–	–	–	–	–	–	–	–	–
2014	–	–	–	–	4	4	–	–	–	–	–	–
2015	–	–	–	–	–	–	–	–	4	4	–	–
2016	–	–	–	–	–	–	–	–				



Schematic

Figure 1-3. **INDIAN POINT STATION CIRCULATING WATER SYSTEM**

Source: Consolidated Edison 1977b

1.2.2 Intake System

Details of the Units Nos. 2 and 3 intakes are shown on Figs. 1-4 through 1-9. Figs. 1-6 and 1-9 show simplified cross-sections of a typical screenhouse bay at Units Nos. 2 and 3, respectively, and indicate the recirculation lines, two per pump, which are normally closed except in the winter. During the winter, the recirculation line valves are opened, and flow-restricting orifices are placed at the outlet water boxes of each condenser (Fig. 1-12, Location G) so that 40 percent of the flow is bypassed directly back into the intake to reduce the total flow through the screens and trash racks. The orifice plates have been designed to keep the pumps operating at their design point to avoid the vibration problems that would occur at reduced flows.

1.2.2.1 Screening System

1.2.2.1.1 Intake Openings

Each of the Units Nos. 2 and 3 intake structures has six forebays for the circulating water pumps and one opening for the service water system. Each forebay is 13'-4" in width, the bottom of each opening being set at elevation -27'-0" MSL (mean sea level). The river bottom in front of each screenhouse has been dredged to this approximate depth.

A curtain wall forms the upper boundary in front of each intake, extending down to elevation -1'-0" MSL to keep floating debris from entering each screenhouse.

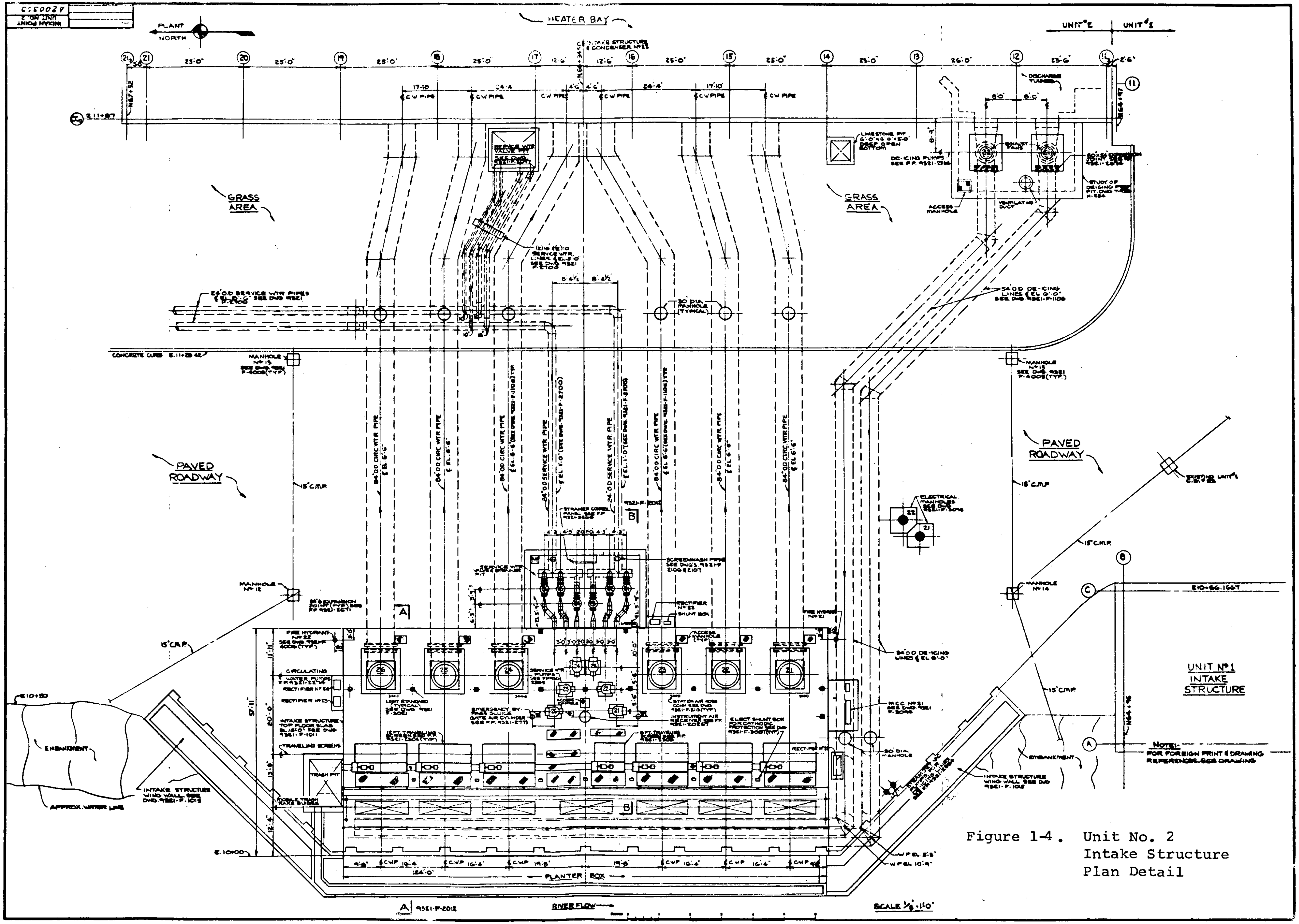
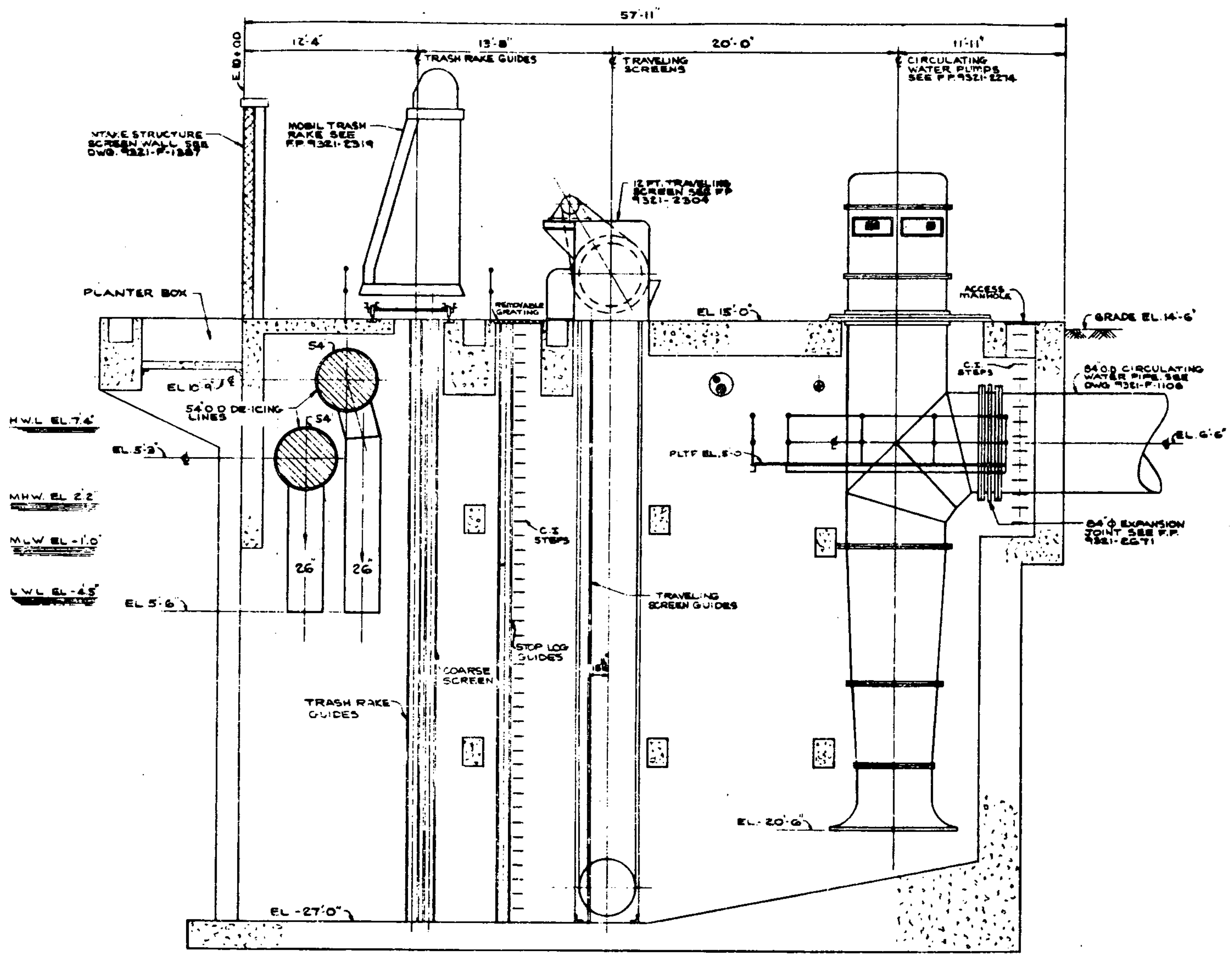
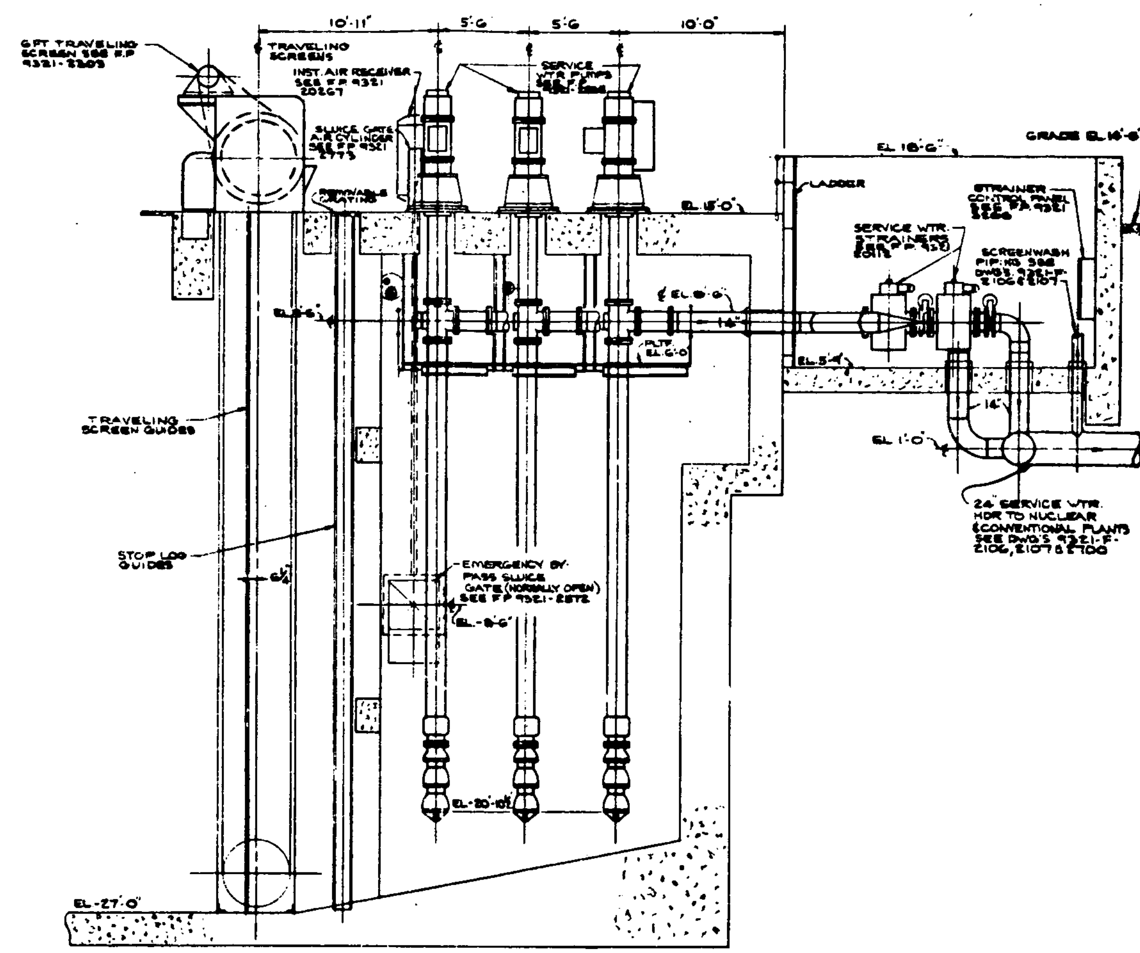


Figure 1-4. Unit No. 2 Intake Structure Plan Detail



SECTION A-A
LOOKING NORTH
SCALE 1/4" = 1'-0"



SECTION B-B
LOOKING NORTH
SCALE 1/4" = 1'-0"

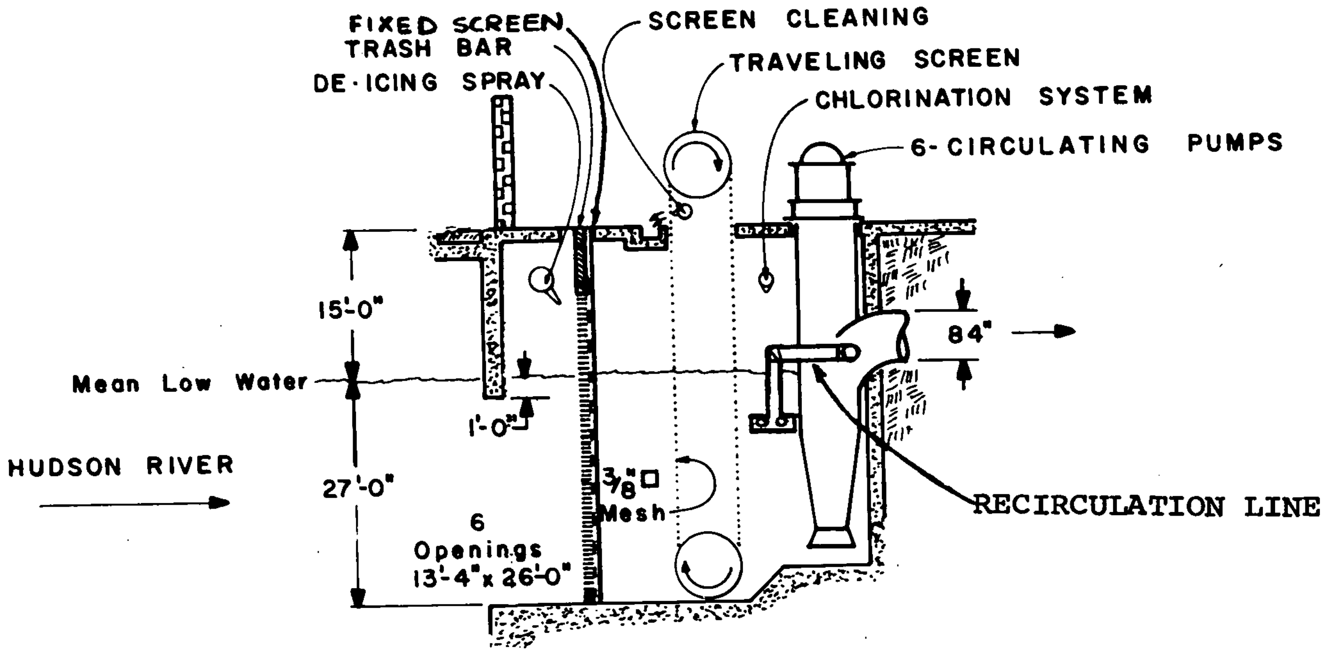
REFERENCE DWG'S

DESCRIPTION	UE&C DWG Nº
PLOT PLAN	9321-F-1008
INTAKE STRUCTURE TOP FLOOR SLAB	9321-F-1011
INTAKE STRUCTURE CONCRETE SECTIONS	9321-F-1013
INTAKE STRUCTURE WING WALLS	9321-F-1015
CIRCULATING WATER & DEICING PIPING	9321-F-1106
INTAKE STRUCTURE SCREEN WALL	9321-F-1387
STUDY OF DEICING PUMP PIT	T-9321-H-254
TURBINE BLDG. SERVICE WTR PIPING	9321-F-2097
SERVICE WTR PIPING @ INTAKE STRUCTURE	9321-F-2106
SERVICE WTR PIPING @ INTAKE STRUCTURE	9321-F-2107
YARD AREA - STATION & INST AIR PIPING	9321-F-2113
SERVICE WTR PIPING - YARD AREA	9321-F-2700
INTAKE STRUCTURE - LIGHTING	9321-F-3021
INTAKE STRUCTURE CATHODIC PROTECTION	9321-F-3087
CONDUIT LAYOUT - INTAKE STRUCTURE	9321-F-3098
YARD STORM DRAINS	9321-F-4005
YARD FIRE PROTECTION	9321-F-4006
COMPOSITE PIPING-UNDERGROUND	T-9321-F-486

FOREIGN PRINT REFERENCES

DESCRIPTION	UE&C F.P. Nº
OUTLINE - DEICING PUMP	9321-2366
STRAINER CONTROL PANEL	9321-3266
SERVICE WATER STRAINERS	9321-20112
60"x54"Φ EXPANSION JOINT (DEICING LINES)	9321-2674
84"Φ EXPANSION JOINT (CIRC WTR LINES)	9321-2671
OUTLINE - CIRCULATING WATER PUMPS	9321-2274
EMERGENCY BY-PASS GATE, AIR CYLINDER	9321-2773
OUTLINE - SERVICE WATER PUMPS	9321-2585
12 FT TRAVELING SCREEN	9321-2304
6 FT TRAVELING SCREEN	9321-2303
INSTRUMENT AIR RECEIVER	9321-20267
STEAM JET VACUUM PUMPS (DEICING LINES)	9321-2834
OUTLINE MOBIL TRASH RAKE	9321-2319

Figure 1-5. Unit No. 2
Intake Structure
Section Detail



Schematic
Figure 1-6. Intake Bay Cross-Section of Indian Point Unit No. 2.

Source: USAEC 1972

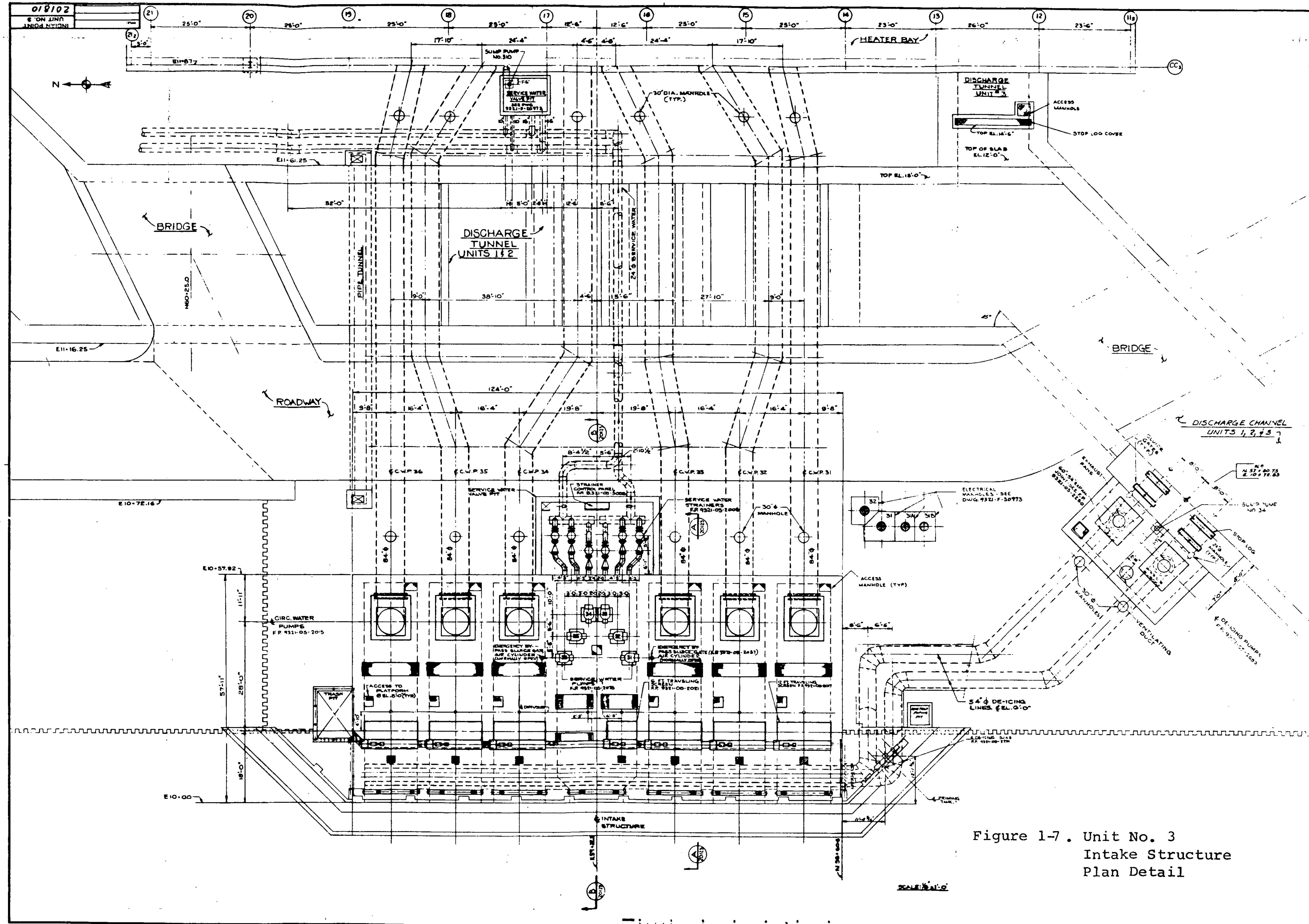
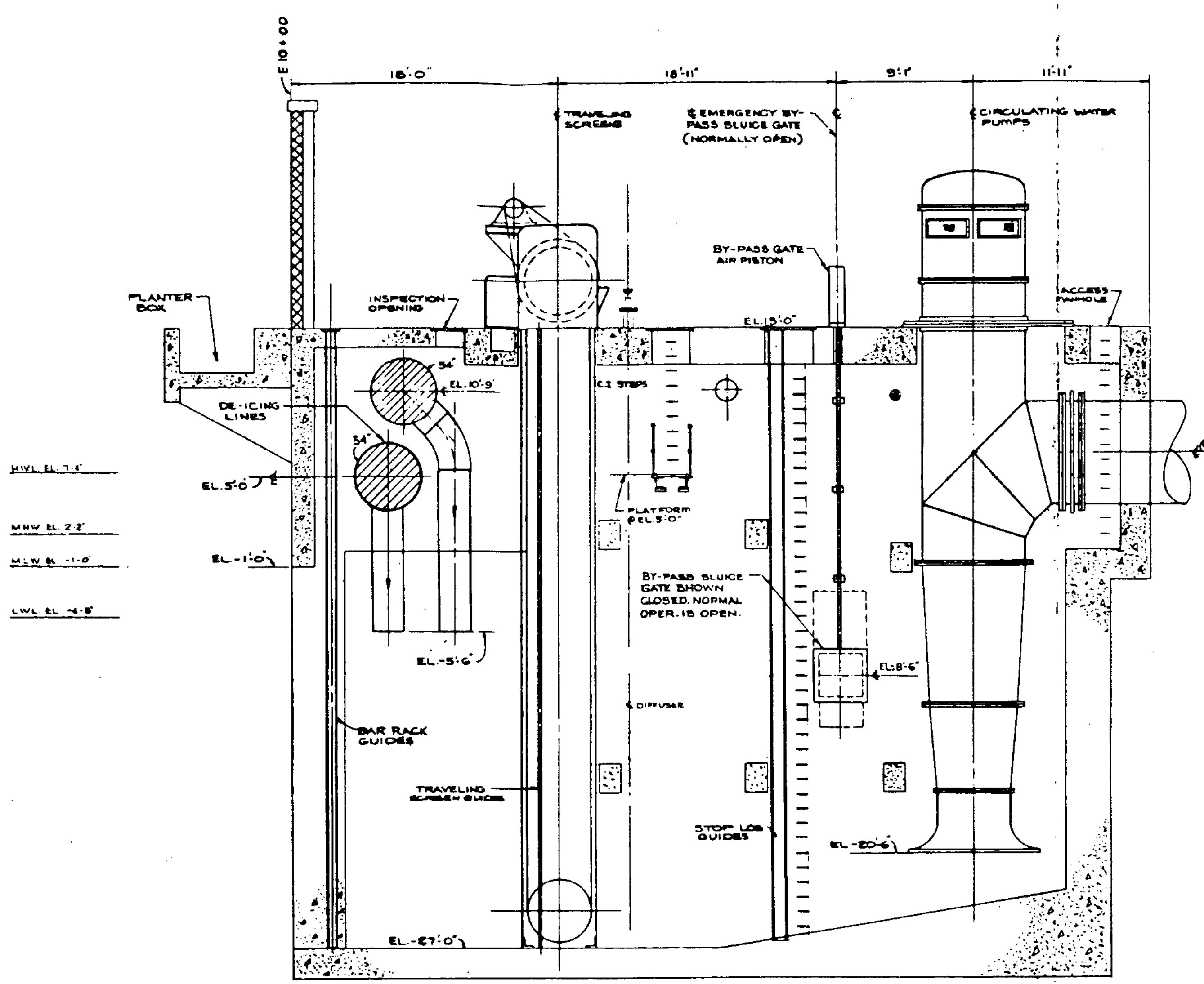


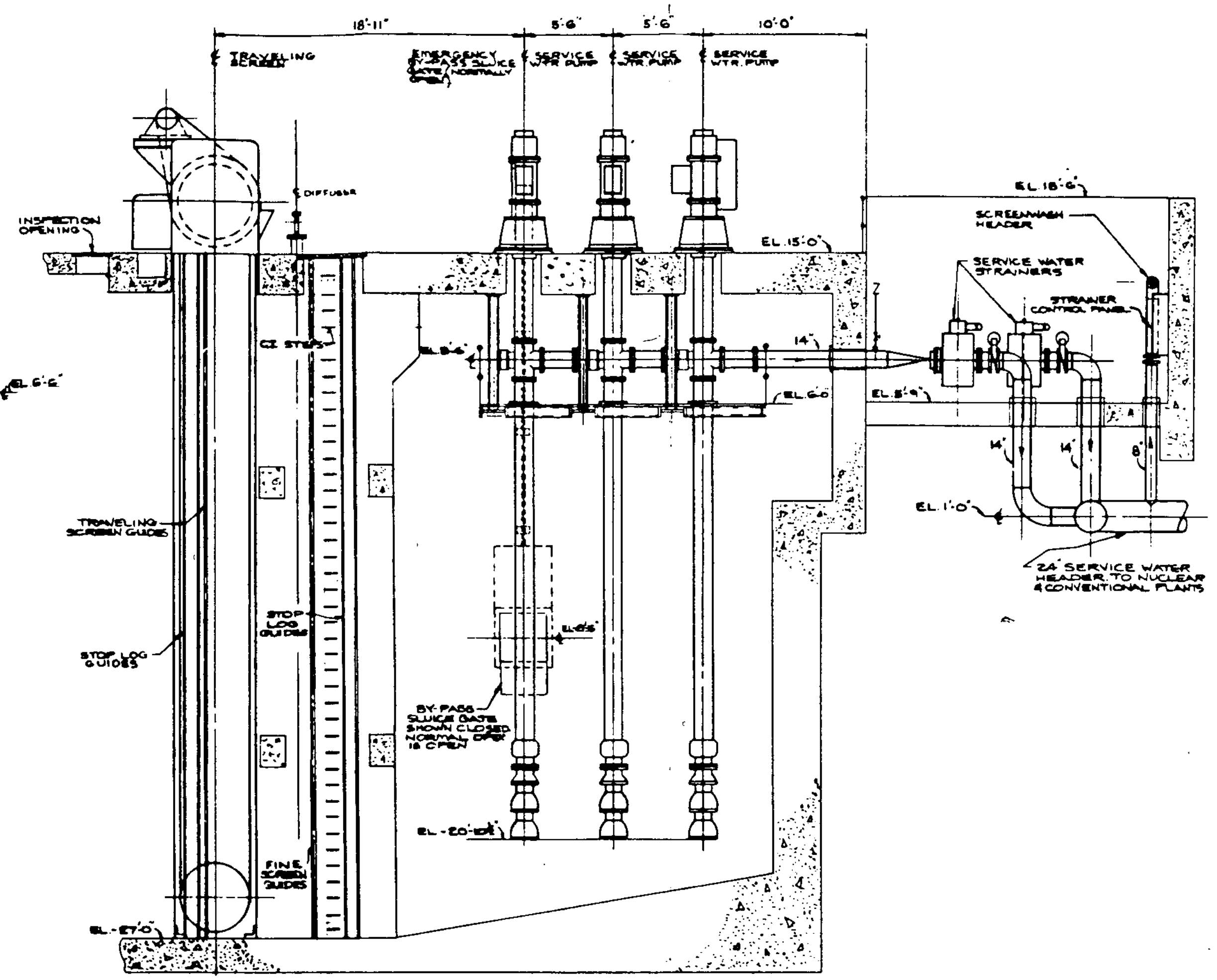
Figure 1-7. Unit No. 3
Intake Structure
Plan Detail



SECTION "A-A"

SCALE 1/4"=1'-0"

DWG. 9321-F-20113

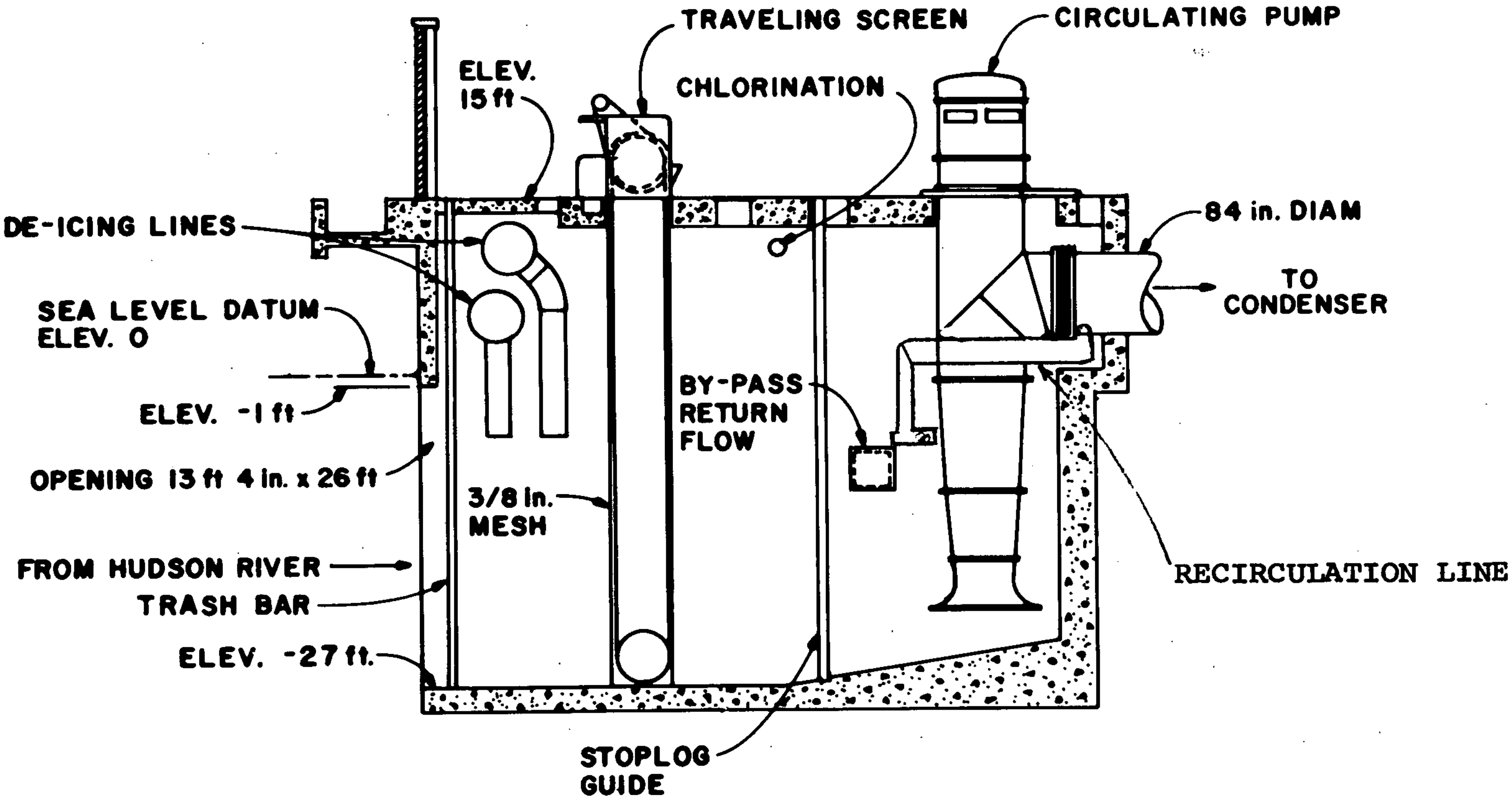


SECTION "B-B"

SCALE 1/4"=1'-0"

DWG. 9321-F-20113

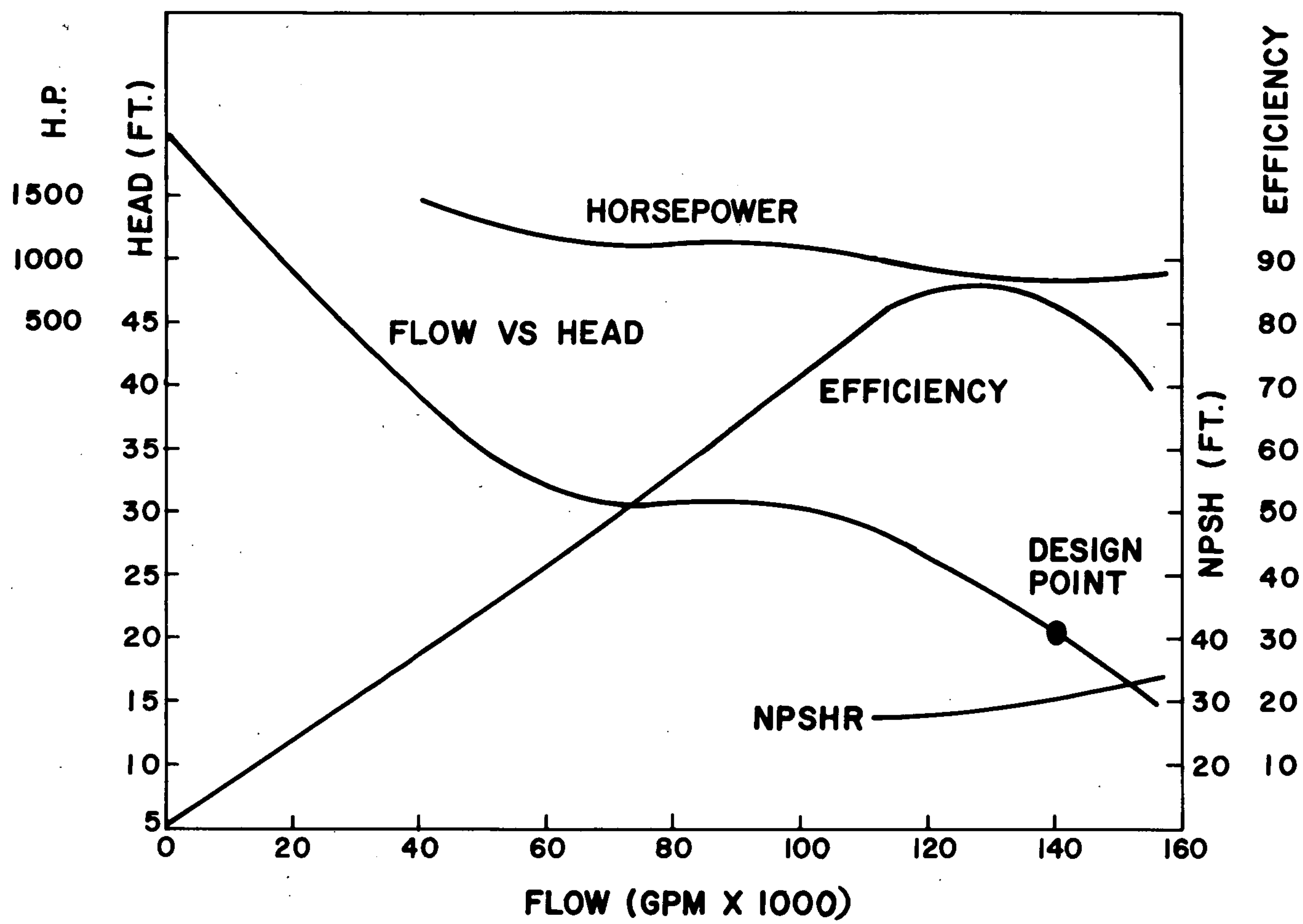
Figure 1-8. Unit No. 3
Intake Structure
Section Detail



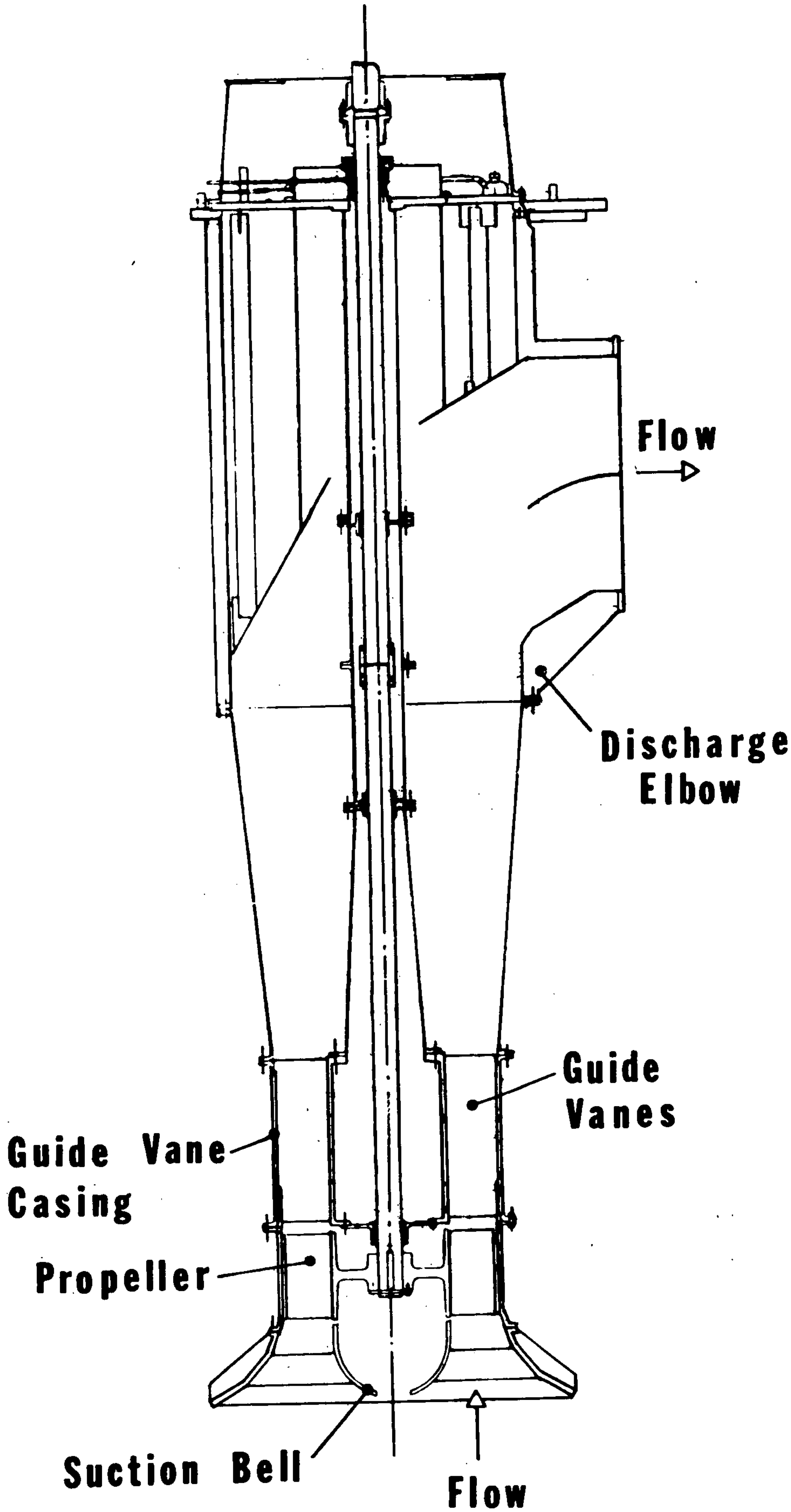
Schematic
Figure 1-9. Intake Bay Cross-Section of Indian Point Unit No. 3.
Source: USNRC 1975a

Figure 1-10.

CIRCULATING WATER PUMP PERFORMANCE CHART



Source· **Babcock & Wilcox** Pump Performance Chart



Typical
Figure 1-11. Pump Cross Section.

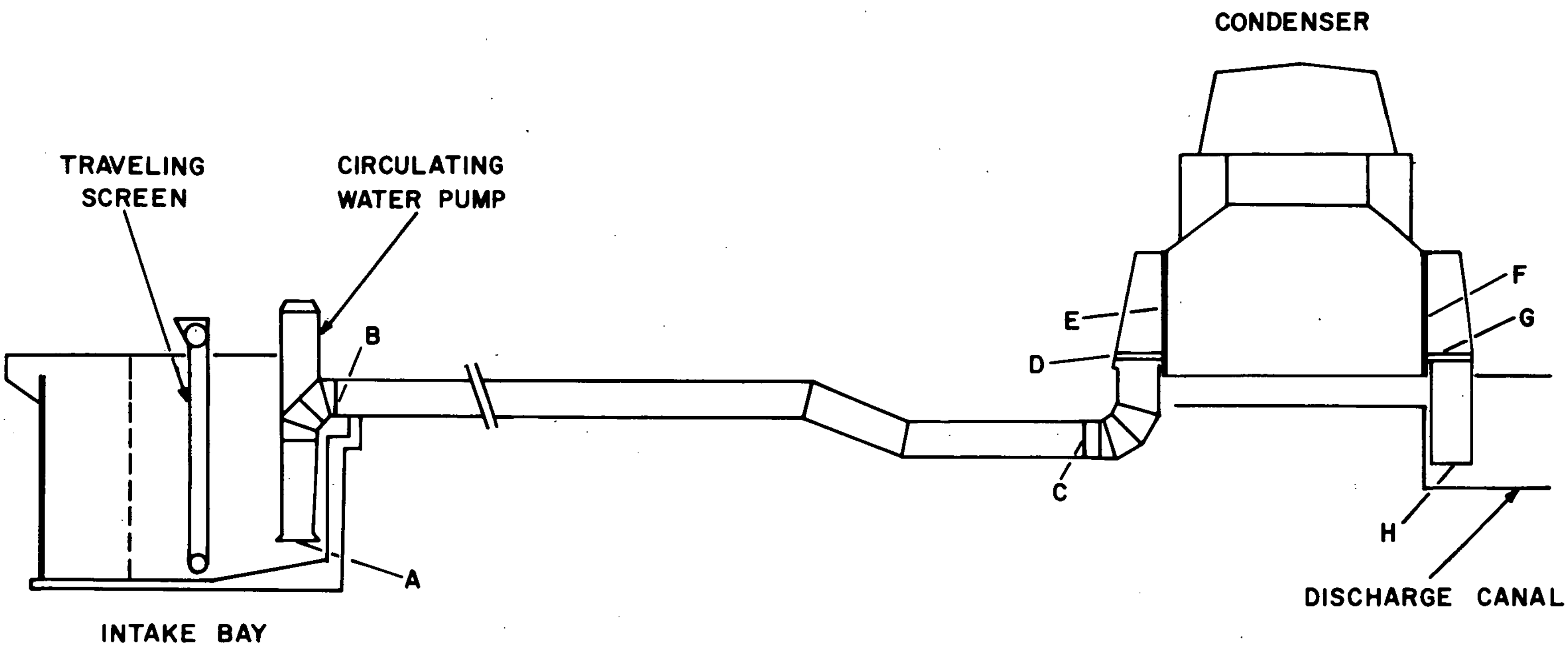


Figure 1-12. Cross-Section Through Intake Structure.
Source: **Con Edison 1972d**

1.2.2.1.2 Trash Racks

As shown on the intake drawings, (Figs. 1-6 and 1-9), trash racks are placed across each intake, behind the curtain wall. Each rack extends from the bottom of the screenhouse to the top deck. The open distance between each of the trash rack bars is 3 inches. Thus, the racks serve to prevent large floating and submerged debris from entering the traveling screens and pumps.

1.2.2.1.3 Fixed Screens

In addition to the trash racks, fixed screen panels, shown in Fig. 1-6, are located in front of the Unit No. 2 traveling screens. These screens are made of stainless steel mesh with an open distance between strands of 0.375 in. The effective open area of the fixed screens is approximately 67 percent of the intake area below the water line. Indian Point Unit No. 3 does not have fixed screens.

1.2.2.1.4 Traveling Screens

Six vertical, rotating, front-entry traveling screens are used to remove the relatively fine debris which passes through the trash racks of both units and fixed screens of Unit No. 2. Each screen is 12 feet wide and has a screen mesh size of 0.375 in.

The effective open area of a single travelling screen assembly is approximately 57 percent.

The service water intake has a single six foot wide traveling screen. The mesh size is the same as for the larger screens.

Collected debris from the screens is flushed through a common trough to the north end of each screenhouse, as shown in Figs.

1-4 and 1-7, where it is collected in the trash pit for disposal off site.

1.2.2.2 Deicing System

1.2.2.2.1 Description

The deicing systems shown in Figs. 1-4, 1-5, 1-7 and 1-8, return heated water from the discharge canal back to the pump intake bays during periods of ice buildup. The two 54 in. headers are connected to 26 in. diameter downpipes which distribute the flow to the individual pump bays.

1.2.2.2.2 Mode of Operation

The deicing system is started manually by priming the headers using an ejector arrangement and then starting one or both of the deicing pumps. This is done whenever ambient temperatures are low enough to cause ice buildup on the trash racks and screens.

1.2.2.3 Circulating Water Pumps

1.2.2.3.1 Description

The location of each of the six main circulating water pumps is shown in Fig. 1-4 for Unit No. 2 and in Fig. 1-7 for Unit No. 3. Two 24 in. diameter recirculation lines, one on each side of the pump column, are used at each unit to bypass 40 percent of the flow back to the intake during the winter months. This recirculation reduces the total flow into the plant and also the velocity of water entering the intakes to mitigate impingement of aquatic organisms during the winter.

Pump performance curves are shown on Fig. 1-10. Other important pump parameters are as follows:

Rated Flow	140,000 GPM
Rated Total Dynamic Head (TDH)	21.0 Feet
Speed	292 RPM
Peak Efficiency	86%
Specific Speed	11,137
Motor Capacity	900 HP
No. of Stages	1
Propeller Type	Axial Flow

Fig. 1-11 shows a typical pump cross-section.

1.2.2.3.2 Modes of Operation

Each unit has two modes of pump operation: normal (140,000 GPM per intake) and recirculation (84,000 GPM per intake). Since recirculation is achieved by opening the recirculation lines to the intake and placing orifices in the discharge water boxes of the condensers, the pumps operate at the same design point in either case. (The design point is identified in Fig. 1-10 at 140,000 GPM flow and 21 feet head).

As each circulating water pump has its own separate feed line and condenser half, it may be operated independently of the others. Normally, it is desirable to operate all six pumps when the unit is producing power to avoid abnormal steam flows and excessive condenser back pressures, which sometimes occur if one or more pumps are shut down either because of operating difficulties or to mitigate fish impingement. Reducing the number of pumps in service can also result in vibrations and stress within the condensers that can accelerate the deterioration of the tubes and supports.

1.2.2.3.3 Historical Circulating Water Pump Operation

A summary of circulating water pump operation data for Unit No. 2 is presented in Appendix 1-2 for the period 1974 through 1976. This tabulation presents the total average daily flow for the plant including the circulating water pumps and service water pumps. Historical operation data for Unit No. 3 are not available since the unit only recently began commercial operation.

1.2.3 Transport System from Intake to Condenser

Six 84 in. diameter lines, as shown in Fig. 1-12, are used to transport the water from each circulating water pump to its respective condenser half. The average length of each line is approximately 200 feet.

1.2.4 Condenser System

1.2.4.1 Description

Each of the Units Nos. 2 and 3 condenser systems consists of three shells, with two independent halves per shell. While the halves are connected to one another on the steam side, they are isolated on the circulating water side. Water passes from the pumps to the inlet water boxes, through the condenser tubes, to the discharge water boxes which are connected to the discharge tunnel through separate 96 in. diameter lines.

Each condenser contains 23,472 Admiralty tubes. The 18 gauge tubes are 50 feet long and have a one in. outside diameter.

1.2.4.2 Modes of Operation

Normally, all six condenser halves of each unit are operated together for optimum steam flow and performance. Each half can be independently taken out of service, for example, for inspection or to clean the water boxes. This is accomplished by shutting down the corresponding circulating water pump. Once a pump is shut down, the tubes and water boxes begin to drain unless the priming jets are used to keep the condenser half full of water. To put a condenser half back in service after de-watering, the priming jets must be put on to fill the system before starting the circulating water pump.

1.2.5 Transport System from Condenser to Outfall Structure

The cooling water from the Indian Point Units Nos. 2 and 3 condensers flows downward from the discharge water boxes, via six 96" OD downpipes and exits beneath the surface of the water in the discharge canal. The discharge canal, as depicted in Fig. 1-13, is designed for the combined flow of three units of the Indian Point Station. The portion of the canal exclusively serving Indian Point Unit No. 2 is about 18 feet wide with an elevation varying from 12 to 17 feet below mean low water (refer to locations A, B, and C in Fig. 1-13). The water from Unit No. 2 then joins the water discharged from Unit No. 3 in a 40 foot wide discharge canal. The discharge velocity in this canal (location F in Fig. 1-13) is approximately 4.5 fps at the full flow of Unit Nos. 2 and 3. The average transit times for Unit No. 2 and Unit No. 3 cooling water traveling from condenser to

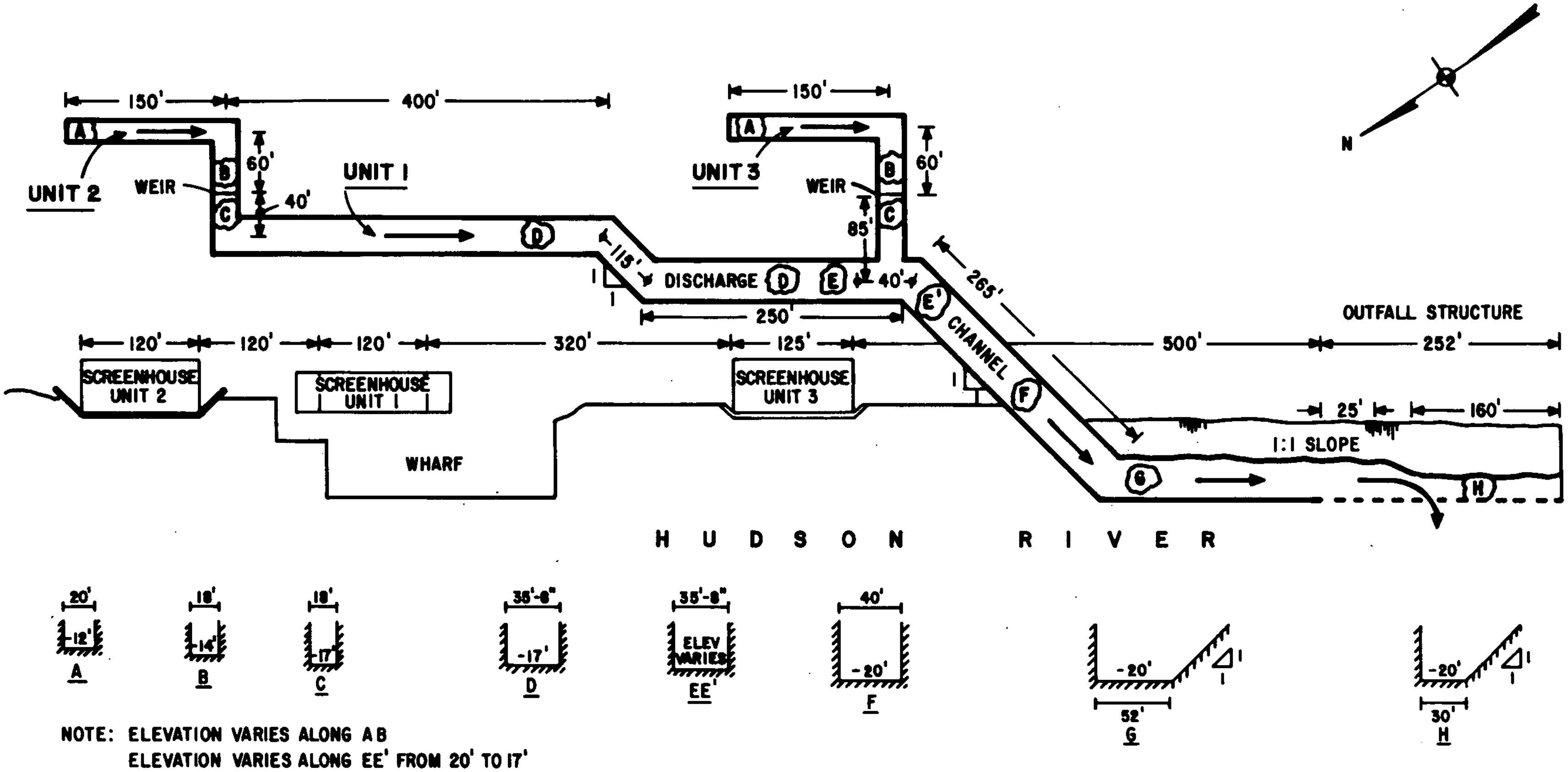


Figure 1-13. Indian Point Discharge Canal.

outfall structure are presented in Tables 1-3 through 1-8 for different operating conditions.

1.2.6 Outfall Structure

1.2.6.1 Description

The outfall or discharge structure for the Indian Point facility is designed to enhance mixing of cooling water and river water in such a way as to minimize thermal impact in the river. It can accommodate the combined cooling water flow from all three Indian Point units (about 2,058,000 gpm including service water).

The cooling water from the discharge channel is released to the Hudson River via an outfall structure located south of Indian Point Unit No. 3. The outfall structure, as depicted schematically in Fig. 1-14, consists of twelve submerged rectangular ports equipped with adjustable gates which are in line and parallel to the river axis. The ports, 4 feet high by 15 feet wide and spaced 21 feet apart (center to center), are submerged to a depth of 12 feet (center to surface) at mean low water. The first upstream port is approximately 600 feet from the Indian Point Unit No. 3 intake and the the length of total port section is approximately 252 feet.

1.2.6.2 Modes of Operation

The modes of operation of the Indian Point outfall structure are specified in the Environmental Technical Specification Requirements (ETSR) for the Indian Point Station.

The discharge port gates must be adjusted mechanically to maintain a minimum hydraulic head differential across the outfall

Table 1-3. **Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 2 (minutes)**

With Indian Point Unit No. 1 Not Operating

Circulating Pumps Operating at Unit No. 2

Circ. Pumps Operating at Unit No. 3	3	4	5	6
3	19.4	15.4	12.6	10.8
4	18.6	14.6	12.1	10.3
5	17.8	14.1	11.6	10.0
6	17.3	13.6	11.3	9.7

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser: 0.14 minutes.

Table 1-4. Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 2 (minutes)

With one circulating pump operating at Unit No. 1

Circ. Pumps Operating at Unit No. 3	Circulating Pumps Operating at Unit No. 2: 3	4	5	6
3	16.9	13.7	12.0	11.0
4	16.3	13.1	11.1	10.0
5	15.3	12.7	10.7	9.3
6	14.7	12.1	10.4	9.0

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser: 0.14 minutes.

Table 1-5. Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 2 (minutes)

With two circulating pumps operating at Unit No. 1

Circ. Pumps Operating at Unit No. 3	Circulating Pumps Operating at Unit No. 2: 3	4	5	6
3	15.3	12.5	11.0	10.0
4	14.8	12.1	10.2	9.2
5	14.1	11.7	9.9	8.7
6	13.5	11.2	9.7	8.5

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser: 0.14 minutes.

Table 1-6. Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 3 (min)

With Indian Point Unit No. 1
Not Operating

Circ. Pumps Operating at Unit No. 3	Circulating Pumps Operating at Unit No. 2: 3	4	5	6
3	11.2	10.5	9.7	9.2
4	9.2	8.5	8.0	7.5
5	7.7	8.0	6.7	6.4
6	6.7	7.2	5.9	5.6

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser 0.14 minutes.

Table 1-7. Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 3 (min)

With two circulating pumps operating at Unit No. 1

Circ. Pumps Operating at Unit No. 3	Circulating Pumps Operating at Unit No. 2: 3	4	5	6
3	9.6	8.0	7.2	6.7
4	9.2	7.5	6.4	5.9
5	8.4	7.2	6.1	5.4
6	7.8	6.6	5.9	5.2

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser: 0.14 minutes.

Table 1-8. Average Transit Time for Cooling Water from Intake to Discharge into River — Indian Point Unit No. 3 (min)

With one Circulating Pump operating at Unit No. 1

Circ. Pumps Operating at Unit No. 3	Circulating Pumps Operating at Unit No. 2			
	3	4	5	6
3	10.3	8.5	7.8	7.3
4	9.7	7.9	6.8	6.3
5	7.9	7.5	6.4	5.6
6	6.4	6.9	6.1	5.4

Notes: All pumps at 100% flow, 312 cfs.

Transit time through condenser: 0.14 minutes.

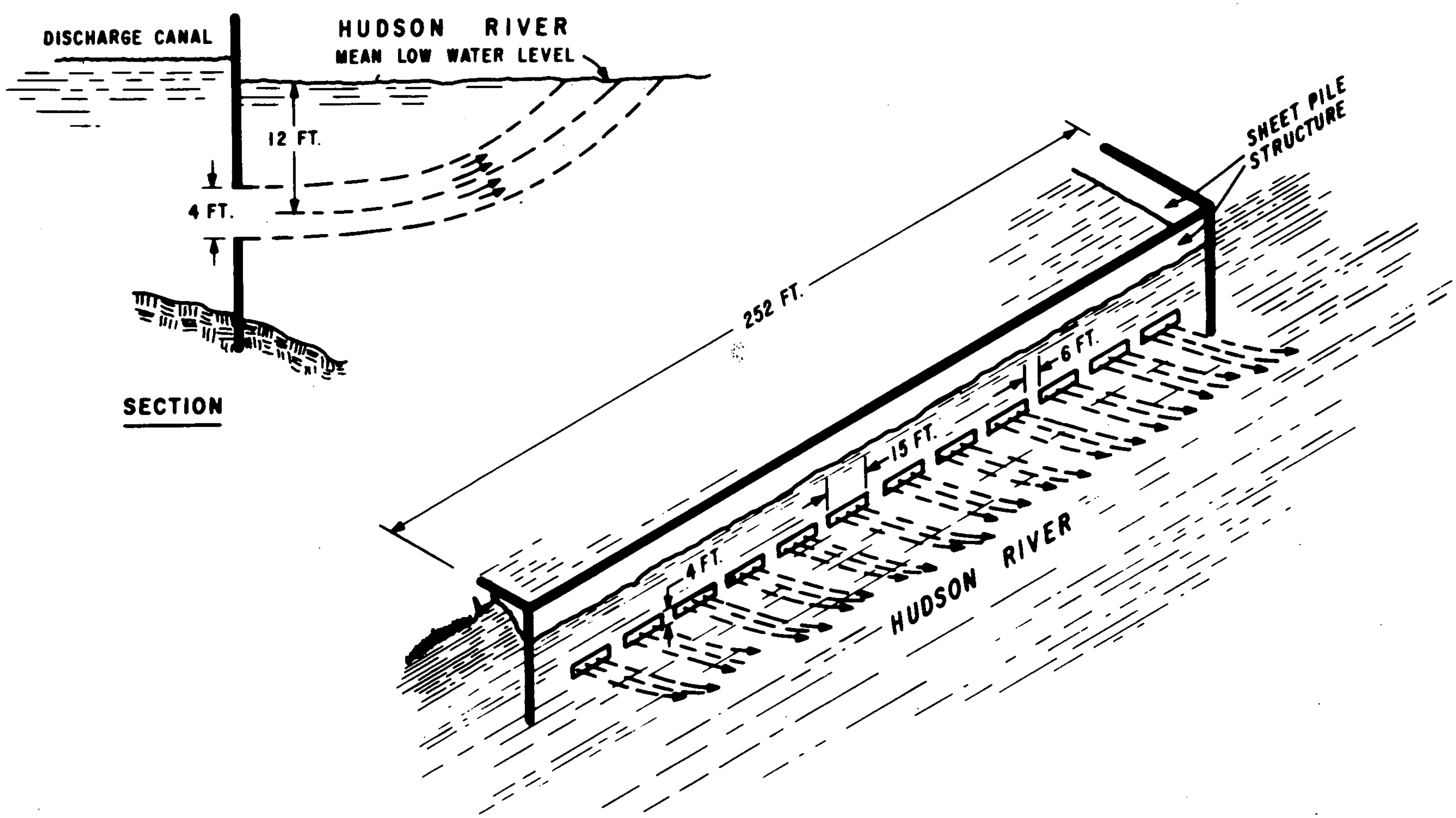


Figure 1-14. Diagrammatic Sketch of Indian Point Discharge Structure.

Source: Con Edison 1974

structure of 1.5 feet to 1.7 feet in order to assure a minimum discharge velocity of 10 fps under various flow rates. Gate adjustment is made within four hours of any change in the flow rate of the circulating water pumps.

ETSR also specifies that when the temperature in the discharge canal does not exceed 90F the discharge canal head differential can be less than 1.5 feet provided the thermal discharges meet the New York State thermal criteria.

1.3 Operating Dynamics

1.3.1 Circulating Water Pump Flow Characteristics

As previously indicated, there are two modes of operation for each circulating water pump. At normal or non-winter operation no cooling water is recirculated from the pump discharge line back to the intake bay, and the flow rate is 140,000 gpm. During winter operation with 40% cooling water recirculation, the intake flow is 84,000 gpm.

Since the recirculation lines are placed in the discharge line of the pump as depicted in Figs. 1-6 and 1-9, all pumps operate in either case at the same design point (i.e., 140,000 gpm at 21 feet TDH). A pump performance chart is presented in Fig. 1-10.

1.3.2 Cooling Water System Velocities

1.3.2.1 Intake System Velocities

A complete description of the Indian Point intakes is given in Subsection 1.2.2. Table 1-9 shows the average velocities through the intake openings, the fixed screens (Unit No. 2 only) and the traveling screens. The calculations are based on a river level equal to mean sea level.

1.3.2.2 Plant Velocities

As the cooling water progresses through the system from the intake openings to the discharge structure, the water velocity changes with each change of cross-sectional area. A summary of plant velocities is presented in Table 1-10.

1.3.3 Heat Rejection

The amount of heat rejected to the condenser is primarily dependent upon the electrical output of the power plant. Since the turbine performance is sensitive to exhaust steam temperature, the condenser waste heat is also dependent upon the inlet temperature and flow rate of the condenser cooling water. Tables 1-11 and 1-12 show the heat rejection rate versus plant capacity and river temperature for Indian Point Units Nos. 2 and 3, respectively.

It is noted that the plant load decreases with decreasing steam flow which results in a lower heat rejection rate. Also, a higher river temperature and/or smaller cooling water flow can reduce turbine efficiency which in turn may increase condenser waste heat per unit of generation.

Table 1-9.

AVERAGED INTAKE SYSTEM VELOCITIES
(ft/sec)

	Pump with No Recirculation	Pump with 40% Recirculation
Intake Opening	0.90	0.54
Fixed Screen (For I.P. 2 only)	1.29	0.77
Traveling Screen	1.68	1.01

Table 1-10.

SUMMARY OF PLANT VELOCITIES
(ft/sec)

Locations*	Pump With No Recirculation	Pump With 40% Recirculation
Pump Intake (Pt. A-Pt.B)	8.25	8.25
84" diameter pipe (Pt.B to Pt.C)	8.25	4.95
90" diameter pipe (Pt.C to Pt.D)	6.30	3.78
Condenser tube (Pt.E to Pt.F)	6.00	3.60
Condenser Tailpipe (Pt.G to Pt.H)	6.30	3.78

*Location points are identified in Figure 1.12.

Table 1-11. Condenser Waste Heat (10^6 Btu/hr) Indian Point Unit No. 2

Plant Capacity MW	River Temperature °F	Pumps Operated with No Recirculation 6 pumps	5 pumps	4 pumps	3 pumps	Pumps Operated with 40% Recirculation 6 pumps	5 pumps	4 pumps	3 pumps
906	40	-	-	-	-	6602	6636	6821	*
(100% load)	50	6536	6580	6580	6762	6678	6678	6854	*
	60	6578	6615	6608	6825	-	-	-	-
	70	6620	6650	6664	*	-	-	-	-
	80	6662	6720	6804	*	-	-	-	-
766	40	-	-	-	-	5695	5754	5779	5844
(75% load)	50	5670	5705	5768	5775	5771	5775	5796	5844
	60	5712	5740	5796	5838	-	-	-	-
	70	5754	5775	5824	5922	-	-	-	-
	80	5796	5810	5880	*	-	-	-	-
510	40	-	-	-	-	3982	4053	4066	4406
	50	3948	4025	4060	4074	4057	4074	4082	4406
	60	3990	4060	4088	4095	-	-	-	-
	70	4032	4095	4116	4158	-	-	-	-
	80	4074	4130	4144	4242	-	-	-	-

* Turbine backpressure higher than 3.5" Hg

Table 1 - 12. Condenser Waste Heat (10^6 Btu/hr) Indian Point Unit No. 3

Plant Capacity Mw	River Temperature °F	Pumps Operated with No Recirculation 6 pumps	5 pumps	4 pumps	3 pumps	Pumps Operated with 40% Recirculation 6 pumps	5 pumps	4 pumps	3 pumps
1000 (100% load)	40	-	-	-	-	7251	7285	7470	*
	50	7185	7229	7229	7411	7327	7327	7503	*
	60	7227	7264	7257	7474	-	-	-	-
	70	7269	7299	7313	*	-	-	-	-
	80	7311	7369	7453	*	-	-	-	-
766 (75% load)	40	-	-	-	-	5695	5754	5779	5844
	50	5670	5705	5768	5775	5771	5775	5796	5844
	60	5712	5740	5796	5838	-	-	-	-
	70	5754	5775	5824	5922	-	-	-	-
	80	5796	5810	5880	*	-	-	-	-
510	40	-	-	-	-	3982	4053	4066	4406
	50	3948	4025	4060	4074	4057	4074	4082	4406
	60	3990	4060	4088	4095	-	-	-	-
	70	4032	4095	4116	4158	-	-	-	-
	80	4074	4130	4144	4242	-	-	-	-

* Turbine backpressure higher than 3.5 "Hg

1.3.4 Temperature Profiles

The condenser temperature rise is dependent upon the rate of condenser cooling water flow and the amount of waste heat rejection to the condenser. Tables 1-13 and 1-14 show the condenser temperature rises for Indian Point Units Nos. 2 and 3, respectively. It is noted that the effect of river temperature on condenser temperature rise is considered insignificant.

1.3.5 Pressure Profiles

The pressure profiles for the Units Nos. 2 and 3 condenser cooling water systems are presented in Figs. 1-15 and 1-16 for each mode of circulating water pump operation. The calculations are based on a river level equal to mean sea level. Rapid pressure increases occur in two places: (1) from the pump entrance to the pump discharge due to the effect of the pumping dynamics, and (2) from the condenser exit chamber to the discharge tunnel due primarily to a large elevation drop between these two points. Pressure drops occur (1) along the vertical 96 in. diameter conduit leading to the condenser due to a sudden elevation increase and, (2) through the condenser due to friction losses.

1.3.6 Other Aspects

In addition to the specific operating dynamics discussed above, there are other physical forces associated with the turbulence generated by directional and cross-sectional area changes as can be seen in Fig. 1-12. The directional changes may be areas of significant turbulence.

Table 1-13. Condenser Temperature Rise (F) Predictions Indian Point Unit No. 2

Plant Capacity MW	River Temperature °F	Pumps Operated with No Recirculation 6 pumps	5 pumps	4 pumps	3 pumps	Pumps Operated with 40% Recirculation 6 pumps	5 pumps	4 pumps	3 pumps
906 (100% load)	40	-	-	-	-	26.2	31.6	40.6	*
	50	15.8	18.8	23.5	32.2	26.5	31.8	40.8	*
	60	15.9	18.9	23.6	32.5	-	-	-	-
	70	16.0	19.0	23.8	*	-	-	-	-
	80	16.1	19.2	24.3	*	-	-	-	-
766 (75% load)	40	-	-	-	-	22.6	27.4	34.4	44.
	50	13.5	16.3	20.6	27.5	22.9	27.5	34.5	44.
	60	13.6	16.4	20.7	27.8	-	-	-	-
	70	13.7	16.5	20.8	28.2	-	-	-	-
	80	13.8	16.6	21.0	*	-	-	-	-
510 (50% load)	40	-	-	-	-	15.8	19.3	24.2	31.
	50	9.4	11.5	14.5	19.4	16.1	19.4	24.3	31.
	60	9.5	11.6	14.6	19.5	-	-	-	-
	70	9.6	11.7	14.7	19.8	-	-	-	-
	80	9.7	11.8	14.8	20.2	-	-	-	-

*Turbine backpressure higher than 3.5 "Hg

Table 1 - 14. Condenser Temperature Rise (F) Predictions Indian Point Unit No. 3

Plant Capacity MW	River Temperature °F	Pumps Operated with No Recirculation				Pumps Operated with 40% Recirculation			
		6 pumps	5 pumps	4 pumps	3 pumps	6 pumps	5 pumps	4 pumps	3 pumps
1000 (100% load)	40	-	-	-	-	28.8	34.7	44.5	*
	50	17.1	20.7	25.8	35.3	29.1	34.9	44.7	*
	60	17.2	20.8	25.9	35.6	-	-	-	-
	70	17.3	20.9	26.1	*	-	-	-	-
	80	17.4	21.1	26.6	*	-	-	-	-
766 (75% load)	40	-	-	-	-	22.6	27.4	34.4	46.
	50	13.5	16.3	20.6	27.5	22.9	27.5	34.5	46.
	60	13.6	16.4	20.7	27.8	-	-	-	-
	70	13.7	16.5	20.8	28.2	-	-	-	-
	80	13.8	16.6	21.0	*	-	-	-	-
510	40	-	-	-	-	15.8	19.3	24.2	33.
	50	9.4	11.5	14.5	19.4	16.1	19.4	24.3	33.
	60	9.5	11.6	14.6	19.5	-	-	-	-
	70	9.6	11.7	14.7	19.8	-	-	-	-
	80	9.7	11.8	14.8	20.2	-	-	-	-

* Turbine backpressure higher than 3.5 "Hg

Figure 1-15.

PRESSURE VS TIME
ALONG CIRCULATING WATER SYSTEM PIPING
WITH NON-WINTER OPERATING CONDITIONS OF
INDIAN POINT UNIT NO. 2 OR NO. 3 (NO PUMP RECIRCULATION)

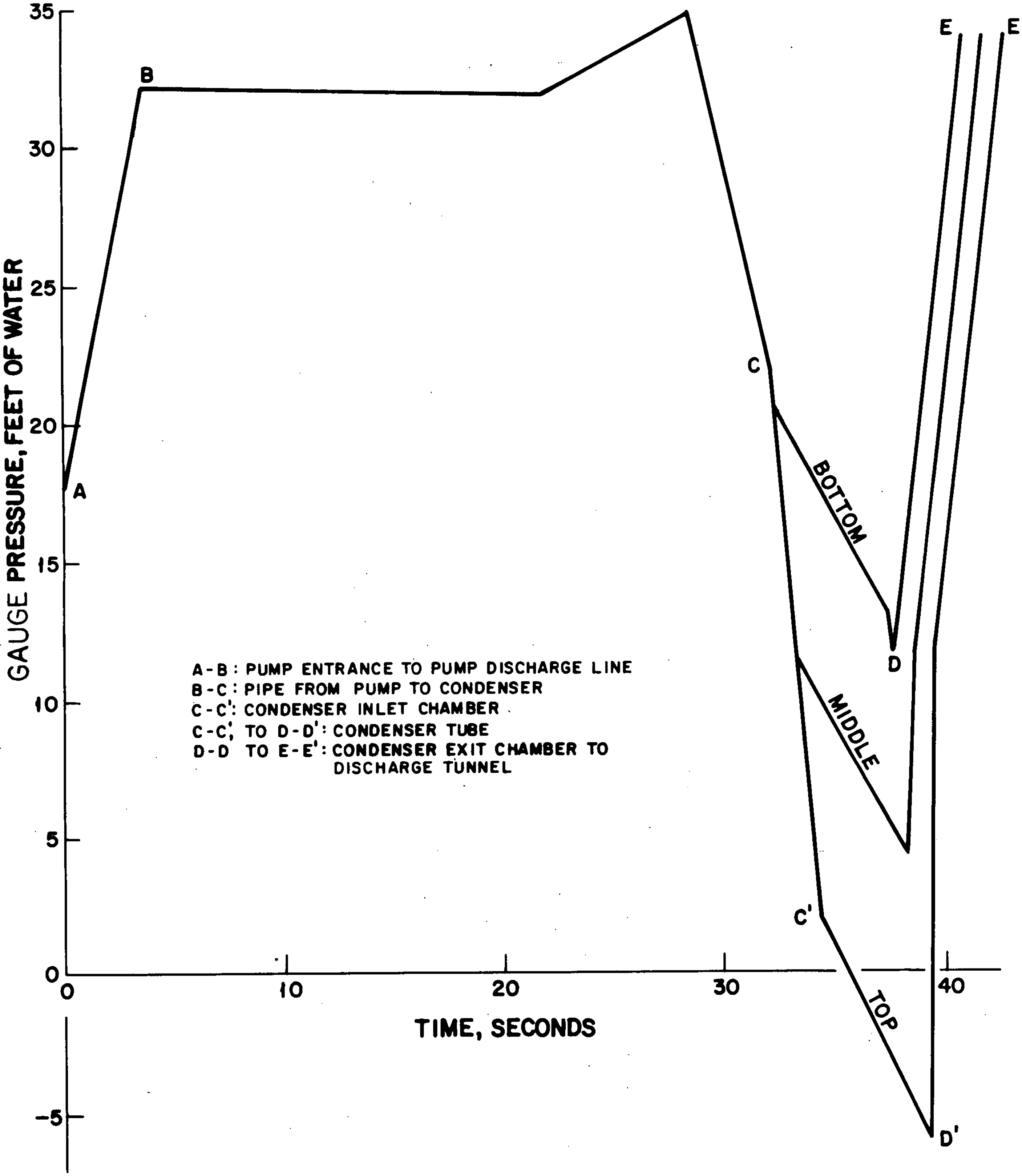
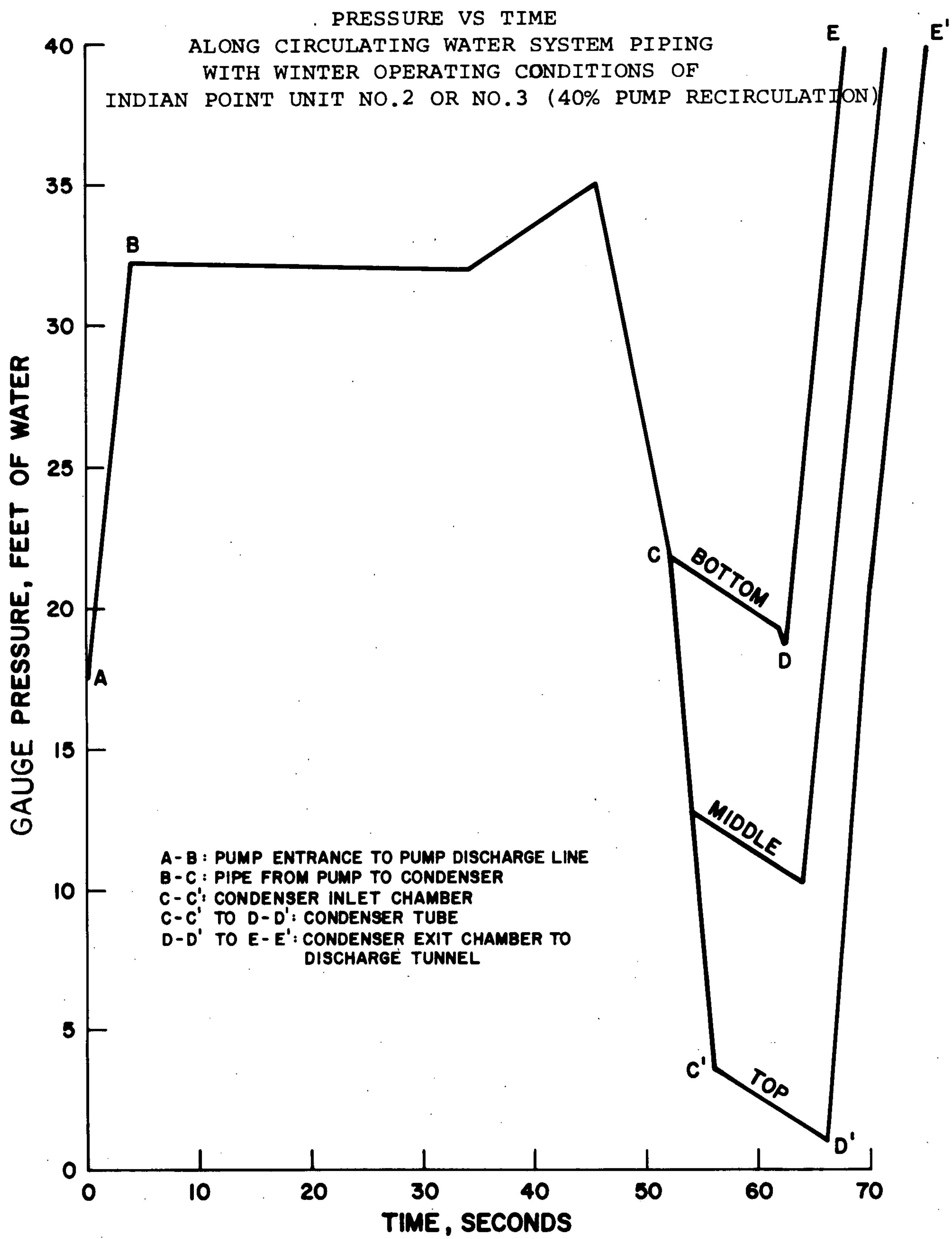


Figure 1-16.


PRESSURE VS TIME
ALONG CIRCULATING WATER SYSTEM PIPING
WITH WINTER OPERATING CONDITIONS OF
INDIAN POINT UNIT NO.2 OR NO.3 (40% PUMP RECIRCULATION)
GAUGE PRESSURE, FEET OF WATER
TIME, SECONDS
0
5
10
15
20
25
30
35
40
50
60
70
A
B
C
D
E
E'
C'
D'
BOTTOM
MIDDLE
TOP
A-B: PUMP ENTRANCE TO PUMP DISCHARGE LINE
B-C: PIPE FROM PUMP TO CONDENSER
C-C': CONDENSER INLET CHAMBER
C-C' TO D-D': CONDENSER TUBE
D-D' TO E-E': CONDENSER EXIT CHAMBER TO DISCHARGE TUNNEL

1.4 Screen Cleaning Processes

1.4.1 Debris Removal From Trash Racks

Floating or submerged debris that accumulates outside the trash racks is removed periodically by divers. This debris is disposed offsite.

