Institute of Environmental Medicine

HUDSON RIVER ECOSYSTEM STUDIES

Effects of Entrainment
by the Indian Point Power Plant
on Biota in the Hudson River Estuary

PROGRESS REPORT FOR 1975

for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
4 Irving Place
New York, New York 10003

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New York University Medical Center

New York, N.Y. 10016

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HUDSON RIVER ECOSYSTEM STUDIES

Effects of Entrainment by the Indian Point Power Plant on Biota in the Hudson River Estuary

Progress Report for 1975

Prepared by

NEW YORK UNIVERSITY MEDICAL CENTER
INSTITUTE OF ENVIRONMENTAL MEDICINE
LABORATORY FOR ENVIRONMENTAL STUDIES

for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
4 Irving Place
New York, New York 10003

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FOREWORD

The research reported herein is part of the larger program of studies of the Hudson River estuary ecosystem begun by Consolidated Edison Company of New York, Inc. (Con Edison) in June 1969 under the supervision of the Hudson River Policy Committee. The initial data-base survey was performed by the Raytheon Company, which identified life forms in the river, compiled quantitative data on abundances through 1970, and monitored basic river chemistry. Based on this information, Con Edison contracted for a broad research program that includes direct empirical/experimental evaluation of ecological effects of the Indian Point plant, as well as a mathematical-modeling approach.

Three major research organizations are involved in the overall study program: The New York University Medical Center Laboratory for Environmental Studies is investigating plant-operation effects on nonscreenable organisms; Texas Instruments Incorporated is studying plant-operation effects on screenable organisms; Lawler, Matusky and Skelly Engineers is responsible for the development and use of a mathematical model to predict entrainment and impingement effects on striped bass populations in light of present and future water use.

This progress report to Con Edison documents the results of research carried out by the New York University Medical Center Laboratory for Environmental Studies during 1975. In addition, it includes the results of some studies

not completed at the time of writing the 1974 Progress Report (New York University Medical Center, 1976a).

In 1975 the results of the New York University research program, and programs conducted by Lawler, Matusky and Skelly Engineers and Texas Instruments, Inc. have contributed significantly to the understanding of the impact of power plants on Hudson River biota and other aspects of the Hudson River ecosystem.

In August of 1975, for example, it was revealed by the State Department of Environmental Conservation that a number of fish species common to the lower Hudson estuary had become contaminated with polychlorinated biphenyls (PCB), a class of organo-chlorine compounds having wide industrial and domestic application. The data base generated by the ongoing Con Edison Hudson River Program was most useful by indirectly providing baseline data for evaluating PCB toxicity and population effects on fishes in the estuarine portions of the River. It is apparent that PCB's discharged to the river from industry, sewage treatment plants, sanitary landfills, etc., are not adversely affecting either the abundance or diversity of organisms in the river stretch from the Tappan Zee to Poughkeepsie (see recent and past reports; New York University Medical Center, 1974-1976a; Texas Instruments, 1973-1976; Lawler, Matusky and Skelly Engineers, 1974-1976; and Quirk, Lawler and Matusky Engineers, 1972-1973). Unfortunately, the PCB content of striped bass in the lower estuary was sufficiently high

to force a state restriction on commercial fishing for the species.

Mechanisms have been set up for cooperation and closer coordination among research organizations conducting studies at Indian Point and other power plants along the Hudson. There is an ongoing exchange of information which has resulted in an overall evaluation of entrainment effects on Hudson estuary biota based on the site-specific studies.

The report summary is organized according to the types of stresses encountered by entrained organisms. The body of the report, other than the introduction and the chapter on physical/chemical studies, is organized according to the major biological groups studied (e.g. phytoplankton, macrozooplankton, etc.). There is a chapter on each group, the first part of which is devoted to studies of river populations and the second to studies of entrainment effects conducted (1) in the laboratory and (2) in the plant intake and discharge canal and, occasionally, at other points in the plant's cooling water system and at other locations. The numbering of the chapter headings and major subheadings has been consistent throughout this series of progress reports, even though not all subjects were covered in each report.

The personnel who participated in the research program and the preparation of this report are listed below. The abbreviations in parentheses indicate graduate degree programs in progress.

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SUMMARY

This report summarizes the progress of studies conducted in 1975 to determine the effects on Hudson River organisms of pump entrainment and plume entrainment by the Indian Point nuclear power station. As in the three previous years of study, emphasis was placed on the potential effects of entrainment on organisms passing through the plant's condenser cooling system. Much of the information is also applicable to effects on organisms entrained in the discharge plume. Preliminary plume-entrainment studies were begun in 1974 and completed in 1975.

In 1975 the Indian Point station included two completed units (Unit 1 and Unit 2) and one unit under construction (Unit 3). Unit 1 was inoperative the entire year. Unit 2 was functional and operated at full rated capacity for most of the sampling season.

River population sampling for all planktonic forms was carried out in 1975 as in 1971 through 1974. Comparisons of abundance and physiology of river populations were limited to the years 1971, 1972, 1974 and 1975 because during the 1973 sampling season, Units 1 and 2 were off-line much of the time. The basic sampling program was modified to focus on spatial and temporal distribution of organisms entrained in the plant intakes. The analysis of 1973 ichthyoplankton data has been completed and is summarized in an addendum (New York University Medical Center, 1976d).

Laboratory thermal tolerance studies in 1975 were done on phytoplankton, microzooplankton, and macrozooplankton. Studies were carried out in the intake and discharge canal at Indian Point, to measure the effects of entrainment on phytoplankton, microzooplankton, macrozooplankton and ichthyoplankton.

The 1975 studies were critical to the entrainment study program for two main reasons: 1) Sufficient definitive results were unobtainable until 1974 because of a conflict between plant operating schedules and the year-to-year variation in the timing of spawning. With the plant operating in 1975, a second year of study at rated plant capacity for a data base was possible. 2) 1975 was the culmination of five year's effort to determine if the operation of the Indian Point power plant adversely affected the Hudson River biota.

Unit 2, which operated at full capacity for all of 1975, produced ΔT's near the design level for full power operation and thus enabled critical testing of hypotheses based upon laboratory simulation of full-rated operation of the Indian Point complex.

In 1974, plume entrainment studies at Indian Point were begun and provided preliminary data as to the impact of the discharge flow on planktonic organisms in the river. Plume studies were conducted on phytoplankton, microzooplankton,

macrozooplankton and ichthyoplankton. This study was completed in 1975 and the results are presented separately (New York University Medical Center, 1976b).

In-plant entrainment studies conducted in 1975 followed the modification in sampling procedure developed in 1974: the attachment of conical velocity-reduction devices on 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.

POPULATION STUDIES

The river biota population studies conducted in 1975 were designed to: (1) measure the temporal and spatial distribution of species susceptible to entrainment by the Indian Point facility; and (2) determine whether observed damage to entrained organisms adversely affected populations of those organisms in the river. The results of population studies completed in previous years are presented in our preceding progress reports.

Phytoplankton River Populations

Studies conducted in 1975 utilized whole-water samples exclusively. Phytoplankton abundances observed in 1975 were similar to those observed in 1974 with maximum abundances

occurring in late spring and early summer. Community structure in 1975 followed a pattern similar to that observed in 1972 to 1974; diatoms and green algae were the dominant groups. Diatom peaks were seen in late April and July, in each case making up to 85% of the population. The seasonal succession of algal groups and the relative timing of their appearance in phytoplankton samples were similar during the years 1972, 1974 and 1975. However, peak numbers for 1975 occurred earlier than in 1974 (May and October, 1975, versus June-July and October-November, 1974). This may be attributed partially to the warmer ambient spring river temperatures in 1975. It was not a result of plant operation and associated thermal inputs. Concentrations of total phytoplankton changed seasonally in a similar manner at all stations. Corresponding observations of phytoplankton abundance at the Indian Point plant intake did not differ from river samples.

Supplemental measurements for chlorophyll a content in phytoplankton and sub-surface light measurements were taken in the Indian Point vicinity from May through December, 1975. Chlorophyll a, used herein as an estimate of phytoplankton standing stock correlated well with total phytoplankton abundance by season and by station. There was no correlation of chlorophyll a with any measured physical (light intensity, temperature) or chemical (dissolved oxygen, pH, salinity) parameters on a yearly basis.

Microzooplankton River Populations

River microzooplankton populations were dominated in 1975 by crustaceans (Phylum Arthropoda), rotifers (Phylum Rotatoria) and protozoans (Phylum Protozoa). The most abundant species were the estuarine copepods Eurytemora affinis and Acartia tonsa. Subdominant species occurring in the study area were the cyclopoid copepods Diacyclops bicuspidatus and Halicyclops fosteri, the cladocerans Bosmina longirostris and Diaphanosoma brachyurum, the rotifers Nothalca accuminata and Keratella cochlearis and shelled amoebae of the genera Centropyxis and Difflugia.

Comparisons of the microzooplankton species observed revealed similarity of species from 1971 through 1975. The most frequently occurring copepods and cladocerans (A. tonsa, E. affinis, B. longirostris and D. brachyurum) were identical for all years. Two protozoa, Centropyxis sp. and Difflugia sp. were the dominant species throughout the sampling periods. In 1971 the most common rotifer was Brachionus angularis; however, in 1974 and 1975 the predominant rotifer was N. accuminata.

The abundance of dominant and subdominant forms, as well as less common species, varied significantly with season and was correlated with the seasonal progression of temperature in the river and varying salinity at the Indian Point plant site. The microzooplankton community was composed

exclusively of estuarine and euryhaline freshwater forms, with the species inventory for any sampling date reflecting the typical microzooplankton successional phenomenon characteristic of Atlantic coastal estuaries.

River microzooplankton populations were most abundant in the spring and summer months, reaching concentrations of more than 200 organisms per liter late in May. Copepods accounted for the majority of microzooplankton collected throughout the year and reflected, in general, microzooplankton abundance in the Hudson.

Daytime abundance of total microzooplankton was similar at all stations, although in three instances, differences among stations at night were observed: 1) B. longirostris was more abundant at station D than at station G; 2) Crustacea distribution data indicated a station effect, but specific differences could not be detected; and 3) total microzooplankton distribution data indicated a station effect, but specific differences could not be detected.

Based upon the abundance of species and total numbers, as well as seasonal distribution patterns from 1971-1975, microzooplankton in the river have not been affected by the operation of the Indian Point station.

Macrozooplankton River Populations

A total of 28 macroinvertebrate groups were identified from 1975 samples, three more than were observed in 1974,

five more than in 1972, and seven more than in 1971. In all five years macrozooplankton samples were dominated by three taxa, Gammarus spp. (mostly G. daiberi), Monoculodes edwardsi and Neomysis americana. These forms accounted for 71% of the total macrozooplankton collected during the daylight hours, and 63% of the total nighttime catch. Because there was a greater abundance of some forms collected in 1971-72 and because of increased numbers of species collected in the study area in 1974 and 1975, the proportional representation of Gammarus, Monoculodes and Neomysis in 1974 and 1975 samples is less than that observed in 1971 (87%) and 1972 (97%).

The seasonal occurrences of N. americana at Indian Point were found to coincide with salinity pulses in the river. The occurrence of other species, including M. edwardsi also appears related to the salinity of the river water. Several other taxa, (e.g., Gammarus spp.) were present through nearly all of the sampling season. However, Gammarus was most abundant when the water was fresh or nearly so. This pattern of seasonal occurrence for various of the macroinvertebrates has been observed throughout the study and constitutes an aspect of Hudson River ecology critical to the understanding of system function in the vicinity of Indian Point. Basically, it may be stated that discrete epibenthic species having similar roles in the

macrozooplankton community do not overlap extensively in salt preference or tolerance, and replace one another as hydrologic factors related to salt intrusion vary at specific locations.

Total abundances of macrozooplankton were highest in late summer and occurred in lower numbers in mid to late fall. Macrozooplankton abundances in 1975 were much greater at night than during the day and much greater toward the bottom than near the surface. This confirms the patterns observed in 1971 through 1974. The stations (A and G) where macrozooplankton abundances differed significantly from other stations in 1975 were not exactly the same as those that were different in 1971 (B, G, F), in 1972 (A, D) or in 1974 (A, B, C, E). On the basis of four years of study, operation of the Indian Point plant appears to have little effect on the distribution and abundance of river macrozooplankton.

Ichthyoplankton River Populations

Of the more than 50 species of fish known to occur in the mid-portion of the Hudson River--i.e., from the Tappan Zee Bridge to Cementon--life stages of 21 species were found in the 1975 ichthyoplankton collections. Of these 21 species, 16 have been collected each year from 1971 to the present. The species composition of the ichthyoplankton was similar to that found in 1971, 1972, 1973 and 1974.

Seasonal comparisons of abundance show that the life stages of the bay anchovy (Anchoa mitchilli) are the most abundant. They were followed, in descending order, by life stages of the striped bass (Morone saxatilis); white perch (M. americana) and clupeids of the Alosa spp. complex. Further, the results show that the seasonal occurrence for the various species appear to be dependent upon temperature and water salinity rather than calendar date.

Abundance of striped bass life-history stages from river samples was compared to the abundance in the power plant. With the exception of eggs, the abundances of the various life stages collected at night at the plant and in the river per 1000 m^3 of water are generally consistent. Only night comparisons are discussed here because samples at the plant were collected at night only.

PHYSICAL-CHEMICAL DATA

Physical-chemical data from 1972 to 1975 were analyzed and compared to identify trends of change in various parameters throughout the study period. Mean air temperatures in 1975 were measurably higher than in 1974, but were similar to those in 1973. Water temperature and dissolved oxygen profiles were generally similar for 1972, 1974 and 1975. Maximum mean water temperature recorded in 1972 of 26.3 C (79.3 F) was slightly less than the 26.8 C (80.2 F) recorded

in 1974. Values for 1973 to 1975 were greater than those recorded in 1972.

Secchi disc readings, used as an index of water clarity were not substantially different from those recorded in 1972, varying without trend from 0.9 to 3.9 ft. No secchi disc readings were taken in 1971 or 1973. The 1975 salinity profile followed a trend similar to that recorded in previous years; salinity was highest in mid-to late summer, and generally occurred as pulses rather than as a gradual increase. Major differences in the salinity profiles from 1971 to 1975 appear to be the time of earliest salt intrusion at Indian Point and the magnitude of salinity intrusion. Measurements of pH in the Indian Point vicinity ranged from 7.2 to 7.6, which was the same range observed in previous years' data.

IN-PLANT STUDIES

Acclimation temperature, exposure time, ΔT, and life-history stage all affected the temperature tolerance of the entrainable organisms studied. During full-flow operation, organisms will be exposed for as long as 33.3 minutes at a ΔT of 9.1 C (16.4 F). Under reduced-flow conditions, exposure times and ΔT's will range from 55.5 minutes and 11.6 C (20.9 F) to 9.8 minutes and 15.1 C (27.2 F). Reduced-flow operations are projected to occur between November and March of each year, which is a period of minimum entrainment.

Ambient water temperatures during this time of year are generally less than 10 C (18 F).

Phytoplankton

Laboratory thermal tolerance and intake-discharge canal studies of the phytoplankton community in the Indian Point vicinity were continued in 1975. Representative phytoplankton assemblages were collected from the river, intake canal, or discharge canal in the presence and absence of a plant ΔT and incubated in the laboratory during each study period. Carbon-14 uptake rates were measured on a monthly schedule from January through December, 1974, to provide physiological information on the thermal tolerance of the algal communities present during each time interval. Chlorophyll *a* measurements were taken to provide corollary information on the potential for photosynthetic activity within the algal community. Communities were also examined for delayed effects upon ^{14}C uptake and chlorophyll *a* content at 4 and 24 hours after thermal exposure.

The response of the phytoplankton community to plant passage and to controlled thermal shock in the laboratory appeared to be a function of the river ambient temperature and the community present as well as a specific response to some threshold maximum temperature. In-plant studies and laboratory thermal tolerance experiments conducted since

1972 revealed a range of thermal effects (from no effect to stimulation and inhibition) for short exposures to varying ΔT's and are listed below:

1. ΔT above 10 C and final temperature above 33 C... inhibition.
2. ΔT above 10 C and final temperature below 33 C... no effect.
3. ΔT below 10 C and final temperature near 22 C... stimulation.

These generalizations do not consider the specific composition of the algal population, the physiological state of the algal samples when they are collected, the availability of nutrients in the enclosed sample during the study period, or the presence or absence of soluble chemical inhibitors during the time of the tests. It is understood that there will be varying degrees of response depending on the composition of the population at the time of testing.

Results obtained in plant studies and laboratory simulations suggest that any impact on phytoplankton due to entrainment would be primarily thermal effects, since essentially the same responses of phytoplankton to thermal shock are obtained in plant and laboratory studies.

Microzooplankton

Microzooplankton collections at the Indian Point intake and discharge stations included essentially the same species as were collected in previous years. Copepods were the most abundant forms; the four major species were E. affinis, A. tonsa, D. bicuspidatus and H. fosteri. No significant differences in microzooplankton abundance occurred among stations or sampling periods.

The survival of cyclopoid and harpacticoid copepods as well as cladocerans were unaffected by entrainment; greater than 85% of these organisms were captured alive at all stations. In 1975 as in 1974 (New York University Medical Center, 1976a), calanoid copepods (E. affinis and A. tonsa) were more sensitive, generally showing survival of 14 to 85% in the discharge canal samples.

Our studies from 1972-1975 showed that there was little to no effect of plant entrainment on the viability of certain microzooplankton species. There appeared to be some damage to the copepod E. affinis if the final temperature (ambient water temperature + ΔT) during plant passage rose above 26.7 C (80 F). However, this condition would be prevalent during mid-summer only, and would be minimal at other times of the year.

Macrozooplankton

The results of viability assessments based on intake and discharge canal samples of some of the dominant macroinvertebrate species (Gammarus, Monoculodes, Leptocheirus, Chaoborus) showed that at the rated ΔT for Unit 2 of 8.3 C (14.9 F) and an ambient water temperature of 20 to 25 C (68-77 F), entrainment into the cooling water flow of the Indian Point plant had little or no effect on survival.

On the other hand, Neomysis americana exposed to similar conditions suffered mortalities upwards of 40%; this is down from 90% in 1974. The impact of this on the Neomysis population in the river is not known. This may be minimal, as the occurrence of Neomysis at Indian Point is irregular. Neomysis is abundant in the vicinity of Indian Point during intervals when salt concentrations exceed 1 o/oo.

Supplementary thermal tolerance experiments with Gammarus spp. conducted in 1974 and 1975 showed that adult females were able to tolerate 30-minute laboratory exposures to a ΔT of 11 C (19.8 F) at an ambient water temperature of 26 C (78.8 F). However, similar exposures of eggs and/or young contained in the marsupium of the females resulted in almost total mortality of the eggs and/or young with a significant reduction of young released. The importance of these data for assessing plant impact on river populations of macrozooplankton is not yet known. However, river population studies

executed between 1971 and 1975 show no measurable impact on macrozooplankton populations.

Ichthyoplankton

Ichthyoplankton studies conducted in 1974 and 1975 did not include laboratory studies of thermal tolerance. Thus, estimates of ichthyoplankton viability and latent mortality reflect the synergistic effects of thermal and/or chemical effects with pressure, velocity shear, and mechanical damage.

Intake and discharge canal data on short-term ichthyoplankton viability were compared by calculating the differences between the mean percentages of live, stunned or dead organisms at the intake and discharge stations. The results showed that for all life stages of striped bass, the proportion dead increased with distance downstream in the cooling-water flow from intake stations through discharge station D-2. This indicated that the time/temperature exposure of life stages of striped bass at the Indian Point plant was cumulative and that the additional time of exposure to warm water between station D-1 and D-2 increased the probability of death. No samples were collected from the discharge port stations (DP-3 and DP-8).

Assuming that the difference in the numbers of dead or stunned individuals between the discharge canal and the intake stations was caused by plant passage, and that those

dead or stunned at the intakes were the result of natural mortality and collection trauma, then the plant entrainment effects are less than 50% for all striped bass life stages examined (see New York University Medical Center Report, 1976c, on the effects of sampling gear on ichthyoplankton mortality).

Living striped bass eggs and live and stunned striped bass yolk-sac larvae and larvae from intake and discharge samples were tested for latent mortality to determine if entrainment in the cooling-water flow at Indian Point had significant effects on survival three days after exposure. It was found that striped bass ichthyoplankton which survived plant passage (live or stunned) showed substantial mortality (ranging from 50% to 100% over the 72-hours following plant passage). However, O'Connor and Schaffer (1977) have demonstrated that, in a test flume with velocities similar to the intake and discharge at Indian Point, sampling gear alone may account for the majority of latent mortality, especially when collection velocities exceed 1.5 feet per second.

1. INTRODUCTION

The objective of this research program is to determine the effects of entrainment by the Indian Point power plant on Hudson River biota.

The operation of steam electric power plants involves two types of organism entrainment, pumped entrainment and plume entrainment. In pumped entrainment, the organisms are suspended in water that is pumped through the cooling system of a power plant. Only organisms small enough to pass through the intake screens (3/8 inch square mesh) are subject to pumped entrainment. In plume entrainment, organisms are brought into contact with the cooling-water discharge plume by turbulent mixing of the discharge and the receiving water.

During the first 3 years (1971-1973) of the scheduled 5-year study program research had concentrated on the effects of pump entrainment, although much of the information obtained was relevant to plume entrainment. Preliminary studies of plume entrainment were begun in the fourth year (1974), and completed in 1975.

Pump-entrained organisms are exposed to potential stresses that include: abrupt changes in temperature and pressure; mechanical buffeting and velocity-induced shear forces; and the introduction of chemicals into the cooling water system. Plume-entrained organisms are exposed to elevated temperature, discharged chemical residuals, and

velocity-induced shear; these potential stresses are reduced as dilution progresses. The stresses imposed on organisms entrained in the Indian Point power plant cooling water system are described in detail on the following pages.

1.1 ORGANISMS SUBJECT TO ENTRAINMENT

The groups of organisms potentially subject to entrainment by the Indian Point power plant include suspended bacteria, phytoplankton, zooplankton, and the planktonic eggs and larvae of invertebrates and fish. These groups differ greatly with respect to abundance, reproductive processes, generation time, trophic or food-chain function, and other life processes.

Bacteria play an indispensable role in the aquatic ecosystem. They are the decomposers that break down the litter and wastes produced by other living organisms (including man) into their mineral components. These components then become fertilizer for a new cycle of plant growth.

Planktonic algae, or phytoplankton, use energy from the sun to convert carbon dioxide, mineral nutrients and water into organic matter (including more algal cells) that contribute to the food supply for the other trophic levels in the ecosystem. For this reason, the phytoplankton are often referred to as the primary producers.

The consumers are the zooplankton, which include a variety of species of small animals which, during most of

their existence, remain suspended or swim feebly in the water column. Zooplankton "graze" on phytoplankton, bacteria, other zooplankton, and detritus. They, in turn, are eaten by larger invertebrates and fish. Zooplankton also include a "non-consuming" segment comprised of eggs and various life stages of the consumer group which do not feed actively.

The zooplankton may be divided into two groups based upon their life-history and the proportion of time they are truly planktonic. The first group, the holoplankton or euplankton are forms which remain planktonic throughout their entire life-history (e.g. copepods, many species of rotifers, cladocerans etc.). The meroplankton are organisms which spend only a portion of their lives suspended or swimming in the water column. They may be epibenthic organisms, such as Neomysis, which undertake diurnal vertical migrations into the water column, or organisms which, like many fishes, polychaete worms, and bivalves, may spend their egg and larvae stages in the plankton community.

The planktonic life stages of fish are collectively referred to as ichthyoplankton. They include eggs, yolk-sac larvae, larvae, and young up to about 30 mm long. (Although not actually planktonic forms, young fish up to 30 mm long have been included in our ichthyoplankton studies since they are of entrainable size and are captured in the plankton nets.) The probability of their being entrained is related to the reproductive and developmental strategies of the

species in question. The eggs of such species as striped bass (Morone saxatilis), which depend on a planktonic mode for their development, are far more subject to entrainment than demersal (non-buoyant) eggs (e.g. white perch, M. americana) or the eggs of nest-building species such as the centrarchids.

The spatial distribution of these potentially entrainable organisms is notably uneven. Distributions are clumped and are subject to change on diel, seasonal, and yearly cycles. Life stages critical to population maintenance may be subject to entrainment only for short periods of the year, periods that may or may not coincide with operating conditions that would cause substantial damage to that life stage. This is true for striped bass eggs and various life stages of other species that move with the salt front. Actual liability to entrainment may vary considerably from one life stage to another, at different ages within a life stage, or among species, depending on location in the river and the water column relative to the cooling-water intake and the discharge plume.

1.2 THE INDIAN POINT FACILITY

The Indian Point facility consists of three nuclear-fueled electric generating units with a combined capacity of 2103 MW_e. All three units are designed to use Hudson River water for once-through condenser cooling. Unit 1, initially

placed in operation in October 1962, uses 318,000 gallons of water per minute (gpm) at maximum flow (708 cfs); Unit 2, which went operational in 1974, and Unit 3, which went operational in 1976, will require 870,000 gpm, each, at full flow, bringing the total maximum operational demand of the station to 2,058,000 gpm or 4,586 cubic feet per second (cfs). This maximum demand exceeds the freshwater flow rate of the river during drought conditions, and is about 1.5 to 1.8% of the maximum tidal flow at Indian Point (250,000 to 300,000 cfs).

Each of the three units has a separate shoreline intake structure for withdrawal of water from the Hudson River (Figure 1-1). There are four rectangular intake openings at Unit 1 and six each at Units 2 and 3. The openings extend 26 feet (7.9 m) below mean sea level (MSL) at Unit 1 and 27 feet (8.2 m) below MSL at Units 2 and 3. The approximate relationship of the intake openings to the river cross-section at Indian Point is shown in Figure 1-2. The water from all three units flows through a single discharge canal, and is returned to the river through a series of submerged discharge ports in a 250-foot (76.2 m) length of the canal wall near the downstream end of the canal (Figure 1-1).

1.2.1 Passage Times

The total time required for water to pass from the intakes through a given unit, and then through the discharge

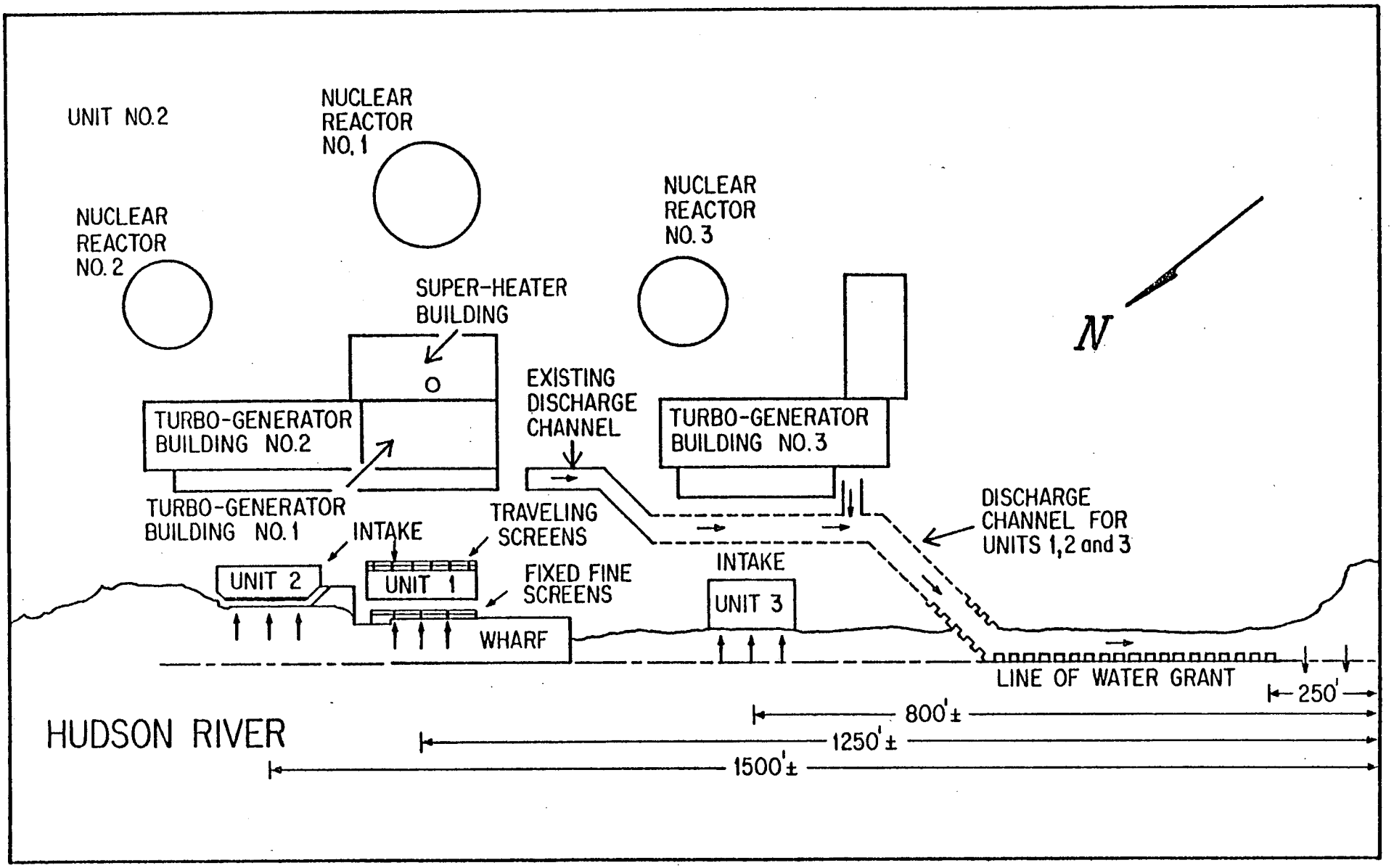

Figure 1-1. Schematic diagram of Indian Point nuclear generating facility.

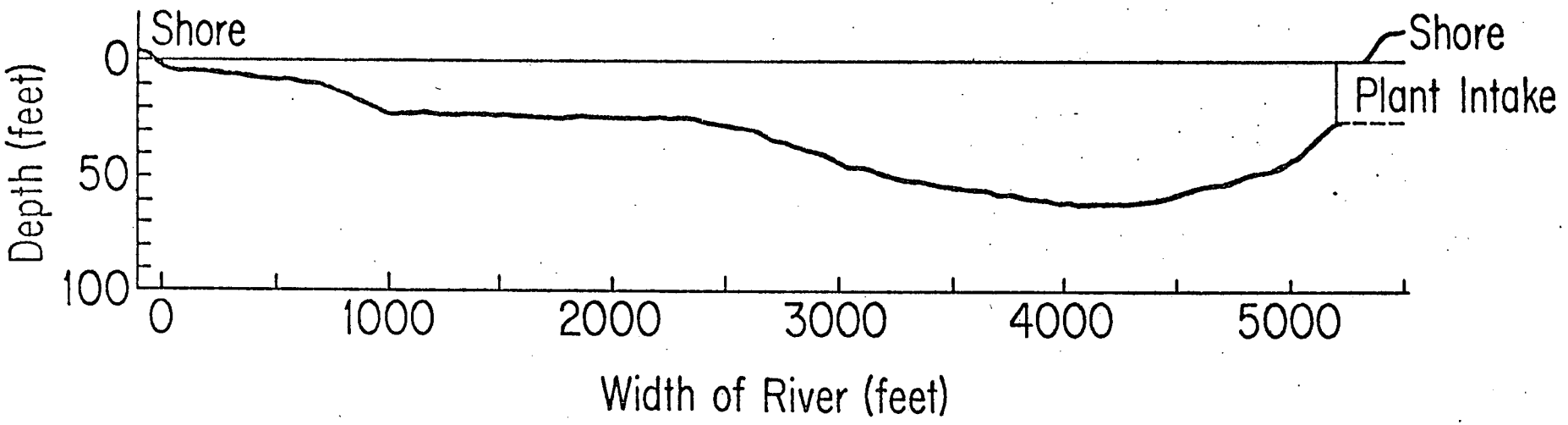

Figure 1-2. Cross section of Hudson River at Indian Point plant intake. For clarity, vertical scale has been expanded by a ratio of 10:1. Data from U.S. Geological Survey Peekskill (N.Y.) Quadrangle, 1957.

canal to the discharge ports depends on the individual and combined operational flow rates of the three units (Table 1-1). At full flow, the total time for passage is estimated to range from a minimum of 5.9 minutes for Unit 3, during simultaneous operation of all three units, up to 33.3 minutes for Unit 1 operating alone.

Consolidated Edison plans to operate the facility at a reduced flow rate (at 60% of design flow) from approximately November through March of each year to reduce intake flow velocities and impingement of fish on intake trash screens. This reduced-flow operation increases the calculated passage times (Table 1-1).

The actual passage times for the more motile species of organisms pumped through the Indian Point plant may differ from the calculated values due to the behavior of the organisms while in the cooling water systems. As the velocity of flow through the discharge canal is increased by multi-unit operation, the effect of organism behavior on passage time is likely to be reduced.

The exposure times of organisms entrained in the cooling-water plume at Indian Point, from entrainment until they reach near-ambient river water conditions (i.e. ambient plus 4 F (2.2 C) isotherm), are not precisely known but are not expected to exceed a few hours. The time for passage of plankton organisms through the plume would vary depending on where the organisms enter the plume, the flow-velocity

Table 1-1. Average transit times and ΔT for cooling water during full and reduced-flow (60%) operation of Indian Point Units 1, 2, and 3 operating individually and simultaneously

	Individual operation			Simultaneous operation			
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3	Mean
Full flow:							
Time (minutes):							
Intake to condenser	1.16	1.52	1.52	1.16	1.52	1.52	1.51
Condenser transit	0.08	0.14	0.14	0.08	0.14	0.14	0.13
Condenser to effluent	32.08	13.52	7.05	6.12	7.90	4.25	6.07
Total transit time	33.32	15.17	8.71	7.36	9.55	5.91	7.71
Temperature rise (^{o}F):							
Condenser	12.6^{o}	14.9^{o}	16.3^{o}	12.6^{o}	14.9^{o}	16.3^{o}	15.1^{o}
Condenser & service water	12.0^{o}	14.6^{o}	16.0^{o}				14.8^{o}
Reduced flow:							
Time (minutes):							
Intake to condenser	1.93	2.53	2.53	1.93	2.53	2.53	2.52
Condenser transit	0.14	0.23	0.23	0.14	0.23	0.23	0.22
Condenser to effluent	53.47	22.53	11.75	10.18	13.17	7.08	10.12
Total transit time	55.54	25.30	14.52	12.25	15.93	9.84	12.86
Temperature rise (^{o}F):							
Condenser rise	21.0^{o}	24.8^{o}	27.1^{o}	21.0^{o}	24.8^{o}	27.1^{o}	25.2^{o}
Condenser & service water	18.6^{o}	23.8^{o}	26.5^{o}				23.8^{o}

component moving them through the plume, and the distance traversed through the plume.

1.2.2 Temperature Exposure

The temperature rise (ΔT) encountered by organisms passing through the Indian Point plant depends on the cooling-water flow rates and levels of power output. At full flow and 100% of rated generating capacity, the design ΔT across the condensers is 12.6 F for Unit 1, 14.9 F for Unit 2, 16.3 F for Unit 3, and 15.1 F for the combination of all three units (Table 1-1). The amount of time organisms will be exposed to these maximum temperature elevations depends on which unit withdraws the organisms from the river, and on the individual and combined flow rates of water through the units. Very little temperature reduction occurs as the water passes from the condensers to the discharge ports, except when the units are operating at substantially unequal ΔT's (New York University Medical Center, 1974, 1976a). Under such circumstances the higher-ΔT output will be diluted by the lower during passage down the discharge canal. Calculated exposure times (i.e. from the condenser to the discharge ports) for full-flow operation range from 4.25 minutes for Unit 3, during simultaneous operation of all three units, to 32.08 minutes for Unit 1 operating alone (Table 1-1).

The ΔT encountered by pump-entrained organisms increases in the winter, when cooling water circulation is reduced to 60% of full flow. The maximum temperature rise at 60% design flow is expected to range from 21.0 to 27.1 F. Calculated exposure times also increase with the reduced flows. The relationships of ΔT to calculated exposure time for individual and combined-unit operation at 60% flow are given in Table 1-1.

The maximum possible time/temperature combinations encountered by organisms during passage through the Indian Point facility are shown diagramatically in Figure 1-3. Figure 1-4 shows the mean maximum temperatures expected throughout the year at Indian Point. These were obtained by adding the maximum temperature rise projected to occur at rated-capacity operation to the mean river-water temperatures recorded by the U.S. Geological Survey at Peekskill from 1959 to 1969. Maximum temperatures in the condensers will exceed those shown in Figure 1-4 when the intake water temperature exceeds the mean values plotted.

1.2.3 Pressure Exposure

Organisms pumped through the Indian Point facility are exposed to rapid increases and decreases in hydrostatic pressure. The degree and rate of such pressure changes depend on the location of the organism in the water column prior to being drawn into the pumps, the design and height

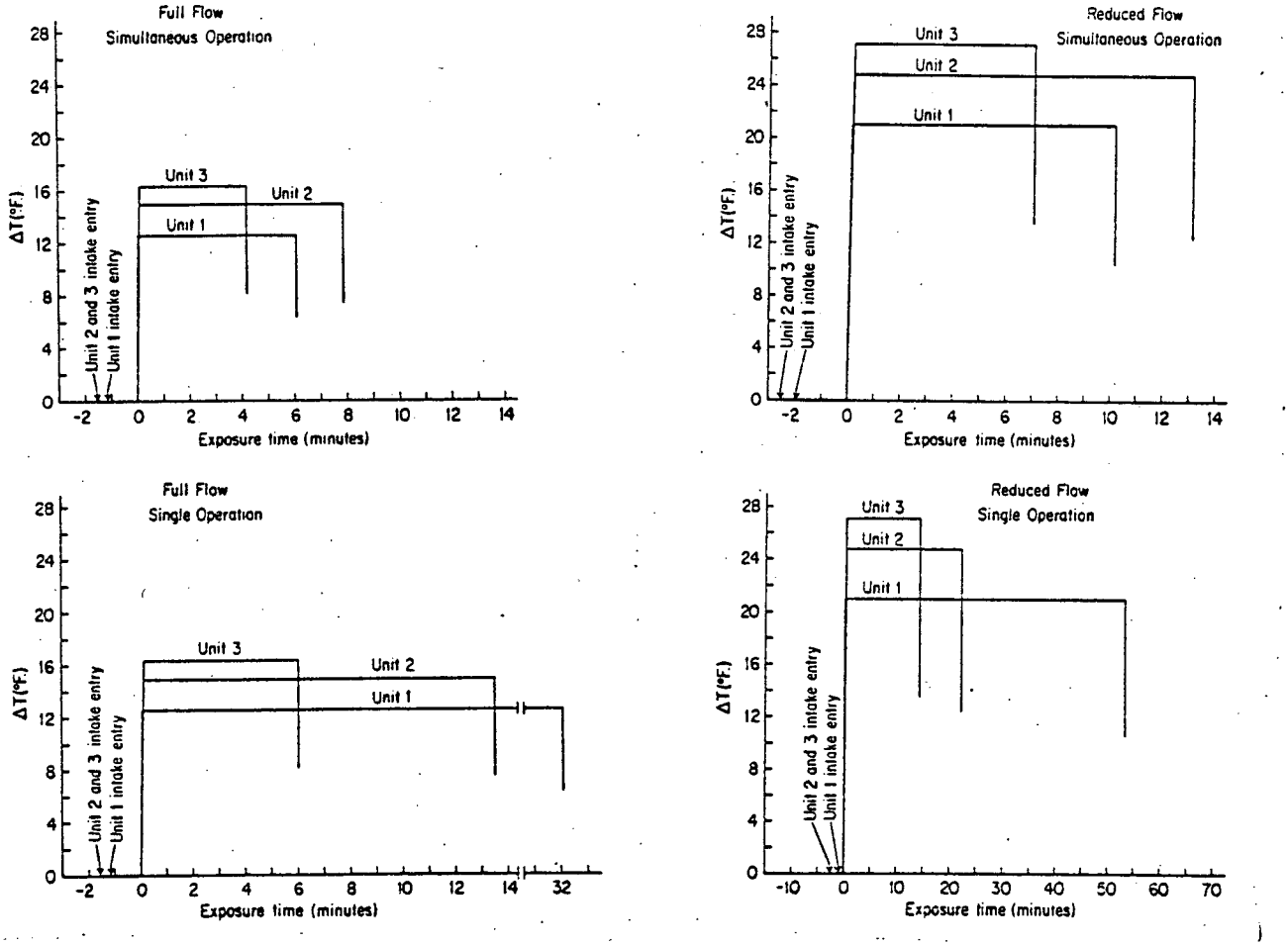

Figure 1-3. Schematic diagrams of temperature elevations and exposure times in the Indian Point condenser cooling system when operating at rated generating capacity.

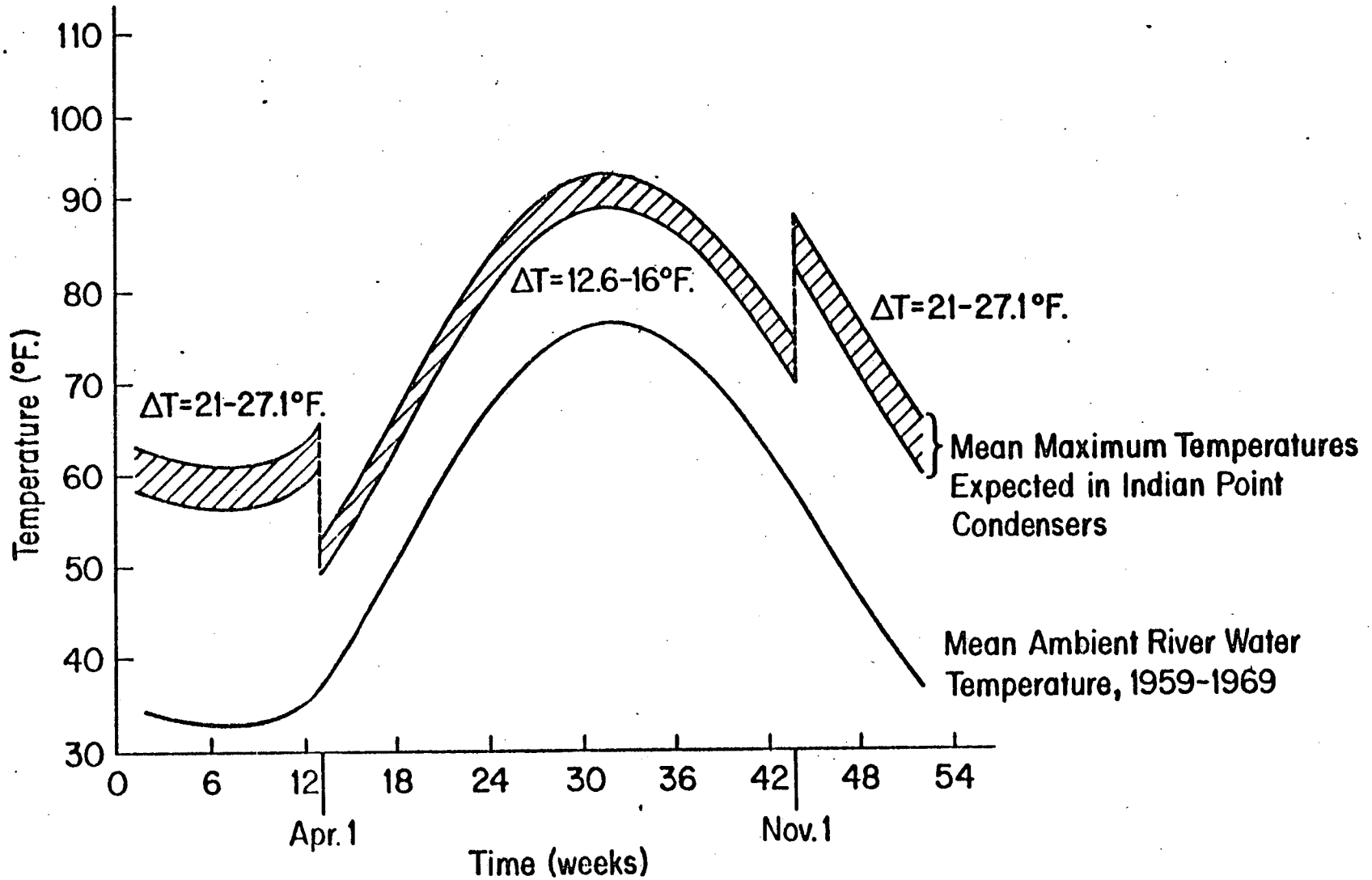

Figure 1-4. Temperatures encountered in Indian Point condensers at proposed cooling water flow rates when plant is operating at rated generating capacity.

of the pipes through which the cooling water passes, the velocity of the flow through component parts of the system, and the depth at which the organisms are discharged.

Schematics of the upper, lower and average pressure changes experienced by pump-entrained organisms as they pass from the discharge side of the circulating water pumps through the condensers of the Indian Point plant are shown in Figures 1-5 and 1-6. These range from a minimum of 4.3 to a maximum of 23.6 psia within a 48 second span. New York University Medical Center (1976e) has reported on the effects of pressure change on entrained Hudson River organisms and discussed the potential adverse effects of pressure on survival of several river organisms, including striped bass.

1.2.4 Velocity Shear Exposure

Organisms pumped through the Indian Point facility are exposed to rapid increases and decreases in velocity. The degree and rate of the velocity change experienced depend on the location of the organism in the water column prior to being drawn into the pumps, the design and diameter of the pipes through which the cooling water passes, surface irregularities within the pipes, and the design and number of circulating pumps in operation. Figures 1-5 and 1-6 show the absolute head encountered by organisms entrained in Units 1 and 2, respectively. The resulting velocities within the condenser are in the range of 5.5 to 8.1 fps (168 to 247 centimeters per second; CMS) for Unit 1 and 6.0 to 8.1 fps

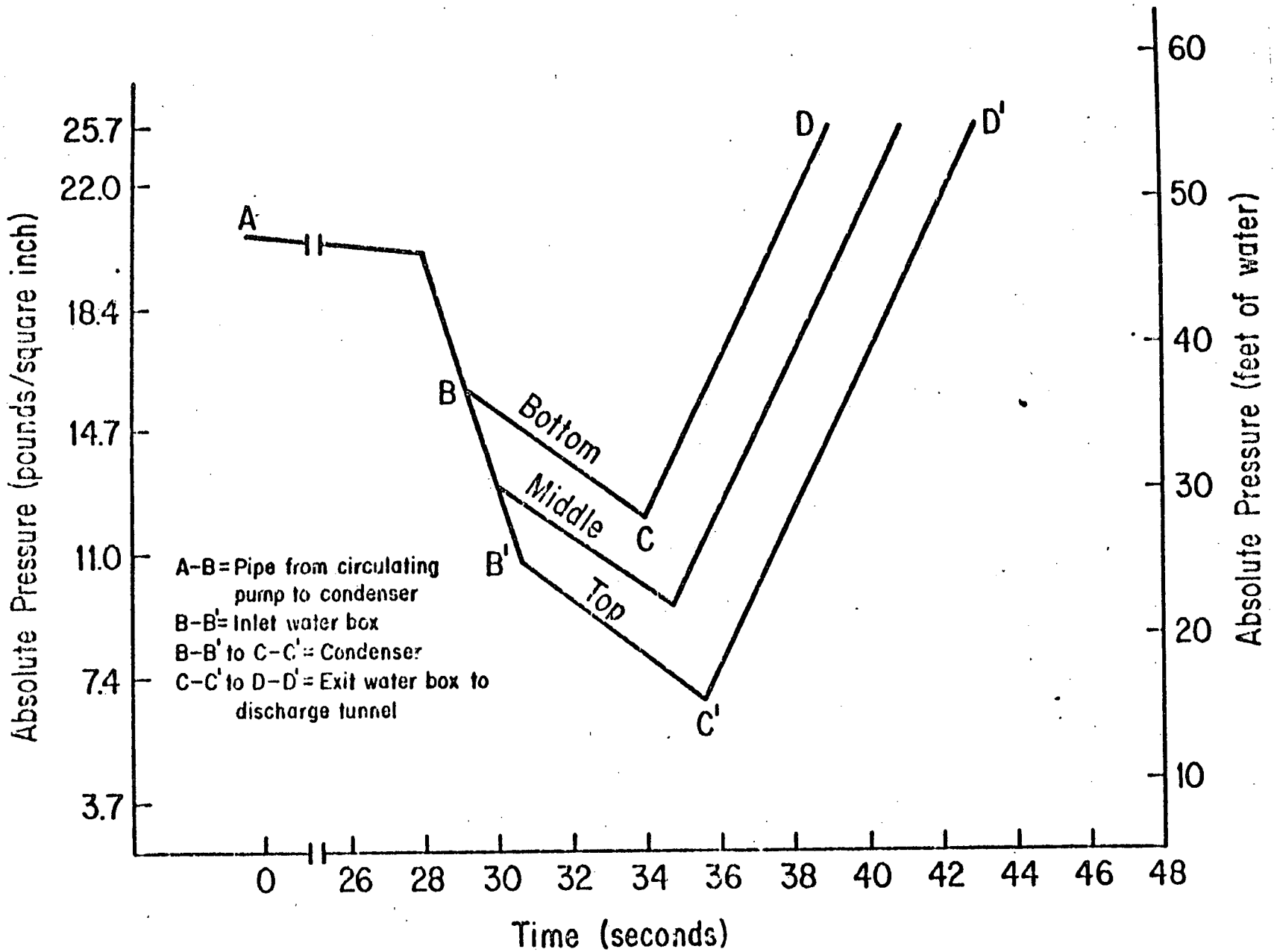

Figure 1-5. Absolute pressure in relation to time from intake to discharge pipe of Indian Point Unit 1 circulating water system.

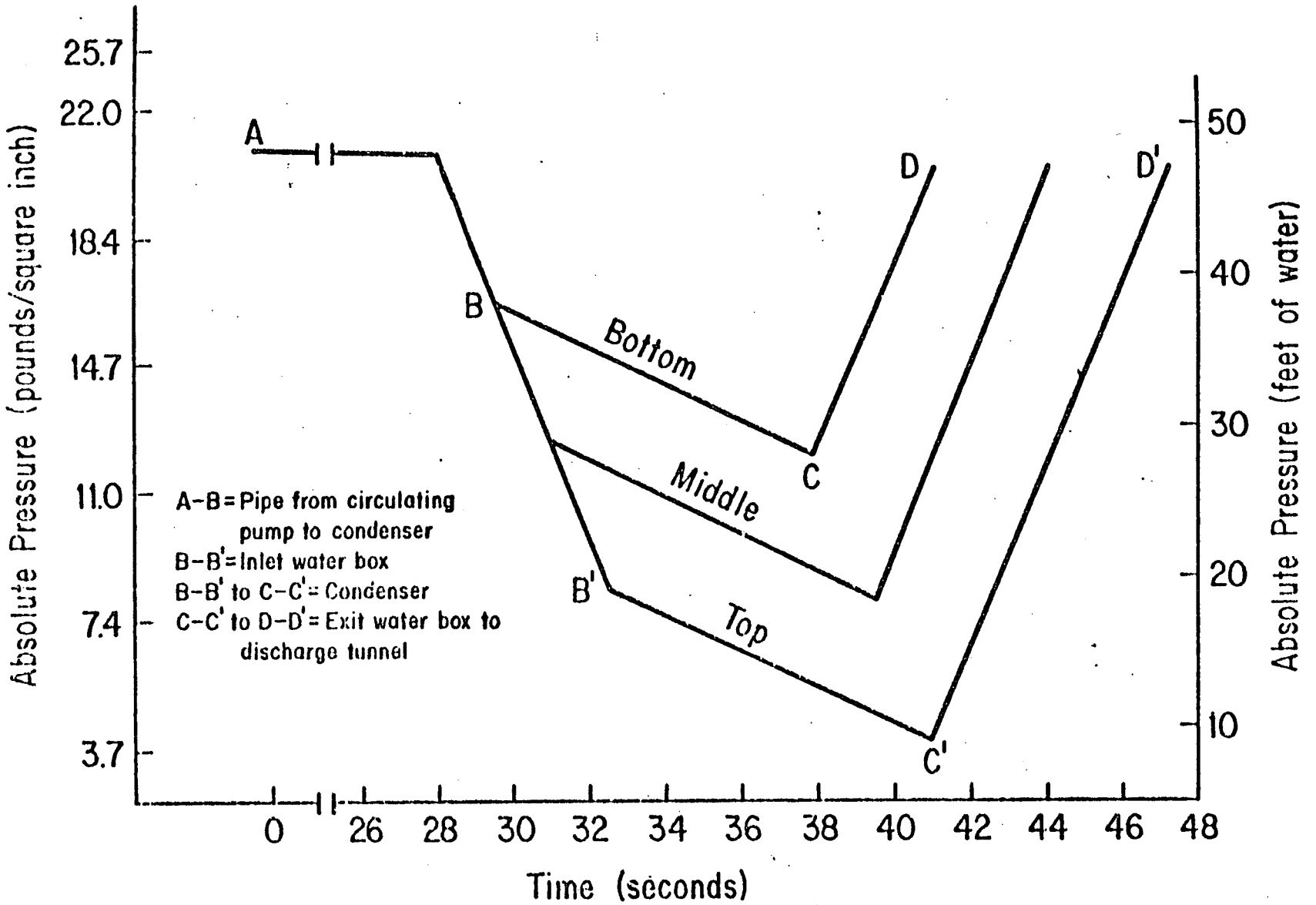

Figure 1-6. Absolute pressure in relation to time from intake to discharge pipe of Indian Point Unit 2 circulating water system.

(183 to 247 CMS) for Unit 2. Pressures and velocities in Unit 3 are expected to be similar to Unit 2. Table 1-2 shows the estimated cross-sectional flow velocities at other selected points in the Indian Point cooling water system under various operating conditions at 100% design flow.

For most forms, the velocities at which organisms are moved through the system seem to be of little importance in themselves. For example, in two independent studies of the effects of condenser passage and related velocity-induced hydraulic stress Coutant and Kedl, 1974 (see also Kedl and Coutant, 1974) demonstrated that neither ΔT nor velocity-induced stress factors alone or in combination had a significant lethal effect on a variety of entrainable organisms. Tests included striped bass larvae, frog tadpoles and Daphnia. The authors concluded that the condenser was probably not the locus of significant entrainment mortality in power stations. The effects of shear forces within power plants have not been studied as an independent stress, and, therefore have not been included in most evaluations of entrainment effects. The results of our studies at Indian Point suggest that shear and/or abrasion do not contribute substantially to mortality of entrained organisms, since little or no deformation of specimens is observed in live samples.

1.2.5 Mechanical Buffeting Exposure

Mechanical buffeting that organisms experience during passage through the Indian Point facility cooling water has

Table 1-2. Estimated cross-sectional flow velocities (feet per second) at existing and proposed sampling points in the Indian Point plant cooling water system when operating at 100% of design flow and at mean low water in the Hudson River. The numbers given decrease by 10% at high slack tide and by 5% at low slack tide. The numbers decrease by 40% when the system is operating at 60% of design flow.

Sampling location	Generating units operational						
	1	2	3	1+2	1+3	2+3	1+2+3
Intakes	velocities (feet per second)						
Unit 1	0.7	0	0	0.7	0.7	0.7	0.7
Unit 2	0	0.9	0	0.9	0.9	0.9	0.9
Unit 3	0	0	0.9	0.9	0.9	0.9	0.9
Discharge canal							
Station D-1	1.1	3.1	0	4.4	1.1	3.3	4.4
Station D-3	0	0	6.6	0	6.6	6.6	6.6
Station D-2	0.8	2.5	2.5	3.4	3.4	5.0	5.8
Station DP	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Note: At Units 1 and 2 the sampling rigs are positioned between the trash bars and the traveling screens, as shown in Figure 1-11. The sampling rigs at Unit 3 will be positioned immediately in front of the traveling screens.

not been quantitatively determined. While mechanical buffeting effects cannot be isolated and evaluated directly, we have evaluated them in conjunction with velocity-shear effects and pressure by observing the condition of organisms passed through the condensers when there was no ΔT and no chlorination.

1.2.6 Chlorine Exposure

The condensers at the Indian Point station are treated with sodium hypochlorite to remove fouling organisms. One-half of a unit's condensers is chlorinated for one-half hour, during daylight hours, for a total treatment time of 1 hour per unit (Table 1-3). The frequency of chlorination was once per week during the summer months of 1975.

The water from the chlorinated and unchlorinated sections of a unit mixes after leaving the condenser, resulting in a 1:1 dilution. Flows from other units add to the dilution. Total dilution in the cooling system may be as high as one part treated water to 11.94 parts untreated water, depending on the combination of units in operation at the time (Table 1-4). Free chlorine is reduced rapidly by the chlorine demand of the cooling water. Discharge concentrations to the river are usually 0.1 ppm or less at a 1:1 dilution rate in the cooling system.

Studies of chlorination in the plant discharge canal and plume-entrainment zones were executed to provide as full

Table 1-3. Chlorination schedule for Indian Point units.

Time period	Chlorination cycles per week	Hours per week per unit
Jan. 1 - April 15	0	0
April 16 - June 30	2	2
July 1 - Sept. 30	3	3
Oct. 1 - Dec. 15	2	2
Dec. 16 - Dec. 31	0	0

Table 1-4. Dilution of chlorinated cooling water exiting condensers of Indian Point units during individual and combined unit operation.

Combination of units on flow	Unit being chlorinated	Ratio of chlorinated to unchlorinated water
Any single unit		1:1
Units 1 & 2 or 3	Unit 1	1:6.47
Units 1 & 2 or 3	Unit 2 or 3	1:1.73
Units 2 & 3	Unit 2 or 3	1:3.1
All units	Unit 1	1:11.94
All units	Unit 2 or 3	1:3.73

an assessment of plant impact as possible under all conditions. The results of these studies have been reported elsewhere (New York University Medical Center, 1976b).

1.3 DESIGN OF THE RESEARCH PROGRAM

The initial design of the research program was based on information available in 1970 on the variables described above. Appropriate changes in design were made as new information became available and portions of the Indian Point complex were completed (e.g. the discharge ports in 1972, and Unit 3 in 1976).

1.3.1 Objectives

The specific objectives of the research program are to:

1) Determine the species composition, abundance, and temporal and spatial distribution of organisms in the Hudson River that are subject to entrainment by the Indian Point plant. This is done by studies of the populations of organisms in the water column that are small enough to pass through the 3/8-inch mesh of the plant's intake screens.