1.4.1 Screen Cleaning

1.4.2.1 Fixed Screens

The fixed screens at Unit No. 2 are usually washed daily by a spray mechanism, although during periods when debris loading is high, several washings may be required each day.

Debris that collects on the fixed screens is flushed into the traveling screens which, upon operation, move the various materials to the disposal trough that connects to the trash pit at the north end of the screenhouse. There are no fixed screens at the Unit No. 3 intake.

1.4.2.2 Traveling Screens

The six main traveling screens, as well as the smaller traveling screen for the service water system, are cleaned by rotating the mesh-covered baskets in front of a spray wash nozzle arrangement. Debris is then flushed into the trough which connects to a trash pit as indicated on Figs. 1-4 and 1-7 for Unit Nos. 2 and 3, respectively.

The traveling screens are operated for a short period, usually less than an hour each day, to remove accumulated small debris. During periods when relatively large amounts of leaves, grasses, and other materials are present, the screens are cleaned more frequently, as necessary.

The accumulated debris from the trash pit is disposed offsite. Fish that have been accumulated on the traveling screens are periodically removed from the trough or collection pit for counting and identification in accordance with the ETSR.

1.4.3 Debris Removal From Condenser

Debris that passes through or around the traveling screen system must periodically be removed from the inlet water boxes of each condenser half if the material is not small enough to pass through the tubes.

Water boxes can be cleaned manually when a condenser half is out of service.

1.4.4.1 Chlorination - Frequency and NPDES Limitations

In accordance with the Environmental Technical Specification Requirements for Indian Point Units Nos. 1, 2 and 3, the maximum frequency of chlorination of the circulating water system is three (3) times per week when the intake water temperature is 45F or higher, and the maximum concentration of the total residual chlorine in the cooling water discharge to the Hudson River cannot exceed 0.5 ppm nor average greater than 0.2 ppm during a maximum of two one-hour periods a day. The NPDES permit also states that the total residual chlorine cannot exceed 0.5 ppm. Assuming chlorination would be required from mid-April through early December when the river water is warmer than 45F, and the frequency of chlorination is three times per week, the total number of chlorination periods would be approximately 100 per year. During the last two years, however, the actual chlorination frequency has been much lower than that estimated above. The Indian Point Unit No. 2 cooling water system was chlorinated only 16 times in 1974 and 14 times in 1975. In order to minimize chlorine impacts on aquatic biota, a new chlorination procedure was adopted for the Indian Point Station which requires physical examination of the condenser to determine whether chlorination is necessary or not.

SECTION 2

RIVER PHYSICS AND CHEMISTRY

TABLE OF CONTENTS

2. RIVER PHYSICS AND CHEMISTRY

2.0 SUMMARY

The Hudson River near the Indian Point Station can be characterized as follows: surface widths and cross-sectional areas are approximately 5000 feet and 160,000 square feet, respectively. Depths range from about 10 to 40 feet below mean sea level within 200 feet of the plant. Bottom sediments are composed of extremely fine particles of sand, silt and clay. Mean tidal flows are on the order of 140,000 cfs, while average monthly freshwater flows range from approximately 5,500 cfs in August to 32,000 cfs in April. Dissolved solids range from less than 100 ppm during periods of high freshwater flow to near 10,000 ppm salinity during periods of very low freshwater flow. The salt front is generally below Indian Point during March, April and May when freshwater flows of greater than 20,000 cfs are normally present.

Changes in ambient water temperature generally follow changes in air temperatures and range from 32F to almost 80F. Extensive thermal surveys have shown that the Indian Point thermal plume has a minimal effect on the thermal distribution of the River and is within New York State criteria for cross-sectional area and width.

Results of hydraulic model studies conducted during 1976 indicated that the extent of the zone of withdrawal and the amount of water recirculated were dependent upon tidal behavior in the river, and that recirculatory effects were minimal.

The quality of the river water in the vicinity of the Indian Point Station is generally unstressed with plant discharges having an insignificant effect on river chemical concentrations. Concentrations of residual chlorine have been practically undetectable in the discharge. Under normal and extreme operating conditions, with the large dilution capacity of the Hudson River, chemical discharge concentrations will not exceed established toxicity limits.

2.1. LOCAL HYDROLOGY

2.1.1 Topography

2.1.1.1 River Cross-Sections and Surface Width Each Half Mile, Within Local Zone

In the river segment near Indian Point, from Verplanck north to Peekskill Bay, the surface width of the Hudson River ranges from 3500 to 6300 feet, and the cross-sectional areas based on mean depth are on the order of from 160,000 to 180,000 square feet. The surface width and cross-sectional area at the discharge canal are 5000 feet and 160,000 square feet, respectively. Approximate river cross-sections and surface widths at half-mile intervals at locations within the Indian Point vicinity are as follows:

General Location	River Mile	Width	Cross-Sectional Area
		ft	ft^2
Peekskill Bay	44.0	6300	180,000
Jones Point	43.5	4800	174,000
Indian Point	43.0	4400	175,000
Unit 2 Intake	42.8	4500	165,000
Discharge Canal	42.5	5000	160,000
Ovhd. Cables	42.0	3800	160,000
Verplanck	41.5	3500	165,000

2.1.1.2 Bottom Contours Near Intake and Discharge

River depths in the vicinity of the station range from about 10 feet below mean sea level (MSL) on either side of each intake structure to about 40 feet below MSL within 200 feet of the plant. The river bottom immediately in front of the intakes is slightly more than 27 feet below MSL while depths in front of the discharge canal are near 20 feet. Bottom contours near the intakes, and discharge are shown on Fig. 2-1.

2.1.1.3 Characterization of Bottom Sediments

The substrate characteristic of the river region near Indian Point is composed primarily of extremely fine particles. A Wentworth sediment particle analysis was conducted during October and November of 1973 at Indian Point and on the opposite shore at Jones Point. Results of analyses of samples from 12 locations indicated that sediments in the Jones Point region were characterized by slightly higher percentages of sand than the

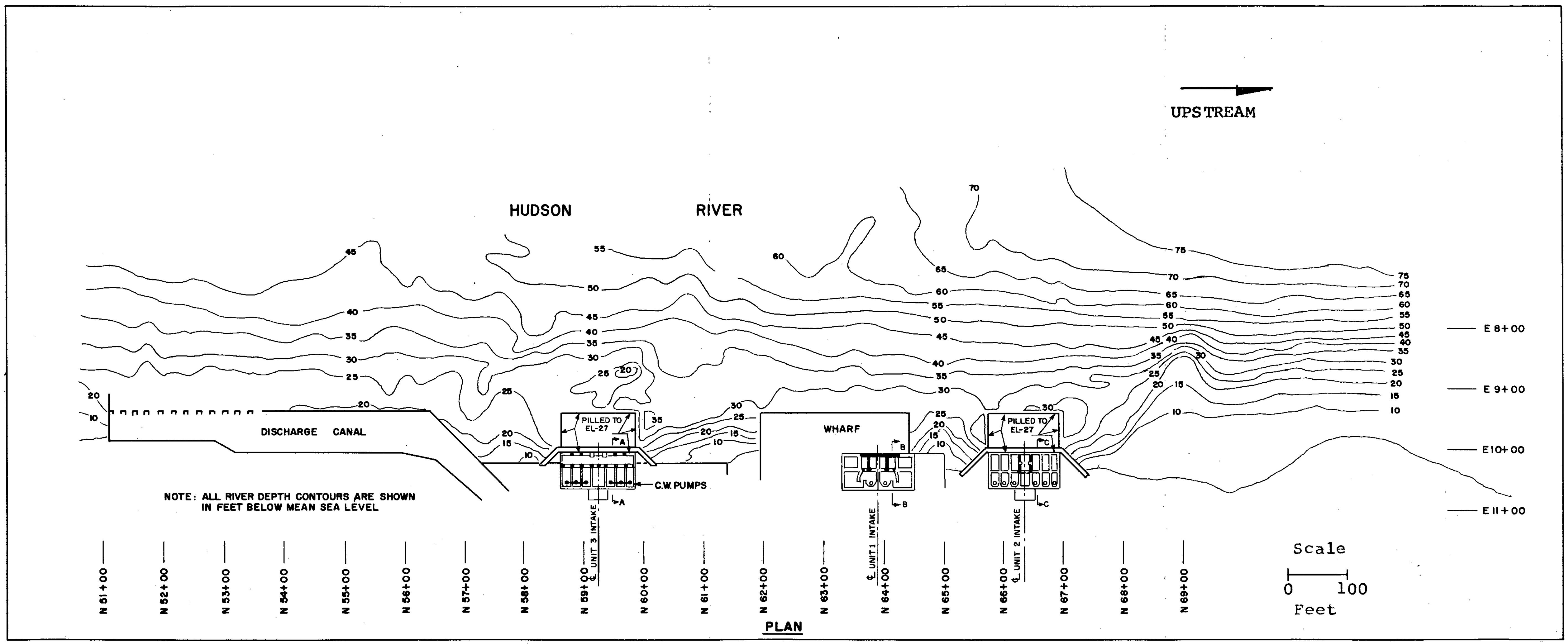


Figure 2-1 BOTTOM CONTOURS NEAR INDIAN POINT INTAKES AND DISCHARGE

Source: Stone & Webster 1976

sediments at Indian Point, but that at both locations particles of very fine sand, silt and clay comprised the majority of the total weight of the samples (TI 1974a).

The fine particle composition of the sediments in this region of the Hudson varies appreciably only in restricted areas which receive occasional deposition of organic detritus due to eddy effects and in those in which high current velocity scours finer particles leaving higher percentages of coarse sands (TI 1973d).

2.1.1.4 Plant Impact

The Indian Point discharge ports are four feet high, extending from 10 to 14 feet below the mean low water level. The river bottom near the discharge ports is about 20 feet deep. The center of the ports is situated at a sufficient distance from the bottom (about eight feet) to minimize any impact on bottom characteristics.

2.1.2 River Hydrodynamics

2.1.2.1 Freshwater Flow

2.1.2.1.1 Long-Term Average

The major portion of the freshwater flow in the Hudson River Estuary enters at its head at Troy, about 150 miles north of the mouth. Because of the inability to directly measure freshwater flow in tidal waters due to masking by the larger tidal flows, the USGS gauging station at Green Island just above Troy is used to establish freshwater discharges into the estuary (LMS 1975a). The freshwater flow near Indian Point may be estimated by multiplying measured flows at Green Island by seasonal flow factors developed from United States Geological Survey (USGS) data. These factors account for the flow from the drainage area between Green Island and Indian Point and average about 1.2 (Con Ed 1972a; Dames & Moore and Con Ed 1976). Long-term monthly mean, minimum and maximum freshwater flows at Green Island for the period 1947 to 1975 are presented in Table 2-1 (TI 1976e). Freshwater flow varies during the year with maximum flows occurring predominately during the spring months and low flows occurring generally in the late summer and early fall. Discharge at Green Island during the high flow month of April averaged 31,519 cfs during the period 1947 to 1975, while discharge during August, the low flow month, averaged 5533 cfs. The minimum average seven consecutive day flow which may be expected once in ten years is approximately 3000 cfs (USNRC 1975a; Con Ed 1977a).

2.1.2.1.2 Recent Data

Monthly average freshwater discharge data at Green Island for the period 1971 through 1975 are presented in various reports (TI 1976e; Con Ed 1977d). The recent data follow the historical trend, with, generally, the highest flows occurring during April and the lowest, during August (Table 2-2).

2.1.2.1.3 Plant Impact

Units Nos. 2 and 3 circulate a maximum of 1,740,000 gallons per minute (3877 cfs) of Hudson River water for condenser cooling (1,680,000 gpm) and other plant operational needs (60,000 gpm). Essentially all of this water is returned to the river. Generally, when freshwater flows of more than 20,000 cfs are

Table 2-1.

Monthly Mean Freshwater Flow(cfs) at Green Is.,N.Y.

1947-1975

Month	Maximum	Minimum	Average
January	33,970	4,187	13,844
February	31,970	6,259	14,062
March	36,280	9,123	20,957
April	51,670	15,630	31,519
May	40,520	9,431	19,229
June	29,630	3,573	10,239
July	18,380	3,131	6,788
August	8,929	2,912	5,533
September	16,980	3,724	6,197
October	10,140	2,967	6,761
November	26,150	3,270	11,001
December	27,010	6,096	14,290

Source: TI 1976e.

Table 2-2.

Monthly Freshwater Flow (cfs) at Green Island, N. Y.

For Years 1971 through 1975

	1971	1972	1973	1974	1975
January	9002	13410	26210	22010	19070
February	12110	10930	20460	18640	19370
March	20220	26860	29410	20730	23680
April	37270	37960	30960	30170	25580
May	35240	40520	27600	22960	20000
June	7334	29630	13050	8791	12970
July	6223	18380	10390	11780	7464
August	8929	7616	5591	6359	8966
September	9315	6309	4791	10390	17030
October	7811	7291	5650	9049	23360
November	7291	26150	8280	17180	22420
December	17000	27010	26420	19380	18647

Source: TI 1976e.

present near Indian Point, salt intrusion is not evident and the river water is completely fresh from top to bottom (one-layered). Under this condition, the water circulated by the plant represents less than 20% of the fresh water flow in the river. However, during periods of salt intrusion a two-layered system generally exists in the river due to density differences between salt and fresh water. Under this condition, estimation of freshwater usage is extremely difficult since the water available for use includes both upper and lower layer net flows, which are mixtures of saltwater and freshwater. Since any freshwater used for cooling is continuously returned to the river, the plant has no impact on the quantity of freshwater flow in the Hudson River.

2.1.2.2 Tidal Flow

2.1.2.2.1 Long-Term Average

The Hudson River is tidal from its mouth at the Battery up to the Federal Dam at Troy. The magnitude of tidal flow at any section is determined by such factors as ocean tide, channel friction, wave reflection and freshwater flow. Mean tidal flow over any period represents the average of mean ebb and mean flood flows. Average tidal flow near Indian Point is approximately 140,000 cfs based on low summer freshwater flows of about 6,000 cfs. Higher freshwater flows into the estuary generally decrease tidal flood velocities and flows and increase ebb velocities and flows in the estuary (LMS 1975a). Maximum tidal flow generally ranges from 200,000 to 300,000 cfs (USNRC 1975a).

Generally, due to density differences between salt and freshwater, a two-layer flow system exists in the Hudson River in the vicinity of Indian Point under conditions of low to medium freshwater discharge (summer, fall and winter months). These layers are not separated by any distinct boundary since vertical mixing occurs between them. (USNRC 1975a). The net flow in the upper layer which is predominantly freshwater is in the downstream direction, while the lower layer, predominantly salt water, has a net upstream flow. For a freshwater flow range between 6,000 and 12,000 cfs, the net upper layer flow at Indian Point has been reported at a relatively constant 35,400 cfs (QLM 1974). During periods of high freshwater flow (spring season), the estuary is characterized by a one-layer flow system with net flow in the downstream direction.

2.1.2.2.2 Recent Data

Tidal currents were measured on August 26, 1974 at a transect located at the Indian Point station as part of the 1974 intensive thermal survey program (Dames & Moore and Con Ed 1974). Current measurements were also taken on September 25, 1974 at a transect located approximately one-half mile south of the station. The measurements are shown on Figs. 2-2 and 2-3 along with predicted values from the National Ocean Survey (US Dept. of Commerce 1975).

The results indicate that the measured tidal currents are generally close to the predicted tidal currents for both tidal times and magnitudes.

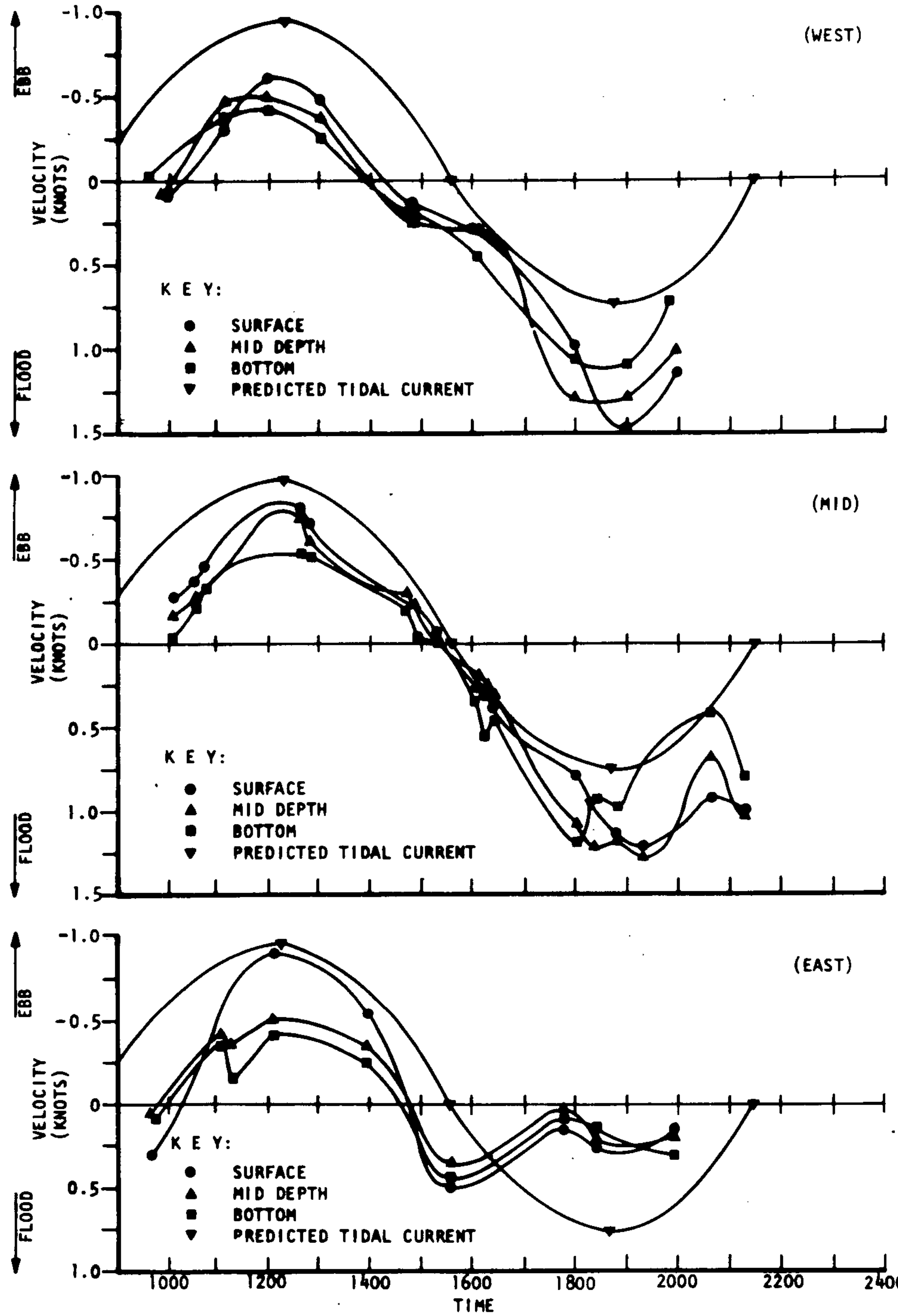


Figure 2-2.

CURRENT VELOCITY VS TIME AT 3 STATIONS AUGUST 26, 1974

Source: Dames & Moore and Con Edison 1976.

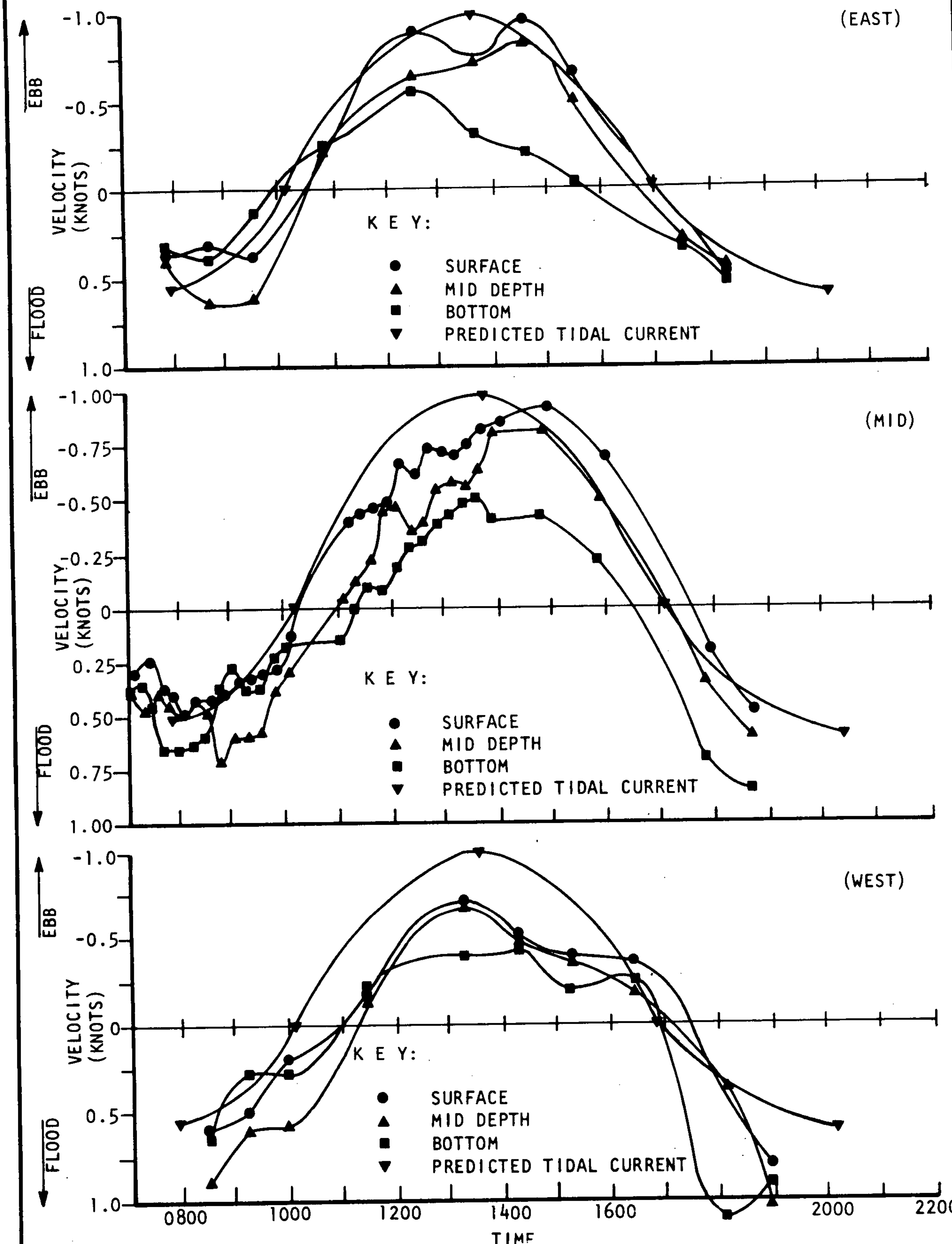


Figure 2-3. **CURRENT VELOCITY VS TIME SEPTEMBER 26, 1974**

Source: Dames & Moore and Con Edison 1976.

Generally, the ebb and flow currents at the surface were higher than those at the bottom. Channel (mid-transect) surface velocities at maximum ebb were approximately 1.4 and 1.6 feet per second for the August and September dates, respectively. These velocities correspond to maximum tidal flows of 230,000 and 257,000 cfs for a cross-sectional area of 160,000 square feet. These values lie within the reported range for maximum tidal flows.

2.1.2.2.3 Plant Impact

Units Nos. 2 and 3 generally circulate approximately 2.8% of the average tidal flow of the Hudson River (tidal flow 140,000 cfs under low freshwater flow conditions) for cooling, a usage which has essentially no impact on tidal flow in the river.

2.1.3 Estuary Characteristics

2.1.3.1 Salinity Intrusion

2.1.3.1.1 Long-Term Average

At Indian Point, the lighter freshwater which is flowing downstream in the upper layer of the River mixes downward, while the heavier ocean-derived salt water flowing upstream beneath mixes upward. This mixing, which results from turbulent eddies produced by tidal motion, is incomplete and results in a vertical salinity gradient which increases from top to bottom (Fig. 2-4). The salinity in the upper and lower layers decreases steadily from the ocean entrance to the head of the estuary (LMS 1975a). In addition, salinity varies with tidal phase in a sinusoidal fashion, increasing with incoming tide and generally reaching a

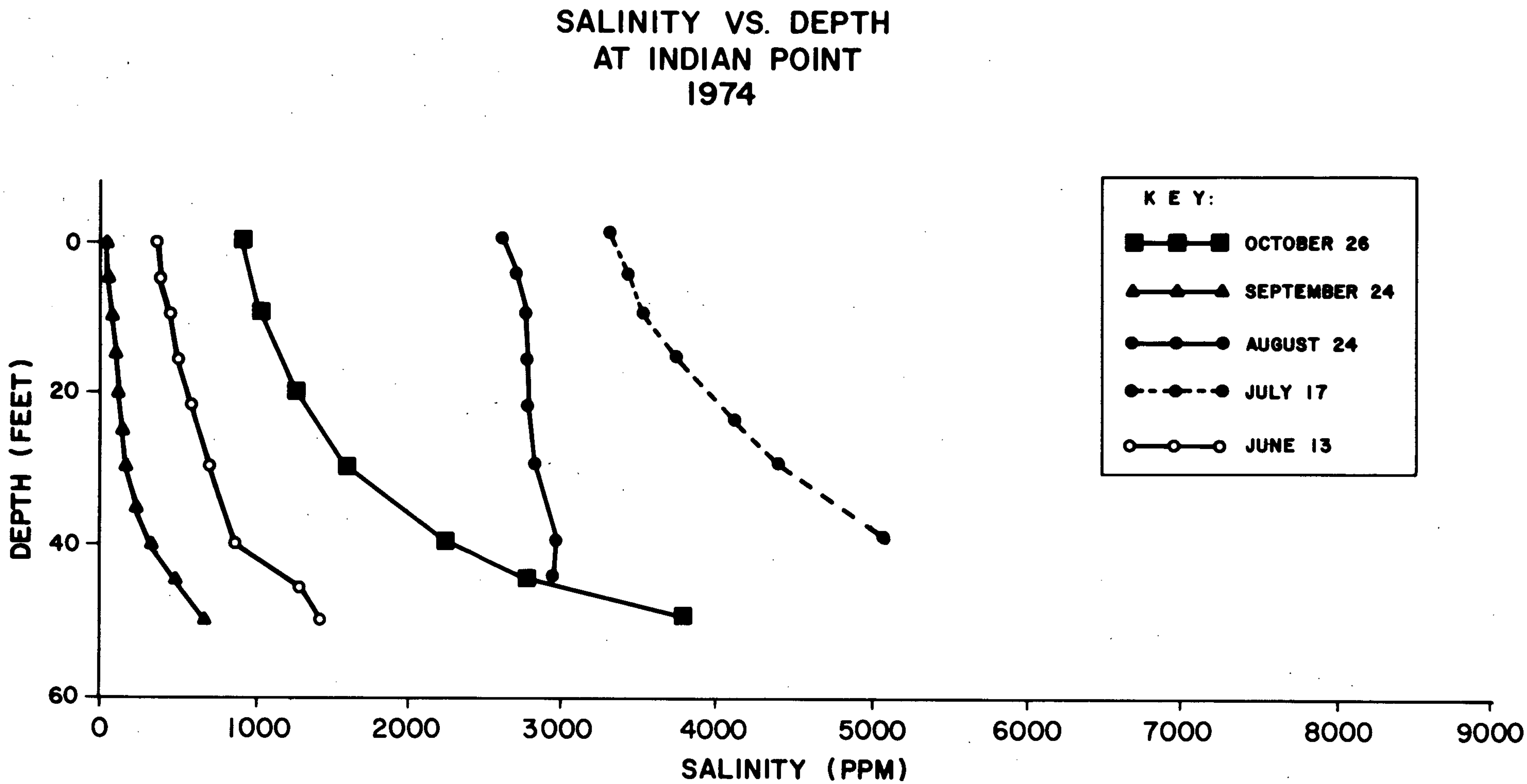


Figure 2-4.
Source: Dames & Moore and Con Edison 1976.

maximum at High Water Slack. Concentrations decrease during ebb tide to minimum levels at Low Water Slack (Dames & Moore and Con Ed 1976). Generalized mean salinity profiles have been presented for freshwater flow ranges observed at Indian Point in various reports (QLM 1974; LMS 1975a). Dissolved solids at Indian Point are generally less than 100 ppm (defined here as the salt front concentration) for freshwater flows greater than 20,000 cfs. For extremely low freshwater flows in the range of 2,000 to 3,000 cfs, mean salinities are generally near 10,000 ppm (LMS 1975a).

2.1.3.1.2 Recent Data

The location of the salt front above the Battery during each year for the period 1971 through 1974 is shown in Fig. 2-5 (TI 1976e). This figure shows that the salt front is generally below Indian Point (milepoint 43) during the high freshwater flow months of March, April and May, and above Indian Point during the low freshwater flow months in late summer and early fall.

2.1.3.1.3 Plant Impact

Since the amount of water used in Units Nos. 2 and 3 is small compared to the tidal flow and since essentially all of the water is continuously returned to the River, the plants do not exert any influence on the location of the salt front.

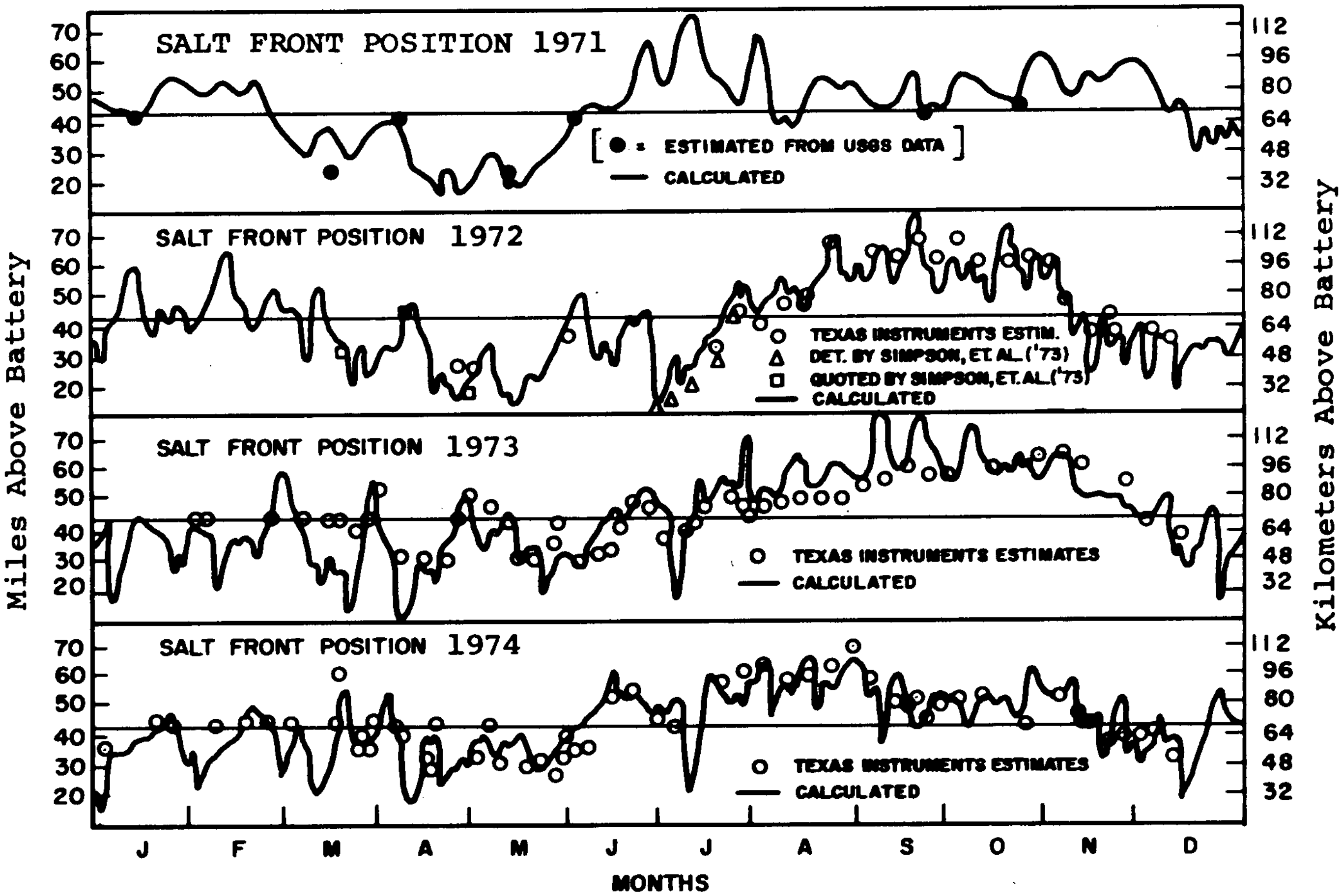


Figure 2-5. Location of Salt Front Above the Battery for Years 1971-1974

Source: TI 1976e.

2.1.3.2 Stratification

2.1.3.2.1 Long-Term Average

The degree of mixing of saltwater and freshwater in an estuary may be represented by a vertical stratification factor (VSF) which is the ratio of the tidal flow to the freshwater flow. When the VSF of an estuary is less than 10, between 20 and 200, or over 2,000, the estuary is classified as highly stratified, partially stratified, or well mixed, respectively (QLM 1971). Under normal conditions, the salt-intruded reach of the lower Hudson River has a VSF of greater than 10 and may be considered as a partially stratified estuary. The VSF of the Hudson River near Indian Point varies seasonally and is approximately 10 during fall and winter and 23 during the summer months. Generally, during the spring, mixing of salt and fresh water is not evident since the salt front is below Indian Point (LMS 1975a).

2.1.3.2.2 Recent Data

The magnitudes of freshwater and tidal flows observed during the last few years (1971-1975) indicate that the degree of stratification is similar to that observed over the long term.

2.1.3.2.3 Plant Impact

With the exception of some very local mixing near the intakes and discharge which may reduce the degree of stratification near these structures, there is no evidence of plant impact on stratification in the river.

2.1.3.3 River Temperature

2.1.3.3.1 Long-Term Average

Seasonal changes in ambient water temperature at Indian Point reflect changes in air temperature and range from freezing during late December to late February, to water temperatures of almost 80F during August, the month in which the river water characteristically reaches its highest ambient temperature. Monthly mean, minimum and maximum water temperatures measured by the USGS during the period 1959 through 1969 are given in Table 2-3 (Con Ed 1972b). These USGS measurements are not generally indicative of ambient temperatures at the Indian Point station since they were taken in the shallow waters of Lents Cove (1959-1966) and near the west bank of the river (1966-1969) at Jones Point, regions in which temperatures may be influenced significantly by solar heating and reduced mixing. Furthermore, in collecting their data, the USGS was not specifically preparing for thermal surveys. This is reflected in the accuracy of their measurements. USGS data were measured to the nearest degree F with a thermometer (1959-1966) or, after 1966, with a thermister (Con Ed 1972b).

2.1.3.3.2 Recent Data

Data collected during the period from 1970 through 1974 indicate that changes in water temperatures generally reflect changes in air temperatures with minor differences occurring only during periods of high freshwater flow. Under high flow conditions, upstream water from above Green Island, which is normally cooler

Table 2-3.

Hudson River Water Temperature (°F) in the Vicinity of I.P.

(U.S.G.S. 1959-1969)

Month	Maximum	Minimum	Average
January	42.0	32.0	34.0
February	38.0	32.0	33.2
March	43.0	32.0	35.0
April	57.0	37.0	44.6
May	67.0	48.0	57.3
June	78.0	60.0	68.2
July	81.0	71.0	75.9
August	81.0	73.0	76.9
September	80.0	64.0	73.0
October	73.0	57.0	64.2
November	61.0	43.0	52.9
December	51.0	32.0	40.8

Source: Con Edison 1972b.

than downstream water since it is derived from the cooler and more turbulent freshwater reaches of the Hudson River, may lower the temperature of the downstream water slightly. This effect has been observed in the spring and early summer (TI 1976e). Determinations of the ambient temperature outside the influence of the thermal plume have been made through analysis of extensive data collected during eleven routine and intensive thermal surveys by Consolidated Edison in 1974, 1975, and 1976. These data indicate that the maximum area average ambient temperature based on measurements outside of the thermal plume did not exceed 79.4F during any tidal phase. On a tidal average basis, the maximum area average ambient temperature did not exceed 78.9F (Dames & Moore and Con Ed 1974-76; 1976; Con Ed 1977b).

2.1.3.3.3 Plant Effects - Near and Far Field

The effect of the Indian Point thermal plume on the near and far field environs of the Hudson River is minimal as indicated by the extensive data collected during the routine and intensive thermal surveys. As part of the thermal survey program, the October 1976 survey was the first to be conducted with both Units Nos. 2 and 3 in operation (Con Ed 1977b). Results from this survey and all ten previous surveys have shown that, under the existing hydrological and meteorological conditions, the Indian Point thermal discharge did not contravene State thermal criteria for cross-sectional area and surface width. (See Table 2-4). In addition, with the exception noted below, the 90F surface criterion has not been contravened. During the four day August

Table 2-4.

Indian Point Thermal Survey Summary

Survey Series (Date)	MWe[4]	Max. Tidal Phase[1] Excess Temp. °F	% river width[2] (Tidal Phase)	% cross-sectional[3] area (Tidal Phase)	Tidal Average Excess Temp. °F	% river[2] width	% cross-sectional area[3]
1. (5/31/74)	1075	3.2	46 (LWS)	19 (LWS)	3.4	27	8
2. (6/13/74)	975	3.9	36 (LWS)	16 (LWS)	3.6	28	12
3. (7/17/74)	810	3.8	40 (EBB)	15 (Flood)	3.2	28	12
5. (8/20-24/74)[5]	1140	3.8	33 (HWS)	14 (HWS)	3.7	24	11
6. (9/24/74)	1135	4.0	35 (LWS)	20 (LWS)	3.5	26	16
7. (10/22-25/74)[6]	1160	3.9	53 (LWS)	18 (LWS)	3.6	30	13
8. (11/20/74)	700	4.0	49 (LWS)	18 (LWS)	3.4	30	11
9. (4/23/75)	900	4.0	18 (HWS)	6 (Flood)	3.8	14	4.3
10. (5/13-15/75)[7]	900	4.0	16 (LWS)	5 (LWS)	3.4	11	4
11. (10/13-15/76)[8]	1400-1800	4.0	49.4 (LWS)	10.2 (LWS)	4.0	28	8

Notes:
(1) "Max. Tidal Phase" is designated as the tidal phase at which the most severe thermal impact occured.
(2) Percent of the river surface width bounded by the isotherm representing the excess temperature.
(3) Percent of the river cross-sectional area bounded by the isotherm representing the excess temperature.
(4) Total MWe from Units 1 and 2. IP1 not operating since 11/74.
(5) Data taken on 8/23/74
(6) Data taken on 10/23/74
(7) Data taken on 5/13/75
(8) First thermal survey for Units 2 and 3 combined. Data taken on 10/13/76.

Source: Consolidated Edison 1977a.

1974 intensive survey, surface temperatures in excess of 90F were recorded on four different occassions in the immediate area of the outfall structure. The surface temperature recorded ranged from 90.2 to 91.6F, with an average of 90.6F. The areas in excess of the 90F isotherm were less than 3/4 of an acre, with an average area of about 1/3 of an acre (Con Ed 1977a).

A detailed discussion of the survey program and results is contained in the routine monthly thermal monitoring reports (Dames & Moore and Con Ed 1974-76) and in the intensive thermal survey reports (Dames & Moore and Con Ed 1976; Con Ed 1977b).

2.1.4 Zone of Withdrawal

2.1.4.1 Introduction/Decription

Cooling water from the Hudson River is drawn in through two sets of intakes during operation of Indian Point Units Nos. 2 and 3. The river region containing water susceptible to plant intake may be called the zone of withdrawal. The extent of this zone is a function of the pumping rate, tidal phase (current speed, direction, and tidal elevation), and the presence and strength eddies near the plant.

2.1.4.2 Methods or Types of Studies Used

2.1.4.2.1 Physical Studies

LaSalle Hydraulic Laboratory conducted a study during 1976 of the withdrawal and discharge of water at the Indian Point station utilizing a physical hydraulic model (LaSalle 1976). The objectives of the study were (1) to identify the zones supplying water to the intake and receiving water from the discharge, (2) to determine the predominant flow directions and velocity patterns within these zones during plant operation and (3) to describe in general the physical flow characteristics in the river with and without the plant operating.

2.1.4.2.2 Results

The results of the hydraulic model study indicated that, during flood tide the plant effluent created a substantial eddy in front of the intakes. Water flowing upstream circulated around this eddy and bypassed the intakes. Some of this water was then drawn back downstream towards the plant. The water which originally circulated around the eddy came into the downstream end of the eddy from a zone about 300 to 350 feet wide along the east shore (Fig. 2-6).

During ebb tide, water drawn into the intakes came from a narrow (200-250 foot wide) zone of water flowing downstream along the east shore (Fig. 2-7). At slack tide, cooling water drawn into the intakes came from the local area just in front of the plants, or from the upstream direction when the effluent discharge restricted the supply of downstream water (Fig. 2-8). Detailed

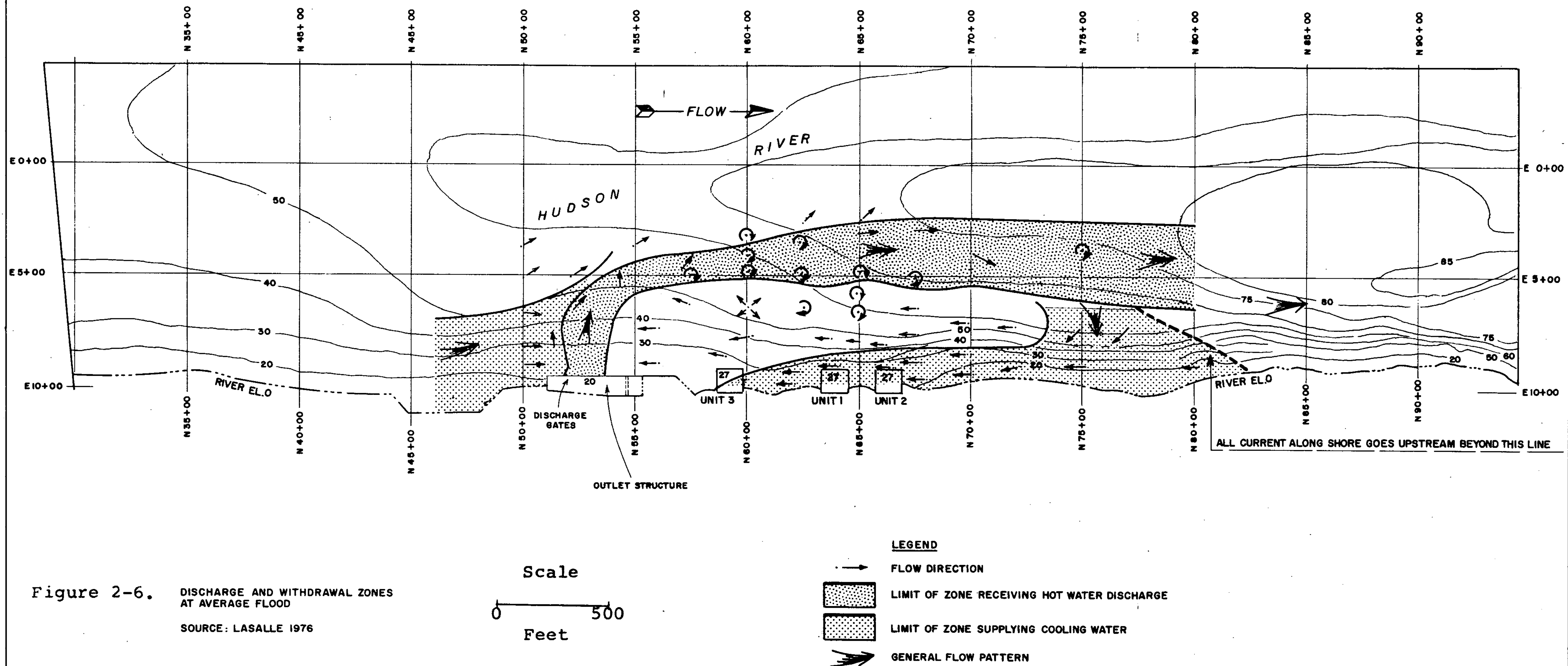


Figure 2-6. DISCHARGE AND WITHDRAWAL ZONES AT AVERAGE FLOOD

SOURCE: LASALLE 1976

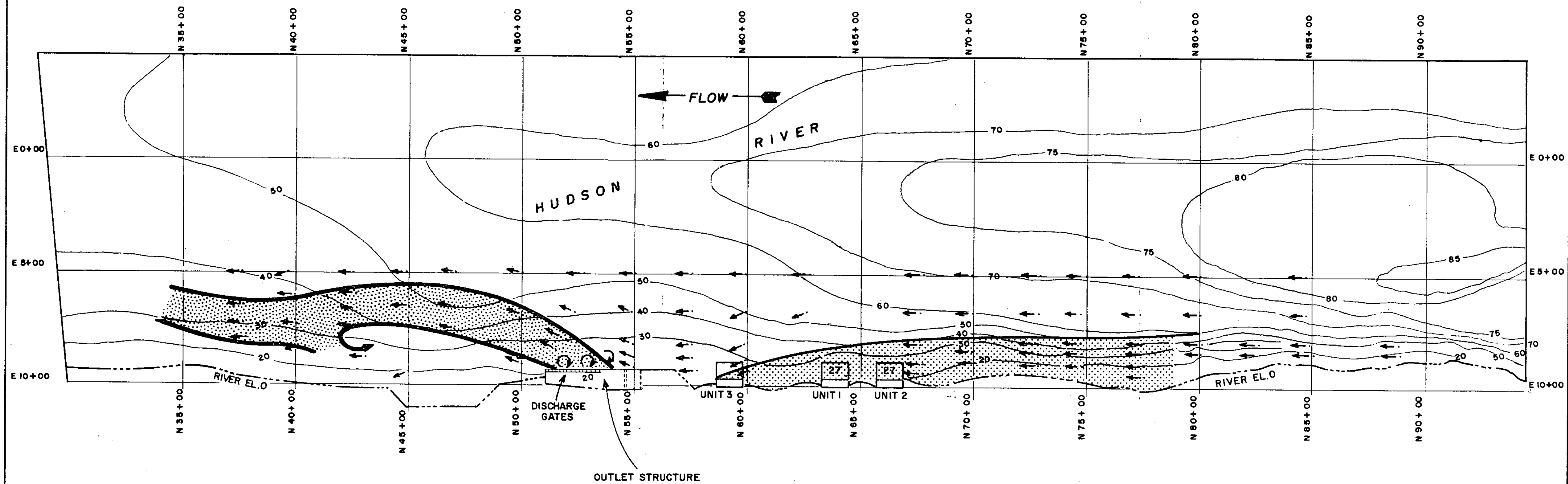


FIGURE 2-7. DISCHARGE AND WITHDRAWAL ZONES AT AVERAGE EBB

SOURCE: LASALLE 1976

SCALE

0 500

FEET

LEGEND

FLOW DIRECTION

LIMIT OF ZONE RECEIVING HOT WATER DISCHARGE

LIMIT OF ZONE SUPPLYING COOLING WATER

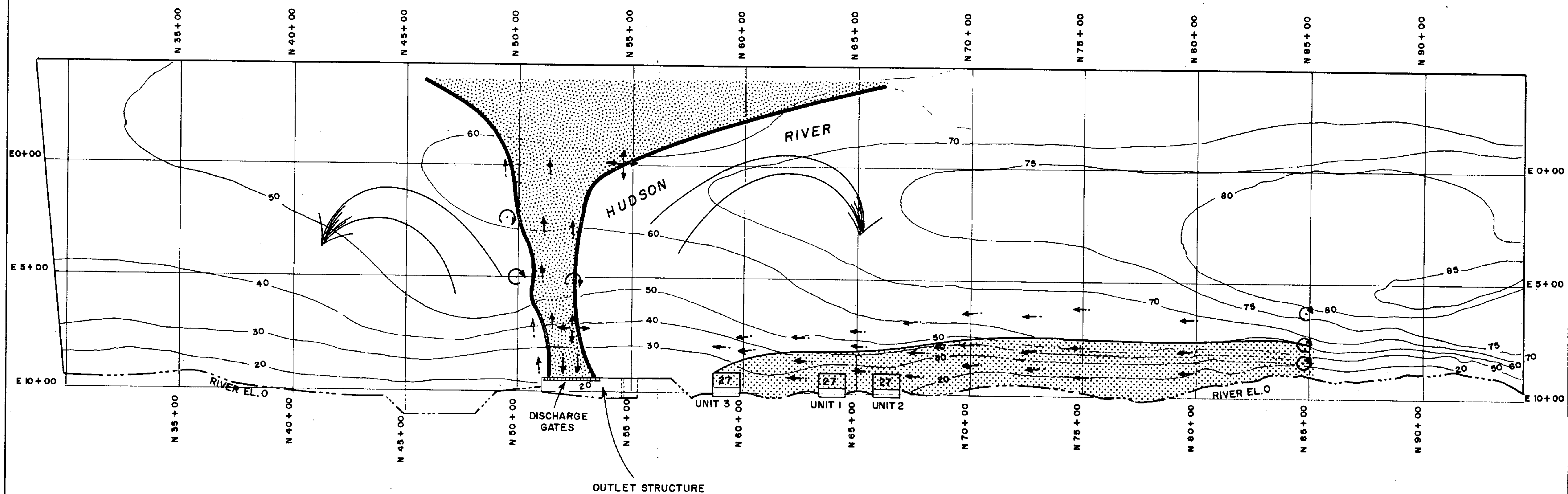


FIGURE 2-8. DISCHARGE AND WITHDRAWAL ZONES AT SLACK

SOURCE: LASALLE 1976

SCALE 0 FEET 500

LEGEND

- FLOW DIRECTION
- LIMIT OF ZONE RECEIVING HOT WATER DISCHARGE
- LIMIT OF ZONE SUPPLYING COOLING WATER
- GENERAL FLOW PATTERN

descriptions, analyses and results are presented in the hydraulic model study (LaSalle 1976).

2.1.4.3 Recirculation

2.1.4.3.2 Introduction/Description

Discharge of water from the Indian Point Station occurs downstream of the intakes. Depending upon tidal phase and local circulation patterns, some of this water may be carried back upstream and into the zone of withdrawal, ultimately reaching the plant intakes. This effect, known as recirculation, has been studied at Indian Point.

2.1.4.3.2 Methods or Types of Studies Used

Recirculatory effects were examined using the hydraulic model discussed prevously (LaSalle 1976).

2.1.4.3.3 Results

Calculations of recirculation using a simulated mean tide indicated that about 8% of the effluent water would make its way back into the cooling water intakes over a complete tidal cycle.

2.2 WATER QUALITY

2.2.1 River Water Quality

2.2.1.1 Methods and Materials

Dissolved oxygen, conductivity, pH and temperature have generally been measured at the Indian Point intakes on a daily basis since 1973. Methods and materials used to obtain these and other measurements are described in Standard Operating Procedures (TI 1976f) and in various appendices of reports cited throughout Section 2.2. Measurements of chlorine concentrations in the discharge canal have followed the standard procedures outlined in Standard Methods for the Examination of Water and Wastewaters, A.S.T.M. Standards or Methods for Chemical Analysis of Water and Waste. Analyses of chemical discharges for various constituents have also been in accordance with these standard procedures.

2.2.1.2 Water Quality Data

The water quality of the Hudson River is dependent upon the interaction of a number of factors including geomorphology and hydrology, hydrodynamics, meteorology and man made inputs. The region near Indian Point, being located away from the major population areas of New York and Albany, does not exhibit the stressed condition characteristic of these metropolitan areas. At Indian Point, the water quality tends to be generally unstressed. Dissolved solids are primarily derived from the geologic formations of the region and variations in the concentrations of dissolved solids are dependent upon the position of the salt front. The region has been classified SB by the NYSDEC, that is, for primary and secondary contact recreation and other uses except for the taking of shellfish for market purpose. Minimum, maximum and average values, including seasonal trends for various water quality parameters measured near Indian Point are presented in Table 2-5.

During the period 1970 through 1974 concentrations of dissolved solids including potassium, calcium, magnesium, sodium, sulfates and chlorides were generally lowest during the high freshwater flow months while the highest values were observed during periods

TABLE 2-5

WATER QUALITY OF THE HUDSON RIVER NEAR INDIAN POINT [1]

OCTOBER 1970 TO SEPTEMBER 1974

Concentrations in mg/l Unless Otherwise Noted

CHEMICAL PARAMETERS	MIN.-MAX.	MEAN	SEASONAL TREND: LOW AND HIGH QUARTER [2]											
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Potassium (K)	0.9 - 48	10.5			1.4	1.6	1.6				31	28	23	
Calcium (Ca)	5.5 - 75	31				23	21	21		37	50	49		
Magnesium (Mg)	2.8 - 150	30			4.5	5.0	5.4				85	91	68	
Sodium (Na)	4.2 - 1300	251			10	14	20				764	708	580	
Silica (SiO_2)	0.4 - 6.0	3.3		4.8	5.1	4.6					1.6	1.5	1.7	
Sulfate (SO_4)	16 - 300	86			23	24	20				178	181	170	
Chloride (Cl)	6 - 2300	500			17	23	32			1058	1222	1285		
Fluoride (F) [3]	0 - 0.5	.16				.10	.07	.10			.27	.28	.28	
Iron (Fe) in µg/l	10 - 3600	-				Data not conclusive								
Manganese (Mn) in µg/l	0 - 370	58	18	0	30				72	152	85			
Bicarbonate (HCO_3)	42 - 84	65					55	52	61		76	73	74	
Alkalinity as $CaCO_3$	34 - 69	53					45	43	50		63	60	64	
Hardness	61 - 770	203			75	79	73				473	499	366	
Total Dissolved Solids	79 - 4180	894			118	129	139				2537	2380	1938	
COD	7 - 28	16				Trend not evident								
Total Phosphate as P	.01 - .33	.14	.12	.06	.14					.19	.17	.16		
Organic Nitrogen	.07 - 3.2	.49					1.1	.60	.46		.38	.36	.38	
Total Nitrogen	0.9 - 4.1	1.4				Data insufficient								
Nitrate Nitrogen	.56 - 1.0	.72		.79	.87	.82		.63	.61	.69				
Dissolved Oxygen [4]	6.1- 13.8	-		13.8	13.5	13.3		6.9	6.4	6.5				
BOD - 5 Day [5]	1.4 - 4.6	2.7				Data insufficient.								
PHYSICAL PARAMETERS														
Temperature in °F [6]	32 - 79	55	38	33	38				74.5	78.0	73.5			
pH	6.8 - 7.8	7.3					Trend not evident							
Color (Pt-Co Units)	1 - 24	13							3	1	4	24	18	19
Sp. Conductance (µmhos/cm)	148 - 7860	1775			208	234	365				4155	4261	3580	

1 Data collected by U.S. Geological Survey at Verplanck, N.Y. unless otherwise noted.

2 Monthly average values for the quarters during which the parameter averaged lowest and highest.

3 Parameters listed up to and including Fluoride were measured as dissolved.

4 From Texas Instruments studies at Unit 1 Intake (1973-1975). Min.-Max. (Month).

5 From IBM Intake.

6 From LMS 1975a Figure IX-5 : values are long-term averages at I.P. (1949-1972).

Source: U.S. Dept. of Interior Geological Survey of low freshwater flow. Hardness and alkalinity followed this trend and averaged 203 and 53 mg/l as $CaCO_3$, respectively over the period 1970-74. Nitrate and phosphate concentrations reflected, for the most part, inputs of organic material to the Hudson. Nitrate nitrogen and total phosphate as P ranged from .56 to 1.0 mg/l and from .01 to .33 mg/l, respectively. A seasonal trend in pH was not evident; values ranged from 6.8 to 7.8. Dissolved oxygen concentrations were generally influenced by water temperature effects on solubility and biological activity, averaging 6.6 mg/l during the period June through August and 13.5 mg/l from February through April.

2.2.2 Plant Impact

2.2.2.1 Chemical Usage in the Plant

2.2.2.1.1 Circulating Water System

Sodium hypochlorite is used in the condenser cooling system to control biological fouling. Generally, during the past two years, chlorinations were necessary only during the months of July and August. Both the frequency of chlorination and the use of chlorine at Indian Point have been significantly reduced in the last few years (Con Ed 1975). In addition, the residual chlorine in the effluent has been determined to be practically undetectable, i.e. 0.05 ppm since the accuracy of a residual chlorine analysis is 0.05 ppm (Con Ed 1977a). The very low residual chlorine levels, coupled with the infrequency of chlorination, leads to the conclusion that chlorination does not cause any significant adverse environmental impact. Numerous discussions on chlorine are contained in various reports. (Con Ed 1971; 1972c; 1973; 1975; USAEC 1972; USNRC 1975a; TI 1973f; 1974c; LMS 1975a; NYU 1976b).

2.2.2.1.2 Dissolved Oxygen

Analytical studies and field surveys conducted during the last five years have indicated that operation of the Indian Point station results in no discernible difference between dissolved oxygen levels measured at the intake and those measured at the discharge (Lawler 1972; 1973; Con Ed 1977c). Furthermore, during Consolidated Edison's thermal and dissolved oxygen surveys slightly higher levels of dissolved oxygen were found in the immediate vicinity of the discharge canal, suggesting that the turbulence created by the effluent aerated the water slightly in the area near the discharge (Con Ed 1977a).

2.2.2.1.3 Chemical Discharges

In addition to sodium hypochlorite which is used in the circulating water system, normal operation of Indian Point necessitates the use of chemicals in the primary (reactor core coolant) and secondary (chemical and volume control) systems of the plant. Consequently, releases of certain chemicals to the Hudson River from plant operations occur. The most common chemicals used are:

(1) Phosphates (trisodium and disodium), used in combination with sodium hydroxide in the treatment of plant service boilers;

(2) Hydrazine, used in the secondary system to control oxygen in the steam generators;

(3) Cyclohexylamine or morpholine, used in the secondary system to adjust feedwater and steam pH;

(4) Lithium hydroxide, used in the primary system for pH control;

(5) Boric acid, used in the primary system to control the neutron reactivity;

(6) Potassium chromate, used in the core coolant water system as a corrosion inhibitor;

(7) Sodium hydroxide, used in the primary system demineralizers;

(8) Detergent, used in the plant laundry; and

(9) Sulfuric acid which is used as a chemical regenerant in the water treatment process.

2.2.2.2 Determination of Chemical Concentration Discharged into the Hudson

2.2.2.2.1 Chemical Discharge Concentrations

Chemical discharge concentrations are regulated by the NPDES permits (USEPA 1975), 401 Certifications (NYSDEC 1975) and USNRC ETSR (USNRC 1975b) for the Indian Point Station. These documents specify the limits of the various chemical discharges and require a monitoring program to assure that chemical discharges do not exceed the established limits.

Water from the once-through condenser system or service water system is used to dilute any discharged chemicals. During normal plant operation, dilution of effluent results in chemical concentrations which are insignificant. Even when less water is used during shutdowns or outages dilution factors are high. Discharges are diluted further due to tidal dispersion in the river (Con Ed 1973). The results of the 1975 chemical monitoring program, which were submitted to the USNRC in March, 1976, indicate clearly that the actual chemical discharge concentrations are much less than the maximum permitted levels specified by the ETSR. Similar findings are reported for the first six months of 1976. Maximum concentration levels given in the ETSR and monthly monitoring data for the year 1975 are presented in Tables 2-6 and 2-7, respectively (USNRC 1975b; Con Ed 1976). Discharge concentrations for chemicals used at Indian Point have been presented and discussed in numerous reports (USAEC 1972; USNRC 1975a; Con Ed 1971; 1972c; 1973; 1975; and TI 1973f; 1974c).

2.2.2.3 <u>Comparison of Toxicity Limits With Established Discharge Concentrations</u>

The results of extensive bioassay studies conducted by Gift, Renwoldt, Lauer, Cristin, and Lamont-Doherty are presented in Con Edison 1973. Toxicity limits were determined under normal and extreme conditions for fish species including Atlantic Silverside, mummichog, American eel, carp, killifish, pumpkinseed, white perch and striped bass and for various phytoplankters. Numerous chemicals were tested including those used during the normal operation of the Indian Point Station. These studies indicated that actual discharge concentrations under normal operating conditions are significantly below the median tolerance limits (TLm's) for the species tested (Tables 2-8, 2-9, and 2-10). The significant amounts of tidal water

Table 2-6.

LIQUID EFFLUENT MONITORING SURVEY PER ENVIRONMENTAL

TECHNICAL SPECIFICATION REQUIREMENTS

Parameter Analyzed for	Max. Conc. (ppm)	Collection and Analyses Frequency *
Phosphate (Orthophosphate)	1.5	WK
Hydrazine	0.1	WK
Cyclohexylamine	0.1	WK
pH - (units)	6.0 - 9.0	DD
Lithium Hydroxide	0.01	D
Boron	1.0	D
Chromium (total)	0.05	WK
Residual Chlorine (free and combined)	0.5	D
Chlorine Demand	(Not Applicable)	WK
Sodium Hydroxide	(Not Applicable)	DD
Specified Conductance (Salinity)	(Not Applicable)	WK
Soda Ash	(Not Applicable)	D
Sulfuric Acid	(Not Applicable)	DD
Turbidity (Suspended Solids)	(Not Applicable)	WK
Dissolved Oxygen	(Not Applicable)	WK
Detergent	1.0	MO
Drewgard 100	2.5	MO

* WK (weekly), MO (monthly), D (during discharge), DD (continuously during discharge of regenerant wastes from neutralization facility).

Source: Con Edison 1977a.

Table 2-7.

EFFLUENT MONITORING DATA

1975 (1)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pH	7.2-7.8	7.3-7.8	7.1-7.8	7.3-7.8	7.4-7.7	7.6-7.7	7.4-8.1	7.6-7.7	7.5-7.9	7.4-7.9	7.6-7.8	7.4-7.9
Phosphate mg/l	<0.1-0.2	<0.1	<0.1	<.1-0.6	<0.1-0.2	<0.1	<.1-0.2	<.1	<.1	<.1-.2	<.1	<.1
Hydrazine, mg/l	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Cyclohexylamine mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron, mg/l	≤0.2	≤0.2	≤0.2	≤0.2	≤0.2	≤.2	≤.2-.9	≤.2-.3	≤.2	≤.2-.3	≤.2	≤.2-.6
Chromium, mg/l	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003	<.003
Detergent, mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Free Residual Chlorine, ppm	— (2)	(2)	(2)	(2)	<.05-.27	<.05-.16	<.05	<.05	<.05	(2)	(2)	(2)
Total Residual Chlorine, ppm	— (2)	(2)	(2)	(2)	<.05-.49	<.05-.18	<.06	<.05	<.05	(2)	(2)	(2)
Dissolved Oxygen, mg/l	9.8-15.0	14.8-15.0	13.8-14.8	12.8-14.4	9.4-11.8	7.1-8.7	6.2-7.6	6.3-7.7	5.7-7.9	6.6-10.3	9.5-13.0	12.-15

(1) Data taken from "Annual Environmental Operating Report - 1975," submitted to NRC on 3/30/76.

(2) No Chlorination

Source: Consolidated Edison 1977a.

Table 2-8.

The 96 hour and 48 hour median tolerance limits (TLm's) determined for *Fundulus heteroclitus* and *Menidia menidia* exposed to the various chemical combinations and estimated "safe" concentrations based on a 1/10 safety factor applied to the TLm determinations for *Menidia menidia*.

(Gift, 1971)

Normal Operating Chemicals - 96 hour TLm

1. Boiler Blowdown

Chemical	Mummichog *Fundulus heteroclitus* 96 hr TLm ppm	Atlantic Silverside *Menidia menidia* 96 hr TLm ppm	Estimated "safe" Concentration ppm
PO_4	28.32	9.62	0.96
Cl	140.60	48.12	4.81
SiO_2	0.40	0.14	0.01
SO_4	28.32	9.62	0.96
Hydrazine	2.36	0.80	0.08
Cyclohexylamine	2.36	0.80	0.08

2. Ion Exchange Regeneration Wastes

No toxicity related deaths for *Fundulus heteroclitus* or *Menidia menidia* at 3.77 times mixture concentrations.

3. Chlorination - Using NaOCl

Chemical	*Fundulus heteroclitus* 96 hr TLm ppm	*Menidia menidia* 24 hr Tlm ppm	Estimated "safe" Concentration ppm
Chlorine residual	4.8	0.70	0.07

4.

Chemical	*Fundulus heteroclitus* 48 TLm ppm	*Menidia menidia* 48 hr TLm ppm	Estimated "safe" Concentration ppm
Na_2CO_3	2800.0	465.0	46.5

5.

Chemical	*Fundulus heteroclitus* 48 hr TLm ppm	*Menidia menidia* 48 hr TLm ppm	Estimated "safe" Concentration ppm
Hydrazine	13.3	7.40	0.74
Ammonia	0.57	0.37	0.04

Source: Con Edison 1973.

Table 2-9.

OVERALL RANGES FOR TLM'S TO 96 HOURS IN PPM
(after Renwoldt, 1972)

Goldfish
Carassius Auratus

Metal Ion	TLm range 15°C	TLm range 28°C
Cu++	.81 - 11.8	.80 - 11.5
Zn++	6.7 - 25.5	6.8 - 25.1
Ni++	6.2 - 63.2	6.3 - 63.1
Hg++	.37 - .74	.08 - .42
Cd++	0.3	0.11 - 2.8
Cr+++	10.3 - 31.6	13.9 - 26.3

Source: Con Edison 1973.

Table 2-10.

The 48 hour and 24 hour median tolerance limits (TLm's) determined for *Morone americana* and *Morone saxatilis* exposed to the various chemicals and estimated "safe" concentrations based on a 1/10 safety factor applied to the lowest TLm determination.

(after Lauer, 1972)

Normal Operating Chemicals (24 & 48 hour TLm in ppm)	White Perch *Morone americana*		Striped Bass *Morone saxatilis*		Estimated "safe" concentrations
	24 hr. TLm	48 hr.	24 hr. TLm	48 hr.	
1. Boric Acid	10,040	6850	-	2100	210
2. Cyclohexylamine	40	40	64	64	4.0
3. Detergent	18.8	16.0	16.4	14.8	1.5
4. Soda Ash	705	620	340	198	19
5. Sodium Hydroxide	91	88	58	57	5.7
6. Sodium Hypochlorite[a]	2.8	2.8	2.8	2.8	.3
7. Sulfuric Acid	57	56	65	65	5.7
8. Trisodium Phosphate	510	510	388	385	38.5

a. Concentration expressed as total chlorine. Toxicity based on 3.0 hours due to small residency time of free chlorine; therefore, the TLm are for 2 hours.

Source: Con Edison 1973.

available (at least 9,000,000 gpm in front of the plant and at least 80,000,000 gpm in the river at Indian Point, on the average) would dilute any potentially extreme concentration, even though it is doubtful that, under extreme conditions, discharge concentrations would ever exceed established toxicity limits (Con Ed 1973).

Toxicity data are also presented in Con Edison 1977d, Appendix D.

SECTION 3

DETRITUS

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3. DETRITUS

3.0 SUMMARY

The energy dynamics of the lower Hudson River ecosystem, integrating the energy available from marine, human, and terrestrial systems surrounding the river with primary productivity within the river, are examined.

The Indian Point plant's once-through cooling system has a negligible effect on the river's organic detritus. Most primary detrital decomposition occurs in the tributaries and upper reaches of the river and much of the detrital load in the lower regions is transformed into fine particulates, colloidal or dissolved organic states, all of which are negligibly altered by entrainment.

3.1 INTRODUCTION

Organic materials are introduced into the Hudson River from both man-made and naturally occurring sources. These organic materials (particulate or in solution) are transported from the upper watershed, flow through the dam at Troy, New York and into the lower Hudson estuary. The input of organic materials (as carbon) from the upper Hudson-Mohawk River watershed has been determined to be approximately 6.2×10^7 kg/yr or 620×10^9 kcal/yr (Con Ed 1977d). The transport of particulate organics (detritus) and dissolved organics is highly seasonal and closely follows the runoff streamflow patterns of the watershed.

Many biological sources contribute to the supply of dissolved organic substances in the water. Compounds produced by living plants and animals (e.g. amino acids, carbohydrates and soluble proteins) are washed by rain into the Hudson River estuary. Plant litter (leaves, twigs, bark, fruits, roots, etc.) and animal products (urine, feces, corpses) contribute some soluble organics to surface and ground waters.

Fisher and Likens (1972) reported export of energy in dissolved organic materials from a small watershed covered by northern hardwood forest to be about 2800 kcal/m^2/yr. Assuming this value to be representative of the lower Hudson watershed (5310 mi^2; 13,750 km^2), the total unadjusted energy contribution of dissolved organic substances of terrestrial origin would be 385 x 10^{11} kcal/yr (Con Ed 1977d).

Plant litter is the major contributor to the amount of particulate organic material in the river. The entry of plant litter into aquatic ecosystems is seasonal, coinciding with defoliation in the autumn and with peak runoff from precipitation in the spring. Some litter enters streams directly from the source plant, while wind sweeps in other litter from surrounding areas. Plant debris may be placed in water directly by animals such as beavers and muskrats or it may enter in other animal feces. Similarly, particles (corpses, hair, feathers, etc.) derived from insects and animals enter aquatic systems.

Particulate organic material becomes available as usable energy as it decomposes. Animal fragments are rapidly decomposed to soluble forms and are used by detritivores or bacteria. Soft plant parts (e.g. fruits, leaf parenchyma) are consumed or fragmented soon after their entry into the water. Older leaves are disintegrated slowly and may accumulate with other woody plant parts, their fragmentation and decomposition requiring months or years.

Fisher and Likens (1972) found that the energy export from a northern hardwood forest as particulates was about 1200 $kcal/m^2/yr$. Leaves entering a water body in the northeastern U. S. may contribute 3500 kcal/m of shoreline (approximately 350 gC/m) (Jordan and Likens 1975). Assuming this to be applicable to the lower Hudson River, total annual input (unadjusted for land-use variations) as particulate organics would be about 165×10^{11} kcal. Using the unmodified values for northern hardwood forest (Fisher and Likens 1972; Jordan and Likens 1975), the total input of energy from the watershed would be on the order of 550×10^{11} kcal/yr.

The natural terrestrial input may be influenced by urbanization of the watershed and agriculture with the accompanying loss of forested land. The output of organic material from old fields, croplands, pastures, and urbanized areas is about 2.5 times greater than from forested land (Yu 1971; Loehr 1974). The lower Hudson River watershed contains about 30% urban and agricultural land (Omernik 1976); adjusting for this development, total input is approximately 800×10^{11} kcal/yr.

Additional energy is derived from sewage and other wastes and, to a lesser extent, from the coastal marine ecosystems (Table 3-1).

Table 3-1. Energy Inputs into Hudson River

Source		$kcal/yr \times 10^9$	% of Total
Benthic plants	) Primary	40	0.05
	) Production		
Phytoplankton	)	200	0.24
Upstream watershed		620	0.76
Lower watershed		80,000	97.61
Human effluents		1,100	1.34
Marine		0.17	0.01
	Total	81,960.17	100.0%

Source: Consolidated Edison 1977d.

3.2 EFFECTS OF ENTRAINMENT AND IMPINGEMENT ON ORGANIC DETRITUS

The entrainment of detritus in the cooling systems of the Indian Point power plants is expected to have a negligible effect on the quality or quantity of the river detrital load. The momentary increase in bacterial decomposition brought about by temporary temperature increases is the only conceivable entrainment effect. Chlorination is expected to reduce detrital bacterial populations, but due to the rapid regenerative capacity of these organisms, any reduction would be inconsequential. (Con Ed 1977d).

The quantity of larger detrital material which is impinged on the intake screens and trash racks is a negligible portion of the total detrital load of the river. The detrital material removed from the intake screens and trash racks at Indian Point is not returned to the river.

SECTION 4

DECOMPOSERS

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4. DECOMPOSERS

4.0 SUMMARY

Results of the bacteriological samples collected from the intake and discharge water at the Indian Point plant and from the main channel of the river are presented. The thermal tolerance studies examined conditions designed to simulate the temperature regime and exposure times expected during plant operations and those which are more severe.

These studies indicated that there is no significant effect on bacterial populations after passage through the Indian Point plant. Chlorination will produce only a temporary reduction in bacterial levels which will not extend beyond the chlorination period or beyond the immediate cooling system.

4.1 INTRODUCTION

Bacteria are heterotropic microorganisms or saprophages that aid in the decomposition of organic wastes and litter which are produced by living organisms and are derived from the remains of plants and animals. This type of decomposition transforms dead organic matter into forms used first by microorganisms and then by detritus feeding organisms (detritivores) and their predators. It is an absolutely vital function because, if it did not occur, nutrients would remain unutilized.

Under optimal conditions for growth, populations of bacteria are able to double themselves within 18 to 35 min. If favorable conditions of temperature and food supply were maintained and if predation were non-existant, a single bacterial cell could produce approximately 21 x 10^{27}kg (4.6 x 10^{28}lb) of offspring in 48 hours (Kudo 1966). This tremendous reproductive potential gives bacterial populations the capacity to recover quickly when a portion of the population is killed, assuming that other conditions for growth are not limiting.

The Indian Point power plant has the potential to affect bacterial densities, biomass, and species composition. Discharge temperatures approach optimal conditions for bacterial growth and reproduction during the warmer months. The magnitude of the discharge temperature could determine which species predominate in the vicinity of the plant. This section demonstrates that there is no evidence that this potential has been realized, and that power plant operations have had a negligible effect on bacterial populations in the vicinity of Indian Point.

4.2 METHODS

4.2.1 Intake-Discharge Canal Studies

Bacteriological analyses (APHA 1971; NYU 1973) were performed during 1971 and 1972 on samples collected from the intake and discharge water at the Indian Point plant and from the main channel of the Hudson River. A sample was collected from each point at time intervals reflecting different tidal stages.

4.2.2 Laboratory Thermal Tolerance Studies

Experimental heat exposures were designed to simulate the temperature regime and exposure times expected during plant operations as well as more severe conditions. Intake water samples from Indian Point were subjected to thermal increments from 4 to 44 C above ambient temperatures of 0 to 23.9 C. Exposure times ranged from 2.5 to 45 min. The samples were then cooled to ambient temperature and processed by membrane filter procedure. (APHA 1971; NYU 1973)

4.3 RESULTS

4.3.1 Intake and Discharge-Canal Studies

The results for total bacteria and total coliform counts are shown in Table 4-1. No consistent trends in either total coliform or total bacterial density appeared. There was no significant effect on the bacterial populations after passage through the plant at a ΔT of 3.3 C above an ambient water temperature of 21.1 C (NYU 1973). Adenosine Triphosphate (ATP) analyses revealed that during chlorination, bacterial abundance was temporarily reduced in the cooling water system (NYU 1973).

4.3.2 Thermal Tolerance Studies

Exposing intake samples to temperature increments of from 4 to 22 C above an ambient water temperature of 0 C for 2.5 to 30 min. resulted in no consistent pattern relating either exposure time or temperature to either total bacteria or total coliform colonies.

Increasing the test temperature to the range 22 to 44 C above an ambient water temperature of 0C at exposure times of 10, 20 and 30 min. yielded different results. Total bacterial counts tended to decrease slightly with increasing exposure temperatures, while total coliform counts decreased by approximately 10 colonies per ml. of water for each additional 5.5C rise in exposure

Table 4-1. BACTERIAL POPULATIONS AT INTAKE AND DISCHARGE CANAL STATIONS AND IN THE HUDSON RIVER[a].

Time	Stations			
	Intake (I-1)	Discharge (D-1)	Discharge (D-2)	River (C)
	Total Coliform Colonies/100 ml			
0930	1,500	1,300	1,340	1,450
1100	1,650	1,900	1,100	1,050
1300	1,250	2,200	1,250	1,000
	Total Bacteria Colonies/ml			
0930	590	730	520	510
1100	940	700	500	470
1300	950	890	650	560

(a) Samples were taken on 27 September 1971, when the ambient temperature was 21.1 C and the plant was operating at a delta-T of 3.3 C.

Source: NYU 1973.

temperature from 22-39C. With exposure to a 44 C rise, the number of total coliform colonies dropped sharply. No effects of exposure period were detected over the range examined. (Table 4-2.)

When ambient water temperatures of from 23.4 to 24.4 C were analyzed for total bacterial colonies (Table 4-3), significant differences were observed between the controls and test samples at each experimental exposure time at a ΔT of 22.2C and the 15 min. exposure at a ΔT of 16.7C. However, significant differences were found for total coliform colonies only at the ΔT of 22.2C and 45 min. exposure. Counts of bacteria in the intake and discharge cooling water indicated no significant effects on entrained bacteria with a ΔT of 3.3 C above an ambient water temperature of 21.1 C (NYU 1973).

Table 4-2. TOTAL COLIFORM COLONIES AND TOTAL BACTERIAL COLONIES AFTER EXPOSURE TO TEMPERATURE INCREASES OF 22.2 TO 44.4 C ABOVE AMBIENT TEMPERATURE (0 C)[a]

	Delta-T (C) Above Ambient Temperature									
	Total Coliform Colonies/ml[b]					Total Bacterial Colonies/ml[c]				
Exposure (minutes)	22.2	27.8	33.3	38.9	44.4	22.2	27.8	33.3	38.9	44.4
10	77	58	44	44	22	2,600	4,650	2,250	2,150	1,600
20	66	61	64	49	7	4,200	2,800	2,000	1,650	1,600
30	67	74	55	40	9	3,300	2,450	1,900	2,300	2,650
Mean	70	64	54	44	13	3,700	3,300	2,050	2,033	1,950

(a) After exposure, samples were incubated for 24 hours at 3.9 C and then for 20 hours at 35 C.
(b) Control samples incubated at 35 C (20 hours) = 78/ml.
Control samples incubated at 3.9 C (24 hours) and 35 C (20 hours) = 71/ml.
(c) Control samples incubated at 35 C (20 hours) = 5,800/ml.
Control samples incubated at 3.9 C (24 hours) and 35 C (20 hours) = 5,500/ml.

Source: NYU 1973.

Table 4-3. EFFECTS OF TEMPERATURE ELEVATION ON TOTAL COLIFORM AND TOTAL BACTERIAL DENSITIES AT AMBIENT RIVER TEMPERATURES OF 23.3 TO 24.4C

Test Temp. (C)	Delta-T (C)	Exposure Time (Minutes) 5	15	30	45
Total Coliform [a]					
29.4	5.5	128	94	92	115
35.0	11.1	95	107	108	99
40.6	16.7	97	90	97	83
46.0	22.2	81	64	65	47
Control	0	93			
Total Bacteria [a]					
29.4	5.5	11,807	12,393	10,750	7,650
35.0	11.1	12,028	9,807	11,336	11,743
40.6	16.7	9,786	6,386	7,779	7,652
46.0	22.2	4,759(b)	3,091(b)	2,548(b)	2,628(b)
Control	0	12,377			

(a) Numbers represent means of numerous samples.
(b) Significantly different from control at $\alpha = 0.01$ level.

Source: NYU 1973.

SECTION 5

BENTHOS

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5. BENTHOS

5.0 SUMMARY

The benthic studies (1969-1974) were designed to determine the impact of chemical and thermal effluents from the Indian Point plant in the near-field area. Since benthic invertebrates reside exclusively in the bottom areas, their susceptibility to entrainment effects at Indian Point is negligible.