2) Determine to what extent the temporal and spatial distribution of organisms in the Hudson River affects the rate of entrainment by statistical comparison of the concentrations of biota in river and plant samples.

3) Determine to what extent organisms are affected by entrainment at the Indian Point plant. This is done through

laboratory experiments that measure the organism's tolerance of entrainment stresses, as well as by comparing the conditions of organisms collected in the plant's intake bays with those collected in the discharge canal. Laboratory experiments can evaluate the individual effects of temperature elevation, chlorination, and pressure, but not the effects of mechanical buffeting, velocity shear and sampling mortality. In 1975 a special study was undertaken to determine the extent to which sampling gear may affect intake-discharge comparisons of larval mortality. The results of this study (New York University Medical Center, 1976c) have been applied throughout section 7 of the present report.

4) Determine to what extent river organisms are affected by entrainment into the discharge plume after it leaves the submerged ports of the discharge canal. This is done by in situ experiments wherein organisms (phytoplankton, micro-zooplankton, macrozooplankton, and fish eggs and larvae) not having been exposed to pump entrainment are placed in the discharge plume and allowed to drift in the plume as ambient river water is entrained. The organisms are then examined to determine mortality in relation to control conditions. Plume entrainment studies, included in last year's progress report as Section 8, have been reported separately (New York University Medical Center, 1976b).

5) Evaluate whether and to what extent damage to organisms entrained by the plant adversely affects populations of

those species in the Hudson River. This is done by the same river population studies noted for objective 1.

1.3.2 Sampling Stations and Gear

1.3.2.1 Stations Used in Sampling River Populations

River populations are sampled for objectives 1, 2, 4, and 5. Seven stations, designated A through G, are used in basic sampling design (Figure 1-7). 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 passing 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 the above seven stations in 1971 and 1972. In addition, a special station (H) was established in 1972 to obtain data on populations in the area north of the Bear Mountain Bridge. Later in 1972, after high mortality of entrained Neomysis had been observed at Indian Point, five additional sampling stations were established from Newburgh southward to Yonkers to determine the longitudinal distribution of this species (Figure 1-7). The mile-point locations (referenced to the Battery in New

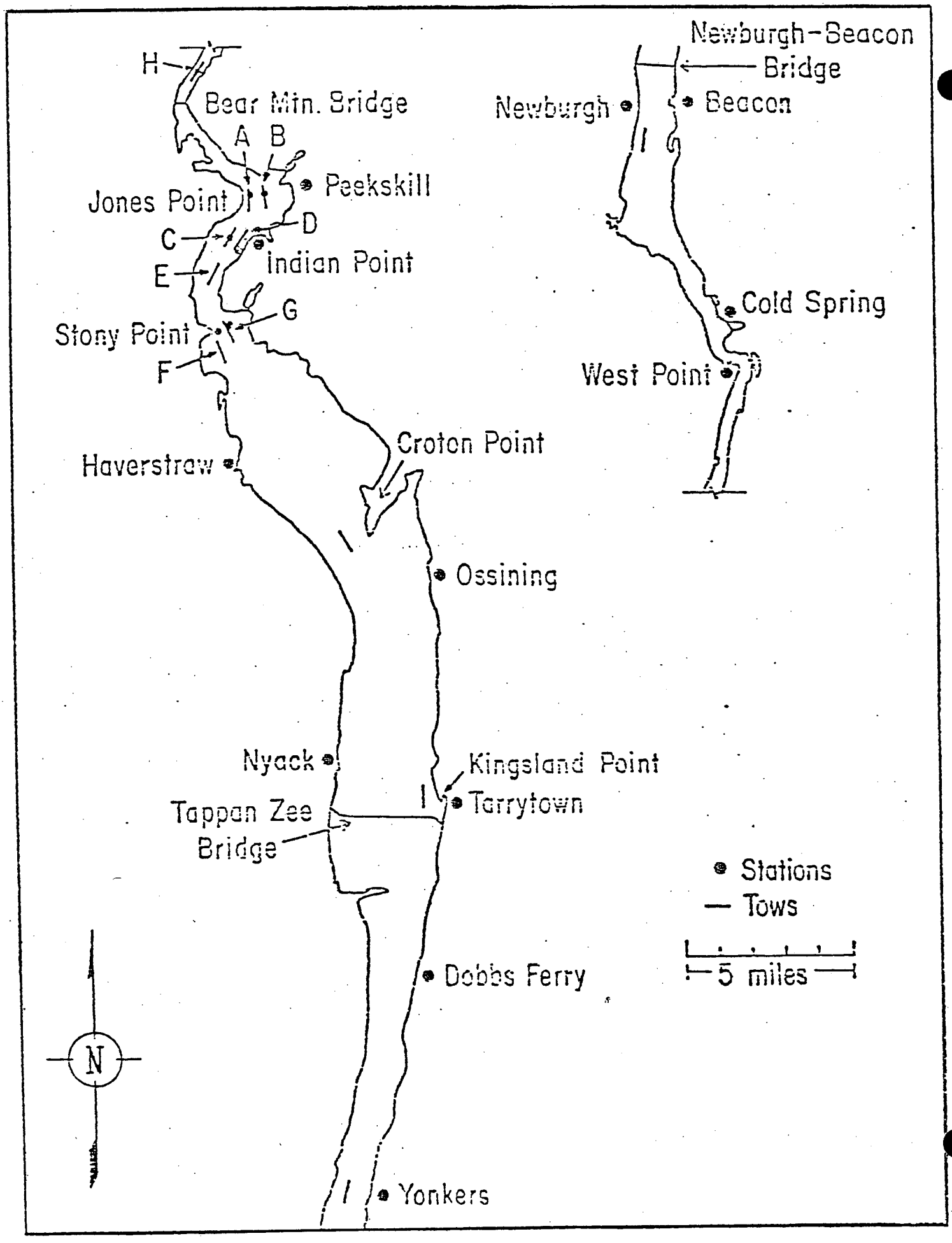

Figure 1-7. New York University Hudson River sampling stations, 1971, 1972, 1974 and 1975.

York City) and river depths for each sampling station are listed in Table 1-5.

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 fish eggs and larvae in the Hudson River to the numbers entrained in the plant intakes.

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 1, 2 and 3, to the shoal area of Tompkins Cove on the west side of the river (Figure 1-8). Table 1-6 shows the river-depth contours and approximate distances from the plant intake for each tow path.

When collections were initiated (May, 1973), a submerged barge, salvage barge, and associated anchor lines limited the down stream excursion of the tow nearest the east shore of the river (R-1); and a submerged obstacle limited the upstream excursion of tow R-4 on the west side of the river. Some of these obstacles were removed as the season progressed (June through August, 1973), but sampling was kept constant to assure consistency in the data.

1.3.2.2 Stations Used in Studies of Pumped Entrainment Effects

Figure 1-9 shows the locations of the sampling stations at the Indian Point plant. The effects of pumped entrainment

Table 1-5. 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.

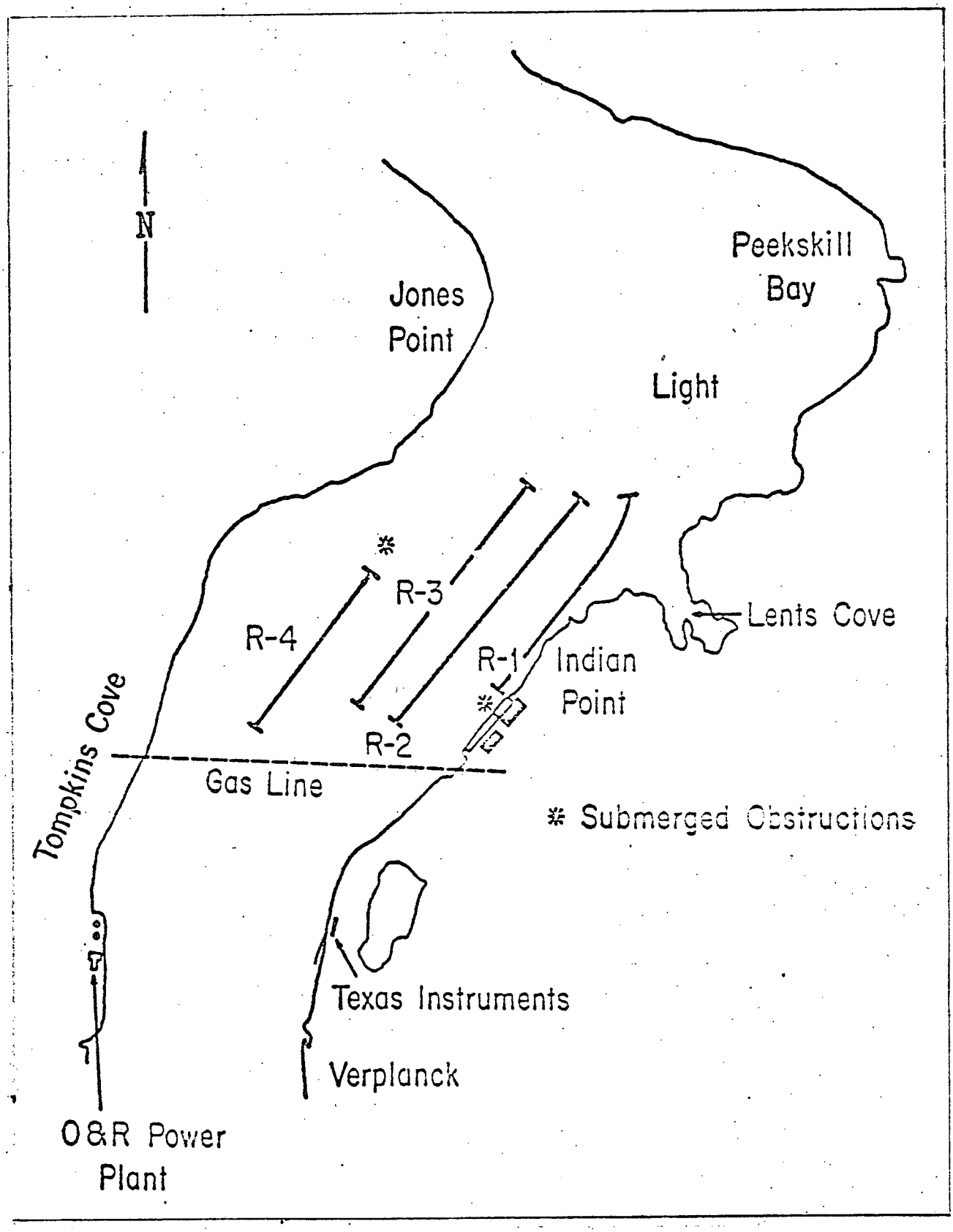

Figure 1-8. New York University Hudson River sampling stations, 1973 and 1974.

Table 1-6. Location of 1973 and 1974 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

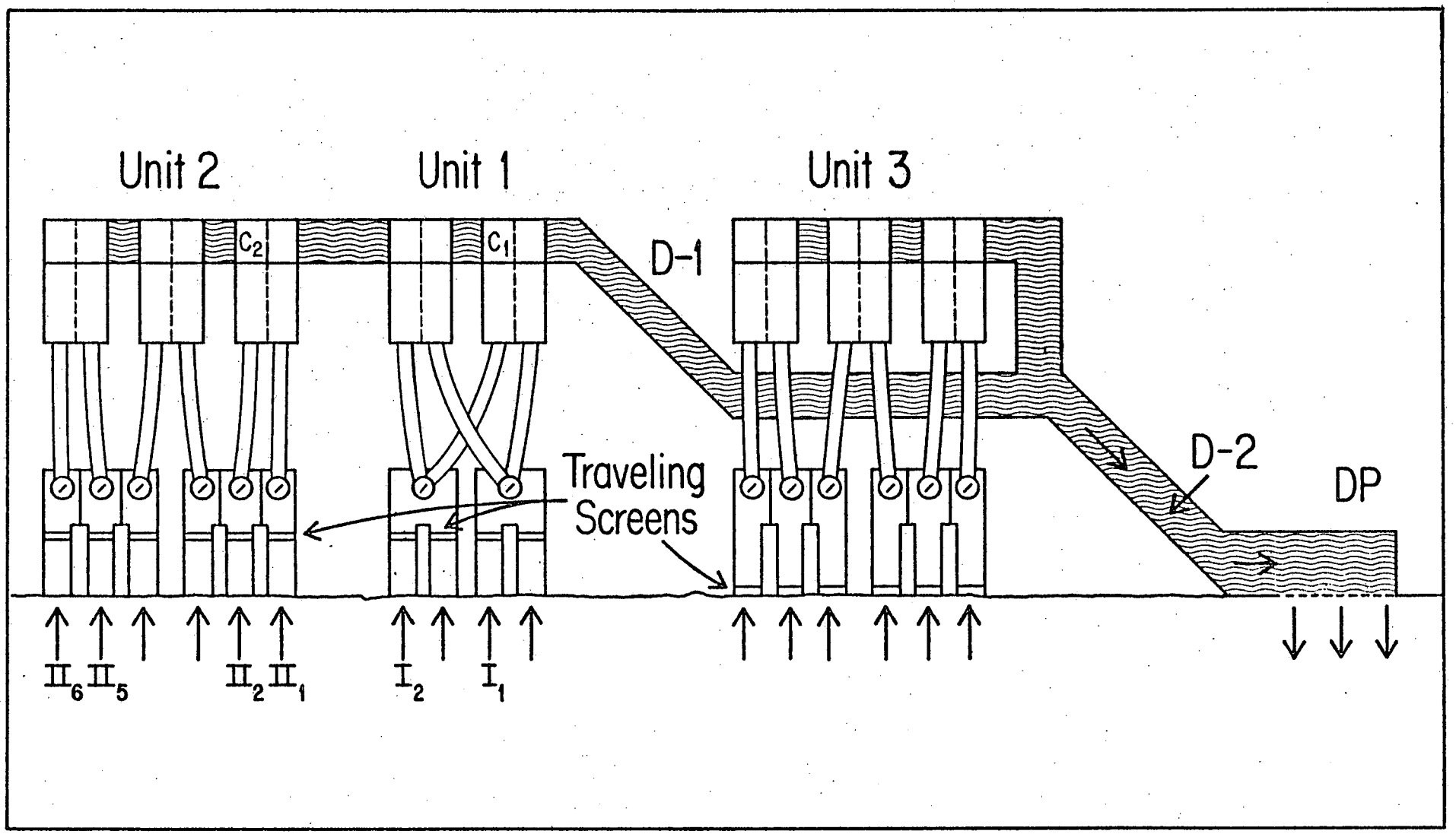

Figure 1-9. Schematic diagram of Indian Point cooling water system showing locations of sampling stations.

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 1, were used in 1972 and 1973. In 1973, with the completion of Unit 2, stations II-1 and II-6 were added to compare the numbers and species composition of organisms there with those at the Unit 1 intakes (the number after the hyphen refers to the intake bay in which the sampling rig is located).

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 D-P.

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 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 D-P, 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.

As in the case of the river population studies, the entrainment effects sampling design was modified in 1973. Since the plant was not on-line for much of the year, we focused on obtaining information on the abundance of organisms entering the Unit 1 and Unit 2 intakes. In addition, detailed studies were performed to ascertain latent effects of entrainment. To obtain post-entrainment specimens for this purpose, as well as to compare damage to organisms from entrainment with and without ΔT, some collections were made at the Lovett Plant of Orange and Rockland Utilities, Inc.

With both units in operation in 1974, the entrainment sampling design of 1972 was re-instituted, but with some modifications. Units 1 and 2 were sampled at various times, depending upon operational status. The use of flowmeters in entrainment sampling gear was discontinued in the late spring and velocity-reduction cones were installed in discharge sampling nets in an effort to reduce the velocity of water passing through the nets. The same sampling stations at Unit 1, Unit 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 2 in operation in 1975 all sampling efforts were concentrated on that Unit, as well as a study on the effects of plume entrainment, and a laboratory study to assess the effects of net-capture on ichthyoplankton survival. Each of these special studies has been reported

elsewhere (New York University Medical Center, 1976b, 1976c).

1.3.2.3 Sampling Gear

Depending on conditions and the kinds of organisms to be sampled, various collection nets were used. The net types and dimensions used from 1971 through 1975 are shown in Table 1-7.

The nannoplankton net was used to concentrate samples of pumped water; the volume of the sample was determined by the pumping rate.

Water passing through each of the other nets was recorded by a TSK digital flowmeter mounted in the mouth opening. Except for the nannoplankton net, all nets were provided with cod-end buckets, 5 cm in diameter and 15 cm long, with a sieve window of the same mesh as the net.

Sampling from surface to bottom was needed at intake and discharge-canal stations to obtain estimates of the species and numbers of macrozooplankton and ichthyoplankton passing through the system. The vertical distribution of macrozooplankton and ichthyoplankton in the water column varied markedly; dependent upon the time of day; phytoplankton and microzooplankton showed little difference in vertical diel distribution.

Sampling rigs capable of simultaneous sampling at three water depths were devised (Figure 1-10), and were installed at each of the intake and discharge-canal sampling stations.

Table 1-7. Nets used in sampling for river-population and entrainment-effects studies.

Biological group	Study	Net type	Net dimensions			Net-opening retainer	Bucket	Period Utilized
			Mesh	Diameter (m)	Length (m)			
Phytoplankton	population	nannoplankton	10μ	0.12	0.3	brass ring	none	1971-72
Microzooplankton, all	population, entrainment	No. 20 mesh	76μ	0.5	1.9	brass ring	SS	1971-75
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.

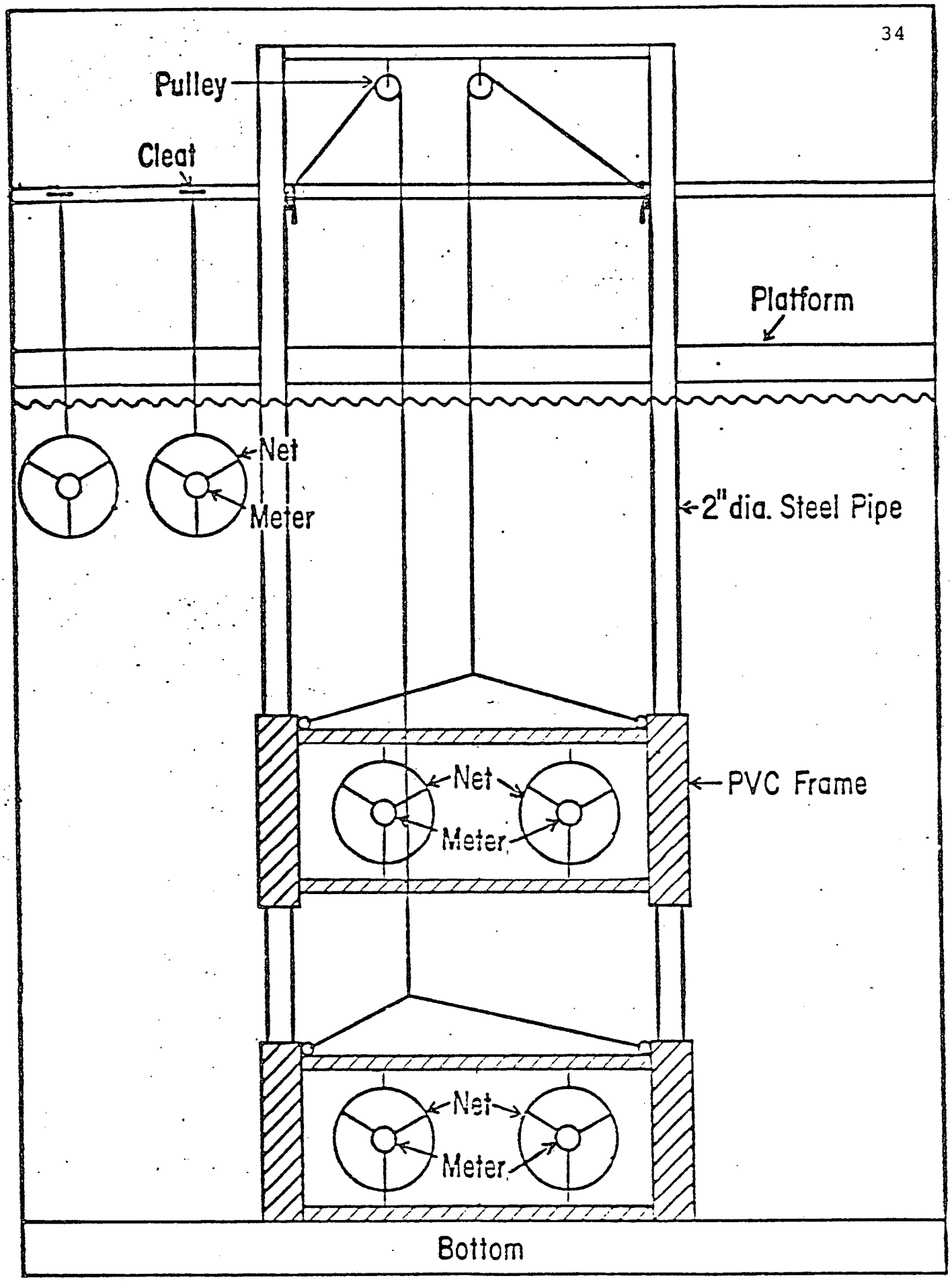

Figure 1-10. Rig used for intake and discharge-canal sampling.

Samples taken just below the surface were obtained using nets on tow lines. Mid-depth and bottom samples in the intakes and in the discharge canal were taken with nets mounted in the sampling rigs. Figure 1-11 pictures the sampling set-up for the Unit 1 intakes; Unit 2 intake structures were similar. There is more room between the bar rack and the traveling screen in Unit 2 than in Unit 1, and nets were mounted about 3 feet back from the bar rack in Unit 2 instead of 6 inches, as at Unit 1.

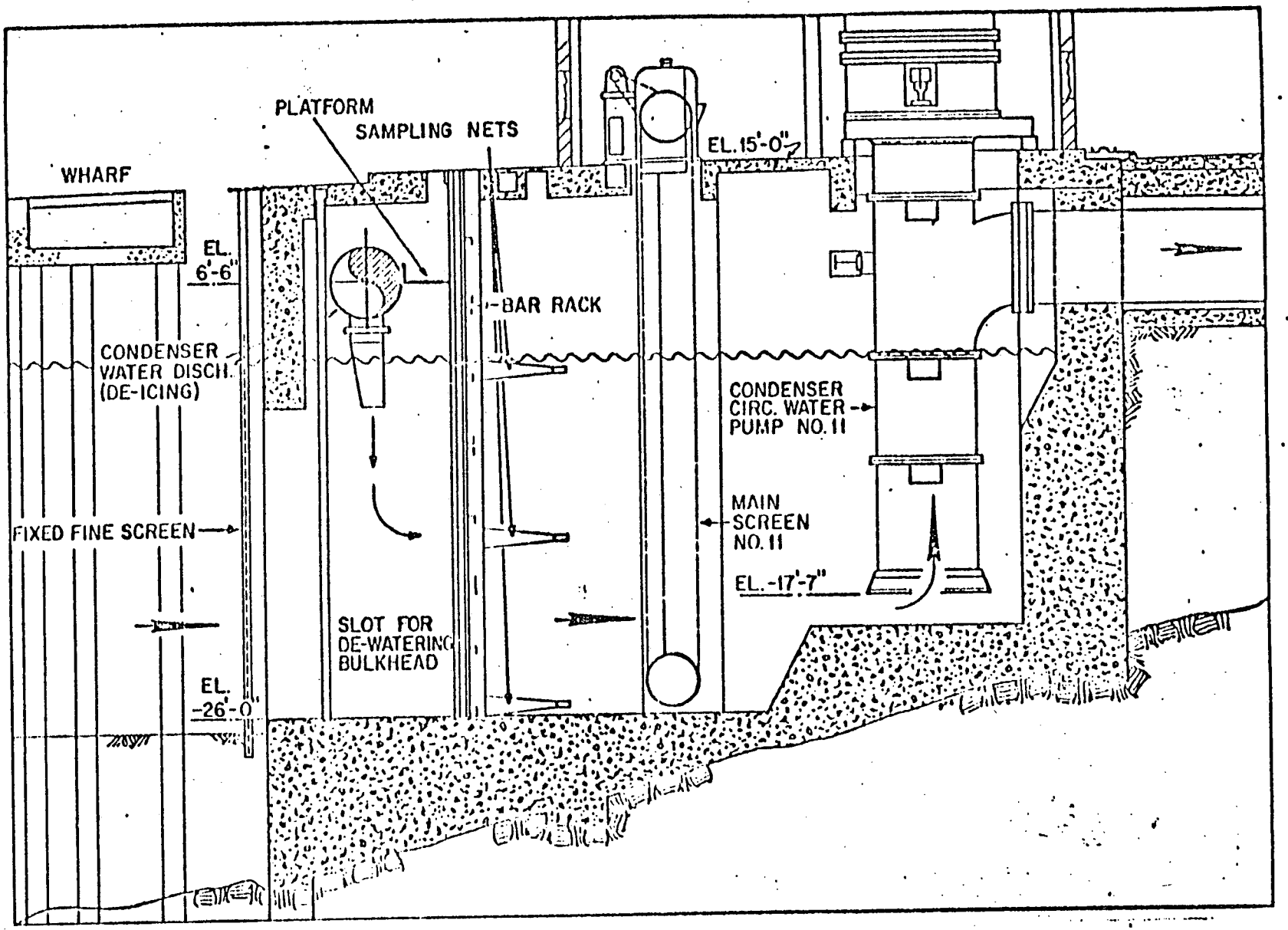

Figure 1-11. Cross-section through Unit 1 forebay showing position of sampling nets. The mouths of the nets are approximately 6 inches behind the bar racks. The configuration of the Unit 2 forebays is similar, but the distance between the bar racks and the traveling screen is greater, permitting the nets to be mounted about 3 feet back from the bar racks. Also, the floor under the pump intake pipe in Unit 2 is sloped rather than stepped.

2. PHYSICAL/CHEMICAL STUDIES

2.1 METHODS

Physical measurements (air and water temperatures, water clarity and pH) were taken and water samples were collected for subsequent analysis of salinity and dissolved oxygen content at river sampling sites A through G (Figure 1-7). Physical and chemical samples were taken simultaneously with biological samples. The procedures used were those employed by the American Public Health Association (1971) for the examination of water and wastewater. Air temperatures were taken with a standard mercury thermometer. Water temperature and salinity measurements were made with a G.M. Industrial Instruments portable induction salinometer. Water clarity was estimated using a Secchi disc and pH was measured with a Hellige color comparator. Dissolved-oxygen levels were determined using the Winkler iodometric method (azide modification).

2.2 RESULTS AND DISCUSSION, 1975.

The general similarity among data trends for each parameter investigated at each depth and station on each sample date permitted the calculation of mean values based on all depths and stations by sample date.

The observed air temperatures during 1975 ranged from 2.7 to 31.4 C (36.9 to 88.5 F; Figure 2-1). Water temperatures

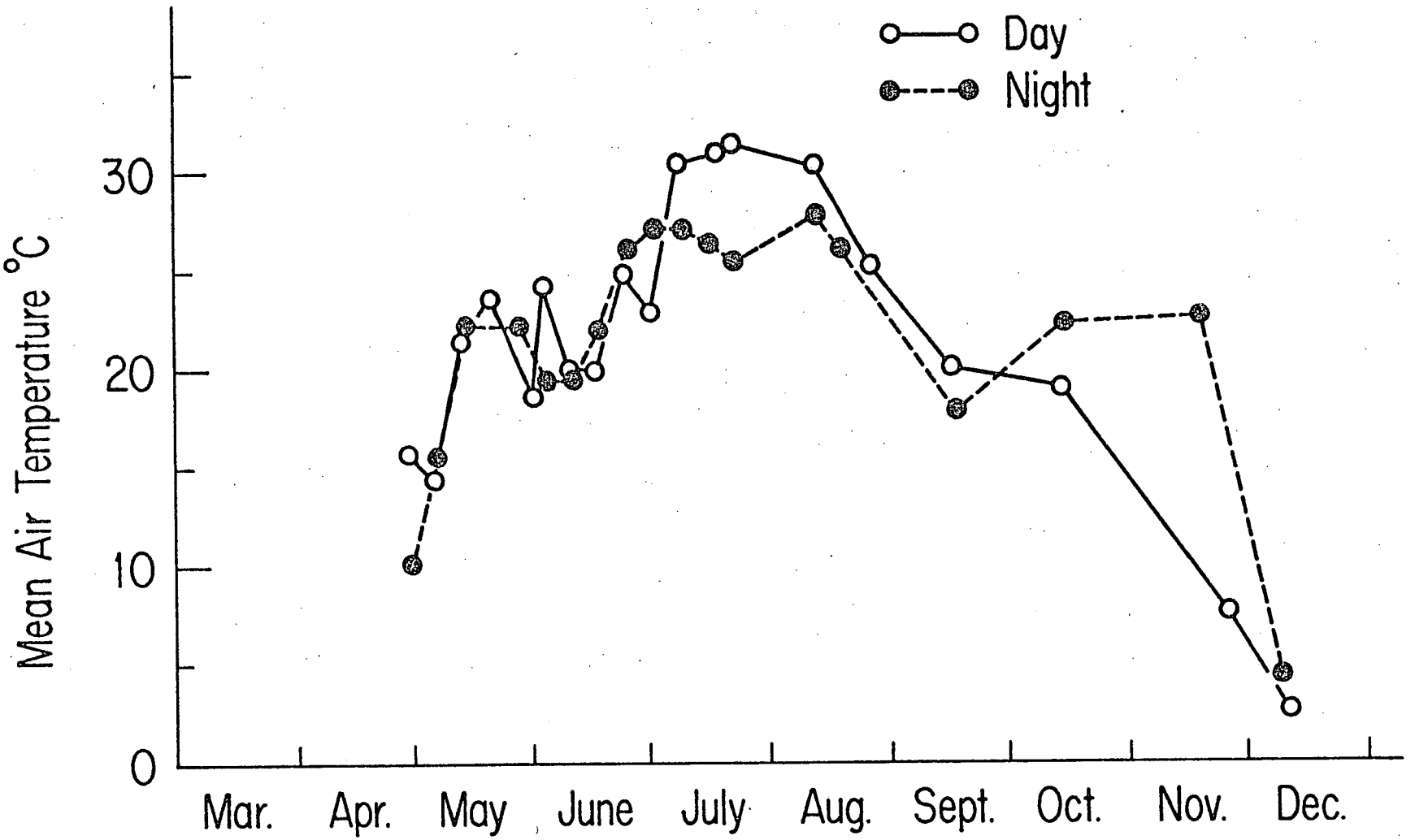

Figure 2-1. Mean day and night air temperatures in the vicinity of Indian Point, 1975.

were highest in July and August and dissolved oxygen was lowest in July and August (Figures 2-2 and 2-3) maintaining an association with high air-temperature regimes. A slight decrease in dissolved oxygen occurred in early July, 1975 (Figures 2-2 and 2-3), which was associated with increased salinity in the Indian Point area. The lower D.O. may have been transported upstream by the advancing salt front (see Section 7). Mean water temperatures recorded for 1975 ranged from 4.6 to 26.3 C (40.3 to 79.3 F). Dissolved oxygen concentrations ranged from 5.8 to 12.4 mg/ℓ.

Secchi-disc readings give a rough index of water clarity; low readings are indicative of turbid conditions. Mean Secchi-disc readings ranged from 0.9 to 3.9 feet (.3 to 1.2 m) with no trends, indicating the water in the study area was well mixed (Figure 2-2). The low values result primarily from suspended particulate matter, made up of inorganic suspended matter, suspended detritus and algal cells. The clearest water occurred during the first week of June (3.9 ft; 1.2 m) during a moderate salinity intrusion event, and a ten-fold decrease in phytoplankton abundance (see section 4.1).

Mean pH values ranged from 7.2 to 7.6 with little variation throughout the Indian Point study area, (Figure 2-4).

The mean salinity in the Indian Point region began increasing in early June (Figure 2-5). A maximum mean level

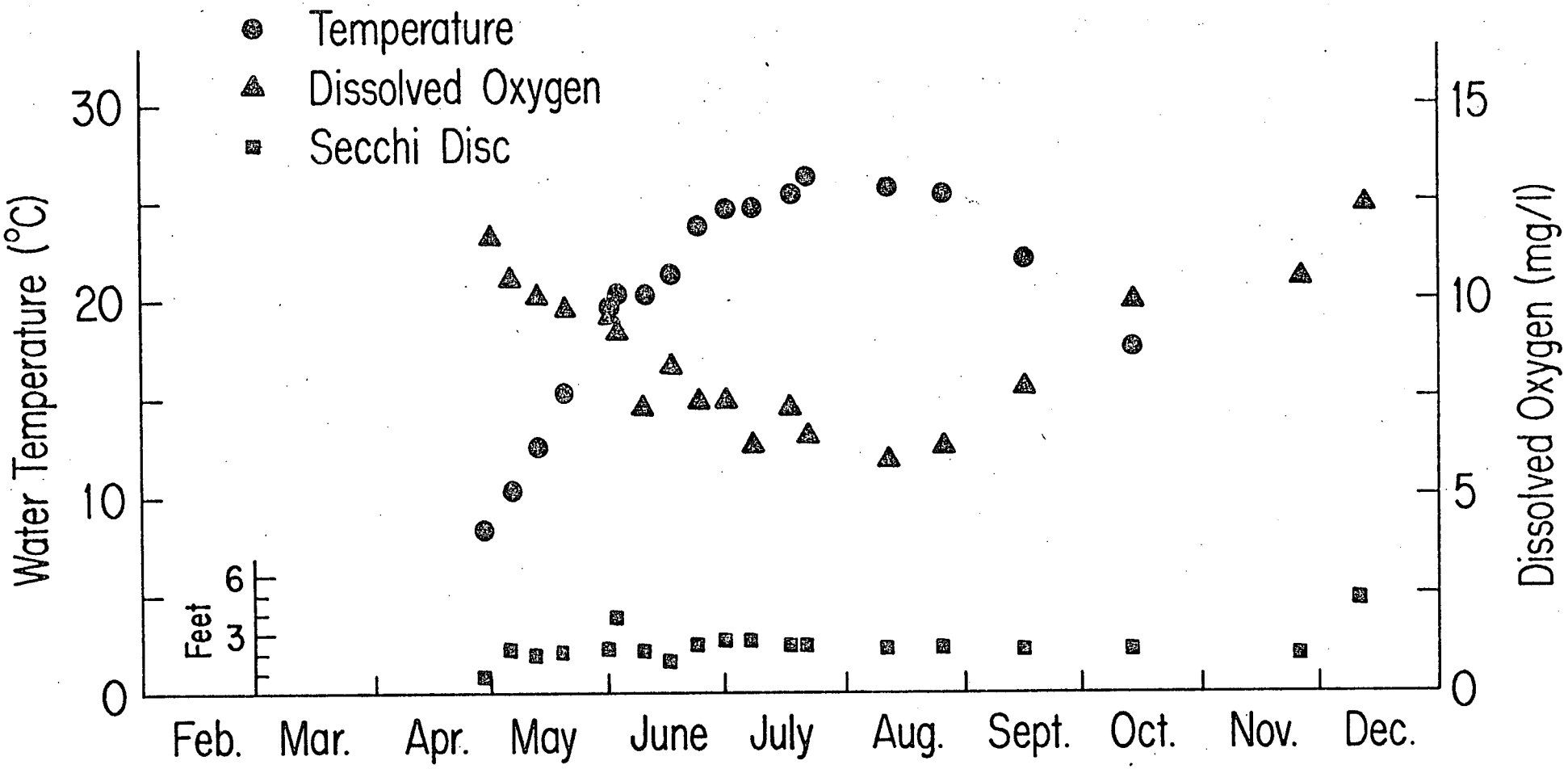

Figure 2-2. Water temperature, dissolved oxygen and Secchi-disc profiles for the Hudson River in the vicinity of Indian Point, 1975. The values shown are mean day surface, mid-depth and bottom values for all stations on each sampling date.

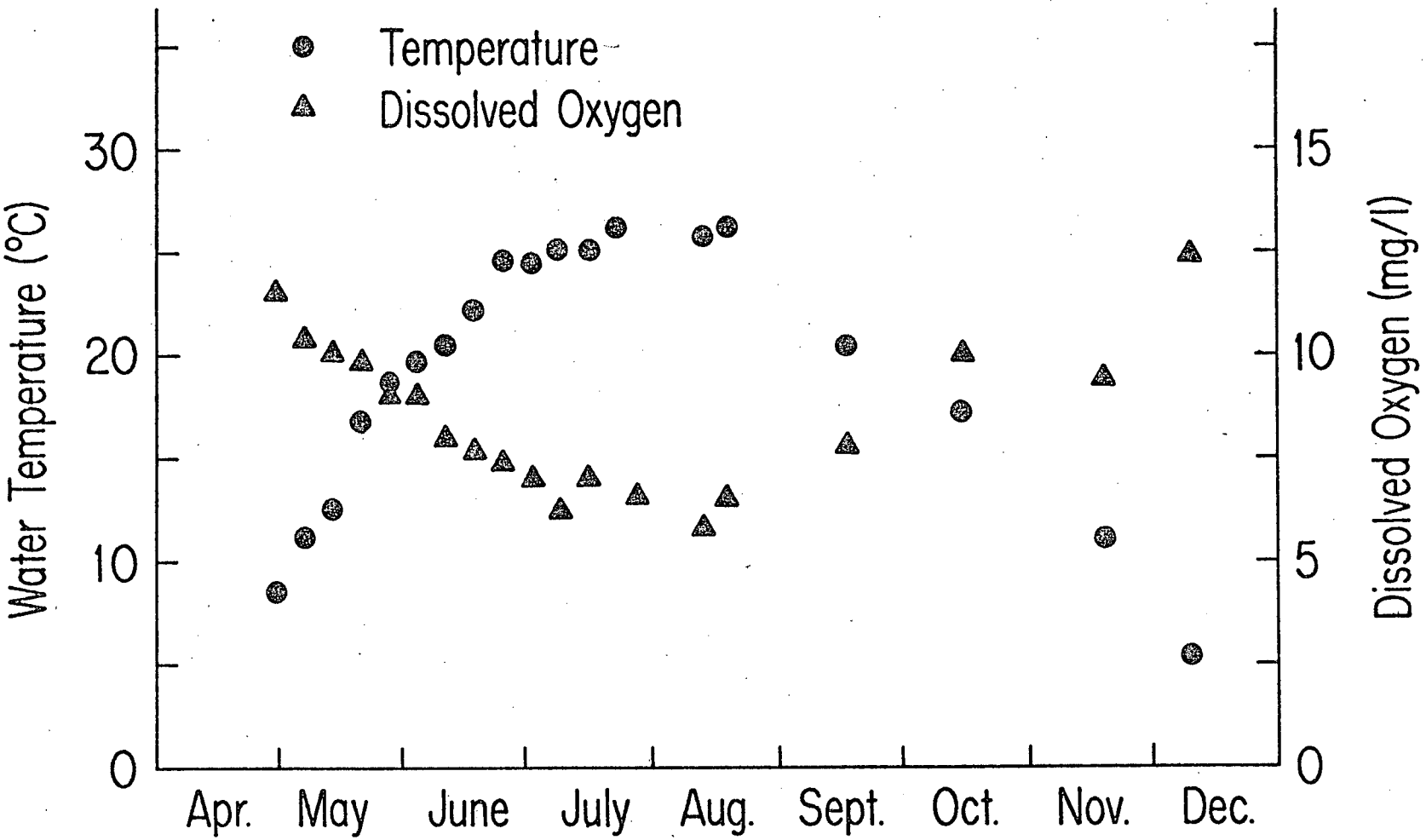

Figure 2-3. Water temperature and dissolved oxygen profiles for the Hudson River in the vicinity of Indian Point, 1975. The values shown are mean night surface, mid-depth and bottom values for all stations on each sampling date.

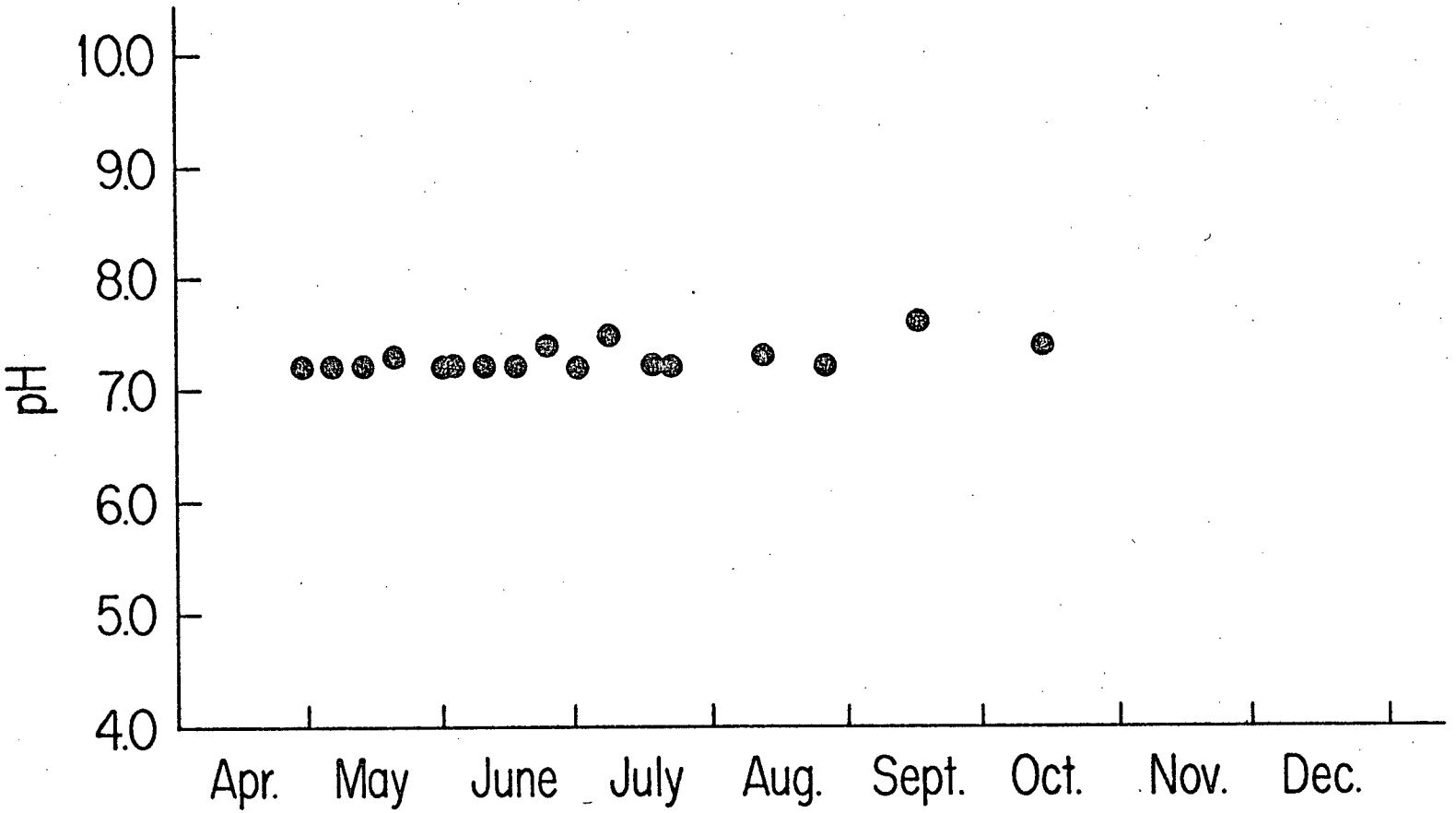

Figure 2-4. pH profile for the Hudson River in the vicinity of Indian Point, 1975. Values shown are mean surface values for all stations on each date.

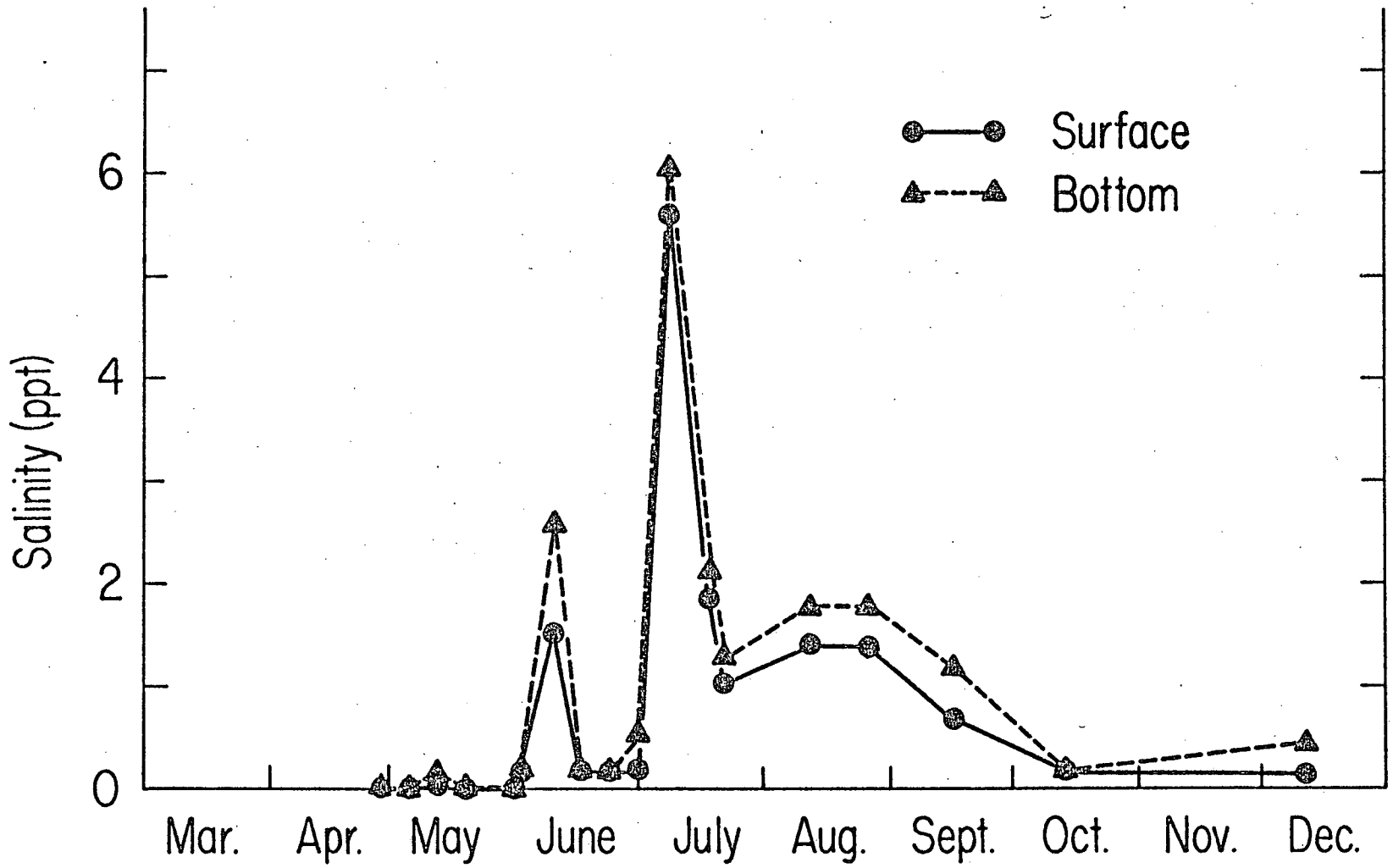

Figure 2-5. Salinity profiles for the Hudson River in the vicinity of Indian Point, 1975. The values are mean day surface and bottom values for all stations on each date.

of 6.28 parts per thousand (ppt, grams per liter) was reached in early July. Salt intrusion occurred as two distinct events, one occurring in the second week of June and the other in the second week of July. Salinity in the Indian Point area remained fairly constant between 1 and 2 ppt through July and August and declined thereafter to an autumn low value of between 0 and 0.1 ppt.

2.3 PHYSICAL CHEMICAL PARAMETERS 1972-1975.

Daytime air temperatures recorded during 1975 sampling efforts were measurably higher than in 1974, but similar to 1973 as regards seasonal maxima (compare Figures 2-1 and 2-6). Water temperatures, which are a reflection and integration of air temperatures, insolation and precipitation in the river basin, were essentially the same in profile and maxima as in 1972, 1974 and 1975. Water temperatures in 1973 were higher than in the other years, reaching a maximum in excess of 27 C (Figures 2-2 and 2-3; 2-7 to 2-9). The pattern of seasonal change in water temperature has remained similar throughout the study period. The spring profile shows a rapid increase, during which temperatures increase from 8-10 C (46.4-50.0 F) in April to 18-20 C (64.4-68.0 C) in early June. The lowest April temperatures during the study period were recorded in 1973 (6-8 C; 42.8-46.4 F). This period of rapid temperature increase in the Hudson River is the period during which the major anadromous fish

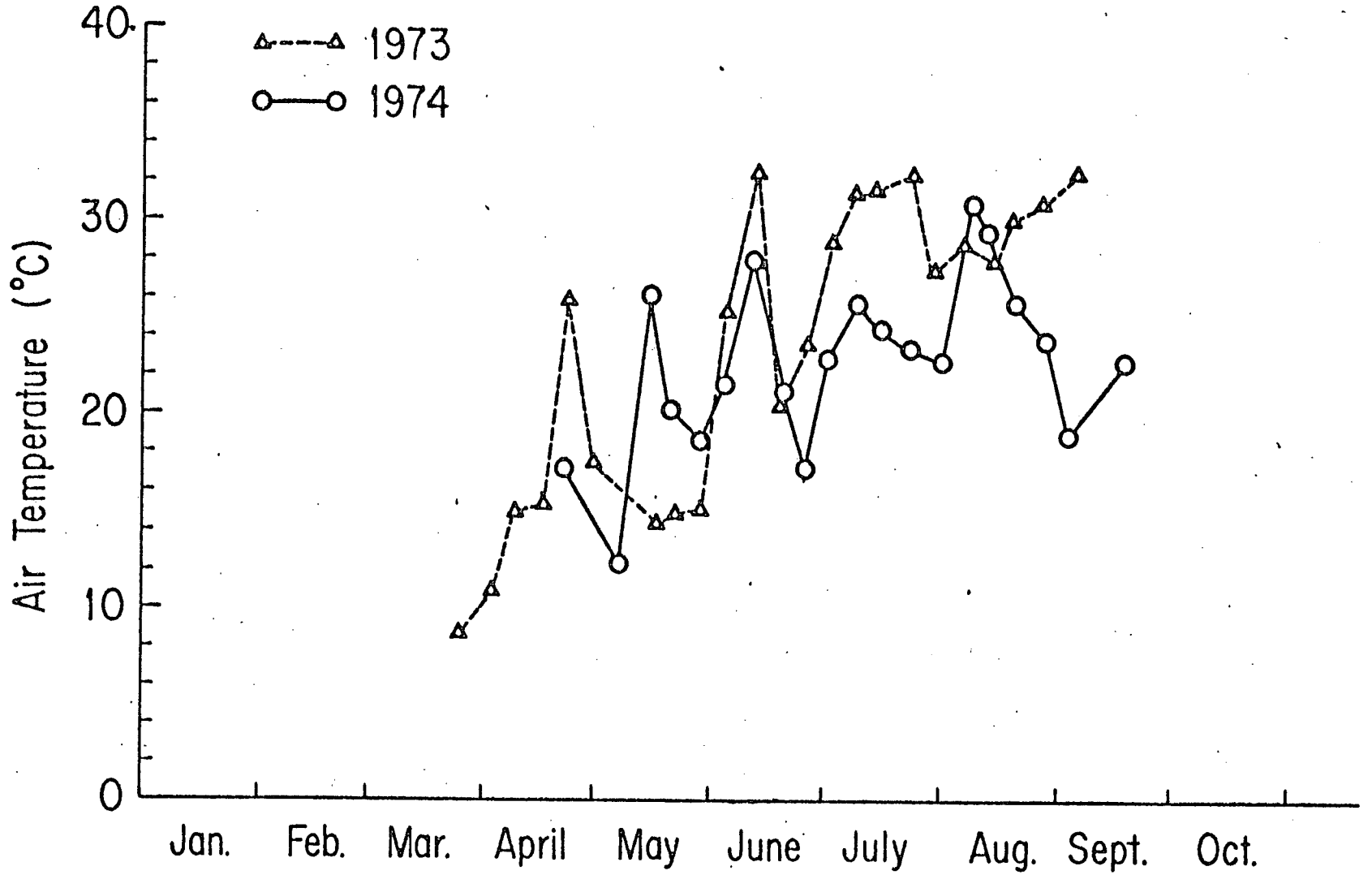

Figure 2-6. Mean daytime air temperatures in the vicinity of Indian Point in 1973 and 1974.

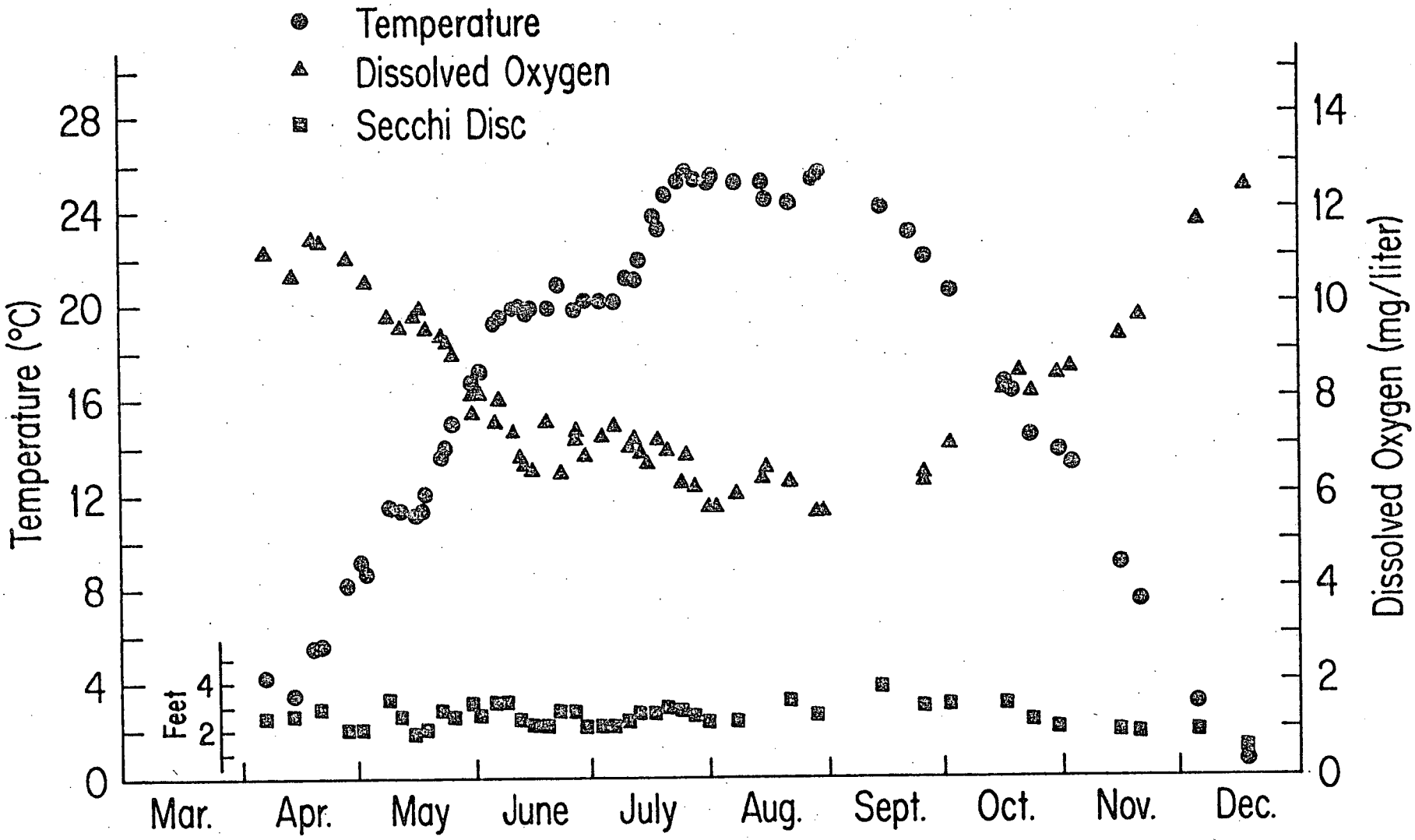

Figure 2-7. Water temperature, dissolved oxygen and Secchi-disc profiles for the Hudson River in the vicinity of Indian Point, 1972. The values shown are mean day and night surface, mid-depth and bottom values for all stations on each sampling date.