A quantitative study of Cyathura polita, which is representative of the benthos is examined. The population dynamics studies presented showed no significant variation of C. polita in the near field area during 1969-1974. There is no discernible effect on the benthos of the Hudson, beyond a limited scour area in the immediate vicinity of the effluent ports.

5.1 INTRODUCTION

The effects of once-through cooling processes have been frequently discussed as sources of potential impact on the aquatic community. The sedentary nature of some benthic organisms causes them to be more susceptible to prolonged stresses imposed on the ecosystem than are the more motile pelagic forms which have the ability to migrate into or out of stress areas. Since the benthic community is an important source of food for higher trophic levels, analyses of composition, abundance, and response to physicochemical variables provide indices of the direct and indirect effects of environmental changes on the benthic community as well as on higher trophic levels.

Benthic studies at Indian Point were designed to assess the effects of thermal and chemical effluents from the plant on benthic invertebrates and on general river conditions in the area. Specific study objectives included:

(1) estimation of community composition, diversity, and standing-crop biomass of benthos during the different seasons,

(2) characterization of sediment particle-size composition,

(3) evaluation of the response of the benthic community to natural and plant-related physicochemical variations,

(4) comparison of benthic community structure and seasonal variation in a test area near the generating facility with those of a control area beyond the effects of plant operation,

(5) comparison of the population dynamics of the estuarine isopod Cyathura polita in test and control areas.

5.2 METHODS

Studies of the effects of thermal and chemical effluents from the Indian Point nuclear generating facility on the Hudson River benthos began in April 1972.

Sampling stations and various gear used during the 1972, 1973, and 1974 study years are shown in Fig. 5-1 and Table 5-1.

5.3 COMMUNITY COMPOSITION

Collections from the macrobenthic infaunal community of the Indian Point region between April 1972 and December 1974 consisted of 86 taxa representing nine phyla (Table 5-2). This

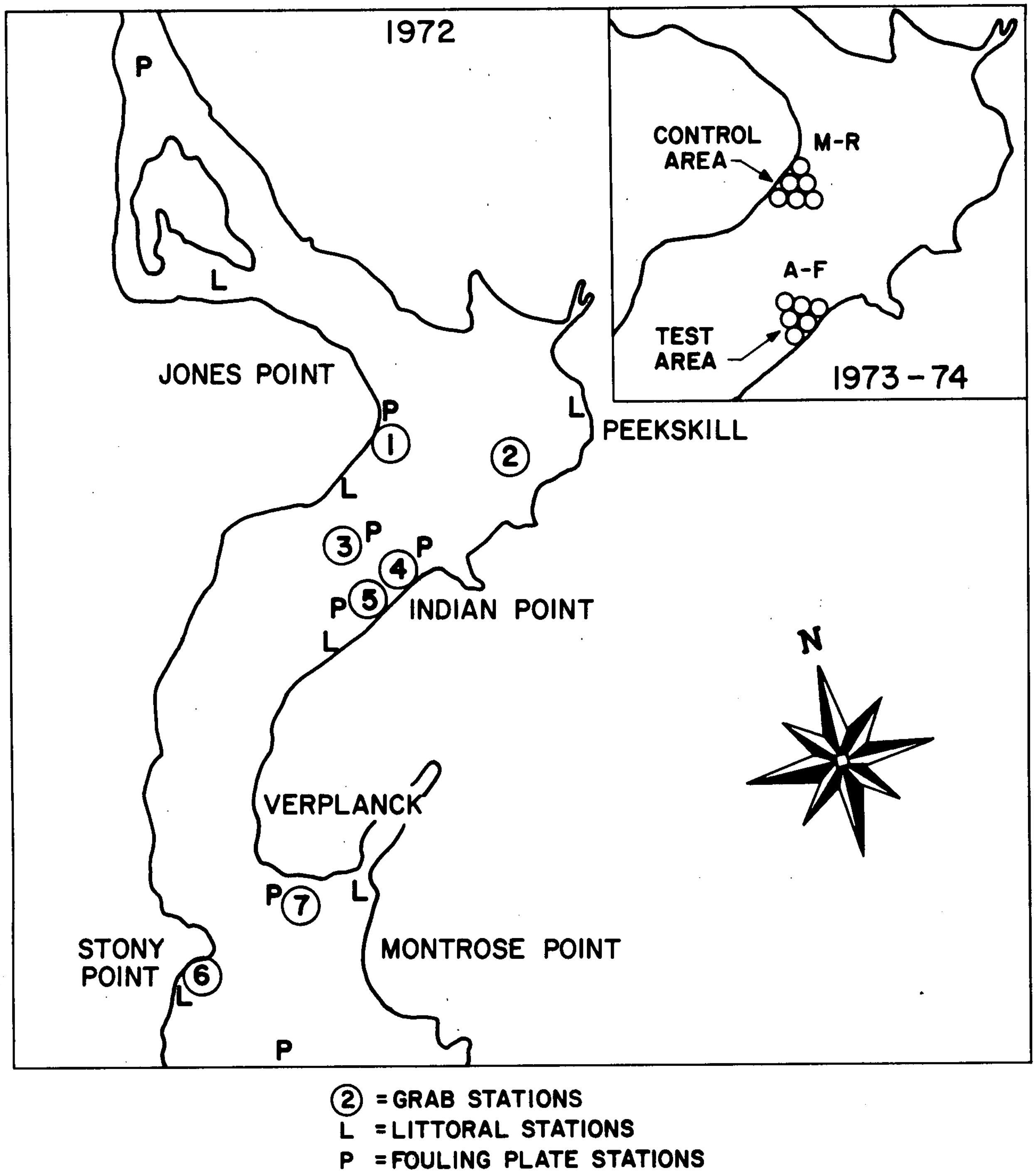

Figure 5-1. Location of Benthic Sampling Stations in Hudson River near Peekskill, New York during 1972, 1973 and 1974.
Source: TI 1976b.

Table 5-1. Gear Analysis for 1972, 1973 and 1974

GEAR	TYPE	SAMPLE	U.S. Standard Mesh Size (mm) for Sample Washing 1972	1973	1974	COMMENTS
PETERSEN GRAB	QUANTITATIVE	SESSILE EPIFAUNA BENTHIC INFAUNA	0.25	0.5&0.25	0.5&0.25	April-December
BIOLOGICAL DREDGE	QUALITATIVE	EPIBENTHIC	4.0	4.0		Monthly
EPIBENTHIC SLED	QUALITATIVE	EPIBENTHIC			0.25	Monthly
SWEEP NETS, MINNOW SEINES, SAND SEINES DIPNETS.	QUALITATIVE	LITTORAL FAUNA	0.5			Bimonthly
(ASBESTOS SIDING PLATES	SEMIQUANTITATIVE					6 Locations
PHLEGER CORER	QUALITATIVE	SEDIMENT				6 Times During Sample Season (TI, 1973a)

Table 5-2.

Taxon List for Hudson River Ecological Survey Benthic Collections at Indian Point, April 1972 - December 1974

CNIDARIA
- *Cordylophora lacustris*
- *Hydra americana*

PLATYHELMINTHES
- Planaridae
- *Dugesia* sp.
- *Dugesia tigrina*

NEMERTEA
- Paleonemertea

NEMATHELEMENTHES
- Unidentified Nematoda

ACANTHOCEPHALA
- Sipunculida

ANNELIDA
- Polychaeta
  - *Scolecolepides viridis*
  - *Boccardia hamata*
  - *Hypaniola* sp
  - Nereis larvae
  - *Nereis succinea*
  - Serpulidae
- Oligochaeta
  - *Limnodrilus* sp
  - *Peloscolex* sp
  - *Stylaria* sp
  - Unidentified
  - Naididae
- Hirudinea
  - Hirudinia
  - Glossiphoniidae
  - *Piscicola* sp

ARTHROPODA
- Crustacea
  - Decapoda
    - *Crangon septemspinosa*
    - *Rhithropanopeus harrisi*
    - *Orconectes limosus*
    - *Palaemonetes pugio*
    - *Callinectes sapidus*
  - Mysidacea
    - *Neomysis americana*
  - Amphipoda
    - *Gammurus* sp
    - *Monoculodes* sp
    - *Corophium* sp
    - *Leptocheirus* sp
    - Unidentified
    - *Crangonyx* sp
  - Isopoda
    - *Livoneca ovalis*
    - *Cassidina lunifrons*
    - *Cyathura polita*
    - *Edotea* sp.
    - *Chiridotea almyra*
    - *Asellus* sp.
  - Cumacea
    - Unidentified
  - Cirripedia
    - *Balanus improvisus*
  - Copepoda
    - Harpacticoida
    - Cyclopoida
    - Calanoida
  - Ostracoda
    - Unidentified
  - Cladocera
    - Cladoceran ephippium
    - Macrothricidae
    - *Daphnia* sp
    - *Bosmina* sp
    - *Latona* sp
    - *Leptodora kindti*
- Insecta
  - Phloethripidae
  - Isotomidae-Collembola
  - Unidentified insect larvae
  - *Agraylea* sp
  - Leptoceridae
  - Trichopteran adult
  - *Limnophora* sp
  - *Amphiagrion* sp
  - *Enallagma* sp
  - *Ischnura* sp
  - Odonata larvae
  - *Cryptochironomous* sp
  - *Palpomyia* sp
  - Chironomid larvae
  - Chironomid pupae
  - *Chaoborus* sp
  - Trichopteran larvae
  - Ephemeroptera larvae
  - Dipteran pupae
  - Ceratopogonidae larvae
- Arachnida
  - Hydracarina

MOLLUSCA
- Gastropoda
  - *Amnicola* sp
  - Nudibranchia
  - Unidentified juvenile
  - *Ferrissia* sp
- Pelecypoda
  - Lamsilinae
  - Sphaeridae
  - *Congeria leucophaeta*
  - *Pisidium* sp
  - *Ellipto* sp

ECTOPROCTA
- *Cristatella mucedo*
- *Hyalinella* sp
- *Pectinatella magnifica*
- *Lophopodella carteri*

Source: TI 1976b.

assemblage was dominated in numbers of taxa by the Crustacea (30), Insecta (19), and Annelida (14).

5.4 RELATIVE ABUNDANCE

In 1973, the tubificid worm Limnodrilus was the most common form in the control area (TI 1974a); during 1974, however, its dominance was reduced and, in the test region, its mean annual numbers were exceeded by those of Scolicolepides virides (Polychaeta) and Amnicola sp. (Gastropoda). While some variation in absolute ranking of major taxa was observed between the test and control areas, the same taxa constituted the dominant assemblage in both areas.

5.5 COMPARISONS OF STUDIES 1969-74

Studies of the Indian Point benthic community in 1969-70 and 1972-73, indicated that during the latter period the community was dominated by freshwater organisms, while during the former period halophilic (salt-tolerant) species predominated. Bottom salinities at Indian Point during 1969-1970 (Raytheon 1971) were approximately the same as those observed during 1972-1973; but the salt front persisted for a longer period of time during the earlier study. During 1973 and 1974, the duration of salt intrusion in the Indian Point region increased over the 1971-1972 period. By 1974, benthic community composition and relative abundance had shown a general reversal of the earlier trend, again favoring the halophilic organisms (Table 5-3 and 5-4).

Table 5-3.

Comparison of Relative Abundance of Dominant Taxa
During August-December Periods of 1969, 1972, 1973, and 1974

Taxon	Mean No./m^2 1969*	1972	1973 Test	1973 Control	1974 Test	1974 Control
Congeria leucophaeta	56	192	124	64	521	134
Gammarus sp	104	72	320	137	189	76
Cyathura polita	160	192	280	138	555	654
Leptocheirus sp	384	2	3	< 1	24	10
Balanus improvisus	1408	227	86	197	1803	1486
Monoculodes sp	0	< 1	< 1	3	9	7
Nemertea	16	< 1	< 1	2	6	44
Rhithropanopeus harrisi	0	8	9	< 1	31	22
Corophium sp	0	27	94	48	236	285
Edotea	16	5	11	45	23	58

* From Raytheon, 1971

Table 5-4.

Comparison of Relative Abundance of Dominant Taxa
during January-October Periods of 1970, 1972, 1973, and 1974

Taxon	Mean No./m^2 1970*	1972	1973 Test	1973 Control	1974 Test	1974 Control
Congeria leucophaeta	560	107	89	45	239	83
Gammarus sp	320	83	353	211	287	181
Cyathura polita	316	162	260	139	448	411
Leptocheirus sp	224	1	2	< 1	16	6
Balanus improvisus	116	130	62	141	816	943
Monoculodes sp	52	< 1	< 1	2	2	2
Nemertea	36	< 1	< 1	1	4	3
Rhithropanopeus harrisi	24	7	9	1	16	12
Corophium sp.	8	66	72	34	94	195
Edotea sp	< 1	3	8	32	14	40

* From Raytheon, 1971

Source: TI 1976b.

5.6 CYATHURA POLITA STUDIES

An in-depth quantitative study of one important species in the system was performed to document plant effects on the benthos. In 1972, Cyathura polita was chosen for a preliminary study because it was important on a biomass and numerical basis, was an important food source, and was truly benthic (in contrast to Gammarus which is epibenthic to pelagic). The life history, biological and morphological characteristics of C. polita were examined in several successive years (TI 1976b).

Faunal associates of Cyathura were determined on the basis of correlation analyses and are reported in Table 5-5 in descending order of correlation coefficient value.

5.6.1 Population Dynamics

Seasonal variation in population density of the estuarine C. polita during 1974 was similar in the Indian Point test and control areas; both areas exhibited relatively low numbers during the early months, high reproduction and corresponding increases in total number during May-September, and general decreases through the fall and early winter (Fig. 5-2). This pattern was consistent with those determined for the test area during 1972-1973 and for the control area during 1972.

While seasonal fluctuations in the control area during 1973 generally followed this pattern, reproductive success and corresponding population numbers were low; this population disruption was probably due to Cyathura's intolerance to low dissolved oxygen concentrations (Dean and Haskin 1964; Burbanck

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Table 5-5.

FAUNAL ASSOCIATES OF *CYATHURA POLITA* IN
INDIAN POINT REGION OF HUDSON RIVER

Taxon	Correlation Coefficient
Scolecolepides viridis	0.4858
Boccardia hamata	0.3609
Edotea sp.	0.3465
Hypaniola sp.	0.2931
Gammarus fasciatus	0.2719
Amnicola sp.	0.2691
Pelescolex sp.	0.2637
Harpacticoida	0.2247
Corophium sp.	0.2229
Congeria leucophaeta	0.2011
Chiridotea almyra	0.1946
Ostracoda	0.1681
Balanus improvisus	0.1324
Limnodrilus sp.	0.1422
Diptera	0.0503

Source: TI 1973 a.

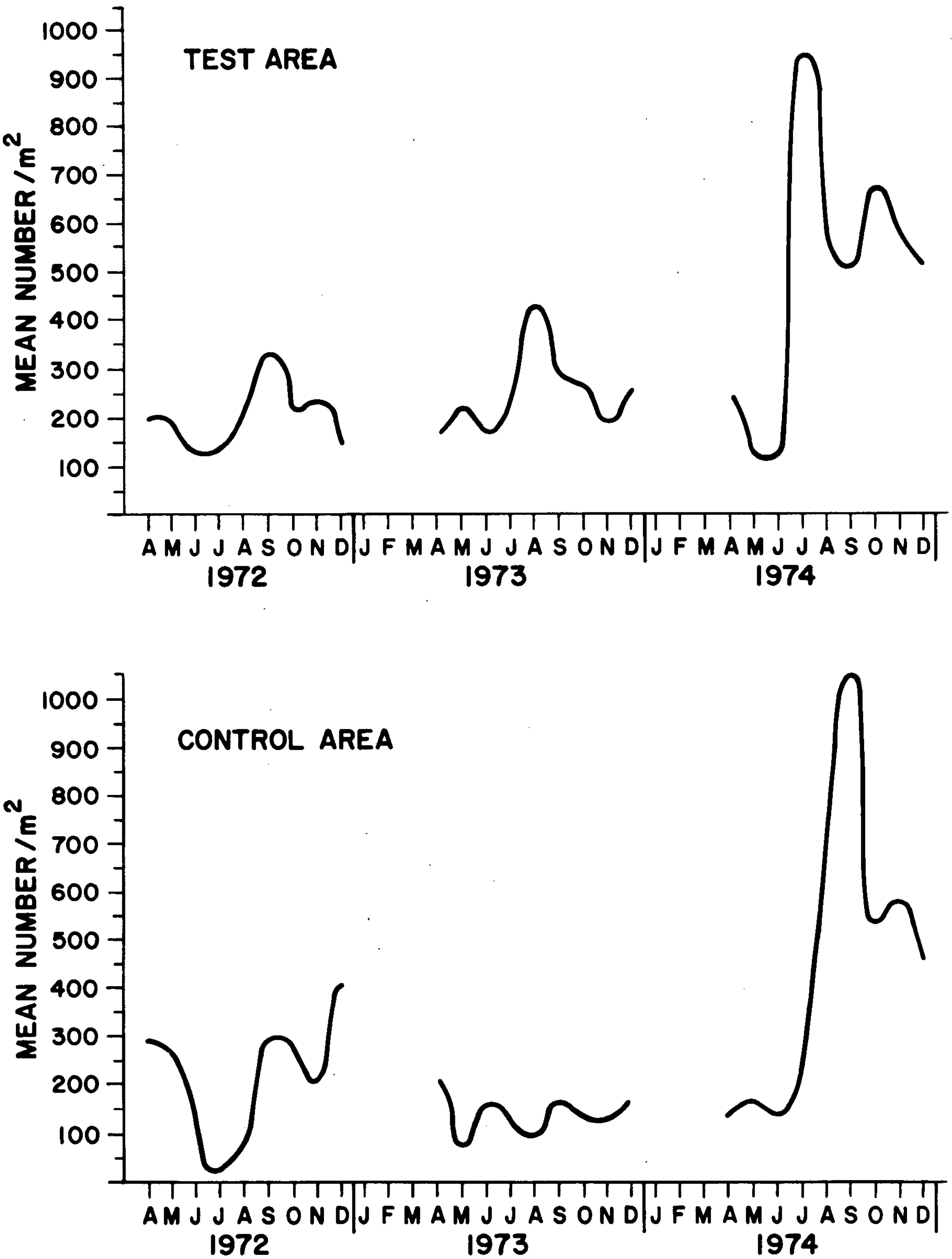

Figure 5-2. Mean Monthly Density of Cyathura polita (Stimpson) in Indian Point Test and Control Areas, April 1972-December 1974.

Source: TI 1976b.

et al 1964) which resulted from deposition of large amounts of detrital material in the area early in the reproductive period (TI 1974a).

5.6.2 Length-Frequency Distribution

Visual inspection of 1972 and 1973 length/frequency distribution indicates that the C. polita population was essentially composed of three year classes with the appearance of a fourth class at about the time or slightly before the disappearance of the last remnants of the oldest group. These data support the three year life span suggested by Burbanck (1962). Distribution during 1972 and 1973 indicated that reproduction occurs within a relatively short period during the summer, with year-class numbers reaching their peak within three months; these numbers then begin to decline, decreasing to approximately 50% of their original value at the end of the first year. The population continues to decline slowly before disappearing completely at the end of the third year (see Fig. IV-4, TI 1976b).

5.6.3 Length/Weight Relationship

Length/weight regression analysis of C. polita populations indicated no significant differences between populations in the test and control areas during 1973 (TI 1976b). Fig. 5-3 illustrates the calculated regression lines for the two areas during July 1973.

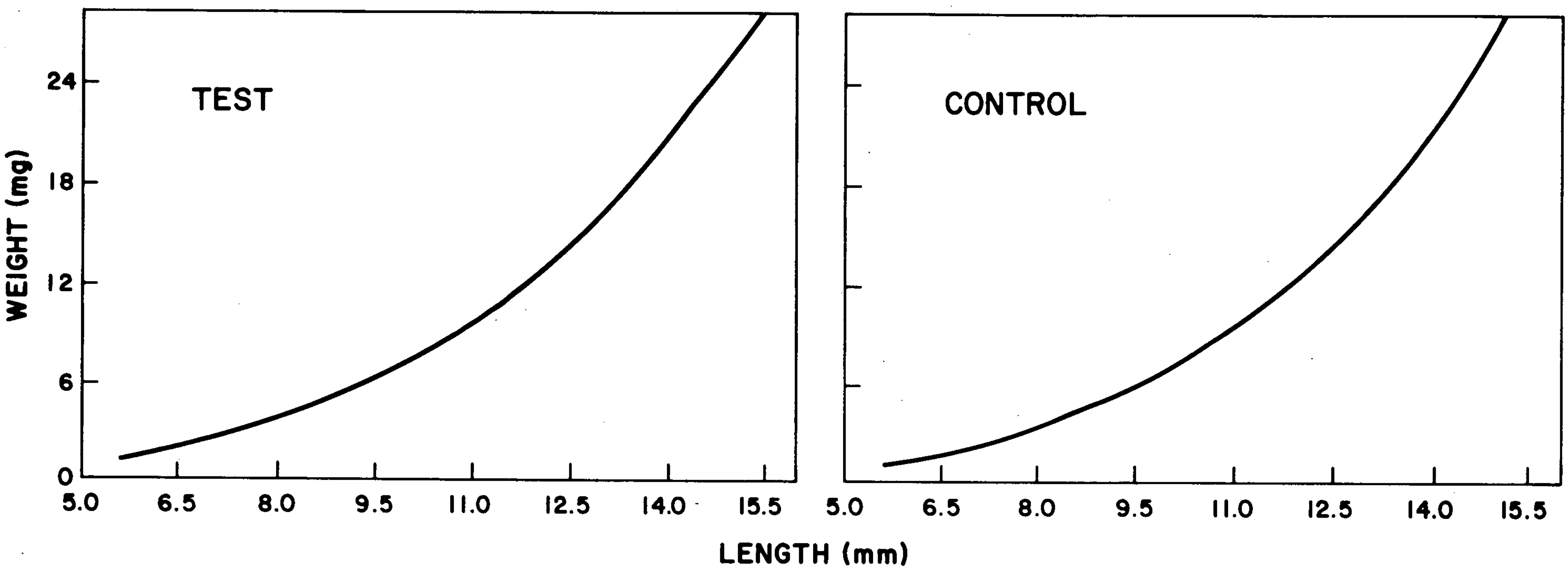

Figure 5-3. Length Weight Regressions for Cyathura polita Calculated on Basis of Data Derived from Test and Control-Area Collections during July 1973.

Source: TI 1976b.

5.6.4 Fecundity

The 1973 reproductive season for C. polita extended from late May through August. Numbers of eggs and embryos observed within the marsupia of reproducing females varied from 1 to 36 with no observable relation to the size of the individual. The process of deposition of eggs in the marsupium apparently extended over a prolonged period; thus, low numbers of eggs present in the marsupium did not necessarily mean low levels of reproduction but could simply have been a function of collection early in the egg-deposition process.

During 1974, 127 and 68 mature female Cyathura were collected in the Indian Point test and control regions, respectively (Table 5-6); these included recently spent individuals as well as specimens containing eggs, embryos, and larvae within the marsupium. Calculation of mean number of young based only on those individuals containing young within the marsupium indicated that control-area young per reproductive female considerably exceeded those in the test area (test = 23.0; control = 42.2). It is interesting to note, however, that theoretical total natality for the two areas (test = 1621.5; control = 1595.3) was almost identical, as was standing crop in the two areas in the latter months of 1974, even though control-area density was significantly lower during 1973 (TI 1976b).

Table 5-6.

Theoretical Natality of *Cyathura polita* in Indian Point Test and Control Area during 1974

	Month (1974)	Total No. Reproductive (N)	No. Reproductive/m^2 (N/m^2)	Mean No. of young (n)	Theoretical Natality/m^2
Test	June	8	4.4	23.0	101.2
	July	52	28.9	23.0	664.7
	August	56	31.1	23.0	715.3
	September	11	6.1	23.0	140.3
	Total	127			1621.5
Control	June	14	7.8	42.2	329.2
	July	8	4.4	42.2	185.7
	August	32	17.8	42.2	751.2
	September	14	7.8	42.2	329.2
	Total	68			1595.3

Source: TI 1976b.

5.7 SEDIMENT PARTICLE-SIZE COMPOSITION

Bottom sediments in the Indian Point region are predominantly sandy clay/silt, with patches of pebbles (Table 5-7). Shoreward areas show effects of human activities through the presence of some construction debris, cinders, and various forms of household refuse. Test-area sediments contained slightly higher percentages of gravel and clay/silt, while the control area was generally sandier.

5.8 SEDIMENT-TEMPERATURE STUDIES

Simultaneously with monthly sampling during 1974, temperatures of sediments and overlying water were determined for each station in the test control areas. *In situ* apparatus designed and built for this application permitted simultaneous measurement of sediment temperature 1 cm below the sediment/water interface and water temperature 2.5 and 30 cm above the interface. Annual and monthly mean test- and control-area temperatures for these three strata appear in Table 5-8.

Analysis of variance among stations, areas, months, and strata indicated that temperatures of sediments were significantly higher than those of the overlying waters. No significant differences among individual stations or between the test and control areas were detected.

5.9 DISTRIBUTION/PHYSICOCHEMICAL ANALYSES

Two analyses of the relationship between patterns of distribution of benthic organisms and physicochemical variation in the environment were performed. The first analysis provided

Table 5-7.

Mean Particle-Size Composition of Sediments in Test and Control Areas, October and November 1973

	Station	> 8	4-8	2-4	1-2	0.5-1	0.25-0.5	0.125-0.25	.0 63-0.125	<.0 63
		Particle Size (mm)								
Test	A	14.8	6.8	3.8	3.0	1.5	8.1	3.9	5.5	54.4
	B	0	0.9	0.8	2.4	1.4	11.7	6.7	8.2	67.9
	C	3.2	3.9	2.3	2.8	0.8	3.7	3.9	5.0	74.4
	D	1.5	0.8	0.6	1.4	0.8	4.3	4.4	9.2	81.5
	E	0	0	0.04	2.4	0.8	2.2	2.8	7.9	83.8
	F	0	0.7	1.5	0.6	0.6	2.9	2.9	5.0	87.8
	Mean	3.25	2.18	1.51	2.10	0.98	5.48	4.1	6.8	74.97
Control	M	5.2	2.7	3.4	3.5	1.9	14.3	19.9	10.4	41.3
	N	4.1	13.8	11.2	12.0	3.6	7.7	10.1	10.9	31.6
	O	0.3	0.5	0.4	0.8	0.7	11.1	9.8	7.0	62.0
	P	3.7	3.6	1.9	1.3	4.2	5.5	10.8	7.9	64.4
	Q	0	0	1.6	0.4	0.3	1.6	3.9	10.0	82.6
	R	0.7	2.1	1.2	0.5	0.4	3.8	9.1	7.7	78.7
	Mean	2.33	3.78	3.28	3.08	1.85	7.33	10.6	8.98	60.1

Table 5-8.

Mean *In Situ* Water and Sediment Temperature (C) for Test and Control Areas during 1974

		April	May	June	July	August	Sep	Oct	Nov	Dec	Annual Mean
Test	Sediment	4.2	12.8	18.8	26.0	25.0	24.0	18.8	11.9	6.8	16.48
	Water										
	2.5 cm	3.5	12.3	17.8	24.0	24.5	24.0	18.7	11.6	6.3	15.86
	30 cm	3.5	12.0	17.8	24.0	24.0	24.0	18.5	11.5	6.3	15.73
Control	Sediment	5.2	12.7	20.0	25.3	24.8	24.5	17.0	14.0	4.8	16.48
	Water										
	2.5 cm	4.2	12.0	19.0	24.3	24.3	24.2	17.1	13.7	4.3	15.90
	30 cm	4.2	12.0	19.0	24.3	24.0	26.0	16.8	13.3	4.3	15.99

Source: TI 1976b.

correlation matrices for the abundance of major taxa with temperature, dissolved oxygen, salinity, and the various combinations of these factors and considered rate of change in abundance and time lag in response to a change in the physicochemical environment (Table 5-9). Salinity and temperature were positively correlated to each other while temperature and dissolved oxygen were negatively correlated. To gain an indication of the relative importance of each factor to distribution, a stepwise regression considered abundances relative to the means of the physicochemical variables at various intervals, the absolute change during a time interval, and the squares of each of these values (Table 5-10). Results of the analyses appear in Table 5-11.

Table 5-9.

Variables Considered in Stepwise Regression

Description	Symbol
1. Temp lagged 0 weeks - Mean temp for 0-week lag	TP 0
2. D.O. lagged 0 weeks - Mean D.O. for 0-week lag	DO 0
3. Cond lagged 0 weeks - Mean cond for 0-week lag	CD 0
⋮	⋮
19. Temp lagged 6 weeks - Mean temp for 6-week lag	TP 6
20. D.O. lagged 6 weeks - Mean D.O. for 6-week lag	DO 6
21. Cond lagged 6 weeks - Mean cond for 6-week lag	CD 6
22. Absolute change* in temp from week 0 to 1 and 1 to 2	C TP 1
23. Absolute change in D.O. from week 0 to 1 and 1 to 2	C DO 1
24. Absolute change in cond from week 0 to 1 and 1 to 2	C CD 1
⋮	⋮
34. Absolute change in temp from week 4 to 5 and 5 to 6	C TP 5
35. Absolute change in D.O. from week 4 to 5 and 5 to 6	C DO 5
36. Absolute change in cond from week 4 to 5 and 5 to 6	C CD 5
37. Square of variable 1	S TP 0
38. Square of variable 2	S DO 0
39. Square of variable 3	S CD 0
⋮	⋮
55. Square of variable 19	S TP 6
56. Square of variable 20	S DO 6
57. Square of variable 21	S CD 6
58. Y variable is change in abundance, i.e., difference abundance at time t minus abundance at time t minus 1	

*Let X_i be the value of an observed physical variable for i lagged weeks; then, absolute change is defined as $\left|X_{i-1} - X_i\right| + \left|X_i - X_{i+1}\right|$ for this analysis.

Source: TI 1976b.

Table 5-10.

Multiple Correlation Coefficients Derived from Stepwise Regression Analysis of Physicochemical Data Relative to Distribution of Benthic Organisms

	Intake			Effluent		
Species	Variable*	Multiple Correlation Coefficiant	F To Remove+	Variable*	Multiple Correlation Coefficient	F To Remove+
Gammarus	S DO 3	-0.929	38.8	S DO 0	-0.758	25.1
	C CD 4	+0.964	4.6	C DO 1	+0.915	8.1
Cyathura	S CD 1	-0.673	452.5	S CD 2	-0.719	171.5
	DO 2	-0.859	356.3	TP 1	+0.944	390.3
	S TP 2	+0.997	174.3	S DO 2	+0.998	88.9
Limmodrilus	C DO 4	-0.855	185.0	S CD 1	-0.816	418.9
	C TP 3	+0.964	24.1	S TP 2	+0.945	159.9
	S CD 3	-0.994	19.3	DO 3	-0.996	52.8
Chironomid larvae	S DO 6	-0.822	38.1	C TP 1	+0.796	31.7
	C TP 2	+0.967	19.7	TP 2	-0.930	8.5
Balanus	C DO 1	-0.610	76.2	C DO 1	-0.785	33.5
	S CD 1	-0.850	61.7	S CD 5	+0.907	42.6
	DO 5	-0.986	37.0	C TP 2	+0.987	23.8
Congeria	S TP 0	-0.617	24.2	S DO 0	-0.795	29.1
	C CD 4	+0.847	19.2	S CD 6	+0.954	15.4
	C TP 1	+0.961	10.9			
Scolecolepides	S DO 4	+0.880	29.9	S TP 2	+0.764	12.0
	CD 1	+0.933	3.8	S DO 4	+0.933	11.1
Boccardia	S TP 0	-0.686	15.9	C CD 1	+0.715	90.9
	C CD 4	+0.895	8.3	C TP 3	+0.974	43.3
Amnicola	S TP 0	-0.775	34.2	C CD 5	+0.609	68.2
	C TP 2	+0.952	16.5	CD 1	-0.857	81.2
				S DO 2	-0.986	33.2

*Variables entered until a temperature, dissolved oxygen, or conductivity variable is repeated or until a large multiple correlation coefficient is obtained.

+Presented only for last set of variables in regression.

Source: TI 1976b.

Table 5-11.

Trends in Responses of Major Benthic Invertebrates
to Variations in Temperature, Dissolved Oxygen, and Conductivity

Species	Temperature	Dissolved Oxygen	Conductivity
Limnodrilus sp.	+	-	-
Amnicola sp.	-	+	0
Scolecolepides viridis	-	+	0
Boccardia hamata	+	+	+
Balanus improvisus	+	-	+
Cyathura polita	+	0	-
Gammarus spp.	-	+	-
Congeria leucophaeta	+	0	+
Chironomid larvae	-	+	0
Corophium sp.	+	0	+
Rhithropanopeus harrisi	+	-	+
Nematoda	+	-	+
Hypaniola sp.	-	+	0

Note: + = positive correlation, - = negative correlation, 0 = no response

Source: TI 1976b.

SECTION 6

PRODUCERS

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6. PRODUCERS

6.0 SUMMARY

The phytoplankton population studies for the years 1969 through 1975 were designed to 1) measure the temporal and spatial distributions of phytoplankton species which are susceptible to entrainment at the Indian Point facility, 2) identify the phytoplankton distributed in the area and to, 3) determine whether observed damage to entrained phytoplankton adversely affected populations of those organisms in the river.

These studies were not continued after 1975 since a thorough analyses of the previous years' data demonstrated that there was little or no effect on the abundance, chlorophyll a content, photosynthetic capacity or primary productivity of the phytoplankton population in the Hudson River as a result of the Indian Point plant operations.

6.1 INTRODUCTION

Phytoplankton are those microscopic unicellular, colonial, or filamentous plants which drift or float in the water column. As primary producers, they convert carbon dioxide, minerals and water into organic matter (including more algae). Thus, they form part of the base of the food web (Section 3.1) and their abundance has an effect on higher trophic levels (Table 3-1). Although phytoplankton are vital primary producers of many aquatic ecosystems, their relatively low abundances and productivity rates (as determined by $_{14}C$ uptake) observed for the Hudson River estuary near Indian Point indicate that other food sources, such as plant detritus and various organic particulate matter, may be the primary source of nutrients for the consumer organisms (Lauer et al 1974).

The U. S. Nuclear Regulatory Commission's assessment of the impact of once-through cooling from Units Nos. 1, 2 & 3 indicated that entrainment of phytoplankton "is not expected to have any measurable effect on the aquatic ecosystem in the vicinity of Indian Point (USNRC 1975)."

6.2 RIVER POPULATION STUDIES

6.2.1 Methods

Seven stations, designated A through G, were used for sampling sites (Fig. 6-1). Stations A and B north of Indian Point, and Stations F and G, south of Indian Point, provide information on the types and quantities of planktonic organisms entering and leaving the vicinity of the Indian Point facility. Stations C and D provide the same types of information on planktonic organisms in front of the Indian Point cooling-water intake bays. They are also used for monitoring effects of entrainment and the effects of plant discharges on river populations. Station E is within the thermal plume, close to the discharge ports. Sampling was conducted at Stations A through G in 1971 and 1972. The mile-point locations (referenced to the Battery) and river depths for each sampling station are listed in Table 6-1. Development of more efficient phytoplankton sampling techniques resulted in the replacement of the 1969 quantitative 10m vertical tow sampler by the pump-nannoplankton net collection and whole-water sampling

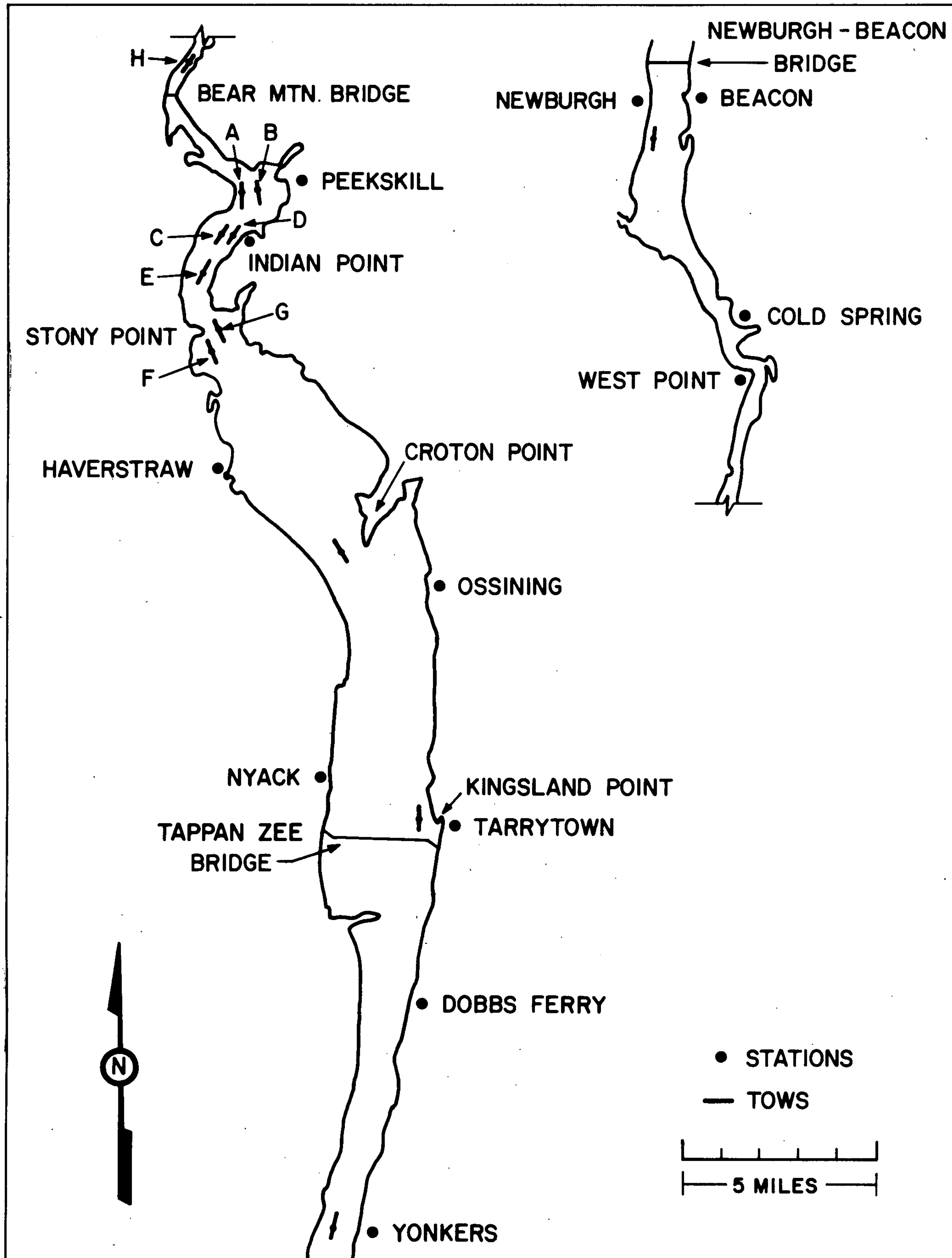


Figure 6-1. Sampling Stations.
Source: NYU 1977.

Table 6-1. Location and river depth at New York University Hudson River sampling stations, 1971 1972, 1974 and 1975.

General Location	Letter designation	River mile-point	River depth (ft)
Newburgh	none[1]	58.5	45
Cold Springs	none[1]	53.0	50
Manitou	H[1]	47.0	65
Jones Point	A	42.7	40
Peekskill Bay	B	42.7	30
Reserve Fleet	C	41.7	50
Indian Point	D	41.7	50
Power line crossing	E	41.0	50
Stony Point	F	39.0	40
Montrose Point	G	39.0	30
Croton Point	none[1]	33.0	30
Kingsland Point	none[1]	27.7	30
Yonkers	none[1]	19.5	50

[1]Sampled only in 1972.

Source: NYU 1976a.

methods used after 1971. The whole water sampling method gave a better quantification of the smaller forms and was found more efficient than the net sampling method (NYU 1977).

Fig. 6-2 shows the location of the sampling stations at the Indian Point plant. The effects of pumped entrainment were determined by comparing data from stations C-1, C-2, C-3, C-4, D-1, D-2, and DP with data from the intake stations. Stations I-1 and I-2, at the intakes of Unit No. 1, were used in 1972 and 1973. In 1973, with the completion of Unit No. 2, stations II-1 and II-6 were added.

In 1974, with both units in operation, sampling was carried out on a variable schedule, according to which unit was in a generating mode. Plant sampling in 1975 was carried out exclusively at stations II-2 and II-5, D-1, D-2, and DP.

Stations C-1, C-2, C-3 and C-4 were small bleeder lines at the condenser water boxes through which limited amounts of water could be obtained. The small volume of the samples at these bleeder lines limited analyses to bacteria, phytoplankton, and chlorine residual.

Stations D-1 and D-2, in the open discharge canal, were suitable for sampling the full array of physical/chemical parameters and pump-entrained organisms included in these studies. Station DP, at the discharge ports, was established in 1973 and sampled throughout 1974 and 1975. No sampling was done at the end of the discharge canal in 1971 and 1972 because the discharge-port structure was still under construction.

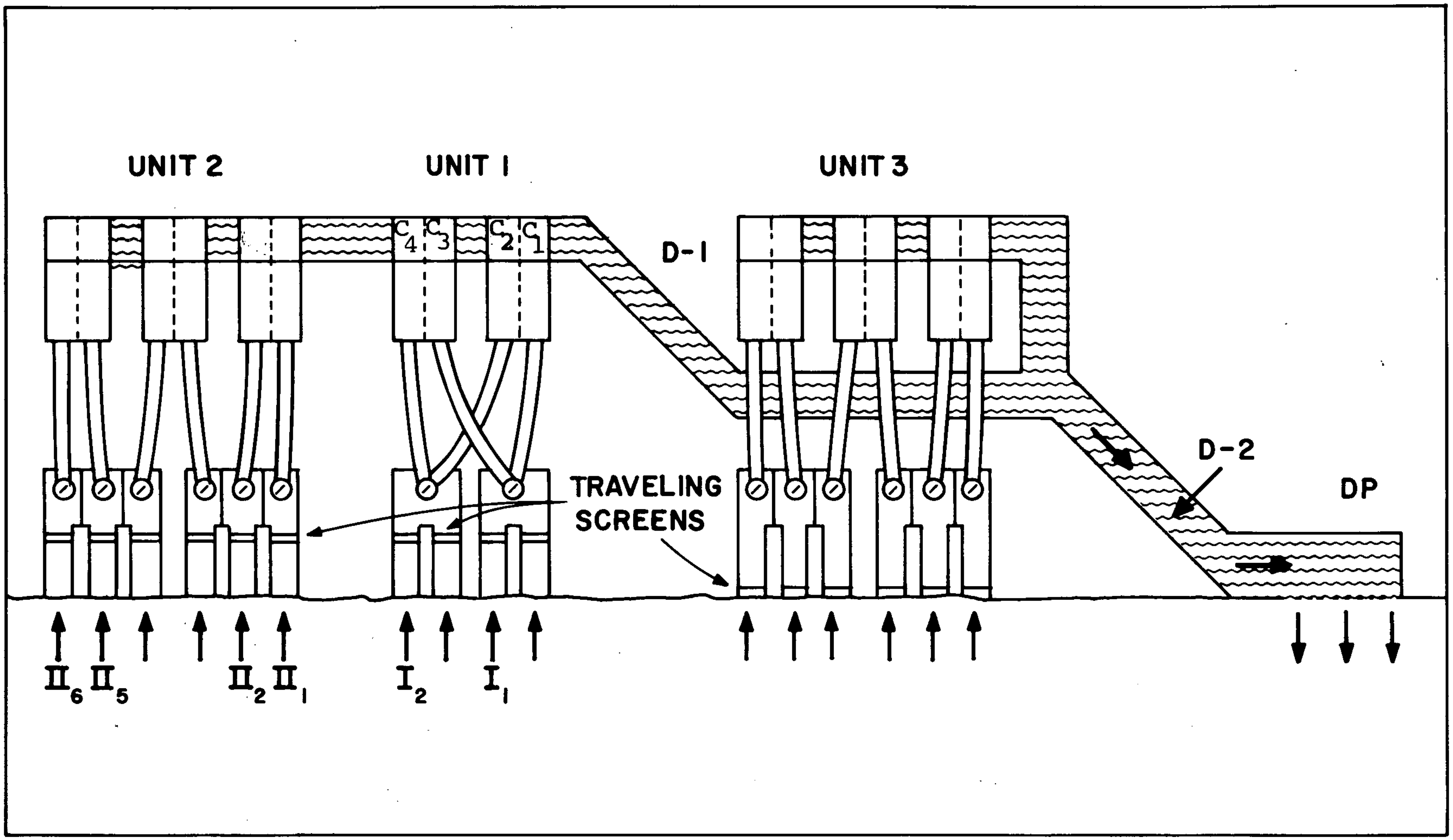


Figure 6-2. Schematic of intake structures at Indian Point - showing sampling locations.
Source: NYU 1973.

6.2.2 Results: River Population Studies

Analysis of variance showed no significant differences among stations with respect to phytoplankton abundance (see Table 4-1, NYU 1977). Comparison of day and night abundances by station and collection dates yielded no significant differences (Tables 6-2 and 6-3).

Based on the data collected from both net and whole-water samples, the species composition of the phytoplankton community at Indian Point varies seasonally and from year to year (Fig. 6-3 and Fig. IV-2, NYU 1977). Diatoms were usually dominant during the winter and spring, while the green algae usually dominated the flora during the rest of the year. From August through mid-October, the blue-green algae, although not the dominant group, became a significant portion of the community (Lauer et al 1974). It has been found that these potentially nuisance algal forms are common components of the phytoplankton community. The presence of these algal groups at Indian Point seems to be determined by their occurrence in the upstream regions of the river (Fig. 6-4).

6.3 ENTRAINMENT EFFECTS STUDIES

6.3.1 Methods & Results

Phytoplankton samples were collected using the same methods described for the river population study (Section 6.2.1). Beginning in 1974, all entrainment studies included the determination for chlorophyll a content, phytoplankton abundance and species composition as well as measurements of ^{14}C-uptake. The determination of these additional parameters allowed the

Table 6-2 . Numbers of phytoplankton per liter in daytime collections, 1971.

Date	Stations A	B	C	D	E	F	G	Mean
4/29	96600	87100	107000	123000	121000	85900	88000	101228
5/3	98200	117000	127000	56500	106000	78400	81200	94900
5/10	111000	104000	115000	104000	77000	121000	154000	112285
5/17	49900	63600	63800	63900	55200	56800	67300	60071
5/24	27000	27800	30500	27200	24500	40900	39800	31100
6/1	57600	35100	55100	82500	39800	113000	38300	60200
6/7	16500	28100	27700	32200	18000	284000	300000	100928
6/14	63600	125000	57800	45500	56500	31500	28500	58343
6/21	10100	15500	15300	20000	22500	16200	13300	16128
6/28	19600	38500	36000	12800	14000	8100	13500	20357
7/6	102000	108000	175000	136000	113000	118000	117000	124143
7/12	9300	7700	11900	9800	12800	14800	12300	11228
7/19	51800	48900	78500	50600	47500	119000	126000	74614
7/26	15800	17700	14900	16000	14400	13200	15700	15386
8/2	48600	43900	35700	38000	38300	51600	43600	42814
8/9	53100	42800	31500	41600	37800	35100	22300	37743
8/17	92100	122000	89200	60700	85400	127000	130000	100914
8/23	55100	46800	20800	17500	36200	36900	42100	36486
8/30	241000	461000	89600	185000	198000	182000	81700	205471
9/9	82400	142000	122000	58100	52200	166000	107000	104242
9/13	103000	154000	82800	61000	69100	71300	83700	89271
9/21	88100	85100	58700	66100	61000	54900	40400	64900
9/27	34000	37400	33300	33800	37100	53800	57200	40942
10/4	18200	16400	15300	16000	13700	21200	26300	18157
10/12	16400	15900	16100	18500	19200	15300	9800	15885
10/18	19200	10600	21800	28700	27200	25500	26600	22800
10/25	18200	18700	15800	13800	20500	13000	8800	15542
11/1	7100	8400	7500	8600	7900	6200	5200	7271
11/8	10500	10400	9100	12800	22900	8100	12300	12300
11/29	9700	8200	8900	10000	7900	7400	15100	9600
MEAN	54190	68253	52453	48340	48553	65870	60233	

Analysis of variance (log transformations)

Source of variation	Degrees of freedom	Sum of squares	Mean square	Calculated F-value	Critical F (0.05)
Dates	29	158.17	5.45	36.25	1.53
Stations	6	0.67	0.11	0.74	2.15
Error	174	26.18	0.15		

D E C A G B F*

* Stations A through G listed in ascending order of geometric means. The difference between any two means is insignificant if the two stations are included within any one line below them. Significance was determined by the Student-Newman-Keuls procedure (Q=0.05).

Source: NYU 1973.

Table 6-3. Numbers of phytoplankton per liter in night-time collections, 1971.

Date	Stations A	B	C	D	E	F	G	MEAN
5/11	98500	110000	140000	96800	136000	154000	178000	130471
6/8	241000	209000	262000	148000	160000	291000	360000	238714
7/8	17400	62100	59200	57600	45000	58500	61900	51671
8/3	56700	66800	57400	72900	70600	51300	46400	60300
9/7	130000	115000	238000	121000	128000	161000	104000	142428
10/4	14800	12700	15100	13300	17100	18700	19100	15828
11/9	5600	7800	9000	6500	5500	6200	6900	6785
Mean	80571	83343	111528	73728	80314	105814	110900	

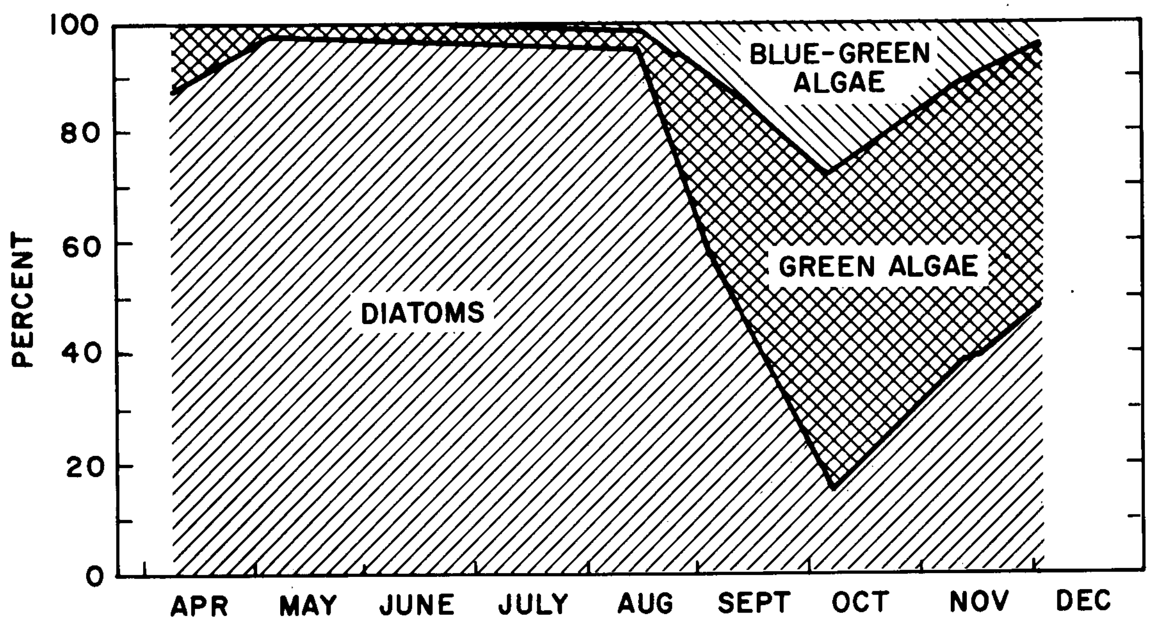
Analysis of Variance (Log Transformation)
Phytoplankton - Number Per Liter

Source of Variation	Degrees of Freedom	Sum of Square	Mean Square	Calculated F-Value	Critical F (0.05)
Dates	6	67.25	11.21	168.39	2.36
Stations	6	0.79	0.13	1.99	2.36
Error	36	2.40	0.07		

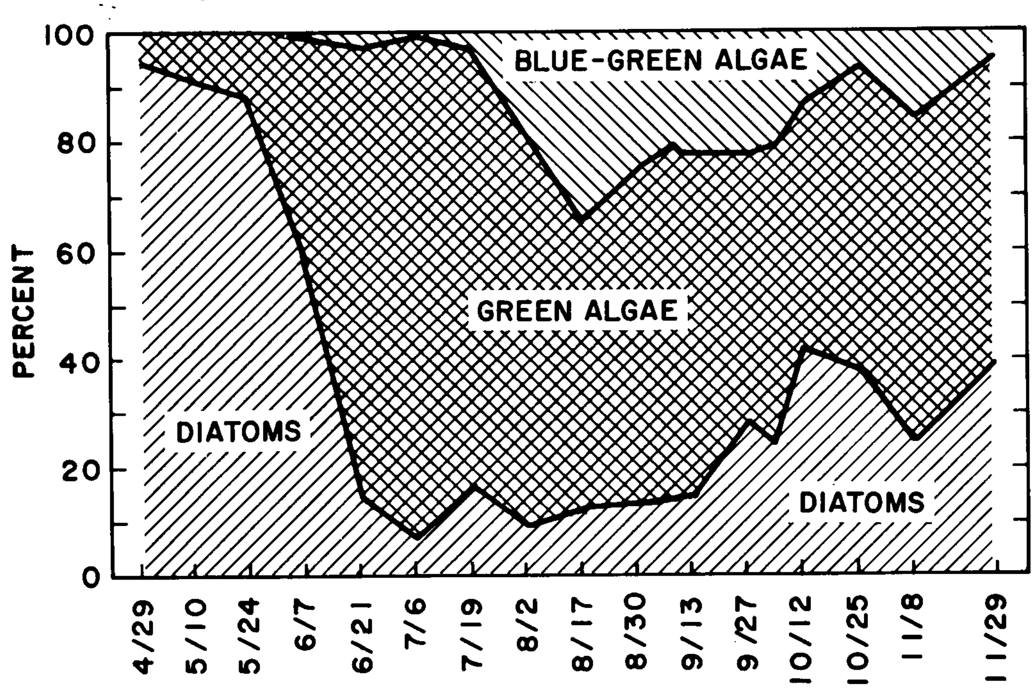
Source: NYU 1973.

Figure 6-3.

PHYTOPLANKTON-PERCENT COMPOSITION, HUDSON RIVER-1970
(MEAN OF 3 SITES OF DAYTIME COLLECTIONS)



PHYTOPLANKTON-PERCENT COMPOSITION, HUDSON RIVER-1971
(MEAN OF 7 SITES OF DAYTIME COLLECTIONS)



Source: Lauer et al 1974.

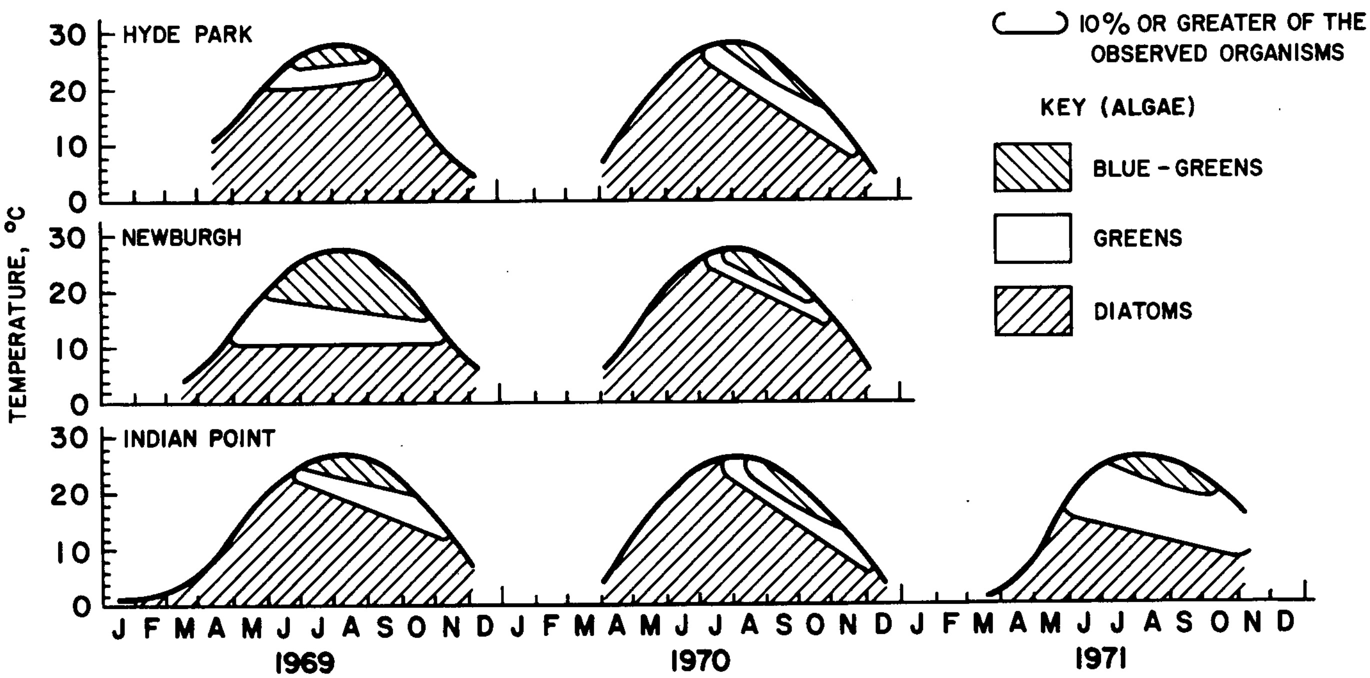


Figure 6-4. Temperature patterns and algal presence in the Hudson River estuary. Note the differences in timing of shifts in dominance among major groups from year to year.

Source: Lauer et al 1974.

establishment of four criteria useful in assessing the effects of entrainment on phytoplankton. These are: 1) primary production (C-uptake/unit volume of cells), 2) chlorophyll a content (a measure of biomass), 3) photosynthetic capacity or assimilation number (carbon fixed/unit weight of chlorophyll a and 4) phytoplankton abundance and species composition.

Chlorophyll measurements were taken to get corollary information on the potential for photosynthetic activity. The flourometric determination of chlorophyll a and phaeophytin was based on the method of Strickland and Parsons (1968). A Turner Model-111 fluorometer was used for measurement of chlorophyll in both extracted and direct continuous flow samples. The fluorometric method is not as precise as the spectrophotometric method, but it is faster and more adaptable to measuring small amounts of chlorophyll (NYU 1973).

6.3.1.1 Microscopic Analysis of Nannoplankton-net samples

Microscopic analysis of the nannoplankton-net samples showed no significant damage to diatoms exposed to increments of 8.3, 12.2, 15.5, 18.3, and 23.3C above an ambient water temperature of 21.7C for periods of 2.5, 30, and 60 min. (Table 6-4). The results of culturing algal samples which had been thermally shocked showed no shift in algal groups from diatoms to greens or blue-greens in these samples as compared to controls. Species diversity also appeared unaffected by the thermal shock (Table 6-5).

Table 6-4.

DAMAGED DIATOMS AFTER HEAT EXPOSURE

Ambient water temperature 39 F
Percent damaged in control samples 39% ± 8.2 (6 samples)
March-April 1971

Exposure Time (mins)	Percentage Damaged Specimens Exposure temperature (F) above ambient 15	22	28	35	42
2½	52	41	44	41	36
30	45	35	30	30	36
60	43	40	46	N.S.	N.S.
Mean	47	39	40	36	36

N.S. = Not studied.

Source: NYU 1974a, appendix.

Table 6-5.

Phytoplankton - Number per Liter and Percent Change
Thermal Shock - Growth Studies (16 Days)
Hudson River 8 to 24 April 1971*

		ΔT(F)									
		15		22		28		35		42	
Exposure Time (minutes)		No./L	% Change from Control	No./L	% Change from Control	No./L	% Change from Control	No./L	% Change from Control	No./L	% Change from Control
2.5	Test	4725000	+194.1	2754000	+ 14.1	2646000	+48.1	3987000	+134.0	5031000	+23.4
	Control	1606500		2403000		1786500		1703984		4077000	
10.0	Test	2046000	+ 14.8	3537000	+141.1	1471500	- 6.1	1062000	- 40.2	2544000	+32.4
	Control	1782000		1467000		1561500		1489500		1921500	
30.0	Test	2304000	- 47.9	2508000	- 5.0	2568000	- 9.7	642600	+102.3	878912	0.0
	Control	4419000		2641500		2844000		317700		878912	
60.0	Test	1380000	- 7.6	1128000	+ 33.2	2208000	- 9.2				
	Control	1494000		842248		2432000					

t-test value (paired) = 1.567

critical t-value (0.05) = 2.110

* Ambient Temperature = 48 F

Source: NYU 1974a, appendix.

6.3.1.2 Whole-Water Sample Studies

The whole-water samples were exposed to elevated temperatures by heating them on magnetic-stirrer hot plates. Once the desired temperature was reached, the sample was maintained at that temperature for the desired exposure time. At the end of the exposure period the samples were returned to an ambient bath. After cooling, each 3-liter whole-water sample was thoroughly mixed and subdivided into six 300-ml BOD bottles. Each set of six bottles consisted of four light (uncovered) and two dark (covered) bottles.

The samples were innoculated with 1 ml of Na $H_{14}CO^3$ (10 microcuries per ml) according to the standard $_{14}C$ uptake procedure (Steemann-Nielsen 1952) with modifications by Saunders et al (1962). After innoculation, samples were placed in a wooden trough for a four hour period. They were maintained at either intake or discharge water temperature by running water supplied to the trough from the intake or discharge canal, respectively. Illumination was from "cool white" fluorescent lamps with intensities ranging from 500 to 600 foot candles. After incubation, 50 ml of each water sample was filtered through a millipore 0.45 micron, 47 mm diameter membrane at 15 in. mercury vacuum pressure. The filters were rinsed with previously filtered Hudson River water and were immediately placed in a scintillation vial containing 20 ml of a toluene-based fluor consisting of 1832 ml toluene, 100 ml Triton X, and 168 ml Packard prepared scintillation fluor.

The activity counts per min. of each sample were automatically counted on a Nuclear Chicago three-channel liquid scintillator for two 10-min. periods. The channels ratio method (Wang and Willis 1965) was used to account for unequal quenching in the samples. A Quench-correction curve was established using a set of Amersham Searle, Inc. homogeneously quenched standards. Using the standardized quench-correction curve, the efficiency of each sample was ascertained and absolute disintegrations per minute for each sample were calculated. Self-absorption effects were modified by rinsing after filtration and reducing the amount of water filtered to 50 ml (approximately 150 mg wet weight of material).

In 1972, the only significant reduction in $_{14}C$ uptake occurred after a 20 min. exposure to a final temperature of 36.1 C, which represented an increase of 16.7 C above the spring season ambient water temperature of 19.4 C. The only significant increase in $_{14}C$ uptake occurred after a final temperature of 34.4 C, which represented a 45 min. exposure to a thermal increase of 9.4 C above the summer season ambient water temperature of 25 C (NYU 1973).

In 1973, samples from the Hudson River algal community were also exposed to a laboratory thermal regime and were evaluated for their tolerance in terms of both $_{14}C$ uptake and chlorophyll content. Exposures to temperatures above seasonal ambient were simulated (Fig. 6-5; Table 6-6). Spring, summer, and fall communities experiencing ambient temperature ranges of 19.5 to

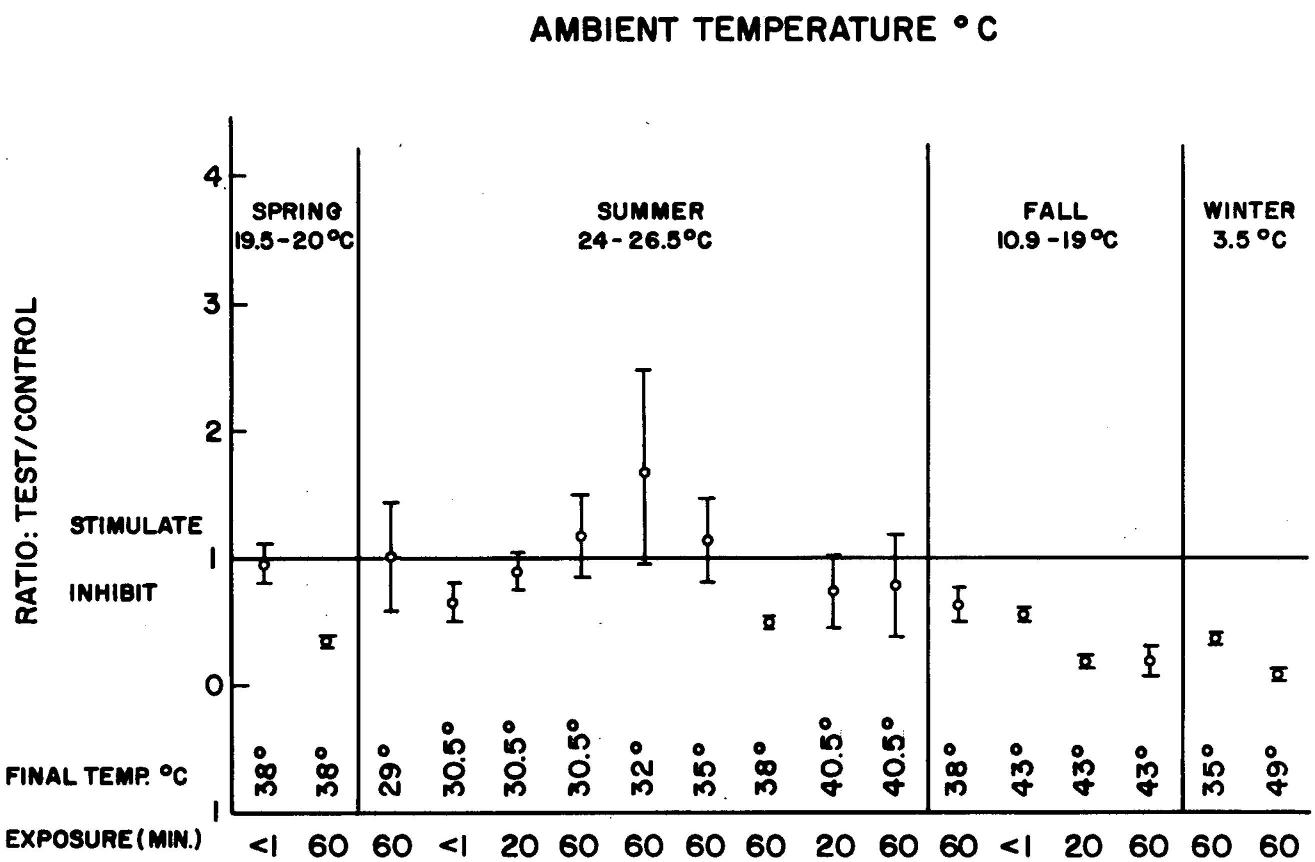


Figure 6-5. Changes in primary productivity of Hudson River phytoplankton after simulated thermal exposures at various seasonal ambient temperatures.

Source: NYU 1974a.

Table 6-6. Changes in primary productivity (^{14}C uptake) of Hudson River phytoplankton after heat shock.

Date	Ambient Temp. (C)	Final Temp. (C)	Exposure	Ratio test/ control	S.E.	D.F.*
Spring						
6/13/73	19.5	38.0	60 min	.35	± .01	10
6/15/73	20.0	38.0	<1 min	.96	± .07	10
Summer						
7/24/73	25.0	29.0	60 min	1.02	± .19	10
7/31/73	26.5	30.5	<1 min	.66	± .06	10
7/31/73	26.5	30.5	20 min	.91	± .06	10
7/24/73	25.0	30.5	60 min	1.17	± .15	10
7/23/73	25.5-26.5	32.0	60 min	3.25	± .49	18
8/22/73						
7/20/73	26.0	35.0	60 min	1.15	± .15	10
7/30/73	26.0-26.5	38.0	60 min	.74	± .028	18
8/22/73						
9/18/73	24.0	40.5	20 min	.75	± .12	8
9/18/73	24.0	40.5	60 min	.78	± .17	8
Fall						
11/29/73	10.9-16.8	38.0	60 min	.64	± .0031	10
10/22/73						
10/22/73	16.8	43.0	< 1 min	.5699	± .053	10
	16.8	43.0	20 min	.202	± .018	10
10/15/73	17.0-19.0	43.0	60 min	.205	± .0032	18
10/24/73						
Winter						
12/19/73	3.5	35.0	60 min	.637	± .015	4
	3.5	49.0	60 min	.08	± .003	4

* D.F. = degrees of freedom.

Source: NYU 1974a.

20.0 C, 24.0 to 26.5 C, and 11 to 19 C, respectively, all showed decreases in productivity following exposure to temperatures of 38.0 C for 60 min. (Fig. 6-5). Summer communities exposed to a combination of a lower overall temperature and exposure time, i.e., 30.5 C for less than one min., showed decreased productivity; a higher temperature increase and longer exposure time, 32.0 C for 60 min., stimulated productivity to some degree. The decreased $_{14}C$ uptake observed when this summer algal community was exposed for less than one min. to a final temperature of 30.5 differs from the trend toward increased $_{14}C$ uptake when the summer algal community was exposed to the same final temperature for a 60 min. exposure period. This response may indicate a potential for acclimation or accomodation on the part of the algal community (NYU 1974a). Winter communities at an ambient temperature of 3.5 C exhibited a lower temperature tolerance, resulting in decreased productivity when exposed to a final temperature of 35 C for 60 min. (NYU 1974a). Similar experiments performed during 1974 (NYU 1976a) also indicated inhibition of photosynthesis at ambient temperatures of 0.9-9.5 C (January-April) upon exposure to ΔT's of 20-34 C.

6.3.1.3 <u>Effects of Latent Thermal Exposure</u>

Phytoplankton communities were also examined for latent effects of thermal exposure. Photosynthetic rate and chlorophyll content were measured four and 24 hours after thermal exposure (Fig. 6-6, Table 6-7). Phytoplankton samples at an ambient temperature of 3.5 C were exposed to overall temperatures of 35 C and 49 C for

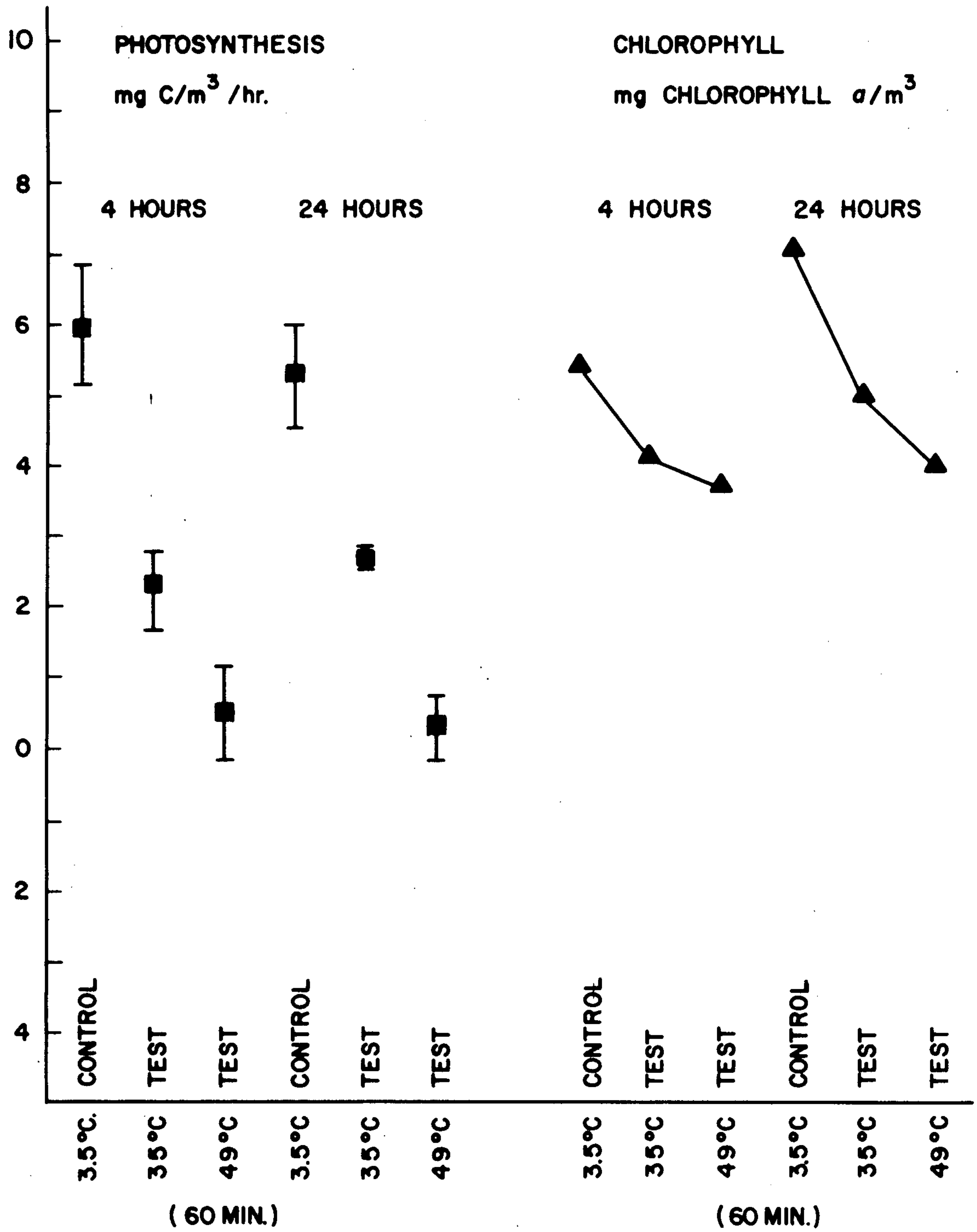


Figure 6-6. Photosynthetic rate and chlorophyll a content of Hudson River phytoplankton 4 hours and 24 hours after thermal exposure.

Source: NYU 1974a.

Table 6-7. Photosynthetic rate and chlorophyll content of Hudson River phytoplankton 4 hours and 24 hours after thermal exposure. Ambient temperature for each experiment was 3.5 C.

Date	ΔT (C)	Exposure time (minutes)	Photosynthetic rate			Chlorophyll a		
			$mgC/m^3/hr$	S.E.	D.F.	mg/m^3	S.E.	N
12/18/73		(control)	5.99	± .35	4	5.35	± 1.51	2
(4 hours after)	31.5	60	2.19	± .20	4	4.09	± .36	2
	45.5	60	0.50	± .23	4	3.70	± .45	2
12/19/73		(control)	5.26	± .26	4	7.03	± .88	2
(24 hours after)	31.5	60	2.68	± .06	4	4.92	± .799	2
	45.5	60	0.28	± .17	4	3.90	± .212	2

Source: NYU 1974a.

60 min. These temperatures, representing 31.5 C and 45.5 C ΔT's, produced a decrease in productivity at four and 24 hours after thermal exposure. Only two samples were used to determine the chlorophyll content 4 and 24 hours after thermal exposure. However, in each case the trend was toward decreased chlorophyll content after 4 and 24 hours exposure.

Fig. 6-7 shows the predicted inhibitory or stimulatory effects on phytoplankton productivity of mean maximum temperatures found at Indian Point condensers.

6.3.1.4 Upper Limits of Temperature Tolerance

The results of 1972 and 1973 studies (Section 6.3.1.2) showed that the $_{14}C$ uptake of Hudson River phytoplankton was not inhibited by ΔT's and final temperatures similar to those generated by the Indian Point plant. In 1973, studies were also conducted to obtain more specific data on the upper range of phytoplankton thermal tolerance. These experiments were performed in the fall of 1973 using samples of Hudson River phytoplankton communities exposed to thermal stress in the laboratory and incubated in the river at a depth of one foot at ambient light and temperature. Similar communities were maintained in the laboratory under comparable light and temperature. As shown in Fig. 6-8, the river-incubated cultures showed a significant decrease in primary productivity after 60 min. exposures at 37.8 and 43 C. The laboratory-incubated cultures also showed a significant decrease in primary productivity after exposure at 37.8 C. The laboratory exposure

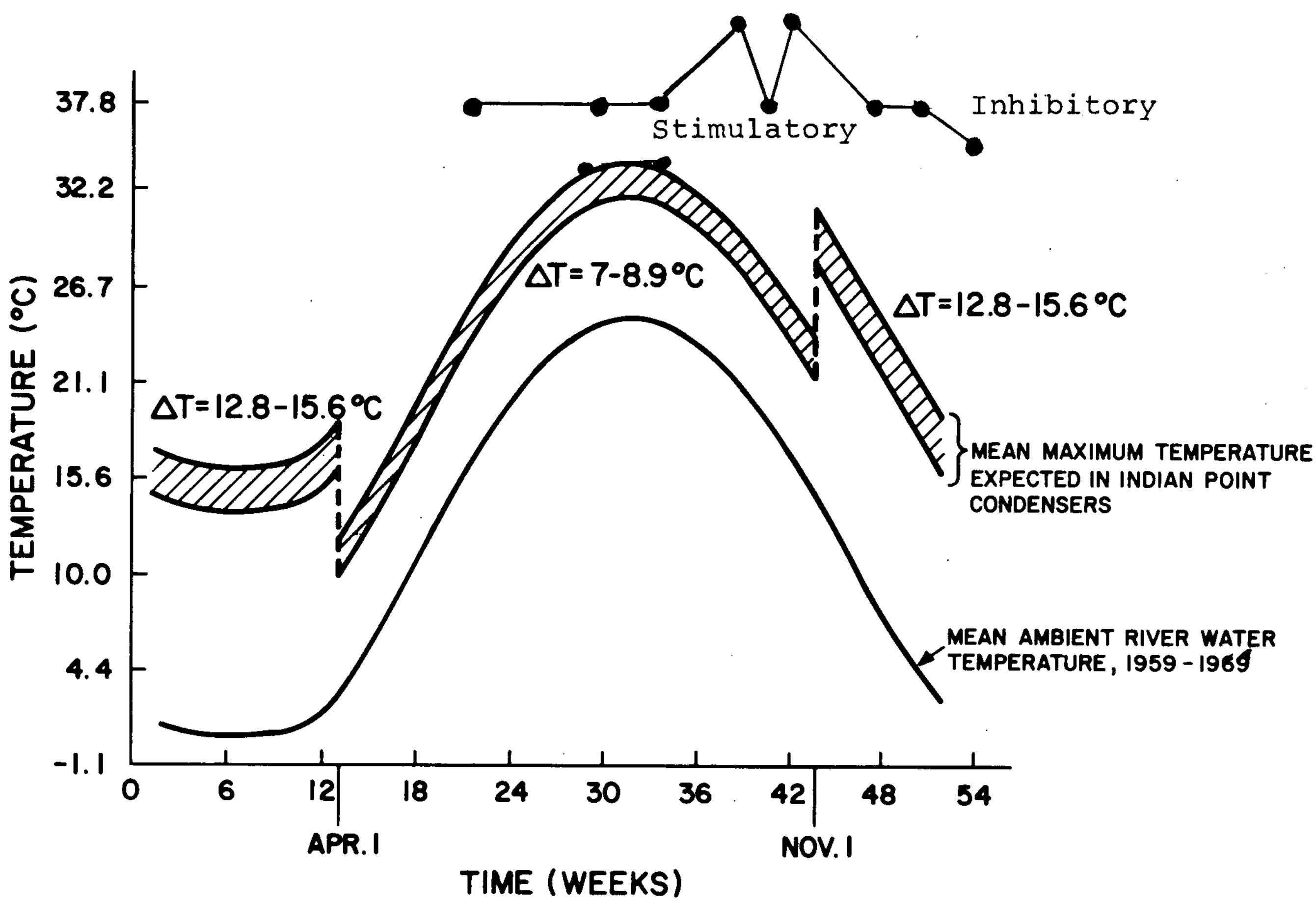


Figure 6-7. Mean of the maximum discharge temperatures expected throughout the year at the Indian Point Plant.

Source: NYU 1974a.

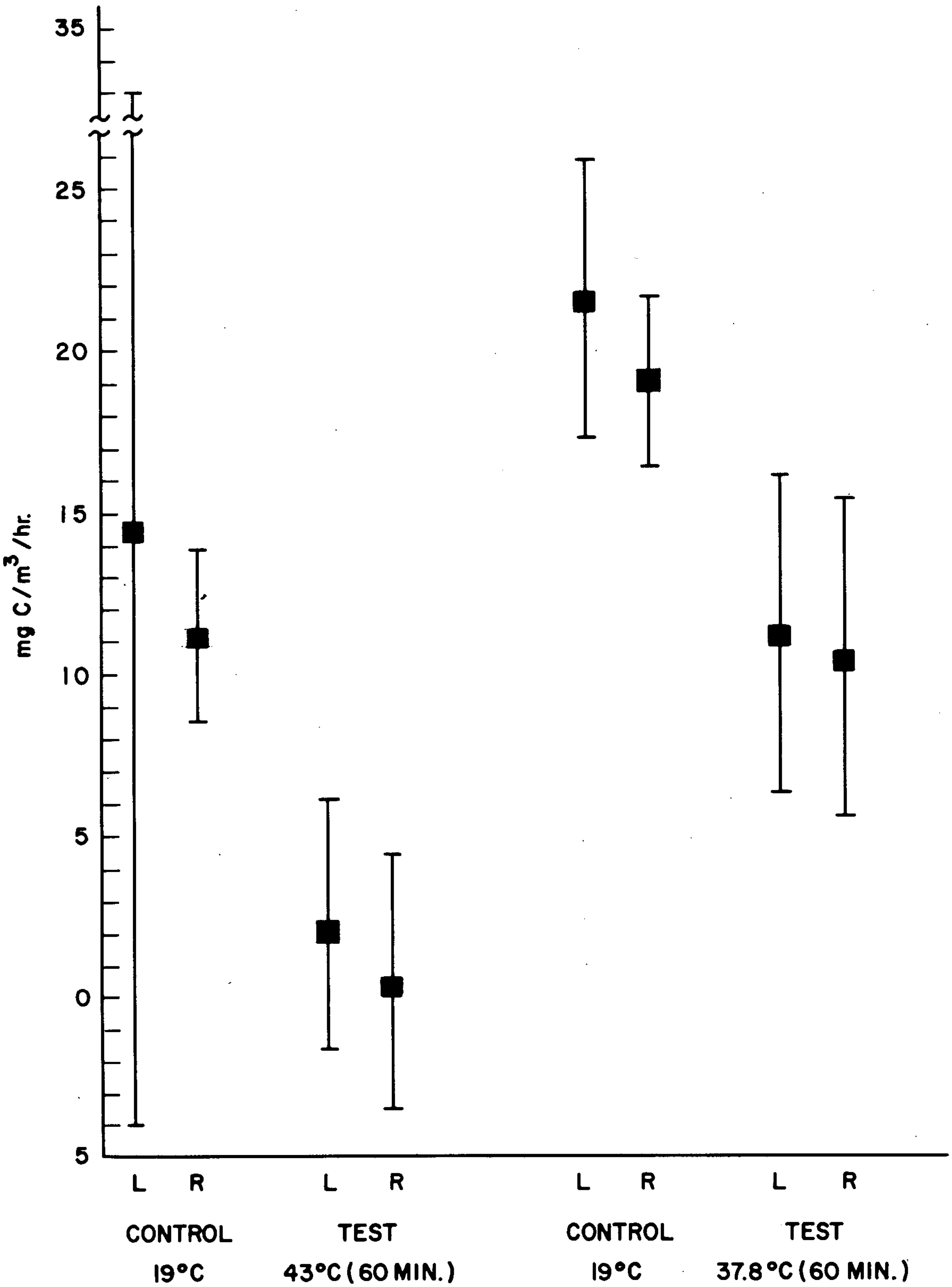


Figure 6-8. Primary Productivity of Hudson River phytoplankton communities incubated in the laboratory and in the River after thermal exposure.

Source: NYU 1974a.

at 43 C was not significantly lower due to the very high variance associated with the control samples (Fig. 6-8).

6.3.1.5 Imposition of Instantaneous ΔT

Laboratory studies simulating pump entrainment employed a slightly different test procedure that permitted a more rapid attainment of ΔT and test temperature and a more rapid return to ambient temperature. In this procedure, 100-ml aliquots in 250-ml flasks were heated to the test temperature in boiling water (30-45 sec). With one exception all tests were run with a ΔT of 8 C and were held at the test temperature for 16, 33, and 60 min. in thermostatically-controlled water baths. Fifty-ml aliquots in 250-ml flasks were cooled in a crushed-ice bath (60-120 sec). Aliquots for algal enumeration, photosynthesis and chlorophyll a determinations were removed and treated according to standard procedures.

Comparison of 1973 (non-instantaneous imposition) and the 1974 results showed that reductions in photosynthetic rate and, on occasion, chlorophyll a concentrations, occurred at lower final temperatures in 1974 than in 1973. Since the abundance and forms of algae in the two years were similar, and all experimental procedures except for the method of heating and cooling remained similar, it is concluded that the imposition of instantaneous ΔT on the phytoplankton may have had more of an effect than slow heating and cooling (NYU 1976a).

Nonetheless, these 1974 studies confirmed that the effects of entrainment of phytoplankton in the cooling water at Indian Point were minimal and would have, of themselves, little or no effect on population abundance and primary productivity in the river. (NYU 1976a).

6.3.1.6 Intake and Discharge-Canal Studies

While the plant was not on-line for power production the operation of the circulating pumps alone allowed visual determination of the extent of any mechanical damage to the flora. Samples were collected from the intake and discharge at two hour intervals (11 samples over a two day period). The samples were analyzed for physical breakage and chloroplast dislocation in the diatom frustules.

The results of analyses of intake and discharge canal samples did not indicate any substantial physical damage to phytoplankton from being pumped through the plant (NYU 1973).

6.3.1.7 Plume Entrainment Studies & Chlorine Effects

In 1974, phytoplankton plume entrainment studies were conducted in addition to the Indian Point cooling system entrainment studies. Phytoplankton were collected from plume water. These were then distributed into bottles which were incubated *in situ* in the plume water. The results of these experiments indicated that there was some reduction in productivity in the surface samples after plant chlorination and heat shock (NYU 1976b).

In 1975, these studies were extended and modified. Laboratory experiments were designed to measure the effect of known concentrations of chlorine and/or increased temperature on the phytoplankton which were entrained within the plume discharge rather than by the Indian Point intake water system.

The limit of chlorine tolerance determined for phytoplankton from laboratory studies was found to be greater than or equal to 1.0 mg/1 chlorine. This exceeds the level (0.05 mg/1) which would be encountered by plume entrained organisms (NYU 1976b).

The 1974 laboratory thermal tolerance studies on plume-extrained phytoplankton concluded that a 2 C and 5 C rise in temperatures would have little effect on the composition of the phytoplankton population.

However, laboratory toxicity tests performed during 1975 indicated that low levels of chlorine and heat do produce changes in the metabolic capacity of the phytoplankton. These additions, however, have not produced any significant changes in the abundance of the Hudson River phytoplankton (NYU 1976b).

SECTION 7

MICROZOOPLANKTON

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7. MICROZOOPLANKTON

7.0 SUMMARY

River abundance studies indicated that crustaceans, rotifers and protozoans were the most abundant taxa in the Indian Point area. Near-field data found essentially similar patterns among years in the composition, abundance and distribution of microzooplankton species in the area (NYU 1977). Results from intake and discharge-canal studies, including latent effects analyses, have shown that survival of copepods and cladocerans is generally quite high throughout most of the year. During mid-summer, however, survival of calanoid and cyclopoid copepods was significantly reduced on those occasions when a ΔT of 8.3 C was attained, or during chlorination. Nevertheless, the data collected indicate that microzooplankton river populations have not been adversely affected by the operation of the Indian Point plant.

7.1 INTRODUCTION

The microzooplankton consist of those primarily holoplanktonic organisms commonly referred to as "the grazers." This trophic level is generally considered to function between the producers (phytoplankton, detritus) and the higher invertebrates. Results from four years of study (NYU 1973; 1974a; 1976a; 1977) have indicated that essentially no substantial differences existed among years. Therefore, any study year would serve equally well to illustrate what has been determined for microzooplankton in the Indian Point area. Results from 1974

(NYU 1976a) were selected to provide most of the detailed analyses contained in this report; conclusions drawn from that year's data also apply to other years (unless otherwise indicated).

7.2 METHODS AND MATERIALS

7.2.1 River Abundance Studies

Day and night microzooplankton samples were collected twelve times during the April through December sampling period at each of the seven Hudson River stations (Fig. 6-1). Sample collections were made every two weeks from the end of April through July and then, once each month from August through December. Microzooplankton were collected and preserved using procedures retained throughout all years (NYU 1977); a #20-mesh plankton net was drawn vertically through 10M of water, the plankton washed into a jar and preserved with 10% formalin. Replicate 1 ml aliquots from each sample were identified and enumerated (NYU 1977). The concentration of organisms in the river samples was calculated using the formula:

$$\text{number of organisms/liter} = \frac{AV}{RC}$$

Where:

A = average of two 1 ml counts

V = volume of sample

R = revolutions recorded on flowmeter

C = volume correction factor for flowmeter; and

RC = volume of water filtered by the net

Microzooplankton data were analyzed by a two-way, factorial analysis of variance (ANOVA) for differences among stations (NYU 1977).

7.2.2 Intake and Discharge-Canal Studies

Replicate microzooplankton samples were collected each month throughout 1974 from two Unit No. 1 intakes (I-1 and I-2), and from two discharge-canal stations (D-1 and D-2) for use in estimating the abundance and viability of entrained microzooplankton (in 1975, intake sampling was performed only at Unit No. 2). Samples were collected with 0.5 m diameter #20-mesh nets equipped with TSK flowmeters. The nets were attached to velocity reduction cones (designed to reduce the flow of water through the nets) and were mounted on a rigid rack assembly at each station (Fig. 8-3). Sampling duration was three min. Abundance comparisons among years were made on the basis of catch per unit effort, C/f (NYU 1976a).

Immediately after collection, the samples were transported to the on-site laboratory for viability analyses and abundance estimates. To study latent effects, the samples were maintained in a circulating water table at ambient river temperature. Two 1 ml samples from each collection were examined and the number of dead organisms was recorded. The criterion for death was the lack of motor response upon probing. After the initial examination, 100 ml of a uniformly mixed sample was placed in a culture dish and returned to the circulating water table for latent mortality assessment; the remainder was preserved with formalin. Abundance estimates for plant samples followed the same procedures used for the river populations (Section 7.2.1).

7.3 RESULTS

7.3.1 River Abundance Studies

The most abundant forms of microzooplankton in the Hudson River in the vicinity of Indian Point area are crustaceans, rotifers, and protozoans (NYU 1976a; 1977). A listing of taxa found during a representative study year (1974) is given in Table 7-1. Seasonal abundance of total microzooplankton is illustrated for this year in Fig. 7-1. There were no significant differences between day and night abundances for each of the three major groups (NYU 1976a). Fluctuations in total microzooplankton abundance paralleled that of each of the major groups, with the peak total microzooplankton abundance occurring from June through August (NYU 1976a).

Eurytemora affinis and *Acartia tonsa* were reported to be the most abundant copepods (class Crustacea) in the lower Hudson during each year sampled (NYU 1973; 1974a; 1976a; 1977). *A. tonsa* was

Table 7-1. Microzooplankton Species List

Crustacea
  Copepoda
    Acartia tonsa Dana
    Canthocamptid
    Canuella sp.
    Diacyclops bicuspidatua Claus
    Ectinosoma curticorne Boeck
    Epischura sp.
    Ergasilus sp.
    Eurytemora affinis (Poppe)
    Halicyclops fosteri M.S. Wilson
    Nauplii
    Copepodids

Cladocera
    Bosmina longirostris (O.F. Muller)
    Chydorid
    Daphnia pulex Leydig
    Diaphanosoma brachyurum (Lieven)
    Leptodora kindtii (Focke)
    Moina sp.

Ostracoda (no further identification)

Cirripedia
  Nauplii

Rotifera
    Asplanchna sp.
    Brachionus agnularis Grosse
    Brachionus calyciflorus Pallas
    Brachionus quadridentata Herman
    Filinia longiseta (Ehrenberg)
    Keratella cochlearis (Grosse)
    Keratella quadrata (Muller)
    Keratella serrulata Ahlstrom
    Kellicottia longispina (Kellicott)
    Lecane sp.
    Notholca accuminata (Ehrenberg)
    Philodina sp.
    Platyias patulus Ahlstrom
    Platyias quadricornis Ahlstrom
    Pleosoma trunctatum (Levander)
    Polyarthra sp.
    Synchaeta sp.
    Trichocerca sp.
    Unidentified sp. # 1
    Unidentified sp. # 3

Table 7-1. (cont.)

Protozoa
- Plasmodroma
  - Mastigophora
    - _Arcella_ sp.
    - _Centropyxis_ sp.
    - _Ceratium hirundinella_ (Muller)
    - _Coelastrum_ sp.
    - _Difflugia_ sp.
    - _Dinobryon_ sp.
    - _Errerella_ sp.
    - _Eudorina_ sp.
    - _Euglypha_ sp.
    - _Pandorina_ sp.
    - _Pleodorina_ sp.
    - _Voluox_ sp.

Ciliophora
- Ciliate
  - _Carchesium_ sp.
  - _Codonella cratera_ (Leidy)
  - _Epistylis_ sp.
  - _Tintinnopsis_ sp.
  - _Vorticella_ sp.

Suctorid
- _Metacineta_ sp.
- _Staurophrys_ sp.

Miscellaneous
- Gastropod veliger
- Polecypod veliger
- Annelid larvae
- Nematode
- Tardigrade

Source: NYU 1976a.

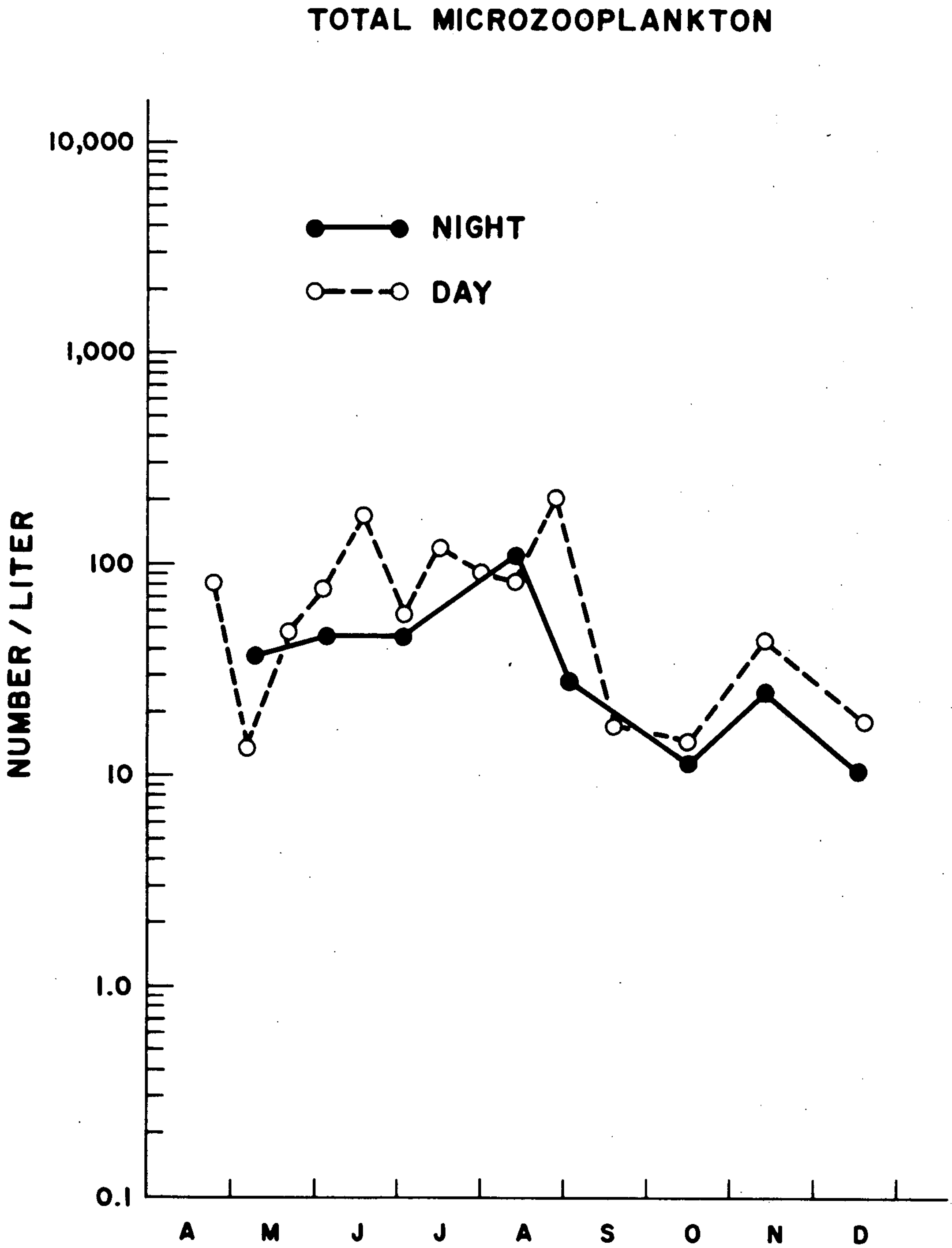

Figure 7-1. Day and night abundances of total microzooplankton, 1974.
Source: NYU 1976a.

observed only during the summer and fall while E. affinis occurred throughout the sampling period. The cyclopoid copepods, Diacyclops bicuspidatus and Halicyclops fosteri, were generally less abundant than the calanoid copepods (such as E. affinis and A. tonsa). D. bicuspidatus was the dominant cyclopoid copepod during fall and early spring, while H. fosteri was the most abundant cyclopoid copepod at Indian Point during June (Figs. 7-2 and 7-3).

The calanoid copepod E. affinis began to increase in numbers in May; it was present consistently from May until November. E. affinis was the most abundant calanoid copepod sampled during August (NYU 1976a).

A. tonsa appeared in samples during July and, along with E. affinis was abundant during August. E. affinis and H. fosteri were the most abundant species in September and October. Harpacticoid copepods were never present in great numbers; the period of greatest abundance was in July and August, when Canuella sp. was present in relatively large numbers. The abundance of cladoceran species (represented primarily by Bosmina longirostris and Diaphanosoma brachyurum) also peak during the summer months (NYU 1976a). D. brachyurum is collected much less frequently at other times, although B. longirostris occurs frequently throughout the sampling year. reaching its highest observed abundance during June. Rotifers, of which Notholca accuminata, is the predominant species, were observed to have

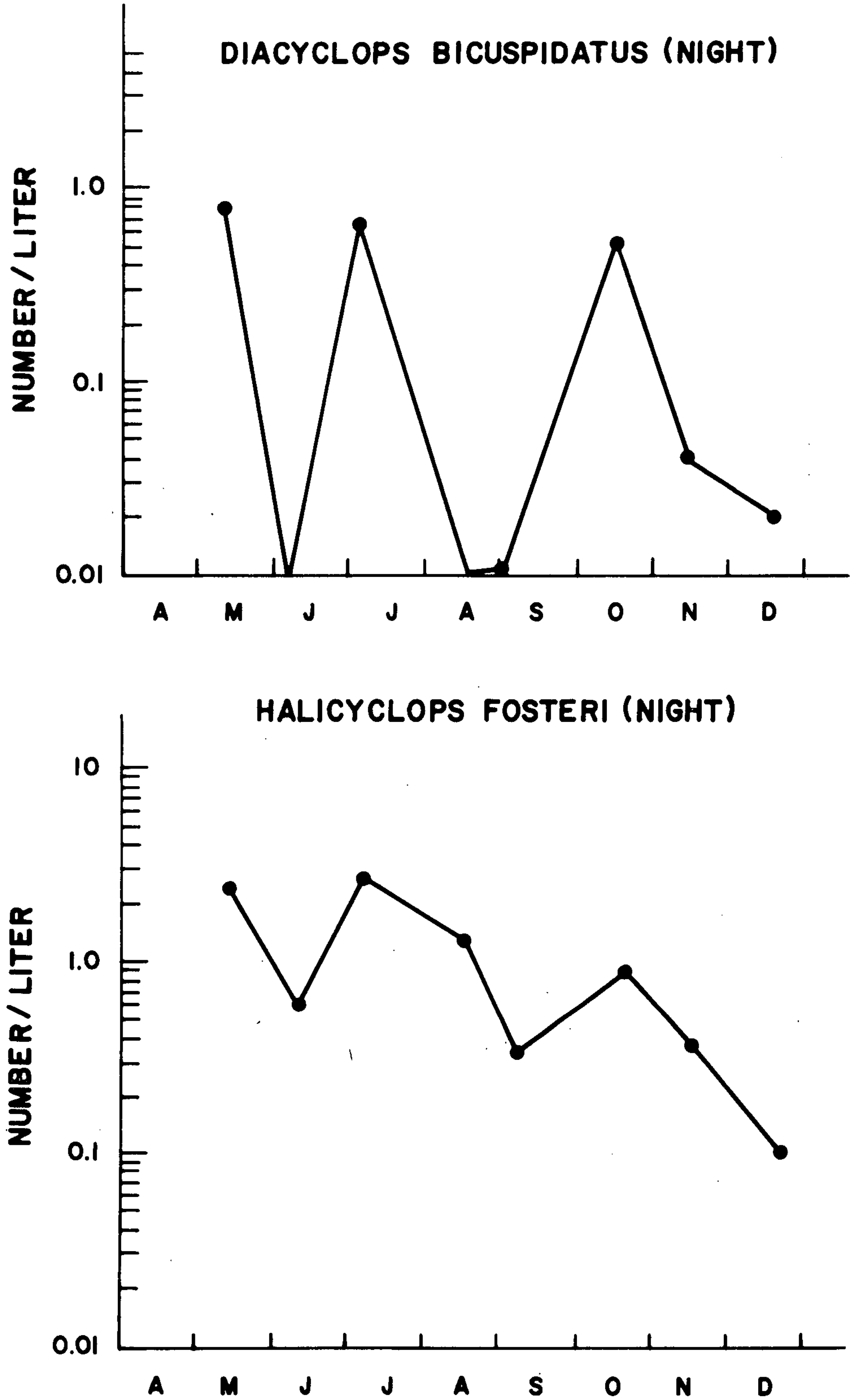

Figure 7-2. Night abundance of cyclopoid copepods <u>Diacyclops bicuspidatus</u> and <u>Halicyclops fosteri</u>.

Source: NYU 1976a.

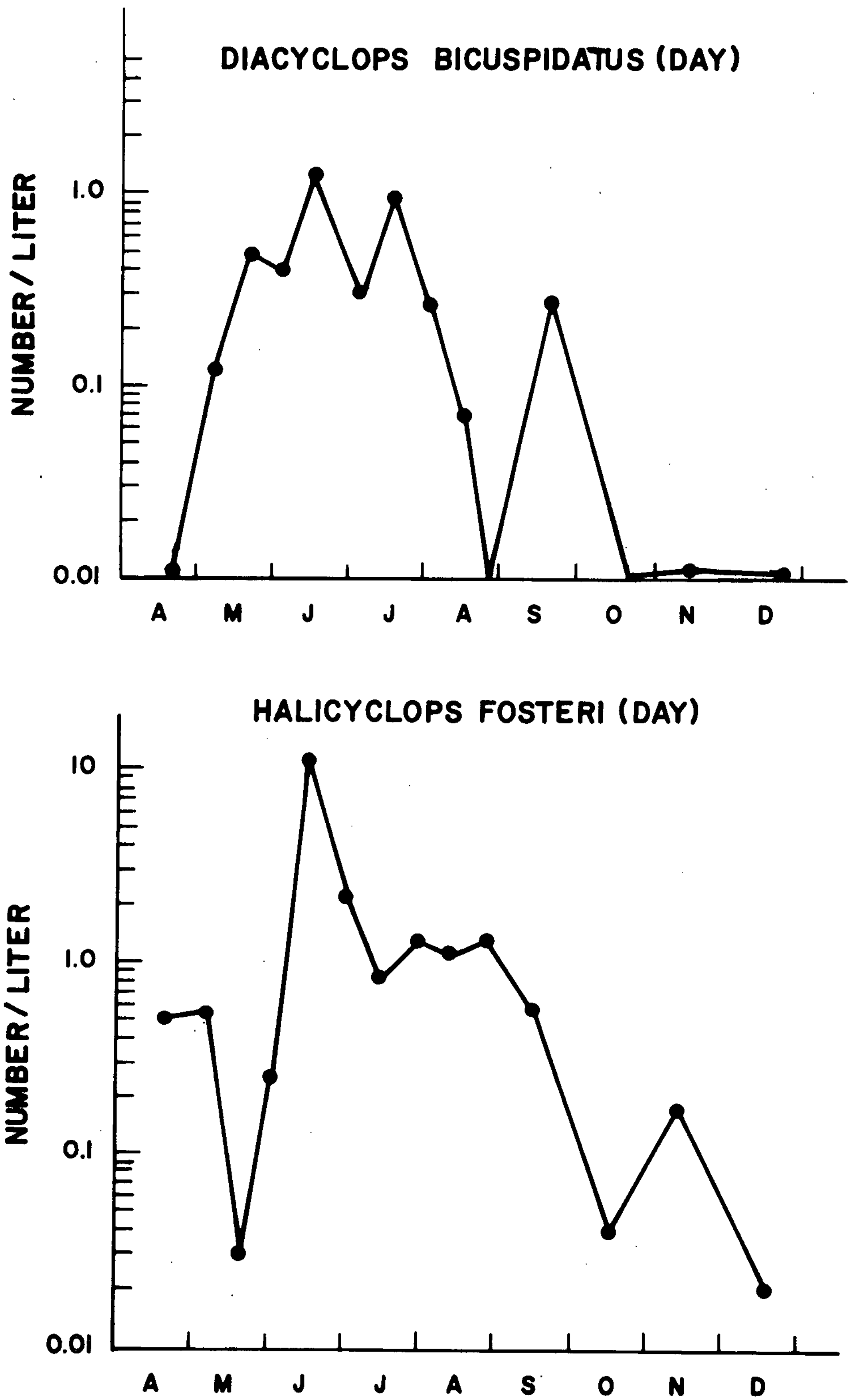

Figure 7-3. Day abundance of cyclopoid copepods *Diacyclops bicuspidatus* and *Halicyclops fosteri*.

Source: NYU 1976a.

peak abundance during the spring and fall, with about 60% being collected during the day (NYU 1976a).

7.3.2 Intake and Discharge-Canal Studies

The survival of selected groups of entrained microzooplankton in plant samples collected each month from March through December 1974 is shown in Table 7-2. There was 100% survival of all organisms at all stations during June. However, it should be noted that during June, the abundance of cyclopoid copepods far exceeded that of the more sensitive (NYU 1973) calanoid copepods. Mortality during July and August for total microzooplankton was primarily attributable to calanoid copepods. In August, microzooplankton survival at the intake stations was significantly higher than at either of the discharge stations. During August and September, although 100% of the cyclopoid copepods collected at Station D-1 survived plant passage, none were alive at D-2 (Table 7-2). Since there is little decrease in ΔT from D-1 to D-2 as the cooling water moves down the discharge canal, and since these two stations are basically similar, these mortalities probably reflect a time-temperature synergism affecting the thermal tolerance of these copepods (NYU 1976a). During most of the year, there was excellent survival of cyclopoid and harpacticoid copepods and cladocerans following plant passage (Table 7-2).

Latent mortality was assessed using several different holding times (Table 7-3). After one week (168 hrs) there was less than 10% survival in samples collected from both the intake and

Table 7-2. Mean percent survival of entrained microzooplankton at Unit 1 intakes (I), discharge-canal stations (D-1, D-2), and discharge port (DP) by month, 1974. Station suffix (Cl) indicates chlorination.

	Mean % Survival ± S.E.					
Month	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copepods	Cladocerans
March						
I	50.0 ± 50.0	0	75.0 ± 35.4	100.0	50.0 ± 50.1	0
D1	50.0 ± 50.0	0	50.0 ± 50.0	50.0 ± 50.0	66.7 ± 33.9	0
D2	N.S.*	N.S.	N.S.	N.S.	N.S.	N.S.
April						
I	94.4 ± 3.4	97.5 ± 1.6	94.9 ± 2.8	100.0	95.9 ± 2.2	0
D1	75.0 ± 1.6	57.1 ± 60.6	90.6 ± 9.4	58.3 ± 36.9	75.9 ± 6.8	1.0
D2	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
May						
I	72.1 ± 21.2	63.5 ± 26.6	100.0	100.0	72.1 ± 21.2	100.0
D1	65.7 ± 2.5	57.0 ± 2.9	100.0	100.0	64.9 ± 4.8	100.0
D2	N.S.	N.S.	N.S.	N.S.		100.0
DP	63.1 ± 4.8	48.8 ± 5.5	100.0	100.0	59.6 ± 2.6	100.0
June						
I	100.0	100.0	100.0	100.0	100.0	100.0
D1	100.0	100.0	100.0	100.0	100.0	100.0
D2	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
July						
I	98.2 ± 18.0	97.4 ± 2.5	100.0	100.0	98.5 ± 2.1	93.8 ± 6.3
D1	98.6 ± 0.9	100.0	100.0	98.0 ± 2.0	99.7 ± 0.3	62.5 ± 37.6
D2	93.1 ± 2.9	89.1 ± 5.4	99.2 ± 0.8	91.1 ± 2.2	93.1 ± 2.5	87.5 ± 12.5
August						
I	97.3 ± 0.9	96.9 ± 1.0	100.0	100.0	97.2 ± 0.9	100.0
D1	80.8 ± 2.2	73.3 ± 2.9	100.0	100.0	80.0 ± 2.3	100.0
D2	89.5 ± 1.8	87.5 ± 2.3	0	93.6 ± 3.1	88.9 ± 1.9	100.0

*N.S. No Sample

Table 7-2. (cont.)

Month	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copedpods	Cladocerans
	Mean % Survival ± S.E.					
September						
I	100.0	100.0	100.0	100.0	100.0	100.0
D1	92.9 ± 3.5	85.7 ± 6.6	100.0	100.0	90.9 ± 4.3	100.0
D2	97.1 ± 2.1	85.7 ± 9.3	100.0	100.0	95.0 ± 3.5	100.0
D1 (C1)	00.0	100.0	100.0	N.P.	1.0	100.0
D2 (C1)	88.0 ± 4.6	93.3 ± 4.6	0.0	100.0	83.3 ± 6.2	100.0
October						
I	94.6 ± 4.0	85.4 ± 7.6	98.2 ± 1.7	75.0 ± 25.1	96.8 ± 2.2	83.4 ± 16.7
D1	87.4 ± 12.6	86.7 ± 13.4	89.1 ± 11.0	78.6 ± 21.5	88.3 ± 11.7	83.3 ± 10.5
D2	76.3 ± 24.3	81.3 ± 18.8	95.2 ± 4.8	100.0	94.0 ± 6.0	100.0
D1 (C1)	88.8 ± 4.9	80.0 ± 14.2	96.0 ± 1.7	91.2 ± 5.7	90.6 ± 4.0	87.5 ± 12.5
D2 (C1)	89.1 ± 9.4	76.2 ± 9.0	100.0	81.2 ± 14.5	88.5 ± 1.0	100.0
November						
I	100.0	0	100.0	100.0	100.0	100.0
D1	80.0 ± 12.7	100.0	100.0	50.0 ± 25.1	87.5 ± 12.3	100.0
D2	93.8 ± 0.9	95.5 ± 4.6	100.0	75.0 ± 15.0	93.4 ± 0.9	100.0
December						
I	84.6 ± 15.4	100.0	78.6 ± 21.5	100.0	83.3 ± 16.7	100.0
D1	60.9 ± 16.5	60.0 ± 1.6	55.9 ± 22.6	100.0	46.7 ± 30.1	100.0
D2	70.0 ± 10.0	0.0	78.6 ± 21.5	100.0	68.8 ± 6.2	50.0 ± 50.0

Source: NYU 1976a.

Table 7-3. Latent mortality of entrained microcrustaceans retained at ambient temperature for 1, 4, 6, 24, and 48 hours following capture at Indian Point. (I1=Unit 1 intake; D1 and D2=Discharge canal stations; Cl=chlorination; S.E.=standard error for duplicate samples).

	Temperature		Percent survival ± S.E.				
Date	Intake	ΔT	1 hr	4 hrs	6 hrs	24 hrs	48 hrs
04/30							
I1	16C	2C	80.6 ± 2.8				62.5 ± 4.2
I1			94.4 ± 5.6				74.2 ± 7.6
D1			57.4 ± 4.4				28.2 19.4
07/31							
I1	25C	3C	95.5 ± .7	76.9 ± 8.0		18.4 ± 9.9	
D1			89.5 ± 7.5	80.3 ± 1.8		72.8 ± 4.2	
D2			91.5 ± 3.1	47.3 14.0		19.8 16.8	
08/18							
I1	25.2C	8.3C	98.1 ± 1.0		85.7 ± 5.0	38.0 ± 6.6	
D1			76.5 ± 4.5		57.5 ± 3.5	31.6 ± 1.3	
D2			89.5 ± .6		75.5 ± 2.3	41.8 ± .45	
09/26							
I1	21.8C	4.7C	100.0			72.0 ± 1.4	
D1Cl			100.0			42.2 27.9	
D2Cl			85.7 ± 2.5			69.1 19.2	

Table 7-3 cont.

	Temperature		Percent survival ± S.E.				
Date	Intake	ΔT	1 hr	4 hrs	6 hrs	24 hrs	48 hrs
09/26							
D1			92.8 ± 7.2			78.5 ± 7.2	
D2			98.6 ± 1.4			98.5 ± 5.2	
10/24							
I1	14.9C	8.6C	91.5 ± 1.4			74.1 ± 2.8	60.8 ± 8.4
D1			79.3 ± 5.4			63.9 ± 1.3	41.5 12.8
D2			88.4 ± 2.7			83.2 ± 5.4	62.5 ± .35
10/31							
IC1	13.5C	9.0C	85.4 ± 1.4			94.7 ± 1.1	
D1C1			75.7 ± 2.6			88.2 ± 1.25	
D2C1			88.2 ± 8.5			84.1 ± .85	

Source: NYU 1976a.

discharge stations; therefore this holding period was not considered a valid test (NYU 1976a). Mortality in both the intake and discharge samples after one hour was 15-20% less than mortalities after 48 hours. Sample retention times of one day were considered optimal for observations of latent mortality of entrained microzooplankton.

In general, the difference between the intake and discharge survivals was not statistically significant; in some instances both values were rather low. This indicates that some common factor present in both intake and discharge samples on that day was responsible for the reduced survivals observed. This factor has not been identified (NYU 1976a).

All rotifers isolated from intake and discharge station samples were alive after 24 hours (NYU 1976a). Samples from the intakes were used as controls in testing for plant effects on the discharge samples. Rotifers held for longer periods of time (36 hours, 168 hours) showed almost total mortality with no apparent trend. It would appear, therefore, that maintaining rotifers for periods longer than 24 hours represented a test of culture technique rather than an assessment of latent entrainment effects (NYU 1976a).

SECTION 8

MACROZOOPLANKTON

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8. MACROZOOPLANKTON

8.0 SUMMARY

The macrozooplankton in each of the years studied were dominated numerically by Gammarus spp., Monoculodes edwardsii and Neomysis americana. The temporal and spatial distributions of these species in the area of Indian Point are discussed. Results from intake and discharge-canal studies indicated that the amphipods Gammarus spp. and M. edwardsi did not suffer significant mortalities during plant passage or throughout a subsequent latent period (except during those periods of condenser chlorination). When discharge temperatures reached 32 C, N. americana suffered significant reductions in survival. However, this species occurs in the Indian Point area only during those times of the year that the salt front is present. Since the salt front only occasionally extends more than a few miles upriver of the plant (Section 2.1.3.1.2), the entrainment mortality observed at Indian Point probably represents an effect on the geographical fringe of this species' distribution in the Hudson River. It has been estimated that the losses incurred at Indian Point are less than 1% of the river-wide population (Lawler, personal communication). Furthermore, it has been found that Neomysis contributes little to the diet of striped bass or white perch, so that its seasonal reduction in abundance as a result of the operation of Indian Point does not affect the available food supply for these fish.

8.1 INTRODUCTION

Macroinvertebrates in the Hudson River occupy both benthic and planktonic habitats. This group of invertebrates constitutes an important trophic link between the detritus and higher organisms in the Hudson River food web. Some macroinvertebrates occupy planktonic niches only during a portion of their life cycle (meroplankton) or may exist in either the benthic or planktonic habitat.

The most abundant macrozooplankton species found in the Indian Point area during 1971, 1973, and 1974 were Gammarus spp (G. daiberi, G. tigrinus, G. fasciatus), Monoculodes edwardsi and Neomysis americana (NYU 1976a; TI 1973a).

8.1.1 Species Addressed and Rationale

In 1974 the three major taxa listed above accounted for 67% of the total daytime macrozooplankton catch and 66% of the total nighttime catch. On a station-by-station basis Gammarus, Monoculodes and Neomysis accounted for between 53% and 87% of the total macrozooplankton daytime catch, and between 60 and 71% of the total nighttime catch (NYU 1976a). (A detailed description of macrozooplankton abundance studies appears in section 8.3.1). In addition to numerical abundance, the Gammarus spp. also occupy an important ecological niche in the lower Hudson River estuary. These three gammarid amphipods are important as food sources for fishes. In 1972, Gammarus spp. was the most important food item for white perch (Morone americana) age one and over. It was also found that 0+ and 1+ age groups of striped bass (Morone saxatilis) feed heavily, but not exclusively, on Gammarus spp. (TI 1973a). These organisms were also the major food source for the Atlantic tomcod (Microgadus tomcod) (LMS 1975a). Monoculodes edwardsi was also found to be an important food item for white perch while Neomysis americana apparently contributes little to the diet of either striped bass or white perch in the Hudson River (Ginn 1977).

8.1.1.2 Range and Limiting Factors of Addressed Species

The genus Gammarus is composed of numerous species distributed in freshwater, marine, and brackish-water habitats of the Northern hemisphere (Ginn 1977). The majority of North American gammarids occupy freshwater habitats; however, some freshwater forms such as G. fasciatus may occur in slightly brackish (1 ppt) waters. G. fasciatus has been recorded in rivers and lakes in the Great Lakes region and on the Atlantic Coastal Plain south to North Carolina (Holsinger 1972).

Gammarus tigrinus occurs from the Gulf of St. Lawrence to Chesapeake Bay. It is a brackish-water euryhaline species and is found in salinites of 1 to 25 ppt (Bousfield 1973).

Little information on Gammarus daiberi has been documented since the species was first identified. Bousfield (1973) indicates that the range of G. daiberi is from Delaware Bay to South Carolina with a possible northward extension to Long Island Sound. G. daiberi seems to prefer salinites of 1-5 ppt, although it has been reported to occur in up to 15 ppt (Ginn 1977).

Monoculodes edwardsi occurs from the Gulf of St. Lawrence to the Gulf of Mexico. The species is generally found in water less than 75 m deep and at salinites from 0.5 to 5.0 ppt.

Neomysis americana is found along the east coast of North America from the Gulf of St. Lawrence to Virginia (Tattersall 1951). The species generally occurs in shallow water at depths less than 60 m (Wigley and Burns 1971). The occurrence of N. americana in the Indian Point area, and thus its susceptibility to plant impact, coincides only with the intrusion of saline water (greater than 2 ppt) into the area (NYU 1974a; Ginn 1977).

8.2 METHODS AND MATERIALS

8.2.1 River Abundance Studies

Seven stations, designated A through G, were used for sampling sites (Fig. 6-1) during the four study years.

In 1973, because it was anticipated that the plant would be off-line for much of the year, the basic river sampling design was modified to focus on the relationship of the spatial distribution of macroinvertebrates (and ichthyoplankton) by the river to the numbers entrained in the plant. Sampling was done by tows at four stations designated R-1 through R-4. They were arranged on a transect extending from in front of Units Nos. 1, 2 and 3, to the shoal area of Tompkins Cove on the west side of the river (Fig. 8-1). Table 8-1 shows the river-depth contours and approximate distances from the plant intake for each tow path. Collection nets utilized in plant entrainment studies did not vary throughout the four-years of intensive study; nets used in

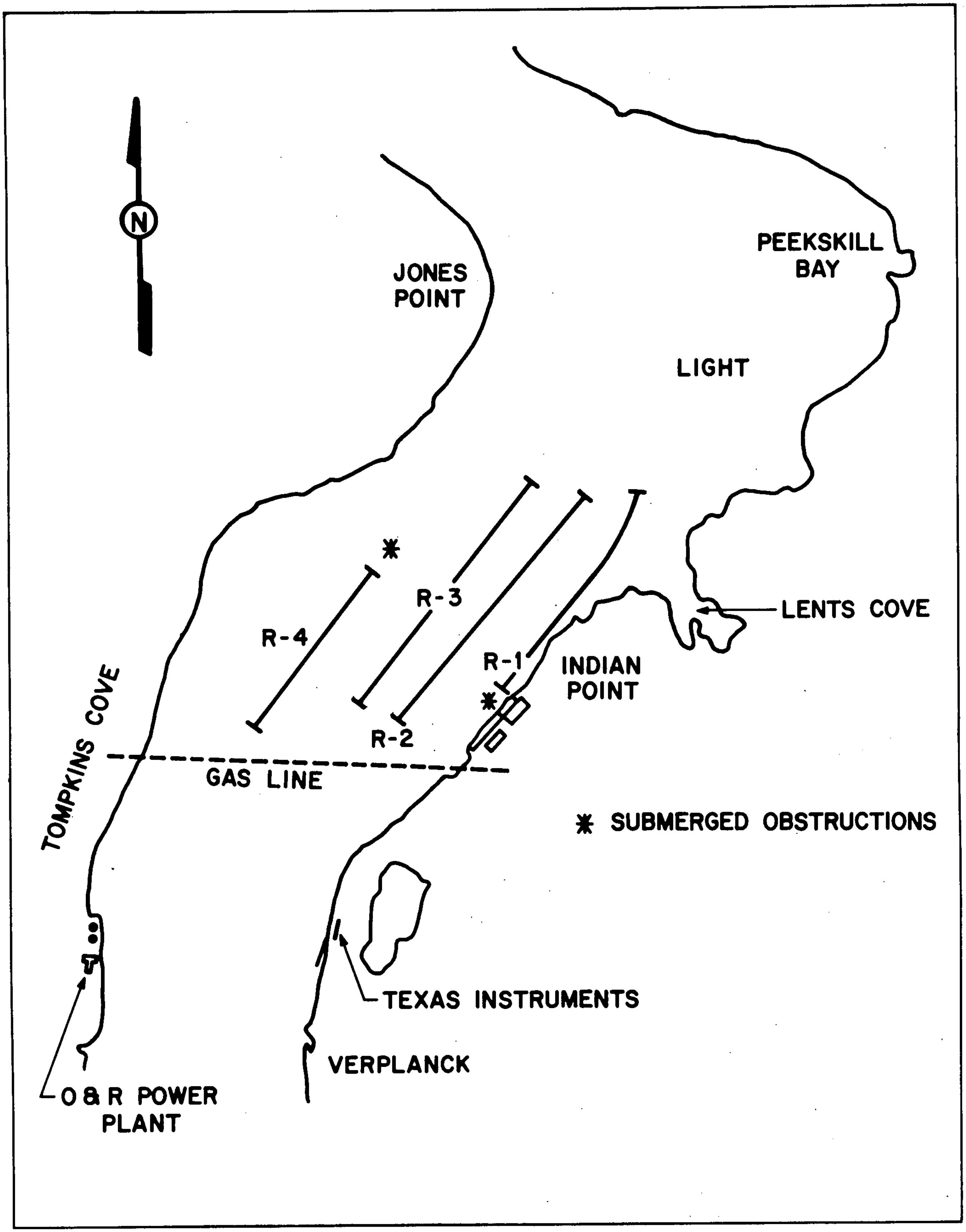

Figure 8-1. Sampling Stations.
Source: NYU 1976a.

Table 8-1. **Location of 1973 Hudson River sampling stations relative to depth contour and distance from Indian Point Unit 2 intake.**

Tow path	Approximate depth contour	Approximate distance from plant intake
R-1	50 feet	125 feet
R-2	60 - 75 feet	1000 feet
R-3	50 feet	1760 feet
R-4	25 - 30 feet	2875 feet

Source: NYU 1976a.

river population sampling varied as improvements in methodology were made (Table 8-2). Deployment of both the 0.5 m and 1.0 m (Hensen-type) river nets was identical (Fig. 8-2), each tow lasting ten min. against the prevailing current. Detailed discussion of both the sampling techniques and collection gear used may be found in the four annual reports (NYU 1973; 1974a; 1976a; 1977).

During 1971 and 1972, macroinvertebrates (and ichthyoplankton) samples were collected from the seven river stations on two days and one night each week during the striped bass egg and larvae season, which usually occurs from late April through July. From July through December, samples were collected one day every two weeks and one night each month.

Each of the four transect plankton tows was conducted concurrently with the 50 min. net sampling for abundance at the Unit No. 1 intake. All stations were sampled once every two hours for a 24 hour period once each week from May 29 through July 24. After July 24, samples were collected once every two weeks until October to encompass the season for the other fish species.

In 1974 and 1975, a return to sampling for macroinvertebrates and ichthyoplankton at the seven river stations was conducted to coincide with the net samples taken at the Indian Point plant. This type of sampling was done each week from the last week in April to the end of July. After July, river sampling was done

Table 8-2. Nets used in sampling for river-population and entrainment-effects studies

Biological group	Study	Net Type	Net dimensions: Mesh	Net dimensions: Diameter (m)	Net dimensions: Length (m)	Net-opening Retainer	Bucket	Period Utilized
Macrozooplankton and Ichthyoplankton	population	No. 0 mesh	571µ	0.5	3.8	PVC cylinder	PVC	1971-72
Macrozooplankton and Ichthyoplankton	population	No. 0 mesh	571µ	0.5	3.8	brass ring	PVC	1973-75
Macrozooplankton and Ichthyoplankton	entrainment	No. 0 mesh	571µ	0.5	1.9* 1.2*	SS ring	PVC	1971-75
Ichthyoplankton	population	1 mm	1mm	1.0	3.8	brass ring	PVC	1972
Ichthyoplankton	population	No. 0 mesh Hensen	571µ	1.0	5.7	SS ring	PVC	1973

* 1.9-meter nets used in Unit 1 intakes and discharge canal and 1.2-meter nets used in Unit 2 intakes where space limitations precluded use of 3.8 or 5.7 meter nets.

Source: NYU 1976a.

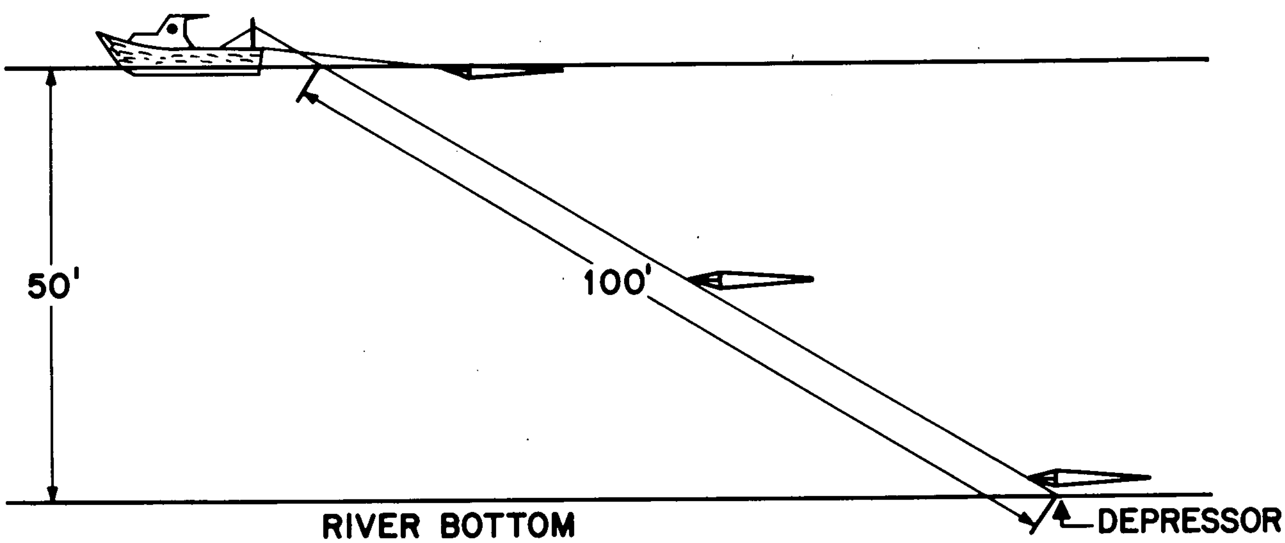

Figure 8-2. Deployment of 0.5 meter and 1.0 meter plankton nets.
Source: NYU 1976a.

every other week until October, and then once per month until the end of December.

Samples for each year were sorted, separating all macroinvertebrates, fish eggs, yolk-sac larvae, larvae and juveniles. These samples were subsequently identified to the lowest taxa possible and enumerated. The samples were preserved in 4% formalin and labeled according to date, station, and species. The abundance data (number/1000 m^3) were analyzed by ANOVA (analysis of variance) and *a posteriori* tests (Sokal and Rohlf 1969) to determine whether significant differences existed in the temporal and spatial distribution of river macroinvertebrates and ichthyoplankton relative to samples at the plant intakes.

8.2.2 Intake and Discharge-Canal Studies

Fig. 6-2 shows the locations of the sampling stations available for the five years of plant entrainment study at Indian Point. The effects of pumped entrainment were determined by comparing viability data from the intake with the discharge stations. Stations I-1 and I-2, at the intakes of Unit No. 1, were used in 1972 and 1973. In 1973, with the completion of Unit No. 2, stations II-1 and II-6 were added to compare the numbers and species composition of organisms there with those at the Unit No. 1 intakes. In 1974, with both units in operation, sampling was carried out at both units on a variable schedule, according to which unit was in a generating mode. Plant sampling in 1975 was carried out exclusively at stations II-2 and II-5, D-1, D-2, and

DP. Stations D-1 and D-2, in the open discharge canal, were suitable for sampling both physicochemical and biological parameters. Station DP, at the discharge ports, was established in 1973 and sampled throughout 1974 and 1975.

Few samples were analyzed at the Indian Point intakes and discharge during 1971, and data collection was conducted primarily as a shakedown to the 1972 study program (NYU 1972a). During 1972, samples were taken at stations I-1, I-2, D-1 and D-2 at one week intervals from January through December. Samples were collected twice a week (one day, one night) from June 27 to August 24, after which the day sampling was discontinued and only night samples were collected until December 26. In all years, the sampling effort was relatively light from January through March due to freezing weather. Early results from these studies indicated that five min. was the optimal sampling time to collect macroinvertebrates, fish eggs and larvae.

(With the change in focus during the 1973 entrainment program, ichthyoplankton were sampled at the 1972 intake and discharge canal stations during a 24 hour sampling cycle once each week from May 8 through July 24. There were additional 24 hour sampling cycles twice in August and October, and once each from September to December. Abundance samples of 50 min. duration were taken every two hours throughout the 24 hour sampling cycle).

With both units in operation in 1974, the entrainment sampling design of 1972 was re-instituted, but with some modifications.

Units Nos. 1 and 2 were sampled at various times, depending upon operational status. The use of TSK flowmeters (to calculate the volume of water filtered) in entrainment sampling gear was discontinued in late spring of 1974 and velocity-reduction cones were installed in discharge sampling nets. The objective was to effect a reduction in the velocity of water across the net mesh in an effort to reduce mortality during collection, and permit more accurate estimates of the viability of entrained ichthyoplankton. The volumes of water filtered at the intake and discharge stations were then calculated from cone-opening diameter, pumping rates of circulators operating and tidal height at the time of sampling. The same sampling stations at Unit No. 1, Unit No. 2 and the discharge canal were used as in previous years. Sampling at the discharge ports (DP) was carried out in 1974.

With only Unit No. 2 in operation in 1975, all sampling efforts were concentrated on that unit. Additionally, a study on the effects of plume entrainment, and a laboratory investigation to assess the effects of net capture on ichthyoplankton survival were performed (NYU 1976b; 1976c).

Since the macrozooplankton and ichthyoplankton in the water column showed a marked vertical diel distribution, sampling was necessary from surface to bottom at intake and discharge canal stations to obtain estimates of species abundance. Sampling rigs capable of simultaneous sampling at three water depths were

devised (Fig. 8-3), and were installed at each of the intake and discharge-canal sampling stations during June 1972.
During 1974 and 1975, the abundance of macroinvertebrates (and ichthyoplankton) in the intakes and discharge canal was determined by weekly sampling from May through mid-July. Sampling prior to May 1 and after July 15 was conducted once-each-month. Samples collected from the nets were brought immediately to a laboratory on the dock at Unit No. 1 for identification and enumeration.

8.2.3 Plume Entrainment Studies

Macrozooplankton (and juvenile striped bass) were randomly sorted into the appropriate test containers approximately one hour before plume transits. Prior to initiation of Unit No. 2 chlorination, several passes were made by boat through the discharge plume. Water temperatures were monitored with a thermister telethermometer. Approximately 20 min. after the initiation of hypochlorite injection, the transit rack and the test containers (Fig. 8-4) were lowered into the plume at a point near the highest observable surface ΔT. The point of immersion was generally adjacent to the confluence of the discharge jet with the water surface. As a control, an identical transit rack was placed simultaneously into a non-plume area of the river near Jones Point, approximatley 1500m north of Indian Point. The transit racks were permitted to drift freely for one hour under the influence of local tidal and current conditions. The location of each transit rack and the surface water temperature

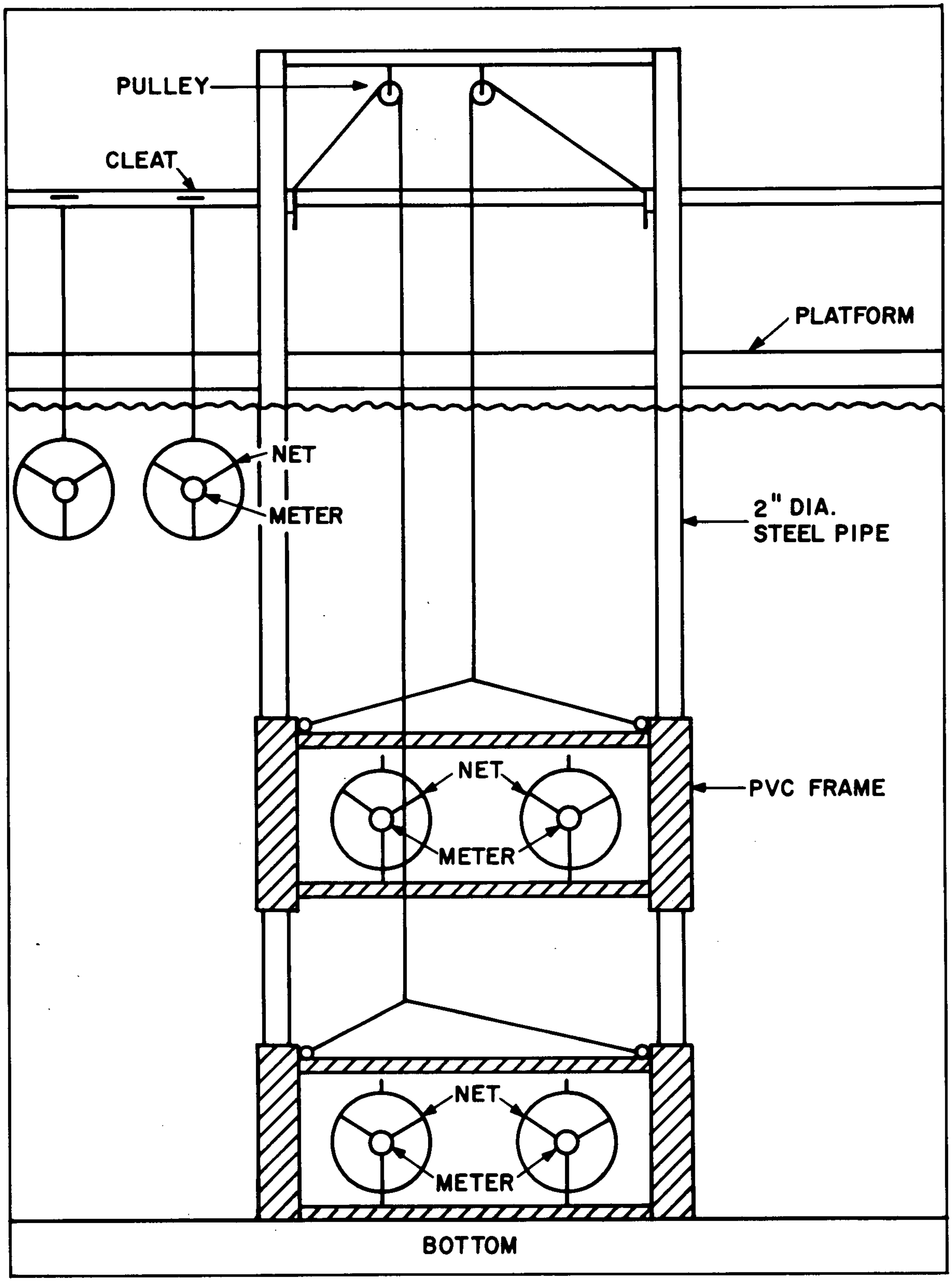

Figure 8-3. Rig used for intake and discharge - canal sampling.
Source: NYU 1973.

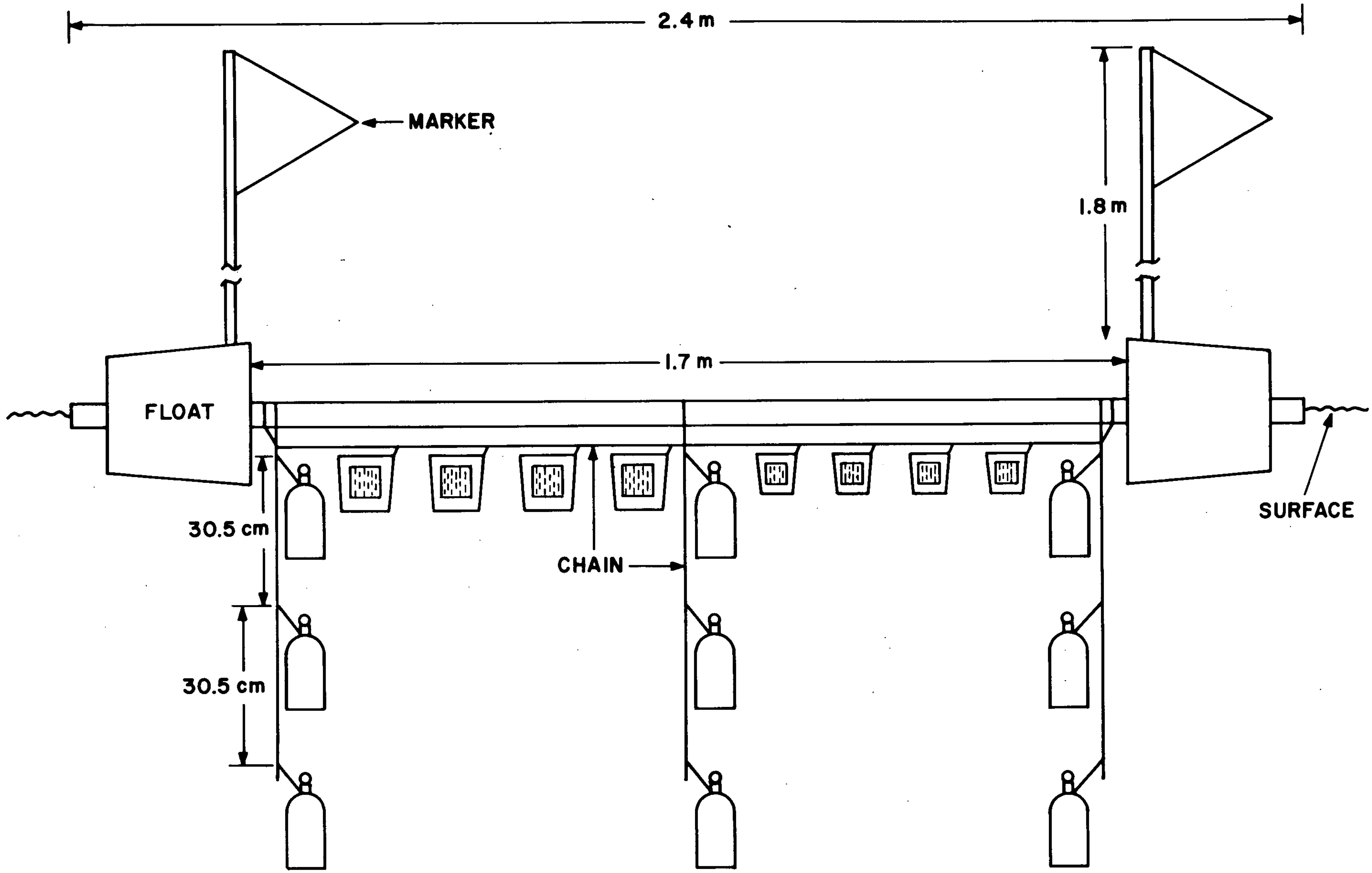

Figure 8-4. Organism exposure rack-simulated plume entrainment.
Source: NYU 1976b.

were recorded at 5 min. intervals. Water samples were collected three times during each transit period (at the beginning, midway and end) and returned to the laboratory for chlorine analysis using amperometric titration. Water temperature and chlorine residuals were also monitored at the power plant condensers and discharge canal in order to characterize levels entering the discharge plume (NYU 1976b).

8.3 RESULTS

8.3.1 River Abundance Studies

Thirty macroinvertebrate taxa representing five phyla have been identified in samples collected at Indian Point (Table 8-3). The macrozooplankton community at Indian Point is dominated by three taxa: *Gammarus spp.*, *Monoculodes edwardsi*, and *Neomysis americana.* Table 8-4 shows these species' high relative contribution during 1971 and 1972.

The abundance of macrozooplankton generally increased from surface to bottom, based on both day and night data. There is a significant nocturnal increase in the number of macroinvertebrate organisms collected at all depths - the average daily catch was about 17% of the average night catch (Ginn 1977). The seasonal distribution of macrozooplankton (for 1971) is shown in Figs. 8-5 and 8-6. Peak abundances generally occurred between June and September (NYU 1973; 1974a; 1976a; 1977). Table 8-5 illustrates the occurrence of various taxa during 1971, 1972, and 1974.

Table 8-3. Macroinvertebrate species occurring in the Hudson River estuary near Indian Point.

Coelenterata - unidentified medusae

Annelida - unidentified obligochaetes and polychaetes

Arthropoda
- Crustacea
  - Decapoda
    - Crangon septemspinosa
    - Palaemonetes sp.
    - Rhithropanopeus harrisii
    - Unidentified zoea
  - Mysidacea
    - Neomysis americana
  - Amphipoda
    - Gammarus fasciatus
    - Gammarus tigrinus
    - Gammarus diaberi
    - Monoculodes edwardsi
    - Corophium sp.
    - Leptocheirus plumulosus
  - Isopoda
    - Chiridotea almyra
    - Edotea triloba
    - Cyathura polita
  - Insecta
    - Chaoborus sp.
    - Dipteran larvae
    - Odonata larvae
  - Arachnida
    - Hydracarina

Mollusca
- Gastropoda

Source: Ginn 1977.

Table 8-4. Contribution of most abundant species to the total number of macrozooplankton collected from the Hudson River estuary near Indian Point in 1971 and 1972.

	Percent of Total	
	Day Collections	Night Collections
1971		
Gammarus sp.	62	62
Neomysis americana	21	12
Monoculodes edwardsi	17	22
1972		
Gammarus sp.	79	86
Neomysis americana	15	10
Monoculodes edwardsi	4	2

Source: NYU 1974a.

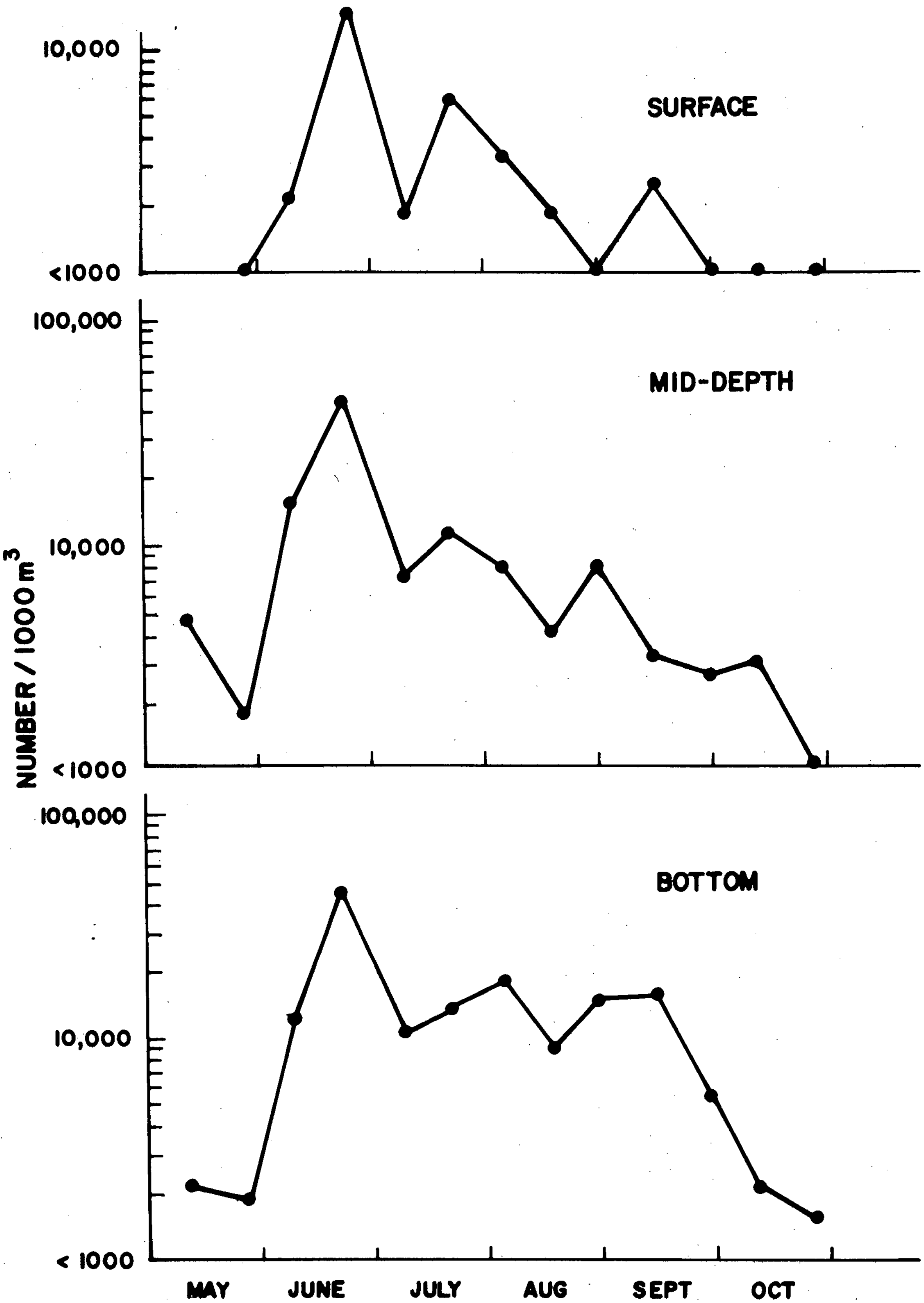

Figure 8-5. Total macrozooplankton/1000 m^3 in night samples, 1971.
Source: NYU 1973.

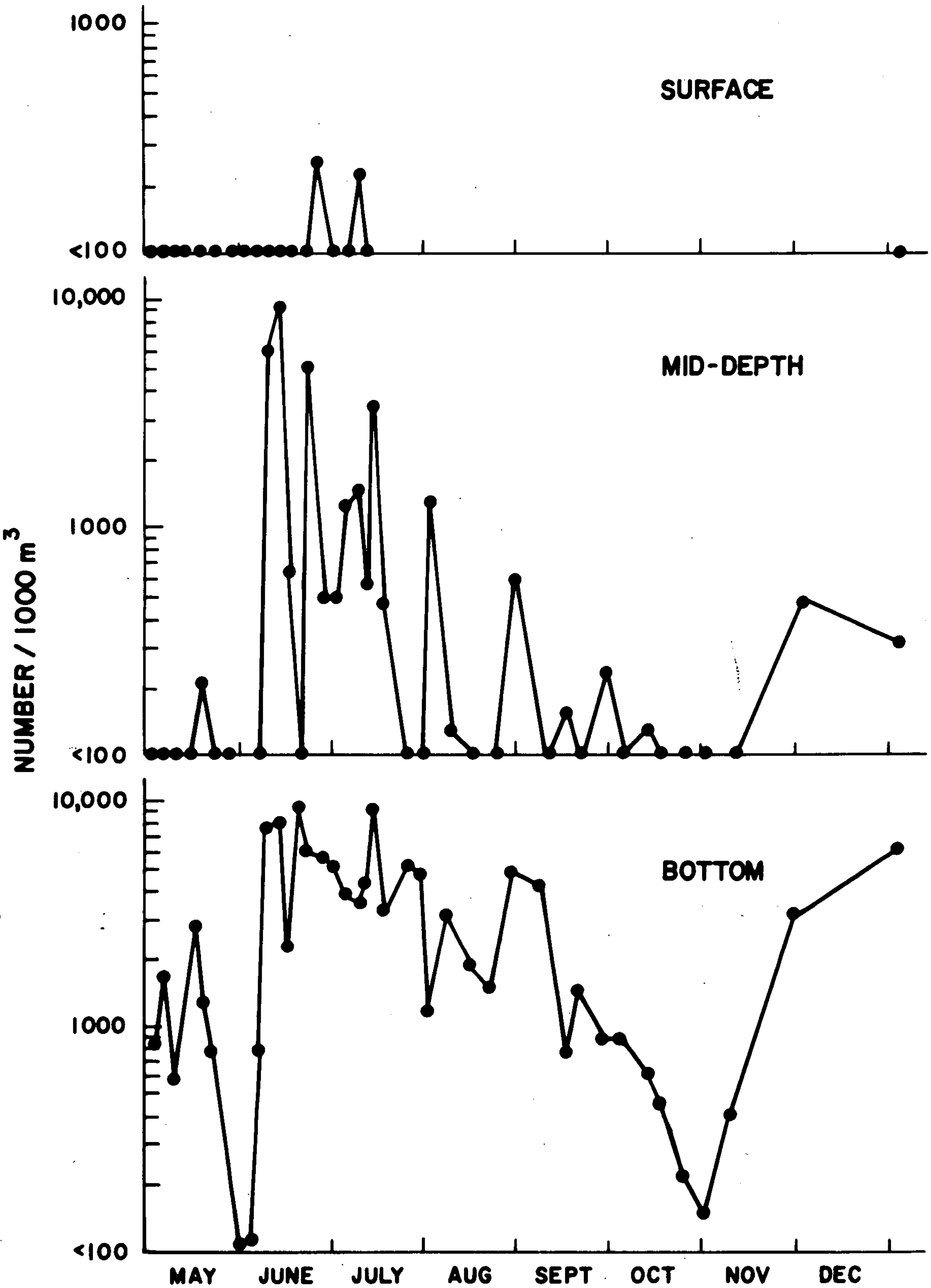

Figure 8-6. Total macrozooplankton per thousand meters cubed in day samples, 1971.
Source: NYU 1973.

Table 8-5. **Macrozooplankton taxa in Indian Point collections, 1971, 1972 and 1974.**

Taxa	1971	1972	1974
Annelida			
Oligochaeta	X	X	X
Polychaeta	X	X	X
Hirudinea		X	X
Arthropoda			
Crustacea			
Mysidacea			
Neomysis americana	X	X	X
Cumacea		X	X
Copepoda			
Caligus Sp.			X
Branchyura			
Argulus sp.			X
Isopoda			
Chirodotea almyra	X	X	X
Cyathura polita	X	X	X
Edotea sp.	X	X	X
Cirolana sp.			X
Amphipoda			
Gammarus sp.	X	X	X
Monoculodes edwardsi	X	X	X
Leptocheirus plumulosus	X	X	X
Corophium sp.	X	X	X
Decapoda			
Crangon septemspinosa	X	X	X
Decapod larva (zoea)		X	X
Insecta			
Chaborus sp.	X	X	X
Odonata (nymph)			X
Odonata (adult)	X	X	
Tendipid (larvae)	X	X	X
Diptera (pupae)	X	X	X
Diptera (adult)	X	X	X
Arachnida			
Hydracarina	X	X	X
Coelenterata			
Medusae	X	X	X
Ctenophora			X
Mollusca			
Gastropoda	X	X	
Bivalvia	X	X	

Source: NYU 1976a.

8.3.1.1 Day vs. Night and Depth Abundances Among Years

Mean daytime abundances of total macroinvertebrates and *Gammarus* spp. *N. americana* and *M. edwardsi* for all years were significantly lower than mean nighttime abundances (NYU 1973; 1974a; 1976a; 1977). Furthermore, in all years, there was also a significant difference in abundance among depths (e.g. in 1972, Table 8-6). In 1972, it was also found that except for *N. americana*, there was a significant interaction between time and depth (Table 8-7). The spatial distribution of macrozooplankton collected in the Indian Point vicinity for 1971 and 1972 is illustrated in Figs. 8-7, 8-8, and 8-9. The usual interpretation of patterns such as these is that abundance increases with depth, with the highest concentrations occurring very near or on the bottom; and that the difference in abundance between day and night collections is the result of the negatively phototactic diel migration of these organisms (NYU 1974a). Another hypothesis is that such patterns may not represent the actual distribution of the organisms but, rather, could result from the organism's being able to visually sense and then effectively avoid the collecting gear in proportion to light intensity (NYU 1974a).

Results of 1974 studies confirm that macrozooplankton abundances are significantly greater during the night than during the day (Table 8-8). As in 1971 and 1972, 1974 results showed the greatest abundance of macroinvertebrates at the bottom of the water column. The relative abundance of macrozooplankton at

Table 8-6. Results of Student-Newman-Keuls tests for significant differences among depths in 1972 macrozooplankton samples.

Species tested	Significant differences in mean abundance among depths ($\alpha < .05$)
Day Samples	
All species combined	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Gammarus sp.	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Monoculodes edwardsi	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Neomysis americana	bottom>middle bottom>surface
Night Samples	
All species combined	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Gammarus sp.	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Monoculodes edwardsi	bottom>middle bottom>surface middle>surface (significant at all 3 depths)
Neomysis americana	bottom>surface middle>surface

Source: NYU 1974a.

Table 8-7. Results of two-way analyses of variance (day/night and depth) in data from 1972 macrozooplankton collections.

Species tested	Significant difference* between day and night	Significant difference* among depths	Significant interaction between time and depth
All species	X	X	X
Gammarus sp.	X	X	X
Monoculodes edwardsi	X	X	X
Neomysis americana	X	X	none

* α = 0.05

Source: NYU 1974a.

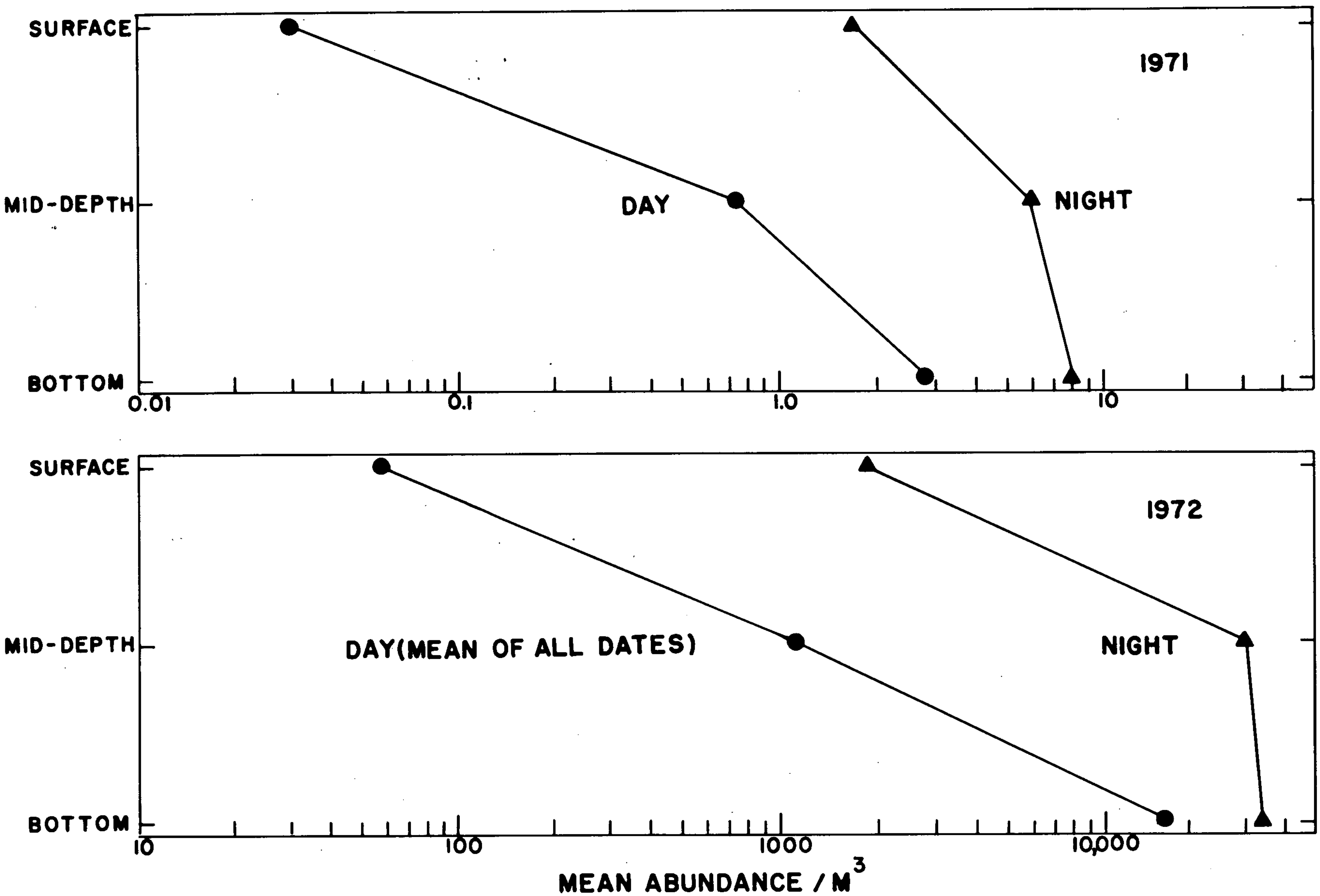

Figure 8-7. Vertical abundance patterns of total macrozooplankton in day and night samples for 1971 and 1972.

Source: NYU 1974a.