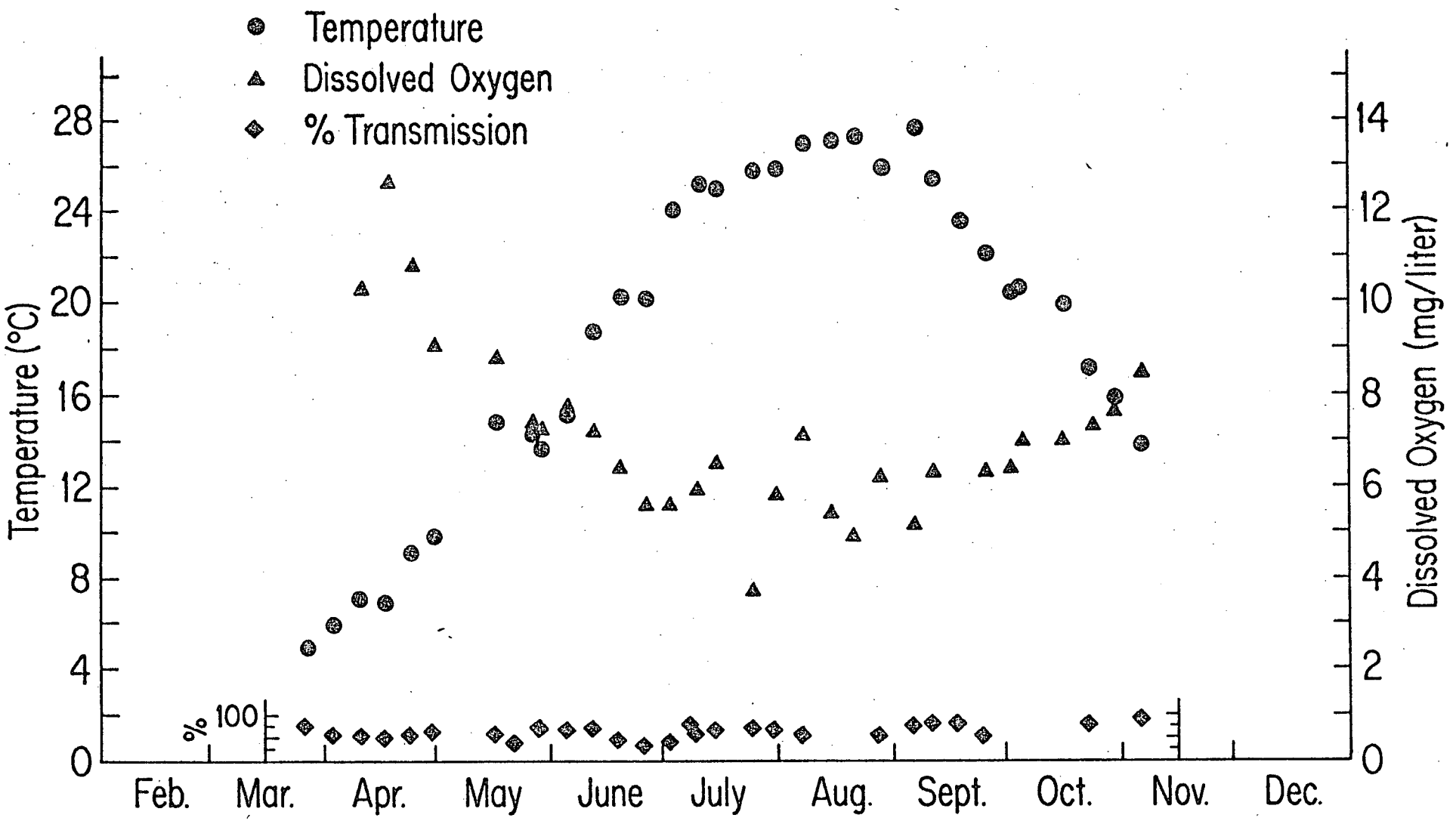

Figure 2-8. Water temperature, dissolved oxygen, and percent transmission (light) profiles for the Hudson River in the vicinity of Indian Point, 1973. The values shown are mean day and night surface, mid-depth, and bottom values for all stations on each sampling date.

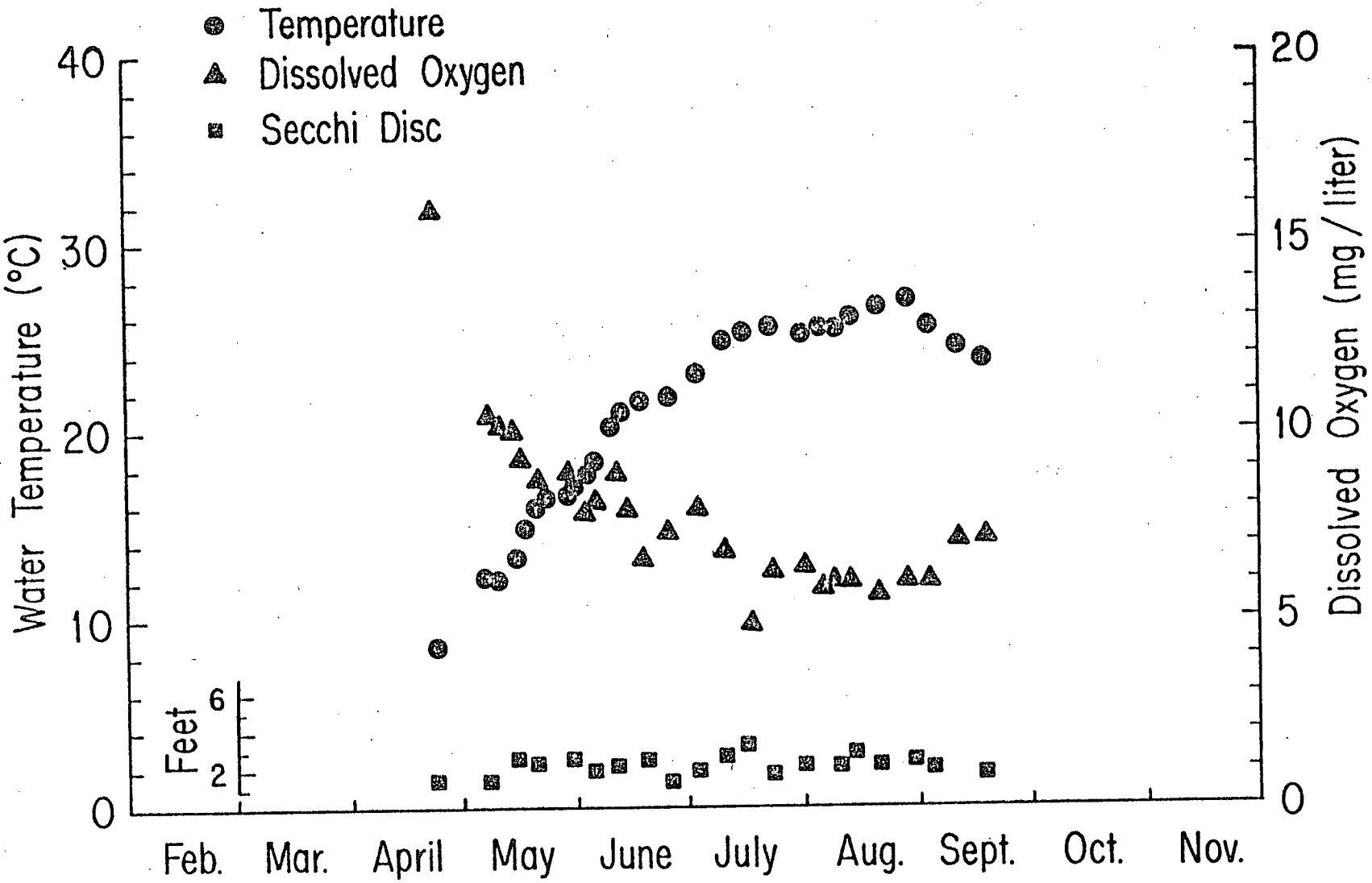

Figure 2-9. Water temperature, dissolved oxygen and Secchi-disc profiles for the Hudson River in the vicinity of Indian Point, 1974. The values shown are mean day and night surface, mid-depth and bottom values for all stations on each sampling date.

spawn (see Section 7). Many authors have noted the tendency for seasonally breeding fishes to time their spawning season by water, temperature, photoperiod and other reliable environmental cues (Rowan, 1926; Harrington, 1959; Collins, 1952; Hasler, 1966). To the extent that water temperature is critical for the migratory behavior and spawning of species such as striped bass, white perch, and various Clupeid species, the data on Hudson River water temperature in the vicinity of the Indian Point station show that operation of the Indian Point station and nearby power plants have not altered seasonal temperature regimes and, consequently, have not altered temperature as an environmental cue critical to spawning.

Dissolved oxygen data for the years 1972-1975 show a regular pattern of seasonal maxima and minima (Figures 2-2 and 2-3; 2-7 to 2-9). The lowest values of dissolved oxygen in the river were recorded in July of 1973 and 1974 (Figures 2-8 and 2-9). With the exception of 1973, when mean dissolved oxygen values were below 4.0 ppm in July, average values have not been below 5.0 ppm, a value considered critical for fishes.

The most variable environmental parameter in the Indian Point study area is salinity. The salinity at Indian Point is related primarily to freshwater discharge, and, as such, is affected profoundly by precipitation in the watershed, snowmelt, and the regulation of river flow at the Federal dam at Green Island in Troy.

The season during which salt concentrations are most likely to vary is the spring, due for the most part to variations in seasonal precipitation, and the annually variable quantity of snowmelt in the Hudson and Mohawk basins. In 1972, 1974 and 1975 (Figures 2-10, 2-11 and 2-5, respectively) salinities at Indian Point during the spring remained essentially zero as the result of high freshwater discharge in the Hudson Basin. In 1973 (Figure 2-10) freshwater discharge was sporadic, resulting in two salt intrusion events at Indian Point during which salinity reached values of approximately 2 o/oo.

The summer-fall salinity pattern is similar for 1972-1975. Salt intrusion generally begins in June and July as run-off decreases, and salinity values reach their maxima in late summer (August-September) declining thereafter as autumn rains increase freshwater discharge in the basin.

The variability in springtime salinity in the Hudson between Haverstraw Bay and Storm King Mountain may well be an important density-independent factor in population control of some anadromous forms, such as striped bass, being at least in part responsible for the phenomenon of variability in year-class strength (Texas Instruments, 1975) and as a determinant of the major sites of striped bass spawning in a given year.

The more predictable pattern of salinity observed during the late summer and fall also serves an important

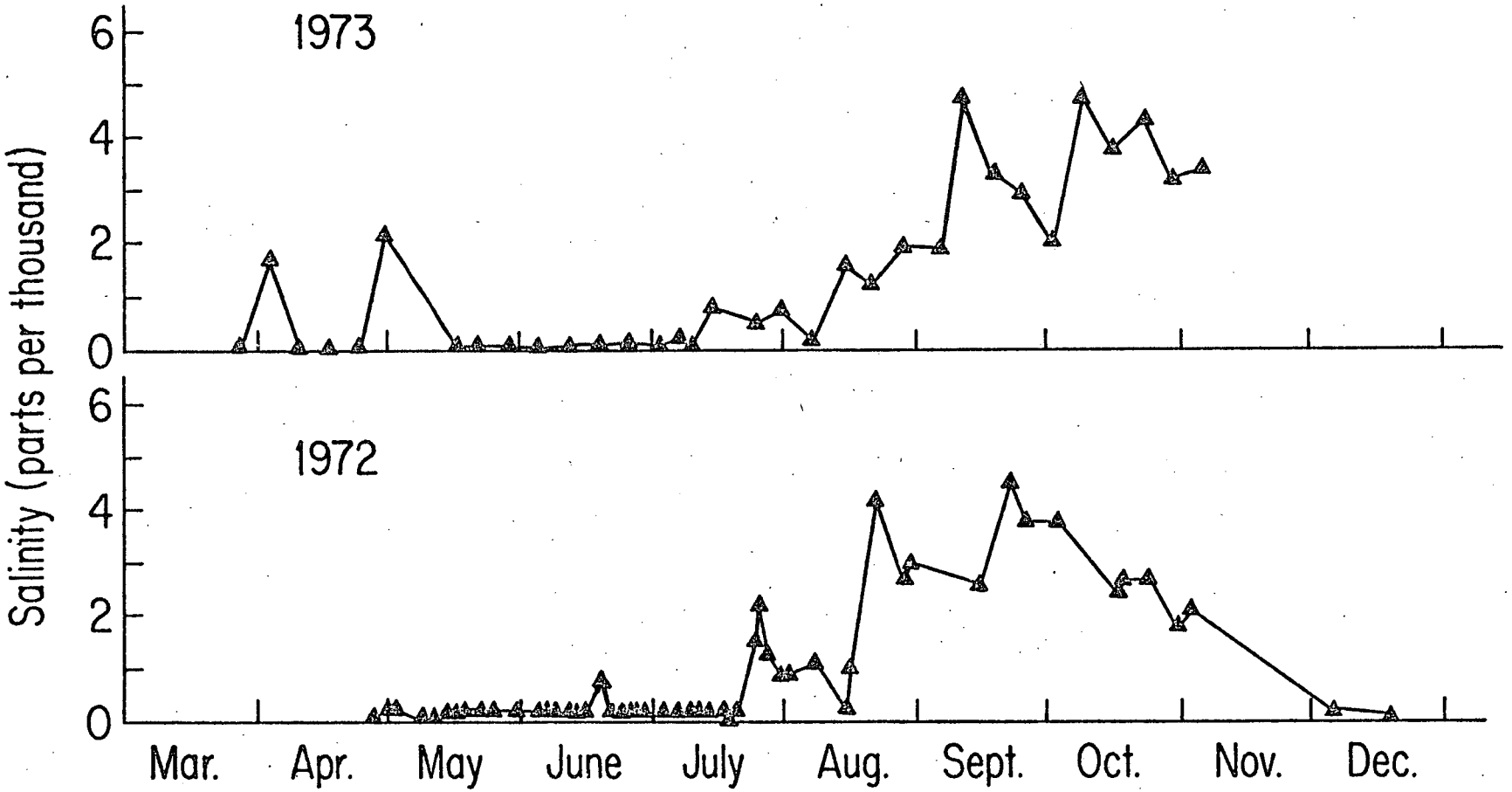

Figure 2-10. Salinity profiles for the Hudson River in the vicinity of Indian Point, 1972 and 1973. The values shown for 1972 are mean day and night surface, mid-depth, and bottom values for all stations on each date. The values shown for 1973 are means for all three depths and for all stations on each date, but based on daytime values only.

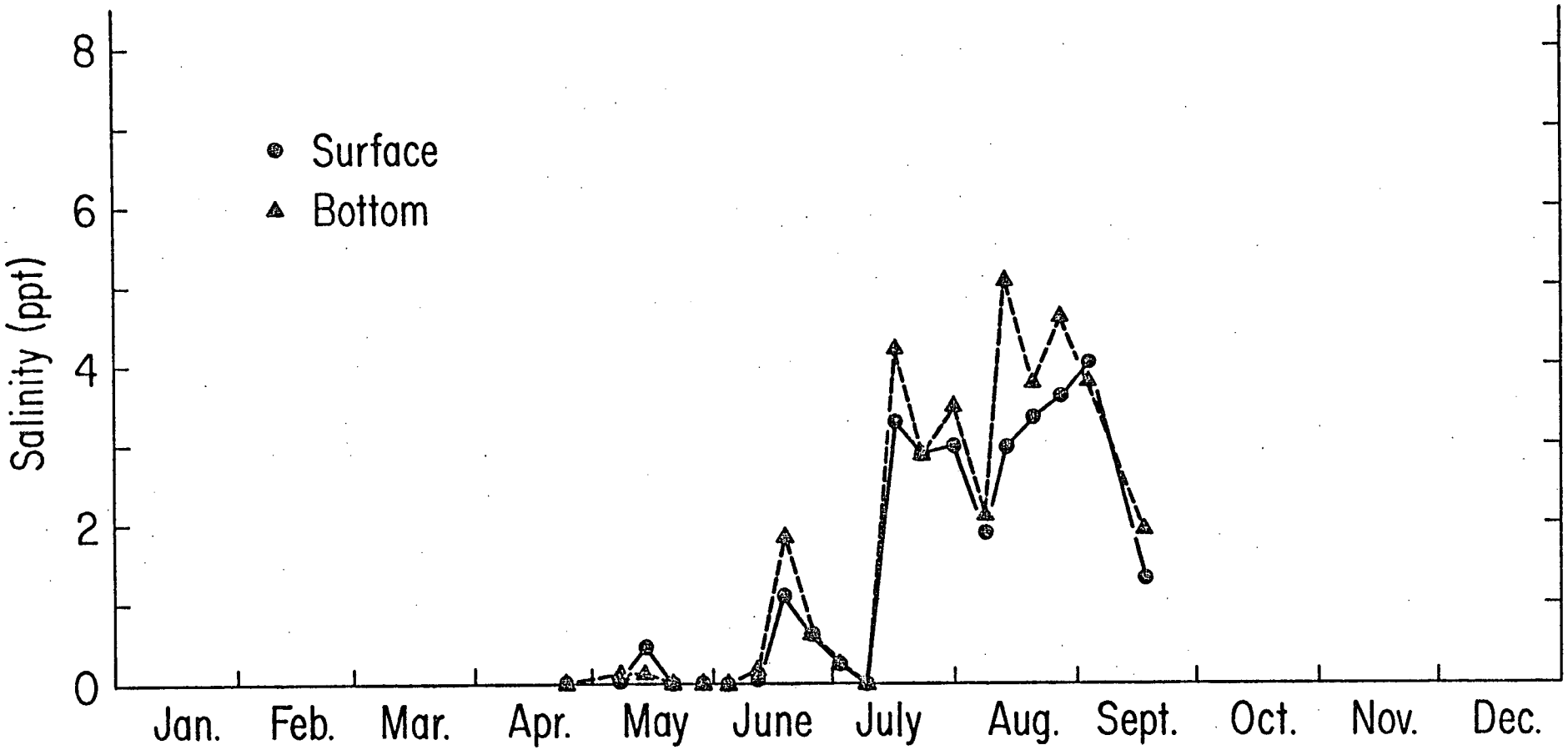

Figure 2-11. Salinity profiles for the Hudson River in the vicinity of Indian Point, 1974. The values shown are mean day surface and bottom values for all stations on each date.

function, making possible the upstream penetration of marine forms (bluefish, crevalle jack, etc.) to the extensive shoal water nursery grounds of the Tappan Zee and Haverstraw Bay.

3. BACTERIA

No bacteriological studies were done in 1975. The section designation for bacteria has been included so that the section numbering for each biological group will be consistent throughout this series of progress reports.

The 1971-72 progress report contains results of studies done in those years (New York University Medical Center, 1973).

4. PHYTOPLANKTON

4.1 River Phytoplankton Studies

4.1.1 Materials and Methods

Samples for phytoplankton population studies were collected biweekly during the spring and summer months at river stations A-G (Figure 1-7). Monthly samples were taken beginning in the fall and continuing through December. Sampling procedures were identical to those used in previous studies (New York University Medical Center, 1976a). The samples were preserved immediately with a modified Lugol's solution. Appropriate samples for cell counts and identification were filtered on gridded Millipore filters, cleared and fixed with Permount (Standard Methods, 1971; New York University Medical Center, 1974, 1976a).

Phytoplankton counts and identifications were made with a Zeiss photomicroscope at a magnification of 1560×. Individual diatoms and green algal cells and colonies were counted as single units. Filaments of blue-green and green algae occupying an entire microscope field were counted as two units. The usual practice was to count and identify approximately 300 units per slide; enumeration of more than 300 units per slide did not increase the sensitivity of the population analysis (New York University Medical Center, 1976a). Phytoplankton abundance per liter (X) was calculated

according to the formula $X = \frac{C}{(F \times P)}$ (New York University Medical Center, 1973), where:

C = specimens counted

F = fraction of filter counted

P = portion of sample filtered

Chlorophyll a content and light intensity values were measured weekly at the seven river locations adjacent to Indian Point (Figure 1-7). Collection techniques and chlorophyll extraction procedures were described previously (New York University Medical Center, 1976a). Data were analyzed using two-way factorial ANOVA.

4.1.2 Results

The concentrations of diatoms and green algae were similar among stations on any given date. Differences among dates were significant ($\alpha = 0.05$). Abundances of phytoplankton are presented in Tables 4-1 through 4-6. Phytoplankton abundance in whole water samples from 1972, 1974 and 1975 are shown in Figure 4-1.

Diatoms and green algae (including unidentifiable forms) were the dominant organisms in 1975 (Tables 4-7 through 4-11 and Figure 4-2). The percent composition (from counts) of the algal groups for the three-year period

Table 4-1 . Total and mean numbers of total phytoplankton (10^5) per liter in whole-river-water collection at station, A through G, with analysis of variance, 1975.

Date	A	B	C	D	E	F	G	Mean
4/28	4.39	3.70	4.55	5.26	4.48	2.59	4.21	4.17
5/12	15.90	16.02	14.35	13.99	11.02	15.55	20.67	15.36
5/26	50.10	71.26	72.67	95.40	60.90	93.30	124.50	81.16
6/17	8.37	7.36	6.02	7.55	7.92	10.21	10.26	8.24
6/23	21.75	15.85	15.43	18.75	23.40	20.18	23.27	19.80
7/07	56.14	69.75	91.85	90.00	82.35	150.53	196.20	105.26
7/28	24.28	27.60	21.45	28.87	27.30	27.15	16.64	24.75
8/11	18.71	18.21	22.95	24.22	23.55	21.15	25.65	22.06
9/15	17.23	14.94	16.20	13.41	14.53	16.06	27.82	17.17
10/13	11.22	9.18	11.45	12.03	18.54	14.31	12.26	12.71
11/17	7.65	5.99	7.92	6.43	8.37	6.86	4.60	6.83
12/09	6.04	4.67	5.12	4.50	5.15	4.78	6.81	5.31
Mean	20.15	22.04	24.16	26.70	23.96	31.89	39.41	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	.1217	6	.0203	2.14
Date	13.7960	11	1.2542	132.02 **
Error	.6248	66	.0095	

* P<0.05
** P<0.01

Table 4-2 . Total and mean numbers of diatoms (thousands) per liter in whole-river-water collections at stations A through G, with analysis of variance, 1975.

Date	A	B	C	D	E	F	G	Mean
4/28	367	311	379	448	394	224	361	355
5/12	1060	1073	860	864	780	1083	1400	889
5/26	1875	3102	2610	4740	2055	4080	4050	3216
6/17	300	326	369	345	371	388	345	349
6/23	960	747	666	841	667	680	826	770
7/07	4399	6424	7654	7897	6210	14258	18067	9273
7/28	534	743	563	637	735	735	540	641
8/11	714	776	1200	953	855	1223	1320	1006
9/15	828	653	657	563	585	1035	1387	815
10/13	298	327	332	242	599	369	277	349
11/17	473	379	467	402	502	396	281	414
12/09	469	356	377	317	390	335	515	394
Mean	1023	1268	1344	1521	1179	2067	2447	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.1122	6	0.0187	1.48
Date	13.9021	11	1.2638	100.30**
Error	0.8331	66	0.0126	

* $P<0.05$
** $P<0.01$

Table 4-3 . Total and mean numbers of green algae (thousands) per liter in whole-river-water collections at stations A through G, with analysis of variance, 1975.

Date	A	B	C	D	E	F	G	Mean
4/28	72	56	72	78	54	35	60	61
5/12	530	528	575	535	323	472	668	519
5/26	3135	4024	4657	4800	4035	5250	8400	4900
6/17	534	371	233	397	413	632	668	464
6/23	1193	815	873	1021	1650	1265	1495	1187
7/07	1204	551	1531	1103	2003	795	1507	1242
7/28	1090	1155	945	1477	1103	1207	821	1114
8/11	978	882	817	1207	1215	570	983	950
9/15	666	639	725	450	594	473	1177	675
10/13	759	558	779	906	1242	1003	934	883
11/17	265	202	298	220	259	254	162	237
12/09	129	109	129	125	122	143	164	132
Mean	879	824	969	1027	1084	1008	1420	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.1677	6	0.0280	2.07
Date	19.0827	11	1.7348	128.50**
Error	0.8928	66	0.0135	

* $P<0.05$
** $P<0.01$

Table 4-4 . Total and mean numbers of blue greens (thousands) per liter in whole-river-water collections at stations A through G, with analyses of variance, 1975.

Date	A	B	C	D	E	F	G	Mean
4/28	0.0	2.5	4.5	0.0	0.0	0.0	0.0	1.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/17	3.0	2.3	0.0	12.5	8.4	0.0	13.4	5.7
6/23	22.5	22.5	4.5	12.8	22.5	73.1	5.6	23.4
7/07	11.3	0.0	0.0	0.0	0.0	0.0	22.5	4.8
7/28	803.7	862.5	637.5	772.5	892.5	772.5	303.5	720.7
8/11	146.1	163.0	277.5	262.5	285.0	322.5	262.5	245.6
9/15	211.5	202.5	207.0	297.0	261.0	81.0	195.0	207.9
10/13	65.3	24.0	31.1	52.6	13.5	58.5	15.0	37.2
11/17	27.0	17.3	26.4	20.4	76.5	36.0	16.5	31.4
12/09	6.1	1.6	6.4	7.1	3.2	0.0	2.2	3.8
Mean	108.0	108.2	99.6	119.8	130.2	112.0	69.7	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Stations	6.2596	6	1.0433	0.96
Dates	348.3578	11	31.6689	29.21**
Error	71.5427	66	1.0840	

* $P<0.05$
** $P<0.01$

Table 4-5. Total and mean numbers of chrysophytes (thousands) per liter in whole-river-water collection at stations A through G, 1975.

Date	A	B	C	D	E	F	G	Mean
4/28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7/07	0.0	0.0	0.0	0.0	22.5	0.0	0.0	3.2
7/28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8/11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/15	9.0	0.0	31.5	27.0	9.0	18.0	22.5	16.7
10/13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11/17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12/09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.75	0.0	2.6	2.3	2.6	1.5	1.9	

Table 4-6. Total and mean numbers of euglenoids (thousands) per liter in whole-river-water collections at stations A through G, 1975

Date	A	B	C	D	E	F	G	Mean
4/28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/17	0.0	36.0	0.0	0.0	0.0	0.0	0.0	5.1
7/07	0.0	0.0	0.0	0.0	0.0	0.0	22.5	3.2
7/28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8/11	33.7	0.0	0.0	0.0	0.0	0.0	0.0	4.8
9/15	9.0	0.0	0.0	4.5	4.5	0.0	0.0	1.3
10/13	0.0	9.0	3.5	0.0	0.0	0.0	0.0	1.8
11/17	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.2
12/09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	3.6	3.7	0.3	0.4	0.4	0.0	0.2	

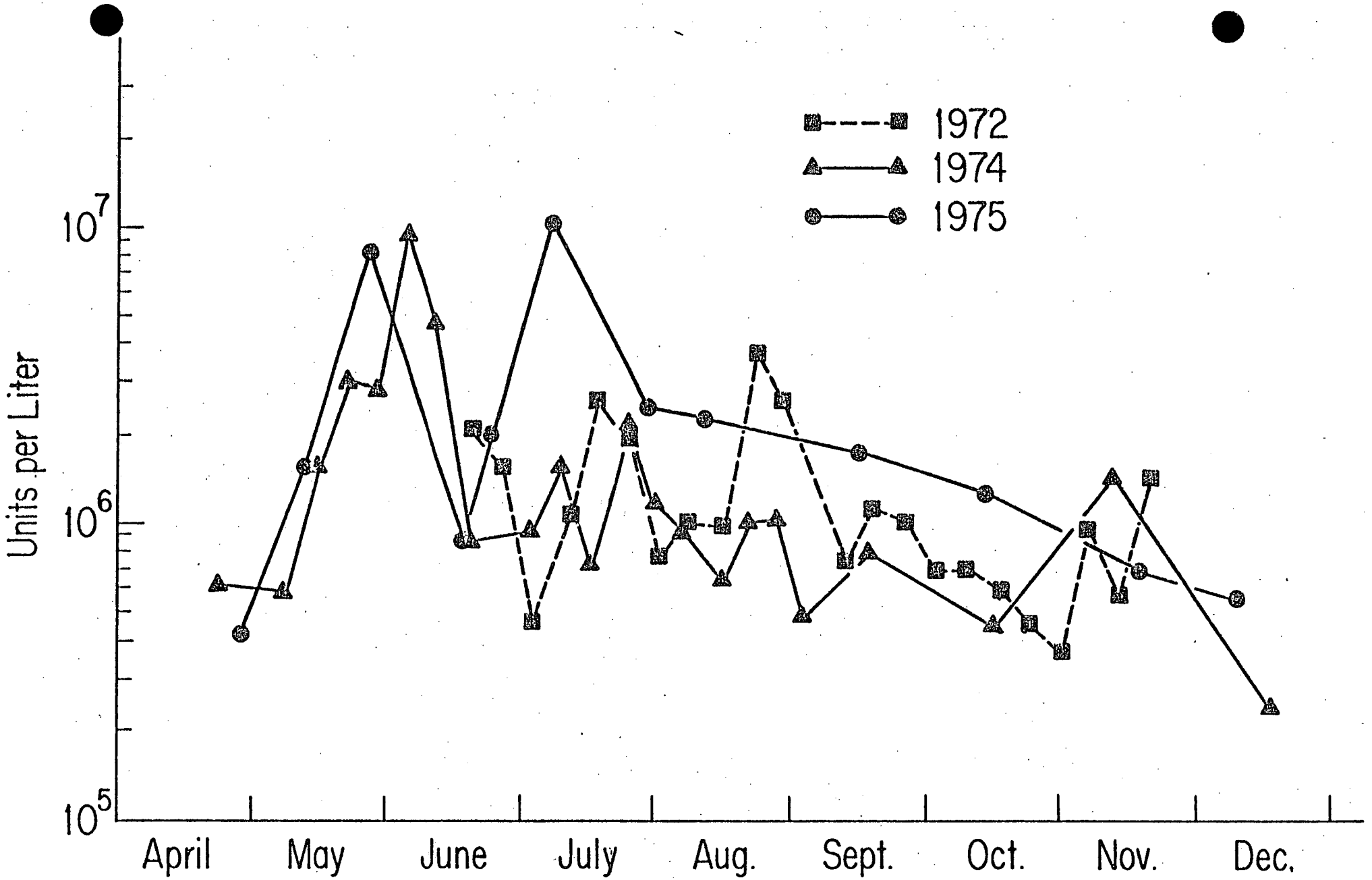

Figure 4-1. Total phytoplankton (units/liter) collected in whole- river-water samples (1972, 1974, 1975).

Table 4-7 . Percent composition of diatoms in whole-river-water collections at stations A through G, 1975.

Date	Stations A	B	C	D	E	F	G	Percent for Date
4/28	84	84	83	85	88	87	86	85.26
5/12	67	67	60	62	71	70	68	66.63
5/26	37	44	36	50	34	44	33	39.20
6/17	36	44	61	46	47	38	34	44.02
6/23	44	47	43	45	29	34	36	39.29
7/07	78	92	83	88	75	95	92	88.04
7/28	22	27	26	22	27	27	32	25.84
8/11	38	43	52	39	36	58	51	45.05
9/12	48	44	41	42	40	64	50	47.26
10/13	27	36	29	20	32	26	23	27.70
11/17	62	63	59	63	60	58	61	60.90
12/09	78	76	74	71	76	70	76	74.40

Table 4-8. Percent composition of green algae in whole-river-water collections at stations A through G, 1975.

	Stations							
Date	A	B	C	D	E	F	G	Percent for Date
4/28	16	15	16	15	12	13	14	14.37
5/12	33	33	40	38	29	30	32	33.37
5/26	63	56	64	50	66	56	67	60.80
6/17	64	50	39	53	52	62	65	54.62
6/23	55	51	57	54	71	63	64	59.74
7/07	21	8	17	12	24	5	8	11.76
7/28	45	42	44	51	40	44	49	44.50
8/11	52	48	36	50	52	27	38	43.59
9/15	39	43	45	34	41	29	42	39.08
10/13	68	61	68	75	67	70	76	69.28
11/17	35	34	38	34	31	37	35	34.72
12/09	21	23	25	28	24	30	24	25.03

Table 4-9. Percent composition of blue green algae in whole-river-water collections at stations A through G, 1975.

Date	Stations A	B	C	D	E	F	G	Percent for Date
4/28	0	1	1	0	0	0	0	0.37
5/12	0	0	0	0	0	0	0	0.00
5/26	0	0	0	0	0	0	0	0.00
6/17	0	0	0	2	1	0	1	0.55
6/23	1	1	0	1	1	4	0	1.14
7/07	0	0	0	0	0	0	0	0.00
7/28	33	31	30	27	33	28	18	28.93
8/11	8	9	12	11	12	15	10	10.90
9/12	12	14	13	22	18	5	7	12.67
10/13	6	3	3	4	1	4	1	2.99
11/17	4	3	3	3	9	5	4	4.53
12/09	1	0	1	2	1	0	0	0.73

Table 4-10. Percent composition of chrysophytes in whole-river-water collections at stations A through G, 1975.

	Stations							
Date	A	B	C	D	E	F	G	Percent for Date
4/28	0	0	0	0	0	0	0	0
5/12	0	0	0	0	0	0	0	0
5/26	0	0	0	0	0	0	0	0
6/17	0	0	0	0	0	0	0	0
6/23	0	0	0	0	0	0	0	0
7/07	0	0	0	0	0	0	0	0
7/28	0	0	0	0	0	0	0	0
8/11	0	0	0	0	0	0	0	0
9/15	1	0	2	2	1	1	1	1.13
10/13	0	0	0	0	0	0	0	0
11/17	0	0	0	0	0	0	0	0
12/09	0	0	0	0	0	0	0	0

Table 4-11. Percent composition of euglenoids in whole-river-water collections at stations A through G, 1975.

	Stations							
Date	A	B	C	D	E	F	G	Percent for Date
4/28	0	0	0	0	0	0	0	0
5/12	0	0	0	0	0	0	0	0
5/26	0	0	0	0	0	0	0	0
6/17	0	5	0	0	0	0	0	0.80
6/23	0	0	0	0	0	0	0	0
7/07	0	0	0	0	0	0	0	0
7/28	0	0	0	0	0	0	0	0
8/11	2	0	0	0	0	0	0	0.30
9/12	1	0	0	0	0	0	0	1.58
10/13	0	1	0	0	0	0	0	0.13
11/17	0	0	0	0	0	0	0	0
12/09	0	0	0	0	0	0	0	0

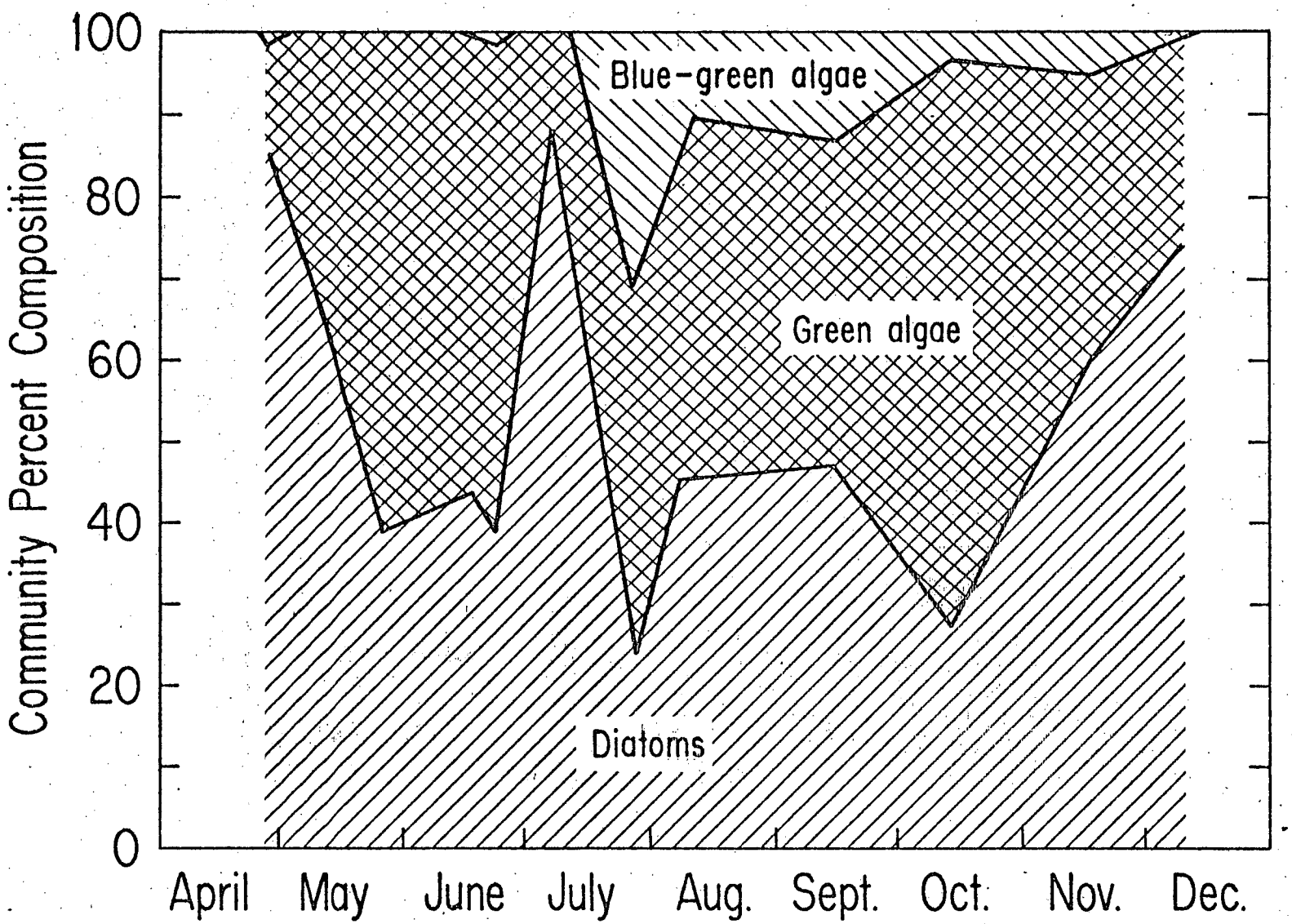

Figure 4-2. Percent composition of phytoplankton community in whole-river-water collections by algae groups, 1975.

previous to and including 1975 showed that algae other than diatoms and green algae were a minor portion of the phytoplankton community (Figure 4-2 and New York University Medical Center, 1974, 1975, 1976a).

One-hundred-thirty-five forms of algae were identified from the seven stations sampled in 1975 (Table 4-12). Of these, 89 species were from station D (located in front of the plant intakes; Figure 1-7), and 75 species were common to stations D and E. Eighty-six, 82, 90, 83 and 87 species were collected at river stations A, B, C, F and G, respectively. The most common species included the green coccoid, Cyclotella glomerata, other green algal forms (mainly Ulotrichales) and Nitzschia spp. (Table 4-12). The percent composition for the dominant algal groups represented in the vicinity of Indian Point (diatoms and green algae) are presented in Figure 4-3) for 1972, 1974 and 1975 where data are available. It is invalid to compare either total phytoplankton abundance or group percent compositions from 1971 with data from the later years because a different collection technique was used (see New York University Medical Center, 1976a).

The average chlorophyll a content for the seven river stations varied seasonally. An analysis of variance indicated a significant difference ($F = 83.5$; $\alpha = 0.05$) among dates. The chlorophyll a value for May 27 (9.97 mg chlorophyll a/m^3) was greater than that for all other dates. Values for

Table 4-12. Phytoplankton species collected at river stations A through G in 1975. The numbers shown are the numbers of collection dates when the species were found at each station.

Species	Stations A	B	C	D	E	F	G	Total
Bacillariophyta								
Achnanthes								
lanceolata (Breb.) Grun.	1	0	1	0	0	0	0	2
linearis (W. Sm.) Grun.	0	1	0	1	0	1	1	4
linearis var. curta H.L. Sm.	0	2	1	0	0	0	1	4
sp.	0	0	0	0	0	0	1	1
Amphiprora								
paludosa W. Sm.	0	0	1	0	0	0	1	2
Amphora								
ovalis Kuetz.	1	1	0	1	0	0	0	3
ovalis var. pediculus Kuetz.	0	0	1	0	0	0	1	2
Asterionella								
formosa Hass.	6	7	8	6	7	6	7	47
Cocconeis								
placentula Ehr.	0	0	1	1	0	0	0	2
placentula var. euglypta Ehr.	0	0	0	0	1	0	0	1
Coscinodiscus								
excentricus Ehr.	8	7	6	8	8	6	9	52
lacustris Grun.	0	1	3	1	0	1	1	7
perforatus type	8	11	8	8	9	9	11	64
sp.	3	1	0	0	0	2	1	7
Cyclotella								
comta (Ehr.) Kuetz.	1	2	1	1	0	1	1	7
glomerata Bachm.	12	12	11	12	12	12	12	83
kuetzingiana Thw.	2	4	3	2	2	3	2	18
meneghiniana Kuetz.	8	7	8	7	9	9	6	54
stelligera Cl. & Grun	1	1	1	0	0	1	0	4
striata (Kuetz.) Grun.	0	0	1	0	0	0	1	2
sp.	1	3	3	1	1	3	4	16
Diatoma								
tenue Ag.	0	0	1	1	1	1	0	4
tenue var. elongatum Lyngb.	0	1	2	0	0	0	0	3
vulgare Bory.	1	0	0	2	0	1	1	5
Diploneis								
smithii var. dilata (M. Perog.) Boyer.	1	0	1	1	0	1	2	6

Table 4-12 (cont.).

Species	A	B	C	D	E	F	G	Total
Fragilaria								
capucina Desm.	2	1	0	1	0	2	1	7
construens (Ehr.) Grun.	0	0	0	0	1	0	0	1
construens var. venter (Ehr.) Grun.	0	0	0	0	0	0	2	2
crotonensis Kitton	3	0	1	1	2	0	2	9
pinnata Ehr.	0	2	0	0	0	0	0	2
sp.	5	4	1	2	1	1	3	17
Frustulia								
rhomboides var. capitata (A. Mayer) Patr.	1	0	0	0	0	0	0	1
Gomphonema								
parvulum Kuetz	0	0	0	0	0	1	1	2
sp.	0	0	0	1	1	0	0	2
Gyrosigma								
macrum (W. Sm.) Griff. & Henfr.	1	1	0	0	1	0	0	3
spencerii (Quek.) Griff. & Henfr.	0	1	0	0	0	0	0	1
wormleyi (Sulliv.) Boyer	0	1	0	1	0	0	0	2
Melosira								
ambigua (Grun.) Muell.	7	7	7	5	5	7	6	44
sp. (auxospore)	0	0	0	0	0	1	0	1
distans var. alpigna Grun.	8	9	10	8	7	8	9	59
granulata (Ehr.) Ralfs.	1	4	1	2	1	1	1	11
granulata var. angustissima Muell.	2	0	2	1	2	2	3	12
italica (Ehr.) Kuetz.	6	2	4	3	4	6	5	30
varians Ag.	0	3	2	1	1	2	2	11
Meridion								
circulare (Greg.) Ag.	0	0	1	0	0	1	0	2
Navicula								
capitata Ehr.	5	8	5	8	8	6	9	49
cryptocephala Kuetz.	4	2	1	2	1	3	3	16
graciloides A. Mayer	0	0	0	0	0	0	1	1
menisculus var. upsaliensis (Grun.) Grun.	0	0	0	0	0	1	0	1
mournei Patr.	0	0	1	0	0	0	0	1
odiosa Wallace	0	0	0	1	0	0	0	1
peregrina (Ehr.) Kuetz.	1	1	1	1	1	1	2	8
pupula Kuetz.	0	0	1	0	0	0	0	1
rhynchocephala var. germainii (Wall.) Patr.	3	6	4	3	3	2	3	24
viridula var. avenacea (Breb. ex Grun.) V.H.	3	2	2	1	1	1	3	13
sp.	5	2	6	1	2	2	5	23

Table 4-12 (cont.).

Species	A	B	C	D	E	F	G	Total
Nitzschia								
accomodata Hust.	3	4	3	3	5	4	4	26
acicularis W. Sm.	1	2	1	0	0	0	0	4
amphibia Grun.	1	1	2	4	0	1	2	11
capitellata Hust.	2	1	2	3	2	2	1	13
closterium (Ehr.) W. Sm.	0	2	0	1	0	0	0	3
commutata Grun.	1	1	3	2	2	1	1	11
dissipata (Kuetz.) Grun.	1	0	0	0	0	1	0	2
fasciculata Grun.	0	0	1	0	0	0	1	2
fonticola Grun.	11	11	10	11	12	10	11	76
frustulum Kuetz.	1	0	0	0	0	0	0	1
holsatica Hust.	0	0	2	2	1	1	0	6
hungarica Grun.	1	1	0	0	0	0	0	2
kuetzingiana Hilse.	0	1	1	0	1	1	0	4
linearis W. Sm.	0	0	0	0	1	0	0	1
lorenziana Grun.	1	0	0	0	0	0	0	1
palea (Kuetz.) W. Sm.	0	1	2	0	3	1	0	7
romana Grun.	1	0	0	0	0	0	0	1
sigma (Kuetz.) W. Sm.	3	4	4	3	6	3	4	27
tryblionella var. debilis (Arn.) A. Mayer	3	5	4	5	5	5	5	32
tryblionella var. levidensis (W. Sm.) Grun.	3	4	5	5	5	4	7	33
tryblionella var. victoriae Grun.	1	1	0	0	0	0	0	2
sp. 1	0	0	1	0	1	1	0	3
spp.	9	12	9	10	11	10	11	72
Pinnularia								
sp.	0	0	0	0	1	0	0	1
Pleurosigma salinarum Grun.	1	0	0	2	0	0	1	4
Rhoicosphenia								
curvata (Kuetz.) Grun. ex. Rabh.	0	1	1	0	0	0	0	2
Stephanodiscus								
astraea (Ehr.) Grun.	6	7	5	6	6	6	2	38
astraea var. minutula (Kuetz.)	9	10	11	10	11	10	9	70
sp.	1	0	0	2	0	0	1	4
Surirella								
ovata Kuetz.	2	4	5	3	5	5	6	30
robusta Ehr.	0	0	0	1	0	0	0	1
spp.	0	0	1	0	0	0	0	1

Table 4-12 (cont.).

Species	A	B	C	D	E	F	G	Total
Synedra								
fasciculata var. truncata (Ag.) Kuetz.	0	0	0	0	1	0	0	1
pulchella Ralfs ex Kuetz.	0	0	0	0	0	1	0	1
rumpens Kuetz.	0	0	0	0	0	0	1	1
ulna (Nitz.) Ehr.	0	0	0	1	0	0	1	2
ulna var. longissima (W. Sm.) Brun.	1	1	2	0	0	1	1	6
sp.	1	0	0	1	2	1	1	6
Tabellaria								
fenestrata (Lyngb.) Kuetz.	2	1	1	3	0	2	2	11
Thalassiosira								
fluviatilis Hust.	1	3	2	2	1	2	2	13
sp.	0	2	0	4	1	1	2	10
Unidentified diatoms	10	9	8	9	8	10	7	61
Chrysophyta								
Dinobryon	1	0	1	1	2	1	1	7
Euglenophyta								
Euglenoids	2	2	1	1	1	0	0	7
Phacus								
longicauda (Ehr.) Dujardin	0	0	0	0	0	0	2	2
Chlorophyta								
Actinastrum								
hantzschii Lagerh.	6	6	6	5	6	5	4	38
Ankistrodesmus								
falcatus (Corda) Ralfs.	4	6	7	8	7	4	6	42
Closteriopsis								
longissima Lemm.	0	3	1	1	0	0	1	6
Crucigenia								
apiculata (Lemm.) Schmidle	0	1	0	0	0	0	0	1
fenestrata Schmidle	1	0	0	1	0	0	0	2
tetrapedia (Kirch.) West & West	5	4	4	5	5	9	7	39
Kirchneriella								
lunaris (Kirch.) Moebius	2	1	1	0	1	1	3	9
sp.	0	0	0	1	0	0	0	1
Pandorina								
sp.	0	0	0	1	0	0	0	1

Table 4-12 (cont.).

Species	A	B	C	D	E	F	G	Total
Scenedesmus								
acuminatus (Lag.) Chodat.	2	0	0	0	0	0	0	2
arcuatus Lemm.	0	0	0	0	1	0	0	1
denticulatus Lager.	1	0	1	0	0	0	0	2
dimorphus (Turp.) Kuetz.	1	1	3	2	2	1	2	12
dispar Breb.	0	0	1	1	0	0	1	3
opoliensis P. Richter	0	0	1	0	0	0	0	1
quadricauda (Turp.) Breb.	7	7	10	9	9	8	9	59
2 cell sp.	6	6	7	7	7	7	7	47
sp.	11	5	6	11	9	9	10	61
Staurastrum								
sp.	1	0	1	2	0	0	0	4
Tetraedon								
caudatum (Corda) Hansgirg	2	1	1	1	4	3	3	15
trigonum var. gracile (Reinsch) DeToni	2	1	3	1	1	2	4	14
sp.	3	2	1	1	1	1	2	11
Unidentified green coccoid unicells	12	12	12	12	12	12	12	84
Green colonies (4 cells)	10	12	11	11	10	9	10	73
Green colonies (8 cells)	7	7	6	8	5	7	7	47
Green colonies (≥ 10 cells)	8	5	8	8	6	7	7	49
Green filaments	9	6	6	7	6	5	5	44
Unidentified green algae	11	12	12	12	11	12	10	80
Cyanophyta								
Anabaena								
circinalis Roben	2	1	0	1	1	1	1	7
sp.	1	0	3	1	2	1	1	9
Gloeocapsa								
sp.	1	0	0	1	0	0	0	2
Blue green trichomes	8	9	7	8	7	6	6	51
Blue green colonies	8	4	5	8	5	4	6	40
Miscellaneous								
Gonyaulax, Gymnodinium and/or Peridinium	0	0	0	1	0	0	0	1

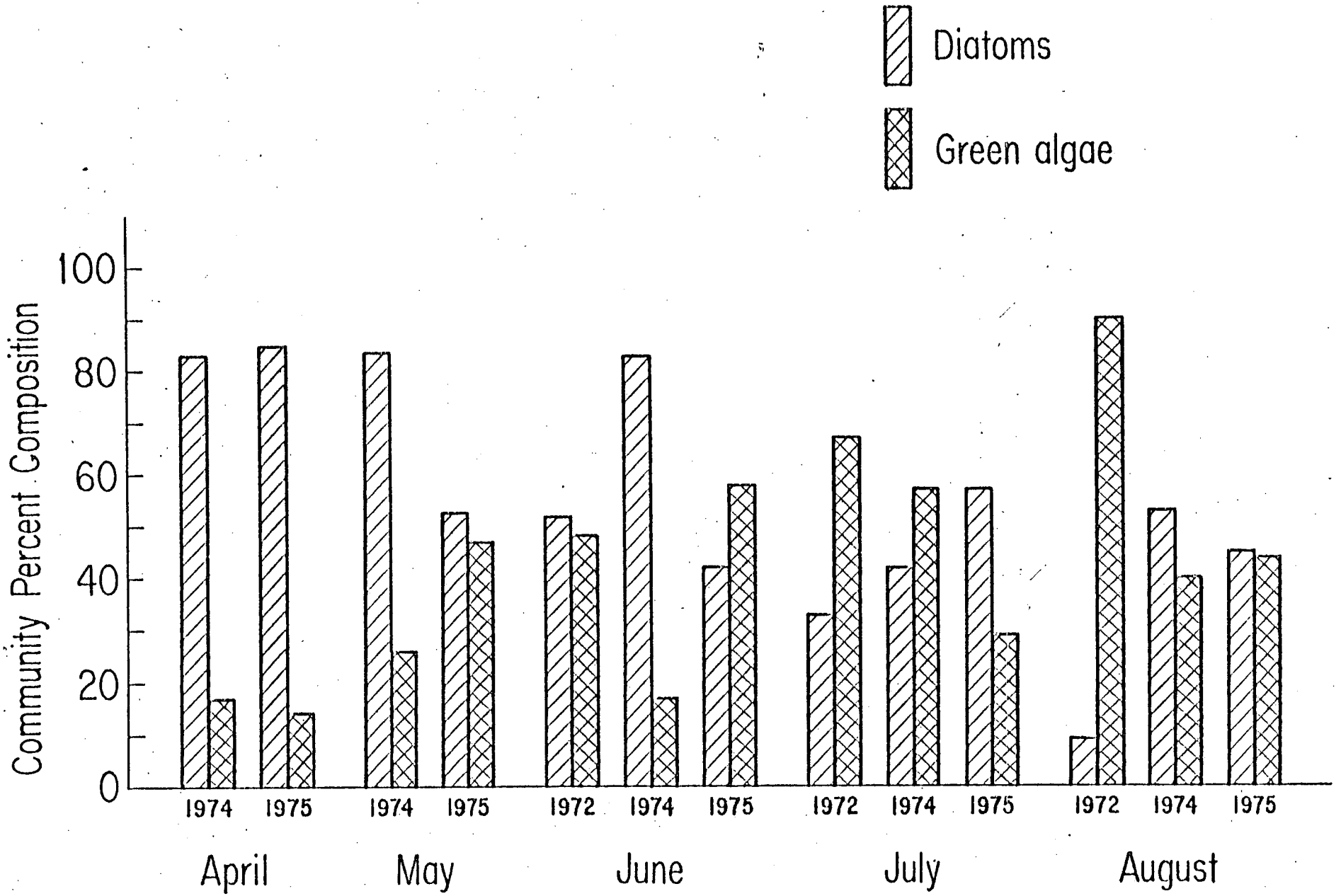

Figure 4-3. Community percent compositon of diatoms and green algae for whole-river-water collections (1972, 1974, 1975).

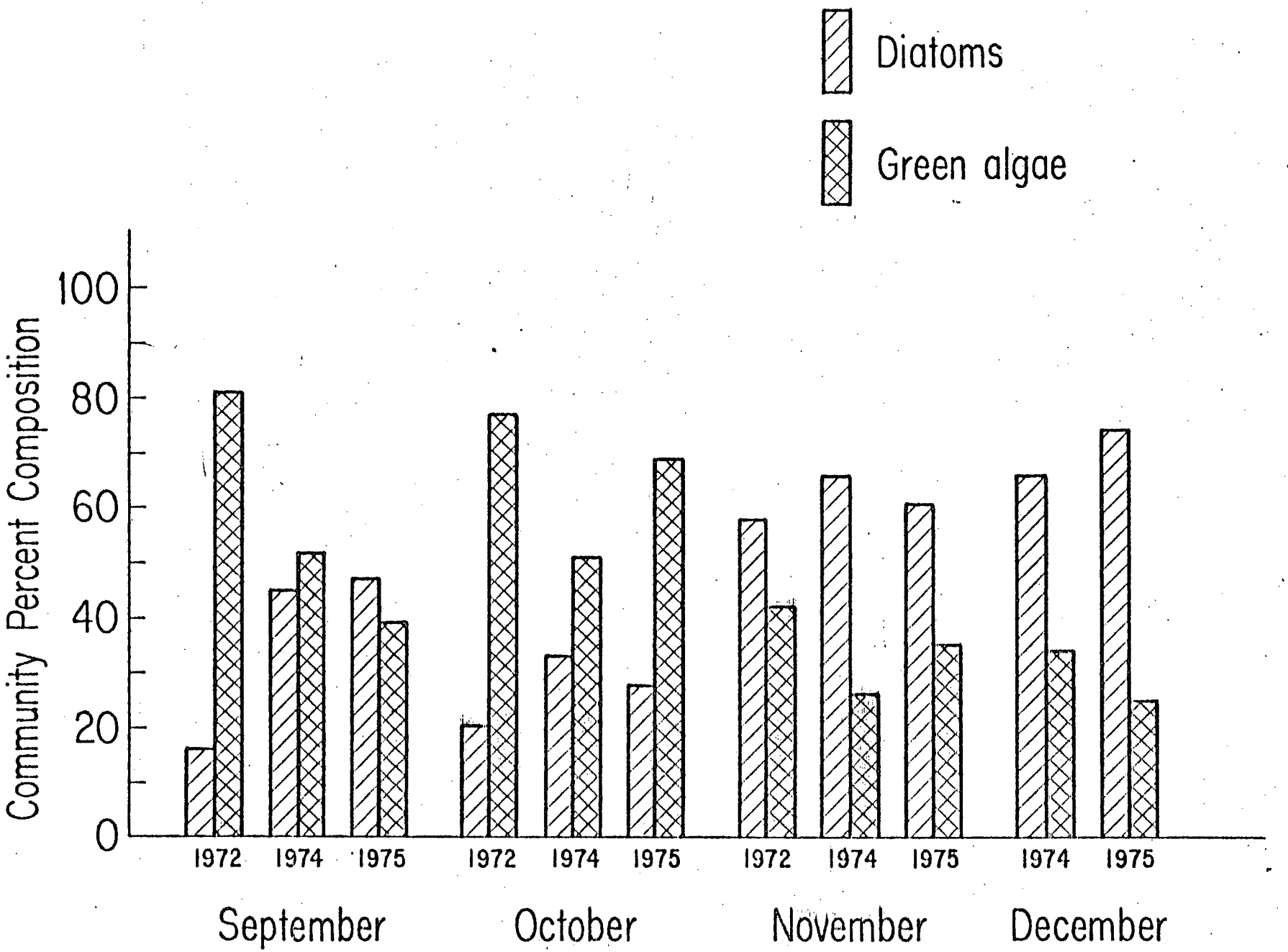

Figure 4-3 (cont.).

July 7 (5.48 mg chlorophyll a/m^3) and October 13 (4.99 mg chlorophyll a/m^3) were not different and were greater than the remaining dates. Chlorophyll values for 1975 were 75% greater than those reported for 1974 (Table 4-13 and New York University Medical Center, 1976a).

Peak chlorophyll concentrations normally appear during the spring and fall in the vicinity of Indian Point. The peak values for 1975 occurred earlier than in 1974 (May and October, 1975, versus June-July and October-November, 1974). This may be attributed partially to the warmer ambient spring river temperatures during 1975. There was an additional summer peak during 1975 (July 28; 6 mg chlorophyll a/m^3). The overall increase in chlorophyll values observed in 1975 is the result of these higher spring and fall values, plus the additional chlorophyll peak in July.

Correlation analysis indicated that chlorophyll a values in 1975 were positively correlated with total phytoplankton abundance (units/liter; $r = 0.6$; $\alpha = 0.05$) and specifically with the occurrence of green algae ($r = 0.92$). There was no correlation of chlorophyll a values with any measured physical (light intensity, temperature) or chemical (dissolved oxygen, pH, salinity) parameters on a yearly basis.

While there were no significant differences in yearly averages of chlorophyll a among the river stations, an

Table 4-13. Chlorophyll "a" and Light transmission values for the Hudson River in the vicinity of Indian Point, 1975.

		Chlorophyll "a"			Light
Date	Station	$mgchl/m^3$	S.E.*	Results of Anova and Schefe' test α=.05	1% transmission Depth (meters)
4/28	A	0.76	±0.04	N.D.	1.1
	B	0.81	±0.05		1.1
	C	0.92	±0.08		1.1
	D	2.94	±0.89		1.1
	E	0.82	±0.03		1.1
	F	0.82	±0.04		0.9
	G	1.08	±0.11		0.9
5/12	A	2.46	±0.71	N.D.	
	B	1.88	±0.14		
	C	2.30	±0.51		2.1
	D	2.02	±0.96		1.5
	E	1.97	±0.13		1.5
	F	1.93	±0.01		2.7
	G	2.15	±0.12		2.4
5/27	A	10.43	±0.59		2.4
	B	10.43	±0.78		2.3
	C	9.75	±0.24		2.9
	D	4.88	±0.60	D<all stations	2.4
	E	11.69	±0.39		1.8
	F	10.88	±0.04		2.3
	G	12.15	±1.35		2.7
6/17	A	3.58	±0.17	N.D.	2.1
	B	3.56	±0.03		2.0
	C	3.43	±0.09		2.1
	D	2.76	±0.23		2.1
	E	2.66	±0.44		1.5
	F	2.96	±0.15		2.3
	G	2.77	±0.92		1.8

*df= 2 for all stations on all dates except 5/12, 5/27 and 6/17
df= 1 for all stations on 5/12, 5/27 and 6.17

Table 4-13(cont.).