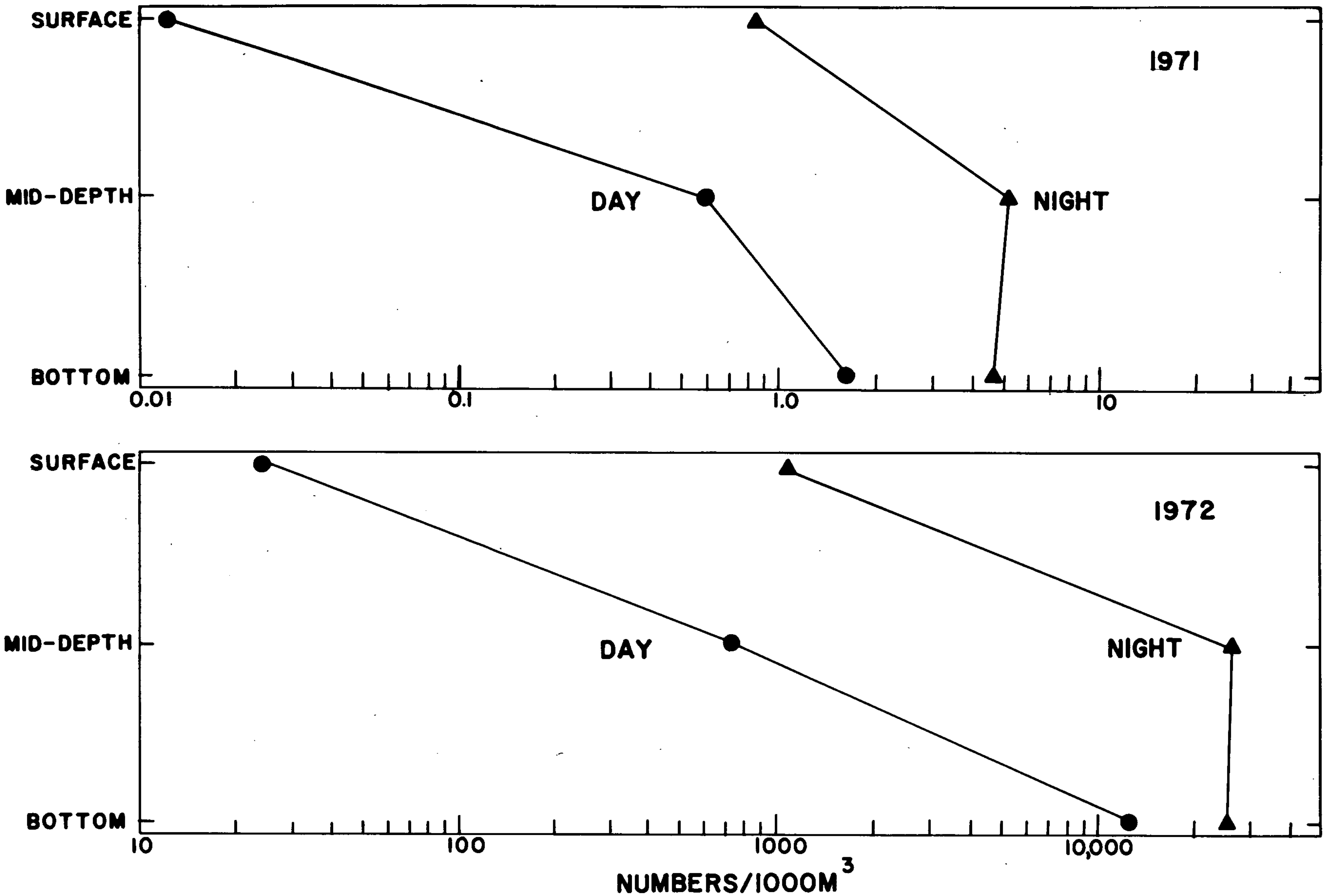

Figure 8-8. Vertical abundance patterns of <u>Gammarus</u> sp. in day and night samples for 1971 and 1972.

Source: NYU 1974a.

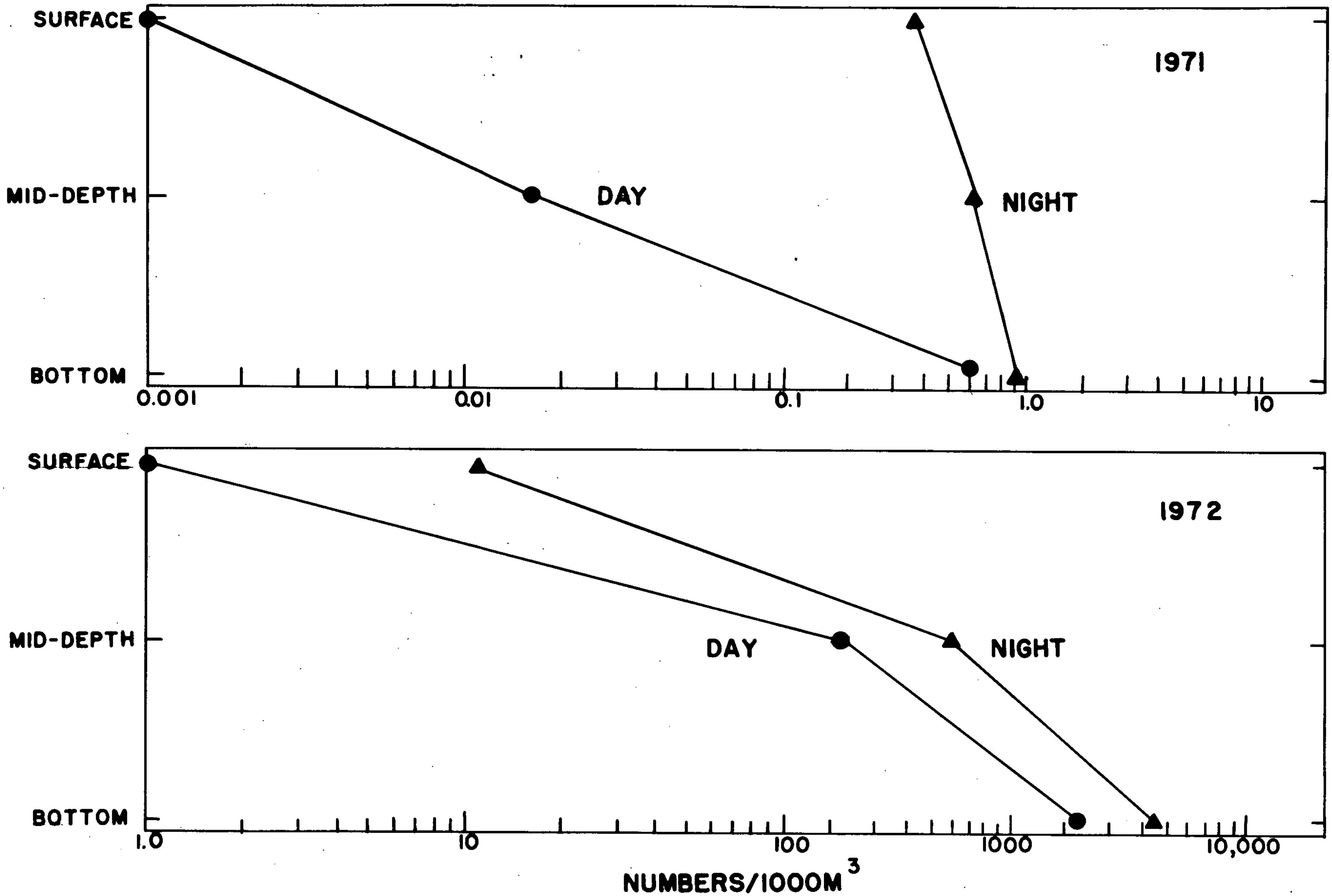

Figure 8-9. Vertical abundance patterns of Neomysis americana in day and night samples for 1971 and 1972.
Source: NYU 1974a.

Table 8-8. Comparison of macrozooplankton abundance in day and night river sampling.

Species	Day + Night
Total	Night > Day
Gammarus	Night > Day
Monoculodes	Night > Day
Neomysis	Night > Day

Source: NYU 1976a.

various depths, as in 1972 (Table 8-7), differed significantly between day and night samples during 1974. Surface and mid-depth abundances at night were greater than in the day by a factor of approximately 10. Nighttime bottom sample abundances were about 53% greater than daytime bottom samples. Data from other investigations in the Hudson River (TI 1975a; LMS 1975a) identify the bottom deposits of the river as an important habitat for the many species collected regularly in macrozooplankton nets.

The distribution of the major macrozooplankton species during the day was essentially similar (Figs. 8-10 through 8-13). Approximately 0.2% of the totals for each group occurred in surface samples, while 68 to 92% occurred in the bottom samples. Neomysis had the sharpest distribution of profile with depth; more than 92% of the Neomysis recorded were from the bottom strata during 1974 (NYU 1976a). Depth distribution of these forms was more evenly dispersed for nighttime samples during 1974. For Gammarus spp., the nighttime abundance at mid-depth and in bottom samples exceeded that of the surface, but mid-depth did not differ from bottom (NYU 1976a). Monoculodes and Neomysis showed significant differences among all strata with a gradient of decreasing nightime abundance from bottom to surface. The greatest difference in depth distribution between day and night was observed for Neomysis, whose surface abundance increased by approximately 1000 at night, and whose mid-depth abundance increased approximately tenfold at night. Abundance in surface

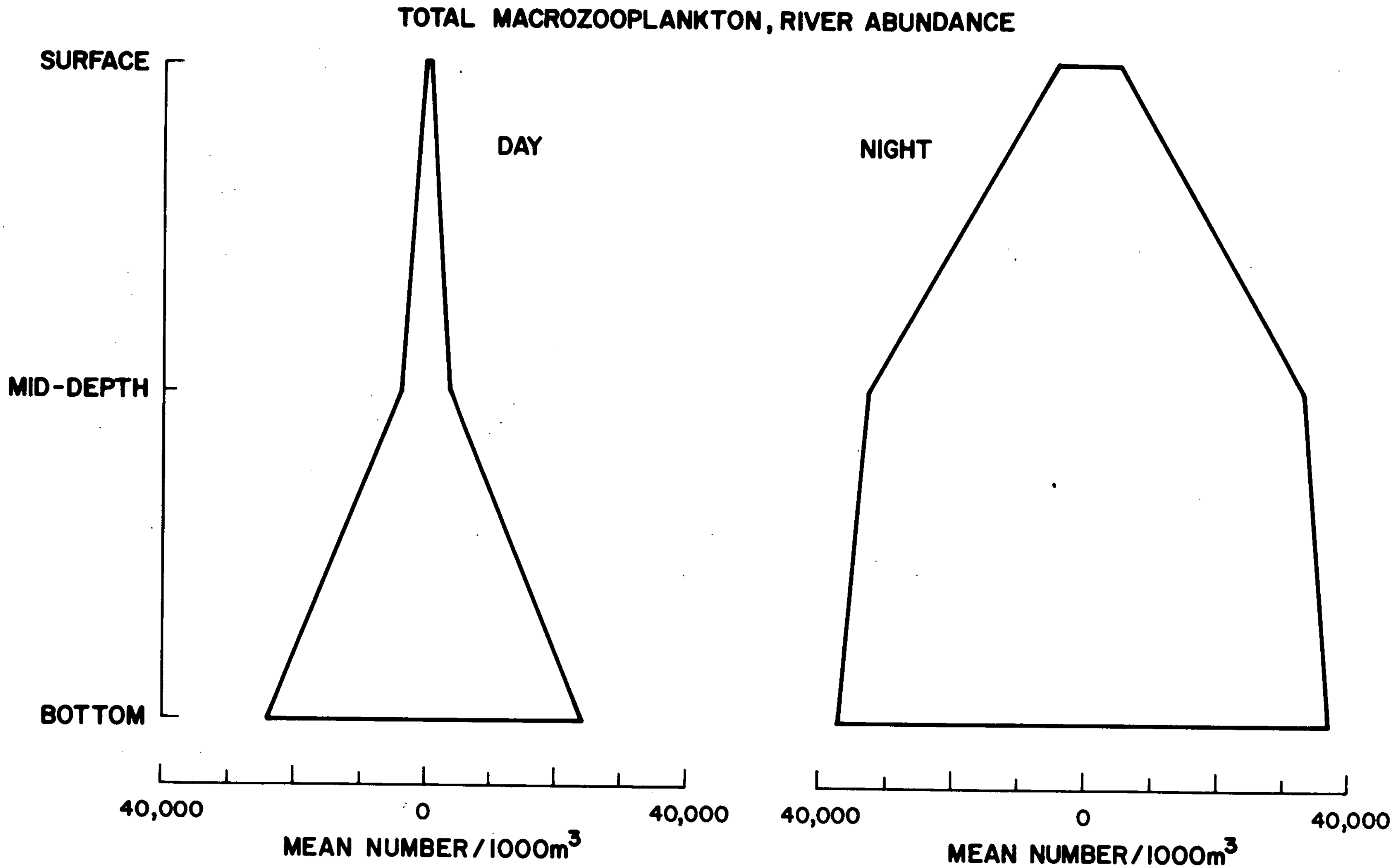

Figure 8-10. Depth distribution of total macrozooplankton in day and night samples in the Hudson River at Indian Point, 1974.
Source: NYU 1976a.

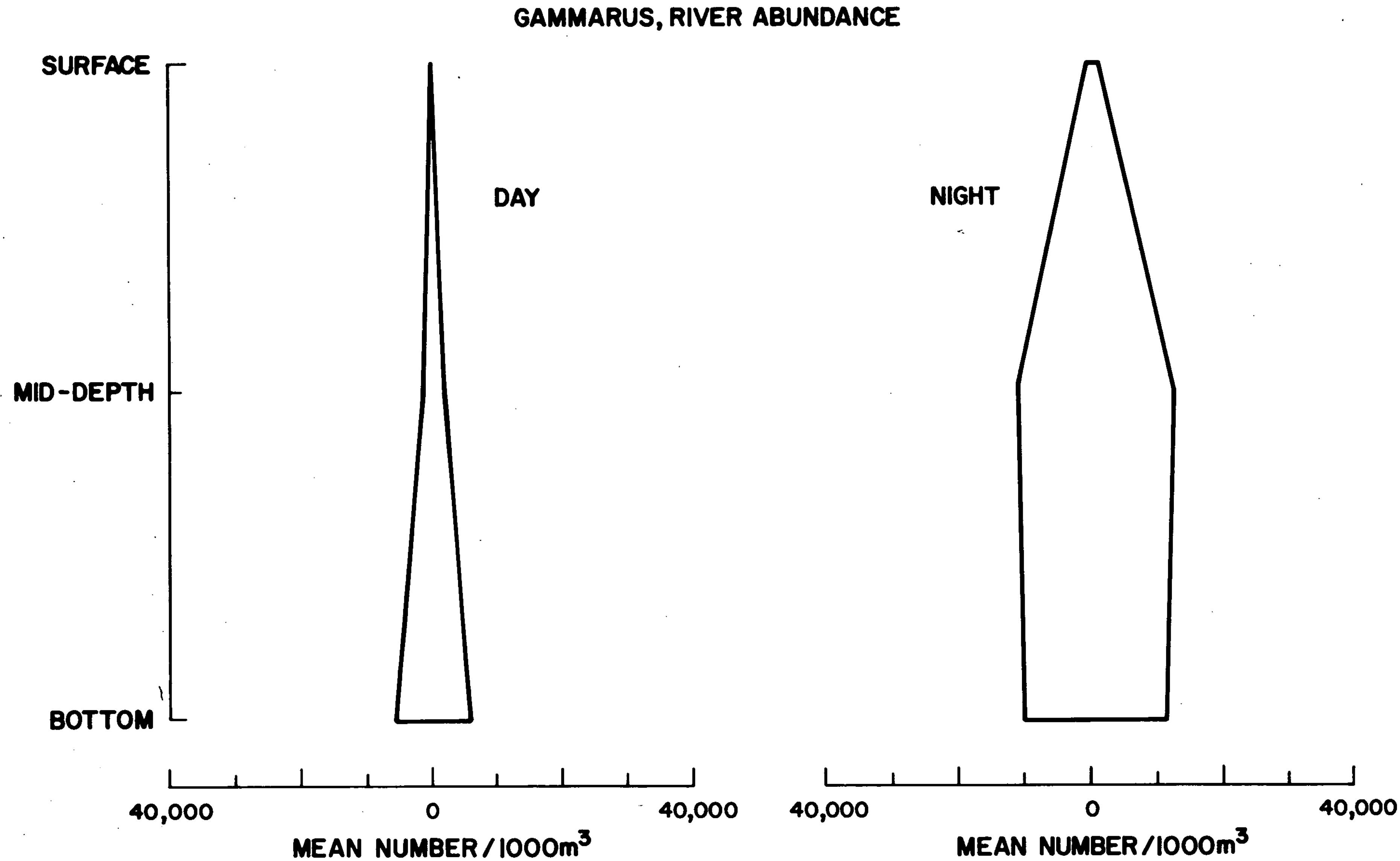

Figure 8-11. Depth distribution for *Gammarus* spp. in day and night samples in the Hudson River at Indian Point, 1974.

Source: NYU 1976a.

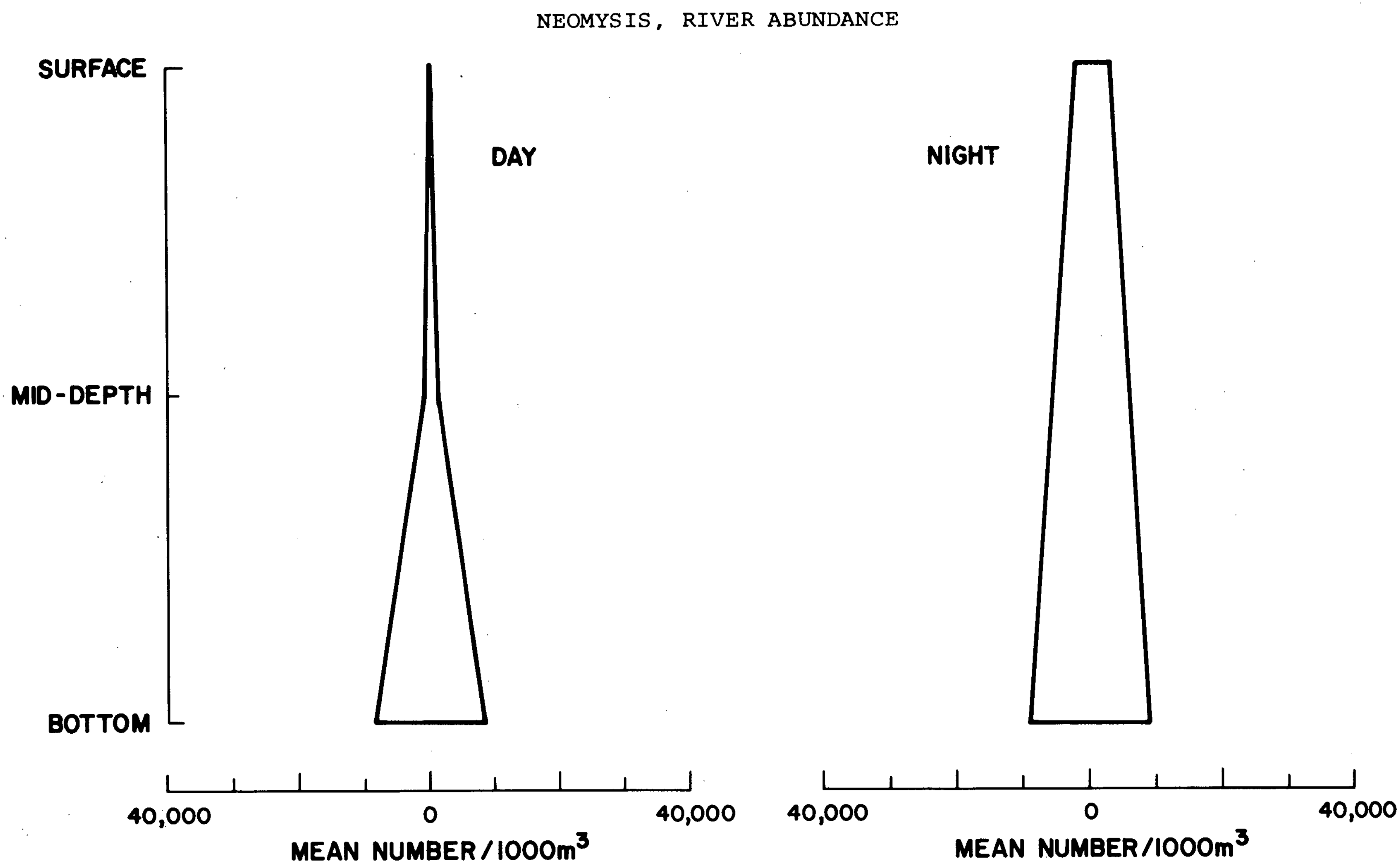

Figure 8-12. Depth distribution for <u>Neomysis</u> <u>americana</u> in day and night samples in the Hudson River at Indian Point, 1974.

Source: NYU 1976a.

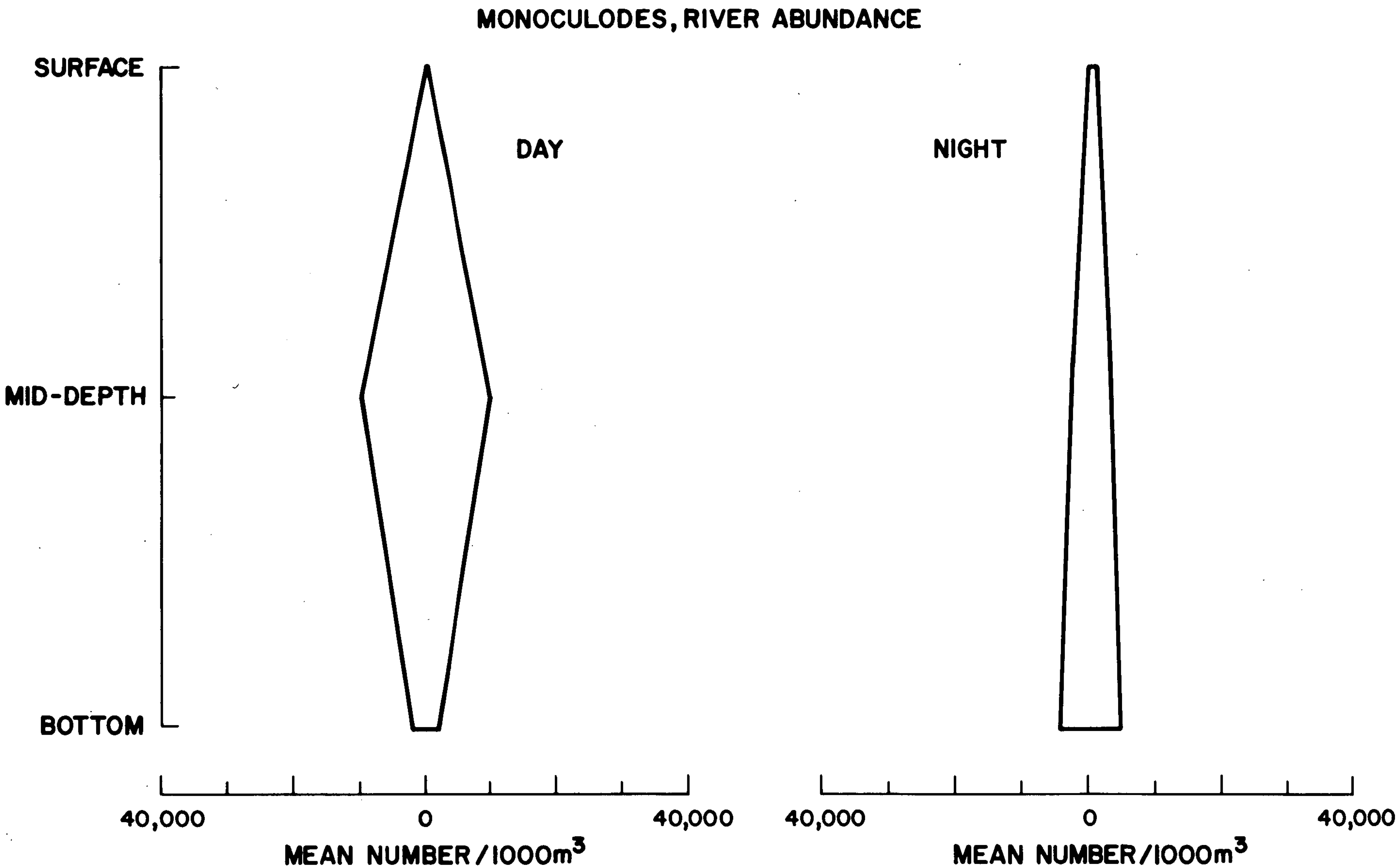

Figure 8-13. Depth distribution for Monoculodes edwardsi in day and night samples in the Hudson River at Indian Point, 1974.

Source: NYU 1976a.

and mid-depth samples for all three dominant forms increased by at least a factor of ten between day and night.

8.3.1.2 Seasonal Occurrences of Macrozooplankton

On an annual basis Gammarus spp., M. edwardsi, N. americana and Chaoborus larvae have accounted for over 90% of the total macrozooplankton collected (NYU 1973; 1974a; 1976a). Gammarus populations reached their highest densities in late May and June when abundances were approximately 100 times higher than in January (Ginn 1977). Gammarus also exhibited a population peak in November (Fig. 8-14).

A decrease in the percentage occurrence of Gammarus was coupled by an increase in abundances of N. americana during July through September. This was documented in 1972 when on July 20, 1972 a significant saline intrusion of 2 ppt, corresponded with the initial yearly collection of N. americana at Indian Point (Ginn 1977). Salinity remained above 2 ppt throughout early November after which the salt intrusion retreated and N. americana were no longer observed. This limiting factor of 2 ppt for N. americana has been observed in each sampling season. Additional salinity intrusions occur at Indian Point during low flow periods in January and February (TI 1976a). These occurrences were documented in 1975 when they were accompanied by the appearance of N. americana (Ginn 1977).

The occurrence of N. americana in 1975 correlated well with the summer salt intrusion. Salinities approaching 6 ppt were recorded during the first week of July and lower levels (1-2 ppt)

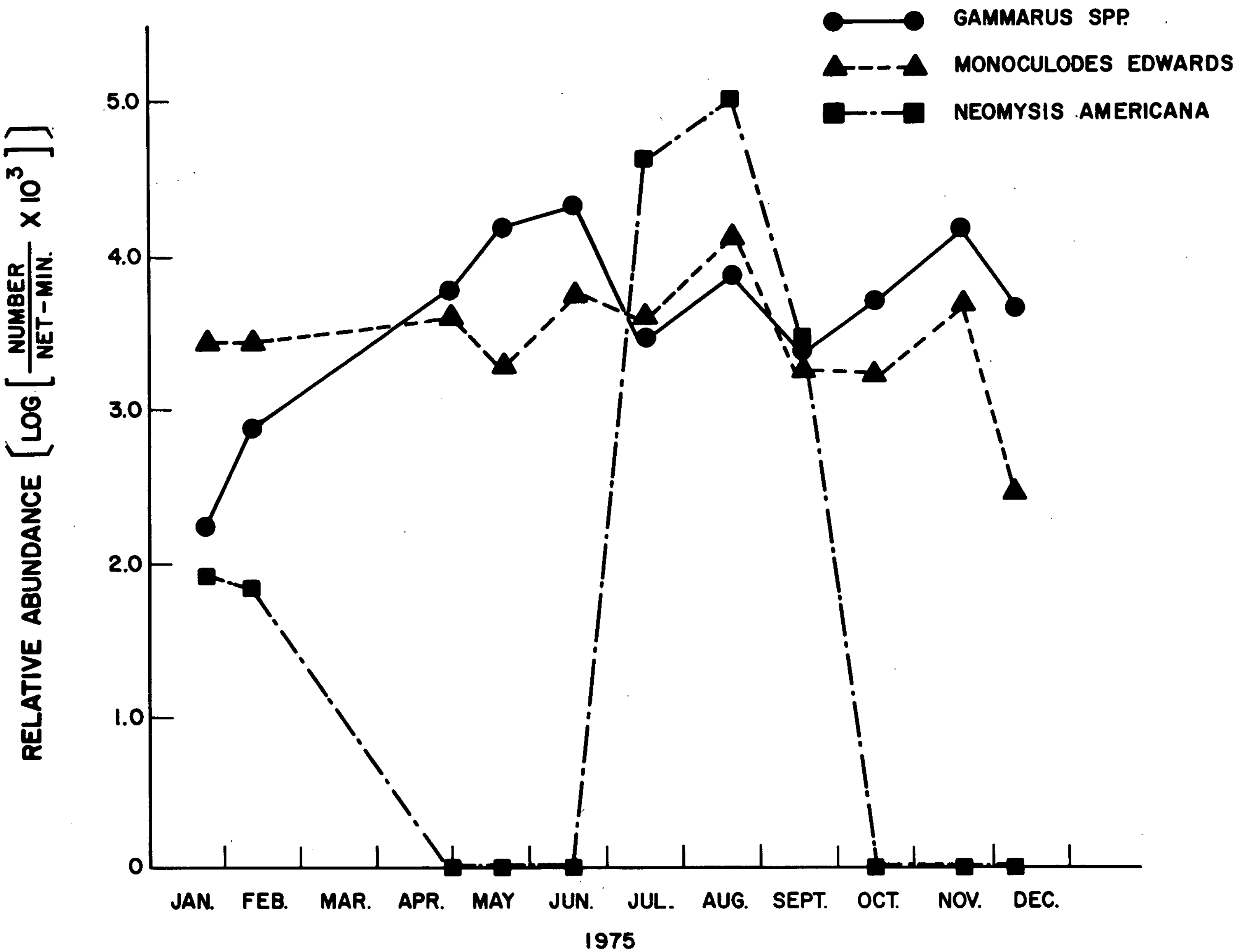

Figure 8-14. Relative abundance of major macrozooplankton species at Indian Point.
Source: Ginn 1977.

persisted until mid-September. During this period N. americana was the most abundant macroinvertebrate sampled near Indian Point (NYU 1976a). During its peak occurrence, N. americana comprised over 75% of the total macrozooplankton catch.

The abundance of M. edwardsi remained relatively constant through 1975 (Fig. 8-14). The highest percentage occurrence of M. edwardsi was during the winter (Figure 8-15). During the remainder of the year M. edwardsi accounted for 8.2-23.7% of the macrozooplankton. Larvae of the phantom midge, Chaoborus sp., were most abundant at Indian Point during the summer (Ginn 1977). During June and July, Chaoborus larvae accounted for about 30% of the macrozooplankton sampled; however, percentage abundance was generally 10% during the remainder of the year.

Numerous minor species accounted for the remaining portions of the macrozooplankton sampled near Indian Point. During periods of high freshwater runoff (i.e. low salinity) several species of oligochaetes and polychaetes (Annelida) occurred in the plankton samples. Some isopods (e.g. Chiridotea triloba) were present at consistently low levels of abundance.

8.3.2 Thermal Tolerance Studies

Gammarus spp. display seasonal variation in thermal tolerances, which correspond to seasonal variation in ambient river temperatures (for 30 min. exposure; Fig. 8-16). These data indicate that Gammarus spp. can tolerate higher temperatures if acclimated at higher temperatures, or that they can withstand temperatures about 11 C higher during the summer than during

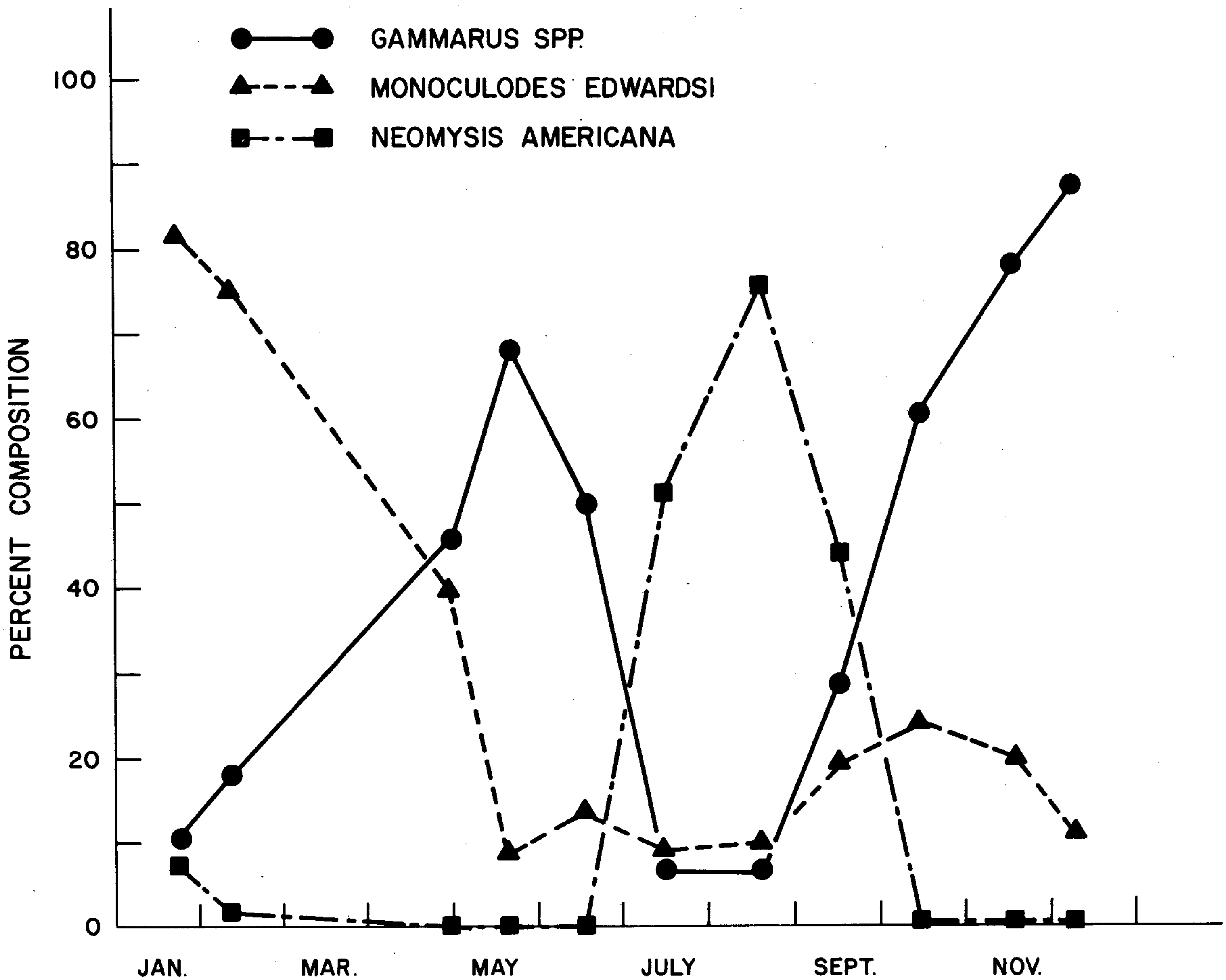

Figure 8-15. Percent composition of macrozooplankton samples at Indian Point in 1975.

Source: Ginn 1977.

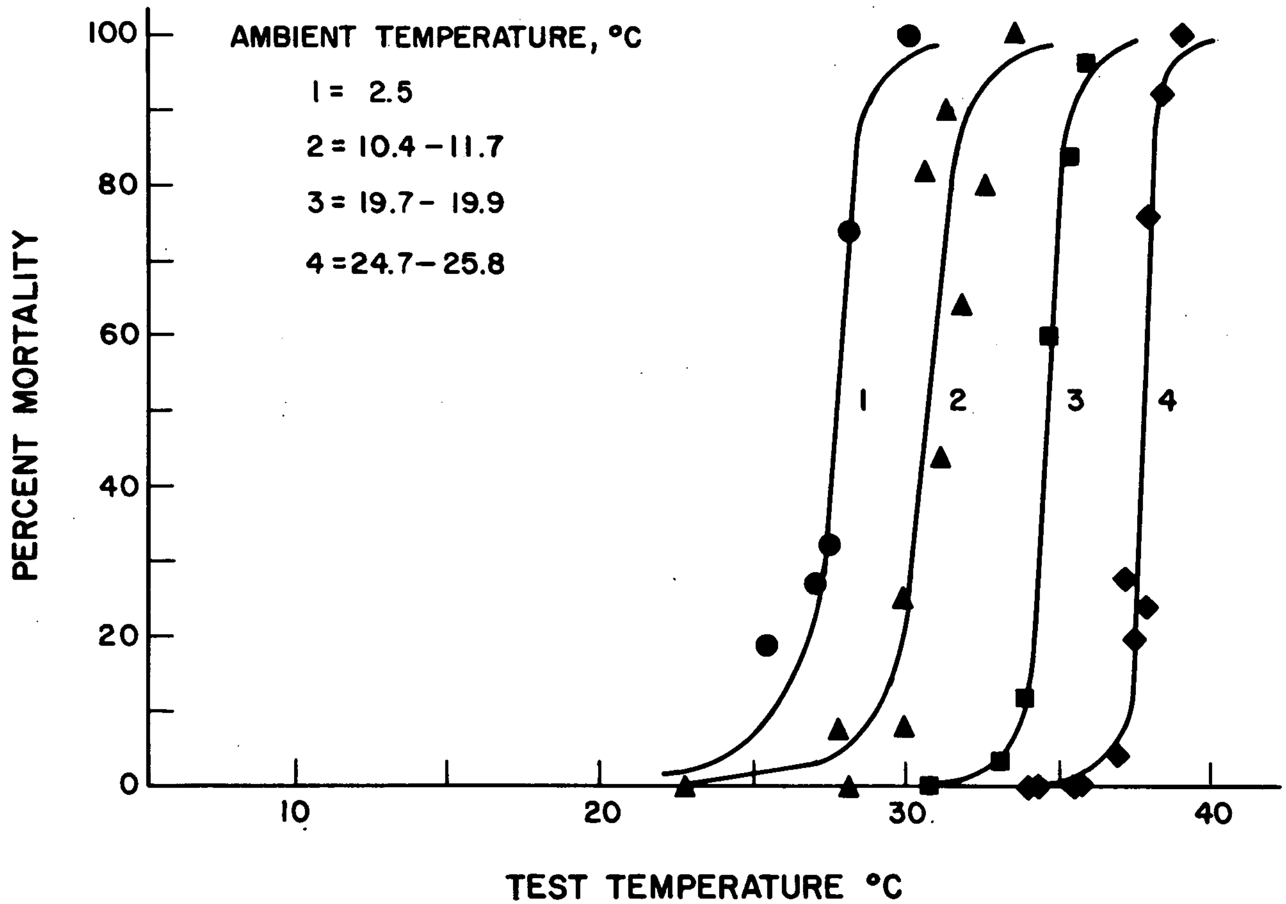

Figure 8-16. Temperature tolerance of <u>Gammarus</u> spp. during ambient temperatures of 2.5 to 25.8 C (30 min. exposures).

Souree: Ginn 1977.

winter. Gammarus spp. exhibited a threshold-like response in that the TL_{50} values are generally less than 2 C higher than the TL_5's (Table 8-9).

Figs. 8-17 and 8-18 illustrate that exposure temperature of Gammarus spp. to thermal shock is time dependent. During most of the year, test organisms could tolerate approximately 2 C higher temperatures in 5 min. exposures than in the 60 min. exposures. This time-temperature dependence is further demonstrated in that test organisms tolerated considerably higher temperatures during short-term exposures (5 to 60 min.) than during the 48 hour exposures. At the same ambient temperatures near 25 C, 60 min. tolerance limits to ΔT were approximately 5 C higher than the 48 hour tolerance limits (Ginn 1977).

It was also found that the 24 hour survival of Gammarus exposed for 5 to 60 min. showed no increase in mortality at test temperatures less than 35.0 C for an ambient of 25 C, but that the 24 hour survival decreased rapidly as test temperatures increased above 37 C (Ginn 1977). At ambient river temperatures below 10.0 C, Gammarus spp. could theoretically live for extended periods in a power plant discharge canal if other conditions (e.g. flow, velocity, substrate, food supply) were favorable. During such periods organisms expelled from the cooling water system would experience a considerable negative ΔT. Gammarus spp. that were fully acclimated to a sustained 15.6 C ΔT above an ambient of 9.1 C experienced no adverse effects when the temperature was reduced immediately to ambient. Therefore, it

Table 8-9. TL5 and TL50 (C) of major Hudson River invertebrates in 5-minute and 30-minute exposures at summer ambient temperatures. (25 C).

Species	TL5		TL50	
	5 min	30 min	5 min	30 min
Gammarus sp.	38.0	37.2	38.7	37.8
Neomysis americana	32.5	31.7	34.0	33.0
Monoculodes edwardsi	35.5	34.8	37.3	36.3

Source: Ginn 1977.

Table 8-9. TL5 and TL50 (C) of major Hudson River invertebrates in 5-minute and 30-minute exposures at summer ambient temperatures. (25 C).

Species	TL5		TL50	
	5 min	30 min	5 min	30 min
Gammarus sp.	38.0	37.2	38.7	37.8
Neomysis americana	32.5	31.7	34.0	33.0
Monoculodes edwardsi	35.5	34.8	37.3	36.3

Source: Ginn 1977.

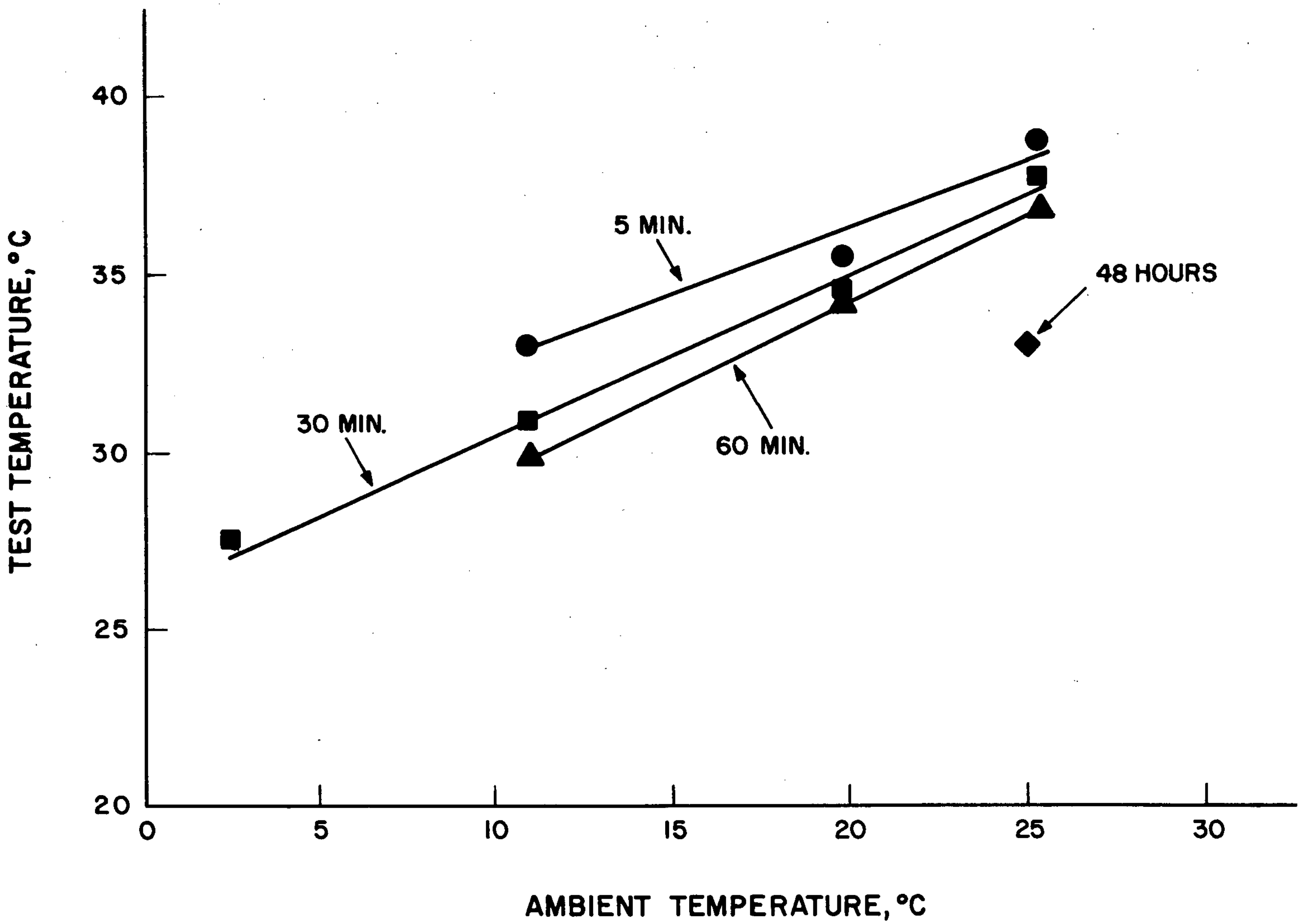

Figure 8-17. 50% Temperature tolerance limits (TL_{50}) for Gammarus spp.

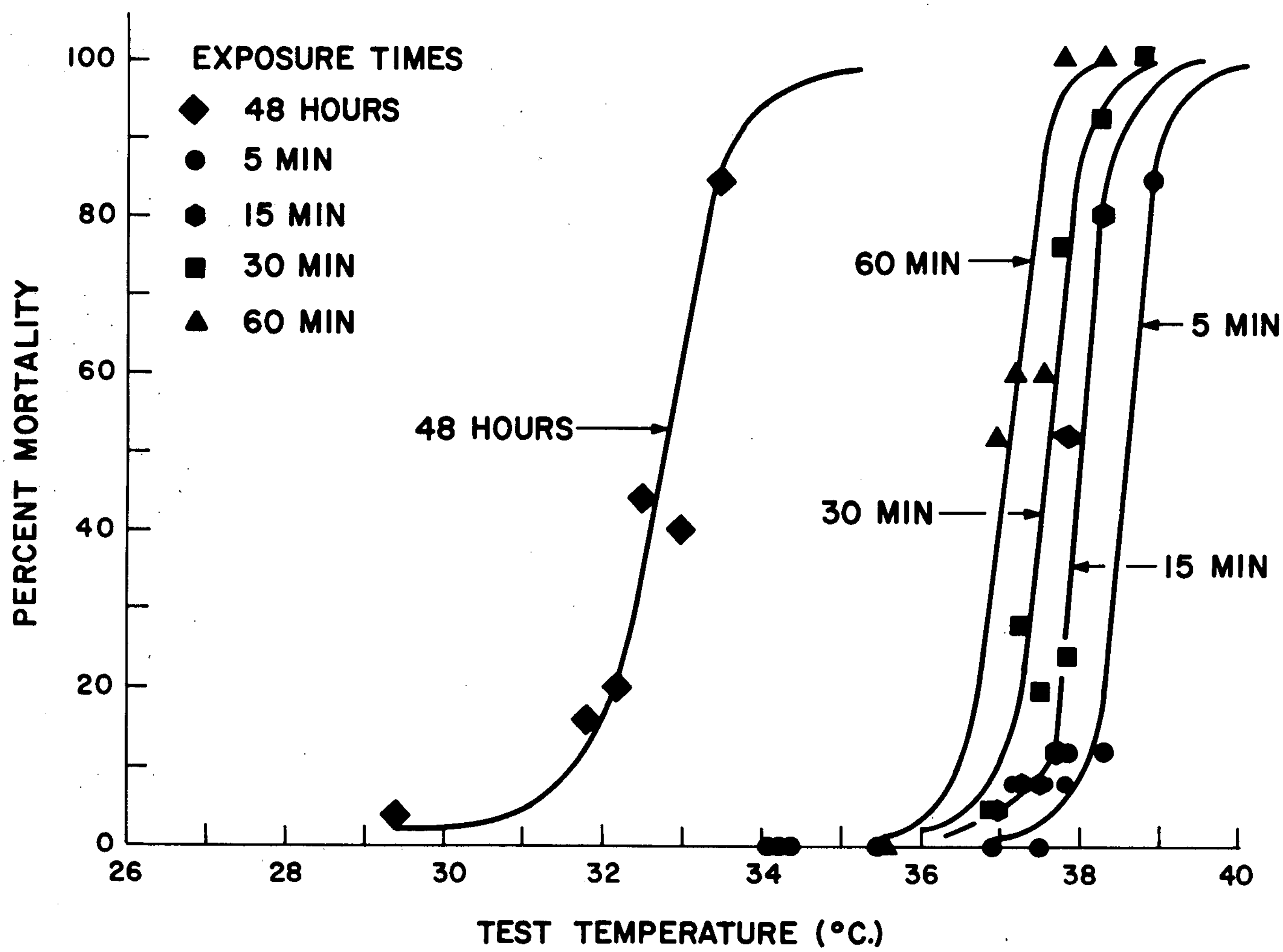

Figure 8-18. Temperature tolerance of Gammarus spp. at an ambient temperature of 24.7 to 25.8 C.

Source: NYU 1973.

appears that "cold shock" under the conditions examined does not produce significant impact (NYU 1973).

N. americana was tested for thermal tolerance during peak abundance in late summer when ambient water temperature was 24.2 to 25.7 C. Table 8-9 indicates that TL_5 and TL_{50} were lower than for either *Gammarus spp.* or *M. edwardsi.* Fig. 8-19 illustrates that significant mortality of this organism occurs when temperatures exceed 33 C.

The short-term tolerance of *M. edwardsi* to temperature elevations above ambient temperature of 11.7 to 24.7 C is presented in Fig. 8-20. The upper lethal temperature was approximately 4 C lower at 11.7 C ambient when compared with the tolerance during the summer ambient of 24.7 C. Temperature tolerance during summer ambient water temperatures was intermediate to that for *Gammarus spp.* and *N. americana.*

As previously indicated, *Gammarus* did not suffer any immediate mortalities below 35 C. In latent effects studies, it was found that at summer ambient temperature and a ΔT of 8.3 C, survival was still quite good (Table 8-10). Survivals after 10 days were 90% for controls, 90% for 5 min. exposures, 88% for 30 min. exposures and 92% for the 60 min. exposures. These differences were not significant. The results of this same experiment performed at an ambient temperature of 27.7 C is reported in Table 8-11. Table 8-12 summarizes the results of this experiment perform with a ΔT of 11.1 C and an ambient of 26.5 C with the exposure times again remaining the same. Both 30 and 60 min.

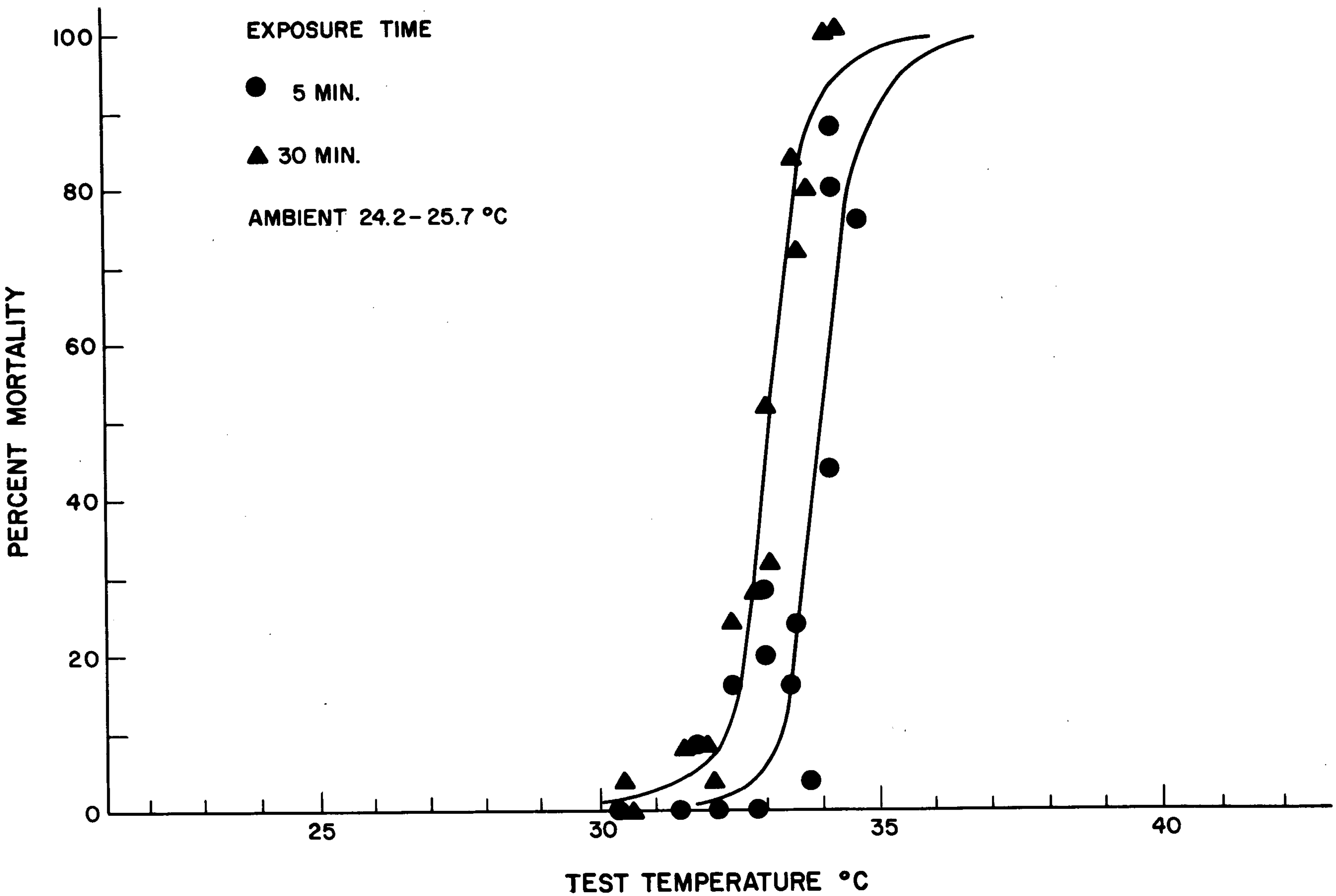

Figure 8-19. Temperature tolerance of Neomysis americana.

Source: NYU 1973.

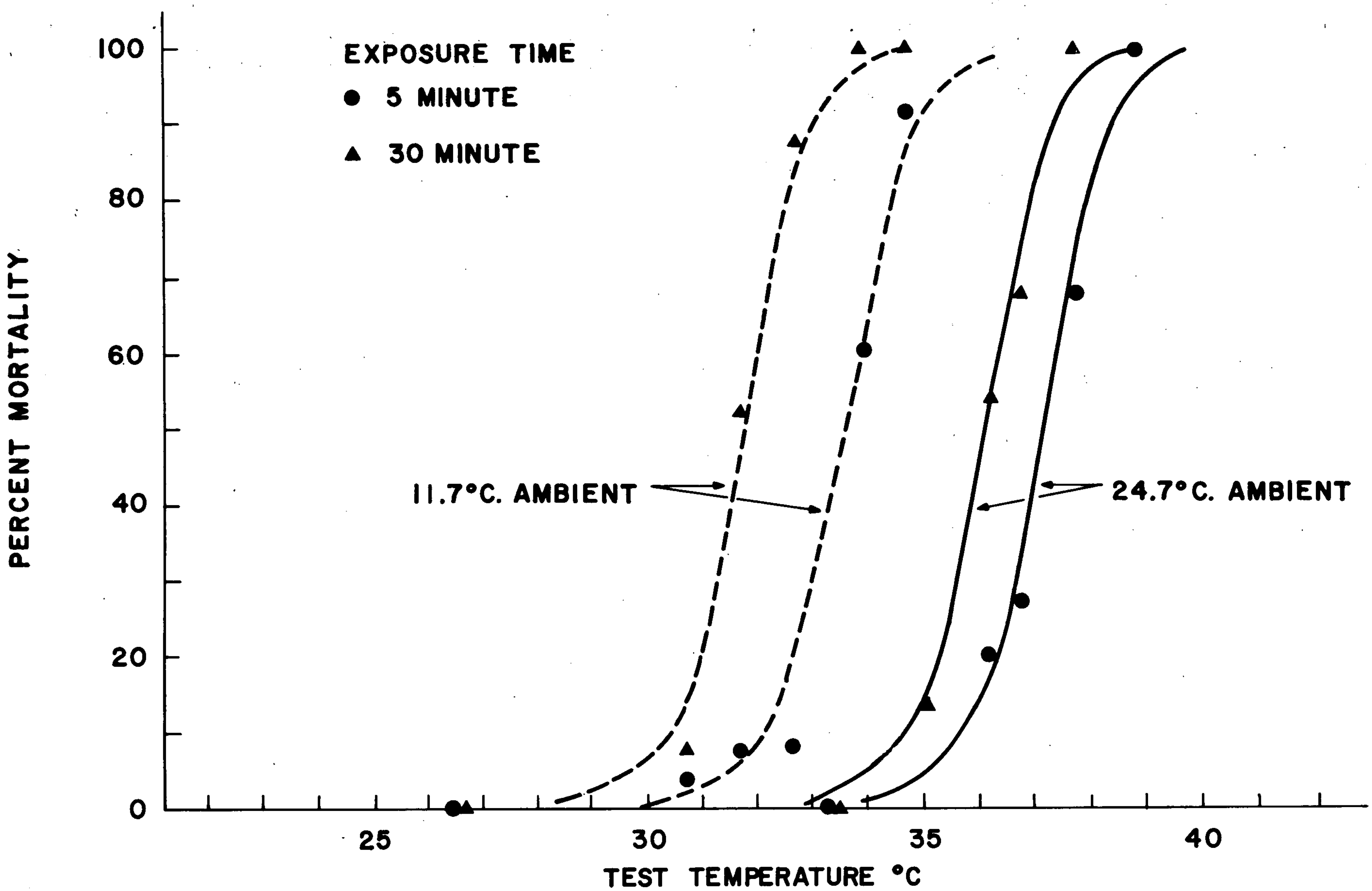

Figure 8-20. Temperature tolerance of Monoculodes edwardsi.
Source: NYU 1973.

Table 8-10. Percent survival of *Gammarus* spp. exposed to an 8.3C ΔT at an ambient temperature of 25.5C (100 organisms per test group).

Exposure Time	Immediate	5 day	10 day
0 (control)	100	97	90
5 minutes	100	97	90
30 minutes	100	95	88
60 minutes	100	96	92

Source: Ginn 1977.

Table 8-11. Percent survival of *Gammarus* spp. exposed to an 8.3C ΔT at an ambient temperature of 27.7C (100 organisms per test group.)

Exposure Time	Immediate	5 day	10 day
0 (control)	100	71	60
5 minute	100	80	62
60 minute	99	71	59
180 minute	96	13	11

Source: Ginn 1977.

Table 8-12. **Percent survival of Gammarus spp. exposed to an 11.1 C Δ T at an ambient temperature of 26.5 C (organisms per test group).**

Exposure time	Immediate	5 day	10 day
0 (control)	100	98	89
5 minute	98	88	75
30 minute	91	57	44
60 minute	64	3	3

Source: Ginn 1977.

exposures resulted in significant immediate reductions in survival as compared to controls. After 10 days, survival was significantly reduced in the 30 and 60 min. groups.

When *Gammarus* spp. were exposed to ΔT's of 8.3 C and 16.7 C above an ambient temperature of 11.7 C, there were no significant reductions in survival immediately or after 10 days for exposure times up to 180 minutes (Table 8-13). Fig. 8-21 indicates that for *Gammarus* spp. exposed to a sustained 8.3 C ΔT at an ambient temperature of 27.7 C, the times to 5% and 50% mortality were at 194 min. and 395 min., respectively. *Gammarus* spp., exposed in lots of 40, to temperatures as high as 39.9 C for 20 sec. followed by 30 min. exposures to 34.2 C, displayed no reductions in immediate or five day survival (Table 8-14). These data exemplify the importance of exposure time in the determining thermal tolerances, since five min. exposures to temperatures near 40 C result in 100% mortality of *Gammarus* spp. Upon immersion for 20 sec. in the water bath at exposure temperatures of 12 and 14 C above ambient, the test organisms displayed almost instantaneous loss of orientation followed by immobility. Normal activity of test organisms resumed within 30 min. after return to ambient temperature (Ginn 1977).

8.3.3 Reproductive Studies

The numbers of young produced by ovigerous female *G. daiberi* exposed for varying time periods to an 8.3 C ΔT above a summer ambient temperature of 26.0 C indicated no significant differences in the numbers of young produced by controls, 5 min.

Table 8-13. Survival of *Gammarus* spp. exposed to Δ T's of 8.3 C and 16.7 C at an ambient temperature of 11.7 C (80 organisms per test group). Numbers are percent survival of exposed organisms.

T C	Time (minutes)	Immediate	5 day	10 day
0	control	100	96.3	92.5
8.3	180	100	97.5	93.8
0	control	100	98.8	95.0
16.7	5	100	96.3	90.0
16.7	60	100	97.5	91.3
16.7	180	100	97.5	95.0

Source: Ginn 1977.

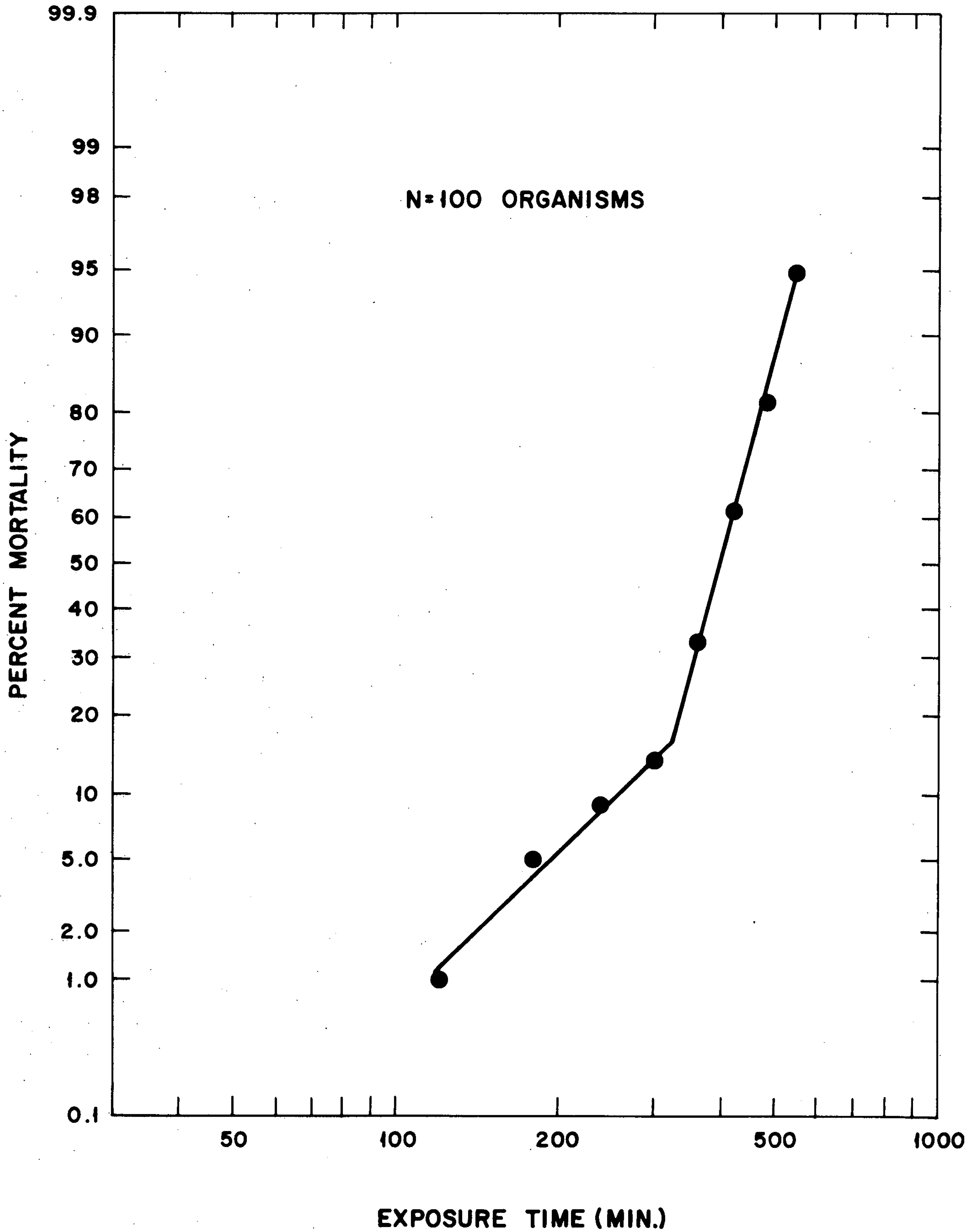

Figure 8-21. Time-mortality response of Gammarus spp. exposed to an 8.3 C ΔT at an ambient temperature of 27.7 C.

Source: Ginn 1977.

Table 8-14. Survival of *Gammarus* sp. exposed to 20-second ΔT's of 10, 12, and 14C followed by an 8.3C ΔT at an ambient temperature of 25.9C.

		Number alive	
Initial 20-sec. ΔT	Subsequent exposure time to 8.3C ΔT	Immediately after exposure	5 Days after exposure
0C	0 sec.	40	38
	0 sec.	40	38
10C	280 sec.	40	40
	1780 sec.	40	38
12C	280 sec.	40	39
	1780 sec.	40	40
14C	280 sec.	40	39
	1780 sec.	40	38

Source: Ginn 1977.

or 60 min. groups. However, a 30 min. exposure to an 11.0 C ΔT reduced the number of young produced (Table 8-15).

Ambient temperature has been shown to be an important controlling factor in the reproduction of gammarid amphipods (Clemens 1950; Smith 1973). Exposure of G. daiberi to a typical operating power plant ΔT of 8.3 C does not retard their subsequent reproductive capability. Eggs and/or young contained in the marsupium of female G. daiberi were able to tolerate an 8.3 C ΔT without a reduction in survival (Ginn 1977). However, as the upper lethal time temperature combination is approached at an 11.0 C ΔT for 30 min. (26.0 C ambient), there was a reduction in the number of young released (Table 8-16). Since separate experiments indicated that all of the ovigerous females survived the 30 min. 11.0 C ΔT (Ginn 1977), it appears that developing young are apparently more sensitive to thermal shock than the adults.

Long-term exposure of Gammarus spp. to 15.6 C ΔT's during ambient temperature near 10.0 C stimulated reproductive activities during the period from November to December (Ginn 1977). Ovigerous females are not normally observed at that time (Bousfield 1973). Apparently Gammarus spp. do not require a period of cold winter ambient temperatures to stimulate reproduction. Similar observations have been noted for G. lacustris and G. pseudolimnaeus (Smith 1973).

Table 8-15. Number of young produced by ovigerous female *Gammarus* spp. exposed to 8.3C and 11.0C ΔT's at an ambient temperature of 26.0C. Test organisms exposed to an 11.0C ΔT were larger than those exposed to an 8.3C ΔT.

	8.3C T			11.0C T		
	Exposure Time (min)					
	0 (Control)	5	60	0 (Control)	5	30
Total Young	77	99	90	143	153	3
$\bar{X}$ (from surviving females)	9.6	9.9	10.0	14.3	15.3	0.3
95% C.I.	7.7-11.6	7.7-12.1	8.3-11.7	8.4-20.2	9.9-20.7	0.0-0.8

Source: Ginn 1977.

Table 8-16. Reproduction of <u>Gammarus</u> spp. following 8.3C ΔT at an ambient temperature of 26.0C.

Time after Exposure (Days)		Control 1	Control 2	5 minute 1	5 minute 2	60 minute 1	60 minute 2
5	Number alive	20	20	18	18	20	18
	Amplectic pairs	8	9	7	6	8	6
10	Number alive	18	20	16	17	14	17
	Amplectic pairs	1	0	1	1	0	1
	Ovigerous Females	7	10	6	7	9	6
15-17	Total number of young	141		118		115	
	$\bar{X}$ (for surviving females)	8.29		8.43		8.21	
	95% C.I.	6.34-10.24		5.91-10.95		6.54-9.88	

Source: Ginn 1977.

8.3.4 Intake and Discharge-Canal Studies

The condition of *Gammarus* spp. collected from June through December during 1972 at Indian Point Unit No. 1 is presented in Tables 8-17 and 8-18. Organisms were classified as alive, stunned or dead. Except during periods of condenser chlorination, survival was high, generally exceeding 90%. *Monoculodes edwardsi* was examined for viability in intake and discharge samples during the period of peak abundance from August 22 to November 28, 1972. No immediate mortalities were observed in non-chlorinated discharge samples, although discharge temperatures reached 31.1 to 33.3 C. Sufficient numbers of *M. edwardsi* for chlorination survival analysis were obtained only during periods of lower ambient water temperatures. A significant reduction in survival is apparent, however, and would be expected to occur throughout the ambient water temperature range (Table 8-19).

The survival of *N. americana* collected at Indian Point Unit No. 1 during the three month period of their maximum abundance (for 1972) is summarized in Table 8-20. When discharge temperatures were below 31.1 C, there was no detectable decrease in survival in discharge canal samples except during periods of chlorination. As discharge temperatures reached 32.2 to 33.3 C, there was a reduced mean survival at discharge station D-1 of 54.9% compared with 94.6% survival at the intake. Survival of *N. americana* during chlorination was reduced to approximately 50% regardless of discharge temperature.

Table 8-17. Condition of Gammarus sp. collected in 307 samples at the Indian Point Unit 1 intake and discharge stations from June 27 through September 26, 1972.

Temp. C		I-1	I-2	D-1	D-2	D-1 during chlorination	D-2 during chlorination
		Mean Percentage and 95% Confidence Interval					
Ambient= 20.0-21.7 T= 0 Discharge= 20.0-21.7	Alive	97.3 ±4.1	95.4 ±2.6	95.6 ±2.8	94.4 ±9.7	73.8 ±18.1	81.2 ±26.6
	Stunned	0.2 ±0.3	0.8 ±0.9	2.7 ±3.0	4.3 ±9.9	18.1 ±12.5	8.4 ±10.2
	Dead	2.6 ±4.2	3.8 ±2.3	1.7 ±1.5	1.3 ±2.4	8.0 ±5.7	10.4 ±17.0
Ambient= 22.6-25.7 T= 4.4-7.2 Discharge= 28.2-31.3	Alive	97.2 ±1.1	96.1 ±1.8	92.0 ±3.2	94.6 ±2.3	51.9 ±11.6	70.6 ±14.1
	Stunned	0.2 ±0.2	0.3 ±0.4	2.3 ±1.9	2.0 ±1.4	21.4 ±7.8	11.2 ±7.2
	Dead	2.6 ±1.2	3.6 ±1.9	5.7 ±2.4	3.4 ±1.6	26.8 ±8.9	18.1 ±10.8
Ambient= 24.9-26.0 T= 7.1-8.3 Discharge= 32.2-33.2	Alive	98.5 ±1.3	97.4 ±2.0	90.1 ±5.6	96.8 ±2.5	50.5 ±13.2	78.9 ±12.2
	Stunned	0.5 ±0.8	0.3 ±0.3	4.0 ±2.3	0.6 ±0.8	26.0 ±8.3	8.6 ±4.3

Source: Ginn 1977.

Table 8-18. Survival of *Gammarus* sp. ($\bar{X}$ and 95% confidence interval) collected at Unit 1 intake and discharge stations from October 3 to December 12, 1972. During this period ambient temperatures declined from 21.2 to 3.3 C; discharge temperatures ranged from 29.2 to 11.1 C; and the ΔT ranged from 5.6 to 10.6 C.

	Stations											
Chlorine	I-1			I-2			D-1			D-2		
	A	S	D	A	S	D	A	S	D	A	S	D
no	96.5 ±1.6	0.3 ±0.3	3.2 ±1.5	97.8 ±1.2	0.3 ±0.4	1.8 ±1.2	94.6 ±2.5	0.9 ±0.7	4.4 ±2.5	94.9 +2.4	1.0 +1.2	4.1 ±2.0
yes	-	-	-	-	-	-	63.6 ±8.1	25.5 ±5.7	9.9 ±3.2	74.4 ±7.0	17.8 ±5.0	7.8 ±2.8

A = alive
S = stunned
D = dead

Source: Ginn 1977.

Table 8-19. Survival of <u>Monoculodes edwardsi</u> collected in 146 samples at the Indian Point Unit 1 intake and discharge stations from August 22 to November 28, 1972. Numbers are percentage of organisms examined.

Ambient Temp. C	ΔT C	Discharge Temp. C	Chlorine	Stations I-1	I-2	D-1	D-2
6.2-15.2	5.6-10.6	16.4-21.7	No	95.9 ±2.0	93.4 ±2.9	92.3 ±3.8	88.3 ±7.6
			Yes	-	-	61.3 ±12.7	73.2 ±10.2
21.2-24.1	4.4-8.0	28.2-29.8	No	93.7 ±7.2	96.8 ±3.6	94.8 ±3.6	95.7 ±2.8
			Yes*	-	-	-	-
25.1-25.4	5.5-7.9	31.1-33.3	No	98.1 ±2.4	95.0 ±2.5	91.7 ±5.6	94.1 ±4.4
			Yes*	-	-	-	-

*Insufficient samples for analysis during chlorination.

Source: Ginn 1977.

Table 8-19. Survival of Monoculodes edwardsi collected in 146 samples at the Indian Point Unit 1 intake and discharge stations from August 22 to November 28, 1972. Numbers are percentage of organisms examined.

Ambient Temp. C	ΔT C	Discharge Temp. C	Chlorine	Stations I-1	I-2	D-1	D-2
6.2-15.2	5.6-10.6	16.4-21.7	No	95.9 ±2.0	93.4 ±2.9	92.3 ±3.8	88.3 ±7.6
			Yes	-	-	61.3 ±12.7	73.2 ±10.2
21.2-24.1	4.4-8.0	28.2-29.8	No	93.7 ±7.2	96.8 ±3.6	94.8 ±3.6	95.7 ±2.8
			Yes*	-	-	-	-
25.1-25.4	5.5-7.9	31.1-33.3	No	98.1 ±2.4	95.0 ±2.5	91.7 ±5.6	94.1 ±4.4
			Yes*	-	-	-	-

*Insufficient samples for analysis during chlorination.

Source: Ginn 1977.

Table 8-20. Survival of Neomysis americana collected in 230 samples at the Indian Point Unit 1 intake and discharge stations from August 1 to October 31, 1972. Numbers are percentage of organisms examined.

Ambient Temp. C	ΔT C	Discharge Temp. C	Chlorine	Stations I-1	I-2	D-1	D-2
14.1-18.9	5.6-7.2	19.7-26.1	No	83.7 ±9.0	87.1 ±16.3	71.1 ±7.6	83.1 ±11.3
			Yes	-	-	47.5 ±17.5	57.9 ±17.5
21.2-25.6	3.9-8.0	28.2-31.1	No	89.6 ±3.3	86.2 ±4.6	76.4 ±7.0	86.7 ±4.3
			Yes	-	-	45.8 ±14.0	64.3 ±8.4
24.9-26.1	7.3-7.9	32.2-33.3	No	94.6 ±6.1	94.6 ±7.7	54.9 ±14.1	67.8 ±27.7
			Yes	-	-	55.9 ±12.9	70.4 ±18.1

Source: Ginn 1977.

Observations made on less common species suggest that significant mortalities did not occur for these forms during entrainment. Survival of all isopods and of Chaoborus sp. larvae was nearly 100% for intake and discharge samples, except during chlorination (Ginn 1977).

Results of 1974 and 1975 corroborate work from earlier years. Gammarus spp. collected during ambient temperatures of 13-24.9 C at ΔT's of 5.4-10.1C displayed no reduction in survival. However, Gammarus spp. collected in the discharge canal during periods of condenser chlorination had reduced survival when compared to intake samples (NYU 1976a). M. edwardsi were collected in sufficient numbers for viability analysis from June 13 to November 12, 1974. There were no detectable differences in survival between intake and discharge canal collections (NYU 1976a).

Although the 1974 survival data for N. americana varied considerably (i.e. with ΔT) the combined results produced sufficiently large sample sizes for statistical analyses. The mean percent alive at Station D-1 reached a maximum of 67.3% on June 18 when the operating ΔT was 5.5 C at an ambient temperature of 20.5 C, The intake survival on that day was 82.7%. On August 20, however, the percent alive at station D-1 was only 7.8% at a ΔT of 8.1 C above an ambient temperature of 25.9 C, This represents a substantial mortality since the intake survival on August 20 was 96.3% (NYU 1976a).

The results of these viability assessments performed on intake and discharge-canal samples of some of the other macrozooplankton species show that at the rated ΔT for Unit No. 2 of 8.3 C and an ambient temperature of 20 to 25 C, entrainment into the cooling-water flow of the Indian Point plant had little or no effect on survival (NYU 1976a), except for Neomysis. Neomysis exposed to the plant conditions described above suffered mortalities upwards of 90%. This mortality was limited to those times of the year when the salt front was present in the Indian Point area. Since the salt front (and thus the occurrence of Neomysis) only occasionally extends more than a few miles upriver of Indian Point, the extensive cropping of Neomysis by the plant probably represents an effect on the fringe of the species' distribution in the Hudson River. Despite the high entrainment mortality, it has been estimated that the Indian Point plant reduces the river-wide population of Neomysis by less than 1% (Lawler, personal communication).

8.3.5 Plume Entrainment Studies

The survival of Gammarus spp. exposed to control and plume transits was greater than 90% for both experiments. No statistical differences were detected between 120 hour survivals of both control and plume transit groups. Test groups of Gammarus spp. exposed to the full-strength Unit 2 discharge for one hour during chlorination also displayed no reductions in immediate or latent survival (NYU 1976b). Other studies have indicated that Gammarus spp. can experience short-term exposures (less than 1 hour) to total chlorine concentrations below 0.5 mg/l without adverse effects on immediate or subsequent survival. Gammarus spp. are also able to detect and avoid chlorine-temperature combinations substantially below short-term lethal levels, so that it would appear that the discharge plume poses little threat to Gammarus spp. survival (NYU 1976b).

SECTION 9

ICHTHYOPLANKTON

TABLE OF CONTENTS

9. ICHTHYOPLANKTON

9.0 SUMMARY

The results of studies investigating the abundance and distribution of ichthyoplankton in the vicinity of Indian Point are examined. The presence of these fish eggs, larvae and juveniles in the plant and nearby river, and thus their susceptibility to entrainment, is primarily determined by a variety of physicochemical factors. Interpretation of the results from intake and discharge-canal studies has been complicated by the uncertainty associated with the collection efficiency of net sampling. Laboratory experiments have indicated that water velocity (which is significantly different between the Indian Point intake and discharge sampling stations) exerts a major influence in determining the extent of sampling mortality.

Nevertheless, intake and discharge-canal studies at Indian Point and other Hudson River plants have indicated that entrainment survival is primarily related to thermal, rather than mechanical factors. Survival throughout the years studied was variable, but for striped bass, larvae and juveniles showed consistently higher survival than eggs and yolk-sac larvae. Laboratory studies have found that the temperature tolerances of early striped bass egg and yolk-sac larvae were exceeded when the maximum ΔT (8.3 C) at rated capacity was produced, although the experimental exposure time was longer than would be encountered during normal plant operation. Plume studies have indicated that striped bass larvae

and juveniles can tolerate short-term exposures to chlorine concentrations considerably higher than those occurring in the Indian Point thermal plume. Bioassays performed to simulate condenser transit during Unit No. 2 chlorination also found that the low concentration of chlorine used for defouling would not adversely affect striped bass juveniles.