Date	Station	Chlorophyll "a" mgchl/m^3	S.E.*	Results of Anova and Schefe' test α=.05	Light 1% transmission Depth (meters)
6/23	A	4.71	±0.49	N.D.	2.3
	B	3.96	±0.17		2.6
	C	3.45	±0.86		2.3
	D	3.03	±0.22		2.1
	E	3.96	±0.10		1.7
	F	3.90	±0.30		2.7
	G	4.53	±0.27		2.4
7/07	A	3.18	±0.34		3.8
	B	2.91	±0.07		3.4
	C	4.06	±0.33		3.6
	D	2.34	±0.22	D<C	2.9
	E	2.95	±0.18		2.7
	F	4.63	±0.29	F>BDE	3.4
	G	7.69	±0.52	G>all stations	2.4
7/28	A	6.21	±0.52	N.D.	2.7
	B	5.91	±0.49		2.9
	C	6.34	±0.21		2.7
	D	5.69	±0.35		2.3
	E	6.05	±0.41		2.3
	F	5.75	±0.16		2.6
	G	5.94	±0.18		2.7
8/11	A	3.12	±0.23	N.D.	2.3
	B	3.07	±0.24		2.3
	C	2.46	±0.09		2.4
	D	2.89	±0.23		2.3
	E	2.84	±0.25		1.8
	F	2.58	±0.13		2.0
	G	2.41	±0.17		1.9

*df= 2 for all stations on all dates except 5/12, 5/27 and 6/17
df= 1 for all stations on 5/12, 5/27 and 6/17

Table 4-13 (cont.).

Date	Station	Chlorophyll "a" mgchl/m^3	S.E.*	Results of Anova and Schefe' test α=.05	Light 1% transmission Depth (meters)
9/15	A	1.38	±0.11	N.D.	2.3
	B	1.22	±0.10		2.7
	C	1.50	±0.06		2.3
	D	1.44	±0.03		2.1
	E	1.60	±0.11		2.1
	F	1.64	±0.15		2.3
	G	1.58	±0.13		3.0
10/13	A	6.19	±0.31	N.D.	2.6
	B	5.52	±0.11		2.4
	C	4.70	±0.69		2.6
	D	4.58	±0.59		2.3
	E	5.08	±0.11		2.1
	F	5.17	±0.06		2.4
	G	3.67	±0.39		2.6
11/17	A	1.92	±0.01		1.7
	B	1.58	±0.18	B<CDG	1.8
	C	3.78	±0.09	C>all stations	1.8
	D	2.82	±0.19	D>A	1.7
	E	2.02	±0.25		1.6
	F	2.11	±0.23		1.7
	G	2.63	±0.05		1.5
12/09	A	0.53	±0.02	N.D.	2.4
	B	0.46	±0.03		2.4
	C	0.55	±0.04		2.1
	D	0.43	±0.11		2.4
	E	0.68	±0.06		2.4
	F	0.50	±0.06		2.1
	G	0.46	±0.09		2.1

*df= 2 for all stations on all dates except 5/12, 5/27 and 6/17
df= 1 for all stations on 5/12, 5/27 and 6/17

analysis of variance of individual dates (Table 4-13) indicated that there were significant differences among stations on May 27, July 7 and November 17. The chlorophyll a differences noted on May 27 and November 17 did not correlate with any of the biological or physical and chemical parameters observed. There was a strong positive correlation on July 7 between chlorophyll a and units/liter ($r = 0.89$) and euglenophytes ($r = 0.92$). On this date there was also a positive correlation between chlorophyll and dissolved oxygen ($r = 0.80$).

4.1.3 Discussion

Hutchinson (1967) discussed phytoplankton assemblages as cohabitants in a system in which a number of species are competing for resources with slightly varying efficiencies. The result is a series of seasonally dominant organisms not necessarily existing in equilibrium. Unbalanced specific populations, predation, symbiosis, and nutrient variation are mechanisms of diversifying phytoplankton populations (Hutchinson, 1967; Margalef, 1968).

Phytoplankton community structure is correlated with various interacting environmental factors including temperature, water quality, incident light, and available nutrients (Riley, 1946; Patrick, 1968), any one of which may be limiting. Physiological rates and functions inherent in phytoplankton communities may be used to define and es-

tablish steady-state levels of existence. Knowledge of the influence of natural responses to physical and chemical environmental parameters allows the prediction of recovery rates in response to man-made perturbations (Loftus, et al., 1972).

The aim of the five-year examination of the phytoplankton in the vicinity of Indian Point was to elucidate the effects of the power plant on these communities. The seven river stations (Figure 1-7) were selected strategically to sample algal assemblages before and after plant entrainment.

The percent composition of the dominant algal groups in 1971 (diatoms and green algae) resembled the seasonal sucession patterns observed in 1972, 1974 and 1975, despite a change from net sampling (1971) to whole-water sampling (1972, 1974 and 1975). There was a large diatom pulse in April, May and June which accounted for 80-95% of the phytoplankton collected and a smaller peak in October (diatoms comprising about 40% of the phytoplankton). A large percentage of the community (40% from mid summer through November) was green algae (New York University Medical Center, 1974). A change to whole water sampling with the use of a pump in the 1972 collections increased the detection level of phytoplankton abundance (units/liter) by an order of magnitude from peak values of about 10^6 per liter to peak values of 10^7 per liter (New York University Medical Center, 1976a). Inspection

of the 1972 species list revealed several algal forms smaller in size than the 35 μm mesh of the collection nets used in 1971. Percent composition of the phytoplankton community in 1972 was similar to that in 1971; diatoms and green algae were the dominant forms (New York University Medical Center, 1974).

The algal community in 1974 was characterized by diatom peaks in May and June (80-90%) and again in November (70%). Blue-green algae and other algal forms were a relatively small portion of the community (New York University Medical Center, 1976a).

Whole-water phytoplankton abundance in 1972 and 1974 showed a maximum abundance in early summer (10^6 units/liter) and declined to values slightly less than 10^6 units/liter in late summer and early fall. In 1975, phytoplankton peaks occurred in May and July, reaching a maximum of 10^7 units/liter. Subsequent months were characterized by a gradual decline in phytoplankton abundance. Community structure in 1975 followed a pattern similar to that observed in previous years' studies; diatoms and green algae were the dominant groups. Diatom peaks were seen in late April and July, in each case making up 85% of the population. The fall diatom pulse began in mid October and increased steadily through the months of November and December.

The numbers of algal species within riverine systems are usually consistent from one river to another (Patrick, 1961), although the species and abundances may differ depending on the inherent water quality. The abundance of Hudson River phytoplankton from 1971 through 1975 suggests that at Indian Point, the Hudson River is a typical Atlantic coastal estuary which supports a highly productive microflora and shows few blooms of noxious algae (New York University Medical Center, 1974, 1976a; Quirk, Lawler and Matusky, 1974; Lawler, Matusky and Skelly Engineers, 1975, 1976).

The fact that temperature increases may cause either stimulation or inhibition of photosynthesis has been shown to be dependent on ambient water temperature (Sorokin, 1971; Morgan and Stross, 1969; Patrick, 1974). Algae in cool waters receiving slight thermal increases usually increase carbon uptake and primary productivity if the optimum growth temperature of the community is not exceeded. At higher, summer temperatures when the upper temperature limit of the algae is approached, carbon uptake and production may be inhibited by thermal increases (Morgan and Stross, 1969).

Analysis of variance showed phytoplankton abundances at the seven river stations in 1975 to be similar. Species occurrence determined for these collections was similar (86, 82, 90, 89, 75, 83 and 84 species, respectively, for stations A through G). Collections made at the Indian Point plant

intake and at the plant discharge showed no detectable effects of temperature stress on algal biomass or species diversity. Of the 89 phytoplankton species identified from station D (intake station) and the 75 forms identified at station E (in the discharge plume), 64 were common to both stations. This similarity of species does not preclude the possible existence of resident populations in the discharge canal or the discharge plume. Patchiness may also explain the different phytoplankton species found at the intakes and at the discharge area.

The seasonal pattern of chlorophyll a values appear to reflect phytoplankton abundance with point source variations. These local variations in chlorophyll a might be used to indicate changes in the species composition or abundance of the phytoplankton population as they may reflect seasonal changes in the chemical and physical environment of the Hudson River proper.

Patrick (1974) did not notice a significant difference in algal species composition or abundance above and below the power station at Chalk Point, Maryland (8 C, 46.4 F ΔT_ or at a power station with effluent water (8-9 C, 46.4-48.2 F ΔT) in the Potomac River. Similarly, Indian Point Unit 2 (ΔT 9.4 C, 48.9 F) did not cause noticeable reductions in phytoplankton assemblages in the receiving waters. Only a small percentage (approximately 1%) of the total

flow (freshwater discharge plus tidal exchange) of the Hudson River is pumped into the cooling water system at Indian Point (870,000 gpm for full flow). As a result, the effect of plant entrainment on the total phytoplankton population is negligible.

4.2 ENTRAINMENT EFFECTS STUDIES

4.2.1 Introduction

Since entrainment involves mechanical, chemical and thermal perturbations, investigations were conducted to determine the effects of each of these together and separately on entrained phytoplankton. These studies were directed at determining 1) if passage through the plant affected the organisms directly (i.e. disruption or disintegration) and 2) if plant passage affected the physiological status of the entrained population by altering the integrity of the primary photosynthetic pigment, or by altering the mechanism of photosynthesis.

Direct (physical) effects were studied by using estimates of the phytoplankton populations collected at sampling sites in the Unit II intakes and condenser water boxes, the discharge canal, the discharge plume and in the river at a "control" location away from plant influences. The discharge plume is defined as that body of water outside the discharge port area, still recognizable as having passed through the plant, based upon temperature gradients.

Indirect (physiological) effects were studied by using estimates of chlorophyll a concentration and photosynthetic capacity. The latter was determined from the rate of ^{14}C-uptake by mixed cultures of algae collected from stations in the Unit 2 intakes and condenser water boxes, the discharge

canal, the discharge plume and in the river at a "control" location away from plant influences.

4.2.2 Methods

Subsamples of phytoplankton samples used for population studies (direct effects) were removed and prepared for species enumeration following the method described for the river population study (Section 4.1). The samples were filtered on Millipore filters and dried in a desiccator over silica-gel prior to the preparation of permanent slides. Data were analyzed using a two-way analysis of variance (α = 0.05) as per Sokal and Rohlf (1969).

Chlorophyll a concentrations were determined by measuring the fluorescence of the acetone extract from a second set of subsamples (Strickland and Parsons, 1972; New York University Medical Center, 1976a). Photosynthesis was determined in experiments using ^{14}C as a tracer to estimate carbon uptake in mixed algal cultures under standard incubation conditions; the techniques used have been described previously (New York University Medical Center, 1976a).

4.2.3 Results and Discussion

4.2.3.1 Abundance of Entrained Algae

Phytoplankton taxa collected at the entrainment stations were similar to those taken at the river sampling sites

(Table 4-14); diatoms were the dominant forms. The total of 126 forms observed included 94 diatoms, 19 chlorophytes (greens), 5 cyanophytes (blue-greens), and 8 miscellaneous forms. The frequency of occurrence for the phytoplankton collected at each station is also given in Table 4-14. Eighty-two forms were observed at the intake station (II), 84 at the condenser station (C), 91 in the discharge canal (D), 85 in the plume (P), and 93 at the "control" river station (R). Sixty forms (48%) were common at all stations. The most common species observed were unidentified "green" colonies and coccoid unicells, and the diatoms Cyclotella glomerata, Melosira distans var. alpigena and Nitzschia spp.

The total and mean concentrations of phytoplankton for each collection date and for the 24-h holding period (second dates) are shown in Table 4-15 and Figure 4-4. Cell densities ranged from a mean of 0.33 $\times 10^6$ units/liter in April to 4.5 $\times 10^6$ units/liter in May.

Analysis of variance indicated no significant differences among stations, although a significant difference among dates was found ($\alpha = 0.01$; Table 4-15). Similar results were obtained for green algae; mean cell densities were 0.06 $\times 10^6$ units/liter in April and 2.5 $\times 10^6$ units/liter in May. Diatom abundance ranged from a low of 0.01 $\times 10^6$ units/liter in September to approximately 2.1 $\times 10^6$ units/liter in May.

Table 4-14. Assigned frequency of occurrence for phytoplankton species collected during entrainment sampling at Indian Point and at a "control" location in the river in 1975. The numbers shown are the numbers of collection dates in which the species were found at each station. II = Unit II intake, C = Unit II condenser water box, D = Discharge canal, P = Discharge plume, R = "Control" location in the river. Samples were taken on 8 dates between April and December.

Species	Stations II	C	D	P	R	Total
Bacillariophyta						
Achnanthes						
lanceolata (Breb.) Grun.	3	0	0	0	0	3
spp.	2	2	1	1	1	7
Amphiprora sp.	0	0	1	0	1	2
Asterionella						
formosa Hass.	11	11	12	11	9	54
Cocconeis						
placentula Ehr.	1	0	1	2	1	5
placentula var. euglypta Ehr.	0	0	0	1	0	1
placentula var. lineata (Ehr.) V.H.	1	0	0	0	0	1
spp.	0	0	0	1	1	2
Coscinodiscus						
excentricus Ehr.	11	11	13	12	12	59
lacustris Grun.	1	2	5	3	1	12
perforatus type	7	7	10	10	6	40
Cyclotella						
comta (Ehr.) Kuetz.	0	2	0	1	1	4
glomerata Bachm.	14	16	12	14	15	71
meneghiniana Kuetz.	13	11	14	15	13	66
stelligera Cl. & Grun.	1	2	1	1	0	5
spp.	12	10	12	9	10	53
Cymbella						
ventricosa Kuetz.	0	1	1	0	4	6
sp.	0	0	1	0	0	1
Diatoma						
anceps (Ehr.) Kirch. var. anceps	1	1	1	2	2	7
tenue Ag.	0	2	0	0	1	3
tenue var. elongatum Lyngb.	0	0	0	0	2	2
vulgare Bory.	2	4	3	2	1	12
Diploneis						
smithii var. dilatata (M. Perag.) Boyer	0	1	0	1	0	2

Table 4-14 (cont.)

Species	II	C	D	P	R	Total
Eunotia						
curvata (Kütz.) Lagerst var. curvata	0	0	0	1	0	1
Eragilaria						
brevistriata Grun.	0	1	0	0	2	3
capucina Desm.	0	2	3	0	2	7
crotonensis Kitton	6	3	6	3	2	20
vaucheriae (Kuetz.) Peters.	0	1	1	1	2	5
spp.	3	1	3	2	3	12
Gomphonema						
olivaceum (Lyng.) Kuetz.	1	1	0	0	2	4
spp.	2	0	1	1	1	5
Gyrosigma						
attenuatum (Kuetz.) Rabh.	0	0	0	0	1	1
distortum (W. Sm.) Griff. & Henfr.	0	0	0	1	0	1
macrum (W. Sm.) Griff. & Henfr.	0	1	2	0	0	3
wormleyi (Sulliv.) Boyer	1	0	0	0	0	1
Hannea						
arcus (Ehr.) Patr.	0	0	0	1	1	2
Melosira						
ambigua (Grun.) Muell.	2	3	1	0	3	9
distans var. alpigena Grun.	14	15	15	14	16	74
granulata (Ehr.) Ralfs.	3	1	1	4	3	12
granulata var. angustissima Muell.	4	3	3	4	1	15
italica (Ehr.) Kuetz.	12	11	14	14	13	64
varians Ag.	1	3	2	3	8	17
Meridion						
circulare (Greg.) Ag.	1	0	1	1	0	3
Navicula						
capitata Ehr.	9	8	10	12	7	46
cryptocephala Kuetz.	8	9	11	10	12	50
lanceolata (Ag.) Kuetz.	0	1	0	0	0	1
menisculus var. upsaliensis (Grun.) Grun.	0	0	1	0	0	1
peregrina (Ehr.) Kuetz.	4	6	4	3	2	19
radiosa Kuetz.	0	1	1	0	0	2
rhynchocephala Kuetz.	0	0	2	0	0	2
tripunctata (O.F. Muell.) Bory	2	0	1	0	2	5
tripunctata var. schizonemoides (V.H.) Patr.	0	0	1	0	1	2
viridula Kuetz.	1	1	0	0	0	2
viridula var. avenacea (Breb. ex Grun.) V.H.	2	2	3	3	3	13
viridula var. rostellata (Kutz.?) Cl.	0	1	0	0	0	1
zanoni Hust.	0	0	1	0	0	1
spp.	11	8	13	9	7	48

Table 4-14 (cont.)

Species	II	C	D	P	R	Total
Nitzschia						
accomodata Hust.	1	0	2	1	1	5
amphibia Grun.	0	1	1	0	0	2
capitellata Hust.	3	4	1	2	4	14
closterium (Ehr.) W. Sm.	3	3	2	3	2	13
dissipata (Kuetz.) Grun.	2	3	4	2	2	13
fonticola Grun.	6	5	5	6	7	29
holsatica Hust.	1	2	3	3	1	10
lorenziana Grun.	0	0	0	1	0	1
parvula Levis	0	0	1	0	0	1
sigma (Kuetz.) W. Sm.	7	6	3	7	8	31
tryblionella Hantz.	5	7	2	6	6	26
tryblionella var. debilis (Arn.) A. Mayer	8	9	7	9	8	41
tryblionella var. levidensis (W. Sm.) Grun.	7	8	7	5	5	32
tryblionella var. victoriae Grun.	0	0	1	1	2	4
sp. 1	0	3	2	3	3	11
spp.	17	16	16	16	16	81
Pinnularia						
microstauron (Ehr.) Cleve	1	0	0	0	0	1
Pleurosigma						
salinarum Grun.	1	0	1	0	1	3
Rhoicosphenia						
curvata (Kuetz.) Grun. ex Rabh.	0	0	0	1	1	2
Skeletonema						
costatum (Grev.) Cl.	0	1	0	1	2	4
Stauroneis						
anceps Ehr.	0	1	0	0	0	1
Stephanodiscus						
astraea (Ehr.) Grun.	13	11	8	11	8	51
astraea var. minutula (Kuetz.) Grun.	7	5	6	8	5	31
hantzschia Grun.	0	1	0	0	0	1
Surirella						
ovalis Breb.	0	0	0	1	0	1
ovata Kuetz.	6	3	5	3	3	20
robusta Ehr.	3	1	2	3	1	10
tenera Gregory	0	0	0	1	0	1
spp.	3	3	5	4	2	17
Synedra						
acus Kuetz.	1	1	0	0	0	2
pulchella Ralfs. ex. Kuetz.	1	0	1	3	4	9
rumpens Kuetz.	0	1	0	0	0	1
ulna (Nitz.) Ehr.	4	3	2	3	4	16
spp.	1	2	1	3	2	9

Table 4-14 (cont.)

Species	II	C	D	P	R	Total
Tabellaria fenestrata (Lyngb.) Kuetz.	4	5	6	3	6	24
Thalassionema nitzschioides Grun.	0	0	0	0	1	1
Unidentified diatoms	16	16	16	16	16	80
Chlorophyta						
Actinastrum hantzschii Lagerh.	5	4	5	5	5	24
Ankistrodesmus falcatus (Corda) Ralfs.	6	6	4	7	4	27
Crucigenia						
fenestrata Schmidle	1	0	0	0	1	2
quadrata Morren	5	8	3	2	5	23
tetrapedia (Kirch.) West & West	1	1	2	4	5	13
Pediastrum						
biradiatum Meyen	6	3	2	4	4	19
duplex Meyen	5	4	3	4	5	21
simplex (Meyen) Lemm.	2	1	3	1	3	10
spp.	0	0	1	1	1	3
Scenedesmus						
denticulatus Lager.	0	0	0	0	1	1
dimorphus (Turp.) Kuetz.	2	3	3	3	4	15
opoliensis P. Richter	0	0	1	0	0	1
quadricauda (Turp.) Breb.	10	7	10	10	9	46
spp.	11	10	8	12	12	53
Schroederia spp.	1	0	1	0	0	2
Staurastrum spp.	0	2	2	3	1	8
Tetraedron						
regulare Kuetz.	1	0	0	0	0	1
sp.	1	0	0	1	2	4
Ulotrichales	13	12	12	13	11	61
Cyanophyta						
Anabaena						
circinalis Raben.	0	1	0	0	1	2
sp.	2	0	2	1	2	7

Table 4-14 (cont.)

Species	II	C	D	P	R	Total
Chroococcus spp.	2	3	2	1	1	9
trichomes	8	10	10	9	11	48
unidentified colonies	1	0	0	0	0	1
Miscellaneous						
Ceratium hirundinella (Muell.) Dujardin	0	0	1	0	0	1
Gonyaulax, *Gymnodinium*, and/or *Peridinium*	0	0	1	0	3	4
unidentified green algae*	11	10	11	12	12	56
unidentified coccoid unicells*	16	16	16	16	16	80
unidentified colonies 10 cells or more	13	14	14	12	12	65
unidentified colonies of 8 cells	9	9	10	13	10	51
unidentified colonies of 4 cells	13	14	14	13	14	68
unidentified filaments	11	4	9	8	8	40
Total frequency distribution for all species sampled at each station in 1975	82	84	91	85	93	

*includes forms which may be chrysophytes and/or other phytoflagellates which have lost their flagella

Table 4-15. Total and mean numbers of total phytoplankton (X 10^6) per liter in whole-water entrainment collections at stations II through R, with analysis of variance, 1975. II = Unit II intakes, C = Unit II condenser water box, D-2 = Discharge canal station 2, P = Discharge plume, R = "Control" location in the river.

Dates	II	C	D-2	P	R	Mean
4/10	0.20	0.31	0.40	0.28	0.46	0.33
4/11	0.64	0.45	0.34	0.34	0.48	0.45
5/27	4.11	4.02	3.38	6.41	4.74	4.53
5/28	6.23	6.01	6.29	10.99	8.89	7.68
6/24	0.89	0.80	0.71	0.97	0.60	0.78
6/25	0.69	1.44	0.97	0.99	0.82	0.98
7/24	0.81	0.64	0.86	0.87	1.43	0.92
7/25	1.59	0.97	1.16	0.86	1.28	1.17
9/30	0.73	0.54	0.63	0.70	0.58	0.63
10/01	0.63	0.47	0.61	0.60	0.88	0.64
10/31	0.41	0.54	0.63	0.70	0.58	0.63
11/01	0.46	0.51	0.45	0.43	0.51	0.47
11/18	0.48	0.51	0.62	0.49	0.55	0.53
11/19	0.55	0.60	0.58	0.53	0.70	0.59
12/10	0.42	0.40	0.43	0.39	0.51	0.43
12/11	0.49	0.44	0.51	0.43	0.45	0.46
Mean	1.21	1.17	1.16	1.61	1.47	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.0506	4	0.0126	1.6154
Dates	10.1932	15	0.6795	87.1154**
Error	0.4702	60	0.0078	

**$p<0.01$

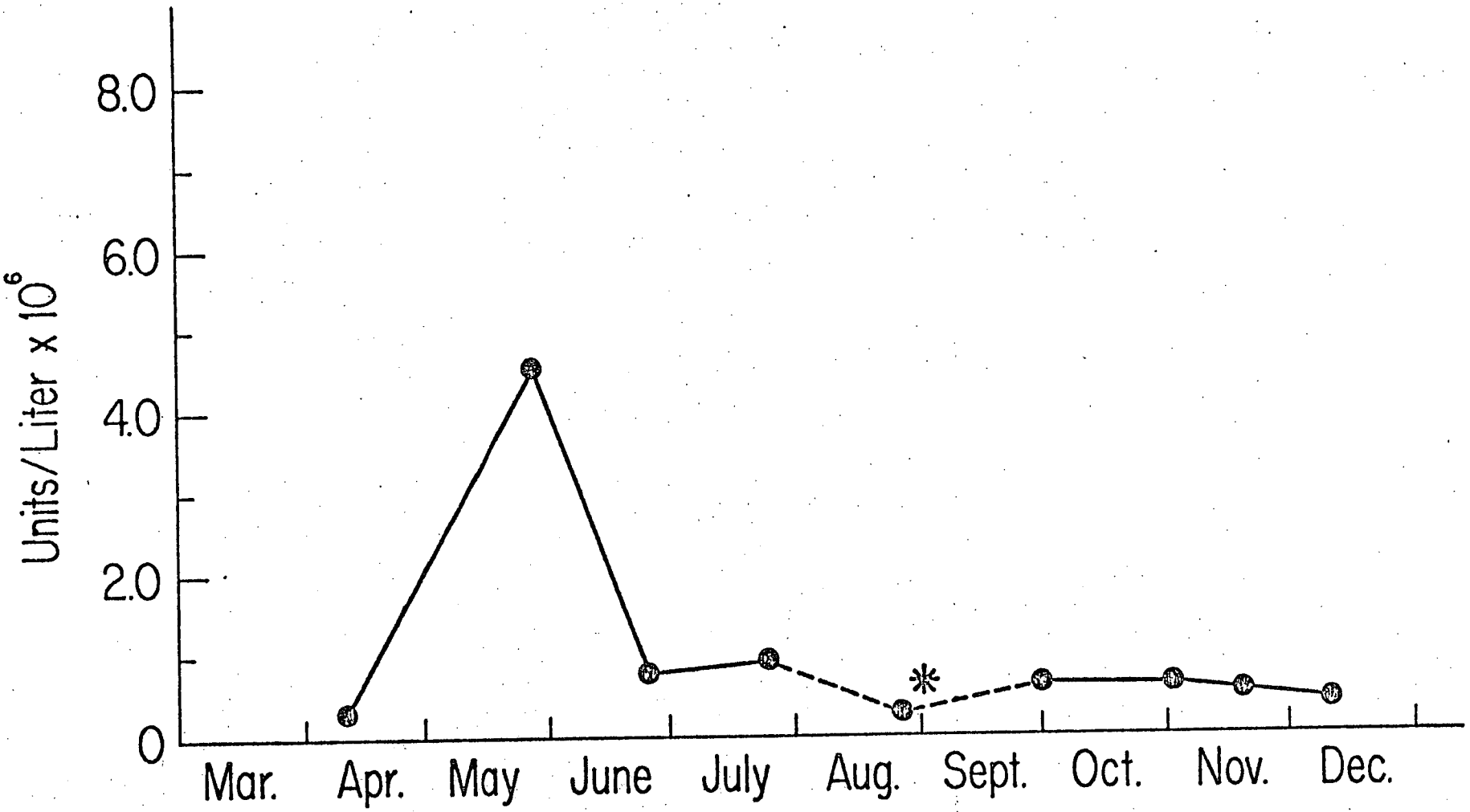

Figure 4-4. Numbers (Mean numbers) of phytoplankton units per liter x 10^6 in entrainment samples collected at Indian Point in 1975. *Number estimated from intake samples only.

Blue-green algal numbers were low for most of the sampling period ($\leq 0.01 \times 10^6$ units/liter). Analyses of variance (immediate and delayed) for these three major groups revealed no significant differences between stations, but significant differences were observed among dates for diatoms and for green and blue-green algae ($\alpha = 0.01$).

The percent composition of the major algal groups revealed a predominance of diatoms and green algae throughout the year (Table 4-16 and Figure 4-5). Over 60% of the total phytoplankton standing crop on the sampling dates in April, October, November, and December were diatoms, but diatoms were less than 40% of the total in July, August and September samples. Correspondingly, green algae were dominant (> 60%) in August and September, but they were less than 40% of the total in April, October, November and December. The greatest abundance of blue-green algae (> 10%) occurred in July and September. There was good correlation in the percent composition between entrainment and river collections on comparable sampling dates (Section 4.1).

4.2.3.2 Primary Production and Chlorophyll a Content of Entrained Algae

The effects of mechanical stresses from Unit 2 pump entrainment on phytoplankton productivity were estimated during those intervals when the unit under study was not

Table 4-16. Percent composition of phytoplankton groups collected during entrainment sampling at Indian Point and at a "control" location in the river in 1975. II = Unit II intakes, C2 = Unit II condenser water box, D2 = Discharge canal station 2, P = Discharge Plume, R = "Control" location in the river. Immed. = composition at collection. Del. = composition 24 hr. after collection.

		Groups			
Date	Station	Diatoms	Greens	Blue Greens	Misc.
4/10 (Immed)	II	84	13	3	0
	C2	77	23	0	0
	D2	76	24	0	0
	P	83	17	0	0
	R	89	10	0	1
4/11 (Del)	II	78	22	0	0
	C2	86	14	0	0
	D2	86	14	0	0
	P	79	21	0	0
	R	94	6	0	0
5/27 (Immed)	II	46	54	0	0
	C2	46	54	0	0
	D2	49	51	0	0
	P	51	49	0	0
	R	35	65	0	0
5/28 (Del)	II	29	71	0	0
	C2	29	71	0	0
	D2	36	64	0	0
	P	32	68	0	0
	R	25	75	0	0
6/24 (Immed)	II	42	58	0	0
	C2	55	45	0	0
	D2	48	52	0	0
	P	49	51	0	0
	R	49	51	0	0
6/25 (Del)	II	48	52	0	0
	C2	63	33	4	0
	D2	47	52	1	0
	P	46	54	0	0
	R	43	57	<1	0
7/24 (Immed)	II	37	53	10	0
	C2	39	45	16	0
	D2	43	45	12	<1
	P	39	56	5	0
	R	36	46	18	0

Table 4-16(cont.).

Date	Station	Groups: Diatoms	Greens	Blue Greens	Misc.
7/25 (Del)	II	42	44	14	0
	C2	46	33	21	0
	D2	35	48	17	0
	P	44	41	15	0
	R	29	44	27	0
9/30 (Immed)	II	14	68	18	0
	C2	16	63	21	0
	D2	17	68	15	0
	P	20	66	14	0
	R	10	57	33	0
10/01 (Del)	II	27	57	16	0
	C2	19	58	23	0
	D2	20	57	23	0
	P	30	53	17	0
	R	26	56	18	0
10/31 (Immed)	II	67	30	3	0
	C2	70	29	1	0
	D2	78	18	4	0
	P	70	27	3	0
	R	70	29	1	0
11/01 (Del)	II	58	41	1	0
	C2	75	25	0	0
	D2	64	34	2	0
	P	68	32	<1	0
	R	66	32	2	0
11/18 (Immed)	II	70	30	0	0
	C2	69	30	1	0
	D2	67	32	1	0
	P	72	27	1	0
	R	64	33	3	0
11/19 (Del)	II	76	24	0	0
	C2	73	26	1	0
	D2	67	32	1	0
	P	72	27	1	0
	R	72	27	1	0

Table 4-16 (cont.).

Date	Station	Groups: Diatoms	Greens	Blue Greens	Misc.
12/10	II	74	25	1	0
(Immed)	C2	76	23	1	0
	D2	82	17	<1	<1
	P	72	28	0	0
	R	74	25	1	0
12/11	II	79	21	0	0
(Del)	C2	83	17	<1	0
	D2	76	24	<1	0
	P	73	27	<1	0
	R	69	30	<1	<1

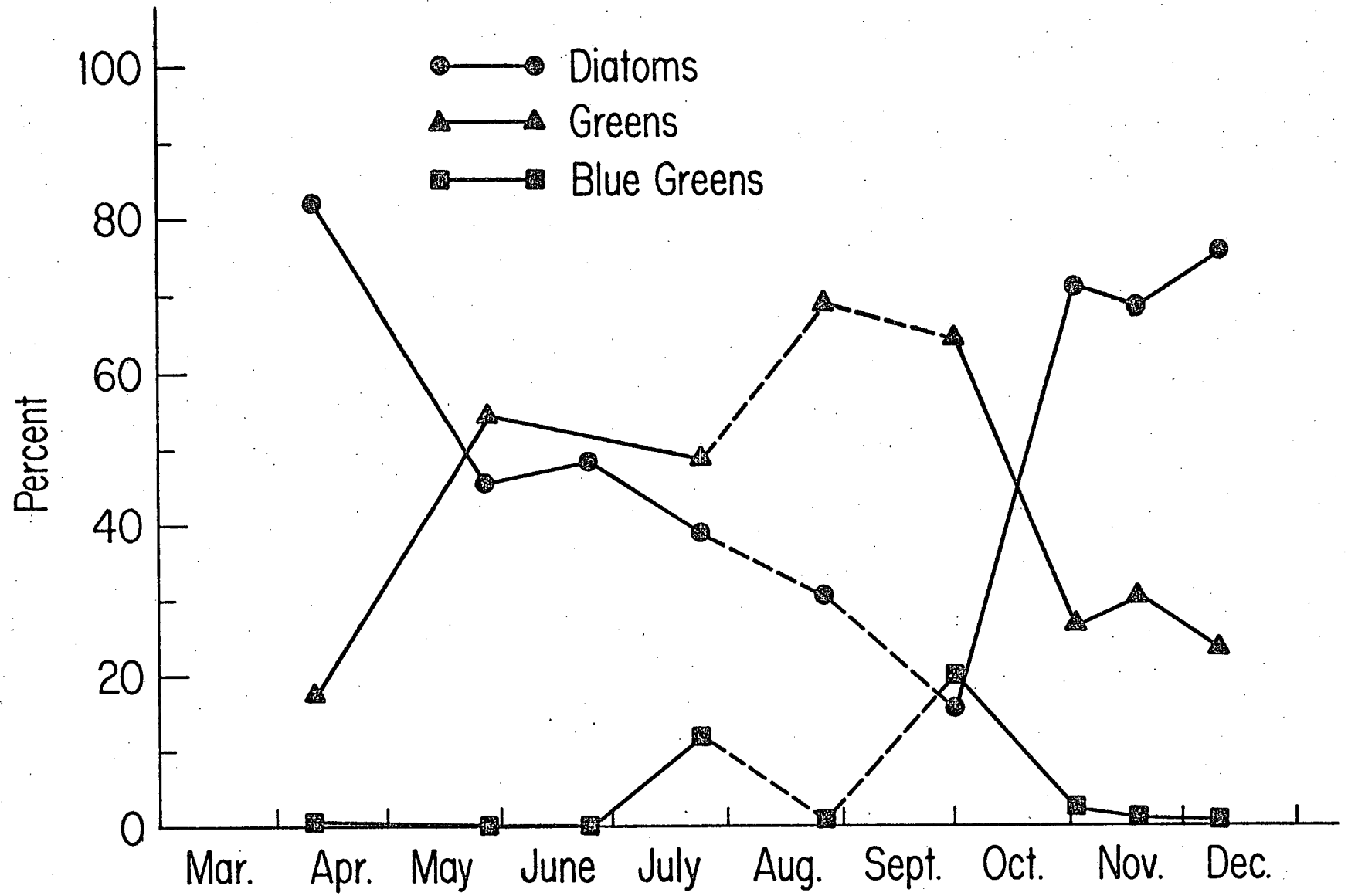

Figure 4-5. The percent composition of phytoplankton by algal groups in entrainment samples collected at Indian Point in 1975.

generating power ($\Delta T = 0.0$). Mechanical damage was estimated in 1972 and 1973 in studies conducted at Indian Point Unit I; the intake forebay (I-1) served as the control, and stations in the discharge canal (Figure 4-6) served as the test locations. With one date as an exception (November 10, 1972) there was no apparent difference in productivity measurements between samples from the intake forebays and those from the discharge canal (New York University Medical Center, 1974).

Indian Point Unit 2 became operational in 1974. At that time sampling stations were established at the Unit 2 intake and condenser water box to examine the effect of the Unit on phytoplankton. Also in 1974, studies of phytoplankton response to entrainment in the thermal plume from Indian Point were established. Beginning in 1974, all entrainment studies included the determinations 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 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.

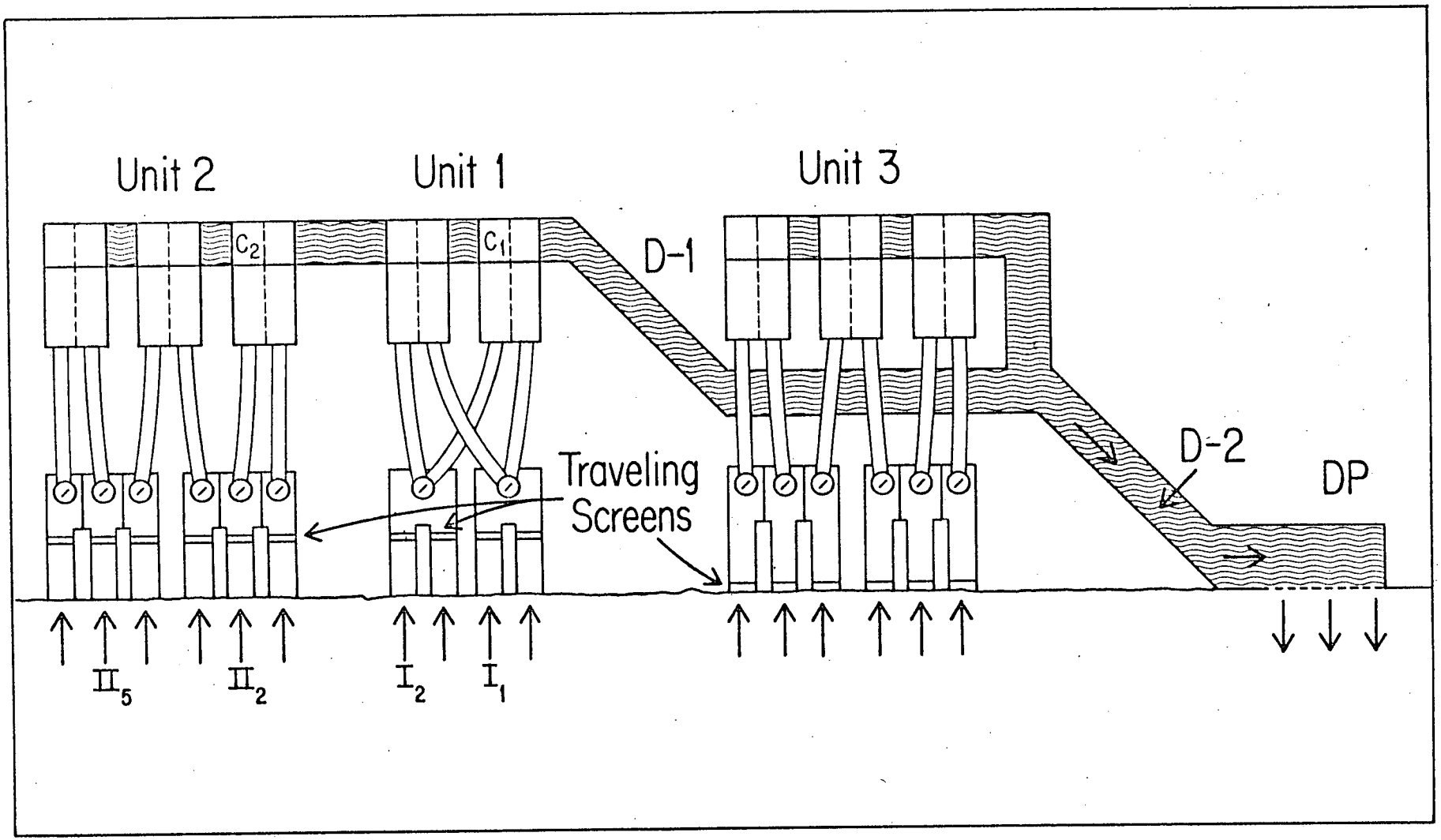

Figure 4-6. Schematic diagram of Indian Point cooling water system showing locations of sampling stations.

Since intake samples are collected in the intake forebays, which are located behind a fixed, fine screen, some alteration of the water mass or its contents may have occurred prior to reaching the forebay. Data from the 1974 studies (New York University Medical Center, 1976a) did not show any difference between intake and river samples.

Only the comparisons made between the river and the Unit 2 intakes and between the river and the intake and condenser water box at Unit 1 on June 24 and October 31, 1975 show any possible entrainment effects from mechanical stress; there was no difference for comparisons made on the other dates in 1975 (Tables 4-17 to 4-19). There was no ΔT for Unit 1 as the unit was used to circulate water for thermal dilution of the Unit 2 effluent only. The data showed that primary productivity at the Unit 1 intake and condenser and at the Unit 2 intake was significantly less than at river stations ($P < 0.001$). However, chlorophyll *a* concentrations and algal abundance and species composition did not differ among stations (Tables 4-14, 4-15 and 4-17). These results are not contradictory, however, since abundant evidence exists in the literature, suggesting that mechanical stress may cause measurable physiological changes in phytoplankton populations without affecting cellular integrity or the structure of the photosynthetic pigments (Nalewajko, 1966; Eppley and Sharp, 1975; Steeman-Nielsen, 1975).

Table 4-17. Effect of entrainment on the chlorophyll "a" content of Hudson River phytoplankton, 1975. I = Unit I intakes, II = Unit II intakes, C1 = Unit I condenser waterbox, C2 = Unit II condenser waterbox, D2 = Discharge canal station 2, P = Discharge plume, R = "Control" location in the river, N.D. = No difference.

Date	Station	Temp. °C	ΔT°C	chlorophyll "a" mg chl/m^3	S.E.*	Results of Anova and Scheffe's test	
1/21	I	1.0	----	1.00	±0.09	N.D.	∝=.05
	II	1.0	----	0.85	±0.13		
	C1	2.0	1.0	0.60	±0.14		
	C2	20.9	20.0	0.53	±0.11		
	D2	11.8	10.8	0.81	±0.11		
2/17	I	1.0	----	0.54	±0.08	N.D.	
	II	1.0	----	0.27	±0.05		
	C1	1.0	----	0.41	±0.06		
	C2	22.0	21.0	0.48	±0.08		
	D2	12.0	11.0	0.31	±0.06		
4/10	II	5.0	----	0.53	±0.08	N.D.	
	C2	17.0	12.0	0.37	±0.35		
	D2	12.8	7.8	0.42	±0.09		
	P	9.5	4.5	0.40	±0.08		
	R	5.0	----	0.69	±0.25		
5/27	II	19.0	----	6.79	±0.31	II<D2P	
	C2	33.0	14.0	7.44	±0.21		
	D2	30.8	11.8	8.01	±0.14		
	P	24.0	3.0	8.43	±0.37		
	R	19.0	----	5.91	±0.24	R<C2D2P	
6/24	I	24.0	----	3.87	±0.13	I<P	
	II	24.0	----	3.56	±0.15	II<P	
	C1	24.5	0.5	4.11	±0.11		
	C2	33.0	9.0	3.76	±0.28		
	D2	31.3	7.3	4.50	±0.15		
	P	30.0	6.0	4.85	±0.32		
	R	23.8	----	4.06	±0.05		

*df = 4 for each station on 1/21 and 2/17
df = 3 for all other dates

Table 4-17(cont.).

Date	Station	Temp. °C	ΔT°C	chlorophyll "a" mg chl/m³	S.E.*	Results of Anova and Scheffe's test
7/24	II	26.8	----	3.56	±0.23	N.D. α=.05
	C2	34.2	7.4	3.56	±0.19	
	D2	34.8	8.0	3.54	±0.03	
	P	31.0	6.0	3.71	±0.07	
	R	25.0	----	3.82	±0.44	
8/26	II	24.8	----	8.47	±2.04	N.D.
	C2	33.2	8.4	2.75	±0.58	
9/30	II	18.8	----	2.52	±0.21	N.D.
	C2	28.9	10.1	2.46	±0.17	
	D2	27.9	9.1	2.65	±0.26	
	P	22.0	3.0	2.38	±0.05	
	R	19.0	----	2.33	±0.29	
10/31	II	11.8	----	3.12	±0.43	N.D.
	C2	22.3	10.5	3.15	±0.48	
	D2	19.0	7.2	3.41	±0.13	
	P	16.0	5.0	3.27	±0.12	
	R	11.0	----	3.47	±0.27	
11/18	II	12.2	----	2.63	±0.07	
	C2	21.7	9.5	3.18	±0.12	
	D2	19.0	6.8	3.20	±0.08	
	P	16.0	5.0	3.29	±0.31	
	R	11.0	----	2.16	±0.01	R<C2D2P
12/10	II	5.5	----	0.58	±0.09	N.D.
	C2	19.1	13.6	0.52	±0.01	
	D2	14.4	8.9	0.52	±0.05	
	P	12.5	7.0	0.67	±0.16	
	R	5.5	----	0.65	±0.12	

*df = 3 for each station

Table 4-18. Effect of entrainment on the primary productivity of Hudson River phytoplankton, 1975. I = Unit I intakes, II = Unit II intakes, C1 = Unit I condenser waterbox, C2 = Unit II condenser water D2 = Discharge canal station 2, P = Discharge plume, R = "Control" location in the river, N.D. = No difference.

				Photosynthesis		
Date	Station	Temp. ^{o}C	$\Delta T^{o}C$	$mgC/m^3/hr$	S.E.*	Results of Anova and Scheffe's test
1/21	I	1.0	----	-1.46	±2.06	N.D. $\alpha = .05$
	II	1.0	----	0.53	±1.92	
	C1	2.0	1.0	0.08	±1.81	
	C2	20.9	20.0	1.62	±2.71	
	D2	11.8	10.8	-1.51	±1.19	
2/17	I	1.0	----	-0.01	±1.36	N.D.
	II	1.0	----	1.81	±1.15	
	C1	1.0	----	0.56	±1.37	
	C2	22.0	21.0	0.56	±0.67	
	D2	12.0	11.0	0.92	±1.18	
4/10	II	5.0	----	2.19	±1.36	N.D.
	C2	17.0	12.0	4.25	±1.58	
	D2	12.8	7.8	3.13	±2.02	
	P	9.5	4.5	2.90	±0.30	
	R	5.0	----	4.85	±1.70	
5/27	II	19.0	----	101.08	±1.31	II>C2D2P
	C2	33.0	14.0	83.42	±2.19	
	D2	30.8	11.8	55.02	±2.42	
	P	24.0	3.0	88.02	±2.47	
	R	19.0	----	103.88	±2.06	R>C2D2P
6/24	I	24.0	----	46.17	±3.17	I<IIC2PR
	II	24.0	----	73.99	±3.30	II>C1D2
	C1	24.5	0.5	43.87	±2.26	
	C2	33.0	9.0	83.88	±2.14	
	D2	31.3	7.3	52.77	±1.23	
	P	30.0	6.0	71.13	±2.19	
	R	23.8	----	85.32	±2.69	R>I,II,C1D2P

Table 4-18(cont.).

Date	Station	Temp. °C	ΔT°C	Photosynthesis mgC/m³/hr	S.E.*	Results of Anova and Scheffe's test	
7/24	II	26.8	----	22.80	±0.94	N.D.	
	C2	34.2	7.4	22.73	±1.54		
	D2	34.8	8.0	21.59	±1.66		
	P	31.0	6.0	25.64	±0.68		
	R	25.0	----	25.56	±1.31		
8/26	II	24.8	----	27.51	±3.82	N.D.	$\alpha = .05$
	C2	33.2	8.4	31.99	±4.58		
9/30	II	18.8	----	37.96	±2.30	N.D.	
	C2	28.9	10.1	39.55	±2.17		
	D2	27.9	9.1	38.91	±1.74		
	P	22.0	3.0	36.19	±2.35		
	R	19.0	----	35.96	±1.62		
10/31	II	11.8	----	12.22	±0.53	II>C2	
	C2	22.3	10.5	-8.68	±1.17		
	D2	19.0	7.2	15.04	±0.85		
	P	16.0	5.0	9.92	±1.37		
	R	11.0	----	15.63	±0.64	R>IIC2P	
11/18	II	12.2	----	6.44	±0.84	II<C2D2P	
	C2	21.7	9.5	9.32	±0.90		
	D2	19.0	6.8	10.67	±0.73		
	P	16.0	5.0	12.20	±0.63		
	R	11.0	----	8.25	±1.04	R<D2P	
12/10	II	5.5	----	3.19	±0.94	N.D.	
	C2	19.1	13.6	4.55	±1.07		
	D2	14.4	8.9	4.51	±1.10		
	P	12.5	7.0	2.49	±1.10		
	R	5.5	----	3.90	±0.68		

*df = 6 for each station on all dates

Table 4-19. Effect of entrainment on the metabolic efficiency (carbon:chlorophyll) of the Hudson River phytoplankton, 1975. I = Unit I intakes, II = Unit II intakes, C1 = Unit I condenser waterbox, C2 = Unit II condenser waterbox, D2 = Discharge canal station 2, P = Discharge plume, R = "Control" location in the river, N.D. = No difference.

Date	Station	Temp. °C	ΔT°C	mg C/mg chl a/hr/m³ Ratio	S.E.*	Result of "t" test ∝ .05
1/21	I	1.0	----	1.46	±2.06	N.D.
	II	1.0	----	0.62	±2.25	
	C1	2.0	1.0	0.13	±2.94	
	C2	20.9	20.0	3.06	±5.15	
	D2	11.8	10.8	1.86	±1.49	
2/17	I	1.0	----	0.02	±2.53	N.D.
	II	1.0	----	6.83	±4.53	
	C1	1.0	----	1.35	±3.30	
	C2	22.0	21.0	1.16	±1.38	
	D2	12.0	11.0	2.96	±3.85	
4/10	II	5.0	----	4.14	±2.65	N.D.
	C2	17.0	12.0	5.99	±3.71	
	D2	12.8	7.8	7.45	±4.84	
	P	9.5	4.5	7.25	±1.52	
	R	5.0	----	7.05	±3.59	
5/27	II	19.0	----	14.89	±0.74	II>C2D2P
	C2	33.0	14.0	11.20	±0.45	
	D2	30.8	11.8	6.87	±0.34	
	P	24.0	3.0	10.44	±0.52	
	R	19.0	----	17.58	±0.88	R>IIC2D2P
6/24	I	24.0	----	11.93	±0.91	I<II
	II	24.0	----	20.78	±1.28	II>D2P
	C1	24.5	0.5	10.67	±0.62	
	C2	33.0	9.0	22.31	±1.76	
	D2	31.3	7.3	11.73	±0.48	
	P	30.0	6.0	14.67	±1.07	
	R	23.8	----	21.01	±0.71	R>IC1D2P

*df = 8 for each station on 1/21 and 2/17
df = 7 for all other dates

Table 4-19(cont.).

Date	Station	Temp. °C	ΔT°C	mg C/mg chl a/hr/m³ Ratio	S.E.*	Result of "t" test α= .05
7/24	II	26.8	----	6.40	±0.49	N.D.
	C2	34.2	7.4	6.39	±0.55	
	D2	34.8	8.0	6.09	±0.47	
	P	31.0	6.0	6.91	±0.22	
	R	25.0	----	6.69	±0.84	
8/26	II	24.8	----	3.25	±0.85	II<C2
	C2	33.2	8.4	11.63	±2.96	
9/30	II	18.8	----	16.50	±1.70	N.D.
	C2	28.9	10.1	16.08	±1.42	
	D2	27.9	9.1	14.68	±1.58	
	P	22.0	3.0	15.21	±1.04	
	R	19.0	----	15.43	±2.04	
10/31	II	11.8	----	3.92	±0.57	
	C2	22.3	10.5	2.76	±0.56	
	D2	19.0	7.2	4.41	±0.30	
	P	16.0	5.0	3.03	±0.43	
	R	11.0	----	4.50	±0.39	R>C2P
11/18	II	12.2	----	2.45	±0.33	
	C2	21.7	9.5	2.93	±0.30	
	D2	19.0	6.8	3.33	±0.24	
	P	16.0	5.0	3.71	±0.39	
	R	11.0	----	3.82	±0.13	
12/10	II	5.5	----	5.50	±1.83	N.D.
	C2	19.1	13.6	8.75	±2.06	
	D2	14.4	8.9	8.67	±2.27	
	P	12.5	7.0	3.72	±1.87	
	R	5.5	----	6.00	±1.52	

*df = 7 for each station

The major chemical stress studied with relation to the phytoplankton community at Indian Point was chlorine and the process of chlorination. These results have been reported in detail elsewhere (New York University Medical Center, 1976b). The conclusions from the study are as follows:

1) Low levels of chlorine and heat do produce changes in the metabolic capacity of the phytoplankton, but that these additions do not produce any significant changes in the abundance of the Hudson River populations.

2) The limits of chlorine tolerance for phytoplankton, defined as greater than or equal to 1.0 mg/ℓ chlorine dose, are beyond levels (< 0.05 mg/ℓ) which would be encountered by plume entrained organisms (river organisms not previously exposed to plant conditions entrained into the plume).

Tables 4-17 to 4-19 and Figure 4-7 show the comparative effects of plant passage on phytoplankton which are entrained into the power plant's cooling water system from substantially different ambient temperatures. Assessments are based upon determinations of photosynthetic capacity (estimated from measurements of ^{14}C-uptake and chlorophyll *a* content) and algal abundance and speciation. Statistically significant effects attributable to plant entrainment were evident at certain periods during 1975 only (May, June, October and November); at the other times of the year, there was no detectable difference between entrained and non-entrained samples.

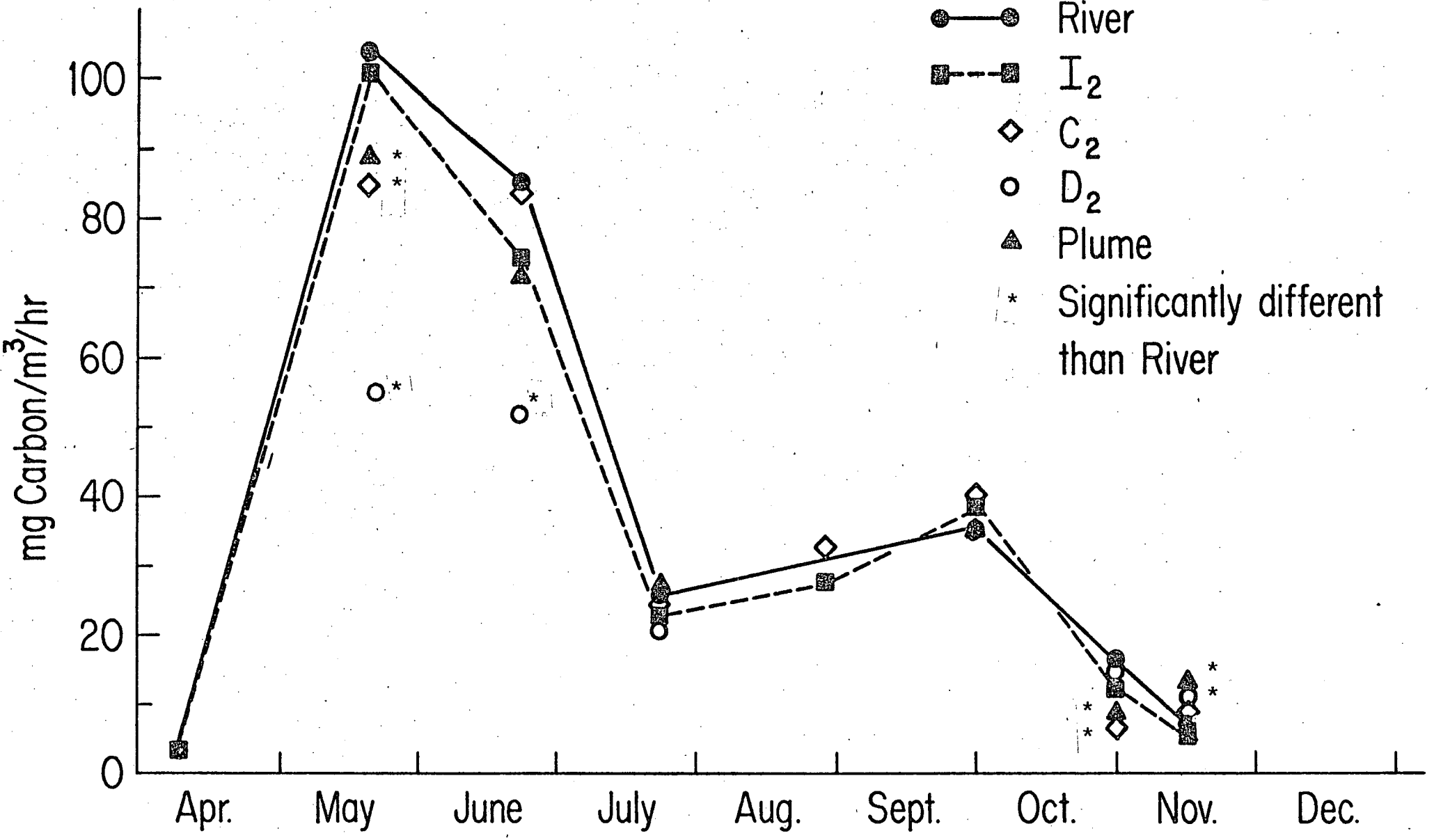

Figure 4-7. The effects of entrainment by the Indian Point power plant upon the primary productivity of Hudson River phytoplankton.

May phytoplankton samples, containing equal numbers of diatoms and green algae, exposed to a ΔT (thermal shock) of 14 C (25.2 F) and a final temperature of 33 C (91.4 F) showed decreased ^{14}C-uptake and photosynthesis. As the chlorophyll a levels in the entrained samples were more than or equal to that for the non-entrained samples, the decrease activity was probably a result of heat inactivation of pertinent enzyme systems in photosynthesis.

June samples, whose composition resembled those collected in May, were exposed to a final temperature of 33 C, also, but at a lower ΔT of 9 C (16.2 F). The data on Table 4-18 indicate a slight increase in ^{14}C-uptake and photosynthetic capacity between the Unit 2 intake and its condenser box where the thermal change occurs. However, this increase was not significant and the sample was comparable to the non-entrained river samples. It was not possible to compare any other samples on this date because of dilution by Unit 1; Unit 1 was running with no ΔT, and was being used to supply water for temperature dilution purposes. Consequently, all discharge canal and plume samples were diluted by organisms not exposed to any temperature regime.

Photosynthesis in diatom-dominated populations was inhibited in October, at a ΔT of 10.5 C (18.9 F) and a final temperature of 22.3 C (72.1 F; see Table 4-18). However, the inhibition was not permanent, or consistent, throughout

the discharge system as the 10.5 C ΔT was in the condenser box only. ^{14}C-uptake and photosynthetic values for the discharge plume samples were similar to condenser values, but both of these were less than those for the intakes, discharge canal and the river, which were all similar.

In November, diatom dominated populations similar to those in October were exposed to ΔT values at or below 10.0 C (18 F) and final temperatures near 22.0 C (71.6 F). All plant samples showed increased photosynthesis relative to intake and river samples (Table 4-18).

Entrainment-induced effects on phytoplankton physiology are the result of interacting physical and biological factors which produce different effects according to seasonal variations in the phytoplankton populations and to ambient river water temperature. As the seasons change, the phytoplankton species change (see Table 4-16). Since each species has a different thermal tolerance, different populations will produce different results (Lanza and Cairns, 1972; Sorokin, 1971). Some forms particularly the green algae, respond favorably to warmer temperatures, while other species, such as diatoms, prefer cooler temperatures (Whitford and Schumacher, 1973). When the green algae are prevalent, a thermal increase may stimulate production. Although diatoms may be stimulated by a slight temperature increase, they may become inhibited at a lower temperature than for the green algae (Sorokin,

1971). Thus, the maximum temperature tolerance of a phytoplankton community composed predominantly of diatoms, at an ambient river temperature of approximately 26 C (78.8 F) in early summer, may be considerably different than that of a community dominated by green and blue-green algae in late summer at the same ambient temperature.

Among samples having similar populations, temperature differences alone can produce variable results in the determination of primary productivity (see Table 4-18). Temperature has a powerful effect upon enzyme activity, and chemical reaction rates increase at higher temperatures. However, in the case of enzyme-catalyzed processes, not only does the reaction rate increase at higher temperatures, but the thermal destruction of the enzyme also may occur more rapidly. Consequently, for any given period of time there may be an optimum temperature, i.e. a temperature at which the greatest amount of chemical change is brought about in a given time by a given amount of enzyme under a given set of experimental conditions. This could be defined as stimulation if this optimum activity exceeds some pre-determined norm. At the same time, there will be a temperature above which enzymes are destroyed and inactivated, or a temperature below which enzyme activity is slowed or inactivated, and the reaction inhibited.

These studies, together with thermal tolerance experiments conducted in the laboratory, and plant entrainment studies conducted at Indian Point in 1974 revealed a range of thermal effects (from no effect to stimulation and inhibition) for short exposures to varying ΔT's and are listed below:

1. ΔT above 10 C and final temperature above 33 C...inhibition.
2. ΔT above 10 C and final temperature below 33 C...no effect.
3. ΔT below 10 C and final temperature near 22 C...stimulation.

These generalizations do not consider the specific composition of the algal population, the physiological state of the algal samples when they are collected, the availability of nutrients in the enclosed sample during the study period, or the presence or absence of soluble chemical inhibitors during the time of the tests. It is understood that there will be varying degrees of response, depending on the composition of the population at the time of testing. The maximum temperature tolerance of a phytoplankton community composed predominantly of diatoms, at an ambient river temperature of approximately 26 C (78.8 F) in early summer, may be considerably different than that of a community dominated by gree and blue-green algae in late summer at the same ambient temperature. Nevertheless, with certain qualifications, these results conform closely to those of Warinner and

Brehmer (1966), Morgan and Stross (1969), Marshall and Tilly (1971) and Fox and Moyer (1973, 1975), who determined that there generally occurred an ambient temperature in the range of 15-20 C (59-68 F) below which populations were unaffected or were stimulated, and above which there occurred inhibition of carbon fixation.

Our studies for the past five years have shown that while plant entrainment into the cooling water flow at the Indian Point power station may occassionally inhibit phytoplankton activity, this impact upon Hudson River phytoplankton is minimal. As we have observed no change in the abundance and diversity of algae in the Hudson River adjacent to the Indian Point power station during the past five years; of operation, we conclude that the Indian Point power station does not adversely affect river populations or their activity as primary producers.

5. MICROZOOPLANKTON

5.1 River Population Studies

5.1.1 Methods

Day and night microzooplankton samples were collected 12 times during the April through December sampling period at each of the seven Hudson River stations (Figure 1-7). 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 following the methods used in previous years (New York University Medical Center, 1974, 1976a) in which a #20-mesh plankton net was drawn vertically through 10 meters of water, the plankton washed into a jar and preserved with 10% formalin.

Replicate 1-mℓ aliquots from each sample were examined for identification and enumeration of zooplankton by scanning two Sedgwick-Rafter cells at a magnification of 100 × (Standard Methods, 1971). The concentration of organisms in the river samples was calculated using the following formula:

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

Where:

A = average of two 1 mℓ counts

V = volume of sample

R = revolutions recorded on flowmeter

C = volume correction factor for flowmeter and

(R)(C) = volume of water filtered by the net.

Microzooplankton data were analyzed by a two-way, factorial analysis of variance (ANOVA) for differences between stations. Where ANOVA indicated significant differences, a Scheffé test ($\alpha > 0.10$) was performed to locate the difference (Ostle, 1963).

5.1.2 Results

The major microzooplankton taxa collected in 1975 were the classes Crustacea and Rotifera and the phylum Protozoa (Table 5-1). The Crustacea, primarily the Copepoda and the Cladocera, were the most abundant constituents of the microzooplankton populations sampled in the Hudson River near Indian Point. Mean Rotifera abundance peaked at 135.0 organisms per liter on May 27 (Table 5-2 and Figure 5-1). This value was similar to the maximum mean abundance of Crustacea (134.0 per liter) on July 7 (Table 5-3 and Figure 5-2). For the majority of the sampling season rotifer mean abundance values were between 1 and 10 per liter (Table 5-2, Figure 5-1) while the mean abundance of crustaceans was between 10 and 100 per liter.

During the April through December sampling period, total microzooplankton mean abundances were highest in late May and early July and lowest in April, November and December (Table 5-4 and Figure 5-3). The total Crustacea

Table 5-1 . Microzooplankton Species List

Crustacea
  Copepoda
    Acartia tonsa Dana
    Canthocamptid
    Canuella sp.
    Diacyclops bicuspidatus 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 angularis 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.

Table 5-1. (cont.)

Rotifera (cont.)
- Trichocerca sp.
- Unidentified sp. #1
- Unidentified sp. #2
- Unidentified sp. #3

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.
- Volvox sp.

Ciliophora
Ciliate
- Carchesium sp.
- Codonella cratera (Leidy)
- Epistylis sp.
- Tintinnopsis sp.
- Vorticella sp.

Suctorid
- Metacineta sp.
- Staurophrys sp.

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

Table 5-2. Day and night abundances of Rotifera, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	2.30	3.18	2.58	1.04	1.53	2.79	.10	1.93
5/12	1.11	.78	1.25	.81	.33	.91	.71	.84
5/27	214.96	192.80	96.70	147.32	66.65	117.65	108.82	134.99
6/17	.30	.00	.55	.24	1.34	.36	.45	.46
6/23	4.08	.98	1.88	1.64	1.33	*	4.09	2.33
7/07	8.56	1.85	4.08	2.70	.00	10.36	3.81	4.48
7/28	1.32	3.63	4.93	3.04	.33	2.15	2.05	2.49
8/11	.71	.27	.24	.70	.76	.20	.42	.47
9/15	2.93	.71	2.63	.34	.30	.00	.57	1.07
10/13	5.55	10.50	9.47	8.37	9.47	10.88	19.29	10.51
11/17	7.65	4.13	2.04	2.67	2.06	1.66	2.17	3.20
12/09	17.95	18.84	21.95	21.15	21.88	15.06	12.00	18.40

Night

4/29	3.81	1.52	2.03	1.77	.84	.39	.15	1.50
5/13	.67	.34	.11	1.30	.79	1.05	.71	.71
5/28	*	149.02	115.15	*	88.58	98.78	66.28	103.56
6/16	.29	.36	.17	.63	.60	.47	1.32	.55
6/24	3.15	10.54	5.20	4.99	6.58	2.30	7.23	5.71
7/08	.66	.29	.64	1.31	.00	4.17	2.05	1.30
7/29	3.04	10.15	2.65	1.64	3.78	3.43	.88	3.65
8/12	.89	.61	.00	.38	.00	.27	.13	.32
9/16	.45	.63	.12	.29	.26	.48	.58	.40
10/13	6.51	13.09	4.40	4.50	4.09	7.28	11.58	7.35
11/18	9.40	4.05	3.87	12.58	2.27	39.14	.40	10.24
12/09	7.09	2.74	9.38	14.51	10.67	7.45	7.19	8.43

* sample missing due to loss or breakage.

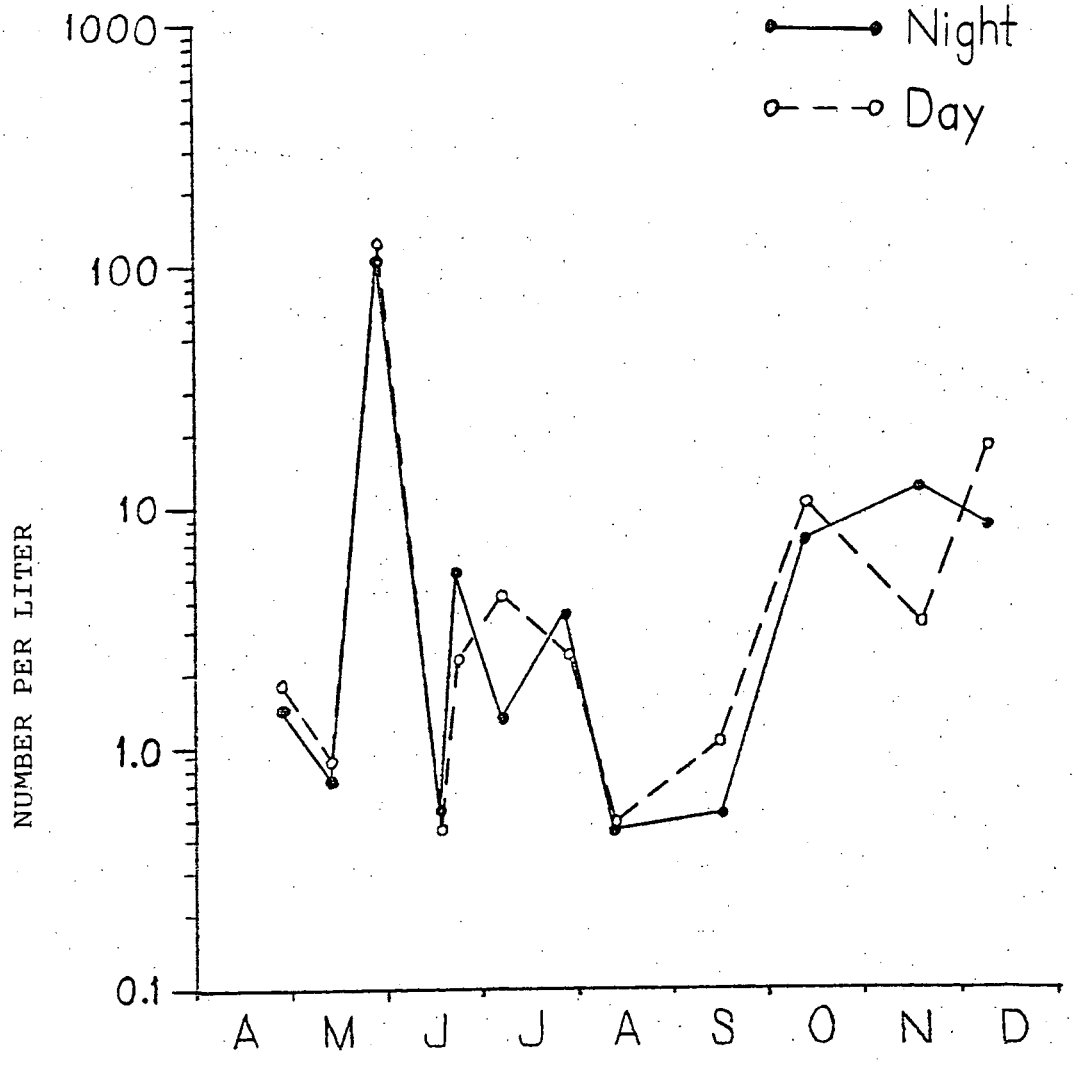

Figure 5-1. Mean day and night abundances of total Rotifera, 1975.

Table 5-3 . Day and night abundances of Crustacea, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	5.2	8.5	7.4	5.4	6.0	12.6	4.3	7.1
5/12	21.8	26.7	20.1	34.6	25.5	24.5	28.7	26.0
5/27	99.9	97.6	48.5	120.4	101.4	65.8	80.6	87.7
6/17	26.7	21.6	41.7	27.5	64.9	33.7	36.7	36.1
6/23	42.7	21.4	37.0	31.2	21.6	*	65.7	36.6
7/07	223.0	132.0	142.0	111.2	55.2	120.1	152.8	133.8
7/28	44.0	37.5	34.0	23.9	14.5	40.8	45.4	34.3
8/11	30.6	44.4	22.1	32.5	45.2	53.3	41.6	38.5
9/15	35.7	29.9	75.4	7.3	8.0	18.8	30.5	29.4
10/13	7.2	15.0	10.3	9.2	8.6	13.5	12.1	10.9
11/17	4.6	5.7	4.8	7.3	5.7	5.1	5.1	5.5
12/09	.8	1.9	.7	2.0	1.3	1.3	.6	1.2

Night

4/29	7.1	6.9	5.5	8.3	6.2	6.9	2.3	6.2
5/13	12.2	7.9	4.7	12.5	9.8	13.5	13.0	10.5
5/28	*	114.0	60.3	*	55.6	61.4	47.2	67.7
6/16	30.3	49.3	28.6	37.9	22.1	53.4	60.8	40.3
6/24	31.0	47.5	25.8	33.7	65.4	86.5	183.3	67.6
7/08	124.8	101.3	94.9	94.1	96.1	114.6	223.1	121.3
7/29	43.0	83.7	58.9	61.5	58.1	115.5	56.2	68.1
8/12	55.5	49.3	81.2	36.6	31.9	101.3	15.2	53.0
9/16	13.9	14.3	8.6	12.8	10.7	68.9	11.9	20.1
10/13	12.8	16.8	12.7	30.0	24.2	20.3	15.3	18.9
11/18	5.9	4.0	1.4	8.9	1.8	15.4	1.3	5.5
12/09	.5	.3	.8	1.3	1.4	.7	1.3	.9

* sample missing due to loss or breakage.

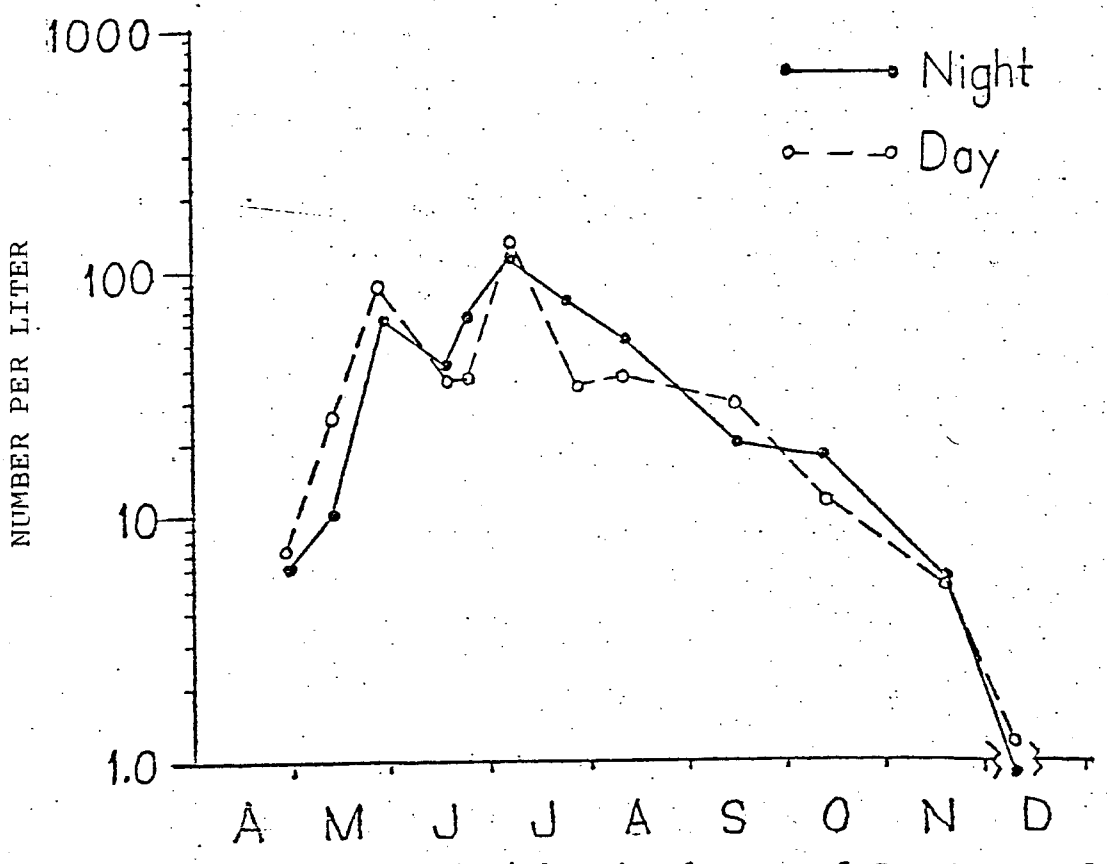

Figure 5-2. Mean day and night abundances of Crustacea, 1975.

Table 5-4. Day and Night abundances of total Microzooplankton, 1975. Number per liter.

Day

Date	Station A	B	C	D	E	F	G	Mean
4/28	8.2	12.8	10.9	7.0	7.9	18.7	4.7	10.0
5/12	23.6	28.5	22.4	36.6	26.4	26.3	30.1	27.7
5/27	316.7	293.1	145.6	270.0	168.0	185.3	190.0	224.1
6/17	27.6	22.2	43.1	28.2	70.0	35.5	38.7	37.9
6/23	47.6	22.4	39.0	33.0	23.3	*	69.9	39.2
7/07	232.4	140.0	154.2	118.0	62.9	135.0	171.5	144.9
7/28	46.8	43.0	41.9	28.9	15.1	45.2	50.1	38.7
8/11	32.4	45.4	22.5	33.6	46.7	54.1	43.7	39.8
9/15	40.4	31.9	79.1	8.9	8.9	19.2	31.1	31.3
10/13	13.2	26.4	21.1	18.5	19.3	25.6	33.2	22.5
11/17	12.6	10.2	7.2	10.2	7.8	7.3	7.4	9.0
12/09	19.0	20.9	23.2	23.2	23.3	16.6	12.9	19.9

Night

4/29	13.0	10.1	8.9	12.5	7.6	7.8	3.1	9.0
5/13	13.5	8.9	5.2	15.5	11.2	14.9	14.3	11.9
5/28	*	265.5	176.9	*	147.1	160.9	114.8	173.0
6/16	31.7	50.9	30.4	39.9	23.5	55.5	63.6	42.2
6/24	35.0	59.0	31.8	39.2	73.2	89.2	191.8	74.2
7/08	129.0	104.4	102.6	102.4	99.4	123.3	239.1	128.6
7/29	51.7	105.9	66.8	66.6	70.3	125.8	62.4	78.5
8/12	58.4	51.7	84.0	38.3	34.1	103.2	15.6	55.0
9/16	16.1	16.9	10.7	14.5	11.7	70.0	13.7	21.9
10/13	19.5	30.9	18.0	35.3	28.4	28.7	27.8	26.9
11/18	15.5	8.1	6.2	25.2	4.7	58.7	1.7	17.1
12/09	7.8	3.0	10.2	15.8	12.2	8.2	8.5	9.4

* sample missing due to loss or breakage.

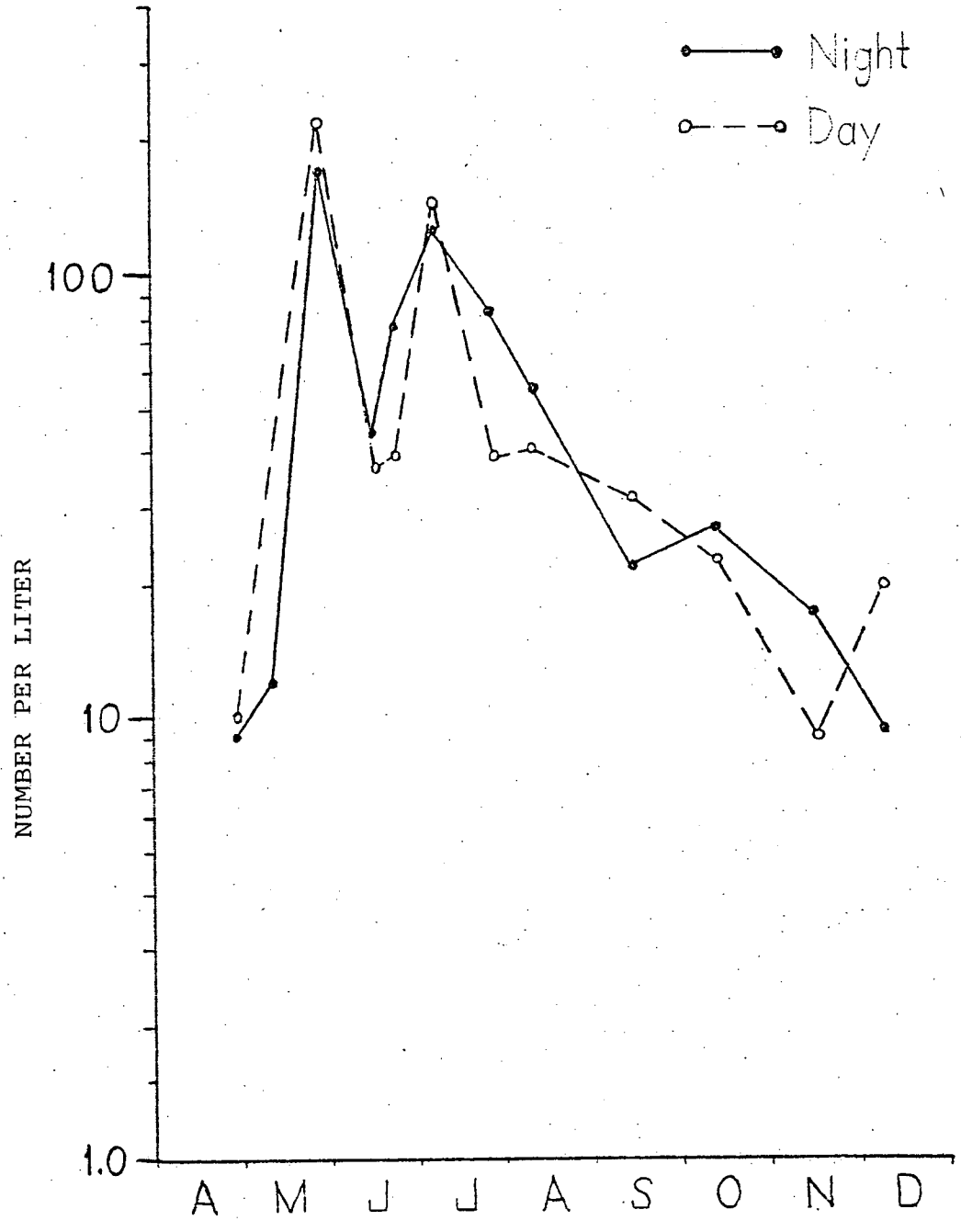

Figure 5-3. Mean day and night abundances of total microzooplankton, 1975.

seasonal mean abundance parallels the seasonal mean abundance pattern of the total microzooplankton (Figures 5-2 and 5-3). Maximum copepod reproduction occurred from late spring through summer, as indicated by the increased numbers of copepod nauplii present during this period (Tables 5-5 to 5-7 and Figure 5-4).

The calanoid copepods, Acartia tonsa and Eurytemora affinis (Figures 5-5 and 5-6), were the most abundant adult copepods observed during the sampling period. A. tonsa (Figure 5-5) was observed only during the summer months while E. affinis (Figure 5-6) occurred throughout the sampling year with peak mean abundances observed in spring and through the summer. The cyclopoid copepods, Diacyclops bicuspidatus (Figure 5-7) and Halicyclops fosteri (Figure 5-8), were generally less abundant than the calanoid copepods.

The most common cladoceran species were Diaphanosoma brachyurum and Bosmina longirostris (Figures 5-9 and 5-10). D. brachyurum reached peak abundance in late June and late July and were observed only from May through September (Figure 5-9). Peak abundance of B. longirostris (Figure 5-10) occurred on the same dates as the peaks for D. brachyurum, but B. longirostris was approximately five times more abundant on those dates than was D. brachyurum. Except for samples taken on July 7 and 8, in which no B. longirostris were observed in either day or night samples (Figure 5-10), B. longirostris occurred throughout the sampling period.

Table 5-5. Day and night abundances of Copepod nauplii, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	3.10	5.50	4.68	2.81	3.54	8.82	2.56	4.43
5/12	13.06	15.81	11.39	20.85	16.37	21.16	7.70	15.19
5/27	88.30	88.53	43.20	107.82	83.14	52.71	69.30	76.14
6/17	18.59	12.03	22.09	15.81	51.56	23.77	12.59	22.35
6/23	31.45	5.07	23.54	10.16	9.66	*	47.70	21.26
7/07	178.02	72.96	98.24	82.08	24.32	91.30	98.82	92.25
7/28	6.79	12.00	7.02	9.11	1.84	18.25	9.45	9.21
8/11	12.93	6.73	8.87	21.22	36.07	35.51	25.87	21.03
9/15	30.98	13.82	74.08	2.13	4.51	4.49	29.39	22.77
10/13	3.63	4.00	4.81	6.69	5.45	4.90	8.29	5.40
11/17	1.74	1.29	1.08	2.16	1.92	1.36	1.70	1.61
12/09	.50	1.00	.34	.92	.59	.88	.42	.67

Night

4/29	5.08	3.38	2.61	3.89	2.25	3.13	1.04	3.05
5/13	5.33	3.05	1.75	7.64	5.59	8.59	6.91	5.55
5/28	*	50.63	52.28	*	43.80	54.51	39.97	48.24
6/16	12.97	24.39	11.89	13.40	8.44	38.64	43.08	21.83
6/24	14.64	24.25	15.83	13.37	32.10	66.21	155.80	46.03
7/08	97.00	.00	29.64	67.97	60.68	62.08	171.45	69.83
7/29	16.95	59.15	27.62	13.12	21.24	29.73	41.00	29.83
8/12	36.66	22.39	37.12	20.53	18.12	87.65	6.47	32.70
9/16	8.99	4.88	2.67	7.47	4.38	66.04	6.65	14.44
10/13	3.25	8.01	3.48	4.81	2.84	2.61	6.35	4.48
11/18	.70	.58	.29	2.43	.24	6.99	.30	1.65
12/09	.29	.18	.65	.40	.78	.33	.72	.48

* sample missing due to loss or breakage.

Table 5-6. Day and night abundances of copepodids, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	.88	1.81	1.62	1.36	1.06	1.47	.30	1.21
5/12	2.34	2.59	2.31	4.05	2.45	.91	3.42	2.58
5/27	7.24	5.12	2.97	4.65	7.37	3.53	3.45	4.90
6/17	4.11	5.91	8.18	2.55	2.67	3.56	10.79	5.40
6/23	4.19	4.09	4.33	5.38	6.16	*	5.37	4.92
7/07	20.54	34.00	22.99	11.07	10.42	10.74	24.05	19.12
7/28	14.72	9.38	10.80	7.89	6.45	7.16	10.55	9.56
8/11	3.19	10.91	4.56	3.37	2.27	3.59	4.42	4.62
9/15	1.17	4.25	.44	2.13	1.20	5.44	.57	2.17
10/13	2.40	6.30	4.34	1.82	2.29	6.46	2.36	3.71
11/17	.81	1.16	1.80	1.08	2.36	1.97	1.39	1.51
12/09	.20	.36	.23	.81	.59	.39	.21	.40

Night

4/29	1.27	1.28	1.74	1.53	1.41	.91	.59	1.25
5/13	3.11	2.37	1.64	3.17	1.86	2.17	2.14	2.35
5/28	*	58.46	4.39	*	4.90	3.63	2.58	14.79
6/16	9.51	15.36	7.60	4.68	6.63	7.26	6.61	8.23
6/24	3.03	3.35	1.89	3.57	3.70	1.77	4.45	3.11
7/08	7.88	25.18	29.64	8.28	14.62	25.42	25.02	19.43
7/29	9.56	8.56	9.26	14.35	11.80	34.31	5.42	13.32
8/12	4.89	6.35	9.80	1.77	3.02	1.07	2.25	4.17
9/16	1.41	2.75	1.94	1.87	1.80	1.27	1.73	1.83
10/13	7.48	4.50	6.23	13.04	11.19	9.67	5.60	8.25
11/18	.70	.19	.29	1.62	.60	1.40	.50	.76
12/09	.19	.09	.16	.20	.13	.22	.54	.22

* sample missing due to loss or breakage.

Table 5-7. Day and night abundances of adult copepods, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	1.11	1.12	1.14	1.12	1.18	2.20	1.38	1.32
5/12	6.41	8.03	6.23	9.72	6.57	2.42	17.54	8.13
5/27	2.53	2.36	1.59	6.97	9.47	8.97	7.53	5.63
6/17	1.68	2.24	3.82	1.34	.80	2.73	9.44	3.15
6/23	2.54	6.88	4.91	11.80	1.81	*	5.88	5.64
7/07	20.11	17.62	10.38	15.66	19.10	11.51	25.51	17.13
7/28	14.53	6.00	6.92	3.64	3.34	5.25	12.92	7.51
8/11	9.56	20.61	5.64	2.53	2.27	12.77	10.31	9.10
9/15	2.43	10.27	.44	2.13	1.65	8.63	.28	3.69
10/13	.55	1.50	.87	.14	.56	1.67	.52	.83
11/17	1.48	.77	.84	1.15	.59	1.36	.62	.97
12/09	.00	.18	.11	.12	.00	.00	.00	.06
				Night				
4/29	.76	2.10	1.16	2.83	2.53	2.74	.64	1.82
5/13	3.77	2.37	1.31	1.49	2.29	2.69	3.81	2.53
5/28	*	2.47	2.92	*	3.60	1.32	4.38	2.94
6/16	4.61	5.24	5.29	10.74	5.06	6.09	8.33	6.48
6/24	3.87	4.01	1.18	4.28	14.40	6.00	8.35	6.01
7/08	19.93	36.63	35.61	17.43	20.47	25.00	25.02	25.73
7/29	6.52	3.33	5.13	10.25	10.39	27.44	3.37	9.49
8/12	7.55	13.01	25.21	9.50	4.75	8.04	6.21	10.61
9/16	1.11	3.13	3.03	2.59	3.35	1.11	2.60	2.42
10/13	1.79	2.15	2.29	10.87	8.53	6.85	2.24	4.96
11/18	.70	.77	.14	.81	.24	2.80	.20	.81
12/09	.00	.00	.00	.00	.13	.00	.00	.02

* sample missing due to loss or breakage.

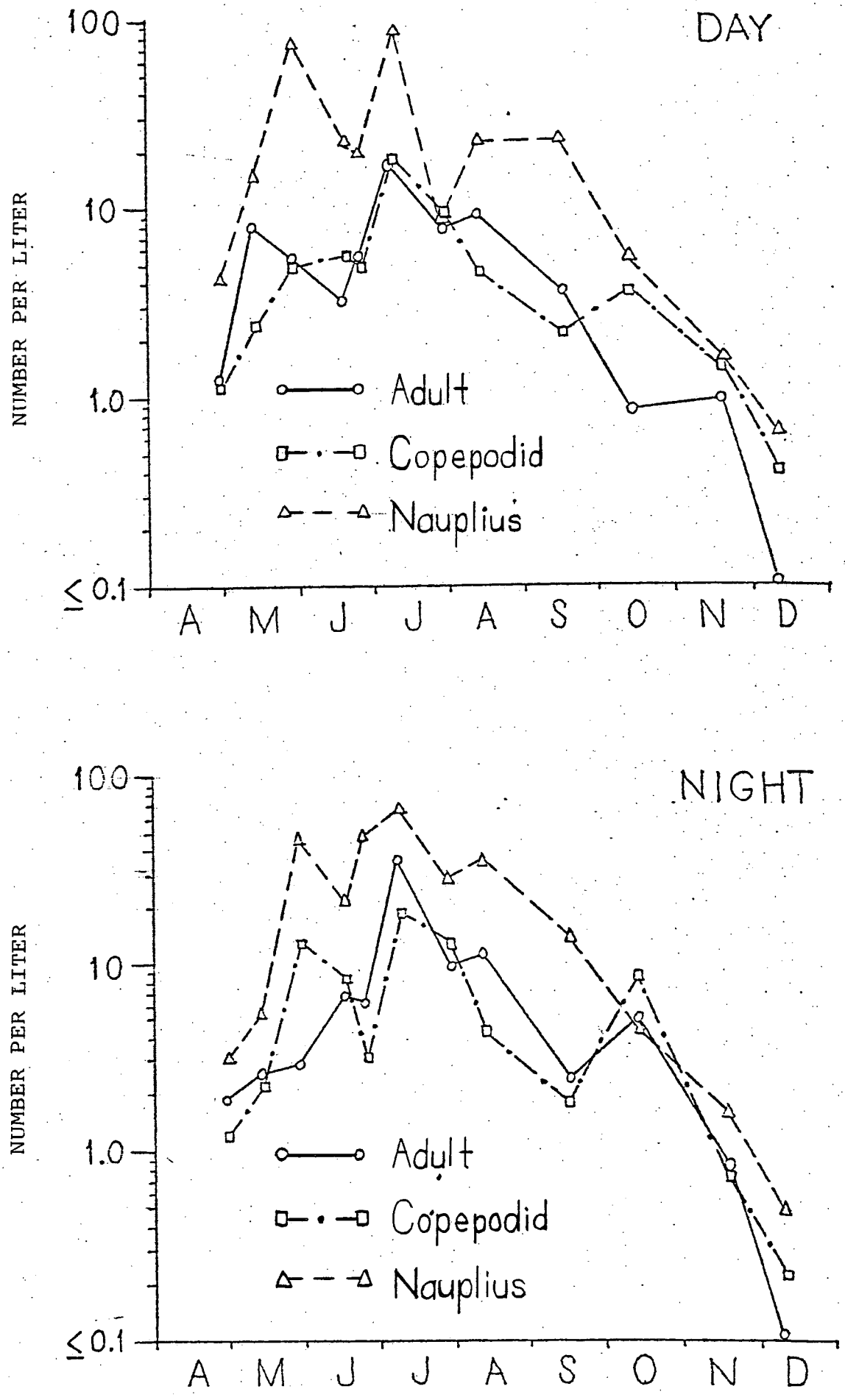

Figure 5-4. Mean abundances of total Copepoda, 1975

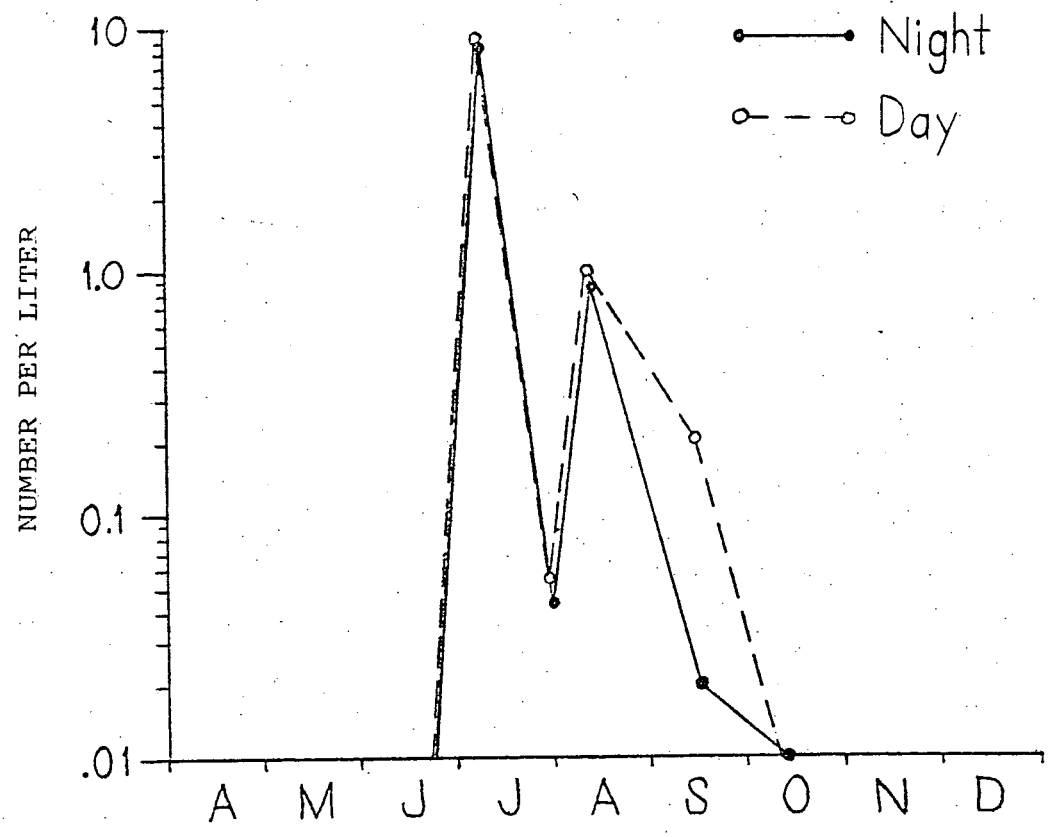

Figure 5-5. Mean day and night abundances of Acartia tonsa, 1975.

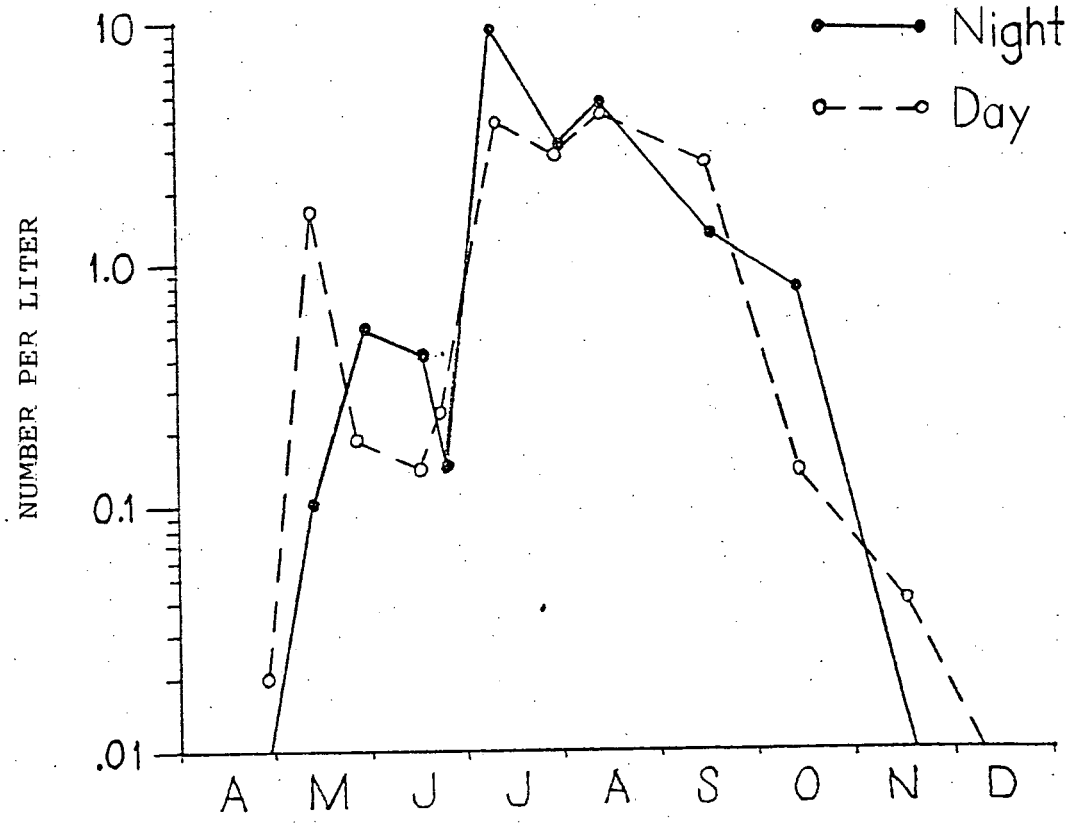

Figure 5-6. Mean day and night abundances of Eurytemora affinis, 1975.

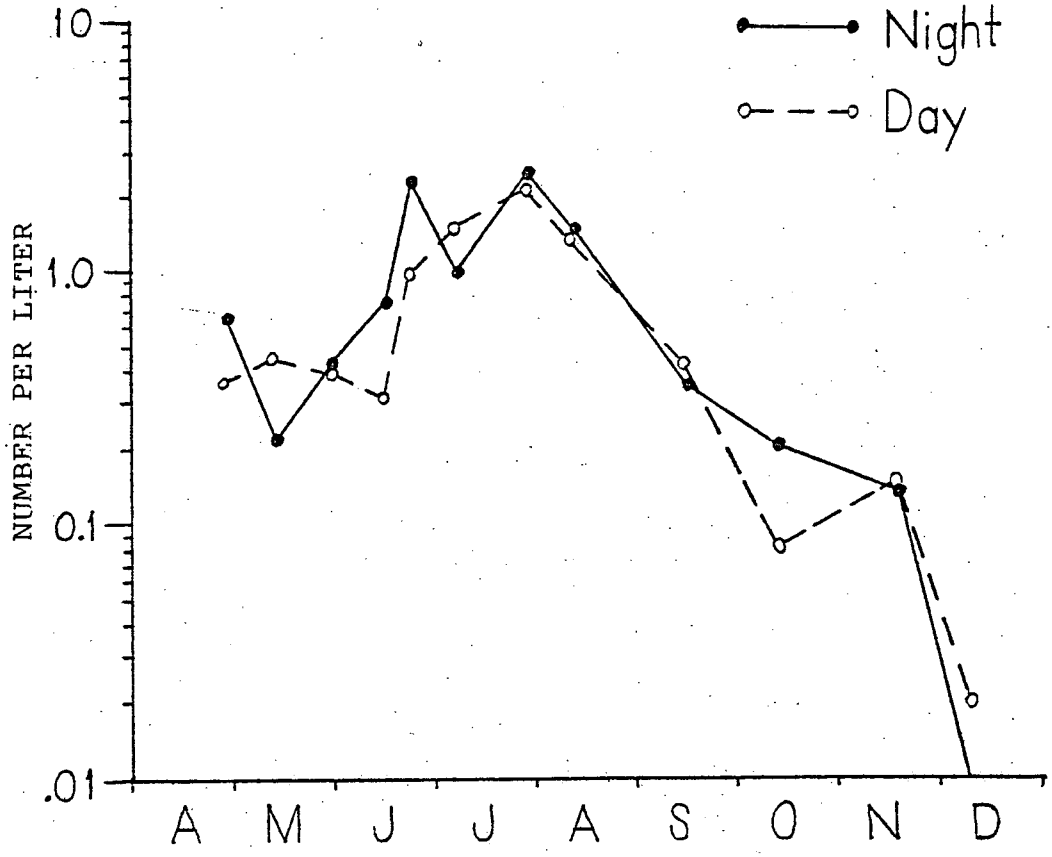

Figure 5-7. Mean day and night abundances of Diacyclops bicuspidatus, 1975.

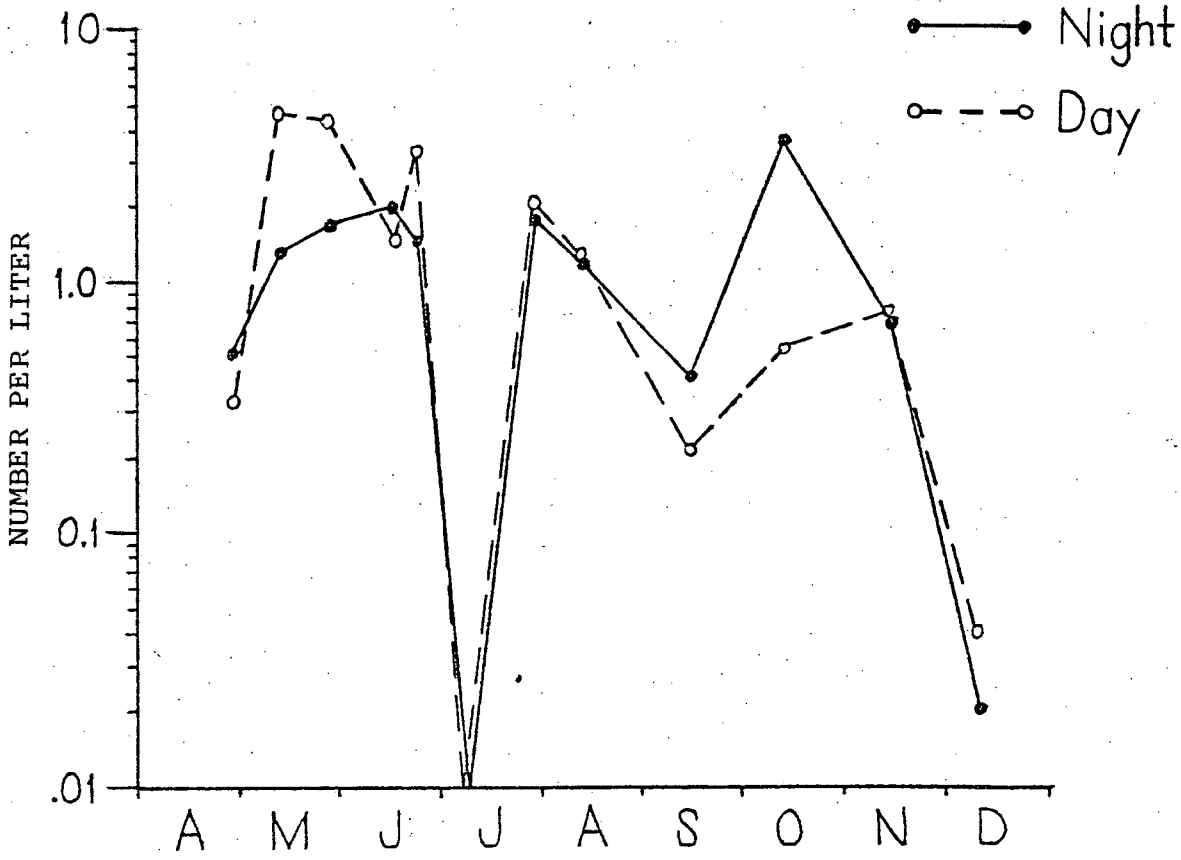

Figure 5-8. Mean day and night abundances of Halicyclops fosteri, 1975.

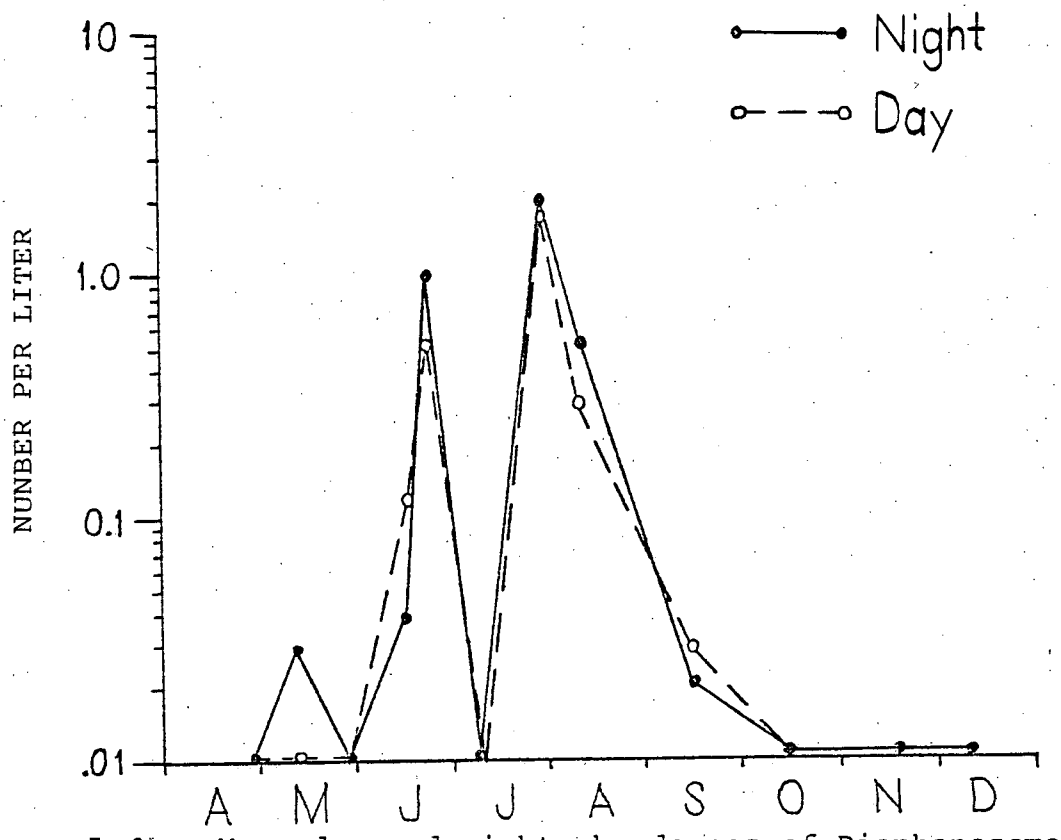

Figure 5-9. Mean day and night abundances of Diaphanosoma brachyurum, 1975.

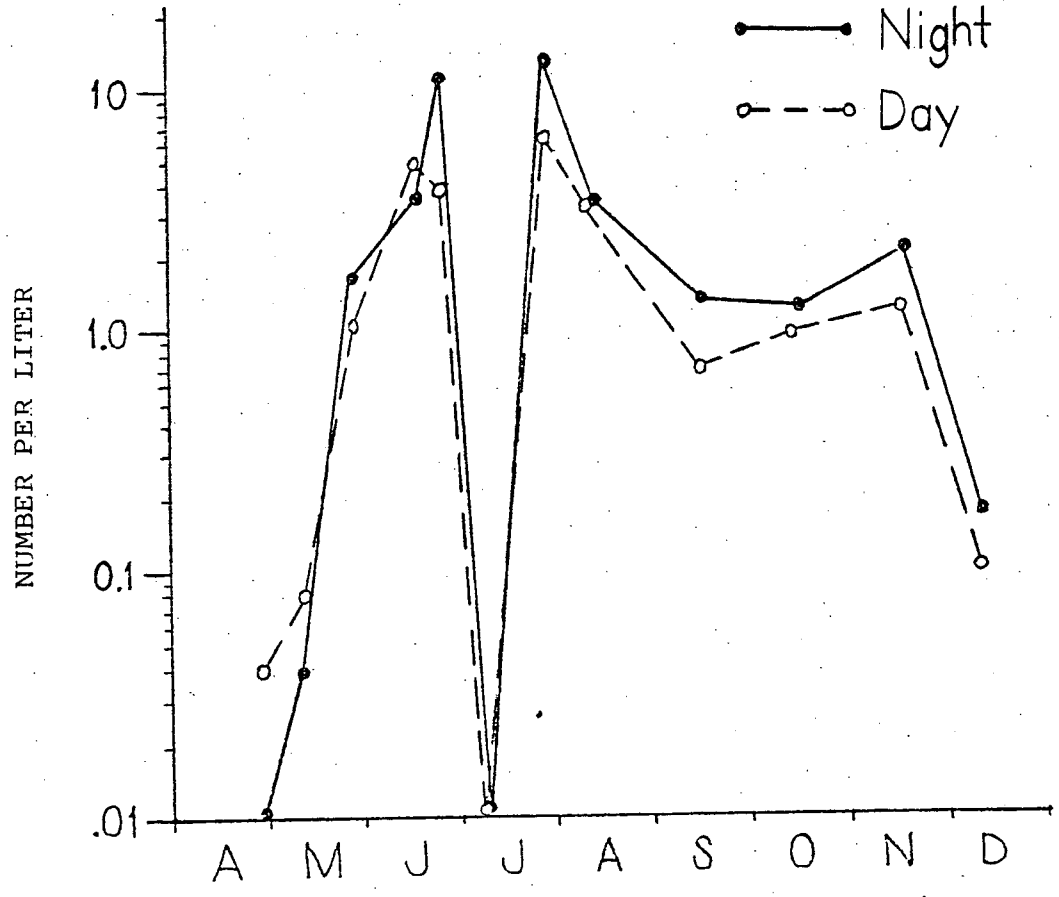

Figure 5-10. Mean day and night abundances of Bosmina longirostris, 1975.

Rotifers reached peak abundance in the spring and fall (Figure 5-1). Notholca accuminata, Keratella cochlearis and an unidentified rotifer comprised the majority of the rotifers observed (86% of rotifers taken in day samples; 90% of those in night samples).

The most frequently observed protozoan species were the shelled amoebae, Centropyxis sp. and Difflugia sp. The colonial peritrichs Epistylis sp. and Carchesium sp. also were common in microzooplankton samples. The protozoans retained in the #20-mesh plankton net reached peak mean abundance in mid-summer and were observed in fewer numbers throughout the remainder of the sampling period (Table 5-8 and Figure 5-11).

The results of 28 ANOVA on various microzooplankton forms indicate, in all but 3 analyses, no effect of station location on abundance (Table 5-9 and 5-10). A significant station effect is shown for the night abundance of total microzooplankton, total Crustacea and of Bosmina longirostris (Table 5-10). A Scheffé test ($\alpha < 0.10$) on total microzooplankton and total crustacea, however, does not indicate differences between stations. Analyses of Bosmina longirostris night abundances shows significant difference in abundance between stations D and G. Abundance at station D was significantly greater than at station G. The analyses of Crustacea night abundances indicates no difference between stations C and E or between stations A and D. In these analyses station

Table 5-8. Day and night abundances of Protozoa, 1975. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
4/28	.73	1.12	.66	.48	.24	2.50	.20	.85
5/12	.74	1.04	.89	1.21	.56	.91	.57	.84
5/27	1.81	2.75	.40	2.32	.00	1.90	.63	1.40
6/17	.61	.61	.82	.49	3.74	1.42	1.57	1.32
6/23	.77	.08	.14	.00	.36	*	.00	.23
7/07	.00	.00	.00	.27	.00	.00	.29	.08
7/28	1.51	1.88	2.83	1.82	.28	2.15	2.21	1.81
8/11	.71	.54	.00	.28	.50	.20	.84	.44
9/15	1.76	1.24	.88	1.19	.60	.35	.00	.86
10/13	.41	.90	1.34	.95	1.18	1.20	1.75	1.10
11/17	.40	.39	.36	.25	.00	.45	.15	.29
12/09	.20	.18	.56	.12	.12	.29	.32	.26

Night

4/29	1.78	1.40	1.02	2.12	.42	.39	.64	1.11
5/13	.67	.57	.44	1.49	.50	.37	.60	.66
5/28	*	2.06	1.46	*	2.94	.66	1.29	1.68
6/16	1.15	1.26	1.65	1.39	.84	1.64	1.45	1.34
6/24	.85	1.00	.83	.53	1.23	.18	1.11	.82
7/08	.00	.00	.00	2.18	.73	.00	.00	.42
7/29	5.65	11.89	5.13	3.28	8.50	6.86	5.27	6.65
8/12	1.56	1.51	2.80	.63	1.29	.54	.13	1.21
9/16	1.63	2.00	1.94	1.44	.77	.64	1.16	1.37
10/13	.16	.98	.73	.78	.18	1.09	.93	.69
11/18	.23	.00	.72	3.65	.60	4.19	.00	1.34
12/09	.19	.00	.00	.00	.13	.11	.00	.06

* sample missing due to loss or breakage.

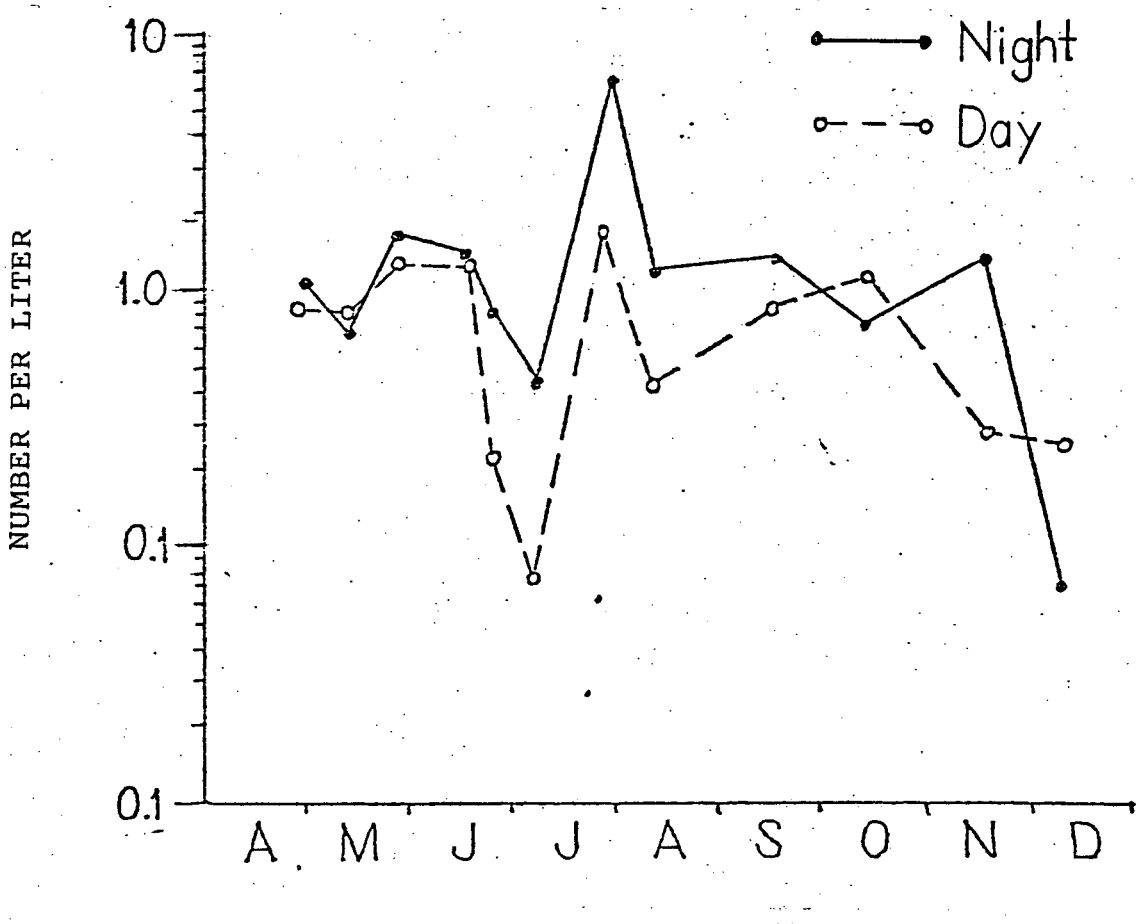

Figure 5-11. Mean day and night abundances of Protozoa, 1975.