9.1 SUSCEPTIBILITY

9.1.1 Introduction

Assessment of the effects of pump and plume entrainment on ichthyoplankton involves the analysis of the abundance, temporally and spatially, of several different life stages, each with specific ecological requirements. These stages include eggs, yolk-sac larvae, larvae and juveniles up to approximately 30 mm in length. The susceptibility of each of these stages to entrainment is related to a variety of physicochemical, hydrological and biological factors. Susceptibility to entrainment may vary considerably from one life stage to another, at different ages within a life stage, or among species, depending on their location in the river and water column relative to the cooling-water system intakes. Physiological factors associated with each life stage (related to its capacity to withstand or avoid entrainment) determine the organism's vulnerability. In this section, emphasis is placed on the susceptibility to entrainment of fish life stages found in the vicinity of Indian Point.

The specific objectives of the river and plant ichthyoplankton population studies were to determine: (1) the species composition, abundance, and temporal and spatial distribution of ichthyoplankton in the Indian Point vicinity of the Hudson River; (2) to what extent the temporal and spatial distribution of fish egg and larval stages affects the rate of entrainment by statistical comparison of the concentrations of ichthyoplankton in river to plant samples; and (3) whether and to what extent the seasonal occurrence and relative abundance of key ichthyoplankton species are altered between study years by observed damage due to entrainment.

9.1.2 Methods and Materials

9.1.2.1 River Population Studies

Ichthyoplankton were collected in samples with macrozooplankton during NYU Statdard Station Surveys, 1971-75. Organisms of these two major biological groups, which were obtained in collections at all seven stations (except during 1973) and at three different depths, were then separated for detailed analysis. The methods and gear used are described in the macroplankton section 8.2.1. Fish eggs and larvae were sorted from the samples, identified and enumerated.

9.1.2.2 Plant Entrainment Studies

Ichthyoplankton were collected with macrozooplankton in plant intakes and discharge. The sampling rigs and methods used are described in section 8.2.2. The ichthyoplankton were separated from the samples, identified and enumerated as performed for the river population samples.

As an estimate of the consistency of volumes sampled, catch per unit effort (C/f) analysis was compared to catch per 1000 m^3 over individual 5 min. sampling events. Since flowmeters were not used after May 1974, this technique served as a control to identify aberrant flows.

The dates and samples selected for abundance comparisons between intake and discharge locations were limited to those dates when all stations involved in the comparisons were sampled (e.g., if, on any given sampling date, samples were collected at stations II-2, II-5 and D-1, but not at D-2, then none of the samples collected on this date was used in the comparisons).

9.1.3 Results and Discussion

9.1.3.1. Species Comparisons

A total of 23 species have been observed in the Indian Point area since 1971. Sixteen of these species have been collected through successive years (Table 9-1). All life stages of each species, however, were not accounted for during each sampling season. The occurrence and abundance of fish life stages in the plankton at Indian Point depends on the location of spawning in the river relative to the power plant, the type of eggs produced and the habitat preferences of the larval and juvenile stages. The presence of variations in location or stage of appearance, which are dependent on the ecology of each particular species, are in turn determined by the physicochemical factors existing in the

Table 9-1. Species comparisons from 1971 to 1975.

Species	1971	1972	1973	1974	1975
Anchovy	+	+	+	+	+
Clupeids	+	+	+	+	+
Striped bass	+	+	+	+	+
White perch	+	+	+	+	+
Tomcod	+	+	+	+	+
Darters	+	+	+	+	+
Cyprinids	+	+	+	+	+
Hogchoker	+	+	+	+	+
Yellow perch	+	+	+	+	+
Smelt	+	+	+	+	+
Silversides	+	+	+	+	+
American eel	+	+	+	+	+
Pipefish	+	+	+	+	+
Killifish	-	+	-	-	+
Menhaden	+	-	-	-	-
Weakfish	-	+	+	+	+
*Sturgeon	+	-	-	-	+
Centrarchid	-	+	+	+	+
Silver perch	-	+	-	-	-
White catfish	-	-	+	-	+
Stickleback	-	+	-	-	-
Gobi	-	-	+	+	-
Windowpane flounder	-	-	-	-	+

+ indicates species presence

- indicates species absence

* species differentiation could not be determined for early life stages.

Source: NYU 1977

river at the time of collection. Other factors, such as the demersal, adhesive nature of several species' eggs (e.g. white perch)--which renders this life stage less vulnerable, played a lesser role.

Overall, the species composition of the ichthyoplankton collected in the Hudson River in the vicinity of Indian Point was consistent throughout five years of study. The life stages and relative abundance, by year, of fish species taken in these samples are shown in Table 9-2. Although total species composition varied little, the annual presence of particular species life stages did show significant variation, especially in the larval stage.

A total of six species and/or groups (anchovy, clupeids, striped bass, white perch, cyprinids and hogchoker) were represented by all life stages during the study (tomcod would have been represented if sampling were performed during the winter). In addition, only members of these species showed consistent occurrence of a particular life stage in the Indian Point area during all years. Of the remaining seventeen species, only the American eel, rainbow smelt, and weakfish were observed as greater than two percent of the relative abundance, and then only in the juvenile stage. From Table 9-2, it is apparent that among life stages, the larvae are represented by the greatest number of different species. Following in decreasing order of percent relative abundance are the juvenile, yolk-sac larvae, and egg stages.

Table 9-2. Annual occurence and percent relative abundance of fish eggs, yolk-sac larvae, larvae and juveniles in the Hudson River between mile 39.0 and mile 47.0 for 1971, 1972, 1974 and 1975. Data for 1973 was not available for all species.

Species	Eggs 1971	Eggs 1972	Eggs 1974	Eggs 1975	Yolk-sac Larvae 1971	Yolk-sac Larvae 1972	Yolk-sac Larvae 1974	Yolk-sac Larvae 1975
Anchovy	----	----	95.9	98.7	----	----	16.3	35.5
Clupeids*	7.2	1.1	+	+	16.6	6.8	3.9	2.6
Striped bass	92.7	87.2	3.1	1.2	55.6	65.6	54.8	43.3
White perch	+	0.8	0.5	0.1	22.2	16.6	22.7	15.3
Tomcod	----	----	----	----	----	13.1	----	+
Darter	----	----	----	----	4.0	4.9	1.7	1.6
Cyprinids**	----	+	0.5	+	1.6	1.9	0.6	0.9
Hogchoker	----	10.9	----	----	----	0.1	0.1	+
Yellow perch	----	----	----	----	----	+	----	+
Weakfish	----	----	----	----	----	----	----	----
Smelt	----	----	----	----	----	----	----	0.7
Silversides	----	----	----	----	----	----	----	----
American eel	----	----	----	----	----	----	----	----
Pipefish	----	----	----	----	----	----	----	----
Centrarchid	----	----	----	----	----	+	----	----
Gobi sp.	----	----	----	----	----	----	----	----
Atlantic sturgeon	----	----	----	----	----	----	----	----
Windowpane flounder	----	----	----	----	----	----	----	----
Killifish	----	----	----	----	----	----	----	----
White catfish	----	----	----	----	----	----	----	----
Species present	3	5	5	5	7	11	10	12

Table 9-2 (Cont.).

Species	Larvae 1971	Larvae 1972	Larvae 1974	Larvae 1975	Juveniles 1971	Juveniles 1972	Juveniles 1974	Juveniles 1975
Anchovy	51.2	30.8	69.8	42.1	99.8	57.4	68.7	49.0
Clupeids*	10.7	47.8	7.9	10.9	+	3.4	1.4	2.2
Striped bass	14.3	7.1	12.2	21.8	+	7.3	0.4	0.2
White perch	21.8	8.0	9.4	23.6	+	30.1	0.1	1.2
Tomcod	----	5.2	----	+	+	----	9.6	16.0
Darter	0.1	0.4	0.1	0.3	----	+	----	0.5
Cyprinids**	+	0.4	0.2	0.3	----	+	+	----
Hogchoker	+	0.3	0.1	0.2	+	1.7	2.0	2.5
Yellow perch	+	0.8	+	+	----	----	----	----
Weakfish	----	+	0.1	+	----	+	2.7	0.5
Smelt	1.2	----	0.1	0.4	+	+	2.7	4.8
Silversides	0.2	+	0.1	+	----	----	0.2	----
American eel	----	----	----	----	+	+	12.9	20.5
Pipefish	----	----	+	+	+	+	0.4	1.2
Centrarchid	----	+	+	+	----	----	----	----
Gobi sp.	----	----	+	+	----	----	----	----
Atlantic sturgeon	----	+	----	+	----	----	----	----
Windowpane flounder	----	----	----	+	----	----	----	----
Killifish	----	----	----	+	----	----	----	1.0
White catfish	----	----	----	----	----	----	----	0.2
Species present	12	15	16	19	11	12	12	13

\+ indicates less than 0.1 percent.

* The clupeids included alewife, blueback herring, and shad. The eggs are presumed to be alewife because of time of occurrence and size. The shad are presumed to be present in larval and juvenile stages for years 1971 and 1972. The yolk-sac larvae stage for shad is easily identified due to its size in the sample (9 to 10 mm) for all years from 1971 to 1975. For years 1974 and 1975 shad were present only as yolk-sac larvae and larvae (fish) in the samples.

** Three possible species: the spottail shiner early in the season, and carp and/or goldfish later during summer months.

Source: NYU 1977.

9.1.3.2 Life Stage Occurrence and Biology

The follow species represent those fish which occur in greater than 1% relative abundance for potentially entrainable life stages at the Indian Point Station.

Striped Bass *(Morone saxatilis)*

Both eggs and larvae of the anadromous striped bass occur in the plankton at Indian Point. Striped bass spawn in fresh water throughout a long reach of the Hudson River estuary from about Kingston downstream to a short distance above the salt water front. Striped bass eggs are rarely taken in water that exceeds 0.5 to 1.0 ppt. Eggs are present in the plankton at Indian Point from early May to mid-June, when the water temperature ranges from about 10 to 19.5 C except when salinity above 0.5 to 1.0 ppt moves into the area (TI 1975c).

Striped bass eggs are only slightly negatively bouyant and are non-adhesive. Thus, although striped bass eggs have a tendency to sink, only a very slight upward movement of water is needed to keep them in suspension. Their abundance at Indian Point increases with depth, but Albrecht (1964) and Bigelow and Schroeder (1953) have found that turbulence in lower water strata is sufficient to keep eggs from completely settling out.

The striped bass yolk-sac larvae have very limited motility and also tend to sink toward the bottom, with the result that they are most abundant near the bottom during the day. Noctural distributions are less stratified, however, with nearly equal mid-depth and bottom densities (Con Ed 1977d). Yolk-sac larvae are widely distributed throughout the estuary from May through June, with greatest abundances occurring in the Croton-Haverstraw through Kingston regions (Con Ed 1977d).

Striped bass larvae become stronger swimmers as they grow larger. They exhibit dramatically different distributions in the water column in day and night collections. Studies (NYU 1974a; 1974b; TI 1976c) have shown that daytime abundance of larvae near the surface was almost zero, with abundance increasing to highest density near the bottom. During the night the larvae were much more evenly distributed from top to bottom. Striped bass larvae usually occur in the plankton at Indian Point for about 10 weeks from about mid-May to mid-July. Their longitudinal distribution is similar to yolk-sac larvae during the June peak abundance period (NYU 1973).

The distribution of larvae reflects a general shoreward and downstream movement of developing juveniles into shore-zone or shallow-water nursery areas (TI 1976c) within the lower Hudson River estuary.

White Perch (*Morone americana*)

The white perch tend to remain within the Hudson River as a discrete self-contained population, generally inhabiting the brackish mid-to-lower portion of the estuary during most of the year. However, they regularly undertake upstream migrations into tidal fresh and slightly brackish water to spawn in the spring (Scott and Crossman 1973; Mansuetti 1964).

White perch spawn in the Hudson from early to mid-May through June, when water temperatures range from 14-21C. The demersal and adhesive characteristics of white perch eggs, described by Mansuetti (1964), and the fact that spawning characteristically occurs in shallow shore zone areas in tributary streams, may account for the relatively small number of eggs collected throughout the study years.

The longitudinal distribution of yolk-sac larvae is similar to that of eggs with peak abundance in late May - early June. White perch larvae occur in the plankton at Indian Point from mid-May through July or early August. The peak abundances of white perch and striped bass larvae occur at about the same time and are difficult to distinguish from each other. The day-night depth distribution of white perch larvae was similar to that of striped bass. They were most abundant at middle and bottom depths during the day, and more evenly distributed from top to bottom at night (NYU 1974a; 1974b).

Perlmutter et al (1967) have shown that juvenile white perch, as do striped bass, tend to move downstream and shoreward into principal nursery areas in mid-summer.

Atlantic Tomcod (*Microgadus tomcod*)

Tomcod adults enter the Hudson River estuary from about mid-October to the end of December. The spawning season lasts from mid-December through February, at water temperatures ranging from 0.0 degrees to 3.9 C. Spawning occurs primarily in shallow brackish water and around stream tributaries (Scott and Crossman 1973).

The eggs are demersal and adhesive and usually not found in the plankton. The eggs require about 24-28 days to hatch into larvae, depending on the water temperature. Newly hatched tomcod larvae are produced in the river from about mid-January through March and are concentrated in the lower estuary and downstream regions of the middle estuary. No plankton sampling is performed during most of that time because of ice cover on the river, so information on presence of tomcod larvae in the plankton is incomplete. The tomcod yolk-sac larvae collected from 1971-1975 showed a preference for bottom waters during the day. Too few larvae were collected during the night to determine depth preference (NYU 1973a).

Abundance of post yolk-sac larvae peaks in early April in the most downstream regions of the lower estuary. This apparent downstream transport during the early larval stage may be assisted by the concentration of post yolk-sac larvae in the channel stratum, where currents are stronger and a slight net downstream flow occurs.

Juvenile Atlantic tomcod are found primarily near bottom in shoal and channel waters of downstream, low-salinity, or brackish regions of the estuary (TI 1976c). Abundance increases to a peak in mid-May, when the population is concentrated in the extreme downstream regions of the lower estuary.

Alewife *(Alosa pseudoharengus)* and Blueback Herring *(Alosa aestivalis)*

The clupeids collected in the vicinity of Indian Point include the alewife, blueback herring and American shad *(Alosa sapidissima)*. Due to difficulty in distinguishing between early developmental stages, and the large number of organisms collected, eggs and larvae of these species were not identified to the species level (NYU 1973a).

Since the peak spawning period of alewife generally precedes that of blueback herring by approximately one month (Warinner et al 1969; Hildebrand and Schroeder; 1928), it is likely that major egg concentrations encountered during early May reflect peak spawning of alewife, while those encountered in early June reflect peak spawning of blueback herring. Based on size and occurrence, the eggs are not presumed to be shad, which spawn principally in areas (Catskill region) of the upper estuary (NYU 1977).

Raney and Massmann (1953) and Hildebrand (1963) indicate that alewife travel far upstream to spawn demersal eggs in tributary creeks and pools, usually in sluggish water only a few inches deep. *Alosa* spp. yolk-sac larvae are also concentrated in the upper estuary during the period of peak abundance from mid-May to early June.

Blueback herring spawn later in the season than alewives, usually when water temperatures reach 21 to 23.4 C. They appear not to run as far toward headwaters of tributary creeks as the alewife, but prefer to spawn mostly in the deeper open water of the Hudson River above Indian Point (Bigelow and Schroeder 1953; TI 1976c). The eggs are demersal and adhesive, and therefore do not occur in the plankton. Since blueback herring spawn in relatively warm water, incubation and growth proceeds rapidly.

Alosa spp. larvae are common at Indian Point and species peaks are distinguished by time of occurrence following their respective spawns. Thus many of the clupeid larvae collected at Indian Point in late June and in July are probably blueback herring. Juvenile *Alosa* spp. are distributed similarly to eggs and larvae, peaking in abundance during July in the channel stratum of the upper estuary. The juveniles averaging 30 mm in total length begin to move into the shorezone in mid-July when they can be accurately identified as blueback herring or alewife (Con Ed 1977d). *Alosa* spp. juveniles are apparently highly tolerant of different salinites (TI 1976c).

Bay Anchovy (*Anchoa mitchilli*)

Dovel (1971) has found that spawning of this small, euryhaline, schooling fish occurs from mid-July through early September at mean water temperatures of 25-27 C. The eggs are buoyant when spawned but gradually become demersal. Data presented by NYU (1974a; 1974b) have indicated that the anchovy larvae were least abundant near the surface and most abundant at the middle and bottom depths both during the day and at night.

Hogchoker *(Trinectes maculatus)*

Spawning of this small, predominantly estuarine flatfish, begins in early June when the water temperature reaches about 20 C and peak spawning takes place at a temperature of about 25 C; greatest concentrations of eggs are taken in the lower estuary at salinities from 10 to 16 ppt (Dovel et al 1969).

Smith (1971) has found that after hatching, young move upstream to low salinity nursery areas, remaining near the bottom in shoal and channel waters.

Rainbow Smelt *(Osmerus mordax)*

Spawning of this anadromous species begins in late winter and early spring when water temperatures reach 4.4C (Scott and Crossman 1973; Boyle 1969). Smelt spawn demersal, adhesive eggs generally on a pebbly bottom and often in brackish water only a few inches deep where there is a current. Smelt larvae are found in the plankton at Indian Point in years when salinity greater than 1 ppt occurs that far upstream during their larval production season; however, the specific level of salinity required is not known. Smelt larvae are present at Indian Point mostly during June, although a few stragglers are taken from late May to August.

Other species, such as the spottail shiner *(Notropis hudsonius)*, white catfish *(Ictalurus catus)*, weakfish *(Cynoscion regalis)*, shortnose sturgeon *(Acipenser brevirostrum)* and Atlantic sturgeon *(Acipenser oxyrhynchus)* observed in the plankton occurred sporadically, usually in extremely small numbers, and will not be discussed further here because of the lack of sufficient numbers for quantitative analysis. This is particularly true for the shortnose sturgeon which was generally not captured in the river samples and was found in extremely small numbers in the entrainment samples; the Atlantic stugeon, was present only in 1972 and 1975 larvae collections and represented less than 0.1% relative abundance (NYU 1977).

9.1.3.3 Susceptibility Assessment

9.1.3.3.1 Distribution and Abundance

The seasonal distribution of fish species from 1971 to 1975 (exclusive of 1973, for which year insufficient data precluded species comparison) and their occurrence relative to water temperature and salinity at Indian Point are shown in Figs. 9-1 to 9-4. The seasonal presence of the various species identified appears to be related to temperature and salinity (NYU 1976a; 1977).

The probability of ichthyoplankton being entrained is related to the reproductive and developmental characteristics of the species. Spatial distribution of these potentially entrainable organisms is notably uneven and distributions are clumped, subject to changes in diel and seasonal cycles. Life stages may be subject to entrainment only for short periods of the year; periods that may or may not coincide with operating conditions that could potentially damage that life stage.

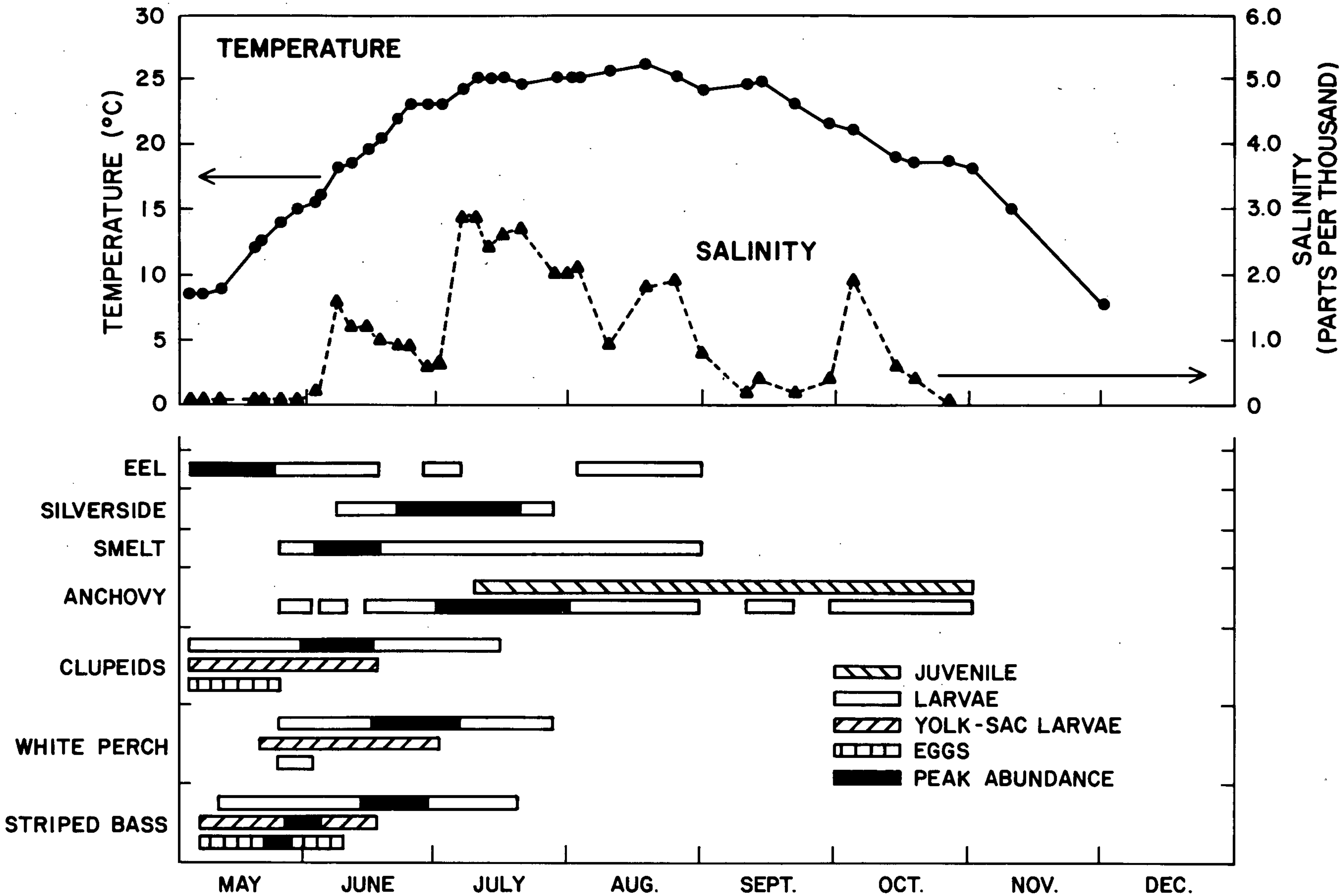

Figure 9-1. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1971.

Source: NYU 1973.

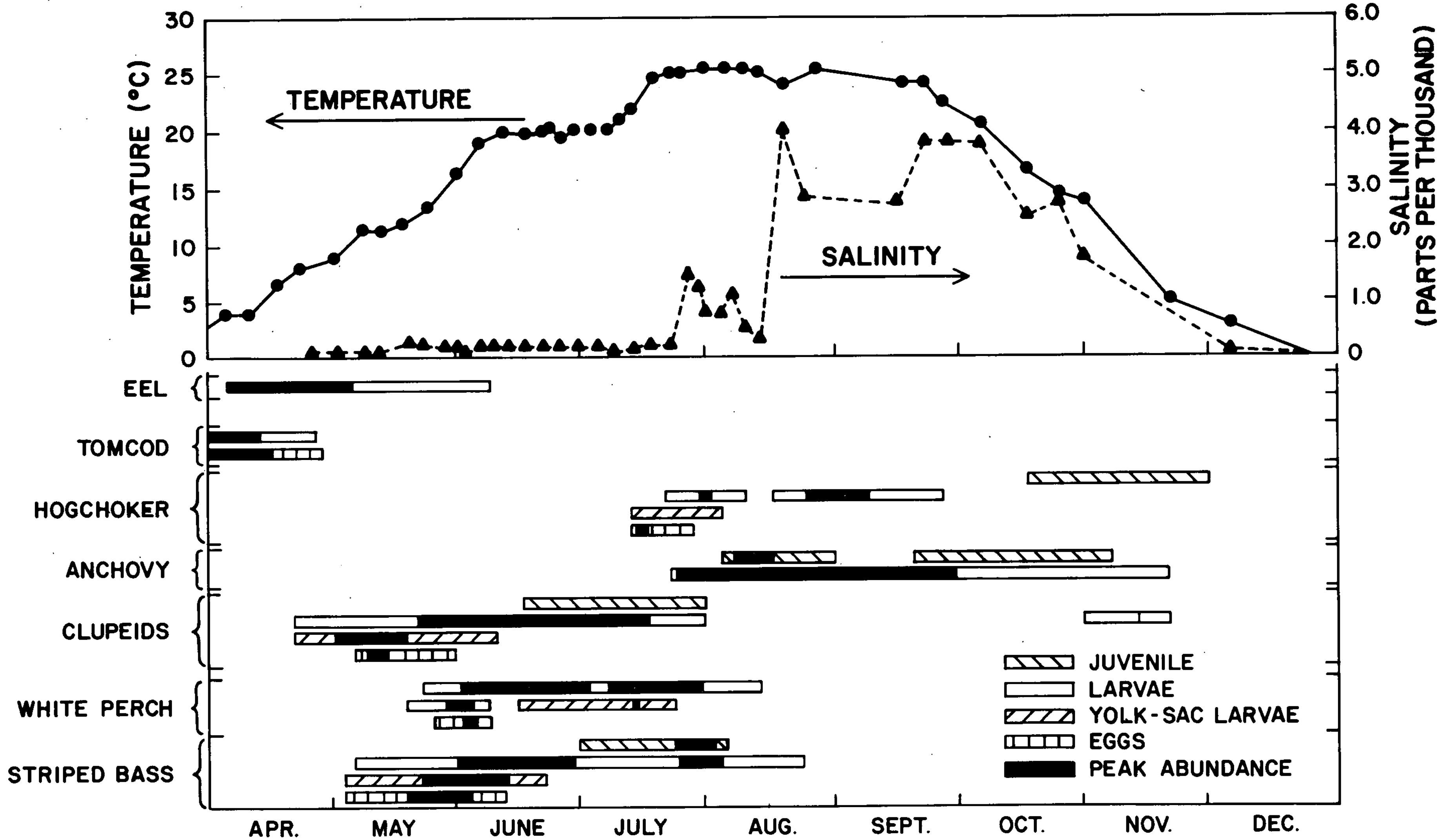

Figure 9-2. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1972.

Source: NYU 1973.

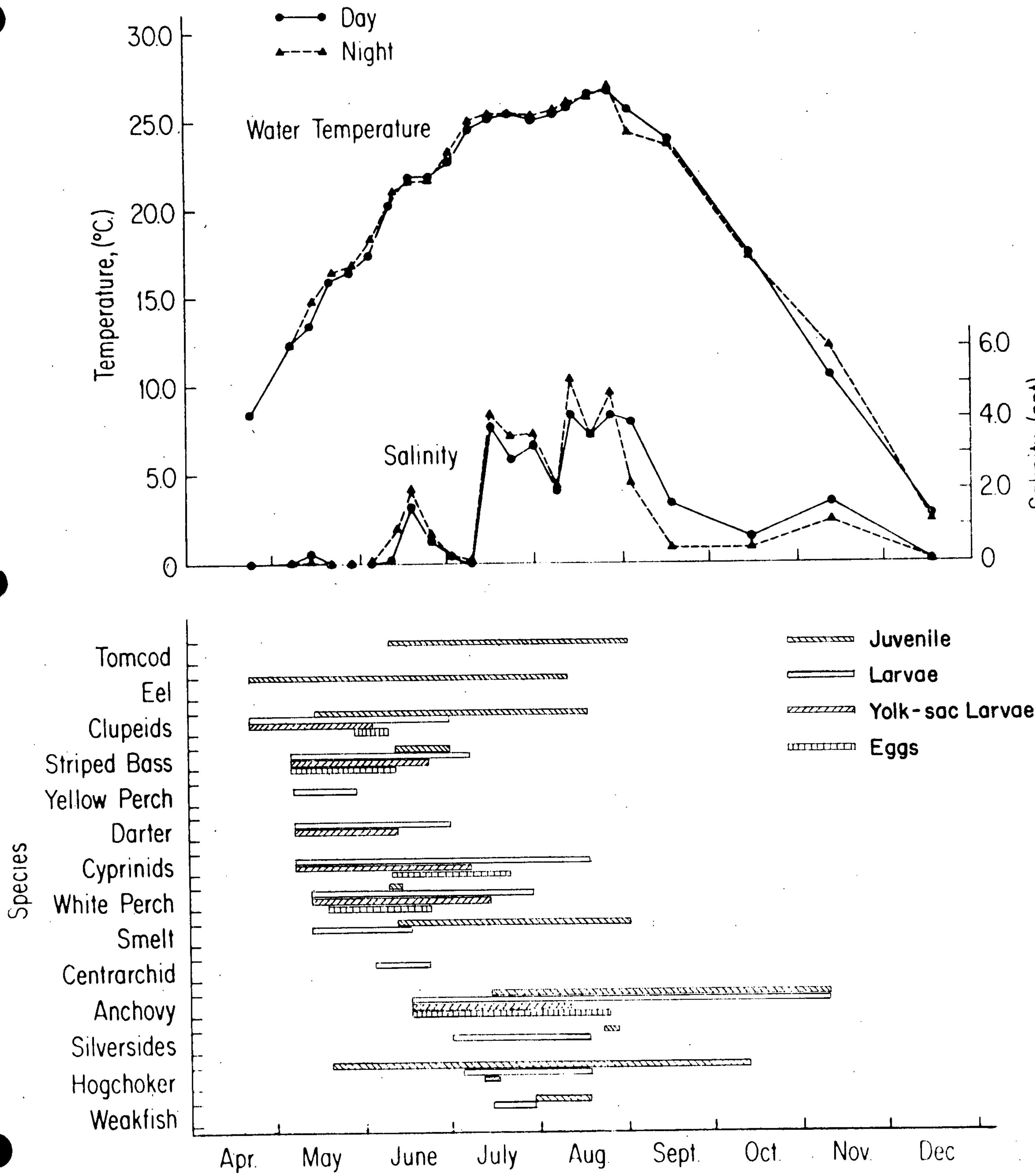

Figure 9-3. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1974.

Source: NYU 1976a.

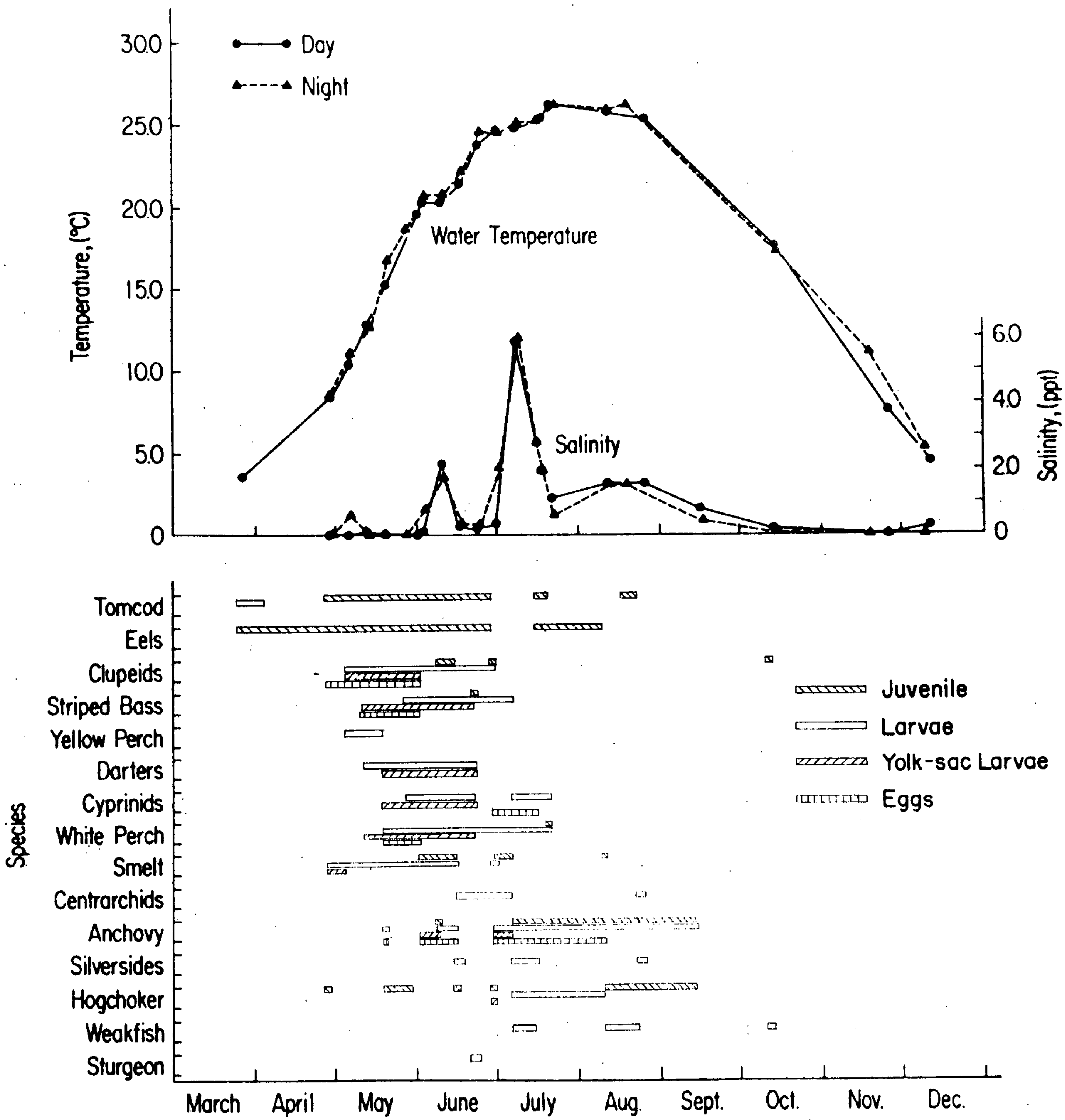

Figure 9-4. Seasonal distribution of fish eggs larvae and juveniles relative to temperature and salinity, 1975.

Source: NYU 1977.

9.1.3.3.1.1 Eggs

Throughout the study period, clupeids and striped bass eggs were first (or nearly so) to occur each year in the Indian Point region, when the salinity was less than one ppt. These were followed by white perch eggs, which occurred in a similar zone of salinity, but at slightly higher water temperatures. With the influx of salt water into the Indian Point region in early June (1971, 1974, 1975) and mid-July (1972), bay anchovy eggs became increasingly abundant. The numbers of anchovy eggs remained high in the Indian Point area of the river as long as the salinity values were high (≥2 ppt). The only other eggs noted during the study period were those of a cyprinid fish (*Notropis* sp.), and the hogchoker, which were found during periods of fresh and saline water respectively (NYU 1973; 1974a; 1976a; 1977). During the four years, only eggs of these six species were collected in standard station sampling for potentially entrainable fish eggs. Although anchovy eggs accounted for the majority of eggs collected during the entire study period, Table 9-2 is indicative of the expected fluctuation of occurrence of the various ichthyoplankton life stages. The percentages of striped bass eggs observed during 1971 and 1972 are relatively high compared to the small number of other species' eggs collected in those years, but are low in 1974-75 due to the large quantities of anchovies collected. The overwhelming presence of anchovy eggs in 1974 and 1975 and their absence in 1971 and 1972 demonstrates dependence of spawning activity on river temperature and salinity (Fig. 9-1 through 9-4).

In 1971 the early June rise in salinity coincided with water temperatures less than 20 C, and thus was not conducive to anchovy spawning (section 9.1.3.2). In 1972, salinity increase in the Indian Point area did not occur until late in the anchovy spawning season (August-September), and egg collection was consequently minimal. Further evidence of the association between life stage occurrence and suitable physicochemical factors is indicated by the lack of anchovy yolk-sac larvae collected during 1971 and 1972 (Table 9-2). Other species, such as the hogchoker, and cyprinids were present in the egg stage in the plankton at Indian Point in one or more of the years but not in all, depending to a large extent on the location of the salt front (section 9.1.3.2).

The abundance of yolk-sac larvae of each species collected closely follows in time, the curves established for its egg abundance (Figs. 9-5, 9-6, 9-7, 9-8). In most instances, the curves for yolk-sac larvae are displaced wholly to the right of those for the eggs and thus show indications of having been derived from the previous peak egg abundance; this is seen for each species (NYU 1976a; 1977).

In the case of white perch, there appear to be more yolk-sac larvae than eggs. Since white perch eggs are adhesive and demersal, they were not proportionately represented in the

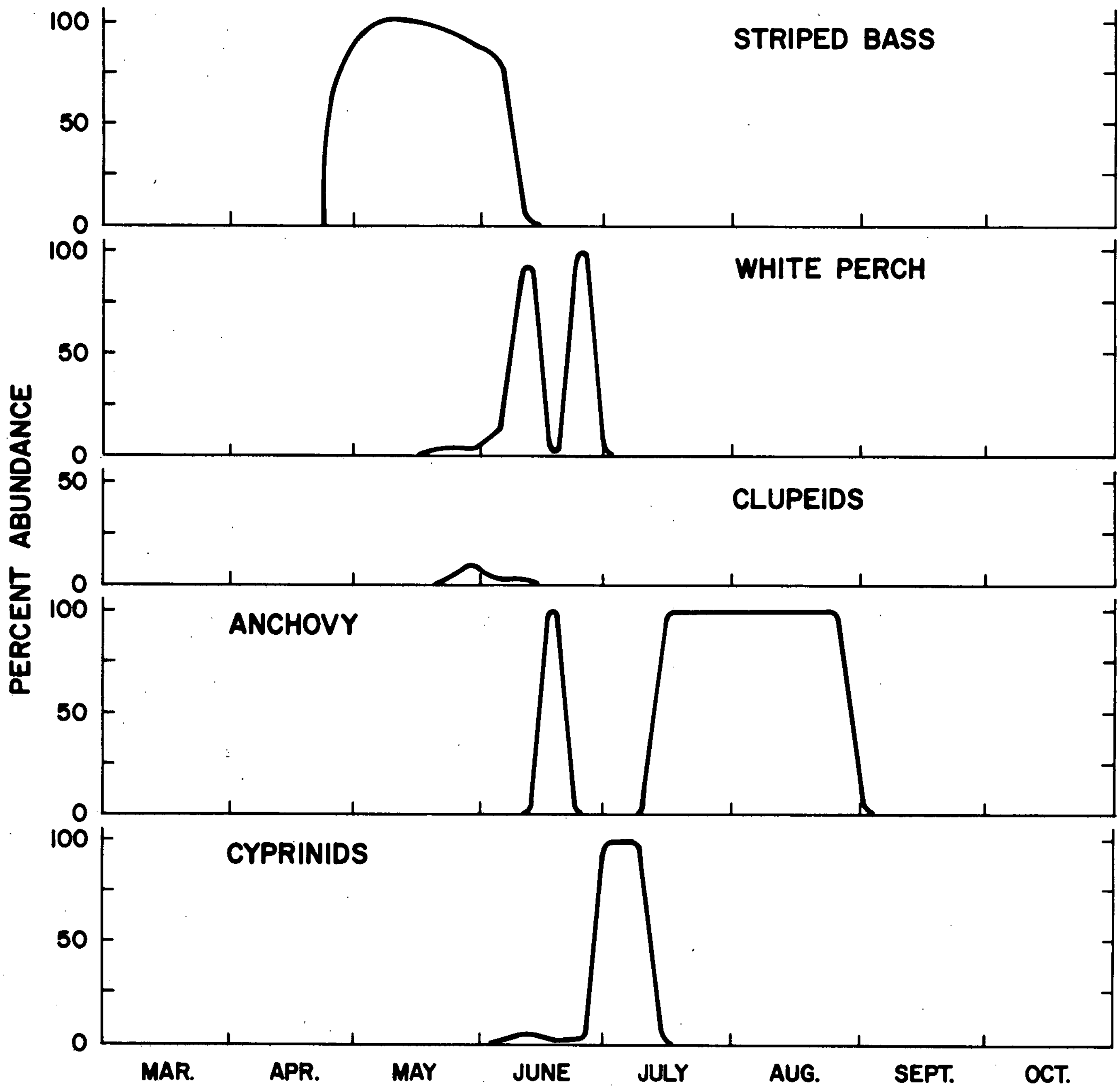

Figure 9-5. Seasonal occurrence and percent abundance for fish eggs by species, 1974; values shown are percent of total fish eggs in the samples analysed.

Source: NYU 1976a.

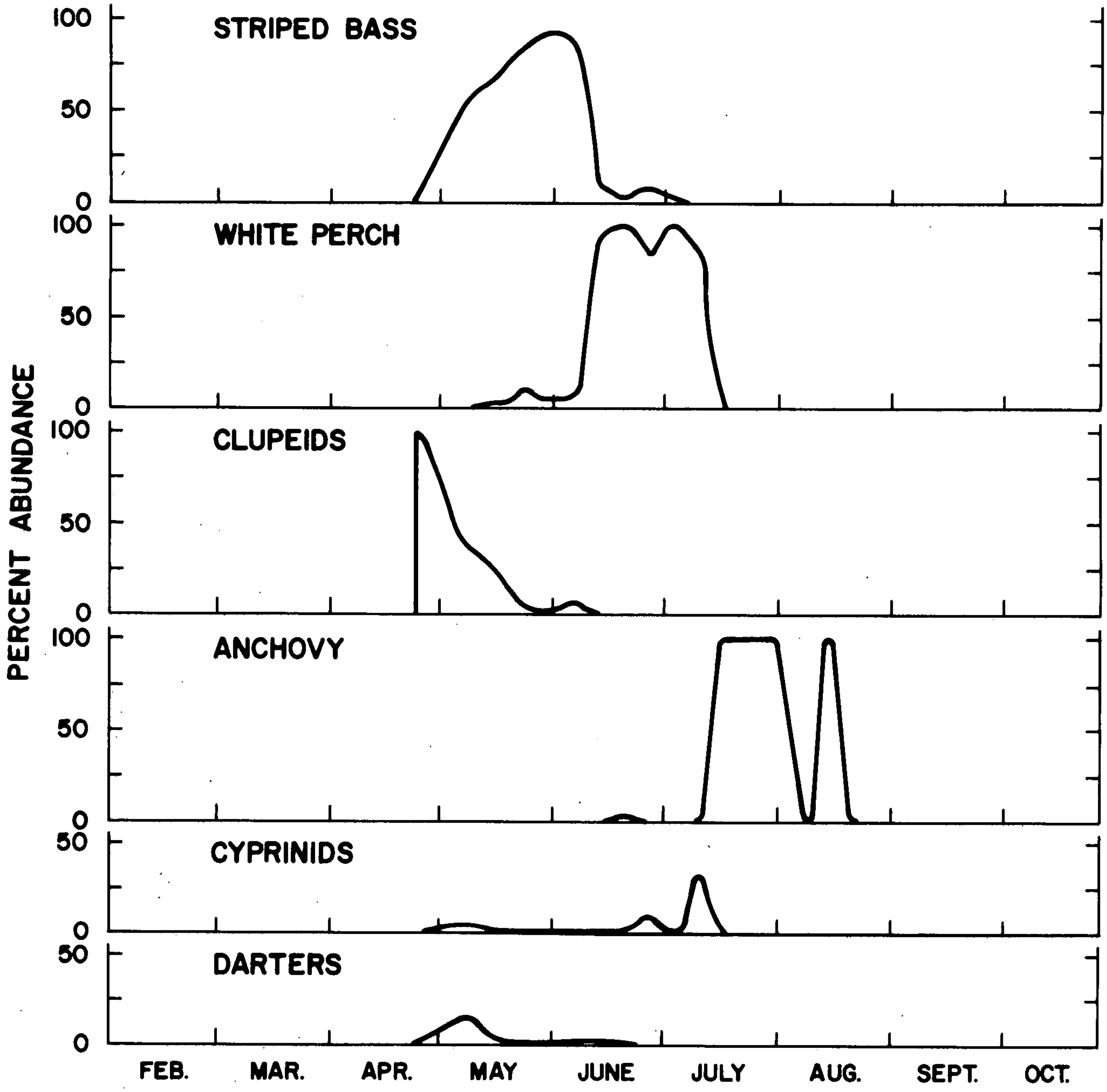

Figure 9-6. Seasonal occurrence and percent abundance for yolk-sac larvae by species, 1974; values shown are percent of total yolk-sac larvae in the samples analysed.

Source: NYU 1976a.

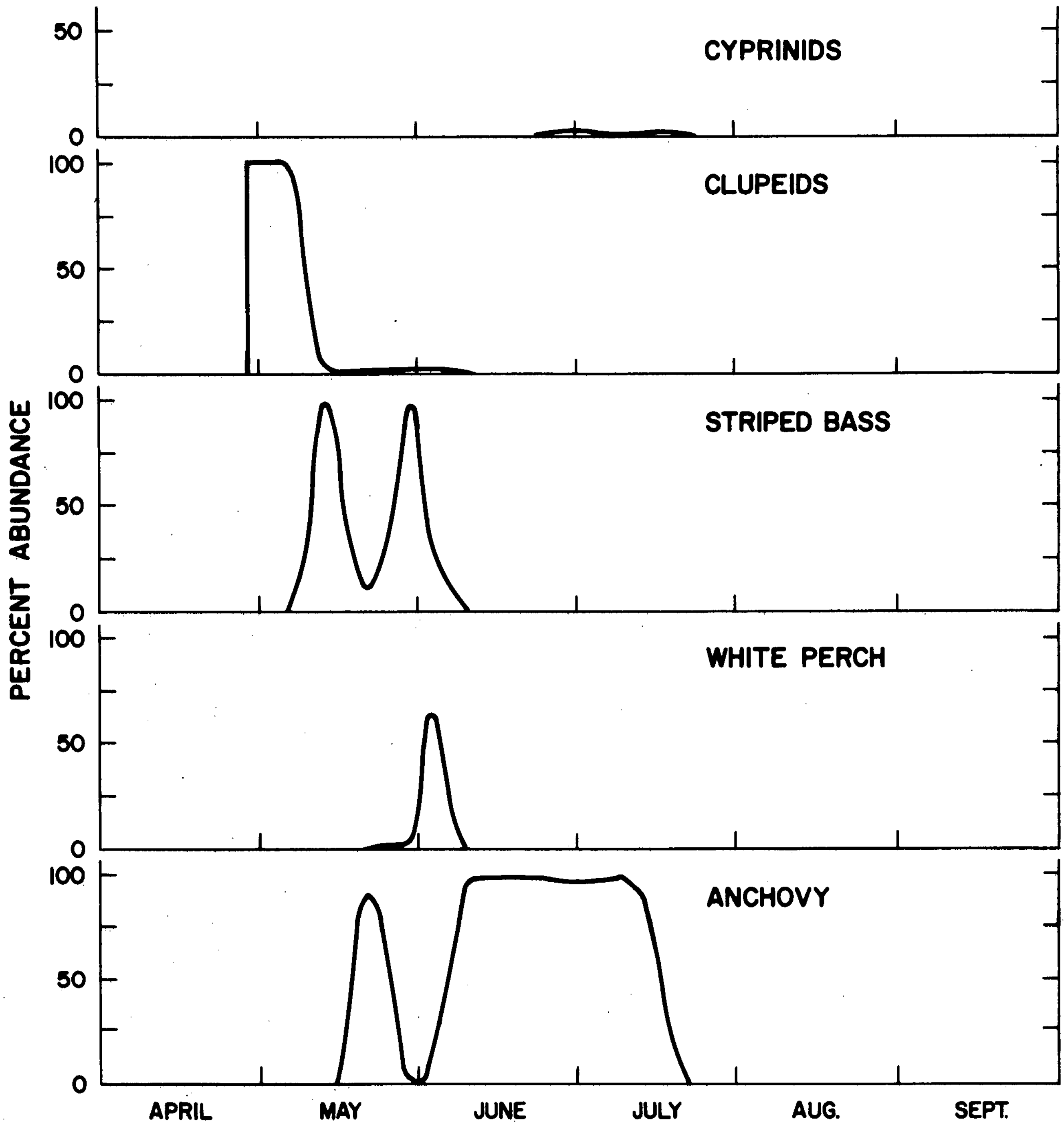

Figure 9-7. Seasonal occurrence and percent abundance for fish eggs by species, 1975; values shown are percent of total fish eggs in the samples analysed.

Source: NYU 1977.

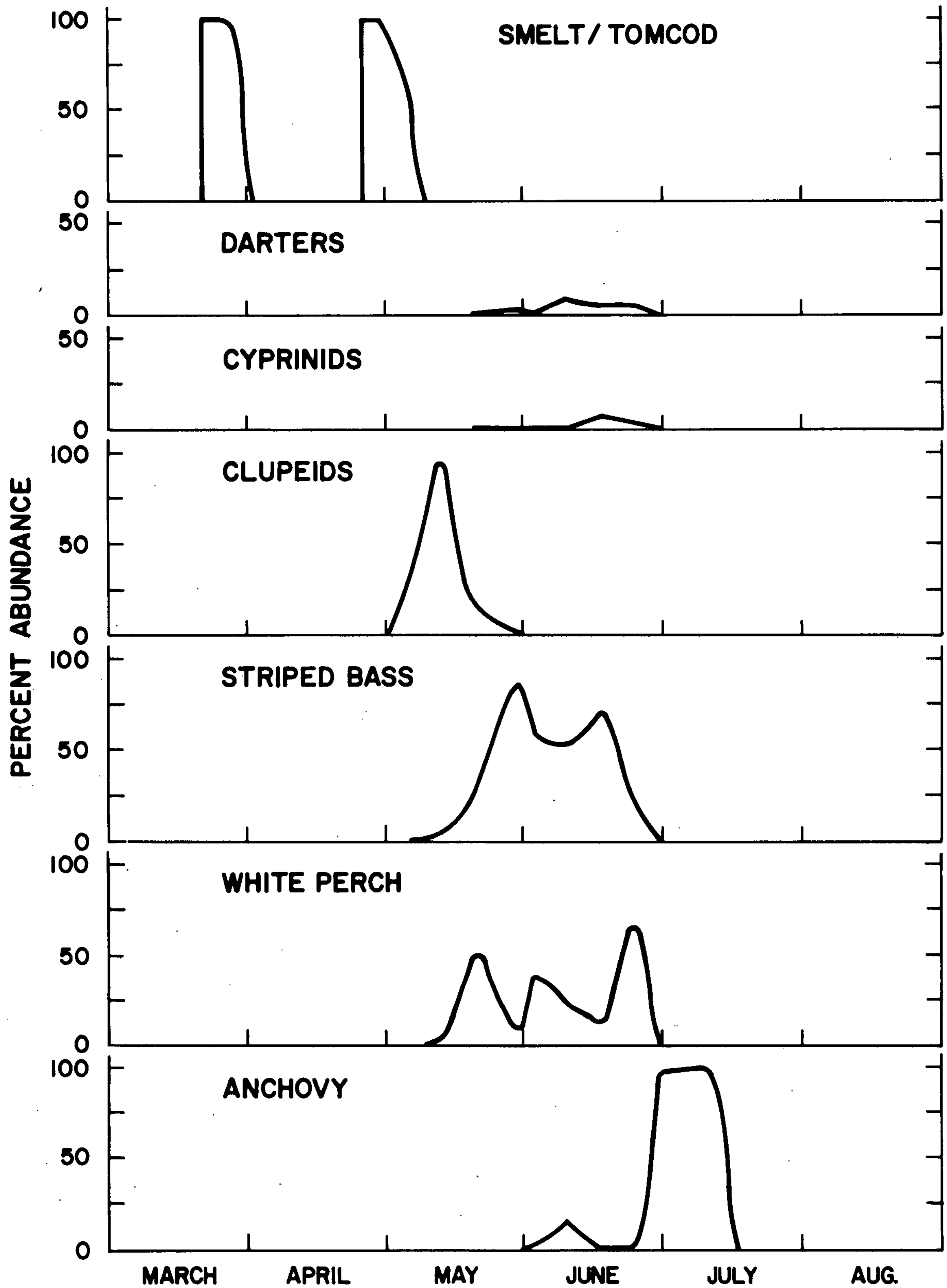

Figure 9-8. Seasonal occurrence and percent abundance for yolk-sac larvae by species, 1975; values shown are percent of total yolk-sac larvae in the samples analysed.

Source: NYU 1977.

collections; the eggs that were collected were usually those that were water hardened without prior attachment (NYU 1974a).

The clupeids were the only species that showed inconsistent patterns of abundance between egg and yolk-sac larvae. The fact that clupeids are represented by three species in the Indian Point region may contribute to this discrepancy. The peak occurrence of clupeid eggs in the collections appeared during May, but maximum abundance for clupeid yolk-sac larvae had been observed prior to this period in 1974, and coincided with peak egg production in 1975. Possible explanations for this occurrence include incomplete overlap of spawning seasons by the alewife and blueback herring (the eggs are not presumed to be shad because of time of occurrence and size), or spawning by just alewife (the earlier spawner) outside the Indian Point region with a sequenced influx of the newly hatched yolk-sac larvae into the area (Figs. 9-6, 9-8).

9.1.3.3.1.2 Yolk-sac larvae.

The order of appearance of yolk-sac larvae in the Indian Point region was similar throughout the study period. The first yolk-sac larvae to occur were those of the tomcod, followed successively by clupeids, striped bass, white perch, and the bay anchovy. Rainbow smelt were observed in 1975 only, and closely followed the tomcod.

Other yolk-sac larvae observed from 1971 to 1975 were those of a darter (*Etheostoma* sp.) two cyprinids (*Notropis* spp.) the hogchoker, yellow perch and a centrarchid (*Lepomis* sp.). The relative abundances of these five species were low, ranging from 4.9 to less than 0.1 percent of the total, and is largely incidental to random planktonic movements. A total of twelve species of yolk-sac larvae were observed from 1971 through 1975. The yolk-sac larval stage is potentially more susceptible to power plant entrainment than the egg stage, particularly for those species which spawn demersal adhesive eggs, not usually part of the plankton.

9.1.3.3.1.3 <u>Larvae</u>

For all years, larvae (post yolk-sac) collected prior to the salt influx into the Indian Point region were predominately clupeids, striped bass and white perch. These were preceded, in time, by those of tomcod and smelt. After salt water intrusion, the dominant larval species collected was the bay anchovy. Anchovies were dominant from July until the end of October. Incidental species occurring at this time were the Atlantic silversides, weakfish and the hogchoker. Although these species were present from the middle of May to the end of August, their numbers were small compared to the major species and thus are shown only in Fig. 9-9 under the headings of "other marine" or "other freshwater" species. The remaining ten of the nineteen larval species collected throughout the study averaged less than 0.1 percent relative abundance (Table 9-2).

The sequence of occurrence for striped bass and white perch is clearly exhibited. Although during the larval stage their occurrence was nearly simultaneous (Figs. 9-9 and 9-10), a

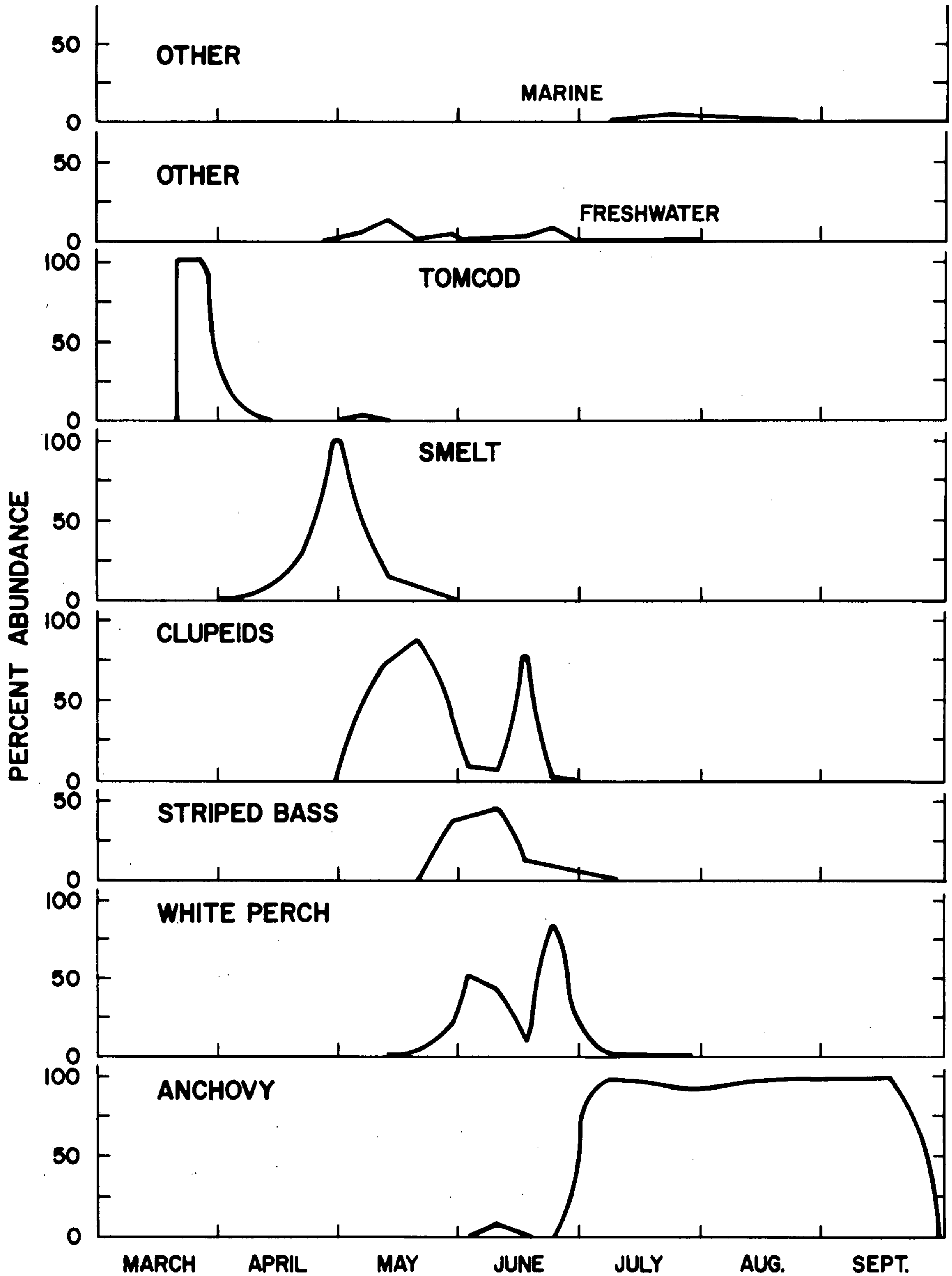

Figure 9-9. Seasonal occurrence and percent abundance for larvae by species, 1975; values shown are percent of total larvae in the samples analysed.

Source: NYU 1977.

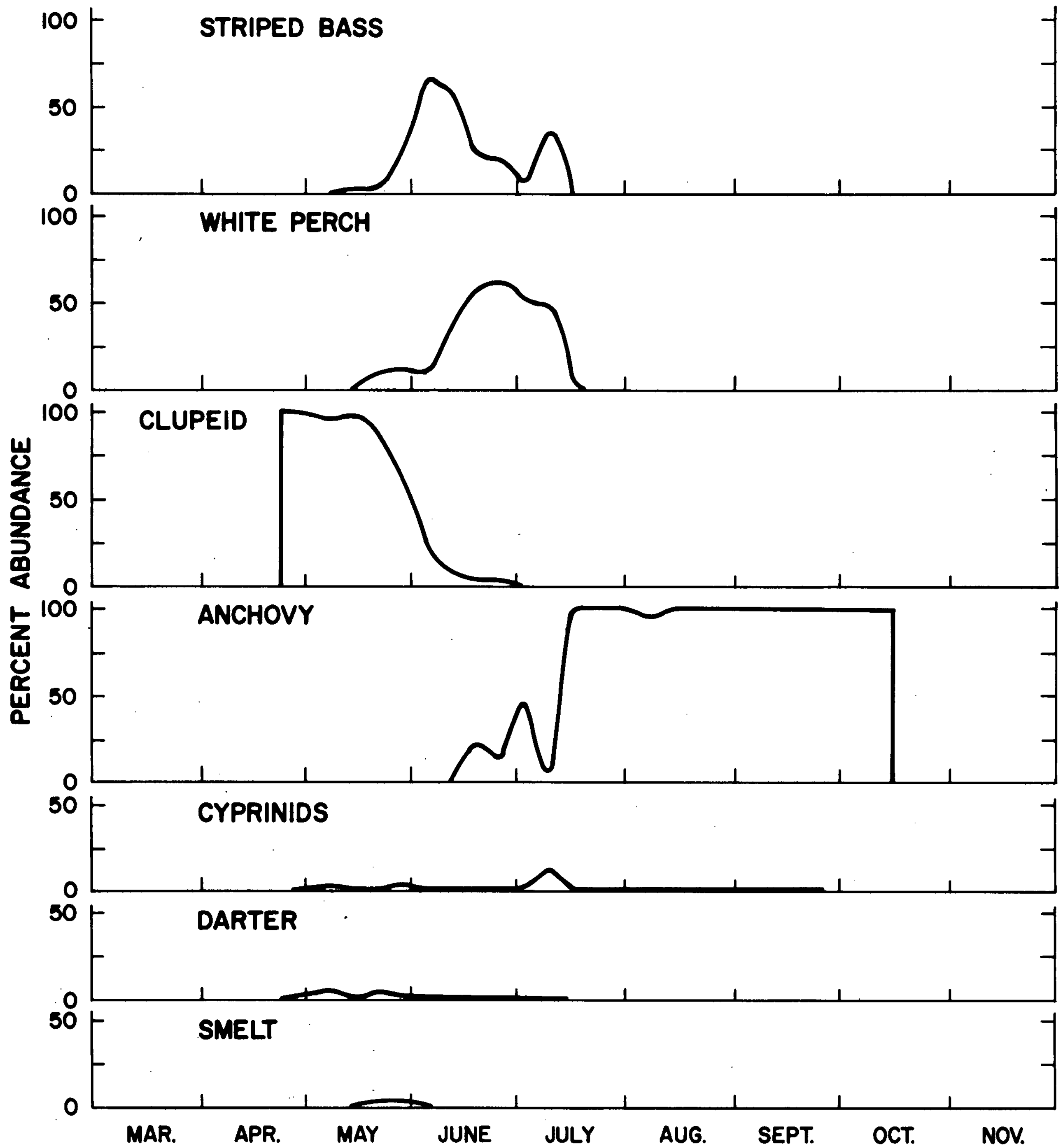

Figure 9-10. Seasonal occurrence and percent abundance for larvae by species, 1974; values shown are percent of total larvae in the samples analysed.

Source: NYU 1976a.

definite separation of collection peaks exists for the eggs and yolk-sac larvae stages (Figs. 9-5, 9-6, 9-7, 9-8). This serves to indicate that the two species have separate spawning times, and therefore separate periods of susceptibility (at least for eggs and yolk-sac larval stages) in the river.

Any significant horizontal movements of larvae result only from the net movement of the water mass but many, if not all, larvae exhibit vertical translocation either in response to physical stimuli or changes in physiological activity with age or season (Raytheon 1971). The depth profiles, taken from 1971 to 1975 indicate that larvae have definite diel changes. These migrations are apparently in response to changes in light. The highest concentrations of all species exhibiting such responses remain on or near the bottom during the day and become more uniform and thus more subject to entrainment at night; the Indian Point power plant withdraws approximately 57% from the surface waters (LaSalle 1976). Short night length during those months when spawning, and therefore larval abundance is greatest, may thereby reduce the possibility of entrainment.

Eggs and most yolk-sac larvae do not exhibit a definite diel change but, as discussed, are more passive and are thus subjected to tidal influences in their bottom distribution (NYU 1977). Thus, this nearly constant concentration of eggs and yolk-sac larvae on the bottom produces the same net result of reduced susceptibility to entrainment as does vertical larval migration. This could be expected to result in a greater reduction for eggs and yolk-sac larvae than for larvae, however, since no nocturnal increase in susceptibility occurs (Raytheon 1971).

9.1.3.3.1.4 Juveniles

Juvenile life stages for the major species observed in 1974 and 1975 are represented in Figures 9-11 and 9-12; all of these are characteristic of brackish and marine habitats. Individual juvenile species collected from 1971 through 1975 remained fairly constant, as did their percent relative abundances, with the exception of white perch (Table 9-2). The high 1972 percent relative abundance of 30.1 for this juvenile is inflated because, although 1972 white perch abundance was somewhat greater than in other years (Fig. 9-13), Table 9-2 indicated that only four other species were compared to it in 1972 as compared to 10 and 12 in 1974 and 1975 respectively. A similar condition is shown for the 1971 anchovy juvenile percent relative abundance.

For all sampling years, the anchovy was the dominant juvenile present; variations in numbers appeared to be directly related to salinity concentrations. Occurrence of the anchovy was preceded by the American eel, (*Anguilla rostrata*), and the Atlantic tomcod. Eels were observed in river samples until the end of summer, whereas tomcod abundance varied in the collections throughout the sampling season.

Juvenile striped bass and white perch were not present in large numbers during any of the four sampling seasons, but their times of occurrence coincided for all years. The remaining ten of the fifteen juvenile species collected ranged in percent relative

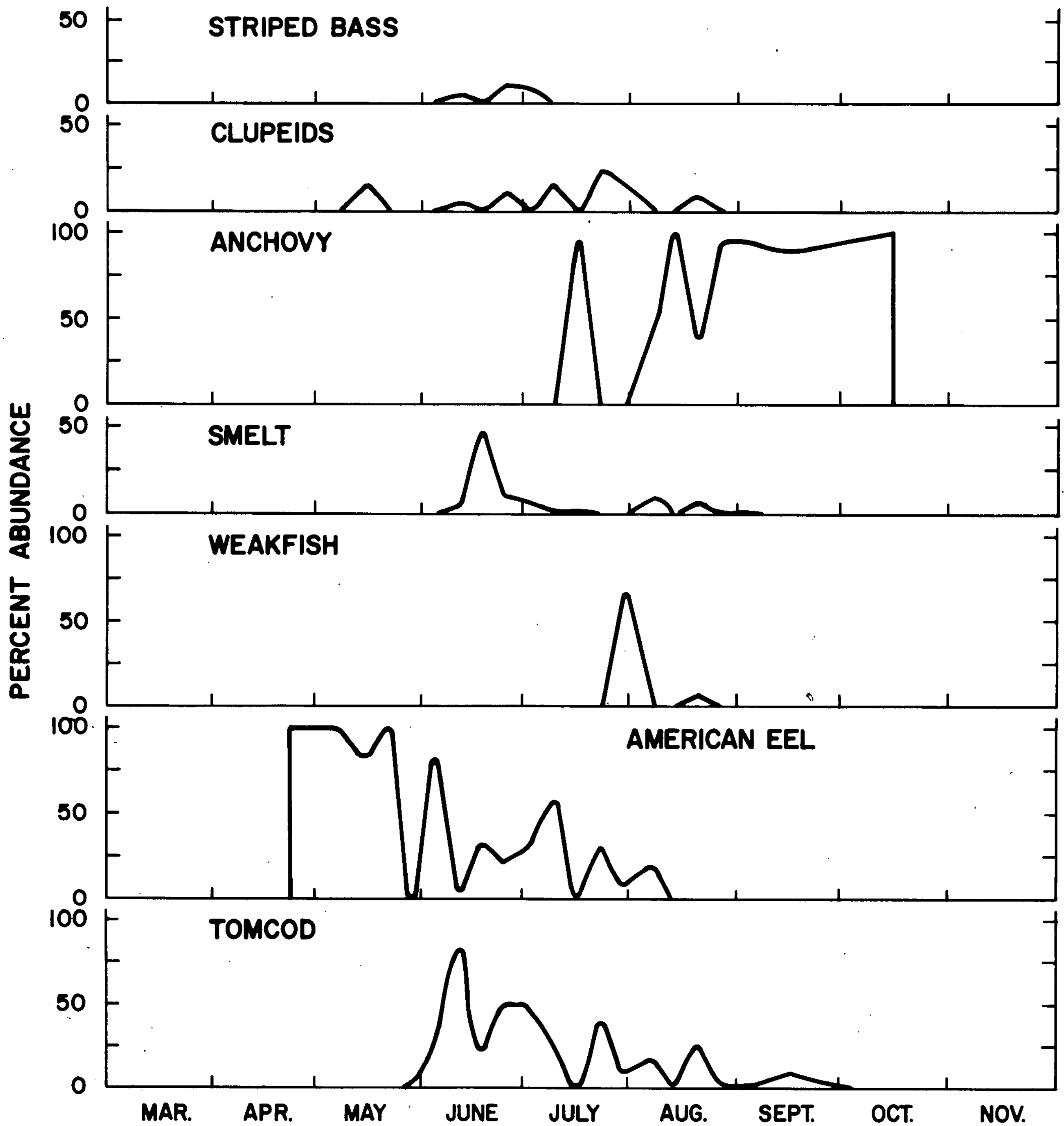

Figure 9-11. Seasonal occurrence and percent abundance for juveniles by species, 1974; values shown are percent of total juveniles in the samples analysed.

Source: NYU 1976a.

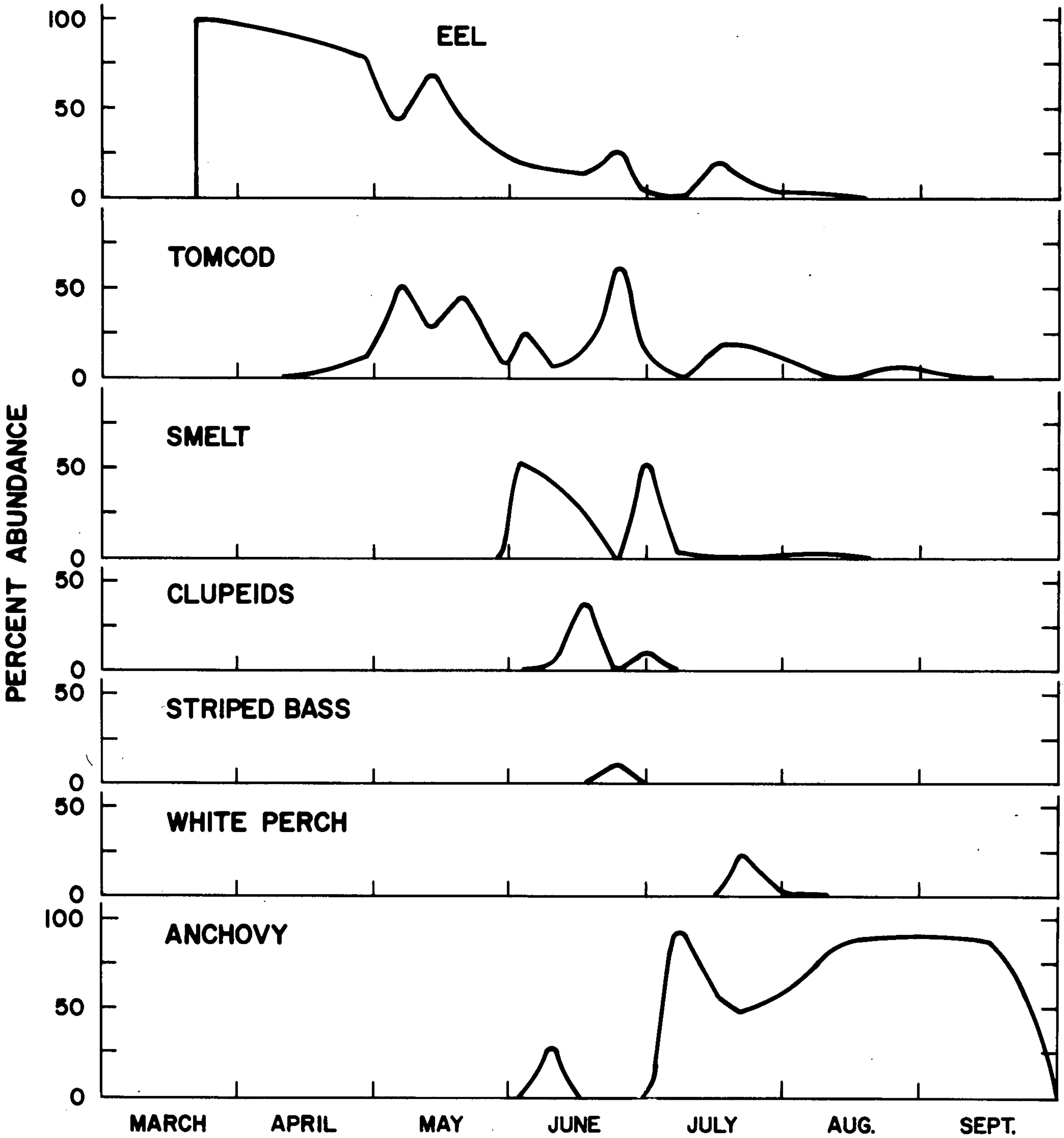

Figure 9-12. Seasonal occurrence and percent abundance for juveniles by species, 1975; values shown are percent of total juveniles in the samples analysed.

Source: NYU 1977.

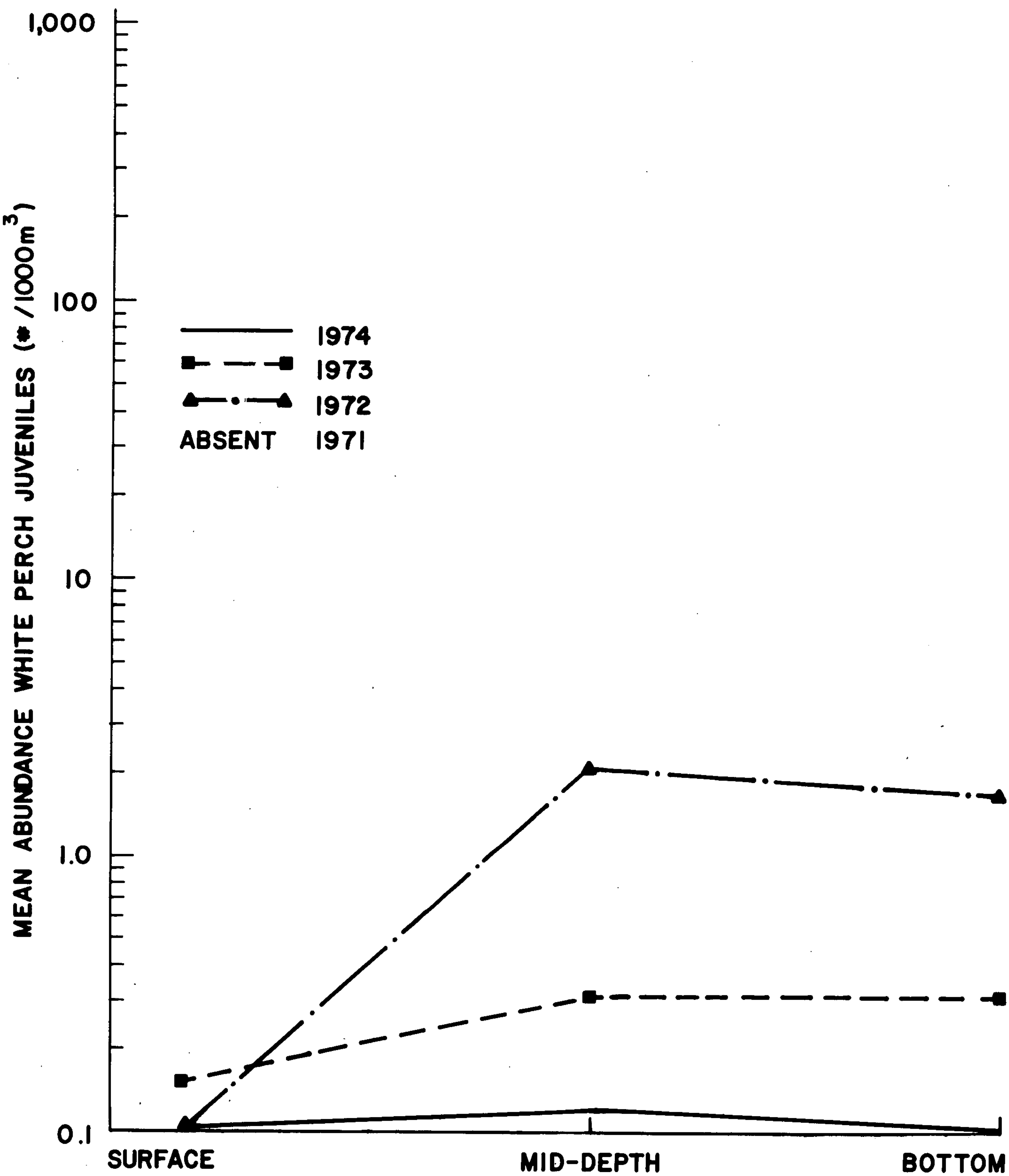

Figure 9-13. Mean abundance (day and night combined) of white perch juveniles collected in river tows from 1971 to 1974.

Source: NYU 1974b.

abundance from less than 0.1 percent to 3.4 percent; of these, clupeids, smelt, weakfish and the hogchoker represented the greatest relative numbers.

The range of susceptibility to entrainment by juvenile fish species extends from equal to that of larvae (at or soon after transformation) to a point at which changes in physical dynamics and/or life cycle behavior considerably reduce the potential to be entrained. With the development of increased mobility, most early juveniles begin to move in search of prey and preferred habitat. Such movement may enhance or reduce susceptibility to entrainment. In general, juveniles tend to prefer nearshore zones, a characteristic that may result in their being relatively protected from the influence of the river's hydrodynamics and plant withdrawals. In addition, as the juvenile grows larger, its motility and sensory systems become more highly developed and increasingly capable of detecting and avoiding currents created by plant withdrawals.

As noted above, the persistence of a life stage at a location in the river, while related to physiological factors is primarily dependent on the spatio-temporal distribution of spawning and on downstream transport. In the case of juveniles, the added factor of active migration effects a more restricted distribution in the river. Thus behavioral adaptations of individual juvenile species limit the predictability of their entrainment as compared to eggs and larvae. Nevertheless, detection, avoidance and escape from the zone of withdrawal is a greater possibility for juveniles than for the earlier life stages.

9.2 ENTRAINMENT SURVIVAL

9.2.1 Intake and Discharge-Canal Studies

9.2.1.1 Introduction

Survival studies were performed at the Indian Point nuclear power plant from 1972 to 1976 by New York University. The objective of the studies was to determine survival rates for ichthyoplankton (and macrozooplankton) that passed through the condenser cooling systems of the plants. The basic design of the studies entailed sampling at the intakes and discharges of the plants. Intake sampling served as a control representing the mortality induced by sampling and handling as well as the number of dead entering the plant; discharge sampling represented mortality induced by sampling, handling, and the entrainment process, as well as any synergistic effects.

Entrainment survival sampling at Indian Point was performed from 1972 to 1975, during which time sampling was extended from one to two units when Unit II became operational. Sampling was usually conducted weekly or twice weekly from early May through July, encompassing the entrainment season of most of the ichthyoplankton species. Sampling was attempted once per month during the other months during most of the four years of sampling. Sampling was usually performed at night to coincide with higher abundances of organisms.

9.2.1.2 Methods and Materials

Sampling was performed as indicated for macrozooplankton, section 8.2.2.

Intake and discharge samples were sorted as soon as possible after sample collection in an onsite laboratory. Organisms were sorted with large-bore pipettes into the categories of live, stunned, or dead based on the following criteria:

Live:	Swimming vigorously, no orientation problems, behavior normal.
Stunned:	Swimming erratically, struggling, responsive to stimulus.
Dead:	No life signs, no body or opercular movements, no response to probing.

Dead organisms were removed from the samples and stored in 10 percent formalin for later identification. All live and stunned ichthyoplankton were held for latent effects observations in containers maintained in ambient water baths. The length of the latent observation period varied from three to five days.

The statistical test used in this report for comparison of survival between control (intake) and treatment (discharge) groups is the binomial test for differences between two proportions (Freund 1967). Survival at each station is calculated as the total proportion alive.