Table 5-9. Results of analysis of variance of day abundances of microzooplankton, 1975.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha<0.10$)
Total	0.9630	N.S.	---
Copepoda-Adults	1.5664	N.S.	---
Copepoda-Copepodids	1.5167	N.S.	---
Copepoda-Nauplii	0.2604	N.S.	---
Eurytemora affinis	1.8006	N.S.	---
Acartia tonsa	1.5773	N.S.	---
Diacyclops bicuspidatus	1.0515	N.S.	---
Halicyclops fosteri	0.4111	N.S.	---
Diaphanosoma brachyurum	0.8800	N.S.	---
Bosmina longirostris	1.2740	N.S.	---
Daphnia pulex	1.0000	N.S.	---
Crustacea	0.6605	N.S.	---
Rotifera	1.7702	N.S.	---
Protozoa	0.8000	N.S.	---

* $P<0.05$

Table 5-10. Results of analysis of variance of night abundance of microzooplankton, 1975.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha<0.10$)
Total	2.3974	*	N.S.
Copepoda-adults	1.4474	N.S.	---
Copepoda-copepods	0.2275	N.S.	---
Copepoda-nauplii	2.1532	N.S.	---
Eurytemora affinis	0.3069	N.S.	---
Acartia tonsa	1.5405	N.S.	---
Diacyclops bicuspidatus	1.1866	N.S.	---
Halicyclops fosteri	1.3096	N.S.	---
Diaphanosoma brachyurum	1.8919	N.S.	---
Bosmina longirostris	2.3970	*	D>G
Daphnia pulex	0.2857	N.S.	---
Crustacea	3.1005	*	N.S.
Rotifera	0.8316	N.S.	---
Protozoa	0.5306	N.S.	---

* $P<0.05$

F was greater than all other stations and stations A and D were less than the other stations.

A comparison of the total microzooplankton abundance data for 1974 and 1975 (Figure 5-12) shows that the magnitude of peak abundances are comparable. The seasonal differences and the magnitude of the variations in abundance of the total microzooplankton are also essentially the same for 1974 as for 1975 (Figure 5-12). The major taxa comprising the microzooplankton community (Figures 5-13, 5-14 and 5-15) show little difference between 1974 and 1975 in seasonal variations and in abundance.

With one exception, dominant species within taxa did not change between 1974 and 1975. The most frequently occurring copepods (A. tonsa and E. affinis) and cladocerans (B. longirostris and D. brachyurum) were the same in both years. Notholca accuminata which was the dominant rotifer in 1974 (see New York University Medical Center, 1976a), made up approximately 25% of the total rotifers in 1975. Keratella cochlearis, which also comprised approximately one-quarter of the total rotifers in 1975 was co-dominant with N. accuminata.

5.1.3 Discussion

Comparisons of microzooplankton abundance within sampling years seldom show differences due to factors other than season. The few differences in abundance between stations

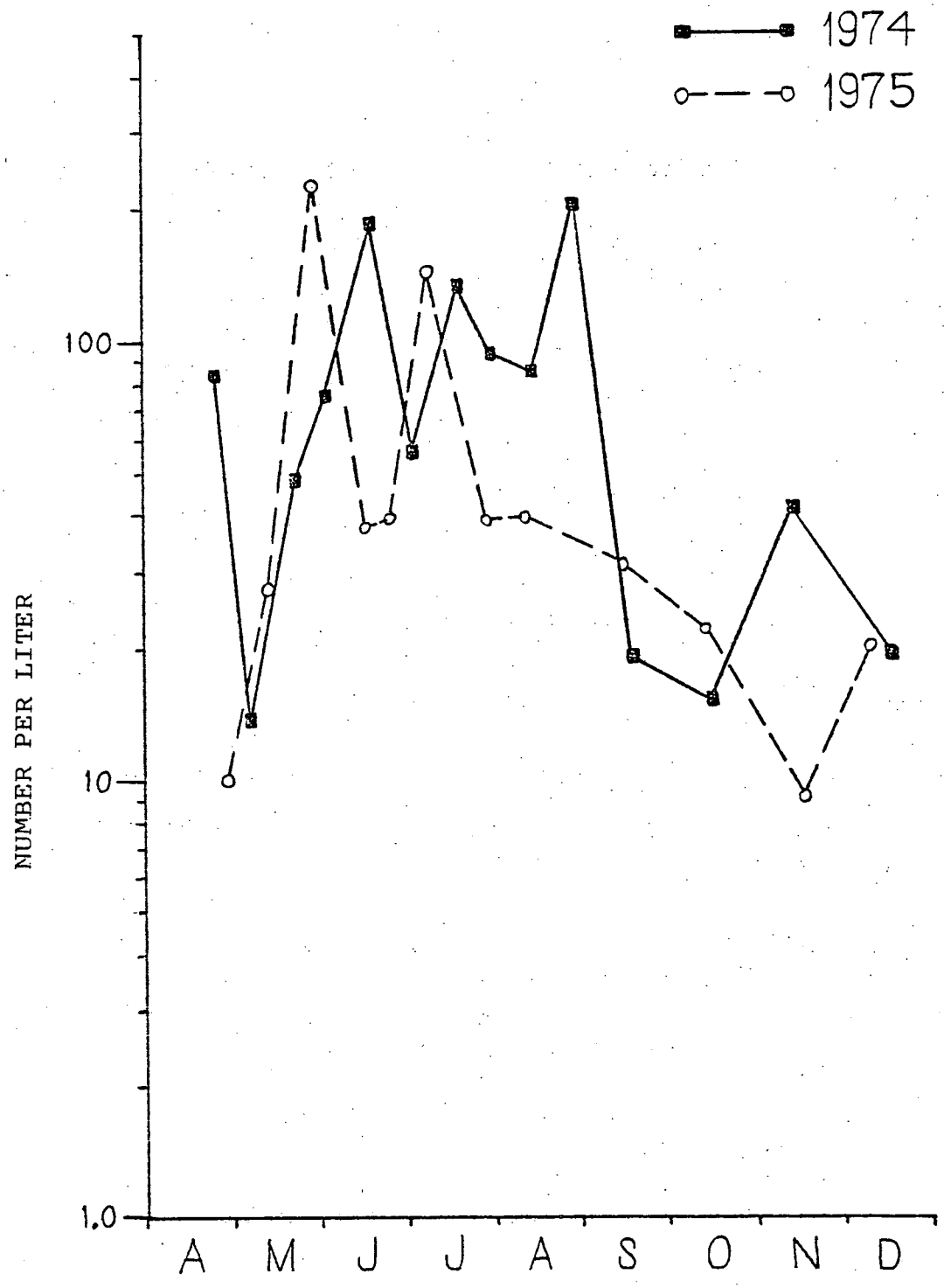

Figure 5-12. Mean day abundances of total microzooplankton, 1974 and 1975.

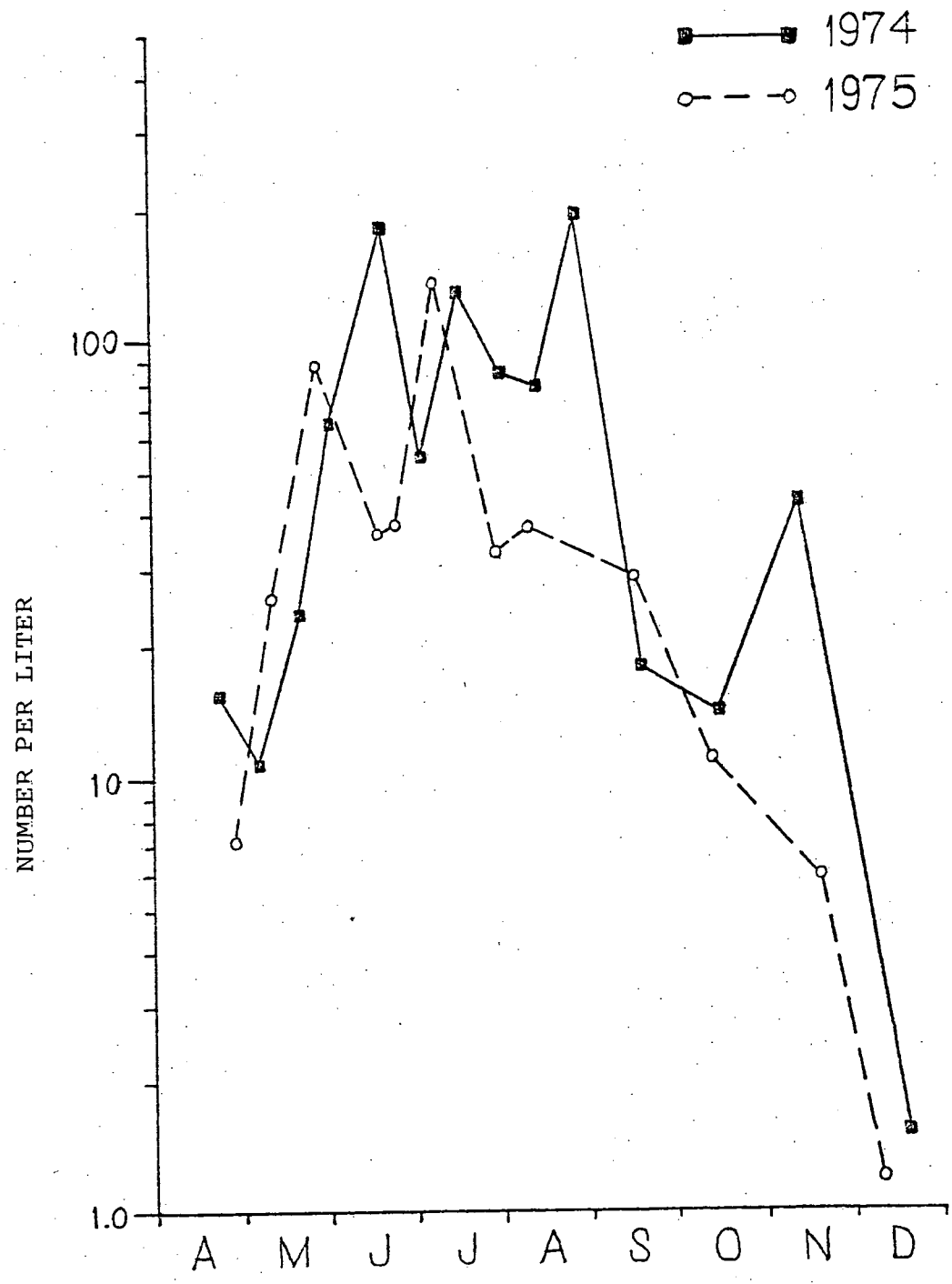

Figure 5-13. Mean day abundances of total Crustacea, 1974 and 1975.

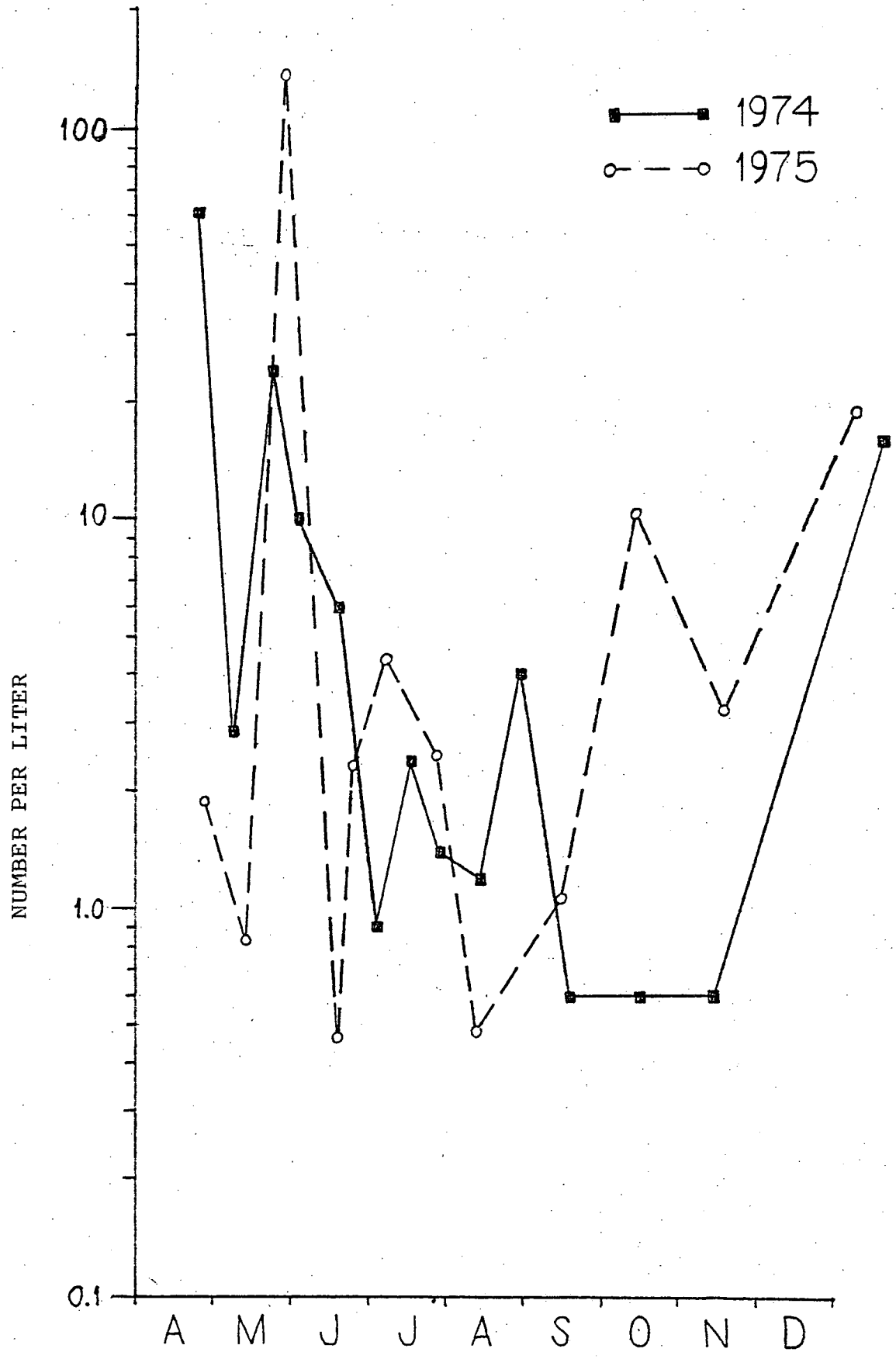

Figure 5-14. Mean day abundances of total Rotifera, 1974 and 1975.

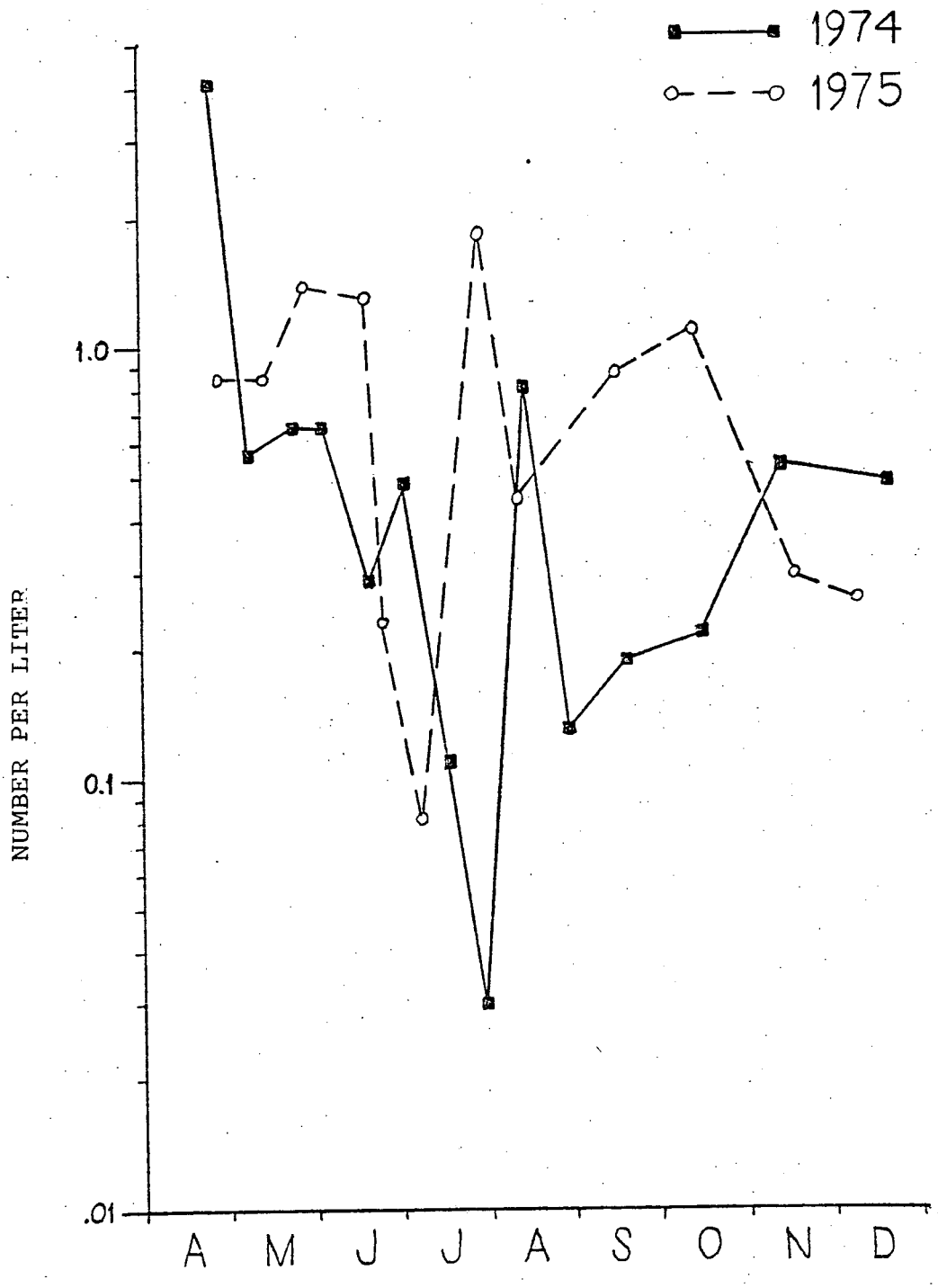

Figure 5-15. Mean day abundances of total Protozoa, 1974 and 1975.

are probably the result of random factors associated with the characteristically patchy distribution of plankton (Wiebe and Holland, 1968; Fleminger and Clutter, 1965). For the same reasons and additional considerations, such as year-to-year variations in river flow, tidal exchange and mixing (Abood, 1974), quantitative comparisons between and among years is probably best executed in non-dimensional terms, such as diversity components and community structure (Pielou, 1975), rather than abundance.

A qualitative comparison of the microzooplankton between and among years indicates that the species composition has remained essentially unchanged through the five year span of this study. Where dominant species within taxa have been found to differ (e.g. the change from the dominance of Notholca in the 1974 rotifer population to the co-dominance of Notholca with Keratella in 1975) it should be noted that year-to-year and station-to-station shifts in dominance have been noted in various taxa throughout the lower Hudson since intensive ecological studies began (see e.g. New York University Medical Center, 1973, 1974; Lawler, Matusky and Skelly Engineers, 1974, 1975).

There exist no data to demonstrate that river populations of microzooplankton have been affected by the operation of the Indian Point power station.

Near-field data (this report and New York University Medical Center, 1974; Lawler, Matusky and Skelly Engineers,

1974) and far-field data (Lawler, Matusky and Skelly Engineers, 1974) indicate essentially similar patterns in seasonal variability of species composition, species numbers, abundance and areal distribution of microzooplankton in the Hudson River from Indian Point to Haverstraw Bay for the years 1971-1975.

5.2 ENTRAINMENT EFFECTS STUDIES

5.2.1 Intake and Discharge-Canal Studies

5.2.2 Methods

Replicate microzooplankton samples were collected each month throughout 1975 from a Unit 2 intake station (II-5) and from two discharge-canal stations (D-1 and D-2) at the Indian Point power station for use in estimating the abundance and viability of entrained microzooplankton. Samples were collected only from surface waters since analysis of previous years' data showed no depth-related differences and vertical tows in the discharge-canal were not possible.

Samples were collected with 0.5 m diameter 20-mesh (76μ) nets equipped with TSK flowmeters. The nets were attached to velocity reduction cones (designed to reduce the flow of water through the nets to 0.5 ft/sec) with spring clips and were then mounted on a rigid rack assembly at each station. Sampling duration was three minutes. As different types of flowmeters were used in 1972 and 1973 and meters were not used consistently in 1974, abundance comparisons among years were made on the basis of catch per unit effort (unit effort = 3 min sample).

Immediately after collection the samples were transported to the on-site laboratory for viability analysis. The same samples were used for abundance determinations, viability estimates and studies of latent effects. Throughout the observation period 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 with a pointed instrument. After the initial examination 100 mℓ of uniformly mixed sample was placed in a culture dish and returned to the circulating water table to await latent mortality assessment 24 hrs later; the remainder was preserved with formalin. Two 1 mℓ subsamples of the preserved sample were counted to determine the total number of organisms present in the sample, and abundance estimates for plant samples followed the same procedures as for the river populations.

Analysis of microzooplankton viability data followed an R×C contingency table analysis using the G-test (Sokal and Rohlf, 1969). Analysis was for survival each month at the intake and two discharge stations. Significant sets were tested for maximum non-significant subsets by an a posteriori simultaneous test procedure. All comparisons were made at an $\alpha = .05$.

Analysis of initial and latent survival over the whole year at the intake and two discharge stations was conducted by the Kruskal-Wallis test, a nonparametric analogue of the single classification analysis of variance. If any analysis indicated significance an a posteriori comparison of survival was conducted by the Mann-Whitney U-test (Mann and Whitney, 1947).

5.2.3 Results

5.2.3.1 Seasonal Abundance

The species composition of the microzooplankton collected at the Indian Point plant stations was similar to that of the river, and those microzooplankters most frequently seen in river samples were the ones most frequently seen in plant samples. The dominant groups were protozoans and representatives of the classes Crustacea and Rotifera. Although these same three groups of organisms were collected in previous years, only the abundance of Crustacea (excluding nauplii) were analyzed (Tables 5-11 and 5-12).

The monthly abundance for total microzooplankton and for the various microzooplankton groups are presented in Tables 5-13 to 5-19 and Figures 5-16 to 5-21. As in previous years, the peak abundance for total microzooplankton occurred in June (June 3), when mean numbers reached 357/liter (Figure 5-16); this date was within one week of the date (May 27) of peak abundance in the river. Two additional microzooplankton peaks were observed in plant samples, one in February and the other in August. A second microzooplankton abundance peak was observed in river samples and occurred in July. The river was not sampled during the months January through March.

Microcrustaceans were the most abundant organisms sampled and accounted for 70% of the total microzooplankton population collected. Of this group, copepods were the most

Table 5-11. Inventory of microzooplankton collected at the intake and discharge-canal stations and used for survival and abundance studies.

	Presence			
	1972	1973	1974	1975
Crustacea				
Copepoda				
Acartia tonsa Dana	X	N.S.	X	X
Canthocamptid 1.	X	N.S.		X
Canthocamptid 2.	X	N.S.		
Canuella sp.	X	N.S.	X	X
Diacyclops bicuspidatua	X	N.S.	X	X
Ectinosoma curticorne	X	N.S.	X	X
Epischura sp.	X	N.S.	X	X
Ergasilus sp.	X	N.S.	X	X
Eurytemora affinis	X	N.S.	X	X
Halicyclops fosteri	X	N.S.	X	X
Nauplii	X	N.S.	X	X
Copepodids	X	N.S.	X	X
Cladocera				
Bosmina longirostris	X	N.S.	X	X
Chydorid	X	N.S.	X	X
Daphnia pulex	X	N.S.	X	X
Diaphanosoma brachyurum	X	N.S.	X	X
Leptodora kindtii	X	N.S.	X	X
Moina sp.	X	N.S.	X	X

N.S.* Not sampled as the plant was not operational most of the year.

Table 5-12. Inventory of additional microzooplankton considered in 1975 abundance studies of the intake and discharge canal studies.

Rotifera
- Asplanchna sp.
- Brachionus agnularis Grasse
- Brachionus calyciflorus Pallas
- Brachionus quadridentata Herman
- Filinia longiseta (Ehrenberg)
- Keratella cochlearis (Grasse)
- Keratella quadrata (Muller)
- Kellicottia longispina (Kellicott)
- Notholca accuminata (Ehrenberg)
- Philodina sp.
- Platyias patulus Ahlstrom
- Pleosoma trunctatum (Levander)
- Polyarthra sp.
- Trichocerca sp.

Protozoa
- Plasmodroma
  - Mastigophora
    - Centropyxis sp.
    - Difflugia sp.
    - Eudorina sp.
    - Voluox sp.

Ciliophora
- Ciliate
  - Carchesium sp.
  - Epistylis sp.

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

Table 5-13. Plant abundances of total Microzooplankton, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	3.7	5.9	8.8	6.8	5.7	7.6	6.4	.7
2/11	83.2	70.3	75.8	63.3	99.7	80.9	78.8	5.1
3/27	14.7	19.2	10.8	25.5	*	*	17.5	3.2
4/21	21.7	20.4	18.0	13.9	12.3	14.5	16.8	1.6
5/08	60.7	107.1	13.2	17.0	27.8	22.2	41.3	14.9
5/27	114.6	84.0	61.2	37.8	231.8	172.6	117.0	29.9
6/03	561.0	1063.8	23.7	202.4	152.5	138.0	356.9	159.8
6/10	87.6	55.7	156.1	*	69.6	83.5	90.5	17.3
6/17	*	*	38.4	*	41.6	*	40.0	1.6
7/08	145.4	181.0	17.0	31.9	79.7	82.0	89.5	26.0
8/19	428.5	268.9	48.1	36.0	68.9	80.0	155.1	64.9
9/11	242.4	210.3	14.8	21.0	40.1	54.0	97.1	41.5
10/14	27.1	39.2	11.1	11.2	34.4	247.4	61.8	37.4
11/18	15.0	14.0	12.8	13.0	128.8	24.7	34.7	18.9
12/16	91.0	63.5	11.9	15.8	55.0	55.2	48.7	12.3

* Indicates missing samples.

Table 5-14. Plant abundances of Crustacea, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	1.42	2.82	1.41	2.75	2.57	2.66	2.27	.27
2/11	64.71	54.34	57.91	52.38	78.16	58.90	61.07	3.83
3/27	2.03	2.56	1.62	3.41	*	*	2.40	.39
4/21	9.86	10.60	11.40	6.94	7.99	9.80	9.43	.68
5/08	59.44	105.57	12.28	16.18	25.43	19.70	39.77	14.87
5/27	51.92	45.06	35.17	22.11	119.76	86.72	60.12	14.86
6/03	215.58	419.08	23.75	110.43	68.24	51.88	148.16	60.69
6/10	84.11	50.66	149.14	*	66.50	79.07	85.90	16.83
6/17	*	*	37.76	*	40.50	*	39.13	1.37
7/08	137.00	169.39	12.97	26.74	73.84	64.47	80.85	25.12
8/19	427.00	267.77	47.04	34.91	67.15	78.26	153.75	64.95
9/11	238.62	205.83	14.08	20.08	38.27	51.89	94.80	40.89
10/14	23.05	24.77	9.83	8.92	21.77	160.58	41.48	23.98
11/18	8.77	8.79	7.64	7.82	56.21	15.22	17.41	7.85
12/16	59.99	39.74	9.10	8.81	41.51	34.04	32.20	8.16

* Indicates missing samples.

Table 5-15. Plant abundances of Copepoda Nauplii, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	.71	2.11	.78	2.20	2.20	2.13	1.69	.30
2/11	61.31	53.08	54.45	49.71	72.96	53.01	57.42	3.48
3/27	1.30	2.12	1.20	2.67	*	*	1.82	.35
4/21	6.94	8.86	9.85	5.70	5.49	6.54	7.23	.72
5/08	46.60	81.45	10.59	13.57	13.75	12.00	29.66	11.77
5/27	41.62	36.13	29.44	16.47	106.45	69.86	49.99	13.40
6/03	176.17	290.13	.00	70.22	49.65	39.20	104.23	44.33
6/10	72.14	39.64	44.83	.00	52.92	56.53	53.21	5.59
6/17	*	*	15.51	.00	21.65	*	18.58	3.07
7/08	63.79	103.61	6.48	12.00	9.96	9.53	34.23	16.48
8/19	408.82	248.21	34.62	23.57	39.69	43.54	133.08	65.25
9/11	219.53	192.32	12.76	19.04	35.23	48.63	87.92	37.83
10/14	7.79	12.13	3.60	5.28	12.28	85.20	21.05	12.91
11/18	2.76	2.20	1.72	2.79	18.74	2.99	5.20	2.71
12/16	54.81	37.02	5.89	7.71	37.15	31.14	28.95	7.72

* Indicates missing samples.

Table 5-16. Plant abundances of Copepoda copepodids, 1975. Number per liter. (II-1, II-2 = Unit 2 intake replicates 1 and 2; D1-1, D1-2 = discharge canal station 1 replicates 1 and 2; D2-1, D2-2 = discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	.00	.00	.16	.37	.18	.35	.18	.07
2/11	.57	1.02	.86	.67	1.43	1.37	.99	.15
3/27	.31	.44	.21	.30	*	*	.32	.05
4/21	.90	.39	.39	.47	.48	1.31	.65	.15
5/08	6.21	6.89	.45	1.25	2.41	1.54	3.13	1.12
5/27	3.43	4.06	.00	.00	.00	.00	1.25	.79
6/03	2.32	27.28	.00	10.55	4.86	.94	7.66	4.22
6/10	5.16	3.91	34.70	*	4.35	7.68	11.16	5.92
6/17	*	*	12.14	*	7.32	*	9.73	2.41
7/08	36.59	41.91	1.84	4.99	23.32	22.05	21.78	6.60
8/19	4.16	3.93	2.05	2.39	5.88	5.06	3.91	.61
9/11	1.91	4.50	.39	.19	1.06	.74	1.47	.66
10/14	12.53	10.58	4.20	2.15	6.14	55.71	15.22	8.25
11/18	2.76	1.10	1.15	.19	11.71	1.90	3.13	1.75
12/16	.00	.68	.00	.37	.42	.36	.30	.11

* Indicates missing samples.

Table 5-17. Plant abundances of Copepoda Adults, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	.53	.70	.47	.18	.18	.18	.37	.09
2/11	2.84	.25	2.59	2.00	3.59	4.52	2.63	.59
3/27	.36	.00	.21	.44	*	*	.26	.10
4/21	2.02	1.16	1.16	.65	2.03	1.96	1.49	.24
5/08	6.63	16.60	1.24	1.36	9.28	6.15	6.88	2.33
5/27	3.00	2.84	3.63	4.45	11.09	12.04	6.18	1.72
6/03	23.18	32.24	12.00	7.25	5.70	2.35	13.79	4.73
6/10	3.27	3.77	60.88	*	5.63	8.18	16.35	11.17
6/17	*	*	2.87	*	1.87	*	2.37	.50
7/08	31.05	18.63	4.12	9.15	38.33	32.17	22.24	5.62
8/19	2.58	3.19	4.24	5.22	10.73	14.32	6.71	1.93
9/11	11.45	5.15	.77	.32	1.19	1.33	3.37	1.76
10/14	2.14	1.68	1.56	.83	2.42	16.39	4.17	2.45
11/18	1.50	3.57	1.91	2.61	11.71	7.06	4.73	1.62
12/16	5.17	1.87	3.21	.73	3.94	2.53	2.91	.64

* Indicates missing samples.

Table 5-18. Plant abundances of Rotifera, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	2.13	2.82	6.74	3.67	2.75	4.78	3.81	.69
2/11	18.16	16.00	16.42	10.65	20.97	21.60	17.30	1.63
3/27	12.60	16.17	9.15	21.47	*	*	14.85	2.63
4/21	8.74	7.90	4.89	5.12	3.46	4.25	5.73	.86
5/08	.83	1.25	.23	.31	1.37	.62	.77	.19
5/27	62.22	38.97	25.42	15.29	106.45	84.31	55.44	14.45
6/03	345.39	642.26	.00	91.64	83.66	84.98	207.99	99.14
6/10	3.40	4.88	6.72	*	2.82	4.41	4.45	.68
6/17	*	*	.34	*	.62	*	.48	.14
7/08	.48	1.46	.09	.00	.23	.00	.38	.23
8/19	.34	.32	.29	.30	.58	.14	.33	.06
9/11	.00	.00	.00	.00	.40	.00	.07	.07
10/14	2.99	12.90	1.20	1.32	10.42	65.54	15.73	10.16
11/18	5.01	4.40	4.58	5.21	65.58	8.42	15.54	10.03
12/16	29.99	23.77	2.85	6.79	13.49	21.00	16.32	4.26

* Indicates missing samples.

Table 5-19. Plant abundances of Protozoa, 1975. Number per liter. (II-1, II-2= Unit 2 intakes replicates 1 and 2; D1-1, D1-2= Discharge canal station 1 replicates 1 and 2; D2-1, D2-2= Discharge canal station 2 replicates 1 and 2).

	Stations							
Date	II-1	II-2	D1-1	D1-2	D2-1	D2-2	Mean	S.E.
1/14	.18	.23	.63	.37	.37	.18	.32	.07
2/11	.28	.00	1.44	.22	.54	.39	.48	.21
3/27	.05	.35	.00	.44	*	*	.21	.11
4/21	2.69	1.54	1.61	1.71	.83	.49	1.48	.31
5/08	.41	.31	.68	.52	1.03	1.85	.80	.23
5/27	.43	.00	.38	.45	4.44	.80	1.08	.68
6/03	.00	2.48	.00	.33	.63	1.17	.77	.39
6/10	.13	.14	.20	*	.17	.00	.13	.03
6/17	*	*	.34	*	.47	*	.40	.07
7/08	1.20	.58	.00	.24	.00	.12	.36	.19
8/19	.79	.85	.44	.30	.92	1.01	.72	.12
9/11	3.82	4.50	.70	.78	1.46	2.08	2.22	.65
10/14	1.10	1.55	.12	.99	2.23	21.30	4.55	3.36
11/18	1.25	.82	.38	.00	7.03	1.09	1.76	1.07
12/16	1.03	.00	.00	.18	.00	.18	.23	.16

* Indicates missing samples.

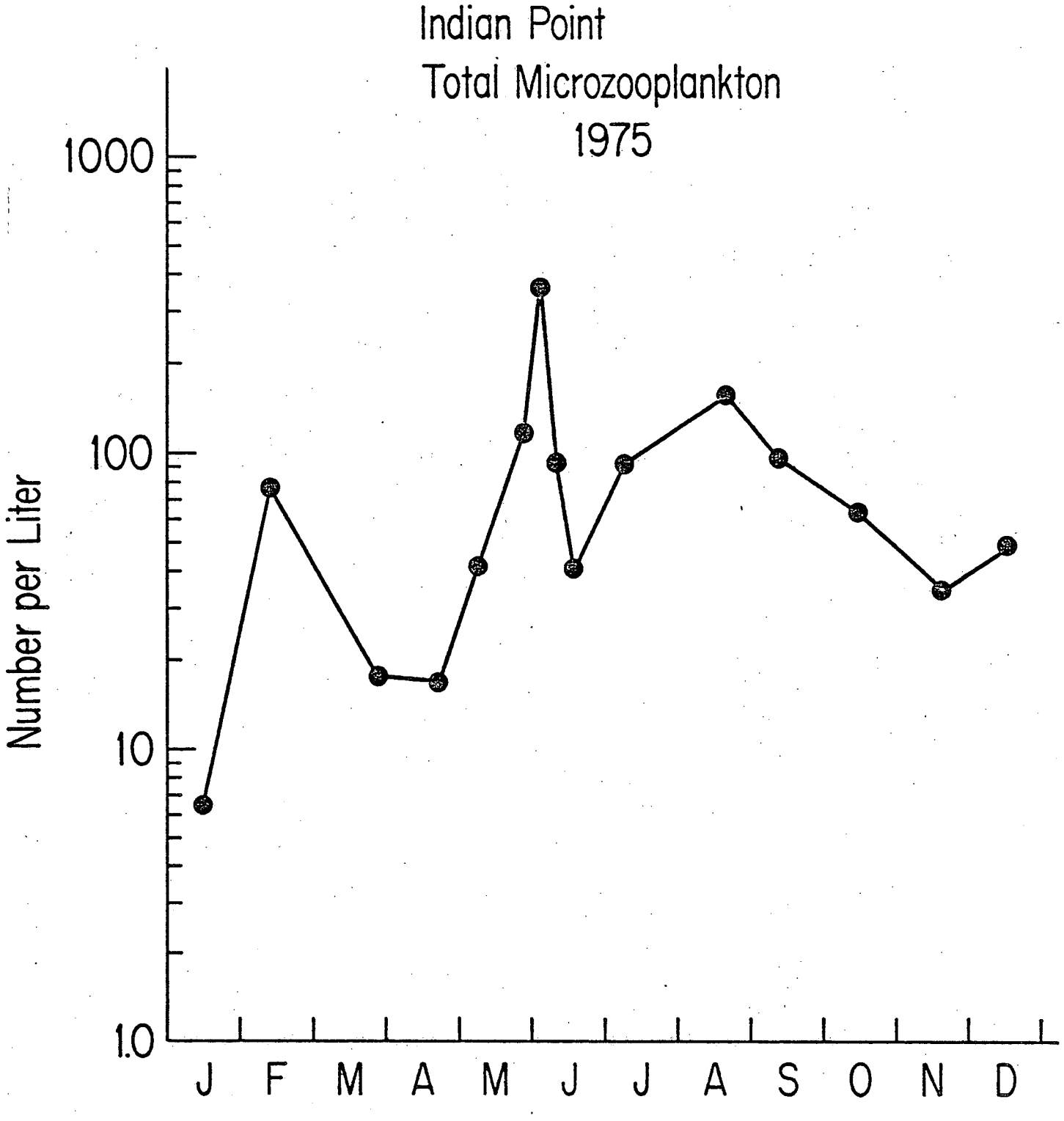

Figure 5-16. Daytime abundance of total microzooplankton, 1975.

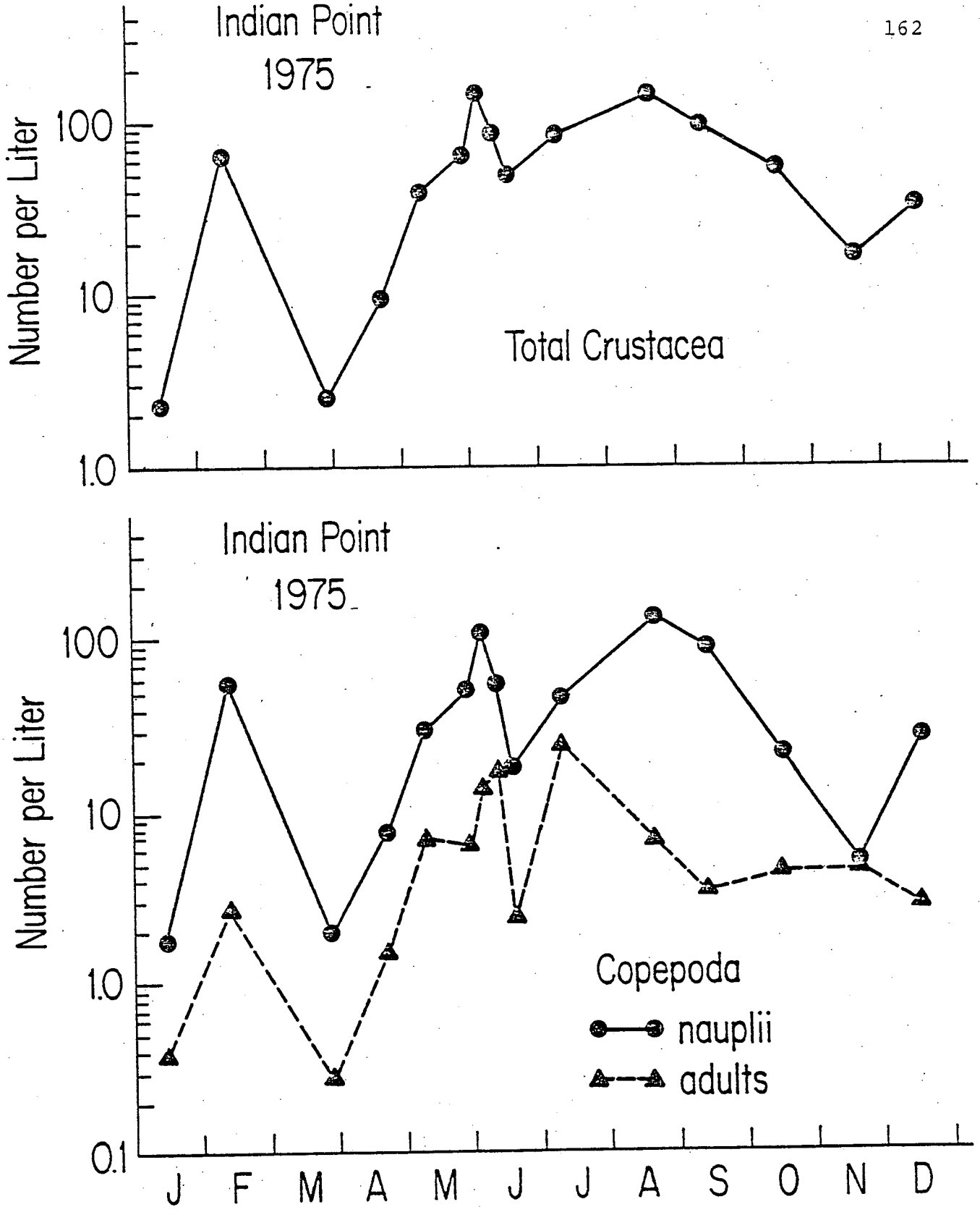

Figure 5-17. Daytime abundance of total Crustacea and total copepods, 1975.

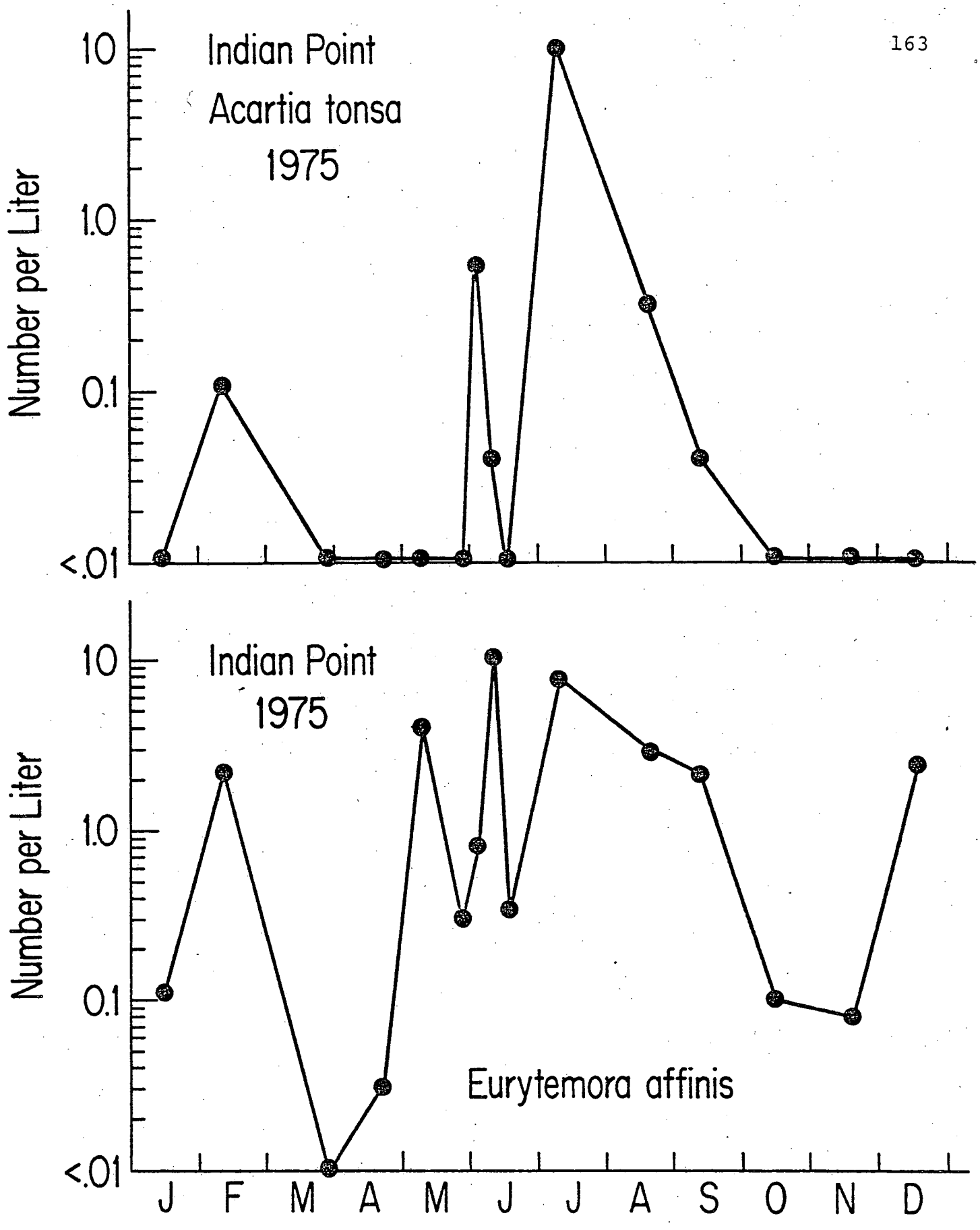

Figure 5-18. Daytime abundance of calanoid copepods, Acartia tonsa and Eurytemora affinis, 1975.

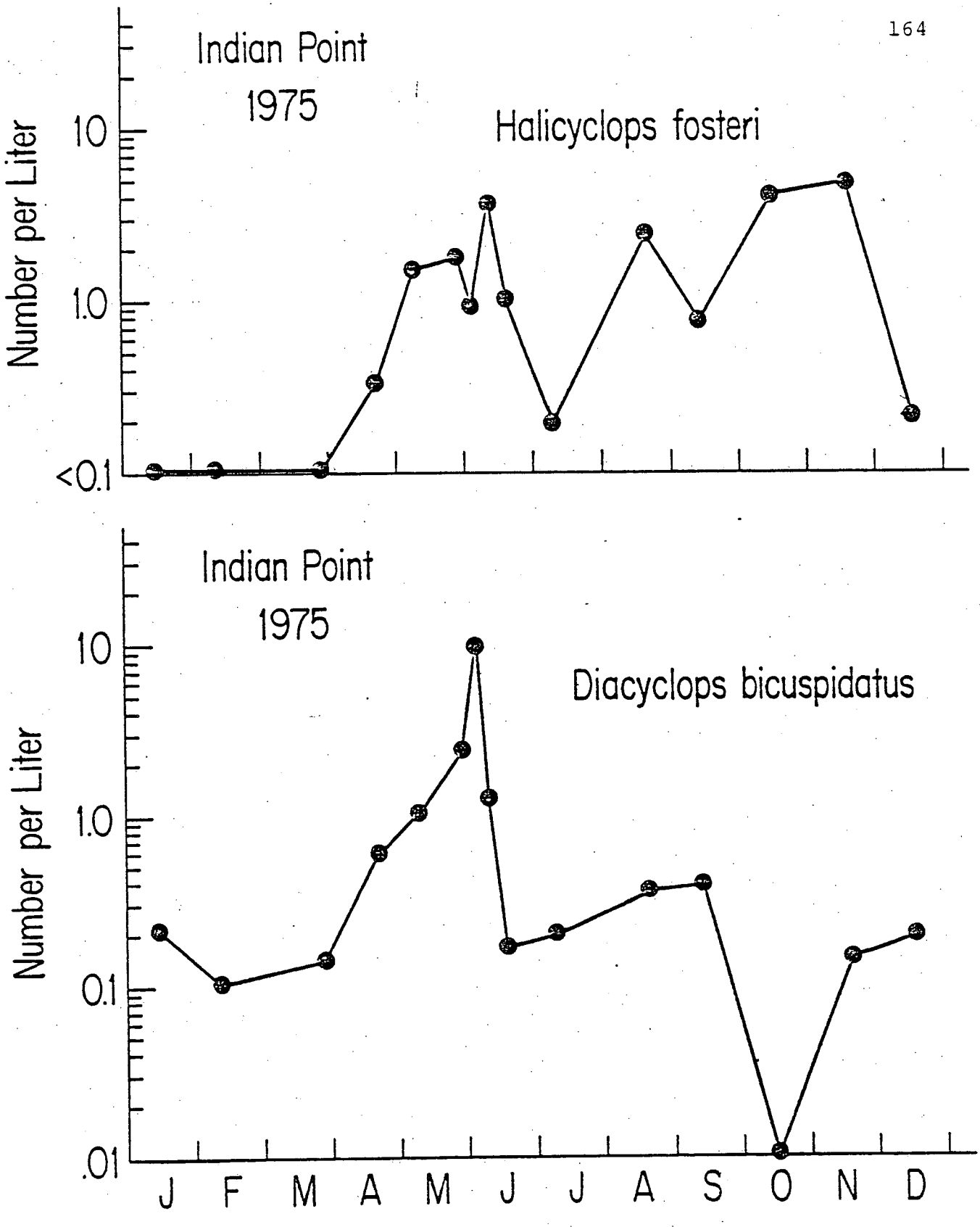

Figure 5-19. Daytime abundance of cyclopoid copepods, Diacyclops bicuspidatus and Halicyclops fosteri, 1975.

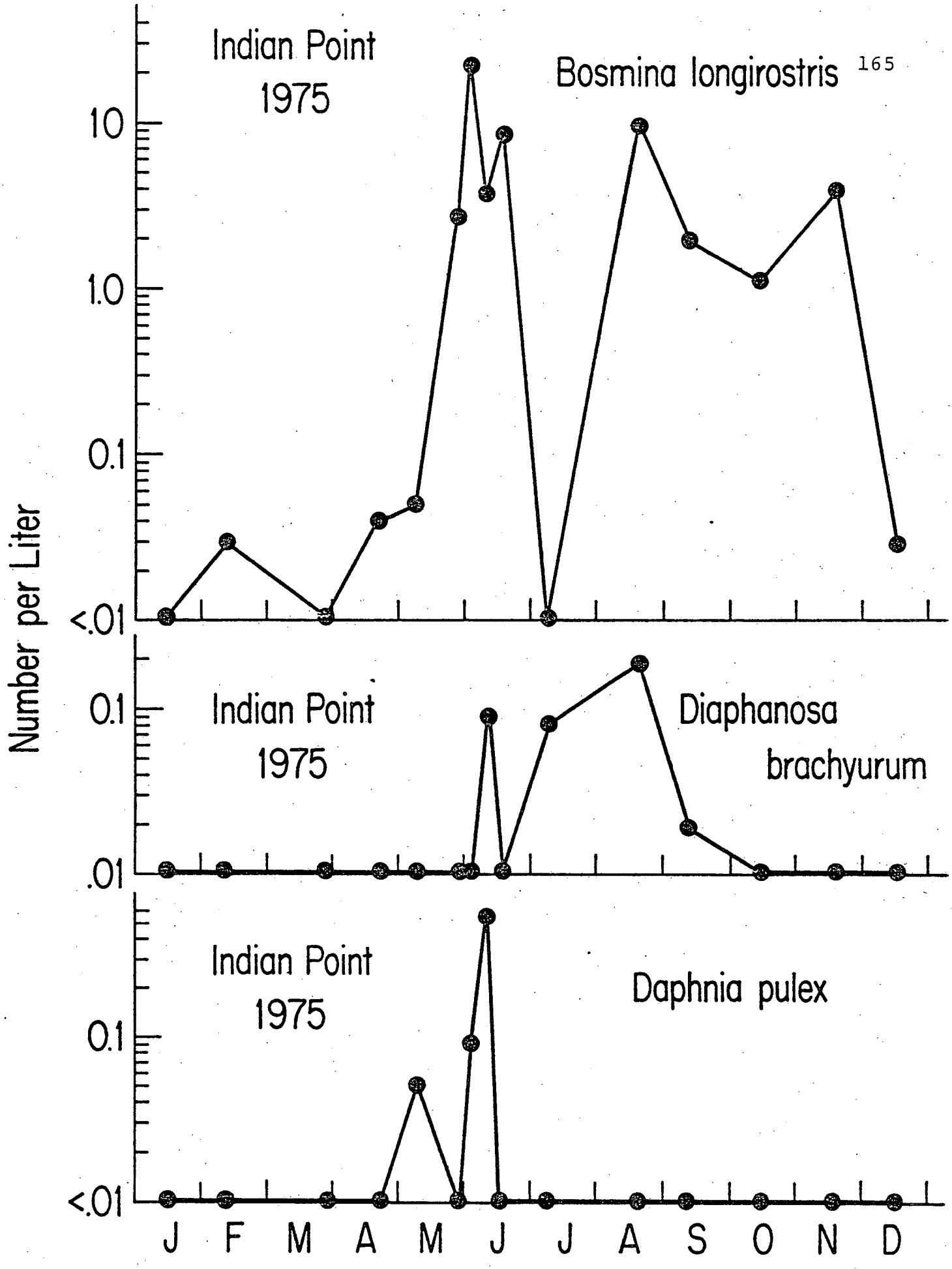

Figure 5-20. Daytime abundance of cladocerans, Bosmina longirostris, Diaphanosoma brachyurum and Daphnia pulex, 1975.

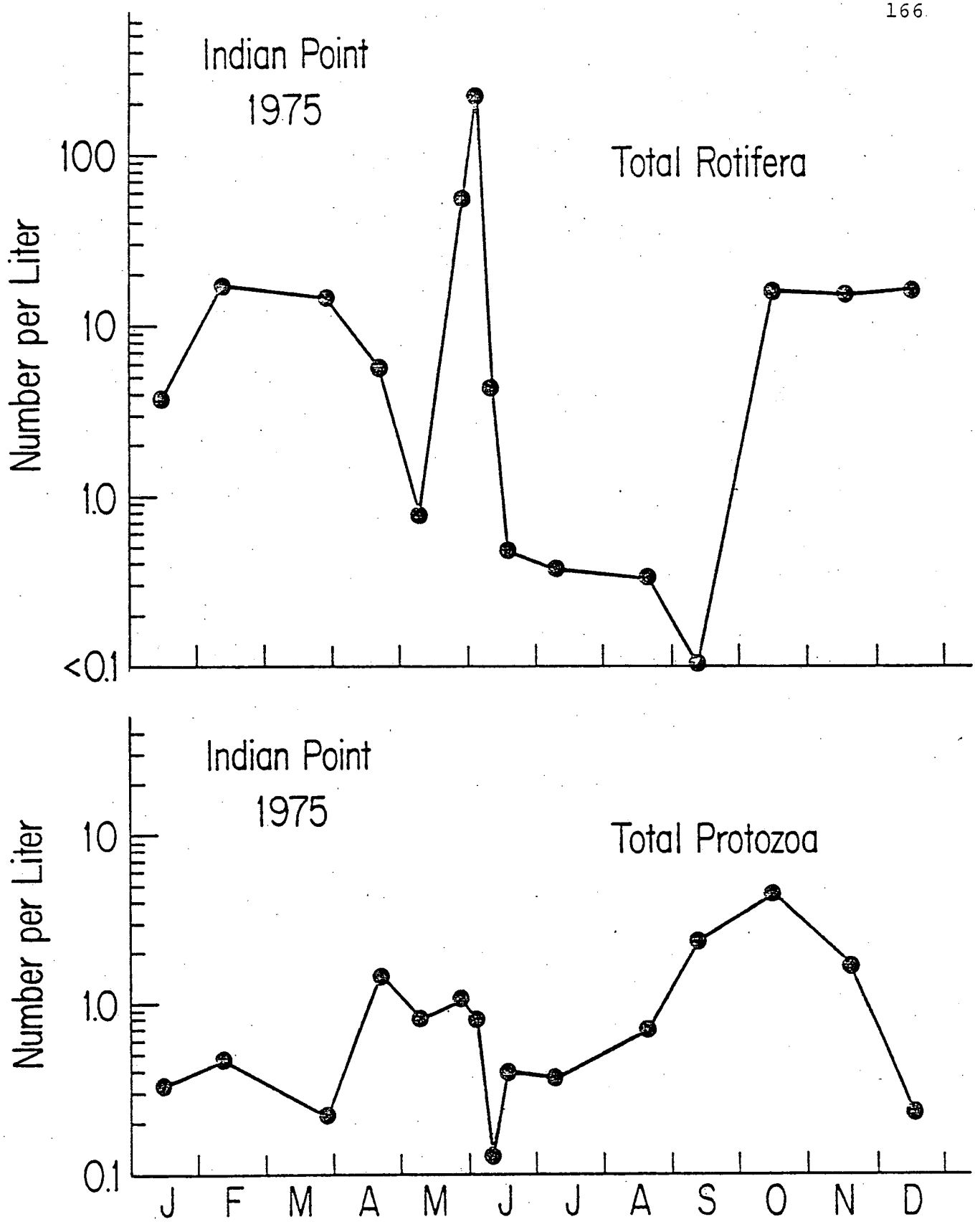

Figure 5-21. Daytime abundance of total Rotifera and total Protozoa, 1975.

abundant (64.7% of the total); cladocerans accounted for most of the rest at 4.3%. Although the numbers of rotifers collected represented 29% of the total microzooplankton population, their peak abundance was greater than that of the microcrustaceans. Rotifer abundance peaked at 208/liter (Table 5-18) as compared to the microcrustacean peak of 154/liter (Table 5-14). Protozoa accounted for approximately 1% of the microzooplankton. Numbers in the samples peaked at 1.5/liter (Table 5-19).

Of the microcrustaceans collected, the calanoid copepods were the most abundant. They were followed, in order, by the cyclopoid copepods and the harpacticoid copepods. Nauplii were consistently the most abundant copepod stage collected (Figure 5-17). The adult copepods were slightly more abundant than the copepodid stage. Eurytemora affinis, a calanoid copepod, was the most abundant adult copepod collected; it occurred throughout the sampling period (Figure 5-18). The most abundant adult cyclopoid copepods, Diacyclops bicuspidatus and Halicyclops fosteri (Figure 5-19) were each more abundant than the adult Acartia tonsa, the second most abundant calanoid copepod. A. tonsa was observed only during periods of increased salinity.

Bosmina longirostris, Diaphanosoma brachyurum and Daphnia pulex were the major cladocerans found in Indian Point plant samples (Figure 5-20). Relative to river samples D. pulex occurred more frequently in plant samples (it was

observed on only one date in river samples), while D. brachyurum was slightly more abundant in river samples.

Dominant rotifers observed in plant samples included Notholca accuminata, Keratella cochlearis and an unidentified rotifer. These same three were observed to be the dominant species in river samples.

Antropyxis sp., Difflugia sp., Opistylis sp., and Carchesium sp. were the most frequently collected protozoans in plant samples as well as in river samples.

Analysis of variance (ANOVA) results indicated that there was a station effect on abundance for five microzooplankton groups. A Scheffés test in each of these cases (Table 5-20) showed no difference between replicate intake samples. However, total abundance was greater at the intakes than at D-1 and D-2, and less at D-1 than at D-2 (this was true only if crustacean adults and nauplii and rotifers were considered). But if H. fosteri and copepod adults were considered, then the abundance at D-2 was greater than at the intakes. With D. pulex as the exception, there was a "date" effect on microzooplankton abundance (Table 5-21). This was as expected and may be reflective of the seasonal changes in microzooplankton species in response to changes in river salinity and temperature. The lack of date effect in the case of D. pulex was probably the result of the very low numbers of D. pulex collected throughout the year.

Table 5-20. Results of analysis of variance of plant abundances of microzooplankton for date effect, 1975.

Microzooplankton Group	"F"	Station Effect	Scheffe Test ($\alpha<0.10$)
Total	7.6227	*	II>D1;II>D2;D2>D1
Diacyclops bicuspidatus	0.7197	N.S.	
Halicyclops fosteri	3.0720	*	D2>II; D2>D1
Bosmina longirostris	1.0110	N.S.	
Diaphanosoma brachyurum	0.6000	N.S.	
Daphnia pulex	0.7143	N.S.	
Acartia tonsa	0.9259	N.S.	
Eurytemora affinis	0.5545	N.S.	
Nauplii	6.1042	*	II>D1; II>D2; D2>D1
Copepod adults	3.3389	*	II>D1; D2>II
Crustacea	8.1595	*	II>D1; II>D2; D2>D1
Protozoa	1.6051	N.S.	
Rotifera	3.0149	*	II>D1; II>D2; D2>D1

N.S. = Not significant
* significant at $\alpha < 0.05$

Table 5-21. Results of analysis of variance of plant abundances of microzooplankton for date effects, 1975.

Microzooplankton Group	"F"	Date Effect
Total	10.7049	*
Diacyclops bicuspidatus	9.2588	*
Halicyclops fosteri	10.9748	*
Bosmina longirostris	18.2026	*
Diaphanosoma brachyurum	6.0000	*
Daphnia pulex	0.8571	N.S.
Acartia tonsa	26.2100	*
Eurytemora affinis	9.2556	*
Nauplii	10.0529	*
Copepod adults	8.3313	*
Crustacea	15.7905	*
Protozoa	2.5635	*
Rotifera	17.6289	*

N.S. = Not significant
* significant at $\alpha < 0.05$

The seasonal patterns for total microzooplankton abundance in 1972, 1974 and 1975 are compared in Figure 5-22. As explained earlier, this comparison was made on the basis of catch per unit effort rather than on the numbers per unit volume of water filtered through the nets. The comparisons show that the seasonal variations as well as the magnitudes of variation are similar. There was an overall increase in the number of organisms collected in 1975. The major taxa comprising the microzooplankton community showed little difference in seasonal variation and abundance between years (New York University Medical Center, 1973; 1974; 1976a). For samples collected in the years 1972, 1974 and 1975, copepods (excluding nauplii) constituted 72, 92, and 77% of the microcrustacean population, respectively. The copepod composition was nearly equally divided between calanoid and cyclopoid copepods with about 10% harpactacoid copepods. The calanoid copepod E. affinis, alone, accounted for about 15-30% of the microcrustacean population (Table 5-22).

5.2.3.2 Viability Studies

The initial survival of selected groups of microzooplankton (cladocerans, copepodid and adult copepods) in plant-entrained samples collected throughout 1975 is shown in Table 5-23; latent survival after 24 hrs is presented in Table 5-24. The initial survival of microcrustaceans from monthly collections of samples collected within the plant

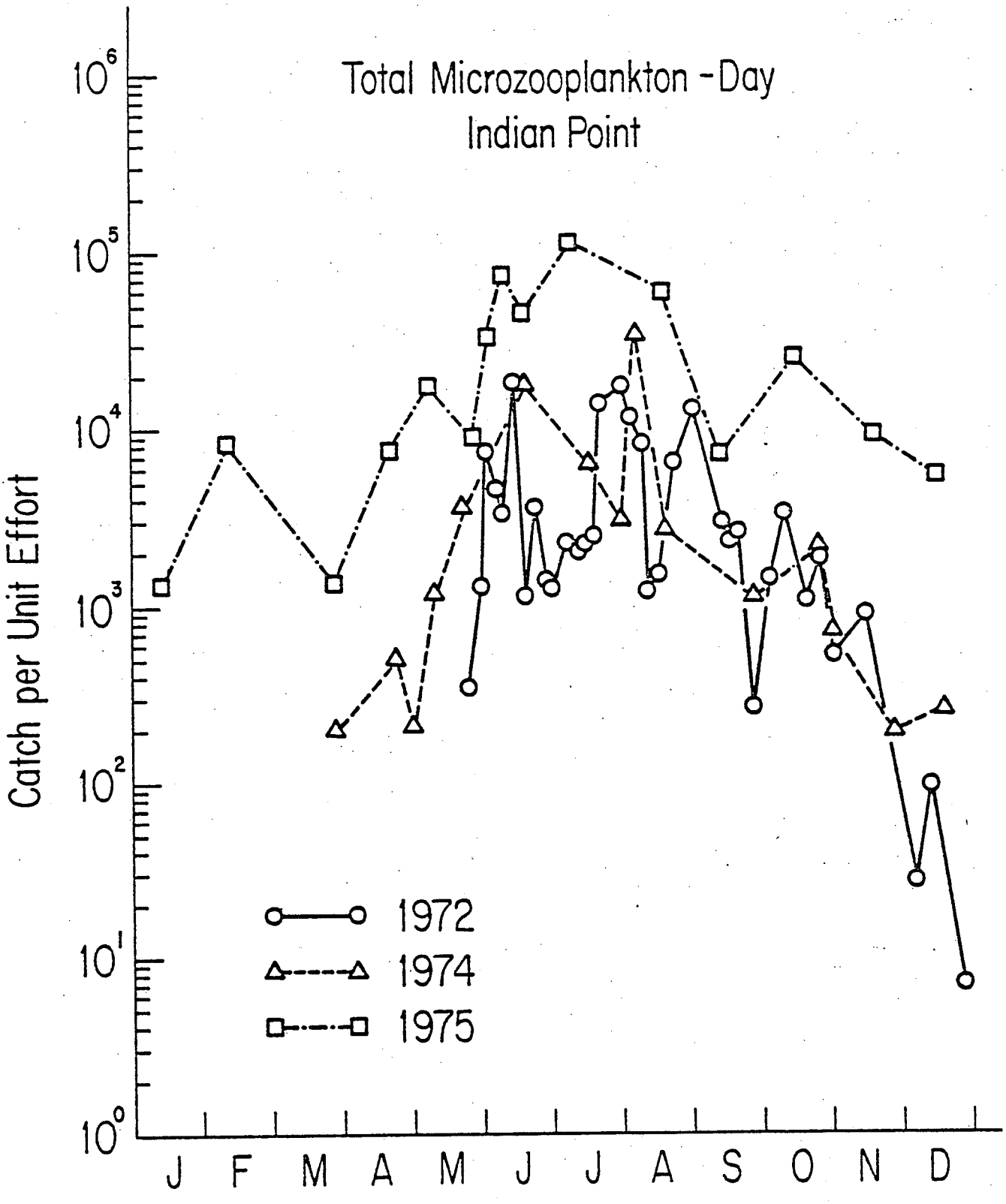

Figure 5-22. A comparison of total microzooplankton collected at Indian Point in 1972, 1974 and 1975 on the basis of catch per unit effort. Unit 1 was sampled in 1972 and 1974, while Unit 2 was sampled in 1975.

Table 5-22. Percent composition of major microcrustacean groups collected at Indian Point in 1972, 1974 and 1975.

Microzooplankton Group	Percent of Microcrustaceans* 1972	1974	1975
Eurytemora affinis	26.4	30.9	14.2**
Acartia tonsa	4.0	8.3	4.7**
Diacyclops bicuspidatus	3.2	6.6	7.3**
Halicyclops fosteri	26.8	37.4	7.3**
Harpatacoid copepods	11.6	8.3	4.9
Bosmina longirostrus	10.6	5.3	22.5
Daphnia pulex	1.6	0.0	0.29
Diaphinosoma brachyurum	3.4	0.7	0.16

* excluding naupli
** adults only

Table 5-23. Initial (1 hour) percent survival of entrained microzooplankton at Unit 2 intakes (II) discharge canal stations (D-1, D-2) by month, 1975.

Month	Mean % Survival ± S.E.					
	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copepods	Cladocerans
January						
I	88.9±11.1	87.5±12.6	100	50.0±50.1	87.5±12.6	100
D1	81.8± 4.0	100	75.0±25.1	50.0±50.1	77.5± 2.5	100
D2	93.8± 8.8	100	87.5±12.3	100	93.8± 6.2	100
February						
I	100	100	100	100	100	100
D1	94.3± 8.1	93.8± 6.2	100	100	94.3± 5.7	100
D2	95.2± 1.6	94.4± 2.1	100	---	95.0± 1.8	100
April						
I	94.0± 3.3	100	86.9± 6.9	95.0± 7.1	93.3± 2.8	100
D1	89.6± 4.2	100	93.4± 4.5	65.9±16.0	91.7± 4.2	25.0±25.1
D2	92.1± 1.2	100	89.7± 5.5	92.1± 1.2	93.0± 3.5	50.0±50.1
May						
I	89.8± 9.2	81.8±18.2	88.3± 2.6	100	87.4± 6.8	95.8± 4.2
D1	86.3± 5.8	84.0	72.8±20.5	88.2± 6.5	83.6± 6.7	94.8± 0.7
D2	76.9±12.6	100	85.3±10.3	54.8±11.9	75.0± 9.8	80.0±20.0
June						
I	91.3± 0.6	72.0	94.9± 0.8	100	90.0± 5.8	90.6± 6.0
D1	91.9± 1.1	94.4± 0.8	84.5± 6.4	100	89.7± 2.9	92.0± 2.9
D2	93.6± 0.14	75.6±15.6	94.1	100	91.7± 1.1	94.9± 0.1
June						
I	88.9± 5.2	75.4±12.9	84.8± 5.8	94.4± 5.6	83.2± 6.1	95.0± 5.0
D1	98.2	98.2	76.6	100	82.9	100
D2	87.2± 0.4	93.2± 0.2	91.2± 0.8	90.9± 2.0	90.9± 0.7	75.6± 1.3

Table 5-23 (cont.).

Mean % Survival ± S.E.

Month	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copepods	Cladocerans
July						
II	89.4± 1.0	85.3± 1.0	100	100	88.6± 0.6	100
D1	89.5±10.5	87.9±12.2	100	100	89.5±11.2	---
D2	94.7± 2.3	93.6± 3.1	100	100	94.6± 2.2	100
August						
II	93.7± 2.8	83.9± 2.9	97.4± 0.4	100	94.7± 2.7	92.7± 4.5
D1	89.3± 2.5	85.8± 7.3	93.7± 1.4	100	89.1± 4.3	91.1±13.6
D2	49.8± 1.8	14.3±12.3	94.1± 2.1	62.8±14.0	61.2± 3.0	44.9±13.0
September						
II	94.6± 1.3	88.8± 2.1	95.6± 2.4	---	92.4± 1.9	100
D1	91.3± 3.4	95.4± 4.6	87.1± 3.8	37.5±37.6	88.7±10.9	100
D2	96.0± 2.1	94.6± 5.8	95.5± 4.6	100	95.6± 1.7	96.6± 3.4
October						
II	96.6± 0.6	97.5± 2.5	96.6± 1.7	100	96.8± 1.0	91.6± 8.4
D1	89.3± 2.3	83.4±16.7	89.5± 4.8	100	89.5± 4.3	72.3± 5.7
D2	87.5± 2.0	97.0± 3.1	93.2± 1.4	100	94.4± 0.1	45.1±45.2
November						
II	94.4± 3.7	100	93.6± 2.2	83.4±16.7	93.5± 3.8	96.7± 3.4
D1	95.9± 2.5	100	96.6± 0.3	50.0±50.1	95.7± 1.8	100
D2	94.9± 2.3	100	92.5± 2.7	100	93.7± 2.1	97.9± 2.1
December						
II	100	100	100	---	100	100
D1	89.3±10.7	95.9± 4.2	95.9± 4.2	---	89.3±10.7	---
D2	96.2± 0.9	98.6± 1.4	98.6± 1.4	100	96.4± 0.8	100

Table 5-24. Latent mortality (24-h) of entrained microzooplankton at Unit 2 intakes (II), discharge canal stations (D-1, D-2), by month, 1975.

Mean % Survival ± S.E.

Month	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copepods	Cladocerans
January						
II	52.8±	50.0±50.1	75.0±25.0	16.7±16.7	44.2±32.7	100
D1	55.7±15.7	50.0±50.1	75.0±25.0	50.0±50.1	71.3±32.7	100
D2	70.9± 4.2	100	57.5±17.6	0.0	68.8± 6.3	100
February						
II	85.5± 8.6	82.5±13.5	0.0	0.0	88.6± 5.2	50.0±50.1
D1	78.8± 9.1	74.7±12.8	100	50.0±50.1	80.0± 8.6	100
D2	92.8± 5.7	96.8± 1.3	100	---	92.6± 5.7	100
March						
II						
D1						
D2						
April						
II	90.1± 2.6	91.6± 8.4	93.8± 6.3	90.0±10.0	89.0± 3.3	100
D1	69.6±13.7	50.0±50.1	85.1± 1.8	0.0	69.8±13.5	50
D2	---	---	---	---	---	---
May						
II	73.1± 8.5	76.1±13.3	88.3± 2.6	60.0±10.0	87.4± 6.8	60.2±14.8
D1	74.2± 5.5	88.5	60.0±26.8	90.9± 9.1	78.8± 4.6	59.9±12.8
D2	69.7± 9.0	0.0	84.0± 9.9	71.4±28.6	66.2± 9.7	82.3± 2.3
June						
II	22.2± 9.7	0.0	61.9±21.1	87.3± 1.6	36.3± 1.2	9.6± 9.6
D1	83.7	85.7	0.0	71.0	0.0	50.7
D2	61.3± 3.0	71.1± 8.6	72.4± 5.7	62.5±12.5	67.6± 4.3	40.6± 0.8

Table 5-24 (cont.).

Month	Micro-Crustacea	Calanoid Copepods	Cyclopoid Copepods	Harpacticoids	Copepods	Cladocerans
July						
II	61.7±19.1	60.9±22.1	77.6±10.9	21.7±21.8	60.0±19.2	100
D1	47.7± 2.3	47.0± 0.4	100	34.4± 1.1	47.6± 2.4	----------
D2	90.0± 2.0	88.9± 3.0	98.4± 1.6	48.4±48.4	90.0± 2.0	100
August						
II	1.7± 0.4	2.5± 2.5	3.6± 0.6	0.0	3.1± 0.9	0.9± 0.1
D1	28.5± 1.0	27.8± 1.6	26.8±11.8	33.3	27.2± 4.3	32.7± 6.9
D2	10.0± 1.5	1.2± 0.4	29.0± 3.3	12.8± 7.2	13.3± 1.8	5.3± 0.4
September						
II	81.8± 1.8	83.2± 3.2	81.2± 1.2	---------	81.9± 3.8	92.3± 7.7
D1	84.8± 3.2	79.8± 2.0	74.2± 7.6	87.5±12.5	88.0±10.2	100
D2	93.6± 1.8	87.1± 0.4	92.8± 7.2	100	91.1± 1.8	100
October						
II	87.2± 3.2	95.8± 4.2	85.6± 4.7	100	87.4± 3.1	80.2± 8.8
D1	83.7± 3.1	50.0±50.1	82.6± 4.8	83.3	84.3± 4.5	77.8±11.1
D2	83.6± 1.4	98.0± 2.1	77.3± 3.1	100	85.0± 2.8	76.4± 3.7
November						
II	87.6± 0.6	45.8±46.0	86.6± 0.9	50.0±50.1	85.6± 1.0	93.1± 0.2
D1	93.3± 3.8	90.0±10.0	89.5± 4.3	100	89.8± 4.9	97.9± 2.1
D2	88.6± 2.9	50.0±50.1	90.2± 0.4	25.0±25.1	86.4± 3.8	93.8± 2.1
December						
II	91.5± 0.2	90.2± 2.7	93.8± 6.3	---------	83.0± 8.0	100
D1	84.4±13.0	90.4± 7.1	50.0±50.1	---------	84.4±13.0	----------
D2	88.7± 0.2	89.4± 1.8	80.0±20.0	100	88.6± 0.4	100

indicate that survival was generally above 85% for all stations. In January survival was 81.3% at D-1 as compared to 90.5% and 94.1% at the intakes and at D-2 (Table 5-25). However, the lower survival at D-1 was not significant. In two instances (May and August), survival was much lower at D-2 (Table 5-25). Contingency table analysis indicates that this reduced survival was significant only in August when the temperature in the discharge canal reached 34 C (93.2 F). Observed mortalities were nearly 50%, and reduced survival was evident in all microzooplankton groups sampled except in the cyclopoid copepods (Table 5-26).

Latent survival of microcrustaceans collected during monthly sampling within the plant was frequently below 85% (Table 5-27). Contingency analysis showed more instances of difference between stations for latent survival than for initial survival (Table 5-28). However, the difference in latent survival was difficult to interpret because of high mortality in the control stations (intake stations).

These initial survival and latent survival data showed that calanoid copepods were the organisms most sensitive to plant entrainment. For example, in August when high mortalities were evident at D-2, calanoid copepod survival was only 14% while cyclopoid copepod, harpacticoid copepod, and cladoceran survival were 94, 62 and 50%, respectively. Similar results indicating calanoid copepod sensitivity to plant entrainment were obtained in the latent survival studies (Tables 5-23 and 5-24).

Table 5-25. Initial survival of entrained microzooplankton in the intake and discharge stations during 1975. I= Unit II intake, D-1=Discharge Canal station 1, D-2= Discharge Canal station 2.

Month	Station	Temp. at Station °C	% Survival microcrustaceans	no. of organisms
Jan	I	5	90.5	21
	D1	17	81.3	16
	D2	15	94.1	17
Feb	I	1	100.0	30
	D1	14	94.5	55
	D2	13	95.2	124
April	I	7	94.1	51
	D1	15	90.2	82
	D2	15	92.1	84
May	I	19	91.1	101
	D1	31	85.5	145
	D2	31	76.9	65
June	I	20	91.0	145
	D1	28	91.0	445
	D2	28	93.6	296
June	I	20	89.1	220
	D1	30	98.2	4536
	D2	30	87.3	640
July	I	22	92.4	1058
	D1	33	86.8	378
	D2	33	94.7	1889
Aug	I	24	93.5	709
	D1	34	89.6	328
	D2	34	49.8	963
Sept	I	23	94.7	94
	D1	28	91.5	71
	D2	28	95.6	92
Oct	I	18	96.9	669
	D1	28	89.3	214
	D2	28	87.3	212
Nov	I	11	94.3	105
	D1	20	97.6	125
	D2	20	93.8	130
Dec	I	6	100.0	52
	D1	16	94.3	53
	D2	16	96.2	78

Table 5-26. Monthly differences in initial microcrustacean survival among the Unit II intake station (II) and the discharge canal stations (D1,D2).

	Crustacean Group					
Month	micro-crustacean	calanoid copepods	cyclopoid copepods	harpatacoid copepods	copepods	cladocerans
January	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
February	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
March	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
April	n.s.	n.s.	n.s.	II,D2>D1	n.s.	n.s.
May	n.s.	n.s.	n.s.	II,D1>D2	n.s.	n.s.
June	D1>II,	n.s.	n.s.	n.s.	n.s.	n.s.
June	II>D2,D1>II D1>II	D1>II,D1>D2, D2>II	n.s.	II,D2>D1	D2>D1	II>D1,D2 D2>D1
July	D2>II,D1	D2>II,D1	n.s.		D2>II,D1	
Aug	II,D1>D2	II,D1>D2	n.s.	II,D1>D2	II,D1>D2	II,D1>D2
Sept	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Oct	II D1,	n.s.	II>D1	n.s.	II>D1	n.s.
Nov	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Dec	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 5-27. Latent survival (24 hr) of entrained microzooplankton in the intake and discharge stations during 1975. I=Unit II intake, D-1=Discharge Canal station 1, D-2=Discharge Canal station 2.

Month	Station	Temp. at Station °C	% Survival microcrustaceans	no. of organisms
Jan	I	5	57.1	21
	D1	17	50.0	22
	D2	15	70.6	17
Feb	I	1	86.7	30
	D1	14	78.6	56
	D2	13	92.7	123
April	I	7	90.2	51
	D1	15	72.0	82
	D2	15	----	
May	I	19	73.5	102
	D1	31	73.5	147
	D2	31	72.0	75
June	I	20	29.4	220
	D1	30	83.7	4536
	D2	30	61.4	640
July	I	22	65.0	1058
	D1	33	47.1	378
	D2	33	90.1	1883
Aug	I	24	1.7	709
	D1	34	25.1	374
	D2	34	10.0	963
Sept	I	23	81.9	94
	D1	28	84.5	71
	D2	28	93.5	92
Oct	I	18	88.5	669
	D1	28	83.6	214
	D2	28	83.7	202
Nov	I	11	87.6	105
	D1	20	93.6	125
	D2	20	90.0	130
Dec	I	6	91.5	59
	D1	16	90.6	53
	D2	16	87.5	80

Table 5-28. Monthly differences (α <0.05) in latent microcrustacean survival (24 hr) among the Unit II intake station (II) and the discharge canal stations (D1,D2).

	Crustacean Group					
Month	micro-crustacean	calanoid copepods	cyclopoid copepods	harpatacoid copepods	copepods	cladocerans
January	n.s.	D2>II	n.s.	n.s.	n.s.	n.s.
February	D2>D1	D2>D1	----	n.s.	n.s.	n.s.
March	----	----	----	----	----	----
April	II>D1	n.s.	n.s.	II>D1	II>D1	n.s.
May	n.s.	n.s.	II>D1	n.s.	n.s.	n.s.
June	----	----	----	----	----	----
June	D1>II,D2>II D1>D2	D1>II,D2>II D1>D2	II>D1,D2>II D2>D1	II,D1>D2 n.s.	II>D1,D2>D1 D2>D1	D1,D2>II n.s.
July	II>D1,D2>II D2>D1	II>D1,D2>II D2>D1	D1,D2>II	D2>II,D1	II>D1,D2>II D2>D1	n.s.
Aug	D1>II,D1>D2 D2>II	II,D1>D2	D1,D2>II	n.s.	D1>II,D2>II D1>D2	D1>II,D2>II D1>D2
Sept	n.s.	D2>D1	II>D2	n.s.	n.s.	n.s.
Oct	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Nov	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Dec	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

There was no consistent "station effect" on latent survival. Survival was not always less at the discharge-canal stations, nor was any one group of microzooplankton repeatedly more susceptible to latent effects than initial effects. Although the initial survival of microzooplankters at D-2 was significantly lower in August than at other times, Kruskal-Wallis analysis (Kruskal and Wallis, 1952) of the initial survival of organisms collected at the intake and discharge stations for the year indicated no difference with station location (Table 5-29). Similarly, Kruskal-Wallis analysis of latent survival (Table 5-30) show little difference among the various plant stations.

5.2.4 Discussion

The operation of the Indian Point power plant's Unit 1 and Unit 2 over the past five years has not affected the microzooplankton populations in the river or in the plant. Population studies from 1971 to the present indicate no major changes in seasonal patterns of abundance. No new species have appeared in abundance at any of the plant stations nor have any disappeared from any of the plant stations during the past years' studies.

A general increase in microzooplankton abundance was observed in plant samples collected during 1975 (Figure 5-22) as per the preceding years. As comparisons between years were made on the basis of catch for a 3-min effort

Table 5-29. Initial viability of microcrustaceans collected at the Indian Point Intake and Discharge stations during 1975.

Crustacean Group	Station		
	Intake Mean	D-1 % Survival	D-2 ±S.E.
Microcrustaceans Young adult and adults	94.0±1.0	90.8±1.4	88.1±3.8
Calanoid copepods	88.2±3.3	93.3±2.1	90.8±5.5
Cyclopoid copepods	95.2±1.5	85.9±5.2	92.3±1.4
Harpatacoid copepods	92.8±4.1	69.4±10.5	91.3±4.8
Copepods	93.0±1.5	88.6±1.6	89.7±3.0
Cladocerans	96.3±1.7	83.4±7.5	86.0±5.4

Table 5-30. Latent survival (24 hr) of microcrustaceans collected at the Indian Point intake and discharge stations during 1975.

Crustacean Group	Station		
	Intake	D-1	D-2
	Mean % Survival ±S.E.		
Microcrustaceans Young adult and adults	68.5±8.8	71.1±6.5	75.2±8.0
Calanoid copepods	75.1±8.1	75.1±6.4	80.9±10.3
Cyclopoid copepods	73.7±9.0	74.3±8.3	77.3±6.4
Harpatacoid copepods	65.0±12.1	64.0±8.9	68.5±12.8
Copepods	68.9±8.7	71.5±6.3	75.3±7.6
Cladocerans	72.3±11.1	74.3±9.0	79.8±10.2

(Table 5-31), the probable explanation may be that greater volumes of water were sampled during the 3-min period in 1975 than in the other years. Unit 1 was sampled in 1972 and 1974, while Unit 2 was sampled in 1975. At full demand Unit 1 pumps river water at the rate of 318,000 gallons per minute (gpm) while Unit 2 pumps deliver 870,000 gpm.

During the study period (1971-1975) the initial mortality of microzooplankton due to plant passage rarely exceeded 50%. Initial mortality was frequently near 25%. There was only one instance in which mortalities were related directly to increased water temperature in the discharge canal. This temperature (34 C; 93.2 F) resulted in the death of 70% of the calanoid copepods in the sample, but only 5% of the cyclopoid copepods.

Studies of microzooplankton entrainment at Indian Point show that about 2×10^{14} microzooplankton pass through the cooling water system each year. Laboratory thermal tolerance studies (New York University Medical Center, 1976a) have shown that, the temperatures experienced during plant passage will have essentially no affect on survival, until discharge temperatures exceed 34 C. On-site studies of entrainment effects confirm this observation (New York University Medical Center, 1976a, this report) and demonstrate that mortality of microzooplankton due to plant passage is insignificant. Field studies of river populations show no differences in microzooplankton which could be related to plant operations between 1971 and 1975.

Table 5-31. Mean annual catch per unit effort of microcrustaceans (excluding nauplii) at the intakes and discharge canal at Indian Point. The data shown are mean numbers of organisms, in thousands collected in 3-minute samples ± standard error. (n=number of samples examined).

Year	Intake	Discharge 1	Discharge 2
1972	2.9±0.5 n=90	4.0±0.8 n=93	3.7±0.5 n=96
1974	1.7±0.6 n=22	2.9±1.2 n=22	1.8±0.5 n=14
1975	24.4±5.8 n=28	23.8±8.7 n=28	35.6±10.5 n=27

6. MACROZOOPLANKTON

6.1 RIVER POPULATION STUDIES

6.1.1 Methods

Macrozooplankton and ichthyoplankton were collected as one sample. Organisms of these two major biological groups, which were obtained in collections at all seven stations and at three different depths, were then separated for detailed analysis. The methods and gear used are described in Section 6-1 (New York University Medical Center, 1976a).

Except for day sampling, the sampling for macrozooplankton at the seven river stations was planned to coincide as nearly as possible with the net samples taken in the Indian Point generating plant. River samples were collected each week throughout the striped bass "larvae season" (from the last week in April to the end of July). After July, samples were collected every other week until October, and then once per month until the end of December, so as to encompass the season for other fish species.

Metered 0.5 m-diameter, 571μ-mesh plankton nets, similar to those used in the intakes and discharge canal were used to sample in the river for macrozooplankton. These nets were towed simultaneously against the tide for 10 minutes at each of three depths (6 to 12 inches below the surface, at mid-depth and at approximately 2 feet off the bottom). Replicate samples were taken at all seven stations.

All macroinvertebrates were sorted from the samples, identified to species (when possible) and enumerated. The data were analyzed by analysis of variance to determine whether significant differences existed in the temporal and spatial distribution of river macrozooplankton relative to macrozooplankton sampled at the plant intakes.

6.1.2 Results and Discussion

6.1.2.1 Species Composition

A total of 786 macrozooplankton samples were collected and analyzed in 1975. These included 401 samples taken during the daylight hours from April 28 through December 11, and 385 samples taken at night from April 29 through December 9.

Twenty-eight invertebrate forms were identified from these samples (Table 6-1). This number is three more than the inventory for 1974 and includes two taxa not previously identified in our samples from the vicinity of Indian Point: the decapod Palaemonetes and a number of plecopteran nymphs. Nonetheless, the species inventory in 1975 resembles closely those for the preceding years, beginning in 1971.

Numerical abundances were determined for 12 of the 28 taxa collected in 1975 (Table 6-9). The remaining taxa were not enumerated either because they were difficult to sample accurately (e.g., jellyfish medusae and ctenophores), or because they were not considered part of the plankton community

Table 6-1. Macrozooplankton taxa in Indian Point collections, 1971, 1972, 1974, and 1975. X denotes the presence of that organism for the given year.

Taxa	1971	1972	1974	1975
Annelida				
Oligochaeta	X	X	X	X
Polychaeta	X	X	X	X
Hirudinea		X	X	X
Arthrophoda				
Crustacea				
Copepoda				
Caligus sp.			X	
Branchyura				
Argulus sp.			X	X
Malacostraca				
Cumacea		X	X	X
Mysidacea				
Neomysis americana	X	X	X	X
Isopoda				
Chiridotea almyra	X	X	X	X
Cyathura polita	X	X	X	X
Edotea sp.	X	X	X	X
Cirolana sp.			X	X
Amphipoda				
Gammarus spp.	X	X	X	X
Monoculodes edwardsi	X	X	X	X
Leptocheirus plumulosus	X	X	X	X
Corophium sp.	X	X	X	X
Decapoda				
Crangon septemspinosa	X	X	X	X
Decapod larva (zoea)		X	X	X
Palaemonetes sp.				X
Insecta				
Odonata (nymph)			X	X
Odonata (adult)	X	X		X
Diptera (larvae)				
Chaoborus sp.	X	X	X	X
Chironomus sp.	X	X	X	X
Diptera (pupae)	X	X	X	X
Diptera (adult)	X	X	X	X
Plecoptera (nymph)				X

Table 6-1 (cont.).

Taxa	1971	1972	1974	1975
Arachnida				
Hydracarina	X	X	X	X
Coelenterata				
Medusae	X	X	X	X
Ctenophora			X	X
Mollusca				
Gastropoda	X	X		
Pelecypoda	X	X		X

(e.g., Argulus, Caligus, Cirolana, Cumacea and some of the insect life stages). Decapod larvae were not enumerated because they were too small to be retained consistently in the 571μ-mesh nets.

As in previous years, the macrozooplankton community was dominated by three taxa, Gammarus spp. (mostly G. daiberi), Monoculodes edwardsi and Neomysis americana (New York University Medical Center, 1974, 1976a; Ginn, 1977). Together these species accounted for 71% of the total daytime macrozooplankton catch and 63% of the total nighttime catch (Table 6-2). On a station-by-station basis, Gammarus, Monoculodes and Neomysis accounted for between 38% and 81% of the total macrozooplankton daytime catch, and between 53% and 66% of the nighttime catch.

The proportional representation of the three dominant forms at stations A through G varied (Tables 6-3 and 6-4). Gammarus was dominant at two stations (B and G) during the daytime, while Neomysis was dominant at the other stations (A, C, D, E and F). Nighttime samples at stations A, B, C and F were predominantly Gammarus, while those at stations D, E and G were predominantly Neomysis. Of these three dominant forms, Monoculodes was the least abundant. The major sub-dominant forms collected in 1975 were the phantom midge (Chaoborus) and other dipteran and tendipid insects.

Table 6-2. Percent composition of macrozooplankton species collected in the vicinity of Indian Point, 1975.

Species	Percent of total	
	Day collections	Night collections
Gammarus spp.	22.26%	25.50%
Neomysis americana	33.69%	22.45%
Monoculodes edwardsi	14.93%	15.18%
"others"	29.12%	36.87%

Table 6-3. Total macrozooplankton river abundance and abundance by major groups in day/night collections, 1975. Data shown are mean numbers caught per 1000 m^3 by station ±95% confidence intervals. n= Number of samples in which the particular species was observed.

	Stations						
Day	A	B	C	D	E	F	G
Total	14196 ±8786 n=57	7553 ±3614 n=56	8528 ±3784 n=57	8581 ±4941 n=57	7089 ±3356 n=57	12751 ±11358 n=60	3923 ±2157 n=56
Gammarus	3517 ±1995 n=57	2028 ±1178 n=56	1970 ±1024 n=58	1385 ±661 n=57	1570 ±789 n=57	1438 ±1154 n=59	964 ±812 n=56
Monoculodes	2414 ±2416 n=57	485 ±227 n=56	1290 ±683 n=59	829 ±545 n=57	1544 ±954 n=57	1340 ±796 n=58	580 ±437 n=54
Neomysis	4614 ±6467 n=39	565 ±592 n=38	2730 ±2497 n=39	3227 ±2964 n=39	4891 ±5814 n=39	5197 ±5019 n=38	734 ±675 n=38
Night							
Total	31509 ±10621 n=53	27251 ±10367 n=56	25177 ±6522 n=55	25767 ±7341 n=57	26080 ±6457 n=57	24803 ±8186 n=54	14986 ±5150 n=52
Gammarus	9362 ±3893 n=53	7474 ±2636 n=56	6813 ±2325 n=55	8224 ±2803 n=57	6797 ±2306 n=57	6483 ±3104 n=53	3309 ±1466 n=52
Monoculodes	4782 ±2096 n=53	3321 ±1331 n=56	5055 ±2213 n=55	2904 ±1034 n=57	3933 ±1445 n=57	5297 ±1888 n=54	3639 ±1898 n=52
Neomysis	6442 ±5642 n=40	5256 ±5513 n=39	4441 ±2587 n=40	9672 ±5501 n=41	8403 ±4756 n=42	6409 ±3462 n=39	3980 ±3020 n=38

Table 6-4. Total macrozooplankton river abundance and abundance by major groups in day/night collections, 1975. Data shown are mean number/catch per unit effort by station ±95% confidence intervals. n=Number of samples in which the particular species was observed.

	Stations						
Day	A	B	C	D	E	F	G
	1409	847	877	711	712	809	418
Total	±778	±431	±405	±435	±353	±515	±257
	n=57	n=56	n=58	n=57	n=57	n=60	n=56
	366	229	191	127	143	141	117
Gammarus	±196	±136	± 97	± 58	± 70	±124	±106
	n=57	n=56	n=58	n=57	n=57	n=59	n=56
	233	54	141	84	123	132	61
Monoculodes	±208	± 25	± 83	± 58	± 65	± 79	± 47
	n=57	n=56	n=59	n=57	n=57	n=59	n=56
	398	59	331	368	363	536	91
Neomysis	±499	± 61	±305	±390	±385	±555	± 77
	n=39	n=38	n=39	n=39	n=38	n=38	n=38
Night							
	2822	2673	2373	2710	2511	2578	1508
Total	±981	±1015	±607	±781	±594	±1013	±504
	n=54	n=56	n=55	n=57	n=57	n=54	n=52
	922	757	638	777	664	723	334
Gammarus	±398	±289	±217	±294	±234	±399	±145
	n=54	n=56	n=55	n=57	n=57	n=53	n=52
	477	316	458	252	384	481	363
Monoculodes	±234	±123	±193	± 78	±135	±175	±184
	n=54	n=56	n=55	n=57	n=57	n=54	n=52
	540	433	458	824	781	566	401
Neomysis	±458	±484	±337	±503	±403	±273	±302
	n=40	n=41	n=40	n=42	n=42	n=39	n=38

6.1.2.2 Day Versus Night Comparisons

Macrozooplankton abundance was significantly greater during the night than during the day (Tables 6-5 through 6-7); total macrozooplankton nighttime catches exceeded daytime catches by a factor of 3.4 (Tables 6-3 through 6-6). The abundance of Gammarus spp. was greatest in nighttime samples, exceeding daytime samples by a factor of approximately four. Gammarus spp. were present in each of the 401 daytime and 385 nighttime samples; they comprised 22% of all macrozooplankton collected in the daytime and were nearly 26% of all those collected at night.

Although Neomysis was found in only 38% of the daytime samples, its numbers accounted for 34% of the total macrozooplankton collected during the day. At night, Neomysis occurred in 67% of the samples collected, but its numbers were only 23% of the total collected. Day versus night differences in abundance (Tables 6-3 through 6-6) were less than that for Gammarus spp. or Monoculodes edwardsi, differing by a factor of 2.2 during the sampling period.

The amphipod M. edwardsi was present in 53% of the daytime samples and in 93% of the nighttime samples collected in the vicinity of the Indian Point power plant. Its abundance at night was significantly greater than during the day (Tables 6-5 through 6-7); the numbers at night were 3.4 times greater than during the day. The proportion of Monoculodes to total macrozooplankton in daytime and nighttime samples was similar (15%; Tables 6-3 through 6-6).

Table 6-5. Macrozooplankton abundance in pooled river samples, 1975. Data are mean numbers caught per 1000m^3 with 95% confidence intervals. n= Number of samples in which species was observed.

Day	Mean	95% C.I.	n
Total	8269	±1868	401
Gammarus	1841	± 434	400
Monoculodes	1235	± 408	398
Neomysis	2786	±1225	270
Night			
Total	28131	±5138	384
Gammarus	7175	±1118	383
Monoculodes	4269	± 728	384
Neomysis	6314	±1655	279

Table 6-6. Macrozooplankton abundance in pooled river samples, 1975. Data are mean numbers/unit effort with 95% confidence intervals. n=Number of samples in which species was observed.

Day	Mean	95% C.I.	n
Total	830	±178	401
Gammarus	213	± 63	400
Monoculodes	128	± 36	401
Neomysis	308	±136	269
Night			
Total	2501	±304	385
Gammarus	689	±109	384
Monoculodes	395	± 62	385
Neomysis	591	±153	282

Table 6-7. Comparison of macrozooplankton abundance in day and night river sampling, 1975.

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

6.1.2.3 Depth Distribution of Macrozooplankton

The abundance of macrozooplankton in river samples was greatest at the bottom of the water column. Since the depths of sampling stations differed (see Section 1) the "bottom" samples from the different stations were, of necessity, from different depths. Nevertheless, samples from the "bottom" strata yielded 90% of the macrozooplankton in daytime samples and 51% of the macrozooplankton in nighttime samples.

The relative abundance of macrozooplankton at the various depths differed significantly between day and night samples (Tables 6-8, 6-14 and Figure 6-1). Surface and mid-depth abundances at night were greater than in the day by a factor of approximately 15. Nighttime bottom samples were about 80% greater than daytime bottom samples. Populations of macrozooplankton susceptible to net capture at night, but not during the day, may be assumed to occupy a daytime habitat not sampled by the gear currently in use. Data from other investigations in the Hudson River (Texas Instruments, 1975; Lawler, Matusky and Skelly Engineers, 1975) identify the surficial bottom deposits of the river as an important habitat for many of the species which are collected regularly in plankton nets. As none of our gear are designed to sample this habitat, it must be assumed that the increased abundance of macrozooplankton at night is due to the nocturnal emergence of epibenthic forms from the

Table 6-8 . Macrozooplankton river abundance in mean numbers caught per $1000m^3$ by depth ±95% confidence intervals for total macrozooplankton and dominant groups. n= Number of samples in which the particular species was observed.

Day	Surface	Middle	Bottom
Total	83 ±2646 n=134	2376 ±2666 n=133	22264 ±2646 n=135
Gammarus	21 ± 606 n=134	666 ± 608 n=133	4816 ± 606 n=134
Monoculodes	4 ± 641 n=134	265 ± 645 n=133	3354 ± 641 n=134
Neomysis	1 ±2460 n= 91	286 ±2500 n= 89	9291 ±2480 n= 90
Night			
Total	6738 ±3587 n=128	30902 ±3587 n=128	39955 ±3587 n=128
Gammarus	35641 ±38710 n=129	9257 ±39024 n=127	9936 ±38878 n=128
Monoculodes	1551 ±1233 n=129	4918 ±1237 n=128	6669 ±1237 n=128
Neomysis	2146 ±2340 n= 88	6251 ±2340 n= 87	12303 ±2360 n= 86

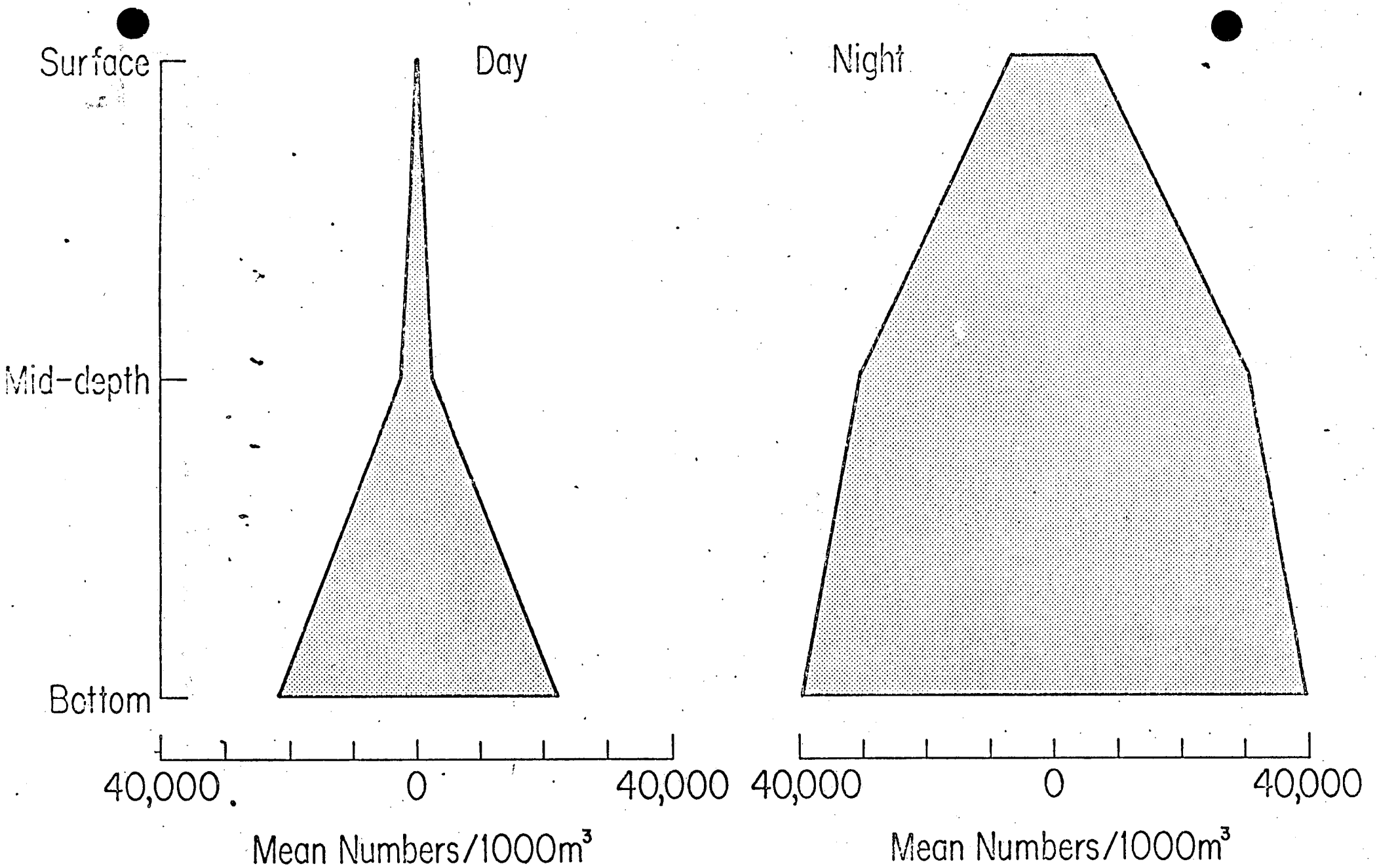

Figure 6-1. Depth distribution for total macrozooplankton in day and night samples collected from the Hudson River at Indian Point.

sediments to assume a planktonic existence.

The distribution of the major macrozooplankton components (Gammarus, Neomysis and Monoculodes) during the day was similar; less than 0.5% of the totals for each group occurred in surface samples, while 88-97% were found in the bottom samples (Figures 6-2 through 6-4). Of these three groups, Neomysis had the sharpest distribution profile with depth, in which, more than 97% of the individuals recorded were from the bottom stratum.

There were considerable differences in the distribution of the three major plankters with depth at night. While Gammarus exhibited a typical distribution profile with depth for night populations (greatest numbers at the surface and decreasing towards the bottom; see Figure 6-2), the profiles for Monoculodes and Neomysis showed differences among all strata with a gradient of increasing abundance from bottom to the surface (Table 6-8 and 6-14, and Figures 6-3 and 6-4). Vast differences in depth distribution between day and night were observed for Gammarus and Neomysis, whose surface abundances at night were nearly 2000 times that for the day. Although increased numbers of Monoculodes were observed for surface samples collected at night over those collected during the day, the difference was not as great (approximately 400 times).

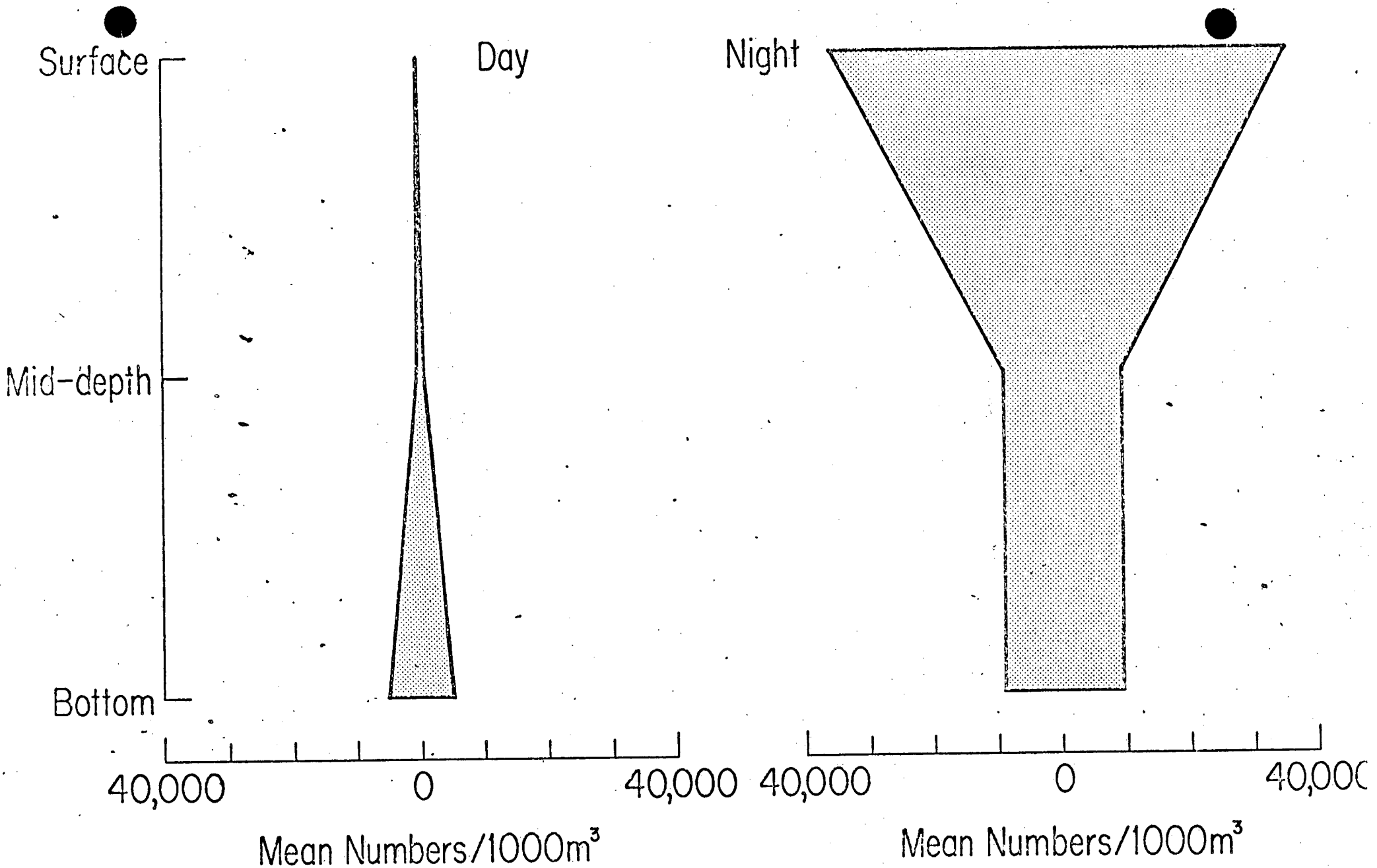

Figure 6-2. Depth distribution for Gammarus spp. in day and night samples from the Hudson River at Indian Point, 1975.

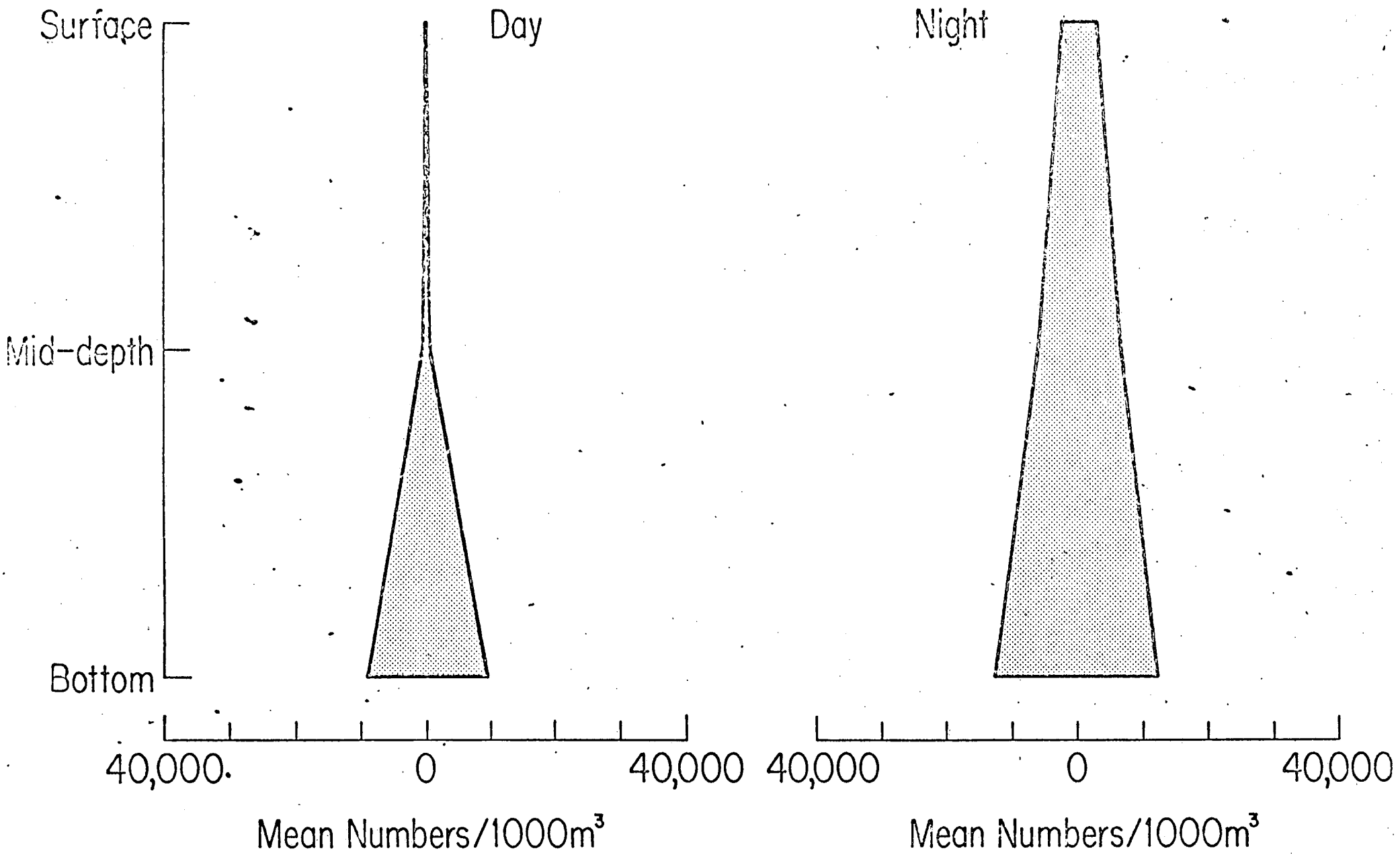

Figure 6-3. Depth distribution for Neomysis americana in day and night samples from the Hudson River at Indian Point, 1975.

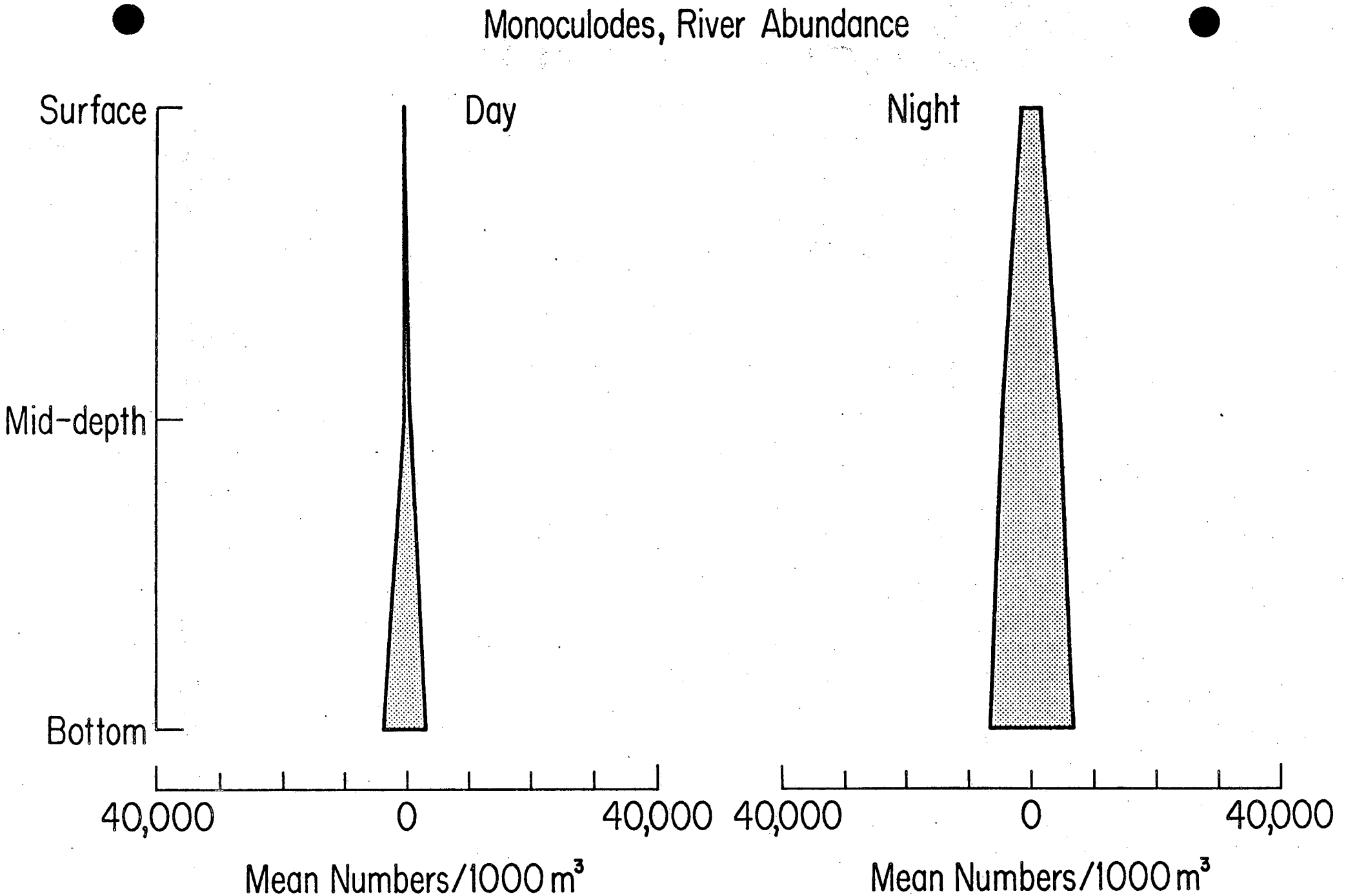

Figure 6-4. Depth distribution for Monoculodes in day and night samples from the Hudson River at Indian Point, 1975.

6.1.2.4 Seasonal Abundance

The abundance of macrozooplankton varied significantly with season (Tables 6-9 through 6-12; Figures 6-5 and 6-6). The total for daytime samples ranged from a mean of 1,893 organisms per 1000 m^3 (October 13) to 23,456 organisms per 1000 m^3 (July 17). Nighttime abundance was greater overall, ranging between 6,519 organisms per 1000 m^3 (September 10) to 62,643 organisms per 1000 m^3 (June 10). In general, the pattern of macrozooplankton abundance was similar for daytime and nighttime samples, showing major peaks in summer and fewer organisms in mid-to late fall (Figures 6-5 and 6-6). Given the pronounced tendency toward diel vertical migration in the zooplankton as a whole, the variability in daytime samples could be attributed to differences in cloud cover on the various sampling dates, thus leading to greater or lesser congregations of the zooplankters at the mud-water interface.