The proportions alive at the intake and discharge immediately following sample collection were compared to determine the initial effects of the entrainment process. The proportion of

Table 9-3. SURVIVAL OF LARVAL FISH AT THE UNIT 1 INTAKE (STATIONS I-1 AND I-2) AND DISCHARGE STATIONS (D-1 AND D-2) OF THE INDIAN POINT PLANT, 1972

Taxon	Station	Discharge Temperature (C)	Number of Fish	Initial Proportion Surviving
Morone (striped	I		657	0.64
bass & white	D	(No ΔT)	188	0.49*
perch, combined)	D	20.6-34.4 (a)	211	0.52*
Atlantic tomcod	I	(No ΔT)	272	0.83
	D	(No ΔT)	180	0.77

(a) Only 14 percent of larvae collected in discharge were collected at temperatures from 31.1 C to 34.4 C; the remainder were collected at temperatures from 20.6 C to 26.1 C.

Note: * indicates significantly lower than intake proportion.

Table 9-3. SURVIVAL OF LARVAL FISH AT THE UNIT 1 INTAKE (STATIONS I-1 AND I-2) AND DISCHARGE STATIONS (D-1 AND D-2) OF THE INDIAN POINT PLANT, 1972

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	D	(No ΔT)	180	0.77

(a) Only 14 percent of larvae collected in discharge were collected at temperatures from 31.1 C to 34.4 C; the remainder were collected at temperatures from 20.6 C to 26.1 C.

Note: * indicates significantly lower than intake proportion.

Table 9-4. SURVIVAL OF STRIPED BASS AT THE INTAKE AND DISCHARGE OF THE INDIAN POINT PLANT, 1973

Station	Temperature Group (C)	Eggs n	Eggs P_s	Larvae Yolk-Sac n	Larvae Yolk-Sac P_s	Larvae Post-Yolk-Sac n	Larvae Post-Yolk-Sac P_s	Juveniles n	Juveniles P_s
Intake Unit No. 1	13.5 - 19.1	962	0.69	131	0.50	849	0.40	175	0.45
Intake Unit No. 2		--	--	--	--	--	--	--	--
Discharge Unit No. 1	≤25.9	301	0.06	58	0.03	2,008	0.19	480	0.11
	26.0 - 29.9	0	--	0	--	2	0.00	1	1.00
	≥30.0	0	--	0	--	0	--	0	--
Discharge Unit No. 2	≤25.9	467	0.13	41	0.27	1,262	0.13	270	0.13
	26.0 - 29.9	0	--	0	--	4	0.25	4	0.50
	≥30.0	0	--	0	--	0	--	0	--

Note: n indicates number of organisms.
P_s indicates proportion surviving.

Table 9-5. SURVIVAL OF STRIPED BASS AT THE INTAKE AND DISCHARGE OF THE INDIAN POINT PLANT, 1974

Station	Temperature Group (C)	Eggs		Larvae: Yolk-Sac		Larvae: Post-Yolk-Sac		Juveniles	
		n	P_s	n	P_s	n	P_s	n	P_s
Intake Unit No. 1	16 - 17	397	0.39	68	0.32	245	0.64	25	1.0
Intake Unit No. 2	16 - 17	499	0.60	84	0.37	220	0.57	3	1.0
Discharge Unit No. 1	≤25.9	101	0.29	9	0.00	0	--	0	--
	26.0 - 29.9	0	--	0	--	212	0.23	7	0.88
	≥30.0	0	--	0	--	0	--	0	--
Discharge Unit No. 2	≤25.9	113	0.25	19	0.00	3	0.0	0	--
	≥26.0 - 29.9	0	--	0	--	29	0.34	7	0.71
	≥30.0	0	--	0	--	0	--	0	--

Note: n - indicates number of organisms.
P_s - indicates proportion surviving.

Table 9-6. SURVIVAL OF STRIPED BASS AT THE INTAKE AND DISCHARGE OF THE INDIAN POINT PLANT, 1975

Station	Temperature Group (C)	Eggs		Larvae				Juveniles	
				Yolk-Sac		Post-Yolk-Sac			
		n	P_s	n	P_s	n	P_s	n	P_s
Intake Unit No. 1		0	--	0	--	0	--	0	--
Intake Unit No. 2		1,318	0.37	107	0.20	1,280	0.56	26	0.65
Discharge Unit No. 1	≤25.9	0	--	0	--	4	0.00	0	--
	26.0 - 29.9	129	0.32	6	0.00	219	0.37	0	--
	30.0 - 33.3	0	--	4	0.00	162	0.34	6	0.33
Discharge Unit No. 2	≤25.9	0	--	0	--	0	--	0	--
	≥26.0 - 29.9	123	0.19	2	0.00	0	--	0	--
	30.0 - 33.3	20	0.00	6	0.00	51	0.16	3	0.67

Note: n indicates number of organisms.
P_s indicates proportion surviving.

those organisms collected alive at the two stations over a specified latent effects observation period was also compared.

9.2.1.3 Results

Variations in the discharge canal velocities, in particular, creation of higher velocities than those at the intakes, have probably biased much of the data and resulted in underestimates of the discharge survival despite the existence of velocity reduction cones on the sampling nets (NYU 1976c). Despite these difficulties, information on survival of entrained organisms was obtained that can be used to evaluate expected potential for entrainment survival. Periods when minimal plant load occurred provide data on mechanical effects of the plants. At higher plant loadings, data was obtained on response of organisms to thermal shock in addition to the mechanical effect due to entrainment.

9.2.1.3.1 Observed Survival at Intake and Discharge

The proportion of organisms initially alive at the intake and discharge is shown in Table 9-3 for *Morone* spp. and Atlantic tomcod collected in 1972. The observed intake and discharge survival for each entrainable life stage of striped bass is shown for 1973 to 1975 in Tables 9-4, 9-5 and 9-6. Intake survivals were determined from the total number of organisms collected during the year. Survival at the discharge stations was calculated by grouping fish into categories determined by the total temperature of the discharge water at the time of collection. Levels of discharge temperature are the result of ambient temperature and plant operation (generating load or circulating water flow).

Survival at Indian Point from 1972 to 1975 was variable due to extremes in plant operation, in particular, discharge canal flows generated from the operation of up to 16 circulating water pumps from the three units. Survival data collected with the sampling gear used at Indian Point (0.5 m plankton nets) proved to be directly related to water velocities at the mouth of the net (NYU 1976a).

Observed survival of eggs in the discharge canal at Indian Point was from 49 to 78 percent lower than that for the intake. Yolk-sac larvae survival reduction was substantially higher. For both egg and yolk-sac larvae collection periods discharge temperatures were below 30 C. Striped bass larvae survival at Indian Point varied from reductions of only about 20 percent in 1972 to as high as 61 percent in 1974 (Tables 9-3 to 9-6). Discharge temperatures varied little between and within years, thus, relative survival over a wide range of temperature conditions was not obtained. Discharge temperatures were less than 30 C for most of the sampling dates during all four years of sampling. Highest survival was obtained in 1972 when only Unit No. 1 was operational and water velocities were similar at intake and discharge stations. Lowest survival occurred in 1974 when some circulators of all three units were pumping.

Survival data was obtained in 1975 and 1976 at higher discharge temperatures at other power plants along the Hudson River (EAI

1976; 1977a; 1977b). These studies indicated that survival was primarily related to the discharge temperature which varied considerably between years, within years, and between plants, and to variations in the temporal occurrence of the striped bass, ambient temperature, and plant operations.

Latent survival (three days) of the striped bass larvae at Indian Point was not significantly different between intake and discharge. No significant differences were observed at any of the four other power plants on the Hudson for which striped bass latent survival information is available (Table 9-7). Discharge survival levels, however, were about 10 to 20 percent lower than intake survival for four of the plants.

Striped bass juvenile survival information at Indian Point was minimal due to low abundance except in 1973 (Table 9-4), when 930 juveniles were collected. The reduction in survival for most temperatures less than 30 C in the discharge was similar to that of larvae for that year. Data collected at Bowline Point indicate high initial survival in discharge for juveniles (96 percent at discharge temperatures less than 33 C). Latent survival of juveniles was, however, significantly lower in the discharge than at the intake for both Bowline Point and Indian Point plants. The latent reduction in discharge survival at 72 hours was 25 percent and 37 percent at Bowline Point and Indian Point , respectively.

Survival of Atlantic tomcod (_Microgadus tomcod_) larvae, which occur during winter rather than spring and summer as do the other

Table 9-7. LATENT SURVIVAL (3 DAYS) OF STRIPED BASS LARVAE COLLECTED IN ENTRAINMENT SURVIVAL STUDIES AT INTAKES AND DISCHARGES OF FIVE HUDSON RIVER STEAM GENERATING STATIONS

Plant	Year	Station	Larvae: Number of Fish	Larvae: Proportion Surviving
Indian Point	1973-1975 (a)	I	1,334	0.32
		D	515	0.29
Danskammer Point	1975	I	22	0.15
		D	24	0.18
Lovett	1976	I	80	0.46
		D	70	0.35
Bowline Point	1975 & 1976	I	210	0.50
		D	193	0.44
Roseton	1975 & 1976	I	151	0.22
		D	123	0.17

(a) Adapted from NYU (1973; 1976a; 1977).

species, was not significantly reduced in discharge collections at Indian Point (Table 9-3) with no ΔT present. Preliminary results of tomcod larvae survival studies at Roseton and Bowline Point during the winter of 1977 with ΔT present also indicated high survival potential.

Survival information for other species of fish at Indian Point was not available. At four other power plants on the Hudson, survival of other ichthyoplankton including white perch (Morone americana), alewife (Alosa pseudoharengus), blueback herring (Alosa aestivalis), bay anchovy (Anchoa mitchilli) and Atlantic tomcod was also related to magnitude of discharge temperature. White perch larvae being of the same genus as the striped bass, responded in a similar manner. For temperatures below 30 C, white perch larvae survival in the discharge collections was not significantly lower than at the intake at Bowline Point or Danskammer, while it was 32 percent and 49 percent lower at Roseton and Lovett, respectively (EAI 1977a). At discharge temperatures from 33 to 36 C white perch larvae survival was reduced 95 percent and 99 percent respectively, at Roseton and Bowline Point. Latent survival of white perch larvae was not significantly reduced in the discharge collections.

Survival of Clupeidae larvae collected in discharge samples is similar to that for Morone. Initial survival of larvae for discharge temperatures below 30 C was reduced 0, 13, 42, and 45 percent, respectively, for Lovett, Bowline Point, Danskammer, and Roseton (EAI 1977a). Discharge temperatures above 35 C resulted in survival reductions of 98 and 100 percent for Roseton and Bowline Point, respectively. Latent mortality was 100 percent generally within the first day of observation for both intake and discharge groups, thus existence or nonexistence of latent effect was not determined.

Clupeidae juveniles were similar in tolerance to larvae based on data from Roseton and Danskammer Point. Reduction in survival was 45, 80, and 100 percent for discharge temperatures below 30 C, from 30 to 33, and 33 to 35 C, respectively. As in the case of larvae, latent effects could not be determined due to poor survival in both intake and discharge groups.

Bay anchovy larvae and juvenile survival was observed at the Bowline Point plant. Poor initial survival limits the interpretation of larval data, although it is apparent that high mortality occurs at discharge temperatures in excess of 30 to 33 C. Initial survival of bay anchovy juveniles was considerably higher than larvae and results indicated no significant reduction in survival below 30 C and a significant reduction of 87 percent above 33 C.

9.2.1.3.2 <u>Entrainment Survival of Striped Bass Young</u>

The effect of the Indian Point plant on survival of striped bass was estimated through comparison of intake and discharge results. Intake survival was used as a control because organisms collected in intake samples were not subjected to the plant, although they did experience handling and sampling stresses as in the discharge collections. Entrainment survival was calculated with the equation:

$$S(\%) = P(D)/P(I) \times 100$$

where;

$P(I)$ = proportion surviving at the intake

$P(D)$ = proportion surviving at the discharge

The differences in water velocities at intake and discharge stations at Indian Point severely complicates the estimation of entrainment effect. Sampling mortality induced by the net collections has been shown to depend directly upon the through-net velocities of water at the time of sampling (NYU 1976c). A significant portion of any observed reductions in survival at the discharge stations may therefore be attributable to the higher water velocities which have usually been present during sampling. Accordingly, differences in net mortalities at the plant intake and discharge must be taken into account to obtain unbiased estimates of the entrainment effect.

Flume studies performed by NYU at the Alden Research Laboratories have provided an estimate of the relationship between sampling mortality and water velocity for egg, yolk-sac, and post-yolk-sac striped bass larvae (NYU 1976c). These studies were performed without velocity reduction cones on the nets and with velocity reduction cones designed for intake nets (0.35 m opening), and no significant difference was observed between the two sets of results. However, velocity reduction cones designed for the discharge stations (0.17-m opening) were not tested in the flume studies. For this reason, the effect of differential water velocities on survivals observed in 1974 and 1975 when the 0.17-m cones were developed cannot be adequately addressed. The 1973 data base has been chosen for estimation of entrainment survival at Unit No. 2. Since no velocity reduction cones were used during the 1973 field studies, that year's results can be validly related to the results of the flume study.

The survival of each life stage of striped bass collected in 1973 at Indian Point is summarized in Table 9-8. Intake and discharge results have been grouped according to the water velocity present at the time of collection. Survival of all life stages clearly decreases as water velocities increase. The results compare closely with the relationships of survival during net sampling and water velocity as determined from the flume studies (Fig. 9-14). The low survival observed at the high water velocities in the plant discharge apparently result primarily from the sampling effect and not from the entrainment process. When the differential sampling mortality is taken into account, it becomes apparent that the entrainment survival of post-yolk-sac larvae and juvenile striped bass is high. For example, the survival of post-yolk-sac larvae collected at low discharge velocity (0.77 fps) was 0.34 compared with intake survival of 0.40 at comparable water velocity (0.70 fps). Entrainment survival based on these values is 85 percent and is representative of mechanical effects only, since practically no thermal load was present during the 1973 entrainment season. Juvenile striped bass survival during

Table 9-8. SURVIVAL OF STRIPED BASS AS A FUNCTION OF WATER VELOCITY[a] AT THE INTAKE AND DISCHARGE OF THE INDIAN POINT PLANT DURING 1973

Station (by groups)	Eggs			Larvae Yolk-Sac			Larvae Post-Yolk-Sac			Juveniles		
	V	n	P_s	V	n	P_s	V	n	P_s	V	n	P_s
Intake 1 & 2	0.50	214	0.71	0.50	49	0.63	0.54	46	0.48	0.47	19	0.79
Intake 1 & 2	0.70	747	0.66	0.70	83	0.42	0.70	784	0.40	0.70	74	0.69
Discharge 1	1.01	54	0.15	0.97	10	0.11	1.01	241	0.39	1.55	43	0.53
Discharge 1	1.52	135	0.07	--	--	--	1.53	850	0.27	2.27	19	0.58
Discharge 1	2.21	135	0.02	2.21	44	0.03	2.32	921	0.07	2.61	4.24	0.07
Discharge 2	0.77	32	0.06	0.83	2	0.0	0.77	169	0.34	1.27	21	0.52
Discharge 2	1.19	171	0.25	1.30	27	0.30	1.22	41	0.31	1.74	24	0.46
Discharge 2	1.72	100	0.12	1.80	8	0.14	1.82	773	0.08	2.02	228	0.09

(a) Velocity estimates were made based on the plant flow reported to exist through the 1973 entrainment season (NYU 1973).

Note: V indicates velocity (fps).
n indicates number of organisms.
P_s indicates proportion surviving.

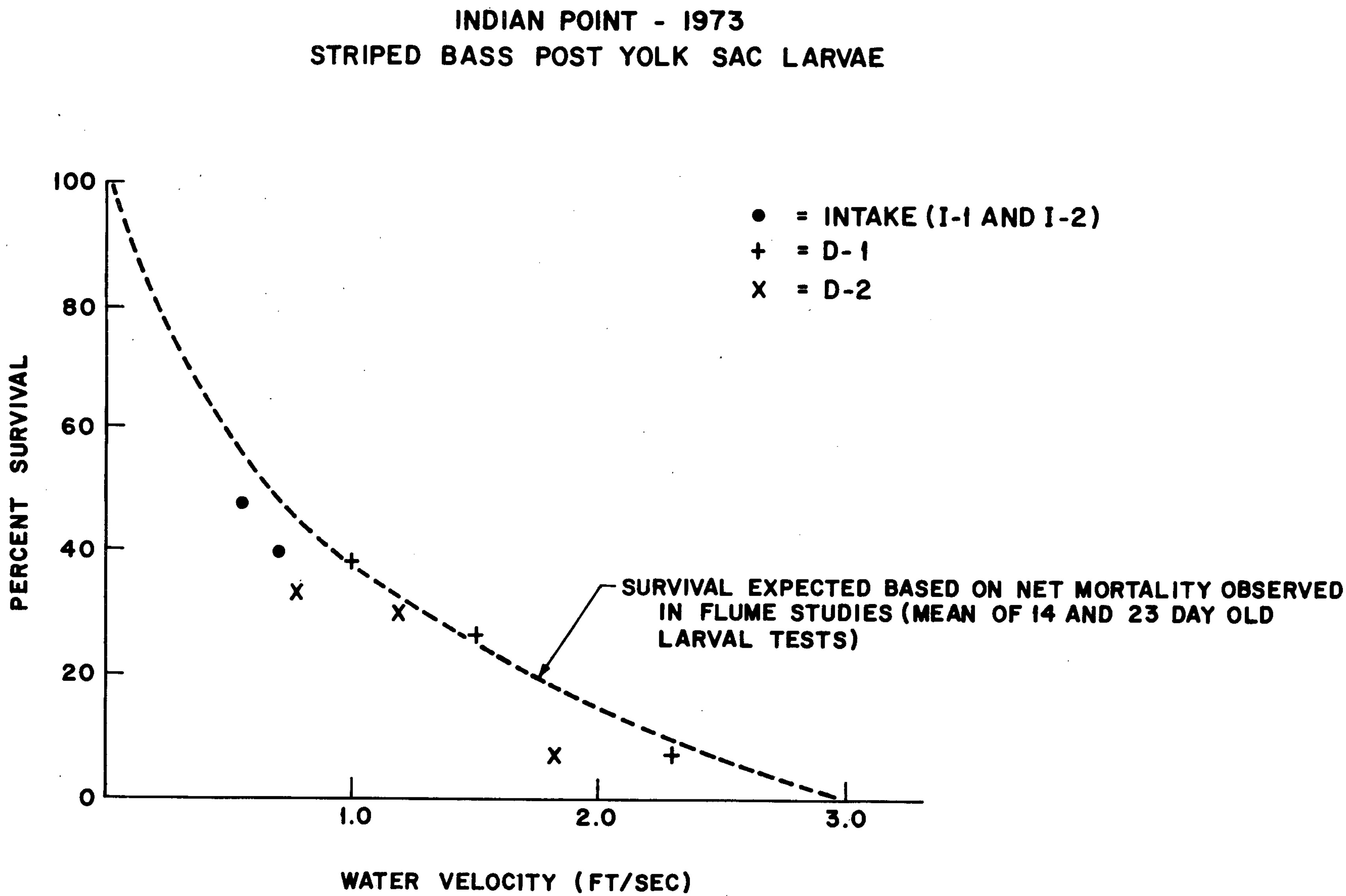

Figure 9-14. Comparison of survival obtained during 1973 field sampling with survival based on net mortality studies conducted in a flume by New York University.

entrainment is probably similarly high. Although juveniles were not collected at discharge velocities comparable to those at the intake, survival at 1.2-1.6 fps was 0.53 in the discharge compared to 0.69 at an intake velocity of 0.7 fps. Entrainment survival is therefore probably greater than 78 percent in the absence of thermal stress.

Good estimates of yolk-sac and egg survival are less easily determined. Discharge survival of yolk-sac larvae at 1.3 fps was 0.30 compared with 0.42 at the intake (0.7 fps); indicating a probable entrainment survival greater than 71 percent. However, survival of 10 yolk-sacs obtained in the discharge at 0.97 fps was only 0.11, suggesting a lower through-plant survival. In view of the relatively rapid increase in net mortality with water velocity observed in the flume studies, it seems probable that entrainment survival of yolk-sac larvae is high, and is similar to that observed for post-yolk-sac larvae.

Although survival of eggs in 1973 decreased as a function of through-net water velocity, the discharge survival was generally much lower than expected from the flume results. Based on all egg data collected at discharge velocities below 1.2 fps and intake survival at 0.7 fps, entrainment survival of eggs is probably greater than 31 percent.

High survival of larval and juvenile striped bass at Indian Point in 1973 is in general agreement with survival observed at Indian Point Unit No. 1 in 1972 (Table 9-3) when intake and discharge water velocities were about equal.

Entrainment survival of striped bass at other power plants on the Hudson has also been shown to be high (66-95 percent) in the absence of thermal effects (Orange and Rockland 1977). The high survivals generally observed at the Hudson River plants indicate that mechanical damage from entrainment is of minor importance under normal operating conditions and that the total temperature of exposure in the discharge is the primary factor controlling the entrainment survival.

9.2.2 Predictive Assessment of Entrainment Survival

The results of the entrainment survival studies indicate that mortality of ichthyoplankton entrained at the Hudson River power plants is a function of a variety of factors that primarily relate to the thermal exposure. Three key factors are the circulating water temperature rise (ΔT) produced by the plant, the ambient water temperature at the time of entrainment, and the duration of exposure to the heated water (transit time).

Temporal variations may occur in many of the factors that control thermal exposure. For example, generating load may fluctuate during a 24 hour period due to diel cycles in the demand for electricity, and ambient water temperature is dependent on season of the year. Entrainment mortality will therefore vary according to season and time of day, and the specific time at which entrainment occurs becomes an important consideration in the assessment of power plant cropping.

An empirical computer model was developed to account for the important factors controlling exposure of organisms during entrainment. The model integrates plant, field, and laboratory information to predict the probable entrainment mortality at the Roseton, Bowline Point, and Indian Point plants. A description of the model and results of predictive assessments are reported elsewhere (EAI 1977c).

The results indicate that entrainment mortality of striped bass larvae and juveniles can potentially be maintained at low levels (<20 percent) by manipulation of circulating water flows to minimize plant discharge temperatures.

9.2.3 Laboratory Studies

9.2.3.1 Introduction

Ichthyoplankton laboratory bioassays were designed to determine the tolerance of fish eggs and larvae to temperature and to the chlorine residual that may be encountered by pump-entrained organisms. Most of the laboratory bioassay study effort was devoted to the eggs and larvae of striped bass, although some earlier work examined the temperature tolerance of tomcod larvae. The striped bass is considered to be the most important sport and commercial fish species in the Hudson River. The tomcod is the only major fish species that spawns in the Hudson River during the winter, at which time the mean ΔT at the plant (at rated capacity operations) increases because of reduced flow-rate operation (Section 1).

9.2.3.2 Methods and Materials

9.2.3.2.1 Temperature Tolerance Experiments

Eggs and larvae used for bioassay tests were propagated from eggs and milt obtained from wild stock. Advantages of using reared specimens rather than natural stock are that all specimens for a given test are of known age and the same stage of development. Moreover, the source is more reliable, and the tendency for collection trauma to result in selection of the most robust individuals for testing is avoided.

Tomcod embryos and larvae were exposed to instantaneous increases in water temperature which ranged from 12.2 to 15.7 C above the ambient river temperature at which they had been incubated. Nine different embryonic and seven different larval stages were characterized and subjected to thermal stress for either 15, 30, 60 or 720 min.

Specimens were removed from ambient conditions and transferred to one of several compartments in a plastic transfer tray. The bottom of the tray had been cut away and replaced with a piece of 571um mesh plankton netting. The tray was allowed to float in a flat dish containing fresh ambient river water while being transported. The transfer tray, together with the experimental organisms, was then quickly removed from the flat dish and placed directly into a preheated water bath, where it floated on the surface of the warm water. Since the bottom of the tray was netted, ambient water immediately left the tray when it was removed from the flat transport dish. Similarly, but in reverse order, heated water instantly filled each partition as the tray was placed into the heated water bath. Embryos were never completely out of water, since a thin film of water adhered to the netting during transfer. More importantly, the thermal shock to which embryos were subjected was for all practical purposes instantaneous. Dissolved oxygen was maintained at near saturation levels by bubbling air into each bath.

The plastic trays were removed at 30, 60 or 720 min. after the initial thermal exposure. Trays were then immediately placed back into the ambient water box. Embryos or larvae were next transferred to clear plastic drinking cups, or to covered plastic petri dishes, both of which were held at ambient water temperature. An immediate viability assessment was performed within 10 min. after the return of organisms to ambient conditions. Experimental and control organisms were exposed to a cyclic photoperiod (12 hour dark and 12 hour light) schedule while being held to detect sublethal or delayed effects of thermal exposure. Larvae were characterized according to the same criteria used for intake and discharge-canal samples (section 9.2.2).

In the case of striped bass, most of the experiments on various developmental stages of embryos and young larvae up to 15 days (360 hour) old were done with specimens propagated from the Santee-Cooper River brood stock by the South Carolina Striped Bass Hatchery at Monck's Corner. Experiments on older larvae of the Santee-Cooper stock and of Roanoke River, North Carolina, stock were done at the Edenton National Fish Hatchery in Edenton, North Carolina, which rears these fish up to one year of age. A batch of striped bass larvae was also obtained from one pair of adults from the Hudson River.

The laboratory experiments on striped bass eggs and larvae involved the thermal exposure of large numbers of organisms to various combinations of temperature elevation and duration.

To perform these exposures efficiently, and with accurate temperature control, two sizes of thermal gradient apparatus were designed and constructed. These are described in detail elsewhere (NYU 1973).

9.2.3.2.2 Chlorine and Temperature Exposures

Striped bass eggs were subjected to one hour laboratory exposures to undiluted and diluted (lower ΔT) Indian Point Unit No. 2 discharge water. Yolk-sac and older (16, 28 and 30 day) larvae were similarly exposed to full strength and diluted discharge water for one and two hour periods. In addition, 15 day and 30 day larvae were exposed for one and two hours, respectively, to the discharge water during condenser chlorination.

Water was pumped through PVC pipelines from the intake area and discharge canal to control and experimental aquaria in the laboratory. The diluted discharge treatment was a balanced system of intake and discharge waters, averaging the temperatures.

The exposure consisted of immersing replicate chambers, the sides and tops of which were covered with nylon mesh to allow a free circulation of water (see Fig. 9-15). Temperature and residual chlorine were monitored throughout each experiment. The larvae were examined for immediate mortality at the conclusion of the experiment and survivors were retained for up to 72 hours to permit observation of latent effects.

9.2.3.2.3 Behavioral Response Experiments

Striped bass juveniles were used in behavioral experiments which were designed for temperature and chlorine avoidance observations. The preference/avoidance chamber subjects the test organisms to a continuous flow of intake water and chlorinated discharge water (see Figure 9-16).

Hudson River water and Indian Point effluent water were injected into chamber quadrants 1 and 4, respectively. Dye studies revealed essentially no transfer of water between quadrants 2 and 3.

The fish were free to move about in the chamber and, therefore, should have actively avoided adverse conditions. At the beginning of the experiment, six juvenile striped bass were introduced into quadrants 1 and 4. Temperatures at seven points within the chamber were recorded and total residual chlorine readings were taken on water samples. At five min. intervals, the fish in each quadrant were counted. A variation of the experimental design was a test which allowed no mixing of the intake and discharge waters in quadrants 2 and 3. Behavioral observations were recorded during this experiment. At the completion of the experiments, the fish were examined for

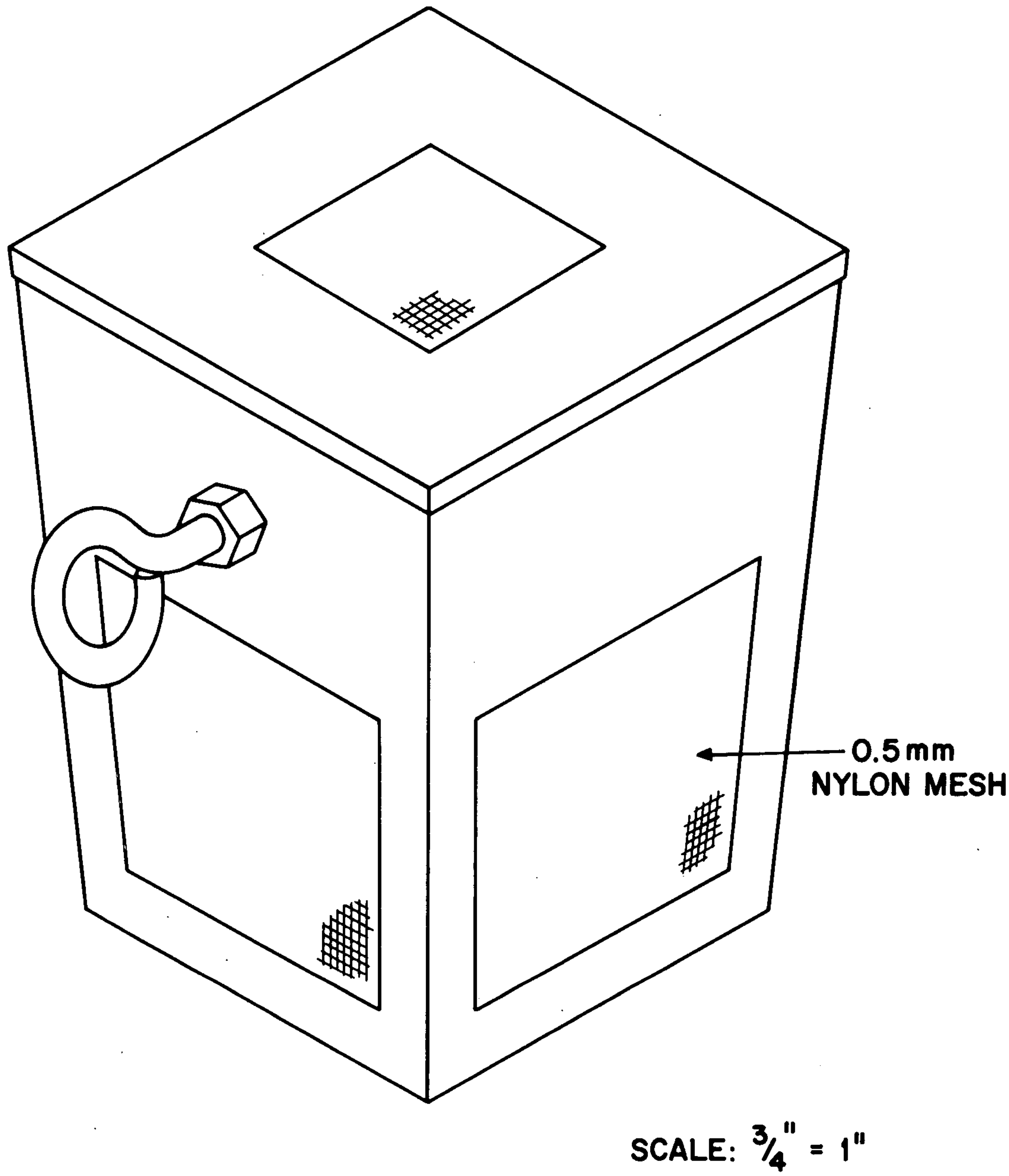

Figure 9-15. Flow-through chamber employed in laboratory and *in situ* chlorine exposures.

Source: NYU 1976b.

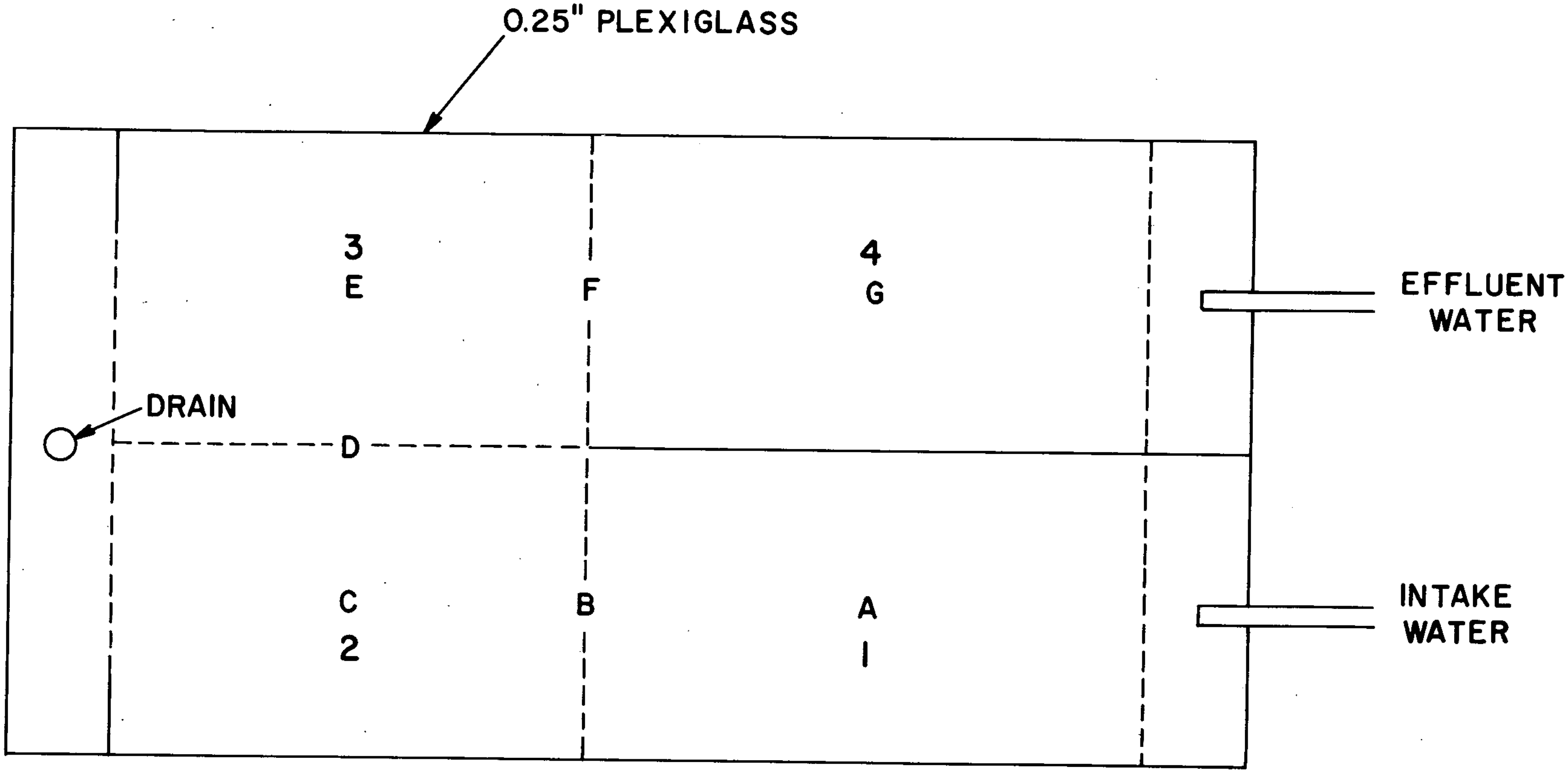

Figure 9-16. Temperature-chlorine avoidance chamber.
Source: NYU 1976b.

immediate mortality and then retained in holding tanks for a 72 hour period.

9.2.3.2.4 Acute Chlorine Bioassays

The objective of the chlorine toxicity bioassays was to determine the effect of different concentrations of chlorine on striped bass juveniles under static conditions. Both seined and hatchery-reared juveniles were used in separate experiments. Tests were performed on five dates using a variety of initial chlorine residual concentrations (NYU 1976b).

Fish were chosen at random and placed into aquaria which were then inoculated with the appropriate amount of stock sodium hypochlorite solution, which was obtained from the Indian Point chlorine tank. The bioassays continued for two hours, during which time total residual chlorine, free chlorine and chloramine concentrations were recorded.

The tanks were flushed at the end of each two hour exposure with fresh Hudson River water replacing the chlorinated test water. Immediate mortality was recorded and the fish were maintained for a 96 hour observation period. Initial and 96 hour percent mortality and initial chlorine concentrations for each bioassay were graphed as linear regressions. Simultaneous replicates were conducted in all bioassays, the results of which were averaged for an overall survival rate.

9.2.3.3 Results

9.2.3.3.1 Temperature Tolerance Experiments

Observed safe temperature exposures for tomcod larvae of various ages are shown in Fig. 9-17. Safe temperature exposures are defined as those combinations of temperature rise and exposure time that resulted in no significant increase in mortality or abnormal behavior compared to controls.

Tomcod larvae 44 hours old (from hatch) and older, were able to tolerate temperature increases of at least 14.4 C (25.9 F) above an ambient of 1.1 C (34 F) for 30 min. All of the older larvae stages tested were also able to tolerate at least the 14.4 C ΔT for 60 min. These tolerances are higher than all transit time ΔT conditions for the Indian Point facility at rated capacity operation.

The 26 hours old tomcod larvae tolerated an 8.9 C (16 F) ΔT above the 1.1 C ambient for the 30 min. exposure. Although this represents a longer exposure time than would normally be encountered, these data indicate that during reduced flow periods, the temperature tolerance of these larvae could be exceeded. Tomcod larvae were observed only in very small numbers in entrainment samples during the winter months (reduced flow period) (NYU 1973; 1974a; 1976a; 1977).

The temperature tolerance of striped bass eggs and larvae varied with the particular developmental stage and increased with decreases in exposure time (Figs. 9-18).

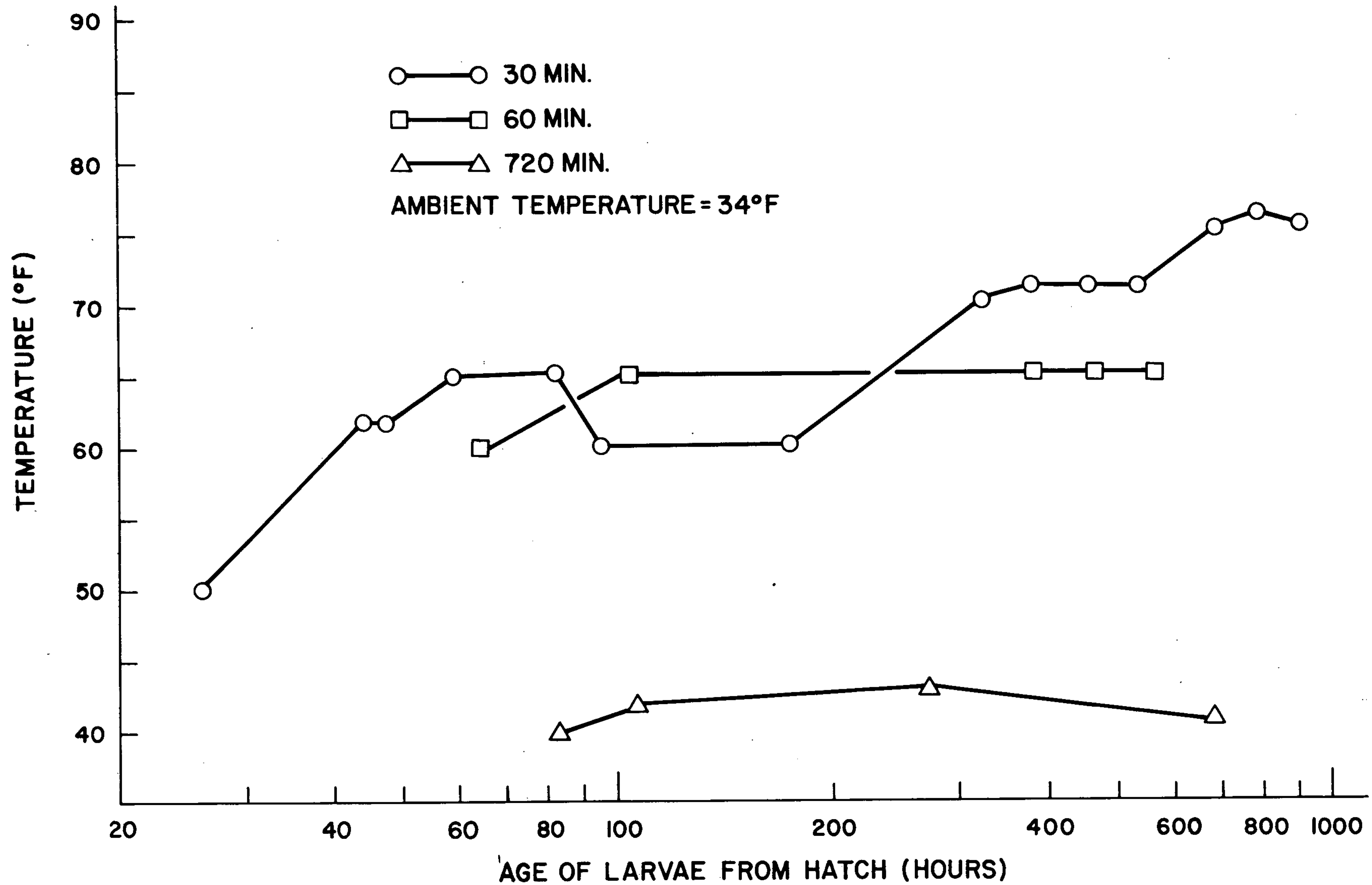

Figure 9-17. Observed safe temperature elevations for Atlantic tomcod larvae exposed to thermal shock for 30, 60, and 720 min.

Source: NYU 1973.

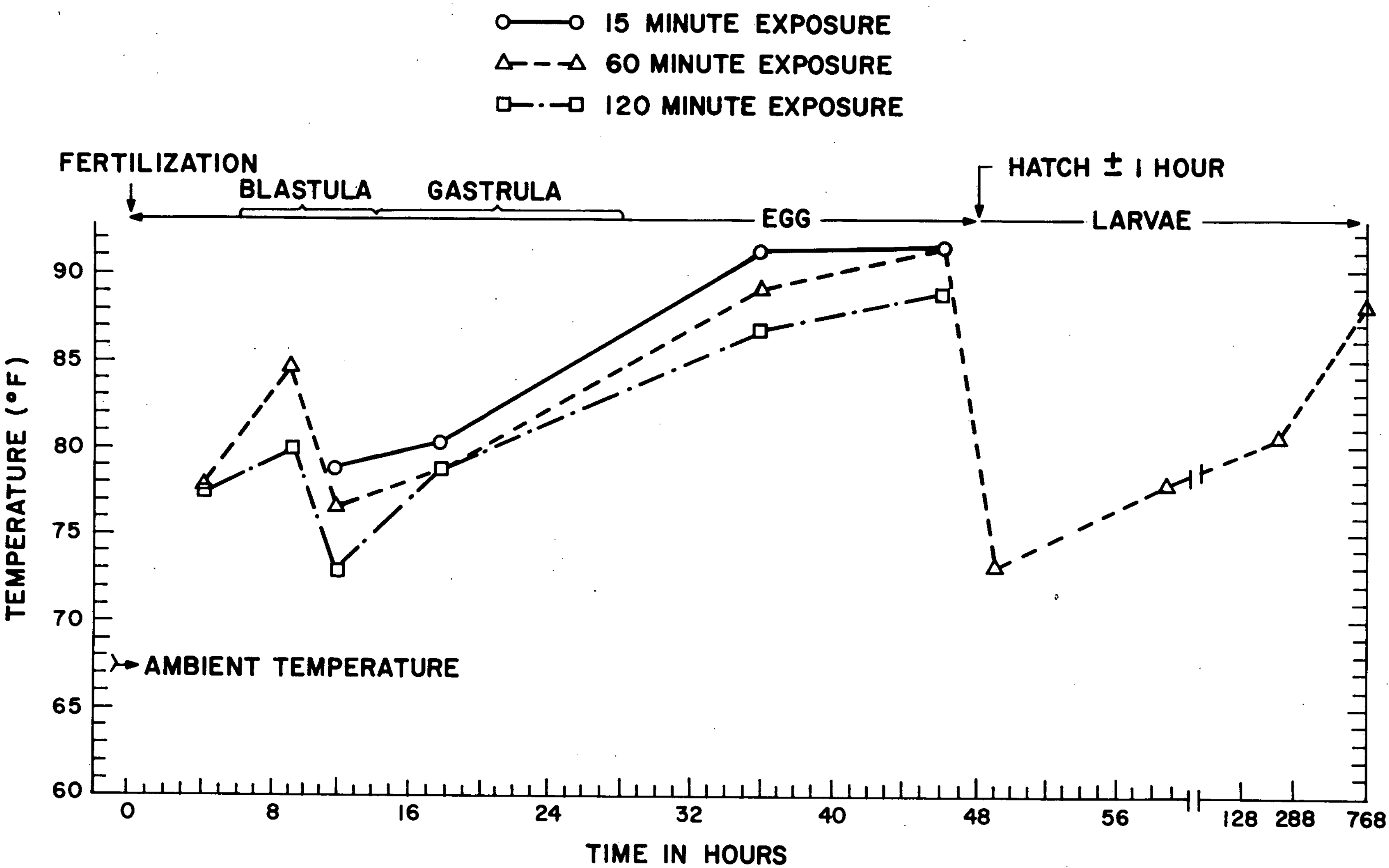

Figure 9-18. Maximum safe temperature for striped bass eggs and larvae from Monck's Corner (S.C.) hatchery stock.
Source: NYU 1973.

The specimens used for the bioassay tests were incubated by the Monck's Corner hatchery at 18.0 to 19.5 C, (64.5 to 67 F) which is the water temperature in the Hudson River at Indian Point near the end of the striped bass egg season. The rated capacity cooling water ΔT of 8.3 C, added to an ambient temperature of 19.5 C, would exceed the temperature tolerance of the most sensitive egg stages for a 15 min. exposure by about 1.7 C (3 F). These early stages of striped bass eggs may be able to tolerate the 8.3 C ΔT for the shorter exposure times expected during simultaneous rated capacity operation of two or three units. These laboratory investigations, also indicated that the older stages of striped bass eggs are capable of surviving the temperature elevations encountered during entrainment through the Indian Point facility. Their temperature tolerances are well above the maximum cooling water temperatures for all combinations of single unit and simultaneous unit rated capacity operation (Section 1).

However, the 60 min. temperature tolerance of young striped bass larvae (up to about 12 days old) would be exceeded by a rated capacity ΔT of 8.3 C and they would be expected to incur damage from such temperature exposures during entrainment. Older larvae, as with the older eggs, were significantly more tolerant of higher temperatures. These temperatures are in excess of those found for any operating conditions at Indian Point (NYU 1973).

9.2.3.3.2 Chlorine and Temperature Exposures

The percent hatch (interpreted as survival) of striped bass eggs exposed for one hour to Indian Point Unit No. 2 discharge water (ΔT=10.1 C) and diluted discharge water (ΔT=4.7 C) was significantly less than control eggs maintained in ambient (18.0 C) intake water (Table 9-9). Ninety-three percent of the control eggs hatched after 24 hours; 75% of these organisms survived to 48 hours. The 24 hour percent hatch of eggs subjected to the full strength discharge water was 68%, decreasing to 29% after 48 hours. Of the 100 striped bass eggs which were subjected to diluted discharge water, 75% hatched within 24 hours while 15% survived to 48 hours. However, yolk-sac (Table 9-10) as well as 16, 28 and 30 day old larvae exposed to the full strength and diluted discharge water did not show significantly lower survival rates than the controls (Eichorn 1977).

Fifteen day old striped bass larvae exposed to Unit No. 2 discharge water (8.5 CΔT) for one hour during chlorination displayed no reductions in immediate or 72 hour survival (Table 9-11). Total residual chlorine determinations averaged 0.10 mg/1 for 42 min. during the exposure period. Striped bass larvae exposed for the same period to diluted Unit No. 2 effluent (0.07 mg/1 chlorine, 4.6 CΔT) also displayed no reduction in survival. Similarly, no decreases in immediate or 72 hour survival were detected for one month old striped bass larvae during one and two hour exposure to Unit No. 2 discharge water (7.8 CΔT). Larvae

Table 9-9. Percent survival (hatch) of striped bass eggs (24 hours) exposed to Indian Point Unit No. 2 discharge water and diluted discharge water.

Exposure	Mean Temperature (C)	Exposure Time (min)	n	Percent Survival (hours) 24	48
Intake	18.0	60	100	93	75
Diluted Discharge	22.7	60	100	75	15
Discharge	28.1	60	100	68	29

Source: Eichorn 1977.

Table 9-10. Percent survival of striped bass yolk-sac larvae (12 hours) exposure to Indian Point Unit No. 2 discharge water and diluted discharge water.

Exposure	Mean Temperature (C)	Exposure Time (min.)	n	Percent Survival (hours) 24
Intake	18.0	60	100	86
Diluted Discharge	23.7	60	100	93
Discharge	28.6	60	100	87

Source: Eichorn 1977.

Table 9-11. Survival of striped bass larvae (15 day old) exposed to Indian Point Unit #2 discharge water during condenser chlorination on 6-5-75.

Exposure	Mean temp C	Total Residual Chlorine (mg/l)	Duration of Exposure (min)	Duration of Chlorine Residual (min)	n	Percent Survival (hours) initial	24	48	72
Intake	20.2	0.0	60	0	100	99	89	86	71
Discharge	28.7	0.1 0.04-0.16	60	42	100	100	90	89	80
Diluted Discharge	24.8	.07 0.06-0.12	60	42	100	98	91	87	85

Source: NYU 1976b.

exposed to diluted discharge water (3.2 CΔT) for one hour experienced no immediate or latent lethal effects. The duration of total chlorine residual (0.15 mg/1) for the one and two hour discharge treatments was 50 min. The total chlorine residual present in the 50 min. diluted discharge exposure was 0.08 mg/1 (Table 9-12).

9.2.3.3.3 Behavioral Response Experiments

Striped bass juveniles actively avoided the chlorinated discharge water (3.5 CΔT, 0.05 mg/1 chlorine) during behavioral studies in the preference/avoidance chambers when intake and discharge waters were mixed. Quadrant counts at 5 min. intervals revealed a definite preference for quadrants 1 and 2, the areas of pure intake water. There were no reductions in immediate or 72 hour survival of striped bass juveniles used in the chlorine avoidance experiment.

Striped bass juveniles, when forced to remain in the chlorinated discharge water in the preference/avoidance chamber, showed no apparent effects or behavioral changes during the 60 min. exposure. The average residual chlorine present in the discharge water (7.9 CΔT) was 0.04 mg/1. There were no reductions in striped bass survival at the end of the 72 hour observation period (NYU 1976b).

9.2.3.3.4 Acute Chlorine Bioassays

The calculated LC_{50} value (that concentration which resulted in the mortality of 50% of the test organisms) for each of the five bioassays are reported in Table 9-13. When the initial total

Table 9-12. Survival of striped bass larvae (one month old) exposed to Indian Point Unit #2 discharge water during condenser chlorination on 6-26-75.

Exposure	Mean Temp C	Total Residual Chlorine (mg/l)	Duration of Exposure (min)	Duration of chlorine Residual (min)	n	Percent Survival (hrs) initial	24	48	72
Intake	24.5	0.0	60	0	100	99	96	92	85
Diluted Discharge	27.7	0.08 0.06-0.09	60	50	100	99	93	88	79
Discharge	32.3	0.15 0.13-0.18	60	50	100	97	94	92	85
Discharge	32.3	0.15 0.13-0.18	120	50	100	93	91	85	75

Source: NYU 1976b.

Table 9-13. Extrapolated LC_{50} residual chlorine concentrations from the acute bioassays.

Bioassay	LC_{50} Total residual Chlorine (mg/l) 2 hours observation	Day IV observation
1 (8-6-75)	1.41	0.88
2 (8-14-75)	0.59	0.41
3 (8-19-75)	0.97	0.94
4 (8-28-75)	1.30	0.88
5 (9-12-75)	1.59	1.53

Source: NYU 1976b.

residual chlorine (TRC) concentrations were plotted against the combined mortality data, it was determined that the overall LC_{50} was 1.3 mg/l (Eichorn 1977). It was also found that the rate of chlorine decay was a function of the initial total residual chlorine concentration; the more rapid decays associated with the higher initial concentrations. In almost every test concentration, the TRC value leveled off at approximately 0.5 mg/l within 20 min. The rapid initial decline of chlorine residual during the first 10 to 20 min. of the test exposures are due primarily to the reduction of free chlorine (HOCL and OC-). Combined chlorine residuals are much more stable than free chlorine and result in the lower decay rates found when initial concentrations are small (less than 1.0 mg/l), and during the latter portion of all exposures (Eichorn 1977).

9.2.3.4 Discussion

The laboratory studies indicate that temperature exposures representative of operating conditions at Indian Point, when considered independently of other potential stresses such as mechanical damage, do not have a significant impact on any entrainable striped bass stage except early eggs and early yolk-sac larvae. Similarly, comparisons of control and test group survival rates revealed no detectable mortalities at any life stage tested resulting from chlorine exposures in full-strength Unit No. 2 effluent. An immediate dilution by the unchlorinated condenser box rapidly reduces the standard plant chlorination value (0.5 mg/1) in the discharge canal. The data presented indicate that striped bass larvae and juveniles are not adversely affected by a chlorine concentration of 0.15 mg/1. Due to rapid, vertical mixing in the thermal plume, chlorine values fall below detectable limits of amperometric titration (0.03 mg/1). It is apparent that striped bass larvae and juveniles can tolerate short-term exposures to chlorine regimes considerably higher than those occurring in the Indian Point thermal plume. Furthermore, data from the behavioral studies conducted in the preference/avoidance chamber indicate that striped bass juveniles are able to detect and avoid low levels of chlorine.

The static short-term bioassay, designed to simulate condenser transit during Unit No. 2 chlorination, exposed striped bass juveniles to direct, high-level chlorine doses. The chlorine doses administered, all higher than those actually used during plant chlorination, decayed naturally in the first 30 min. attaining a constant, low-level chlorine value for the remainder of the bioassay. With the exception of one test (Table 9-13) all the extrapolated LC_{50} values were in excess of the chlorine concentrations used at Indian Point for defouling (0.50 mg/1). It can, therefore, be concluded that striped bass passing through the cooling water system prior to chlorination and remaining in the discharge canal would not be affected by the low level chlorine concentrations. Even if striped bass were to maintain a position at or near the diffuser outlet, the resultant exposure levels during plant chlorination would be below lethal limits (NYU 1976b).

9.2.4 Plume Entrainment Studies

9.2.4.1 Introduction

In addition to pumped entrainment, many organisms are susceptible to entrainment within the discharge plume. To study the effects of possible plume entrainment on fish, juvenile striped bass were exposed to discharge plume water in the presence and absence of chlorination.

9.2.4.2 Methods and Materials

See section 8.2.3.

9.2.4.3 Results

No mortalities were experienced by striped bass juveniles after 60 min. plume exposures during the Unit No. 2 condenser chlorinations. The results from two of these exposures are indicated in Tables 9-14 and 9-15.

9.2.4.4 Discussion

Plume entrainment can be effected in two ways: 1) after plant entrainment and passage through discharge ports, and 2) movement into the plume area directed by river currents (planktonic organisms) or the actual swimming into the area by motile organisms. This series of experiments tested the second possibility. All the experimental organisms were juvenile striped bass. The plume drifts were performed during Unit No. 2 condenser chlorination. The experimental variables were reduced ΔT's and diluted residual chlorine. The movement of the drift apparatus was current-directed, therefore simulating the experience of planktonic organisms.

Table 9-14. Survival of striped bass juveniles after an *in situ* plume exposure at Indian Point during condenser chlorination on 7-17-75.

Exposure	Mean Temp. C	Total Residual Chlorine (mg/l)	Duration of Exposure (min)	Duration of Chlorine Residual (min)	n	Percent Survival (hrs.) initial	24	48	72
River Experiment (plume)	26.0	ND*	60	unknown	20	100	100	100	100
River control	24.3	0.0	60	0	20	100	100	100	100
Discharge	33.7	0.05 0.05-0.07	60	35	20	100	100	100	100

* Not detectable; <0.03mg/l

Source: NYU 1976b.

Table 9-15. Survival of striped bass juveniles after an *in situ* plume exposure at Indian Point during condenser chlorination on 7-24-75.

Exposure	Mean temp. C	Total Residual Chlorine (mg/l)	Duration of Exposure (min)	Duration of Chlorine Residual (min)	Percent Survival (hrs)				
					n	initial	24	48	72
River Experiment (plume)	28.3	N.D*	60	unknown	20	100	90	65	40
River control	26.3	0.0	60	0	20	95	95	90	60
Discharge	34.3	0.06 0.05-0.08	60	40	20	100	80	70	65

* Not detectable; < 0.03 mg/l

Source: NYU 1976b.

Immediate and latent striped bass mortality was not significant for any of the drift exposures. The plume ΔT's were low (1.7, 2.0 and 2.0C) and the plume chlorine concentrations were below the detectable limits of the amperometric titrator. These data indicate that plume entrainment of striped bass juveniles during plant chlorination is not a significant source of mortality.

SECTION 10

FISH IN THE AREA OF INDIAN POINT

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10. FISH IN THE AREA OF INDIAN POINT

10.0 SUMMARY

Data collected between 1972 and 1975 on the fish community in the area of Indian Point were analyzed to determine the catch per unit effort C/f, distribution and relative abundance of a selected set of species. In addition, the biological characteristics of three key species (striped bass, white perch and Atlantic tomcod) were also studied. The results of the analysis indicated that the fish community did not exhibit any significant changes in species composition, distribution and/or abundance throughout the four year study period. However, certain environmental factors, such as temperature and salinity, did influence the biological characteristics (i.e. growth rate, fecundity, food habits, movement, etc.) of the studied species. Impingement data for the period 1972-1976 were also analyzed to determine the seasonal occurrence and numbers of selected fish species collected at Indian Point. Although the impingement rates varied annually, the data indicate strong seasonal impingement trends, reflecting the life history and migratory patterns of the collected species. Impingement data were also evaluated in conjunction with various biological, plant operational and environmental factors to determine any possible relationships between these factors and the incidence of impingement. Of these factors, only conductivity (a beter measure of ionized materials in brackish waters than salinity) demonstrated a consistent relationship with impingement peaks.

Since the onset of the impingement monitoring program, considerable progress has been made in understanding the interaction of the causal factors of impingement. This information is being applied to develop various measures to mitigate the impact of impingement. At the present time, research is underway at Unit No. 1 with the testing of a continuously operating travelling screen, equipped with fish buckets for the retention of impinged fish. It is anticipated that this modified mode of screen operation will greatly enhance the survival of impinged fish at Indian Point. The testing device has also been equipped with a fine mesh screen (2 mm) in an effort to determine whether or not a portion of entrainment can also be reduced. In addition, a submerged weir will be tested to determine its potential for reducing the impingement of bottom dwelling species. Furthermore, intake modifications that guide and bypass impinged fish to safety (angled screens and louvers) have also been tested on a laboratory scale and found to be potentially effective for reducing impingement mortality.

10.1 RIVER ABUNDANCES

10.1.1 Introduction

Sampling of the fish community in the vicinity of Indian Point began in April 1972. During every year (1972-1975) intensive sampling and analysis of the biological characteristics of the fishes of the area were performed. Because of relatively unchanged study design and generally consistent sampling techniques, results of the various years are comparable and reflect the variations in population densities, relative abundance, spatial distribution, and biological characteristics which occur from year to year within the fish community. Biological characteristics of striped bass, white perch, and tomcod included age/growth, length/weight, fecundity, sexual maturity, and food habits.

Data from the physicochemical sampling program which was conducted in coordination with the fisheries program were correlated, when possible, with the results of the biological sampling. In this way, the causes of year-to-year and seasonal variations could be analyzed and factored into predictions of population reactions to various conditions.

10.1.2 Methods and Materials (1972-1975)

1. Standard station beach seines (see Fig. 10-1)

Five standard beach seine stations were sampled weekly during daylight hours with a 100 foot seine with 3/8 inch (9mm) stretch mesh wings and a 3/16 inch (4.5 mm) delta mesh bag. Additional sampling effort is detailed elsewhere (TI 1976a).

2. Standard station bottom trawls (Fig. 10-1)

Seven standard bottom trawl stations were sampled at least biweekly April-December 1972-1975 with an otter trawl of total length 44.3 feet (13.5m) and mesh sizes 3.8 cm body mesh and 3.1 cm cod-end mesh. Trawl duration was 10 min. Additional sampling is detailed elsewhere (TI 1976a).

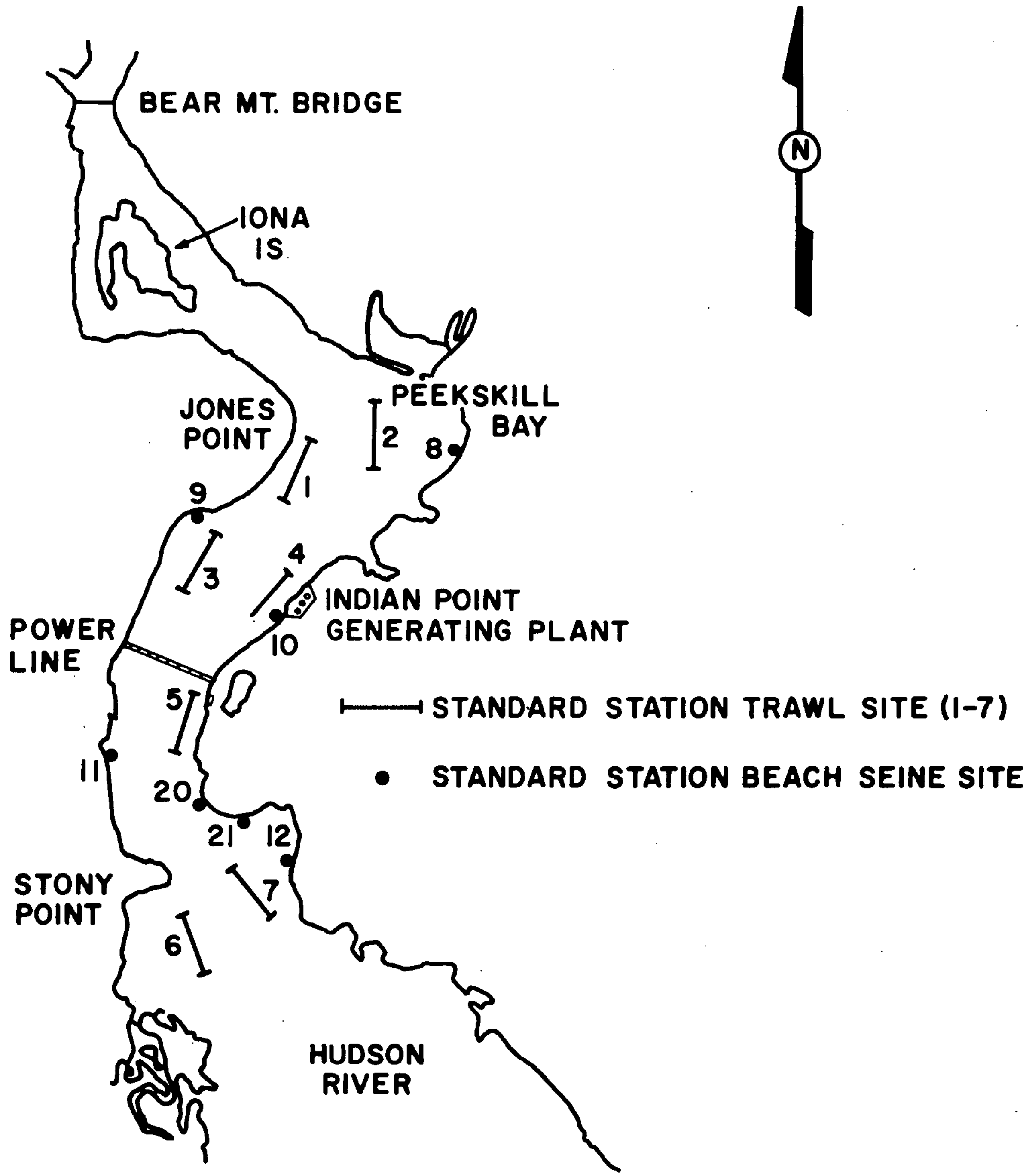

Figure 10-1. Standard Fisheries Stations
Indian Point Ecological Study
Source: TI 1976a.

3. <u>Standard station surface trawls (Fig. 10-1)</u>

Seven standard surface trawl stations were sampled 1972-1975 with a surface trawl modified from a midwater trawl of total length 49.5 feet (15.0m). Sampling schedule generally followed those of bottom trawl. Two boats towed the trawl against the tide at 1 m/sec for ten min.

10.1.2.1 <u>Laboratory Processing</u>

Each year, samples were sorted by species and size class. However, the size classes were different in 1972 from those in the other years.

<u>Size Class</u>

	1973-1974	
<u>1972</u>	<u>Jan.-mid-July</u>	<u>mid-July-Dec.</u>
0-49mm	0-100mm	0 - X mm
50-125mm	101-150mm	X + 1 - 150mm
126-250mm	151-250mm	151-250mm
251+ mm	251+ mm	251+ mm
		X = upper Y-O-Y limit and is species and date specific.

In 1975, the size classes utilized in the two previous years during mid-July-December were used throughout the year.

10.1.2.2 Analysis

Species occurrence was compared among the four years. Community diversity was also compared.

Relative abundance of species among and within years was analyzed by interpretation of c/f values for each year. Distribution among stations was analyzed by c/f as well, although striped bass, tomcod, and white perch were also analyzed by other statistical tests.

10.1.2.3 Mark-Recapture

In the field program, a mark-recapture effort was performed 1972-1975. In 1972, white perch and striped bass were marked and released in the Indian Point study area. In 1973 and for the subsequent years, these fishes were tagged and released throughout the study area. In 1974, tomcod was also tagged and released. For all species tagged, extensive survival studies were conducted to evaluate differences in survival between tagged and untagged fish.

The results of recaptures were analyzed to obtain population estimates, as described in Con Edison 1977d and TI 1973a; 1974a; 1975a; 1976a. However, the movements of tagged fish, especially young-of-the-year, can be monitored by comparing the location and date of release and the location and date of recapture.

10.1.2.4 Biological Characteristics

Fish were collected with the three standard gear at the standard stations, in box traps, gill nets, Tucker trawls, and epibenthic sleds, and from commercial and sport fishermen.

Striped bass and white perch were preserved in 10% formalin in 1972-1973. Beginning in August 1974, fresh fish collected from box traps were used for length/weight analysis. In 1975, fresh fish from standard stations were also used. Adult striped bass caught in gill nets were used fresh for length and weight measurement.

Tomcod sampling occurred from December 1973-1975 with box traps, bottom trawls, Tucker trawls, and epibenthic sleds. Samples from Tucker trawls and epibenthic sleds were preserved in 5% formalin in the field. All other samples were processed fresh.

In the laboratory, fish were weighed and measured and stomach and gonads were preserved.

Aging of scales was determined by the annulus method and a Trisimplex microprojector. It was found that tomcod age could be determined more accurately by examination of the otoliths than by the scale method. Therefore, in 1975 tomcod age estimates were based on the otoliths.

For growth determination, mean monthly total length and weight and monthly age and length frequencies for striped bass and white perch were determined from fish in standard station samples.

Tomcod length-frequency data for 1973-1974 spawning season were obtained from traps set in the vicinity of Indian Point. For the 1974-1975 season and December 1975, data were obtained during the tag-release program.

Sexual maturity was determined by visual examination, egg-diameter, and manual expulsion of gametes, for the Morone species. For tomcod, the percentage of total body weight composed of gonadal tissue was monitored. Fecundity was determined by weighing the ovary, excising a medial portion and weighing it, and counting the mature eggs in the portion. For details on methods of estimates of fecundity for different ages, average tomcod fecundity, and the length: fecundity relationship, see TI 1976a.

10.1.3 Results

10.1.3.1 Standard Station Sampling

The fish community of the Indian Point Study area includes marine, anadromous, catadromous, estuarine, and freshwater species. The marine species are generally represented by juveniles feeding in the estuary during the summer. The freshwater species are present in greatest numbers during periods of high freshwater flow and low salinity. Sixty species were collected by all gear 1972-1975 (Table 10-1). From 1972 to 1975, no change in species composition or community diversity was detected in the Indian Point vicinity other than the natural variations usually found in similar habitats (TI 1976a).

The following species will be discussed:

shortnosed sturgeon	alewife
spottail shiner	American shad
bluefish	Atlantic tomcod
bay anchovy	white perch
blueback herring	striped bass

TABLE 10-1

Fishes Collected in Standard-Station Samples, Yearly and by Gear, Indian Point Region, Hudson River Estuary, New York, 1972-75+

Species	Principal Usage of Estuary ‡	Beach Seine				Surface Trawl				Bottom Trawl			
		72	73	74	75	72	73	74	75	72	73	74	75
STURGEONS - ACIPEMSERIDAE													
Shortnose sturgeon	M-F Life resident; spawning (Sp)	-	-	-	-	-	-	-	-	+	+	+	+
Atlantic sturgeon	M-F Resident during early years; larger adults anadromous; spawning (Sp).	-	-	-	-	-	-	-	-	-	-	+	-
FRESHWATER EELS													
American eel	M-F Catadromous; nursery adult feeding	+	+	+	+	+	-	-	+	+	+	+	+
HERRINGS - CLUPEIDAE													
*Blueback herring	M-F Anadromous; spawning (Sp); nursery (Sp-F)	+	+	+	+	+	+	+	+	+	+	+	+
*Alewife	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	+	+	+	+	+	+
*American Shad	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	+	+	+	+	+	+
Atlantic menhaden	M-F Nursery (Sp-S); adult feeding lower estuary	+	-	+	-	+	+	+	+	+	-	+	+
Gizzard shad	M-F Nursery (S-W)	+	-	+	+	-	-	-	+	-	-	+	+
ANCHOVIES - ENGRAULIDAE													
*Bay anchovy	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	+	+	+	+	+	+	+
TROUTS - SALMONIDAE													
Brown trout	F Life resident (tributary streams)	-	+	-	-	-	-	-	-	-	-	-	-
SMELTS - OSMERIDAE													
Rainbow smelt	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	-	-	+	+	+	+
PIKES - ESOCIDAE													
Redfin pickerel	F Life resident; spawning (W-Sp)	-	-	-	+	-	-	-	-	-	-	-	-
Chain pickerel	F Life resident; spawning (W-Sp)	+	-	+	-	-	-	-	-	-	-	-	-
Northern pike	F Life resident (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-
MIMNOUS & CARPS - CYPRINIDAE													
Goldfish	F Life resident; spawning (Sp)	+	+	+	+	-	-	-	-	+	+	+	-
Carp	F Life resident; spawning (Sp-S)	+	+	+	+	-	-	-	-	-	-	-	-
Silvery minnow	F Life resident; spawning (Sp)	-	-	+	-	-	-	-	-	-	-	-	-
Golden shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	-	-	-	-
Emerald shiner	F Life resident; spawning (Sp-S)	-	-	+	+	-	-	-	-	-	-	-	-
*Spottail shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	+	-	-	+	+	+	+
Spotfin shiner	F Life resident; (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-
Bridle shiner	F Life resident; (Sp-S)	-	+	-	-	-	-	-	-	-	-	-	-
Common shiner	F Life resident; (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-
Redfin shiner	F (1)	-	-	+	-	-	-	-	-	-	-	-	-
Blacknose dace	F Life resident (tributary streams)	-	+	+	-	-	-	-	-	-	-	-	-
SUCKERS - CATOSTOMIDAE													
White sucker	F Life resident; spawning (Sp)	+	+	+	+	-	-	-	-	-	-	+	-
FRESHWATER CATFISHES - INCTALURIDAE													
White catfish	F Life resident; spawning (Sp)	+	+	+	+	-	-	-	-	+	+	+	+
Brown bullhead	F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	+	+	+	+
CODS - GADIDAE													
*Atlantic tomcod	M-F Spawning (W); nursery (Sp-F); adult feeding	+	+	+	+	+	-	-	+	+	+	+	+
NEEDLEFISHES - BELONIDAE													
Atlantic needlefish	M-F Nursery (S); adult feeding (S)	-	-	+	+	-	-	-	-	-	-	-	-
KILLIFISHES - CYPRINODONTIDAE													
*Banded killifish	F Life resident; spawning (Sp-S)	+	+	+	+	-	-	-	-	-	-	-	+
Mummichog	M-F Life resident; spawning (Sp-S)	+	+	+	+	-	-	-	-	-	-	-	-
SILVERSIDES - ATHERINIDAE													
Tidewater silverside	M-F Life resident; spawning (Sp-S)	-	-	+	+	-	-	+	-	-	-	-	-
Atlantic silverside	M-F Life resident; spawning (Sp-S)	+	+	+	+	-	+	+	-	-	-	-	-
Rough silverside	M Nursery (S-F)	-	-	-	+	-	-	-	+	-	-	-	-
STICKLEBACKS - GASTEROSTEIDAE													
Fourspine stickleback	M-F Life resident; spawning (Sp-S)	+	+	+	+	-	-	-	-	-	-	-	-
Brook stickleback	F Life resident; (tributary streams)	-	-	+	+	-	-	-	-	-	-	-	-
Threespine stickleback	M-F Life resident; spawning (sp)	-	+	+	-	-	-	-	-	-	-	-	-
PIPEFISHES & SEAHORSES													
Northern pipefish	M-F Nursery (S); adult feeding (S)	+	+	+	+	-	-	-	-	-	-	-	-
TEMPERATE BASSES - PERCICHTHYIDAE													
*White perch	M-F Anadromous; spawning (Sp-S) nursery (Sp-F); feeding (Sp-F)	+	+	+	+	+	+	+	+	+	+	+	+
*Striped Bass	M-F Anadromous; spawning (Sp) nursery (S-F) feeding	+	+	+	+	+	+	+	+	+	+	+	+
SUNFISHES - CENTRARCHIDAE													
Rock bass	F Life resident; spawning (S)	+	-	-	-	-	-	-	-	-	-	-	-
Red breast sunfish	F Life resident; spawning (S)	+	+	+	+	-	-	-	-	-	-	-	-
*Pumpkinseed	F Life resident; spawning (S)	+	+	+	+	-	-	+	-	+	+	+	-
Bluegill	F Life resident; spawning (S)	+	+	+	+	+	-	+	+	+	+	-	-
Green sunfish	F Life resident; (tributary streams)	-	-	-	+	-	-	-	-	-	-	-	-
Largemouth bass	F Life resident; spawning (S)	+	+	+	+	-	-	-	-	-	-	-	-
Black crappie	F Life resident; spawning (S)	+	+	+	+	-	-	-	-	-	-	-	-
PERCHES - PERCIDAE													
*Tessellated darter	F Life resident; spawning (Sp)	+	+	+	+	-	-	-	-	+	+	+	+
Yellow perch	F Life resident; spawning (Sp)	+	+	+	+	-	-	-	-	+	+	-	-
BLUEFISHES - POMATOMIDAE													
*Bluefish	M-F Nursery (S); yearling feeding (S-F)	+	+	+	+	+	+	+	+	+	+	+	+
JACKS & POMPANOS - CARANGIDAE													
Crevalle jack	M-F Nursery (S)	+	+	+	+	-	-	-	-	-	-	-	-
DRUMS - SCIAENIDAE													
Weakfish	M-F Marine spawner; nursery (S)	-	+	+	-	-	+	-	-	+	+	+	+
Spot	M-F Nursery (S)	-	+	-	-	-	-	-	-	-	-	-	-
Atlantic croaker	M-F Nursery (F)	-	-	+	-	-	-	-	-	-	-	-	-
MULLETS - MUGILIDAE													
Striped mullet	M Nursery (S-F)	-	+	-	-	-	-	-	-	-	-	-	-
White mullet	M Nursery (S-F)	-	-	-	+	-	-	-	-	-	-	-	-
BUTTERFISHES - STROMATEIDAE													
Butterfish	M Incidental	-	-	-	-	-	-	-	-	+	-	-	-
LEFTEYE FLOUNDERS - BOTHIDAE													
Summer flounder	M Nursery (S-F)	-	+	-	-	-	-	-	-	-	-	-	-
SOLES - SOLEIDAE													
*Hogchoker	M-F Life resident; spawning (S)	+	+	+	+	-	-	-	-	+	+	+	+

+ Adapted from Texas Instruments (1975).
‡ General Salinity distributions: F = limited to fresh or low-salinity waters; M = limited to marine or brackish waters; M-F = occurs in both marine and fresh waters (euryhaline); SP = Spring, S = Summer, F = Fall, W = Winter.
* Common Indian Point fish fauna
+ = present; - = absent; (1) = Probable misidentification.

Source: TI 1976a.

All species above except the shortnosed sturgeon were collected regularly.

Shortnose Sturgeon (*Acipenser brevirostrum*)

Yearling and older Shortnose sturgeon have occasionally been collected in the Indian Point vicinity during the studies. A total of eight yearling and older shortnose sturgeon over two years were collected as follows:

Year	Number	Month	Gear
1974	3	August	Epibenthic Sled/Tucker trawl
	1	December	Bottom trawl
1975	2	April	Gill net
	1	September	Bottom trawl
	1	December	Bottom trawl

All collections were made from the near-bottom layer and reflect the demersal behavior of the species. The resulting low rate of catch renders patterns of distribution in time and space obscure. Further detailed information on the ecology and susceptibility of shortnose sturgeon to plant impact appear in Con Ed (1977d).

Spottail Shiner (*Notropis hudsonius*)

Spottail shiner were taken almost exclusively in standard-station beach seines during the 1972-75 study period, indicating a littoral habitat preference. Only rarely did individuals appear in surface trawls, and bottom-trawl catches were negligible except briefly during late fall. Adult and young-of-the-year spottail shiner were most abundant at beach-seine stations 8, 9, and 12, which are located in shallow, heavily vegetated areas. Highest late-fall bottom-trawl C/f values were recorded at stations 2, 3, and 7, which are relatively shallow and adjacent to the beach-seine sites which had earlier produced highest c/f values. Relative abundance and distribution were generally uniform during 1972-1975. C/f values at beach-seine station 10 decreased from 1972-73 to 1974-75 (TI 1976a).

In a typical year, adult spottail shiner were present at all beach-seine stations when standard-station sampling began in late March. Peak C/f values occurred from late April through May when water temperature ranged between 9 and 20C. C/f values subsequently decreased sharply, and appreciable adult catches did not recur until August and September. Young-of-the-year were initially caught in July. Beach-seine catches of adults and young-of-the-year declined through October following an offshore movement in response to falling water temperatures (TI 1976a). In late fall, subsequent to the offshore movement, limited numbers appeared in bottom trawls.

Bluefish (*Pomatomus saltatrix*)

During 1972-75, young-of-the-year bluefish were commonly present in standard-station beach seines and surface trawls but occurred only occasionally in bottom trawls. Beach seines most frequently registered high C/f values. During the four years considered, beach-seine station 11 and surface-trawl station 5, both located along unprotected sections of the river near deeper water, usually accounted for higher C/f values than did the other sites. Consistently lower catches were normally recorded at beach-seine station 8 and surface trawl station 2, located respectively in and at the mouth of Peekskill Bay, a shallow, weedy cove. These distribution patterns suggest a preference for open areas near steeply sloped bottoms.

Bluefish were present in standard-station samples from June or early July through September or mid-October when temperature and salinity requirements are usually met. C/f values were generally highest during July. Yearling and older individuals have never been captured in standard-station samples.

Relative abundance of bluefish in the Indian Point area increased from 1972 through 1974 but decreased slightly in 1975. No changes in nearfield distribution over the four year period were apparent (TI 1976a).

Young bluefish prey on striped bass young-of-the-year. In a year of high striped bass abundance (1973) in the saline sector of the estuary, large numbers of striped bass were found in bluefish stomachs. In a year of lower abundance (1974), little predation occurred (TI 1976g).

Bay Anchovy (*Anchoa mitchilli*)

Both adult and young-of-the-year bay anchovies were collected in large numbers in all three gear types 1972-1975. Catch distribution among gear varied seasonally and among years.

Adults first appeared in beach seine collections during May and peaked in C/f value in late spring/early summer. As beach seine collections declined in July, surface and bottom trawl collections increased. The anchovies appeared to move away from the shore and to the channel during July. By August, all gear collected fewer adult anchovies, and C/f values remained low thereafter. The adults had apparently left the Indian Point vicinity.

Young-of-the-year were collected in all gear during July through October. Catches peaked in August to early October and declined sharply in late October.

Both adults and young-of-the-year preferred open, unprotected beaches such as stations 10, 11, 20 and 21. Catches among the trawl stations were relatively uniform although sporadic.

Both adults and young-of-the-year were more abundant in 1974 and 1975 than in 1972 and 1973 (TI 1976a).

Blueback Herring (*Alosa aestivalis*)

Although all three gear collected adults and young-of-the-year blueback herring 1972-1975, adults were most frequently collected in beach seines and young-of-the-year in surface trawls and beach seines. The open, steeply sloping beach seine stations (10, 11, 20, and 21) generally showed highest C/f values for both adults and young-of-the-year. No clear differences in catch among trawl stations could be detected.

Adults first appeared in collections in mid-April, most frequently in beach seine samples. Peaks occurred in May or early June after which abundance declined quickly. Relative abundance was generally similar among the four years of the study. Young-of-the-year blueback herring behaved very similarly to their alewife counterparts (TI 1976a) in their longitudinal migrations and seasonal patterns of abundance.

Alewife (Alosa pseudoharengus)

Both adults and young-of-the-year were collected in all three sampling gears from 1972-1975, but relative abundance among the gears varied with time. No consistent variation in catch was observed among trawling stations either for the surface or for the bottom trawl. Adults were uniformly distributed among the beach seine stations, but young-of-the-year were found in greater abundance at stations 9 and 12, which contain dense summer vegetation and are adjacent to shoal areas. Abundance of adults was much higher in 1972 than in succeeding years 1973-1975 which were similar in abundance to each other. Young-of-the-year abundance varied from year to year with no apparent trend.

Adults generally began to appear in collections from all gear in late March-early April and reached peak abundance in early May. Catches declined rapidly late in May-June and were virtually zero by July.

Young-of-the-year appeared in collections from late June-early July. Surface trawl catches increased sharply from July to mid-August and declined thereafter. Beach seine catches rose in midsummer but did not decline until late fall. Low bottom trawl catches during the summer indicated that few young-of-the-year inhabited deep channel layers.

From late August to mid-October, surface trawl C/f values of young-of-the-year declined, whereas those for the bottom trawl increased slightly. Beach seine collections showed little change. A sharp peak in collections of both surface and bottom trawls occurred in mid-October to early November. Catches declined until by early December, they were near zero for all gears. No trends in changes of nearfield distribution were observed during the four year study period (TI 1976a).

American Shad (*Alosa sapidissimus*)

Adult shad were rarely collected during the four year study period because of low gear efficiency for this age of fish. Young-of-the-year, however, were collected in all three gears from 1972-1975. Catch distribution among the gears varied during each season. Catch distribution among the beach seine stations appeared homogeneous. No consistent differences in catch were seen among trawl stations and no indications of changes in nearfield distribution were seen.

Young-of-the-year were present in the study area from July-December. They appeared in fluctuating abundance in beach seine collections from July-November, and were collected in highest numbers at stations with a sharp slope (Stations 10 and 11). Surface trawl catches peaked in July and diminished in late October-November. Bottom trawl catches increased sharply in late October-November. A secondary surface trawl peak appeared as beach seine C/f values declined. Young-of-the-year abundance was low in 1972 and increased in 1973. Abundance from 1973 through 1975 was comparable among years (TI 1976a).

Atlantic Tomcod (Microgadus tomcod)

Because Atlantic tomcod spawn during midwinter, very few adults were collected in any standard station gear during the study period. Most were collected in bottom trawls. Box trap data indicate that adults are present in the Indian Point area from December through February. Young-of-the-year were collected in all three gears, but mainly in the bottom trawl. Because of the one year life duration young-of-the-year are the adults in the November-February period. No trend in change in abundance was observed for young-of-the-year from 1972-1975. Each year's abundance was similar to the others'. Local distribution also showed no change from 1972-1975: the deeper sites (Station 4-6) generally yielded somewhat higher catches.

Young-of-the-year first appeared in bottom trawl collections in April-June. C/f values fluctuated during the season and appeared related to the presence of the salt front (TI 1976a).

White Perch (Morone americana)

White perch fluctuated in abundance in the Indian Point area from 1972-1974. The 1973 year-class was the strongest of those years; and the 1972, the weakest. Trends in abundance and local distribution were not detected. Adults and young-of-the-year were collected mainly in beach seines and bottom trawls. The distribution of catch between these gears varied through time.

Both adults and young-of-the-year preferred vegetated, sheltered beaches and beach seine C/f values differed among stations during all four years accordingly. Catch distribution differed among bottom trawl stations only in 1975 when deeper stations yielded higher catches.

Adults appeared in bottom trawls at the beginning of the sampling season (late March-early April) and showed peak abundance in April-May. Beach seine collections began in mid-April to mid-May and peaked during June-July at which time a shoreward movement appeared to occur. After July, collections in both gears declined.

Young-of-the-year began to appear in beach seines in July, and beach seine catches increased until early September-late October. During August or September a decided peak in beach seine collections occurred in the Indian Point area. As beach seine collections declined in fall, bottom trawl collections increased. Peak young-of-the-year bottom trawl catches occurred from mid-November to mid-December. During this period, as well as through the winter months, catches of young white perch appeared to fluctuate in relation to movement of the salt front (TI 1976a).

Striped Bass (*Morone saxatilis*)

Young-of-the-year and subadult (yearling and older) striped bass were collected in all three gear types but collections by bottom and surface trawls were low and infrequent. Adults were captured infrequently in the three standard gear types.

The striped bass preferred open beach near deep water and were collected in greater numbers at stations 10 and 11 than at 8 and 12. Young-of-the-year were first collected in July and peaked in abundance from July-September. Relative abundance of young-of-the-year in the beach seine collections was highest in 1973 and lowest in 1972.

Subadults are collected throughout the sampling period and peak in late May through June. Abundance levels were similar during all years of the study and no trends in abundance or local distribution were observed. Station 10 consistently produced higher subadult catches than any other station.

In late September, beach seine collections decreased but those of bottom trawls increased. During the fall, catches in both gears declined until near zero by mid-December (TI 1976a).

10.1.3.2 <u>Biological Characteristics</u>

The 1972-1975 Indian Point studies included investigation of the following biological characteristics of three species, striped bass, white perch, and tomcod: age/growth, length/weight, fecundity and sexual maturity, and food habits. Differences among years, among seasons within each year, and within the study area were examined.

<u>Striped Bass</u>

The young-of-the-year of 1973, 1974 and 1975 showed similar trends such as greatest incremental growth in July and near termination of growth by October (Fig. 10-2). Table 10-2

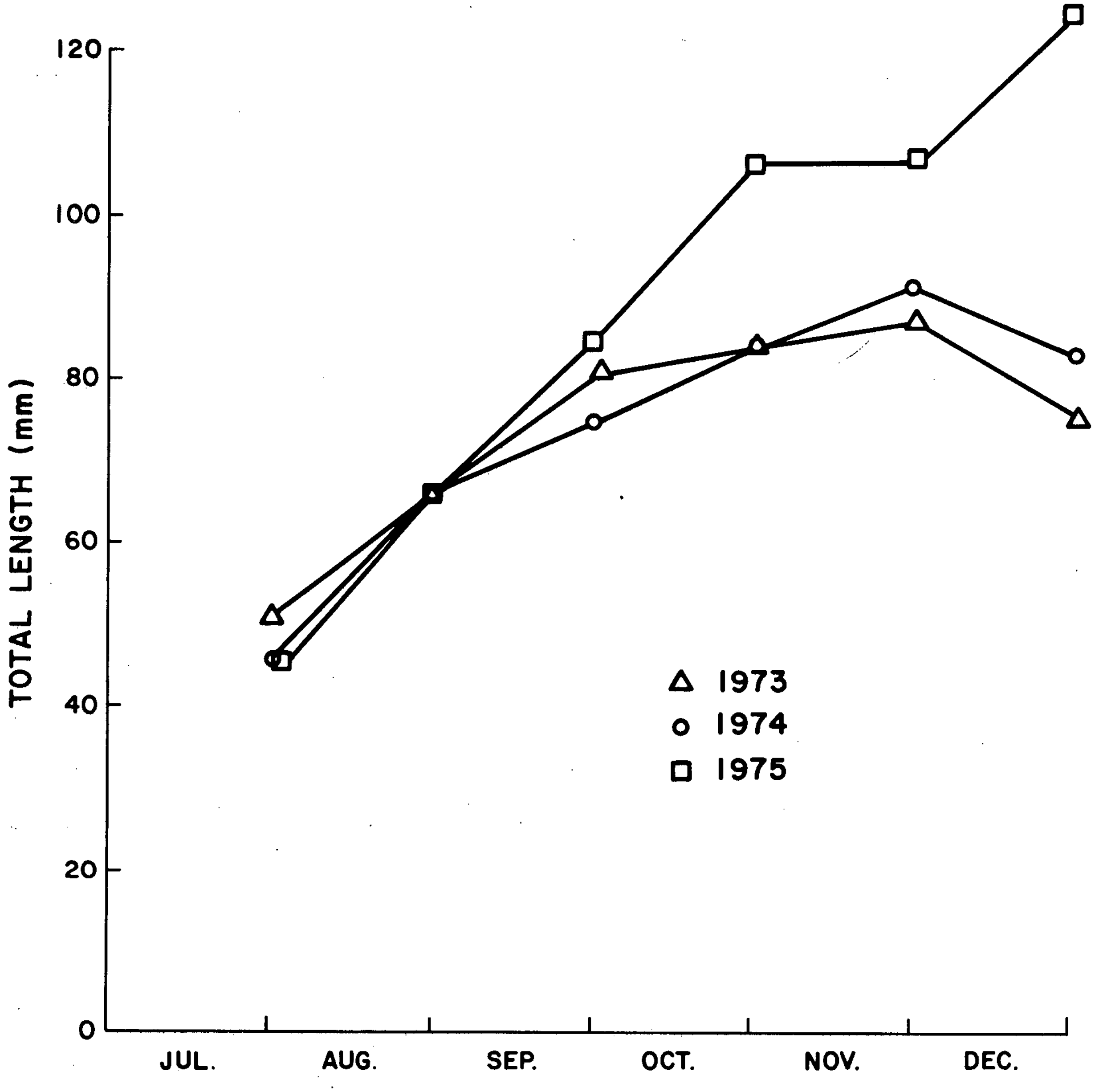

Figure 10-2. Comparison of Monthly Mean Total Lengths of Young-of-the-Year Striped Bass Collected in Standard-Station Beach Seines and Bottom Trawls, July-December 1973-1975

Source: TI 1976a.

Table 10-2.

Monthly Mean Total Lengths of Young-of-the-Year Striped Bass Collected in Standard-Station Beach Seines and Bottom Trawls, July-December 1973-75

	Month																	
	July			August			September			October			November			December		
Year	$\bar{x}$	2 SE*	n+	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n
1973	50.0	1.580	172	66.3	1.484	274	80.7	1.788	311	82.3	1.760	257	87.3	3.132	103	75.9	5.678	15
1974	44.5	1.470	222	66.3	1.370	339	75.4	1.228	395	82.3	2.392	191	91.1	5.620	59	83.9	6.788	13
1975	43.8	1.478	184	66.8	1.308	359	85.6	1.678	312	106.5	2.864	171	107.6	5.224	68	125.6	16.448	8

* Two times the standard error of the mean

+ Sample size

Source: TI 1976a.

presents monthly mean total lengths. Monthly length frequency and age composition for 1973, 1974, and 1975 beach seine and bottom trawl collections are indicated elsewhere, Fig. C-1 and C-2 (TI 1976a). The April - June collections are generally dominated by yearling fish, but by July, young-of-the-year appeared in the beach seines and became the dominant age class. Young-of-the-year appeared in bottom trawls in August and became dominant in those collections also. Occasionally beach-seines collected age III striped bass during the spawning run. For details on age composition of collections, see TI 1976a, especially figures C-3 through C-6.

A comparison of the major striped bass food items consumed by striped bass of different lengths-classes for 1973, 1974, and 1975, indicates that (see Table C-1, TI 1976a) generally, larger food items were consumed as the fish grew. The smallest young-of-the-year began by feeding on copepods, progressed with growth to amphipods, chironomid larvae, and isopods; and became more piscivorous as yearlings. In 1974, yearlings caught in the bottom trawl contained Gammarus and chironomid larvae as dominant food items; those caught in beach seines contained calanoid copepods and Gammarus. As salinity increased during the summer, the diet of striped bass of the Indian Point region was composed increasingly of estuarine invertebrates such as Neomysis and Crangon.

A summary of spring season length/weight relationships for 1973-1975 are presented in Table 10-3. Little difference in this relationship can be observed between years and no trend can be detected.

The mean fecundity of mature striped bass increases with age and with length. No significant difference between 1973 and 1974 was detected in the mean fecundity of age classes VII, IX, and X. Table 10-4 presents a summary of age/fecundity data.

All female striped bass less than age V were immature; all females of age VII and older were mature. Because of the small sample sizes of ages V and VI, the percentage of females which reach maturity is unknown. All males age III and older which were examined were mature (TI 1976a). More up-to-date information on this subject appears in Con Ed (1977d) and its supplement, submitted as exhibits in this proceeding.

<u>White Perch</u>

The general first-year growth pattern of white perch is similar to that of striped bass: maximum incremental growth in July, a slowdown in early fall, and termination of growth in late fall (see Table V-6, TI 1976a for mean monthly length).

First year growth appears to be influenced by temperature and was greatest during the warmer years. Highest July-November temperatures occurred in 1973 and the lowest were in 1974. Table 10-5 presents the mean monthly length.

Table 10-3

Length/Weight Relationship[1] of Striped Bass for Spring 1973-1975*

Sex	Year	Sample Size	Intercept a	Slope b	Correlation Coefficient r	r^2
Male	1973	45	-5.218	3.175	0.9966	0.9932
	1974	100	-5.750	3.265	0.9785	0.9575
	1975	51	-4.703	2.911	0.9954	0.9908
Female	1973	48	5.459	3.175	0.9894	0.9789
	1974	83	-6.180	3.424	0.9773	0.9552
	1975	48	-5.145	3.070	0.9941	0.9883

* March 30-June 5

1 Log Weight = a + b (log length)

Source: TI 1976a

Table 10-4

Mean Fecundity and Age at Maturity for Female Striped Bass, 1973 and 1974

Age	Year	No. Examined	No. Mature	No. Immature	% Mature	Mean Fecundity	Standard Error	Sample* Size
	1973	1	0	1	0			
III	1974	-	-	-	-			
	Total	1	0	1	0			
	1973	7	0	7	0			
IV	1974	9	0	9	0			
	Total	16	0	16	0			
	1973	9 †	0	9	0	-	-	
V	1974	5	4	1	80	591,000	219,500	2
	Total	14	4	10	28	591,000	219,500	2
	1973	3 ‡	2	1	67	276,345	-	1
VI	1974	5	5	0	100	726,507	115,035	5
	Total	8	7	1	88	651,480	294,459	6
	1973	8	8	0	100	1,002,102	267,997	7
VII	1974	6	6	0	100	1,174,340	558,885	2
	Total	14	14	0	100	1,040,377	226,304	9
	1973	15	15	0	100	1,487,084	136,448	11
VIII	1974	16	16	0	100	1,210,577	82,228	14
	Total	31	31	0	100	1,332,240	79,050	25
	1973	9	9	0	100	1,610,329	198,853	7
IX	1974	18	18	0	100	1,497,703	120,367	17
	Total	27	27	0	100	1,530,552	101,299	24
	1973	3	3	0	100	1,980,669	315,066	3
X	1974	16	16	0	100	1,762,574	165,140	14
	Total	19	19	0	100	1,801,061	144,452	17
	1973	-	-	-	-	-	-	
XI	1974	7	7	0	100	1,818,524	452,376	4
	Total	7	7	0	100	1,818,524	452,376	4
	1973	1	1	0	100	1,994,789	-	1
XII	1974	-	-	-	-	-	-	
	Total	1	1	0	100	1,994,789	-	1
	1973	-	-	-	-			
XIII	1974	-	-	-	-			
	Total	-	-	-	-			
	1973	1	1	0	100			1
XIV	1974	-	-	-	-			
	Total	1	1	0	100			1

* Number of fish used to determine fecundity estimate
† Samples taken during March and April
‡ 2 from March, 1 from May

Source: TI 1976a

Table 10-5

Monthly Mean Length by Age for White Perch (Ages 0-VIII) Collected by Standard-Station Beach Seines and Bottom Trawls, April-December 1973-75

			0			1			11			111			IV			V			VI			VII			VIII	
Month	Year	$\bar{x}$	2 SE*	n+	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n	$\bar{x}$	2 SE	n
	1973	-	-	-	64.2	2.664	19	119.0	3.044	33	149.2	4.876	18	176.6	5.688	9	188.8	7.500	4	18.2	0	1	-	-	-	-	-	-
Apr	1974	-	-	-	77.8	1.268	172	127.8	2.464	29	152.7	2.554	63	173.6	4.652	19	183.5	14.388	4	-	-	-	254.0	0	1	-	-	-
	1975	-	-	-	73.7	1.866	108	121.2	1.400	297	155.0	2.532	56	167.0	1.886	101	183.8	3.708	37	201.1	12.858	8	-	-	-	-	-	-
	1973	-	-	-	64.9	1.932	62	119.2	2.514	40	159.1	3.596	39	175.8	4.526	17	189.7	8.104	9	183.9	11.586	4	-	-	-	-	-	-
May	1974	-	-	-	79.6	1.724	84	127.5	9.460	14	154.6	4.284	14	173.4	7.98	9	184	26.0	2	-	-	-	225.0	-	1	-	-	-
	1975	-	-	-	70.2	1.402	145	119.9	2.33	98	153.1	3.146	22	170.8	2.402	63	186.5	2.72	33	197.8	12.366	4	-	-	-	-	-	-
	1973	-	-	-	73.6	1.220	214	120.0	2.064	178	162.0	3.384	30	175.3	4.990	15	188.5	5.286	6	197.6	12.128	3	-	-	-	-	-	-
Jun	1974	-	-	-	83.9	0.906	356	130.6	1.724	42	152.0	2.594	48	171.9	4.192	22	189.1	8.134	9	109.5	7.00	2	-	-	-	-	-	-
	1975	-	-	-	79.8	1.710	143	128.1	2.422	91	159.0	3.340	30	173.3	2.998	60	183.4	4.268	41	192.3	7.986	11	219.3	31.418	3	-	-	-
	1973	39.9	1.64	111	91.2	1.396	129	130.0	3.428	67	160.5	3.256	16	178.1	10.010	8	194.5	1.000	2	190.0	8.000	2	-	-	-	-	-	-
Jul	1974	33.0	2.056	25	94.2	1.276	221	136.0	3.834	16	157.0	4.964	33	174.3	13.776	3	186.3	5.766	6	203.0	0	1	215.0	0	1	-	-	-
	1975	34.1	1.762	55	94.4	2.006	87	133.1	2.188	46	164.0	2.892	13	174.4	3.272	8	190.4	3.174	7	191.8	14.810	5	-	-	-	271.0	0	1
	1973	51.9	1.304	249	103.0	2.706	28	128.2	4.940	24	158.0	14.094	4	181.3	11.616	4	203.0	0	1	-	-	-	-	-	-	-	-	-
Aug	1974	54.3	2.4	84	111.3	1.618	114	166.0	16.0	2	176.3	9.804	8	196.8	8.656	4	-	-	-	-	-	-	-	-	-	-	-	-
	1975	53.3	1.66	249	105.6	2.834	44	144.3	7.572	10	167.5	7.190	17	182.0	6.426	13	197.8	13.962	4	189.5	13.000	2	-	-	-	-	-	-
	1973	63.4	0.978	314	113.0	2.732	33	139.7	3.598	30	164.4	5.068	9	193.5	23.0	2	-	-	-	-	-	-	-	-	-	-	-	-
Sep	1974	66.0	1.25	232	118.4	1.354	139	145.5	4.538	11	165.8	6.012	13	179.8	8.808	4	19.03	7.860	3	-	-	-	-	-	-	-	-	-
	1975	69.9	1.244	285	123.0	2.20	67	150.4	3.104	49	169.0	2.864	27	182.4	5.244	16	196.3	9.358	4	-	-	-	-	-	-	-	-	-
	1973	70.6	1.464	213	118.5	3.344	27	145.3	4.802	20	168.2	4.598	10	177.0	0	1	-	-	-	-	-	-	-	-	-	-	-	-
Oct	1974	69.5	0.84	310	120.5	1.134	252	147.6	3.236	17	165.4	3.648	27	181.7	5.828	10	203.0	2.066	6	215.0	0	1	-	-	-	-	-	-
	1975	74.4	1.79	147	123.1	3.554	33	147.0	4.516	35	174.5	9.196	12	186.8	8.524	12	193.7	5.863	6	222.0	0	1	-	-	-	-	-	-
	1973	77.5	1.24	129	124.8	3.264	24	149.0	2.876	37	166.7	5.086	10	192.2	13.220	6	197.0	0	1	-	-	-	-	-	-	-	-	-
Nov	1974	71.2	1.182	177	119.8	1.946	119	160.0	5.804	10	165.2	15.596	4	178.5	5.0	2	212.0	0	1	-	-	-	-	-	-	-	-	-
	1975	76.1	2.026	95	129.4	5.616	14	150.6	3.040	32	167.3	8.602	9	177.3	10.372	7	200.3	8.110	3	-	-	-	-	-	-	-	-	-
	1973	71.4	426.000	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dec	1974	70.2	1.322	149	122.4	1.870	149	160.9	9.566	7	173.0	6.782	11	200.0	12.166	3	-	-	-	209.0	0	1	-	-	-	-	-	-
	1975	80.3	1.73	122	125.4	2.004	55	150.6	4.098	32	171.0	5.034	3	194.0	0	1	-	-	-	223.0	0	1	-	-	-	-	-	-

* Two times the standard error of the mean
\+ Sample size
\- No sample

For yearling and age II white perch, spring growth began in May-June. Adults (age III and older) did not begin to grow until the July-August period, after the spawning season. It also appeared that adults did not form scale annuli until July-August, whereas younger fish formed them in May-June.

April-June beach seines caught white perch <200mm. After July the catch was dominated by white perch <150mm. From April-December, the bottom trawl collections contained mainly white perch >200mm. In the November-December period, beach seine collections declined and bottom trawl catch increased. (For detailed data on age and length population structure, see Figures C-11 and C-12, TI 1976a)

Young-of-the-year white perch began feeding on harpacticoid, calanoid, and cyclopoid copepods and, as they grew, expanded their pool of food items to include amphipods, isopods, and chironomid larvae. Changes in salinities were reflected in stomach contents: salt water organisms shall as Neomysis americana were eaten when the salt front brought them into the area. In spring, fish eggs were an important food item. A year-to-year comparison of feeding habits is presented elsewhere (Table C-3, TI 1976b).

All female white perch younger than age II were immature. All female white perch of age V and older were mature. A few females were mature at age II; a higher percent at ages III and IV. The

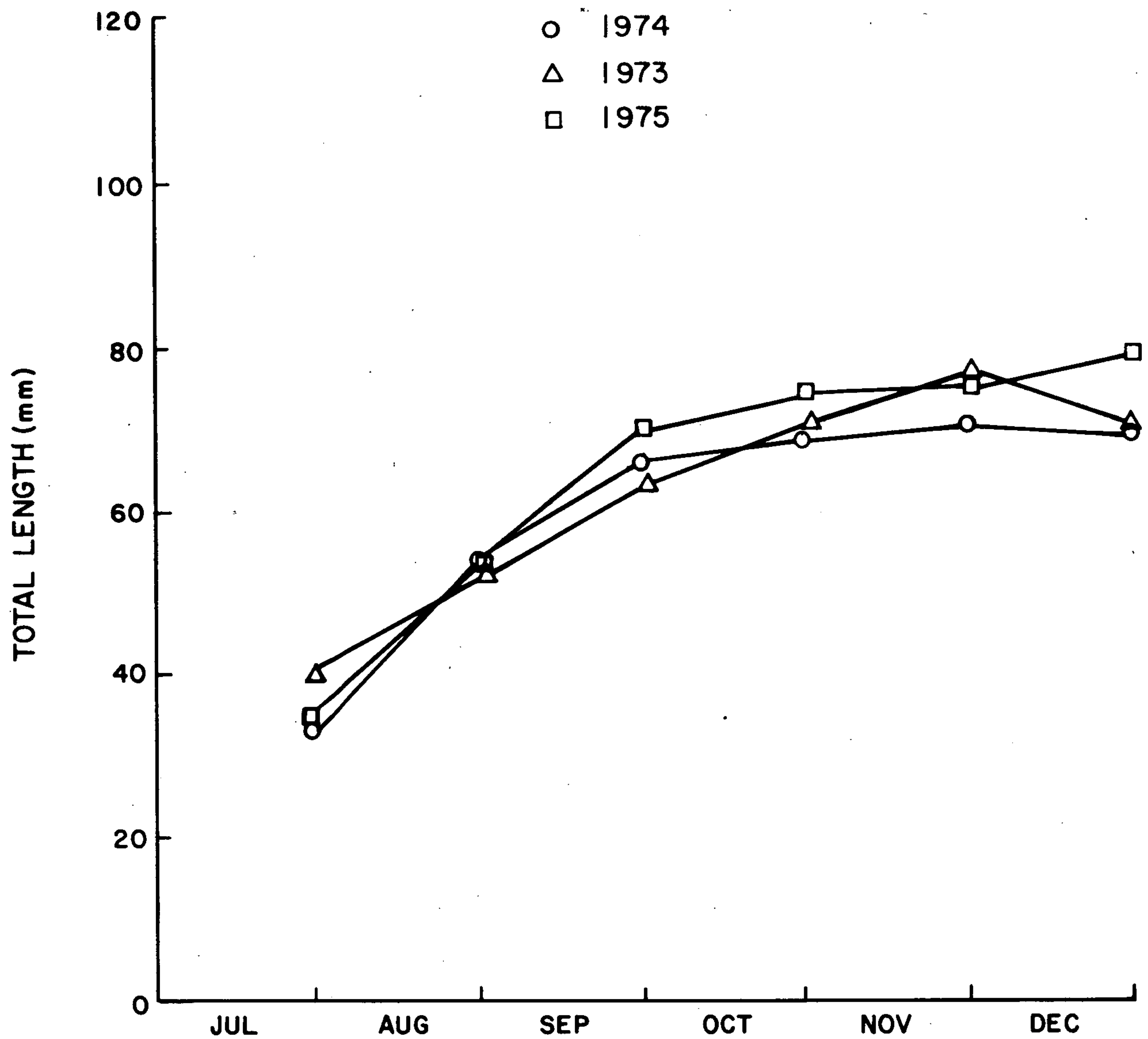

Figure 10-3. Comparison of Monthly Mean Total Lengths of Young-of-the-Year White Perch Collected in Standard-Station Beach Seines and Bottom Trawls, July-December 1973-1975

Source: TI 1976a.

1972-1974 data showed similar patterns. All males were mature by age IV, although many were mature at age II.

The mean fecundity of white perch followed a similar pattern to that of striped bass: an increase with age, (Table 10-6). The methodology employed for counting mature eggs in 1972 was different from that of 1973 and 1974, and the count was generally higher. Therefore, comparisons between 1972 and 1973-1974 were not performed (TI 1976a).

Atlantic Tomcod

During both years of the special tomcod study (1973-1974 and 1974-1975), marks were seen on scales and otoliths indicating summer growth slowdown. These marks were considered annuli. Growth rates for 1974 and 1975 showed similar patterns with a slowdown in growth during the summer. In 1975, slight growth during the summer continued and the mean length in December 1975 was greater than that in December 1974 (Table 10-7).

The great majority of food items found in both juveniles and adults were invertebrates. Juveniles consumed mainly copepods. Adults consumed mainly *Gammarus*, *Neomysis*, *Monoculodes*, *Crangon*, and *Chirodotea*. Very few fish or fish eggs were found in adult stomachs, except during spawning (December-February) when tomcod eggs appeared in stomachs (see Table V-16, TI 1976a).

Fig. 10-4 illustrates the regression of number of eggs on total length for 1973-1974 and 1974-1975. Analysis of variance indicated that the two lines were not equal. Average fecundity

Table 10-6.

Mean Fecundity and Age at Maturity for Female White Perch, 1972-74*

Age	Year	No. Examined	No. Mature	No. Immature	% Mature	Mean Facundity	Fecundity Standard Error	Sample Size
II	1972	19	0	19	0	--	--	--
	1973	17	4	13	24	20,445	8813	15
	1974	26	5	21	19	13,878	3392	6
	Comb.	62	9	53	15	18,568	6461	21
III	1972	8	6	2	75	38,834	6208	5
	1973	28	27	1	96	24,758	1728	68
	1974	18	17	1	95	17,366	3471	16
	Comb.	54	50	4	93	24,220	1562	89
IV	1972	18	18	0	100	58,188	4710	16
	1973	28	27	1	96	38,925	3436	30
	1974	18	17	1	95	22,410	3372	18
	Comb.	64	62	2	97	39,096	2211	64
V	1972	8	8	0	100	66,967	8797	12
	1973	15	15	0	100	49,445	4379	23
	1974	6	6	0	100	24,624	9420	5
	Comb.	29	29	0	100	51,599	3828	40
VI	1972	3	3	0	100	53,912	9070	7
	1973	1	1	0	100	62,418	-	1
	1974	-	-	-	-	-	-	-
	Comb.	4	4	0	100	54,475	7929	8

* 1972 Age at maturity samples obtained from RM 40-46. All fecundity samples are from May and June.

Source: TI 1976a.

Table 10-7.

Percent Length-Frequency Composition, Sample Size, and Mean Length of Atlantic Tomcod Caught in Traps during Spawning Season of 1973-74, 1974-75, and December 1975 of 1975-76 Spawning Seasons

Length Class (mm)	December 1973	December 1974	December 1975	January 1974	January 1975	February 1974	February 1975
91-100							0.3
101-110		0.7		0.2	1.1	0.7	1.0
111-120		4.1	0.3	1.4	6.9	1.0	6.9
121-130	1.2	14.1	3.0	4.2	17.3	4.7	24.5
131-140	2.8	21.3	12.3	8.7	20.6	10.8	23.6
141-150	5.2	20.2	21.8	14.6	18.3	15.2	19.2
151-160	9.2	17.1	23.8	13.6	14.3	18.9	13.0
161-170	12.9	11.2	18.4	13.1	10.9	10.8	7.0
171-180	10.0	5.6	10.5	10.8	6.1	13.5	3.4
181-190	16.1	2.8	4.5	9.3	2.9	8.5	0.9
191-200	11.2	1.4	1.9	6.1	1.1	7.8	0.1
201-210	10.8	0.6	1.2	6.7	0.4	2.7	
211-220	5.6	0.5	0.8	5.5	0.1	2.7	
221-230	7.6	0.1	0.4	2.4		1.7	
231-240	2.4	0.1	0.3	2.3		0.7	
241-250	2.0	0.1	0.2	0.8		0.3	
251-260	2.0		0.2	0.3			
261-270	0.0		0.1	0.1			
271-280	0.4			0.1			
281-290	0.4						
Sample Size	249	6746	13711	7246	9635	467	770
Mean total length (mm)	189.2	147.7	158.4	171.6	145.1	162.9	139.9

Source: TI 1976a.

Table 10-7.

Percent Length-Frequency Composition, Sample Size, and Mean Length of Atlantic Tomcod Caught in Traps during Spawning Season of 1973-74, 1974-75, and December 1975 of 1975-76 Spawning Seasons

Length Class (mm)	December 1973	December 1974	December 1975	January 1974	January 1975	February 1974	February 1975
91-100							0.3
101-110		0.7		0.2	1.1	0.7	1.0
111-120		4.1	0.3	1.4	6.9	1.0	6.9
121-130	1.2	14.1	3.0	4.2	17.3	4.7	24.5
131-140	2.8	21.3	12.3	8.7	20.6	10.8	23.6
141-150	5.2	20.2	21.8	14.6	18.3	15.2	19.2
151-160	9.2	17.1	23.8	13.6	14.3	18.9	13.0
161-170	12.9	11.2	18.4	13.1	10.9	10.8	7.0
171-180	10.0	5.6	10.5	10.8	6.1	13.5	3.4
181-190	16.1	2.8	4.5	9.3	2.9	8.5	0.9
191-200	11.2	1.4	1.9	6.1	1.1	7.8	0.1
201-210	10.8	0.6	1.2	6.7	0.4	2.7	
211-220	5.6	0.5	0.8	5.5	0.1	2.7	
221-230	7.6	0.1	0.4	2.4		1.7	
231-240	2.4	0.1	0.3	2.3		0.7	
241-250	2.0	0.1	0.2	0.8		0.3	
251-260	2.0		0.2	0.3			
261-270	0.0		0.1	0.1			
271-280	0.4			0.1			
281-290	0.4						
Sample Size	249	6746	13711	7246	9635	467	770
Mean total length (mm)	189.2	147.7	158.4	171.6	145.1	162.9	139.9

Source: TI 1976a.

Table 10-7.

Percent Length-Frequency Composition, Sample Size, and Mean Length of Atlantic Tomcod Caught in Traps during Spawning Season of 1973-74, 1974-75, and December 1975 of 1975-76 Spawning Seasons

Length Class (mm)	December 1973	December 1974	December 1975	January 1974	January 1975	February 1974	February 1975
91-100							0.3
101-110		0.7		0.2	1.1	0.7	1.0
111-120		4.1	0.3	1.4	6.9	1.0	6.9
121-130	1.2	14.1	3.0	4.2	17.3	4.7	24.5
131-140	2.8	21.3	12.3	8.7	20.6	10.8	23.6
141-150	5.2	20.2	21.8	14.6	18.3	15.2	19.2
151-160	9.2	17.1	23.8	13.6	14.3	18.9	13.0
161-170	12.9	11.2	18.4	13.1	10.9	10.8	7.0
171-180	10.0	5.6	10.5	10.8	6.1	13.5	3.4
181-190	16.1	2.8	4.5	9.3	2.9	8.5	0.9
191-200	11.2	1.4	1.9	6.1	1.1	7.8	0.1
201-210	10.8	0.6	1.2	6.7	0.4	2.7	
211-220	5.6	0.5	0.8	5.5	0.1	2.7	
221-230	7.6	0.1	0.4	2.4		1.7	
231-240	2.4	0.1	0.3	2.3		0.7	
241-250	2.0	0.1	0.2	0.8		0.3	
251-260	2.0		0.2	0.3			
261-270	0.0		0.1	0.1			
271-280	0.4			0.1			
281-290	0.4						
Sample Size	249	6746	13711	7246	9635	467	770
Mean total length (mm)	189.2	147.7	158.4	171.6	145.1	162.9	139.9

Source: TI 1976a.

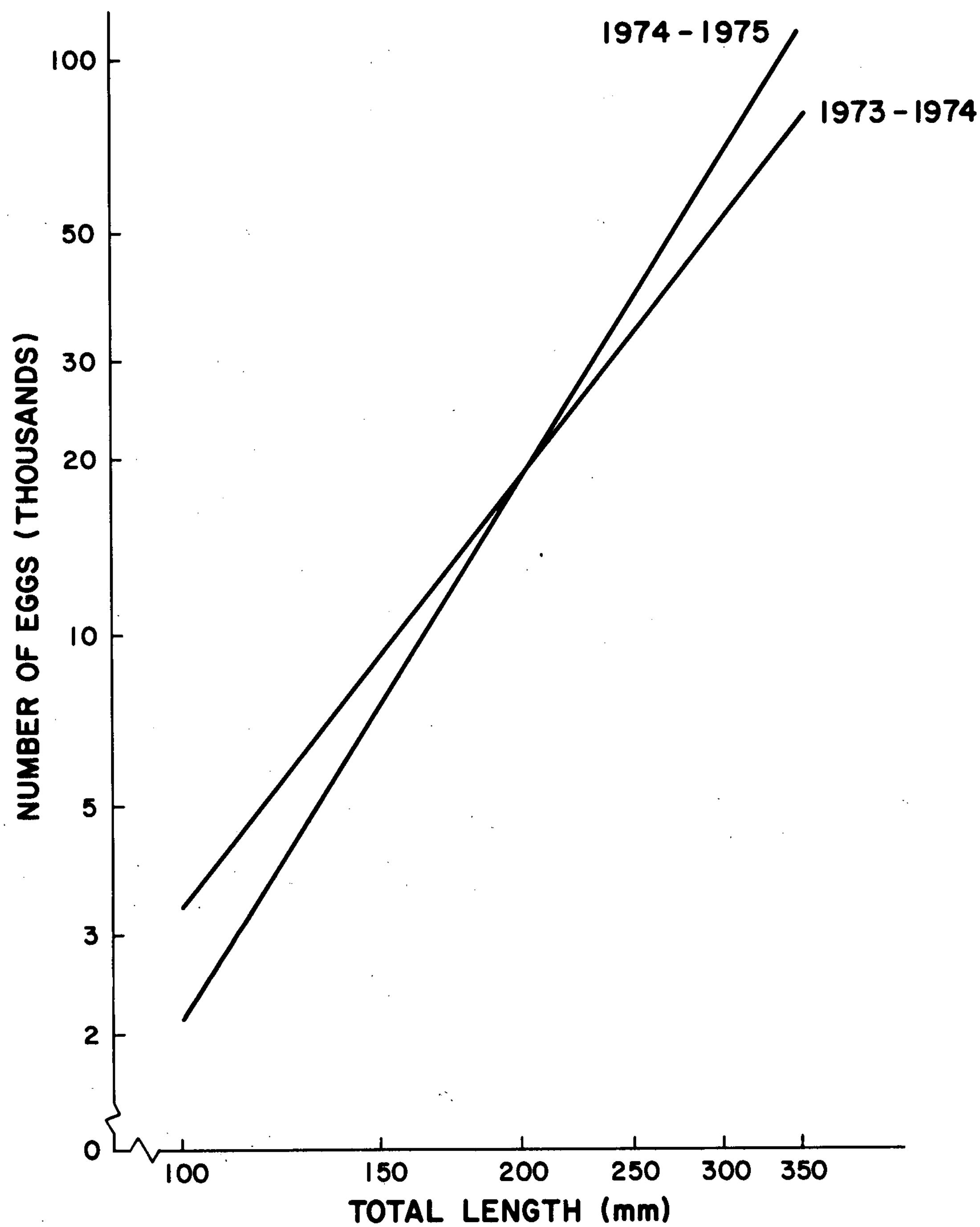

Figure 10-4. Regression of Number of Eggs on Total Length for Atlantic Tomcod, Hudson River, 1973-1974 and 1974-1975 Spawning Seasons

Source: TI 1976a.

in December 1973 was 20,260 eggs and in December 1974, 11,640 eggs. Mean female lengths were 199mm and 157.1mm respectively. Data from both the 1974 and 1975 year classes indicate that tomcod become sexually mature at 11-12 months of age. Gonad maturation rates were similar for both years: maximum testes weight in mid-November (16% of total body weight). The sex ratios of 1974 and 1975 young-of-the-year were similar (40-42% females in June; 47-48% in September). In early December the females composed only 2-3% of the catch in the Indian Point vicinity, but by mid-January, 60%. At the end of January, the 2-3% proportion again prevailed.

10.1.3.3 Mark-Recapture

Beginning in 1972, young-of-the-year and older striped bass and white perch were tagged during the fall by fin clip, or Dennison or Floy fingerling tag and released. Locations of subsequent recaptures were noted and compared with the locations of capture. During September and October of 1972, both species were recaptured in shoals of the same sector of the estuary in which they were initially captured. Little movement appeared to occur. When water temperatures declined in November and December, the fish moved to the channel and into deeper water.

According to the tag study, less than 5% of the striped bass and approximately 10% of the white perch migrated between tagging regions from September to December. These estimates include all tagged age classes. Table 10-8 presents a summary of movement study results.

Approximately 3% of all striped bass tagged in 1972-1973 were recovered; all recoveries were >400mm in total length. Therefore, these fish are present in the area mainly during the spawning run. These results are discussed elsewhere (Con Ed 1977d).

Comparison of region of release vs. region of recapture shows that the young-of-the-year for both species move through, into, and out of the region more frequently than the older fish (TI 1974a).

10.2 IMPINGEMENT AT INDIAN POINT

10.2.1 Introduction

Fish impingement may occur at any facility withdrawing water from an aquatic ecosystem and the severity of the problem is a function of various physical and biological characteristics. Fish are impinged when they are held against the intake screens by the force of water flow or by entanglement in the screen mesh. Impingement problems are unique at each site inasmuch as they are a function of the complex interaction of local species composition, life history, and condition, as well as behavioral and physiological response to variations in the physicochemical character of the organism's environment. Critical to evaluating impingement is an understanding of the spatiotemporal distribution and movements of species in the area, impingement

Table 10-8.

Summary of Movement Data for Tagged White Perch
Recovered during 1973
(including seven fish released during 1972)

Total Length at Time of Release (mm)	No. Recovered	Movement: Distance Traveled (miles-km) Range	Mean	Median	Time at Large (days) Range	Mean	Median	Velocity (mi/day) Range	Mean	Median
100 - 149	57	0-21 (0-33.6)	3.0 (4.8)	0 (0)	0.5-524	53.0	15	0-7.00 (0-11.20)	0.334 (0.534)	0 (0)
150	104	0-58 (0-92.8)	4.9 (7.8)	1 (1.6)	0.5-400	43.9	21	0-6.00 (0-9.60)	0.523 (0.837)	0.03 (0.05)
Total	161	0-58 (0-92.8)	4.2 (6.7)	0 (0)	0.5-524	47.1	20	0-7.00 (0-11.20)	0.456 (0.729)	0.02 (0.03)

Source: TI 1973a.

patterns, the design of intake structures and operating characteristics of the plant. Information on these factors are found in TI 1975a; 1976b; 1976c. As the interaction of these factors becomes better understood, impingement mitigating measures may be applied.

10.2.2 Impingement Monitoring and Quantification

10.2.2.1 Impingement Monitoring Program

Impingement samples have been collected daily at the Indian Point intakes since May 20, 1972. The impingement monitoring program was designed to analyze seasonal occurrence, numbers, species and size composition of fish collected at Unit Nos. 1, 2 and 3. The specific objectives of the program have been to:

a) Determine the factors influencing impingement,

b) Provide data to assess Indian Point impingement's biological impact on the fish populations of the Hudson River,

c) Evaluate methods for reducing impingement.

In addition to addressing these study objectives, the impingement program has also provided data for other aspects of the ecological study program:

a) Collection of impinged fish to supplement samples collected with other fishing gear used in the study of population dynamics, and

b) Assessment of physical, chemical, temporal and species variables associated with fish vulnerability to impact.

10.2.2.2 Fish Collection Methods

Each circulating water pump at both Unit Nos. 1 and 2 is served by an intake forebay with a fixed screen at the entrance and a vertical travelling screen situated approximately 10m behind the fixed screen. Unit No. 3, by comparison, employs only a vertical travelling screen located at the intake of each circulator (detailed intake descriptions are provided in Section 1).

The fixed and/or travelling screens are washed daily, whenever the circulating pumps are operating, and screen wash samples are identified and enumerated. Fish collection methods are detailed in the three annual impingement reports (TI 1974b; 1975b; 1976d). Total numbers and weights of white perch, striped bass and Atlantic tomcod are recorded daily with subsamples taken for all other species to establish numbers - weights relationships. In addition, subsamples of white perch, striped bass and Atlantic tomcod are taken for individual lengths and weights as an indicator of impinged fish condition.

To determine impingement rates, the collection estimates are divided by the volume of water pumped during each collection period. These rates are measured in number of fish per million cubic meters (10^6m^3) and are used to represent C/f.

10.2.2.3 Collection Efficiency

Screen wash collections do not represent the actual numbers of fish killed by impingement (Con Ed 1977d). Collection efficiency can be affected by such factors as fixed-screen wash procedures, tidal stage at time of wash, air-bubbler operation, debris load on the screens and species composition.

To determine the portion of impinged fish not recovered during the collection process, collection efficiency tests, using marked dead fish, were conducted in 1974/1975 and in 1976 at Unit Nos. 2 and 3 respectively. Test methods and analyses for the 1974/1975 study period have been previously discussed (TI 1975b; 1976d). Tests conducted in 1974 indicated that the air curtain was the dominant factor affecting collection efficiency (TI 1975b). The air curtain was observed to have pushed some of the fish removed during fixed-screen washings back into the river, and based on visual observations, the air curtain may have actively removed fish from the fixed screens and carried them into the river. The mean recovery rate for the 1974 efficiency tests, with the air curtain operating, was 12%. The 1975 mean, with the air curtain operating, was 17%, ranging between 2 and 45%. Recovery rates, without the air curtain operating, were analyzed in 1974 and found to be significantly increased (TI 1975b).

Based upon the fact that air curtain operation decreases collection efficiency and does not significantly reduce fish impingement (TI 1975b), Con Edison has been relieved of its requirement to operate the curtain at Indian Point Unit Nos. 1 and 2.

Collection-efficiency tests conducted at Unit No. 3 during the first half of 1976 yielded a mean collection efficiency of 80%.

The greater efficiency at Unit No. 3 may have been due to the wash method that included only travelling screens, thus eliminating loss of fish which occurred during backwash of fixed screens at Unit No. 2 (Con Ed 1977d).

Although limited in nature, the collection efficiency data have been used to calculate scaling factors of 6.5 and 1.2 to adjust striped bass impingement counts at Unit Nos. 2 and 3 respectively (Con Ed 1977d). However, for purposes of this report, fish impingement counts, as discussed in the following section, remain uncorrected for fish loss during the collection process.

10.2.2.4 Results of Monitoring Program

Although the impingement rates of individual species may vary from year to year due to changes in fish distribution and abundances and/or variations in environmental or plant operational parameters, the data indicate strong seasonal impingement trends reflecting the life histories and migratory patterns of the collected species. Tables 10-9 through 10-13 indicate the total number of selected fish species collected and the total flow by month for all units from 1972-1976. These selected species refer to species occurring in Indian Point collections.

More than 90% of each year's total collection was comprised of the following six species: white perch, Atlantic tomcod, bay anchovy, blueback herring, striped bass and alewife. The young-

Table 10-9

Numbers of Selected Fish Species Collected from the Intake Screens and Volume of Water Circulated at Indian Point Station by Month during 1972

Month	June	July	August	September	October	November	December	Annual Total	Ann. % Comp.
Vol Circul. (10^6 m^3)	42.179	39.201	54.063	71.096	48.056	20.396	20.603	295.593	
				Total Number Collected*					
Species									
striped bass	9	51	474	399	425	140	96	1,594	1.72
white perch	337	287	1,579	2,015	12,215	5,218	2,609	24,260	26.21
Atlantic tomcod	4,372	207	5,447	29,642	8,422	82	123	48,295	52.18
blueback herring	1	5	-	39	1,382	138	8	1,573	1.70
alewife	29	6	859	444	183	8	7	1,536	1.66
bay anchovy	2	10	5,325	4,963	1,690	15	24	12,029	13.00
white catfish	4	6	3	5	27	158	100	303	.33
weakfish	-	-	4	416	351	-	-	771	.83
American shad	1	-	25	5	69	-	1	101	.11
spottail shiner	24	14	55	9	18	11	89	220	.24
banded killifish	-	4	4	-	-	-	3	11	.01
Atlantic sturgeon	2	12	10	4	6	-	-	34	.04
shortnosed sturgeon	1	1	2	-	-	-	-	4	< .01
Atlantic silverside	1	1	1	-	2	-	2	7	.01
bluefish	-	3	88	58	38	1	-	188	.20
								90,926	98.24

Total No. All Species Collected / Year = 92,559*

* Not corrected to account for loss of fish during collection process

Table 10-10

Numbers of Selected Fish Species Collected from the Intake Screens
and Volume of Water Circulated at Indian Point Station
by Month During 1973

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total	Annual % Comp.
Vol. Circul. ($10^6 m^3$)	3.012	13.912	47.089	25.059	34.184	50.623	67.130	82.318	47.840	54.601	15.369	9.641	450.777	
							Total Number Collected*							
Species														
striped bass	49	134	502	418	18	33	28	223	21	14	113	101	1,654	1.38
white perch	1,199	9,554	30,232	17,652	5,221	802	381	2,279	218	43	630	1,828	70,039	58.32
Atlantic tomcod	982	1,120	400	602	255	7,928	9,188	3,390	429	1	3	43	24,341	20.27
blueback herring	-	-	2	-	-	13	2	12	23	67	482	204	805	.67
alewife	-	-	7	-	14	39	368	581	51	67	58	12	1,197	1.00
bay anchovy	-	5	-	-	-	5	295	8,421	2,724	413	12	2	11,877	9.89
white catfish	24	47	288	885	395	42	4	1	-	2	7	25	1,720	1.43
weakfish	-	-	-	-	1	-	-	630	403	10	39	2	1,085	.90
American shad	-	1	2	2	1	-	6	-	1	-	4	1	18	.01
spottail shiner	69	39	364	281	22	17	3	13	16	1	-	60	885	.74
banded killifish	-	1	20	5	2	2	-	-	-	-	-	-	30	.02
Atlantic sturgeon	-	-	3	19	3	10	9	3	-	-	1	-	48	.04
shortnosed sturgeon	-	-	1	-	-	-	1	-	-	-	-	-	2	$<$ .01
Atlantic silverside	-	-	11	-	-	-	-	-	-	-	-	-	11	.01
bluefish	-	-	-	-	-	4	79	9	1	-	-	-	93	.08
													113,805	94.76

Total No. All Species Collected/ Year = 120,099*
* Not corrected to account for loss of fish during collection process

Table 10-11.

Numbers of Selected Fish Species Collected from Intake Screens
and Volume of Water Circulated at Indian Point Station
by Month during 1974

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total	Ann. % Comp.
Vol. Circul. (10^6 m^3)	19.568	38.756	54.053	90.651	112.307	181.781	159.839	172.045	168.572	146.631	81.528	68.323	1294.054	
						Total Number Collected*								
Species														
striped bass	453	490	382	746	951	346	401	701	546	354	297	591	6,258	.68
white perch	26,703	29,638	45,468	81,233	61,585	9,573	963	1,397	3,957	15,963	20,470	67,674	364,624	39.56
Atlantic tomcod	218	26	13	4	13,293	161,280	82,684	67,918	43,104	2,779	173	3,558	375,050	40.70
blueback herring	1	18	6	363	1,647	1,525	145	340	498	14,393	18,427	39	37,402	4.06
alewife	1	1	3	31	553	682	839	674	515	2,610	360	165	6,434	.70
bay anchovy	-	-	-	-	174	9,450	31,758	28,172	21,440	3,885	33	9	94,921	10.30
white catfish	30	36	63	422	1,742	279	26	12	14	278	519	699	4,120	.45
weakfish	-	-	-	-	-	-	49	805	463	33	10	1	1,361	.15
American shad	-	-	-	3	-	6	97	324	335	435	282	5	1,487	.16
spottail shiner	34	194	265	254	1,141	49	20	17	22	20	138	759	2,913	.32
banded killifish	-	-	1	-	6	-	-	-	2	22	40	17	88	.01
Atlantic sturgeon	5	2	2	17	31	18	33	9	4	4	5	4	134	.01
shortnosed sturgeon	-	-	-	-	1	1	-	2	-	-	-	-	4	< .01
Atlantic silverside	-	-	-	-	-	-	-	-	-	1	-	-	1	< .01
bluefish	-	-	-	1	-	2,583	1,544	358	111	6	-	-	4,603	.50
													899,400	97.60

Total No. All Species Collected/Year = 921,605*
* Not corrected to account for loss of fish during collection process

Table 10-12

Numbers of Selected Fish Species Collected from the Intake Screens
and Volume of Water Circulated at Indian Point Station
by Month during 1975

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total	Annual % Comp.
Vol. Circul. ($10^6 m^3$)	62.667	62.143	44.146	92.027	112.776	149.130	132.783	91.614	115.149	72.520	103.708	100.124	1138.787	
						Total Number Collected*								
Species														
striped bass	277	1,250	152	543	64	34	1,299	945	596	220	198	359	5,937	.86
white perch	34,267	40,242	19,299	78,776	13,099	1,955	1,818	13,496	11,054	7,152	26,901	42,915	290,947	42.31
Atlantic tomcod	980	714	75	107	722	29,054	15,314	12,505	16,818	283	333	1,605	78,510	11.41
blueback herring	10	41	12	259	276	171	1,299	1,004	656	47,308	91,232	10,273	152,541	22.18
alewife	9	85	9	17	83	373	2,353	136	184	179	715	89	4,232	.62
bay anchovy	1	3	1	-	10	1,611	24,914	38,347	23,368	7,675	2	27	95,959	13.95
white catfish	97	268	71	230	362	50	14	12	69	530	7,734	652	10,089	1.46
weakfish	-	-	-	-	-	-	-	5,173	3,781	-	-	-	8,954	1.30
American shad	6	7	1	1	-	-	461	63	186	222	189	10	1,146	.17
spottail shiner	416	931	347	898	76	8	14	12	15	82	448	681	3,928	.57
banded killifish	27	19	10	31	12	16	3	1	3	25	32	18	197	.03
Atlantic sturgeon	1	-	-	66	19	11	15	2	3	2	3	1	123	.02
shortnosed sturgeon	-	-	-	-	-	1	-	-	-	-	-	-	1	< .01
Atlantic silverside	-	-	-	-	-	-	-	-	30	-	-	-	30	< .01
bluefish	-	-	-	-	-	701	782	44	88	-	-	-	1,615	.23
													654,209	95.11

Total No. All Species Collected/ Year = 687,618*
* Not corrected to account for loss of fish during collection process

Table 10-13

Numbers of Selected Fish Species Collected from the Intake Screens
And Volume of Water Circulated at Indian Point
by Month during 1976

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total	Ann. % Comp.
Vol. Circul. (10^6 m^3)	67.892	70.831	80.438	14.154	72.829	92.249	90.647	90.314	99.159	202.906	101.500	108.367	1091.286	
							Total Number Collected*							
Species														
striped bass	1,811	116	98	27	92	41	70	233	540	1,989	535	485	6,037	.75
white perch	90,722	29,795	17,168	3,211	5,151	1,641	1,056	2,942	3,553	53,763	82,349	135,103	426,454	53.37
Atlantic tomcod	1,284	654	249	9	901	1,682	2,117	4,126	11,720	5,044	647	4,377	32,810	4.10
blueback herring	19	-	1	71	701	609	89	725	1,325	244,498	10,062	7	258,107	32.30
alewife	29	1	-	64	276	169	213	376	281	1,503	623	2	3,537	.44
bay anchovy	-	-	-	81	65	88	2,702	2,397	4,115	2,628	4	-	12,080	1.51
white catfish	493	109	70	244	528	222	27	48	22	8,818	6,797	1,107	18,485	2.31
weakfish	-	-	-	-	-	-	3	48	238	266	-	-	555	.07
American shad	1	-	1	-	4	17	171	299	353	3,161	203	3	4,213	.53
spottail shiner	1,017	501	480	146	176	28	24	18	11	117	175	2,067	4,760	.60
banded killfish	149	42	22	2	15	12	2	6	6	39	3	179	477	.06
Atlantic sturgeon	4	1	1	1	-	1	1	1	2	3	1	-	16	<.01
shortnosed sturgeon	-	1	-	-	-	-	-	-	-	-	-	-	1	<.01
Atlantic silverside	-	-	-	-	-	-	-	-	1	221	2	1	225	.03
bluefish	-	-	-	-	-	684	390	323	93	30	-	2	1,522	.19
													769,279	96.26

Total No. All Species Collected / Year = 799,015*
* Not corrected to account for loss of fish during collection process

of-the-year and yearlings of these species accounted for the majority of the fish collected.

Considering only the six species listed above, white perch, Atlantic tomcod and bay anchovy dominated the 1972-1974 collections, comprising 95%, 97% and 94% of the total collections of these species for 1972, 1973 and 1974, respectively. In 1975 and 1976, blueback herring accounted for 24% and 35% of the total collections of the six species respectively, reducing the percent represented by white perch, Atlantic tomcod and bay anchovy combined to 74% in 1975 and 64% in 1976.

While the annual percent composition of the remaining selected species varied among the years, at no time did the total percentage of these species represent more than a small fraction (highest combined percentage was 5.61% in 1973) of the total yearly collections.

10.2.3 Factors Affecting Impingement

Several biological, plant operational and environmental factors interact to affect the temporal variations in impingement magnitude and species composition. The following three sections discuss this interaction and the relationships between these factors and the incidence of impingement.

10.2.3.1 Biological Factors

The biological factors discussed here refer to seasonal changes in species distribution and abundance and the condition of impinged fish. Species distribution is a function of life history and response to environmental parameters. Susceptibility to impingement is determined, in part, by this distribution. Comparisons of impingement data with standard station c/f bottom trawl and beach seine data indicate that impingement rates correspond to changes in fish location associated with seasonal migration patterns. (TI 1974a; 1975a; 1976a; 1976c). As the fish move between the shoal and channel areas of the estuary, their response to the influence of the intakes is reflected in impingement collection variations.

Young-of-the-year white perch migrate downstream from the spawning areas and from the shoals to deeper water at an impingeable size in late fall. White perch impingement dominates the collections and reaches maximum levels in winter and spring when they are concentrated in the deeper channel areas. Impingement rates decline in the summer when the white perch tend to be located in the shoals.

Young-of-the-year striped bass have distribution and migration patterns similar to white perch, however, at no time do striped bass comprise more than a minor portion (<2%) of the total impingement collections.

Clupeids (blueback herring, alewife and American Shad) demonstrate downstream migration in late summer and fall after utilizing the river as a nursery area during the summer. This migration corresponds to the increased impingement rates of these species at that time.

Bay anchovy spawn in the lower estuary and migrate upstream during the summer. Peak impingement for this species occurs coincident with this migration.

Atlantic tomcod is the major species impinged during the summer months with young-of-the-year comprising a large portion of the collection. Upstream migration of spawning adults during the winter accounts for most of the Atlantic tomcod impingement at that time.

Fish condition is another factor that potentially affects impingement. Tests were conducted in 1972 and again in 1974 to compare the incidence of histopathological symptoms between impinged fish and seined river (control) fish. For indication of physical condition, all fish were examined for gill parasite infestation and pathological deterioration of the gill, spleen, liver and kidney.

Examination of the fish revealed that the incidence of histopathology was somewhat higher in impinged fish (95.7%) than in seined specimens (92.1%). Impinged fish also showed a higher incidence of gill parasites (TI 1975b).

Length/weight relationships for white perch, striped bass and Atlantic tomcod have been monitored as an additional indicator of fish condition. Specimens collected by beach seine and otter trawls at standard river stations were compared with samples collected from the intake screens. Results indicated that impinged fish usually weighed less at specific lengths than did standard station specimens (TI 1976d).

10.2.3.2 Plant Operational Factors

Plant operational factors that affect impingement are intake velocity and cooling water flow rate. Experience has indicated that approach velocities in excess of 1.0 fps result in increased impingement rates (TI 1974b). Daily screen washes prevent the accumulation of debris across the screens which could result in higher velocities. In addition, when river ambient temperature drops below 40F the cooling water intake system at Indian Point is operated at 60% of full capacity, reducing the approach velocity and subsequently the level of impingement. Tests performed in October and November 1971 yielded 76-94% reductions in impingement rates when the intake water flow was reduced to 60% of full flow (Con Ed 1976b).

10.2.3.3 Environmental Factors

Selected environmental and physicochemical variables (particularly conductivity, temperature and dissolved oxygen) have been monitored to determine possible relationships between these variables and peaks in impingement.

No consistent relationship between impingement rates and daily variations in temperature or dissolved oxygen has been detected. However, white perch impingement displays an inverse relationship with seasonal temperature trends, reflecting movement of the species between the shallow beach areas and the deeper channel.

In addition, low oxygen levels during the summer have been observed to coincide with juvenile Atlantic tomcod impingement, the species possibly being stressed by the combination of naturally occurring low summer oxygen levels and high ambient temperatures (TI 1976d). Only conductivity reveals a consistent relationship with peaks in impingement. Impingement rates are not directly related to the level of conductivity but rather to changes in conductivity caused by the movement of the salt front through the Indian Point region.

Salt front movement affects the impingement rates of various species in different ways. White perch impingement peaks can be expected subsequent to conductivity peaks as the salt front recedes from the Indian Point area during the fall, winter and early spring. Data from fishery collections indicate that white perch distribution is concentrated in the deeper channel during this time (TI 1974a). During summer, when the salt front fluctuates in the Indian Point region, white perch are concentrated in the shoal and beach areas, beyond the influence of the intake structures. The response of striped bass to changes in conductivity is similar to that of white perch, with impingement peaks occurring in association with salt intrusion peaks (TI 1974b). Atlantic tomcod impingement peaks can be expected when the salt front approaches or remains in the area of Indian Point. Adult tomcod peaks generally precede the winter incursion of the salt front while young-of-the-year peaks occur with the leading edge of the summer incursion.

Relationships between impingement peaks and conductivity peaks are further supported by increased C/f for white perch and Atlantic tomcod taken by standard station trawls and epibenthic sleds in the vicinity of the salt front (TI 1974a; 1975a; 1976a; 1976b). Recurrent coincidence between catch peaks of other species (blueback herring, alewife, American shad and bay anchovy) with the beginning or end of salt intrusion suggests movement of these species in response to conductivity (TI 1974a). The influence of conductivity on fish distribution in the Indian Point region and on impingement rates may be related to species preference for specific salinity ranges or to feeding habits in the vicinity of the salt front (TI 1976d).

10.2.3.3.1 <u>Predictive Models For Physical Variables</u>

Based on the relationship that has been demonstrated between major peaks in impingement, temperature and conductivity, mathematical models of changes in temperature and conductivity can be developed to predict the time of occurrence of impingement peaks (Con Ed 1977d). Two equations have been derived (see pp. 13.31 and 13.32, Con Edison 1977d); one to predict daily positions of the salt front and the other to describe the temporal change in temperature near Indian Point. Both equations provide very close predictions of actual variation in conductivity and temperature. While the timing of impingement peaks can be predicted, their magnitude cannot, because at this time a probability function to define weekly, seasonal, and annual variations in abundance and distribution of fish has not been developed.

10.2.4 Impingement Impact

Impact assessment to date has assumed 100% mortality of impinged fish. However, visual observations of fish collected from travelling screens, as well as preliminary survival experiments, indicate that fish can survive the impingement process and that survival rate is species-specific. In view of this survival, an assumption of 100% mortality for impinged fishes is a maximum estimate of the reduction in a population caused by impingement. The importance of fish impingement must be viewed in the light of numbers actually killed in relation to the size and resiliency of the natural population. The impact of impingement can be initially evaluated by quantifying the number of fish impinged and estimating the percent loss to the fish population. This percent loss can be put in perspective by being compared to losses resulting from other cropping factors. The impact of impingement on Hudson River striped bass and other fish species is analyzed elsewhere (Con Ed 1977d and Supplement I).

Conversion of Temperature Units (Fahrenheit/Centigrade)

Examples: +23°F = −5.00°C; 99.4°F = 37.44°C; 117°F = 47.22°C; 1210°F = 654.4°C

Fahrenheit – Centigrade

−59 to +79°F (1°F intervals)

	0	1	2	3	4	5	6	7	8	9
−50	−45.56	−46.11	−46.67	−47.22	−47.78	−48.33	−48.89	−49.44	−50.00	−50.56
−40	−40.00	−40.56	−41.11	−41.67	−42.22	−42.78	−43.33	−43.89	−44.44	−45.00
−30	−34.44	−35.00	−35.56	−36.11	−36.67	−37.22	−37.78	−38.33	−38.89	−39.44
−20	−28.89	−29.44	−30.00	−30.56	−31.11	−31.67	−32.22	−32.78	−33.33	−33.89
−10	−23.33	−23.89	−24.44	−25.00	−25.56	−26.11	−26.67	−27.22	−27.78	−28.33
−00	−17.78	−18.33	−18.89	−19.44	−20.00	−20.56	−21.11	−21.67	−22.22	−22.78
+00	−17.78	−17.22	−16.67	−16.11	−15.56	−15.00	−14.44	−13.89	−13.33	−12.78
10	−12.22	−11.67	−11.11	−10.56	−10.00	− 9.44	− 8.89	− 8.33	− 7.78	− 7.22
20	− 6.67	− 6.11	− 5.56	− 5.00	− 4.44	− 3.89	− 3.33	− 2.78	− 2.22	− 1.67
30	− 1.11	− 0.56	0.00	+0.56	+ 1.11	+ 1.67	+ 2.22	+ 2.78	+ 3.33	+ 3.89
40	+ 4.44	+ 5.00	+ 5.56	+ 6.11	+ 6.67	+ 7.22	+ 7.78	+ 8.33	+ 8.89	+ 9.44
50	+10.00	+10.56	+11.11	+11.67	+12.22	+12.78	+13.33	+13.89	+14.44	+15.00
60	+15.56	+16.11	+16.67	+17.22	+17.78	+18.33	+18.89	+19.44	+20.00	+20.56
70	+21.11	+21.67	+22.22	+22.78	+23.33	+23.89	+24.44	+25.00	+25.56	+26.11

80.0 to 109.9°F (1/10°F intervals)

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
80.	26.67	26.72	26.78	26.83	26.89	26.94	27.00	27.06	27.11	27.17
81.	27.22	27.28	27.33	27.39	27.44	27.50	27.56	27.61	27.67	27.72
82.	27.78	27.83	27.89	27.94	28.00	28.06	28.11	28.17	28.22	28.28
83.	28.33	28.39	28.44	28.50	28.56	28.61	28.67	28.72	28.78	28.83
84.	28.89	28.94	29.00	29.06	29.11	29.17	29.22	29.28	29.33	29.39
85.	29.44	29.50	29.56	29.61	29.67	29.72	29.78	29.83	29.89	29.94
86.	30.00	30.06	30.11	30.17	30.22	30.28	30.33	30.39	30.44	30.50
87.	30.56	30.61	30.67	30.72	30.78	30.83	30.89	30.94	31.00	31.06
88.	31.11	31.17	31.22	31.28	31.33	31.39	31.44	31.50	31.56	31.61
89.	31.67	31.72	31.78	31.83	31.89	31.94	32.00	32.06	32.11	32.17
90.	32.22	32.28	32.33	32.39	32.44	32.50	32.56	32.61	32.67	32.72
91.	32.78	32.83	32.89	32.94	33.00	33.06	33.11	33.17	33.22	33.28
92.	33.33	33.39	33.44	33.50	33.56	33.61	33.67	33.72	33.78	33.83
93.	33.89	33.94	34.00	34.06	34.11	34.17	34.22	34.28	34.33	34.39
94.	34.44	34.50	34.56	34.61	34.67	34.72	34.78	34.83	34.89	34.94
95.	35.00	35.06	35.11	35.17	35.22	35.28	35.33	35.39	35.44	35.50
96.	35.56	35.61	35.67	35.72	35.78	35.83	35.89	35.94	36.00	36.06
97.	36.11	36.17	36.22	36.28	36.33	36.39	36.44	36.50	36.56	36.61
98.	36.67	36.72	36.78	36.83	36.89	36.94	37.00	37.06	37.11	37.17
99.	37.22	37.28	37.33	37.39	37.44	37.50	37.56	37.61	37.67	37.72
100.	37.78	37.83	37.89	37.94	38.00	38.06	38.11	38.17	38.22	38.28
101.	38.33	38.39	38.44	38.50	38.56	38.61	38.67	38.72	38.78	38.83
102.	38.89	38.94	39.00	39.06	39.11	39.17	39.22	39.28	39.33	39.39
103.	39.44	39.50	39.56	39.61	39.67	39.72	39.78	39.83	39.89	39.94
104.	40.00	40.06	40.11	40.17	40.22	40.28	40.33	40.39	40.44	40.50
105.	40.56	40.61	40.67	40.72	40.78	40.83	40.89	40.94	41.00	41.06
106.	41.11	41.17	41.22	41.28	41.33	41.39	41.44	41.50	41.56	41.61
107.	41.67	41.72	41.78	41.83	41.89	41.94	42.00	42.06	42.11	42.17
108.	42.22	42.28	42.33	42.39	42.44	42.50	42.56	42.61	42.67	42.72
109.	42.78	42.83	42.89	42.94	43.00	43.06	43.11	43.17	43.22	43.28

110 to 299°F (1°F intervals)

	0	1	2	3	4	5	6	7	8	9
110	43.33	43.89	44.44	45.00	45.56	46.11	46.67	47.22	47.78	48.33
120	48.89	49.44	50.00	50.56	51.11	51.67	52.22	52.78	53.33	53.89
130	54.44	55.00	55.56	56.11	56.67	57.22	57.78	58.33	58.89	59.44
140	60.00	60.56	61.11	61.67	62.22	62.78	63.33	63.89	64.44	65.00
150	65.56	66.11	66.67	67.22	67.78	68.33	68.89	69.44	70.00	70.56
160	71.11	71.67	72.22	72.78	73.33	73.89	74.44	75.00	75.56	76.11
170	76.67	77.22	77.78	78.33	78.89	79.44	80.00	80.56	81.11	81.67
180	82.22	82.78	83.33	83.89	84.44	85.00	85.56	86.11	86.67	87.22
190	87.78	88.33	88.89	89.44	90.00	90.56	91.11	91.67	92.22	92.78
200	93.33	93.89	94.44	95.00	95.56	96.11	96.67	97.22	97.78	98.33
210	98.89	99.44	100.0	100.6	101.1	101.7	102.2	102.8	103.3	103.9
220	104.4	105.0	105.6	106.1	106.7	107.2	107.8	108.3	108.9	109.4
230	110.0	110.6	111.1	111.7	112.2	112.8	113.3	113.9	114.4	115.0
240	115.6	116.1	116.7	117.2	117.8	118.3	118.9	119.4	120.0	120.6
250	121.1	121.7	122.2	122.8	123.3	123.9	124.4	125.0	125.6	126.1
260	126.7	127.2	127.8	128.3	128.9	129.4	130.0	130.6	131.1	131.7
270	132.2	132.8	133.3	133.9	134.4	135.0	135.6	136.1	136.7	137.2
280	137.8	138.3	138.9	139.4	140.0	140.6	141.1	141.7	142.2	142.8
290	143.3	143.9	144.4	145.0	145.6	146.1	146.7	147.2	147.8	148.3

300 to 1890°F (10°F intervals)

	0	10	20	30	40	50	60	70	80	90
300	148.9	154.4	160.0	165.6	171.1	176.7	182.2	187.8	193.3	198.9
400	204.4	210.0	215.6	221.1	226.7	232.2	237.8	243.3	248.9	254.4
500	260.0	265.6	271.1	276.7	282.2	287.8	293.3	298.9	304.4	310.0
600	315.6	321.1	326.7	332.2	337.8	343.3	348.9	354.4	360.0	365.6
700	371.1	376.7	382.2	387.8	393.3	398.9	404.4	410.0	415.6	421.1
800	426.7	432.2	437.8	443.3	448.9	454.4	460.0	465.6	471.1	476.7
900	482.2	487.8	493.3	498.9	504.4	510.0	515.6	521.1	526.7	532.2
1000	537.8	543.3	548.9	554.4	560.0	565.6	571.1	576.7	582.2	587.8
1100	593.3	598.9	604.4	610.0	615.6	621.1	626.7	632.2	637.8	643.3
1200	648.9	654.4	660.0	665.6	671.1	676.7	682.2	687.8	693.3	698.9
1300	704.4	710.0	715.6	721.1	726.7	732.2	737.8	743.3	748.9	754.4
1400	760.0	765.6	771.1	776.7	782.2	787.8	793.3	798.9	804.4	810.0
1500	815.6	821.1	826.7	832.2	837.8	843.3	848.9	854.4	860.0	865.6
1600	871.1	876.7	882.2	887.8	893.3	898.9	904.4	910.0	915.6	921.1
1700	926.7	932.2	937.8	943.3	948.9	954.4	960.0	965.6	971.1	976.7
1800	982.2	987.8	993.3	998.9	1004	1010	1016	1021	1027	1032

Examples: −14°C = +6.8°F; 38.3°C = 100.9°F; 89°C = 192.2°F; 550°C = 1022°F

Centigrade – Fahrenheit

−59 to 0°C (1°C intervals)

	0	1	2	3	4	5	6	7	8	9
−50	−58.0	−59.8	−61.6	−63.4	−65.2	−67.0	−68.8	−70.6	−72.4	−74.2
−40	−40.0	−41.8	−43.6	−45.4	−47.2	−49.0	−50.8	−52.6	−54.4	−56.2
−30	−22.0	−23.8	−25.6	−27.4	−29.2	−31.0	−32.8	−34.6	−36.4	−38.2
−20	− 4.0	− 5.8	− 7.6	− 9.4	−11.2	−13.0	−14.8	−16.6	−18.4	−20.2
−10	+14.0	+12.2	+10.4	+ 8.6	+ 6.8	+ 5.0	+ 3.2	+ 1.4	− 0.4	− 2.2
−00	+32.0	+30.2	+28.4	+26.6	+24.8	+23.0	+21.2	+19.4	+17.6	+15.8

0 to 49.9°C (1/10°C intervals)

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
+0.	32.00	32.18	32.36	32.54	32.72	32.90	33.08	33.26	33.44	33.62
1.	33.80	33.98	34.16	34.34	34.52	34.70	34.88	35.06	35.24	35.42
2.	35.60	35.78	35.96	36.14	36.32	36.50	36.68	36.86	37.04	37.22
3.	37.40	37.58	37.76	37.94	38.12	38.30	38.48	38.66	38.84	39.02
4.	39.20	39.38	39.56	39.74	39.92	40.10	40.28	40.46	40.64	40.82
5.	41.00	41.18	41.36	41.54	41.72	41.90	42.08	42.26	42.44	42.62
6.	42.80	42.98	43.16	43.34	43.52	43.70	43.88	44.06	44.24	44.42
7.	44.60	44.78	44.96	45.14	45.32	45.50	45.68	45.86	46.04	46.22
8.	46.40	46.58	46.76	46.94	47.12	47.30	47.48	47.66	47.84	48.02
9.	48.20	48.38	48.56	48.74	48.92	49.10	49.28	49.46	49.64	49.82
10.	50.00	50.18	50.36	50.54	50.72	50.90	51.08	51.26	51.44	51.62
11.	51.80	51.98	52.16	52.34	52.52	52.70	52.88	53.06	53.24	53.42
12.	53.60	53.78	53.96	54.14	54.32	54.50	54.68	54.86	55.04	55.22
13.	55.40	55.58	55.76	55.94	56.12	56.30	56.48	56.66	56.84	57.02
14.	57.20	57.38	57.56	57.74	57.92	58.10	58.28	58.46	58.64	58.82
15.	59.00	59.18	59.36	59.54	59.72	59.90	60.08	60.26	60.44	60.62
16.	60.80	60.98	61.16	61.34	61.52	61.70	61.88	62.06	62.24	62.42
17.	62.60	62.78	62.96	63.14	63.32	63.50	63.68	63.86	64.04	64.22
18.	64.40	64.58	64.76	64.94	65.12	65.30	65.48	65.66	65.84	66.02
19.	66.20	66.38	66.56	66.74	66.92	67.10	67.28	67.46	67.64	67.82
20.	68.00	68.18	68.36	68.54	68.72	68.90	69.08	69.26	69.44	69.62
21.	69.80	69.98	70.16	70.34	70.52	70.70	70.88	71.06	71.24	71.42
22.	71.60	71.78	71.96	72.14	72.32	72.50	72.68	72.86	73.04	73.22
23.	73.40	73.58	73.76	73.94	74.12	74.30	74.48	74.66	74.84	75.02
24.	75.20	75.38	75.56	75.74	75.92	76.10	76.28	76.46	76.64	76.82
25.	77.00	77.18	77.36	77.54	77.72	77.90	78.08	78.26	78.44	78.62
26.	78.80	78.98	79.16	79.34	79.52	79.70	79.88	80.06	80.24	80.42
27.	80.60	80.78	80.96	81.14	81.32	81.50	81.68	81.86	82.04	82.22
28.	82.40	82.58	82.76	82.94	83.12	83.30	83.48	83.66	83.84	84.02
29.	84.20	84.38	84.56	84.74	84.92	85.10	85.28	85.46	85.64	85.82
30.	86.00	86.18	86.36	86.54	86.72	86.90	87.08	87.26	87.44	87.62
31.	87.80	87.98	88.16	88.34	88.52	88.70	88.88	89.06	89.24	89.42
32.	89.60	89.78	89.96	90.14	90.32	90.50	90.68	90.86	91.04	91.22
33.	91.40	91.58	91.76	91.94	92.12	92.30	92.48	92.66	92.84	93.02
34.	93.20	93.38	93.56	93.74	93.92	94.10	94.28	94.46	94.64	94.82
35.	95.00	95.18	95.36	95.54	95.72	95.90	96.08	96.26	96.44	96.62
36.	96.80	96.98	97.16	97.34	97.52	97.70	97.88	98.06	98.24	98.42
37.	98.60	98.78	98.96	99.14	99.32	99.50	99.68	99.86	100.0	100.2
38.	100.4	100.6	100.8	100.9	101.1	101.3	101.5	101.7	101.8	102.0
39.	102.2	102.4	102.6	102.7	102.9	103.1	103.3	103.5	103.6	103.8
40.	104.0	104.2	104.4	104.5	104.7	104.9	105.1	105.3	105.4	105.6
41.	105.8	106.0	106.2	106.3	106.5	106.7	106.9	107.1	107.2	107.4
42.	107.6	107.8	108.0	108.1	108.3	108.5	108.7	108.9	109.0	109.2
43.	109.4	109.6	109.8	109.9	110.1	110.3	110.5	110.7	110.8	111.0
44.	111.2	111.4	111.6	111.7	111.9	112.1	112.3	112.5	112.6	112.8
45.	113.0	113.2	113.4	113.5	113.7	113.9	114.1	114.3	114.4	114.6
46.	114.8	115.0	115.2	115.3	115.5	115.7	115.9	116.1	116.2	116.4
47.	116.6	116.8	117.0	117.1	117.3	117.5	117.7	117.9	118.0	118.2
48.	118.4	118.6	118.8	118.9	119.1	119.3	119.5	119.7	119.8	120.0
49.	120.2	120.4	120.6	120.7	120.9	121.1	121.3	121.5	121.6	121.8

50 to 199°C (1°C intervals)

	0	1	2	3	4	5	6	7	8	9
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2
100	212.0	213.8	215.6	217.4	219.2	221.0	222.8	224.6	226.4	228.2
110	230.0	231.8	233.6	235.4	237.2	239.0	240.8	242.6	244.4	246.2
120	248.0	249.8	251.6	253.4	255.2	257.0	258.8	260.6	262.4	264.2
130	266.0	267.8	269.6	271.4	273.2	275.0	276.8	278.6	280.4	282.2
140	284.0	285.8	287.6	289.4	291.2	293.0	294.8	296.6	298.4	300.2
150	302.0	303.8	305.6	307.4	309.2	311.0	312.8	314.6	316.4	318.2
160	320.0	321.8	323.6	325.4	327.2	329.0	330.8	332.6	334.4	336.2
170	338.0	339.8	341.6	343.4	345.2	347.0	348.8	350.6	352.4	354.2
180	356.0	357.8	359.6	361.4	363.2	365.0	366.8	368.6	370.4	372.2
190	374.0	375.8	377.6	379.4	381.2	383.0	384.8	386.6	388.4	390.2

100 to 990°C (10°C intervals)

	0	10	20	30	40	50	60	70	80	90
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814

SECTION 11

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