Variation in abundance on a date-to-date basis may be accounted for primarily by variation in the abundance of the three dominant macrozooplankters, Gammarus spp., Monoculodes and Neomysis. On two daytime sampling dates (June 2 and June 30) Gammarus, Monoculodes and Neomysis failed to account for at least half the macrozooplankton collected (Tables 6-9 and 6-11). On these dates, Oligochaeta, Chaoborus, Chirodotea and insect pupae were abundant and accounted for a large percentage of the total. There were no nighttime samples in

Table 6-9. Daytime abundance in mean numbers per $1000m^3$ of individual macrozooplankton taxa by date for all stations, 1975. Percent of total represents the abundance of the major species (Gammarus, Monoculodes and Neomysis) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chiridotea	Polycheate	Corophium	Chaoborus	Leptocheirus	Crangon	Cyathura	Oligocheate	Insect Pupae	Insect Adult
3/26	4	91	970	0	2331	40	61	0	211	0	0	0	0	0	0
4/28	21	83	1862	0	1099	16	81	2	254	45	0	96	125	1	3
5/05	21	82	1219	3	1400	5	60	1	46	4	0	10	442	2	3
5/12	21	73	1799	<1	580	8	60	2	74	0	0	13	715	20	1
5/19	21	90	3313	0	1197	25	28	1	68	10	0	14	231	172	6
5/30	21	74	2123	0	38	54	13	1	88	1	0	14	408	64	7
6/02	21	34	968	0	26	180	1	0	249	2	0	2	1304	190	13
6/09	21	78	590	4735	415	45	14	2	491	4	0	44	713	309	0
6/16	21	75	5998	2	2857	214	13	0	1204	23	0	15	1199	331	3
6/23	21	54	3331	0	669	190	2	2	1896	1	0	10	794	511	17
6/30	21	35	2695	355	759	67	5	3	5600	11	11	10	953	377	11
7/07	21	77	180	3035	490	21	0	8	260	11	12	2	367	25	3
7/17	21	94	403	16145	5078	1	0	9	886	1	4	6	323	163	1
7/21	21	70	482	3996	333	35	0	253	131	1011	31	15	590	13	0
8/11	20	83	1412	6051	3726	0	13	842	871	75	29	11	209	295	14
8/25	21	70	827	3380	590	1	12	208	305	9	10	15	1358	85	0
9/15	21	97	624	921	960	1	4	3	48	2	0	9	11	0	2
10/13	21	74	554	0	433	2	0	6	65	0	0	2	265	0	2
11/25	21	82	3410	3	934	1	3	7	76	1	0	9	884	0	1
12/11	20	89	3291	2505	1207	8	28	0	41	1	0	0	817	0	0

Table 6-10. Nighttime abundance in mean numbers per $1000m^3$ of individual macrozooplankton taxa by date for all stations, 1975. Percent of total represents the abundance of the major species (Gammarus, Monoculodes and Neomysis) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chiridotea	Polycheate	Corophium	Chaoborus	Leptocheirus	Crangon	Cyathura	Oligocheate	Insect Pupae	Insect Adult
4/29	21	86	2318	0	2572	31	109	2	201	43	0	4	382	1	1
5/06	20	94	2849	244	4843	20	70	47	230	10	0	0	127	8	2
5/13	21	81	4365	0	2720	14	180	2	345	150	0	7	858	75	6
5/20	21	70	8607	0	809	44	48	16	537	50	0	49	2854	332	11
5/27	21	91	14968	0	98	379	44	6	409	12	0	51	230	300	7
6/03	21	74	2249	1323	454	53	25	19	503	14	0	20	260	561	11
6/10	20	84	18590	11126	6859	3022	114	29	2143	191	3	242	392	798	29
6/17	21	86	17040	2	4756	447	10	0	1761	21	0	17	731	543	62
6/24	19	61	6775	0	3118	672	2	0	2775	13	0	15	1808	1054	63
7/01	19	63	1828	6678	4085	97	7	10	5516	8	4	23	353	1227	33
7/08	21	82	8423	24448	10283	2769	10	254	4197	205	81	144	389	1162	42
7/15	21	90	1101	23177	5347	34	10	14	2307	22	121	25	110	710	47
7/22	15	64	4857	436	1825	164	0	21	2554	200	0	29	21	937	5
8/12	21	85	3794	9751	14585	15	36	210	2701	427	70	42	269	1241	13
8/18	21	80	2668	9032	5239	26	8	721	2322	127	34	36	105	635	242
9/16	21	94	2497	1035	2355	9	2	23	198	14	27	21	54	17	12
10/14	21	91	4053	5	2466	5	0	18	343	0	1	7	254	2	17
11/18	21	98	15167	0	4339	54	0	45	230	1	0	0	76	0	0
12/09	21	87	8846	11	754	22	0	0	93	0	0	0	1357	0	0

Table 6-11. Daytime abundance in mean number, catch per unit effort of individual macrozooplankton taxa by date for all stations, 1975. Percent of total represents the abundance of the major species (Gammarus, Monoculodes and Neomysis) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Monoculodes	Neomysis	Chiridotea	Polycheate	Corophium	Chaoborus	Leptocheirus	Crangon	Cyathura	Oligocheate	Insect Pupae	Insect Adult
3/26	4	87	74	135	0	3	6	0	21	0	0	0	0	0	0
4/28	21	78	205	54	0	2	10	0	21	5	0	13	14	0	0
5/05	21	83	167	166	<1	1	8	0	6	0	0	1	51	0	0
5/12	21	74	173	61	0	1	6	0	8	0	0	1	65	2	0
5/19	21	81	400	26	0	3	3	0	8	1	0	2	29	20	1
5/30	21	78	291	5	0	7	1	0	12	0	0	2	51	8	1
6/02	21	35	77	2	0	15	0	0	20	0	0	0	97	15	1
6/09	21	74	82	54	489	6	1	0	61	1	0	5	105	42	0
6/16	21	74	591	292	<1	22	1	0	117	2	0	1	132	33	0
6/23	21	54	314	60	0	17	0	0	162	0	0	1	95	45	1
6/30	21	42	277	58	49	5	0	0	401	1	0	1	93	32	1
7/07	21	88	21	55	332	2	0	1	10	2	1	0	38	3	0
7/17	21	93	31	419	1387	0	0	1	86	0	2	1	30	14	1
7/21	21	67	49	50	527	3	0	30	21	166	1	2	80	2	0
8/11	20	83	146	391	643	0	2	85	90	8	3	1	23	33	2
8/25	21	64	80	58	306	0	1	18	76	1	3	1	145	8	0
9/15	21	97	64	95	95	0	0	0	5	0	1	1	1	0	0
10/13	21	71	45	34	0	0	0	1	5	0	0	0	27	0	0
11/25	21	77	321	9	<1	0	0	1	7	0	0	1	88	0	0
12/11	20	86	249	9	168	1	2	0	3	0	0	0	63	0	0

Table 6-12. Nighttime abundance in mean number, catch per unit effort of individual macrozooplankton taxa by date for all stations, 1975. Percent of total represents the abundance of the major species (Gammarus, Monoculodes and Neomysis) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Monoculodes	Neomysis	Chiridotea	Polycheate	Corophium	Chaoborus	Leptocheirus	Crangon	Cyathura	Oligocheate	Insect Pupae	Insect Adult
4/29	21	86	279	317	0	4	13	0	24	6	0	0	47	0	0
5/06	20	94	336	591	37	3	8	5	26	1	0	0	15	1	0
5/13	21	81	472	295	0	2	18	0	38	16	0	1	99	8	1
5/20	21	69	958	91	0	4	6	2	60	5	0	6	362	34	1
5/27	21	91	1494	10	0	43	4	1	41	1	0	5	24	29	1
6/03	21	74	215	47	132	5	2	2	47	1	0	2	28	51	1
6/10	20	85	2073	639	1005	340	10	3	178	16	0	23	33	73	4
6/17	21	87	1809	735	<1	42	1	0	180	2	0	2	79	55	6
6/24	19	61	604	311	0	59	0	0	252	1	0	1	182	97	5
7/01	19	66	109	258	566	7	1	1	363	1	0	2	24	79	2
7/08	21	85	740	919	2052	241	1	20	197	19	7	14	29	105	3
7/16	21	89	94	470	2289	3	1	1	247	1	12	3	9	62	5
7/22	15	63	453	163	29	13	0	1	258	14	0	2	2	82	0
8/12	21	84	396	1397	950	2	3	24	269	46	6	4	32	129	2
8/18	21	83	258	512	844	2	1	65	142	12	3	4	10	62	23
9/16	21	94	222	201	88	1	0	2	20	1	2	2	4	2	1
10/14	21	91	334	200	<1	0	0	2	27	0	0	1	19	0	2
11/18	21	98	1462	418	0	5	0	4	22	0	0	0	7	0	0
12/09	21	86	871	79	1	2	0	0	9	0	0	0	139	0	0

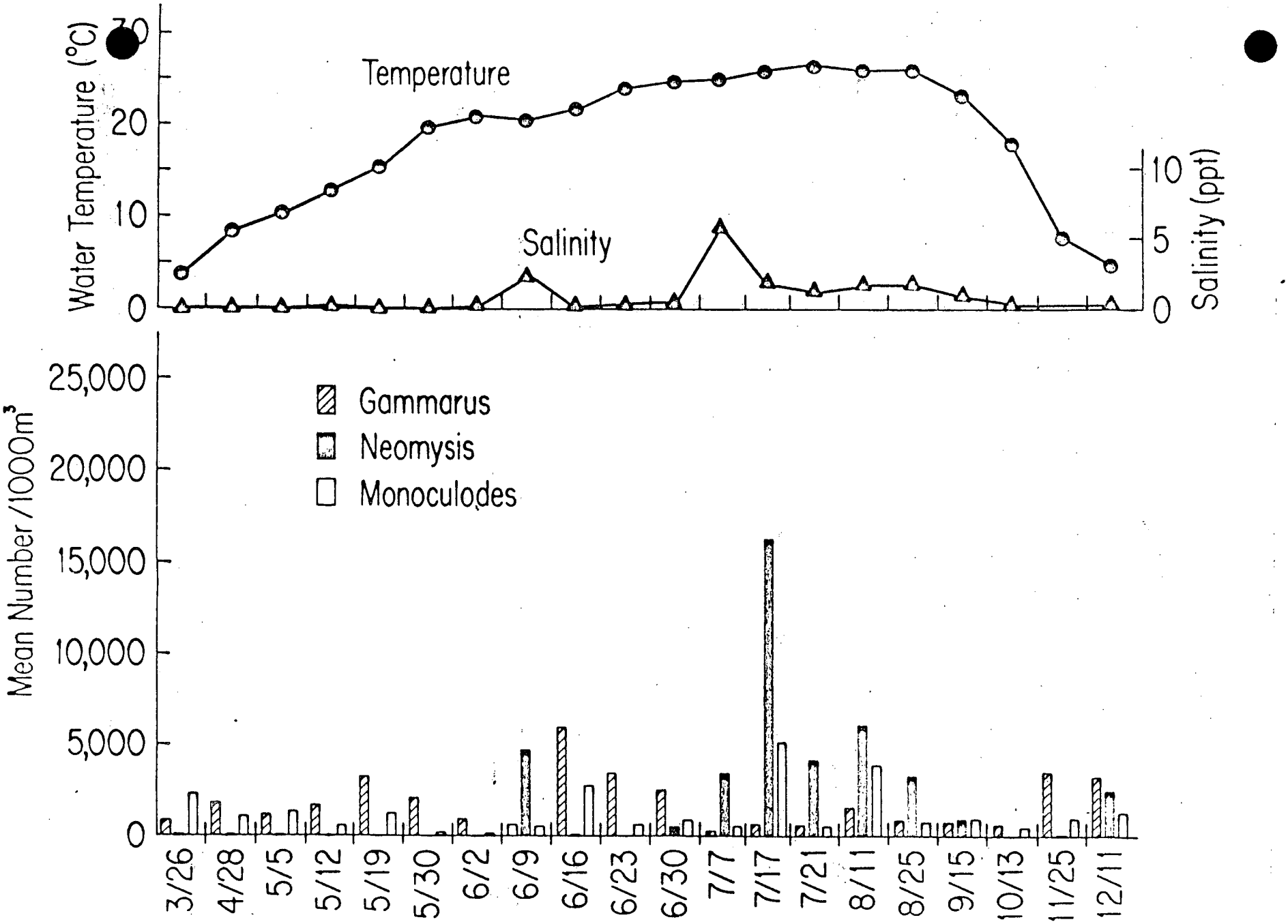

Figure 6-5. Seasonal distribution of Gammarus, Neomysis and Monoculodes relative to temperature and salinity for daytime samples collected in the Hudson River near Indian Point, 1975.

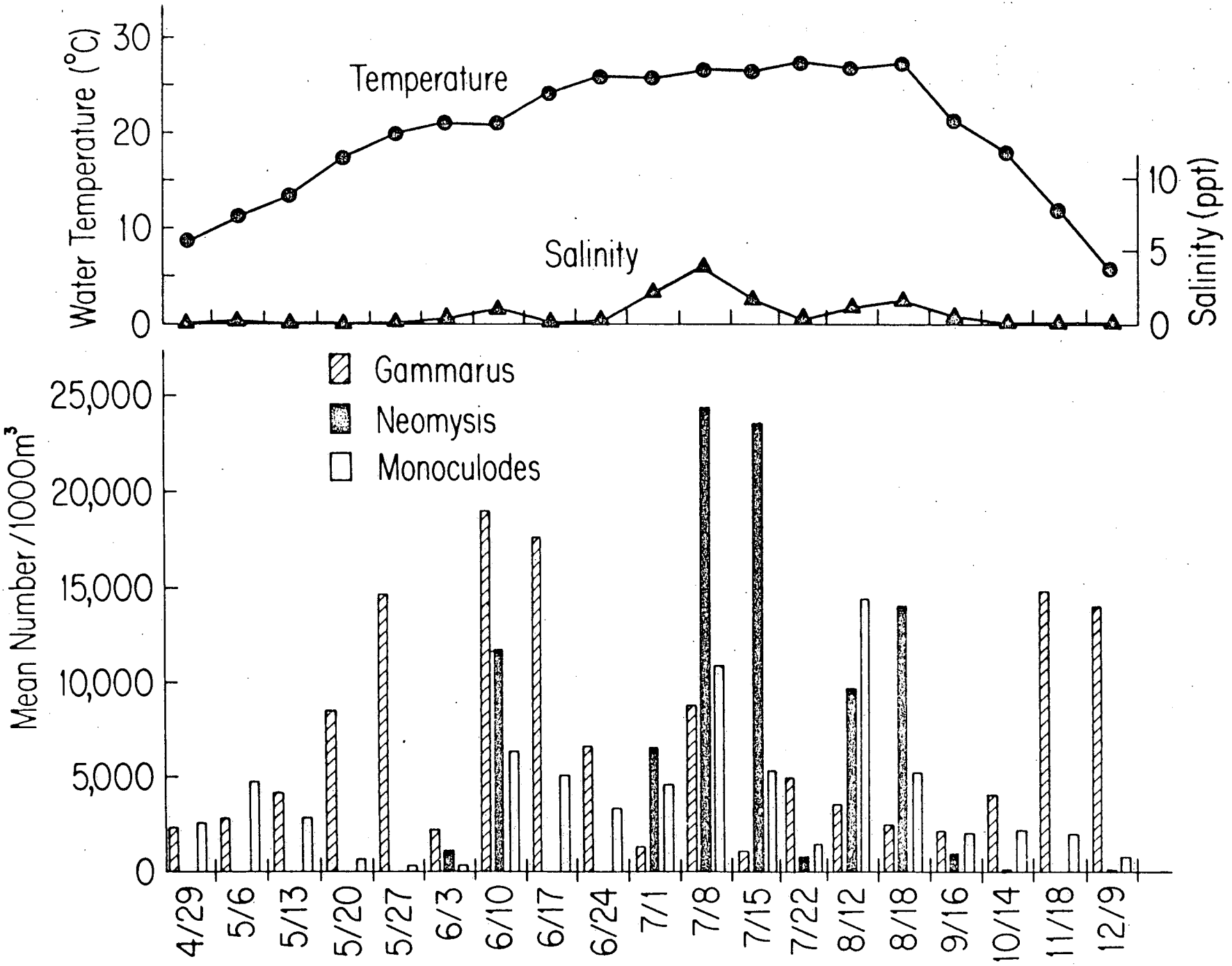

Figure 6-6. Seasonal distribution of Gammarus, Neomysis and Monoculodes relative to temperature and salinity for nighttime samples collected in the Hudson River near Indian Point, 1975.

which the three dominant macrozooplankters failed to account for at least half the total collected (Tables 6-10 and 6-12).

The abundance and proportional representation of the various macrozooplankton taxa on a seasonal basis are attributable directly to two factors; 1) salt intrusion in the vicinity of Indian Point, and 2) the life history of the species present. During periods of high salinity at Indian Point an abundance of Neomysis and Monoculodes was observed, while during low salinity and freshwater periods, the amphipod Gammarus spp. (Figures 6-5 and 6-6) and annelid worms (Oligochaeta and Polychaeta (Tables 6-9 through 6-12) became dominant.

In the mid-summer period Chaoborus sp. and other juvenile insect forms were abundant (Tables 6-9 through 6-12) primarily as aquatic stages preparing for metamorphosis to a terrestrial life.

An analysis of variance (ANOVA) of the data revealed significant differences in numbers by station, by depth and by date (Tables 6-13 through 6-19). There was a significant interaction of station and date in both daytime and nighttime samples for total species and for Gammarus, Monoculodes and Neomysis, which substantiates the seasonal relationship of Gammarus with freshwater periods and of Monoculodes and Neomysis with salinity intrusion (Tables 6-15 through 6-19).

It is fair to assume that holoplanktonic organisms in the vicinity of the Indian Point nuclear generation station

Table 6-13. Differences in macrozooplankton river abundance among stations 1975. Letters refer to the respective river station locations.

Day	
Total	A>G
Gammarus	A>(F,G)
Monoculodes	None [1]
Neomysis	None
Night	
Total	(B,C,D,E,F)>G
Gammarus	A>G; B>(C,E,F,G); C>(F,G); D>(B,C,G); E>(C,G)
Monoculodes	A>G; B>D; C>(B,D,E,G); E>(B,D,G); F>(B,C,D,E,G) G>(B,D)
Neomysis	E>(B,G); F>B

[1] The analysis of variance resulted in a difference among stations. However, the Scheffe´ test (α=0.10) did not show any differences among stations for meaningful contrasts.

Table 6-14. Differences in macrozooplankton river abundance among depths 1975. Depths refer to sample depths from surface to 50 ft. for bottom samples.

Day	
Total	mid>sur; bot>sur; bot>mid
Gammarus	mid>sur; bot>sur; bot>mid
Monoculodes	mid>sur; bot>sur; bot>mid
Neomysis	bot>(sur,mid)
Night	
Total	mid>sur; bot>sur; bot>mid
Gammarus	sur>(mid,bot) bot>mid
Monoculodes	mid>sur; bot>sur; bot>mid
Neomysis	mid>sur; bot>sur; bot>mid

Table 6-15. Analysis of variance for all species of macrozooplankton collected during the day in 1975, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	1.7528	.2921	3.3407*
A/B	14	97.0244	6.9303	79.2520*
C	19	8.3426	.4391	5.0212*
AXC	109	8.8433	.0811	.9278
Error	253	22.1240	.0874	
Total	401	138.0871		

Contrast among Stations	Scheffé test[1] $\log_{10}$ (catch/m^3+1)	
	Critical value	Contrast value
A vs G	.1813	.2262

[1]Only significant contrasts are shown here.

Table 6-16. Analysis of variance for all species of macrozooplankton collected during the night in 1975, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	5.1114	.8519	11.9940*
A/B	14	68.0318	4.8594	68.4167*
C	18	27.6993	1.5389	21.6658*
AXC	106	12.1460	.1146	1.6133*
Error	239	16.9754	.0710	
Total	383	129.9639		

Contrast among Stations	Scheffe´ test Critical value	$\log_{10}$ (catch/m^3 +1) Contrast value
B vs G	.1670	.2410
C vs G	.1679	.2990
D vs G	.1663	.3473
E vs G	.1663	.3936
F vs G	.1686	.2828

[1]Only significant contrasts are shown here.

Table 6-17. Analysis of variance for Gammarus collected at day and night during 1975 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Day				
A	6	1.2610	.2102	4.1210*
B/A	14	28.0370	2.0026	39.2694*
C	19	5.7630	.3033	5.9476*
AXC	109	3.9486	.0362	.7103
Error	252	12.8514	.0510	
Total	400	51.8609		
Night				
A	6	4.3005	.7167	7.6917*
B/A	14	34.7495	2.4821	26.6364*
C	18	26.4799	1.4711	15.7870*
AXC	106	11.8777	.1121	1.2025
Error	239	22.2712	.0932	
Total	383	99.6788		

Table 6-18. Analysis of variance for Neomysis collected at day and night during 1975 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Day				
A	6	.7557	.1260	1.1416
B/A	14	16.6791	1.1914	10.7978*
C	12	8.2128	.6844	6.2030*
AXC	72	4.8690	.0676	.6129
Error	165	18.2051	.1103	
Total	269	48.7218		
Night				
A	6	2.4354	.4059	4.5483*
B/A	14	8.2532	.5895	6.6058*
C	12	46.0646	3.8387	43.0149*
AXC	70	10.6415	.1520	1.7035*
Error	158	14.1002	.0892	
Total	260	81.4949		

Table 6-19. Analysis of variance for Monoculodes collected at day and night during 1975 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)= significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Day				
A	6	.7394	.1232	2.9692*
B/A	14	17.4622	1.2473	30.0545*
C	19	3.8162	.2009	4.8397*
AXC	109	3.2227	.0296	.7124
Error	252	10.4583	.0415	
Total	400	35.6988		
Night				
A	6	1.2940	.2157	3.2470*
B/A	14	20.4080	1.4577	21.9459*
C	18	21.0589	1.1699	17.6134*
AXC	106	12.1625	.1147	1.7274*
Error	240	15.9416	.0664	
Total	384	70.8650		

will be subject to entrainment in the cooling water flow of the power station. River population studies conducted over a period of several years have had as their objective to determine if this entrainment will have any qualitative or quantitative impact upon the river populations.

Comparisons of macrozooplankton abundance within sampling years seldom show differences due to factors other than season; any differences found between stations are probably due to random factors since plankton distribution is characteristically patchy (Wiebe and Holland, 1968; Fleminger and Clutter, 1965). For the same reasons, and additional considerations such as year-to-year variation in river flow, tidal exchange and mixing (Abood, 1974), quantitative comparisons of zooplankton populations between years is probably best executed in non-dimensional terms, such as components and community structure (Pielou, 1975) rather than abundance.

Qualitative comparison of macrozooplankton within and between years indicates that species composition of the plankton has remained essentially the same for the duration of the study (1971-1975). Although there appears to be an increase in the number of individual species observed from 1971 to 1975, many of these are of little consequence; they are marine forms and their abundance depends upon the extent of salt water intrusion into the area.

River populations of macrozooplankton have not been affected by the operation of the Indian Point station.

Near-field data (this report and New York University Medical Center, 1973, 1974, 1976a; Lawler, Matusky and Skelly Engineers, 1974) and far-field data (Lawler, Matusky and Skelly Engineers, 1974) indicate essentially similar patterns in seasonal variability of species of macrozooplankton in the Hudson River from Indian Point to Haverstraw Bay for the years 1971 to 1975.

6.2.1 Temperature Tolerance Studies

No temperature tolerance experiments on macroinvertebrates were planned for 1975. A series of thermal exposures were conducted, however, to simulate the thermal effects of cooling water recirculation on Gammarus spp.

6.2.1.1 Methods

Gammarus spp. collected from the Indian Point Unit 2 intakes and discharge canal station D-P were examined for initial viability and placed in battery jars surrounded by flowing Hudson River water. Return of discharge samples to ambient temperature (22.2 C or 70.0 F) was accomplished within 30 minutes following collection. During collection the plant ΔT was 9.3 C (16.74 F).

Samples were maintained at intake temperatures for 6 hours after collection. Forty organisms from the collections were then placed into each flow-through exposure chamber (Figure 6-7). The experiment was controlled by exposing Gammarus spp. collected from the plant intakes to intake water pumped into 37.8 ℓ all-glass aquaria. Organisms from the discharge canal were exposed for 1 hour to three conditions: intake water, full-strength discharge water and diluted discharge water. Test groups were examined immediately for viability. Survivors were maintained in 800 mℓ battery jars (20/jar) for 120 hours following exposures and examined at intervals for evidence of latent mortality.

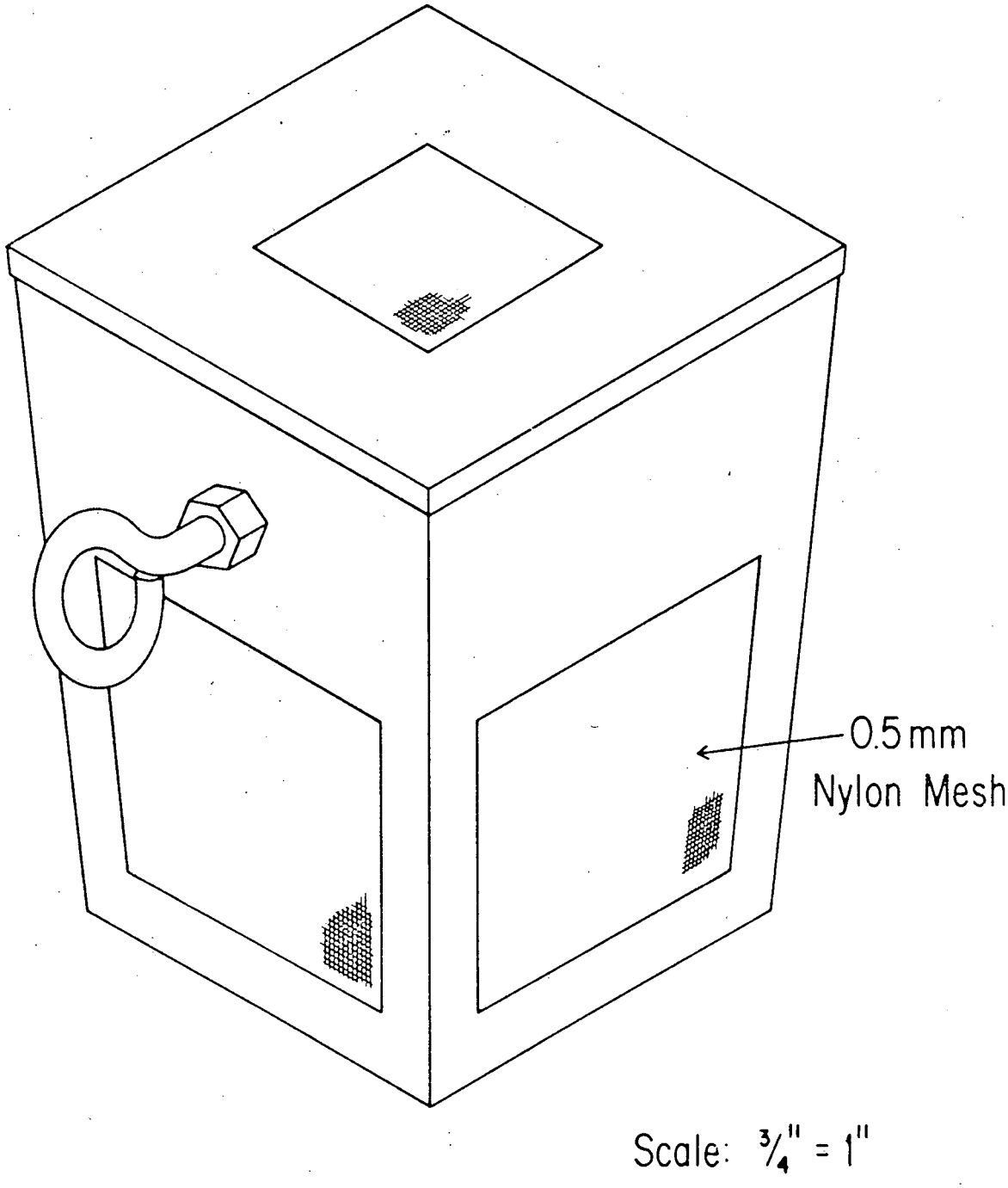

Figure 6-7. Experimental exposure chamber.

6.2.1.2 Results and Discussion

The survival data from Gammarus spp. used in recirculation simulations are presented in Table 6-20. Intake and discharge survivals exceeded 90% and were consistent with the high survival percentages observed in Gammarus spp. collected from the Indian Point cooling water system (New York University Medical Center, 1974, 1976a).

No differences were detected in 1-day or 5-day survival rates among the exposure groups (Table 6-21). The most severe thermal exposure occurred in test groups collected from the discharge canal, returned to ambient temperature for 6 hours and subsequently exposed to a 7.9 C (14.2 F) ΔT for 1 hour. The resultant 5-day survival was 95%.

It is apparent that Gammarus spp. can survive entrainment and subsequent thermal exposure (simulating recirculation) without adverse effects. During the second thermal exposure, Gammarus spp. did not experience the combined pressure, turbulence and temperature regimes normally encountered during condenser entrainment. Although these potential stresses may act synergistically on recirculated organisms, temperature appears to be the primary potential stress encountered by macrozooplankton in the cooling water system (New York University Medical Center, 1974, 1976a; Ginn et al., 1974, 1976). Therefore, these studies serve to indicate that Gammarus spp. can tolerate a thermal exposure following entrainment which might result from recirculation into the cooling water system or entrapment in the discharge plume.

Table 6-20. Initial viability of Gammarus spp. collected at the Indian Point Unit 2 intake and discharge (DP) stations on June 17, 1975.

		Percentage		
	n	Alive	Stunned	Dead
Intake	357	94.1	2.8	3.1
Discharge Canal (DP)	483	90.7	3.9	5.4

Table 6-21. Survival of entrained Gammarus spp. subsequently exposed to Indian Point effluent for 1 hour. Prior to effluent exposures, test organisms were returned to ambient temperature for 6 hours following collection.

Collection site	Temp. at collection °C	one-hour exposure	Exposure Temp. °C	n	Percent Survival 1 day	Percent Survival 5 day
Intake	21.8	Intake	22.2	40	97.5	92.5
Discharge	31.1	Intake	22.2	40	100.0	90.0
Discharge	31.1	Discharge	30.1	40	100.0	95.0
Discharge	31.1	Diluted Discharge	26.2	40	100.0	97.5

6.2.2 Intake and Discharge Canal Studies

6.2.2.1 Reproduction of Gammarus daiberi following entrainment

During 1975, preliminary experiments on the reproduction of Gammarus spp. following entrainment were initiated to supplement the laboratory experiments on Gammarus reproduction conducted during 1973-74.

6.2.2.1.1 Methods

Reproductive studies involved the isolation of ovigerous females and amplectic pairs of Gammarus daiberi from the Unit 2 intakes and discharge canal.

Twelve ovigerous female G. daiberi were isolated from both the intakes and discharge canal station (D-2) on October 14, 1975. During collection the ΔT ranged from 10.2 to 10.3 C (18.4 to 18.5 F) while the ambient temperature was 17.0 to 17.2 C (62.6 to 63.0 F). Ovigerous females were isolated in 200 mℓ culture dishes and observed for release of young. Upon release, the young and females were preserved.

Amplectic pairs of G. daiberi were collected from intake and discharge stations on September 16, 1975. Intake temperatures ranged from 21.6 to 22.2 C (70.9 to 72.0 F); the ΔT was 9.7 to 9.8 C (17.5 to 17.6 F). Ten pairs were isolated from each station. Each pair was maintained in a 200 mℓ culture dish and fed Tetramin daily. Following fertilization, the male was removed and the ovigerous female was maintained until the young were released.

The numbers of young produced in entrainment reproduction studies were analyzed by the Mann-Whitney U-test (Sokal and Rohlf, 1969).

6.2.2.1.2 Results and Discussion

Ovigerous G. daiberi from the intake and discharge canal collections produced young at the rates of 10.0 and 9.27 per surviving female, respectively (Table 6-22). The 12 female in the intake group survived to release young; one specimen from the discharge group died before the young hatched. Statistical analysis revealed no difference between the numbers of young released in the intake and the discharge samples ($P < 0.05$).

Amplectic pairs of G. daiberi collected from the Indian Point Unit 2 intakes produced young at the rate of 9.3 per pair (Table 6-23). Nine pairs collected from the discharge canal produced 8.6 young per pair. One amplectic pair separated without mating 6 days after collection. Although the pair was maintained together for an additional 7 days, no further amplexion was observed.

Statistical analyses (Wilcoxon two-sample) of reproduction following entrainment compared groups collected from the intakes and from the discharge canal for young produced by all pairs and young produced only by mating pairs. No differences were seen in the reproductive capabilities of organisms collected from the intakes and from the discharge

Table 6-22. Release of young from ovigerous female Gammarus daiberi entrained in the Indian Point Unit 2 cooling water system. Intake = 17.0 - 17.2 °C ΔT = 10.2 - 10.3 °C.

Intake		Discharge	
Ovigerous Female	Number of Young	Ovigerous Female	Number of Young
I-1	17	D-1	12
I-2	9	D-2	4
I-3	8	D-3	7
I-4	6	D-4	6
I-5	8	D-5	5
I-6	16	D-6	11
I-7	7	D-7	0*
I-8	17	D-8	14
I-9	9	D-9	9
I-10	14	D-10	12
I-11	4	D-11	10
I-12	5	D-12	12
Total	120		102
$\bar{x}$	10.0		9.27

* Female died before releasing young.

Table 6-23. Young produced by amplectic pairs of Gammarus daiberi entrained in the Indian Point Unit 2 cooling water system. Intake = 21.6 - 22.2°C ΔT = 9.7 - 9.8°C.

Intake		Discharge	
Amplectic Pair	Number of Young	Amplectic Pair	Number of Young
I-1	7	D-1	1
I-2	6	D-2	9
I-3	7	D-3	12
I-4	12	D-4	8
I-5	8	D-5	8
I-6	12	D-6	13
I-7	11	D-7	0*
I-8	4	D-8	7
I-9	11	D-9	11
I-10	15	D-10	8
Total	93	Total	77
$\bar{x}$	9.3	$\bar{x}$	7.7

* pair separated without mating - no subsequent amplexion

canal. The U_s statistic and the corresponding critical values at $\alpha = 0.05$ were: 55.5 (c.v. = 77) and 45.5 (c.v. = 70).

The results of preliminary entrainment reproduction studies are consistent with the results of laboratory reproductive studies reported by Ginn et al. (1976). No reduction in mating or release of young by ovigerous females were noted in groups of Gammarus spp. exposed to 8.3 C (14.94 F) ΔT's for periods up to 60 minutes. Mortalities of young and/or eggs contained in the marsupium were not noted until thermal exposures reached 11.0 C (19.80 F) ΔT for 30 minutes (ambient 26.0 C, 78.8 F).

6.2.2.2 Viability

6.2.2.2.1 Methods

Macrozooplankton samples for viability analyses were collected at the Indian Point intake and discharge stations from April 29 to December 9, 1975. During this period, a total of 132 samples were examined on 12 sampling dates. The total numbers of major macrozooplankton species examined are present in Table 6-24. The intake and discharge temperatures measured at the time of collection on each date are listed in Table 6-25.

Macrozooplankton samples were collected at the intake and discharge stations as described in Section 1; sampling time was 5 minutes. The samples were transported to the laboratory for viability analysis immediately after collection.

Table 6-24. Numbers of macrozooplankton examined for viability during 1975 entrainment studies. The specimens were contained in a total of 132 samples collected on 12 dates.

Species	Examined	Maintained for 5-day latent survival analysis
Gammarus spp.	7457	884
Monoculodes edwardsi	1934	0*
Neomysis americana	2123	271
Chaoborus sp.	4557	225
Total	16071	1380

* Latent survival data for Monoculodes available from previously published data (N.Y.U., 1976a).

Table 6-25. 1975 Macrozooplankton sampling dates and temperature data.

Date	Temperature °C		
	Intake	Discharge	ΔT
4/29	9.0	20.9	11.9
5/06	14.5	25.9	11.4
5/20	17.2	28.0	10.8
6/10	22.2	29.1	6.9
6/17	21.8	31.1	9.3
6/24	25.1	32.8	7.7
7/01	24.2	33.3	9.1
7/08	25.8	34.0	8.2
7/15	25.0	32.4	7.4
9/16	21.6-22.2	31.0-32.0	9.7-9.8
10/14	17.0-17.2	27.3-27.4	10.2-10.3
12/09	6.3	17.0	10.7

Throughout the observation period the samples were maintained in a circulating water table at ambient river temperature. All samples were examined by the same person throughout the study period.

Macrozooplankton in the samples were classified as alive, stunned, or dead. Stunned organisms were alive, but displayed reduced locomotor activity and little response to probing stimuli. Dead and stunned organisms were enumerated and removed from the sample; the remainder of the sample was then preserved in 10% formalin to be counted later. All samples used for viability analysis were examined within 3 hours after collection.

Representatives of the three major macrozooplankton species (Gammarus spp., Neomysis americana and Chaoborus sp.) were removed from the samples and maintained in the laboratory for latent survival analysis. The organisms were removed from the entrainment sample and placed into battery jars (20 per jar) containing 800 mℓ of Hudson River water. Gammarus spp. were held for 120 hours at temperatures equal to ambient river temperature at the time of collection. The photoperiod was 14 hours in the summer and was reduced to 12 hours in the fall. Counts of alive and dead organisms were made at 24 hours and 120 hours after collection. Neomysis americana were treated in a manner similar to that described for Gammarus, but the duration of the holding period was 72 hours.

The aquatic plant Myriophyllum sp. and assorted green algae served as substrate and food in all experiments involving culturing of Gammarus spp. This diet was supplemented with finely ground commercial fish food and presoaked maple leaves. N. americana were fed only finely ground fish food. Larval Chaoborus sp. were fed newly-hatched brine shrimp (Artemia salina) nauplii.

Analysis of all initial macrozooplankton survival was conducted by the Kruskal-Wallis test, a nonparametric analogue of the single-classification analysis of variance (Kruskal and Wallace, 1952; Sokal and Rohlf, 1969). If any analysis indicated a significant effect of collection station on survival, an a posteriori comparison of survival was conducted by the Mann-Whitney U-test (Mann and Whitney, 1947).

Statistical analysis of latent survival experiments followed the method of an RxC test of independence using the G-test. In any analysis indicating statistical significance, maximum non-significant subsets were identified by an a posteriori simultaneous test procedure.

6.2.2.2.2 Results

The initial survival of Gammarus spp. collected at Indian Point Unit 2 during spring and fall ambient temperatures (6.3 to 21.8 C or 43.3 to 71.2 F) is presented in Table 6-26. Mean percentages alive at the intakes, D-1 and D-2 were 93.5, 95.6 and 94.4, respectively. Initial survival among the three collection stations was similar ($p < 0.05$).

Table 6-26. Viability among Gammarus spp. collected at Indian Point Unit 2 from 29 April to 17 June and on 9 December, 1975. Intake temperature = 6.3 - 21.8°C. ΔT = 6.9 - 11.9°C. Values presented are percent of total Gammarus examined on the above dates.

Station	Alive	Stunned	Dead
Intake	93.5 91.2-95.8	2.0 0.9-3.1	4.5 2.6-6.4
D-1	95.6 94.0-97.2	1.7 0.5-2.9	2.7 1.5-3.9
D-2	94.4 92.1-96.7	3.3 0.7-5.9	2.3 1.1-3.5

Mean survivals of Gammarus spp. collected during the summer (temperature range 24.2 to 25.8 C or 75.6 to 78.44 F) also exceeded 90% at each of the collection stations (Table 6-27). Entrained Gammarus spp. examined during the summer also displayed no reductions in discharge canal survival when compared with intake survival.

During the summer sampling period the mean ΔT during the four sampling dates was 8.1 C (14.58 F). Based on previous temperature tolerance experiments, Gammarus spp. should not show measurable mortalities due to temperature from exposure to an 8.1 C (14.58 F) ΔT for periods up to 1 hour.

Gammarus spp. were maintained for latent survival analysis following entrainment on five sampling dates from 4/29 to 6/17. The numbers maintained and the 120-hour survival data are presented in Table 6-28. Contingency table analyses revealed no difference among the numbers of alive and dead Gammarus spp. at the intake and discharge stations.

Entrained Monoculodes edwardsi were examined for viability from April 29 to July 8, 1975, during a period when river ambient temperatures increased from 9.0 to 25.8 C (48.2 to 78.4 F). Although ΔT's ranged from 7.7 to 11.9 C (13.9 to 21.4 F), all of the ΔT's > 10 C (18 F) occurred during cooler ambient temperatures (9.0 to 17.2 C or 48.2 to 63.0 F).

Table 6-27. Viability among Gammarus spp. collected at Indian Point Unit 2 from 24 June to 15 July, 1975. Intake temperature = 24.2 - 25.8°C ΔT = 7.4 - 9.1 °C. Values presented are percent of total Gammarus examined on the above dates.

Station	Alive	Stunned	Dead
Intake	94.0 91.0-97.0	0.6 0.0-1.4	5.3 2.4-8.2
D-1	93.9 92.2-95.9	1.4 0.5-2.3	4.7 3.1-6.3
D-2	94.6 93.3-95.9	2.2 1.2-3.2	3.1 1.9-4.3

Table 6-28. Latent survival of Gammarus spp. collected at Indian Point Unit 2, 1975.

Date	Station	n	120h Survival	
			Alive	Dead
6/10	Intake	73	70	3
	D-1	100	91	9
6/17	Intake	60	55	5
	D-1	60	55	5
	D-2	60	56	4
4/29	Intake	57	51	6
	D-1	55	52	3
	D-2	38	35	3
	D-P	40	39	1
5/06	Intake	60	51	9
	D-1	60	53	7
	D-2	20	18	2
	D-P	31	28	3
5/20	Intake	53	50	3
	D-1	57	51	6
	D-2	60	56	4

Mean percentages of alive M. edwardsi collected from the intake and discharge stations were 87.4 to 88.9% (Table 6-29). No statistical difference was detected among the intake or discharge percentages of alive, stunned or dead M. edwardsi.

Neomysis americana were sampled at Indian Point Unit 2 during July at ambient temperatures of 25.0 to 25.8 C (77.0 to 78.44 F). Mean percent alive at the intake station was 92.6% (Table 6-30). Mean survival decreased to 72.0% and 64.6% at discharge stations D-1 and D-2, respectively.

Kruskal-Wallis (Kruskal and Wallis, 1952) analysis of alive, stunned and dead viability classifications revealed significant ($P < 0.01$) collection station effects in all cases. The resultant a posteriori station comparisons are presented in Table 6-31. Comparisons between the intake stations and both discharge stations reveal differences ($P < 0.01$) at all three viability levels (alive, stunned and dead). No difference was detected between the viability at stations D-1 and D-2.

Neomysis americana classified as alive and maintained for 72 hours following collection at intake and discharge stations displayed no difference in survival rate (Table 6-32). N. americana classified initially as stunned had increased mortalities during the 72-hour holding period. Overall, the 72-hour survival of stunned organisms was 32%, compared to a 99% survival of alive N. americana.

Table 6-29. Viability among Monoculodes edwardsi collected at Indian Point Unit 2 from 29 April to 8 July, 1975. ΔT = 7.7 to 11.9°C. Values presented are percent of total Monoculodes examined on the above dates.

Station	Alive	Stunned	Dead
Intake	88.6 84.8-92.4	2.2 0.7-3.7	9.2 6.1-12.3
D-1	88.9 85.7-92.1	2.2 1.0-3.4	8.9 5.9-11.9
D-2	87.4 83.4-91.4	2.3 0.9-3.7	10.3 6.9-13.7

Table 6-30. Viability among Neomysis americana collected at Indian Point Unit 2 on July 8 and 15, 1975. Intake temperature = 25.0-25.8°C. ΔT = 7.4-8.2 °C. Values presented are percent of total neomysis examined on the above dates.

Station	Alive	Stunned	Dead
Intake	92.6 88.6-96.6	1.4 0.1-2.7	5.9 1.8-10.0
D-1	72.0 60.1-83.9	8.0 4.4-11.6	20.0 7.7-32.3
D-2	64.6 48.4-80.8	8.8 5.8-11.8	26.6 9.7-43.5

Table 6-31. A posteriori comparisons of intake and discharge canal survival of Neomysis americana.

Viability Classification	Station Comparisons	"U" statistic
Alive	Intake vs D-1	49.0 **
	Intake vs D-2	48.0 **
	D-1 vs D-2	31.0 N.S.
Stunned	Intake vs D-1	46.0 **
	Intake vs D-2	49.0 **
	D-1 vs D-2	26.0 N.S.
Dead	Intake vs D-1	45.0 **
	Intake vs D-2	47.0 **
	D-1 vs D-2	27.5 N.S.

** $P<0.01$
N.S. not significant at $P<0.05$

Table 6-32. 72 hour survival of Neomysis americana collected at Indian Point Unit 2.

Station	Viability Condition	n	72-hour Survival Alive	Dead
Intake	Alive	100	87	13
D-1	Alive	52	50	2
D-1	Stunned	28	7	21
D-2	Alive	47	45	2
D-2	Stunned	44	16	28

During 1975 preliminary experiments were conducted on the survival and metamorphosis of Chaoborus sp. larvae following entrainment. Initial viability studies indicate that Chaoborus does not experience measurable mortalities during entrainment (Table 6-33). Survival at the intake and discharge stations exceeded 90% during exposures to ΔT's of 7.7 to 9.3 C (13.9 to 16.7 F) at ambient temperatures of 21.8 to 24.2 C (71.2 to 75.6 F).

Preliminary experiments on the survival and metamorphosis of Chaoborus sp. larvae indicate that organisms collected from the discharge canal display similar survival rates and emergence of adults when compared with organisms from the plant intakes (Table 6-34).

6.2.3 Discussion of 4-Year Study

Analyses of entrained Gammarus spp. at Indian Point during 1972, 1974 and 1975 indicate that this abundant amphipod does not experience significant mortalities during normal plant passage. Although a significant reduction in discharge canal survival was noted at Unit 1 in 1972 (summer only), the overall difference between intake and discharge survival was only about 8%. Entrainment studies at Unit 2 revealed no differences between intake and discharge survival of Gammarus spp.

Studies conducted during condenser chlorination in 1974 and 1975 showed that total mortalities of Gammarus may

Table 6-33. Viability among Chaoborus sp. collected at Indian Point Unit 2 from 17 June to 1 July, 1975. Intake temperature = 21.8 - 24.2 °C ΔT = 7.7 - 9.3 °C. Values presented are percent of total Chaoborus examined on the above date.

Station	Alive	Stunned	Dead
Intake	94.3 90.0-98.6	2.0 0.0-4.1	3.7 1.1-6.3
D-1	92.2 88.5-95.9	2.0 0.7-3.3	5.8 2.5-9.1
D-2	94.0 91.0-97.0	0.6 0.1-1.1	5.4 2.3-8.5

Table 6-34. Survival and metamorphosis of Chaoborus sp. larvae following entrainment in the Indian Point cooling water system. Intake = 24.2 °C ΔT = 9.1 °C.

	Percent		
	Intake	Discharge D-1	Discharge D-2
48 hour			
larvae	94.7	85.3	90.7
pupae	4.0	14.7	9.3
adult	0.0	0.0	0.0
total alive	98.7	100.0	100.0
96 hour			
larvae	60.0	56.0	72.0
pupae	9.3	14.7	12.0
adult	17.3	13.3	8.0
total alive	86.6	84.0	92.0
168 hour			
larvae	41.3	37.3	50.6
pupae	5.3	6.7	9.3
total adult	29.3	26.7	18.7
total alive	75.9	70.7	78.6

approximate 40-50% of the organisms entrained during chlorine injection. Chlorine concentrations occurring in the discharge plume (< 0.05 mg/ℓ) appear, however, to be well below the lethal limits for Gammarus spp.

Mortalities of Gammarus from condenser chlorination represent a minimal percentage of the total numbers entrained at Indian Point because:

1) The total time of chlorine injection is only a fraction of the total operating time,

2) Chlorination is conducted during daylight hours when Gammarus abundance in the cooling water flow is low (see section 6.1).

Examination of the survival of Neomysis americana from the intakes and discharge canal reveals significant mortalities occurring between the plant intakes and station D-1. Of the major Hudson River macrozooplankton species, N. americana appears to be the most sensitive organism to Indian Point discharge temperatures. In-plant mortalities correlate well with temperature tolerances determined in the laboratory. At summer ambient temperatures of ∿ 26 C (78.8 F) and an 8.3 C (14.9 F) ΔT, approximately 50% of the entrained N. americana will die. During chlorination at maximum discharge temperatures, mortalities of entrained N. americana may approach 100%.

We are uncertain as to the impact of the observed entrainment mortalities on the Hudson River N. americana

population. However, the impact on the populations of N. americana on the Atlantic coast is believed to be minimal, since those organisms occurring near Indian Point are on the fringe of the total population's distribution (Tattersall, 1951, Wigley and Burns, 1971). N. americana is abundant at Indian Point on limited occasions, and peak abundance occur generally as a function of salt intrusion (section 6.1; New York University Medical Center, 1974, 1976a). Thus, it is believed that mortalities resulting from entrainment would not adversely affect Hudson River populations of N. americana.

The two other major macrozooplankton species, Chaoborus sp. and Monoculodes edwardsi, do not display increased initial or latent mortalities resulting from entrainment at Indian Point. Although they are likely to be affected during chlorination, the overall effects are believed to be minimal. The reasons for this are as those given earlier relating to Gammarus.

7. ICHTHYOPLANKTON

7.1 River Population Studies

7.1.1 Methods

Ichthyoplankton was collected in samples with macrozooplankton. Organisms of these two major biological groups, which were obtained in collections at all seven stations and at three different depths (Figure 1-7; 1976a), were then separated for detailed analysis. The methods and gear used are described in Section 6-1 (New York University Medical Center, 1976a).

Except for day sampling, the sampling for fish eggs and larvae at the seven river stations was done to coincide as nearly as possible with the net samples taken in the Indian Point generating plant. This type of sampling was done each week throughout the striped bass "larvae season" (from the last week in April to the end of July). After July, river sampling was done every other week until October, and then once per month until the end of December so as to encompass the season for other fish species.

Metered 0.5 m-diameter, 571 μ-mesh plankton nets, similar to those used in the intakes and discharge canal were used to sample in the river for fish eggs and larvae. These nets were towed simultaneously at each of three depths (6 to 12 inches below the surface, at mid-depth and approximately 2 feet off the bottom). Replicate samples were taken at all seven stations.

Fish eggs and larvae were sorted from the samples, identified to species (when possible) and enumerated to determine abundance. The abundance data (Number/1000 m^3) were analyzed by ANOVA and by *a posteriori* tests (Sokal and Rohlf, 1969) to determine whether significant differences existed in the temporal and spatial distribution of river ichthyoplankton relative to ichthyoplankton sampled at the plant intakes.

7.1.2 Results and Discussion

A total of 1638 ichthyoplankton samples were collected from the Hudson River in 1975. One-half of this total (819 samples) were sorted and analyzed; the other half (replicate samples) were not examined, and were kept for reference purposes. The species and life stages identified in these collections are listed in Table 7-1. Twenty-two species were observed, 18 of which have been caught in each sampling year since 1971. The life stages and relative abundance, by season, of fish species taken in these samples are shown in Table 7-2. The life stages of the bay anchovy (*Anchoa mitchilli*) were most abundant. Following the bay anchovy, in descending order, were the striped bass (*Morone saxatilis*), white perch (*M. americana*) and clupeids (*Alosa* spp.).

The seasonal distribution of fish species in 1975 and their occurrence relative to water temperature and salinity at Indian Point are shown in Figure 7-1. The seasonal

Table 7-1. Ichthyoplankton species and life stages in the river population samples, 1975.

Species	Eggs	YSL	Larvae	Juv.	Older
Percichthyidae (temperate basses)					
Morone saxatilis (striped bass)	X	X	X	X	
Morone americana (white perch)	X	X	X	X	X
Clupeidae (herrings)	X				
Alosa aestivalis (blueback herring)		X	X	X	
Alosa pseudoharengus (alewife)		X	X	X	
Alosa sapidissima (American shad)			X		
Engraulidae (anchovies)					
Anchoa mitchilli (bay anchovy)	X	X	X	X	X
Osmeridae (smelts)					
Osmerus mordax (rainbow smelt)		X	X	X	
Cyprinidae (minnows and carps)					
Notropis hudsonius (spottail shiner)		X	X		
Notropis sp.	X	X	X		
Percidae (perches)					
Etheostoma olmstedi (tessellated darter)		X	X		
Perca flavescens (yellow perch)		X	X		
Sciaenidae (drums)					
Cynoscion regalis (weakfish)			X	X	X

Table 7-1 (cont.)

Species	Eggs	YSL	Larvae	Juv.	Older
Atherinidae (silversides)					
Menidia sp.			X		
Soleidae (soles)					
Trinectes maculatus (hogchoker)		X	X	X	X
Anguillidae (freshwater eels)					
Anguilla rostrata (American eel)				X	X
Syngnathidae (pipefishes and sea horses)					
Syngnathus fuscus (northern pipefish)				X	X
Centrarchidae (sunfishes)					
Lepomis sp.			X		
Gadidae (codfishes)					
Microgadus tomcod (Atlantic tomcod)		X	X	X	X
Ictaluridae (freshwater catfishes)					
Ictalurus catus (white catfish)				X	X
Acipenseridae (sturgeons)					
Acipenser oxyrhynchus			X		
Cyprinodontidae (killfishes)					
Fundulus sp.			X	X	X
Bothidae (lefteye flounders)					
Scopthalmus aquosus			X		

Table 7-2. Seasonal occurrence and percent relative abundance of fish, eggs, 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				Yolk-sac larvae			
	1971	1972	1974	1975	1971	1972	1974	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	6.6	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 7-2 (cont.).

Species	Larvae				Juveniles			
	1971	1972	1974	1975	1971	1972	1974	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 cyprinids included Spottail shiner and an unknown cyprinid species.

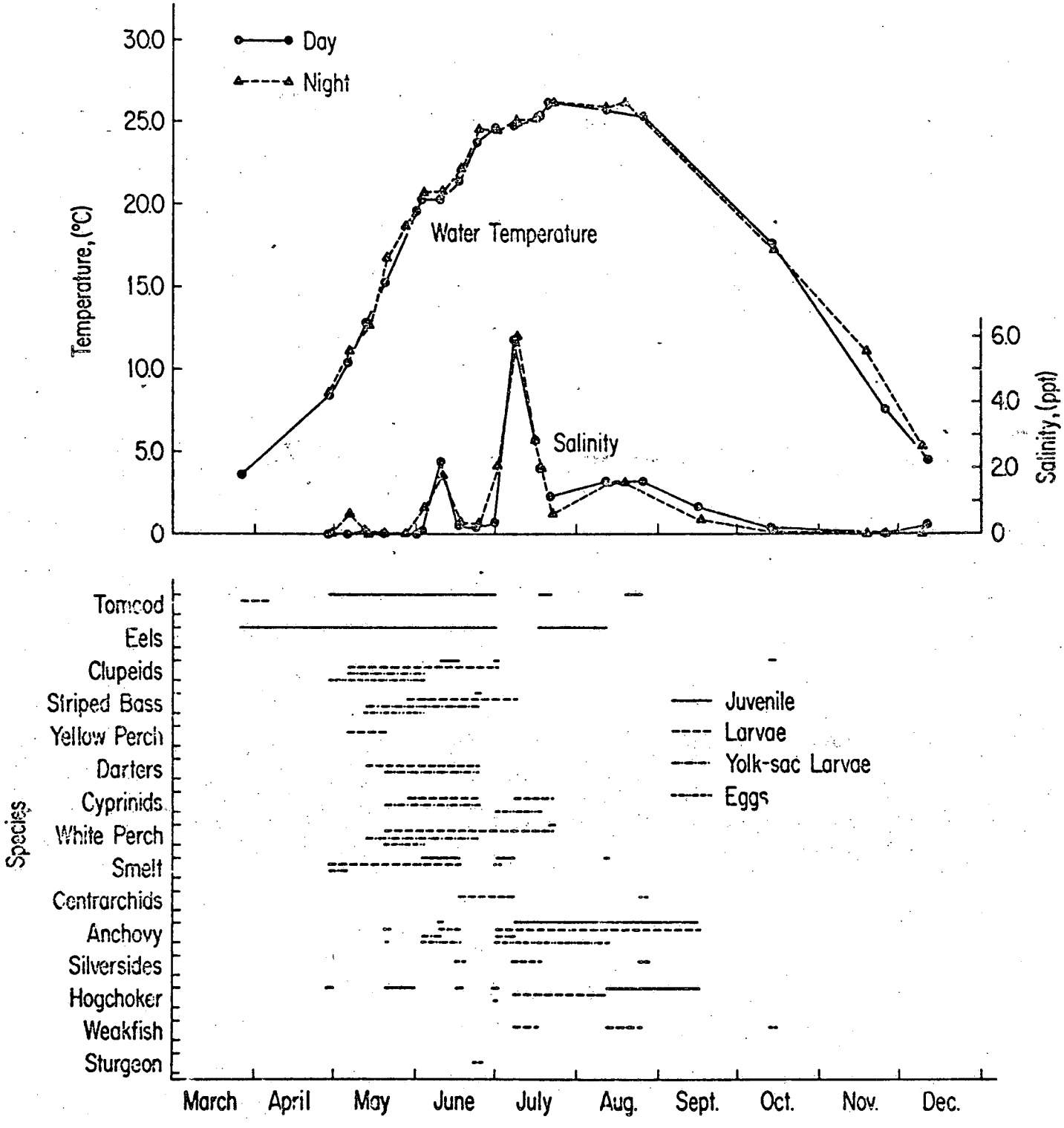

Figure 7-1. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1975.

presence of the various species identified appears to be dependent upon temperature and salinity.

The relative frequency of occurrence for the various life stages of the more abundant species are shown in Figures 7-2 through 7-5. Clupeids and striped bass eggs were first to occur in the Indian Point region when the salinity was less than 1 part per thousand (ppt); these were followed by white perch. With the influx of salt water into the Indian Point region on June 9 (one week earlier than in 1974), 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 ($\geq$ 2 ppt), lasting until the end of the anchovy spawning season in mid-August. The only other eggs noted during this period were those of a cyprinid fish.

Clupeid eggs were present in samples taken from April 27 to June 3 (Figure 7-6); peak abundance (1.0/1000 m^3) was recorded on April 27 and on June 2.

Striped bass eggs were first collected on May 12 and were last seen on June 3. Peak abundance (150/1000 m^3) occurred on May 19 (Figure 7-7).

White perch eggs were encountered in the samples from May 19 until June 3; peak abundance (17.0/1000 m^3) was on June 2 (Figure 7-8).

Anchovy eggs were first observed on May 19, with numbers approaching 2,100/1000 m^3; they were not encountered again

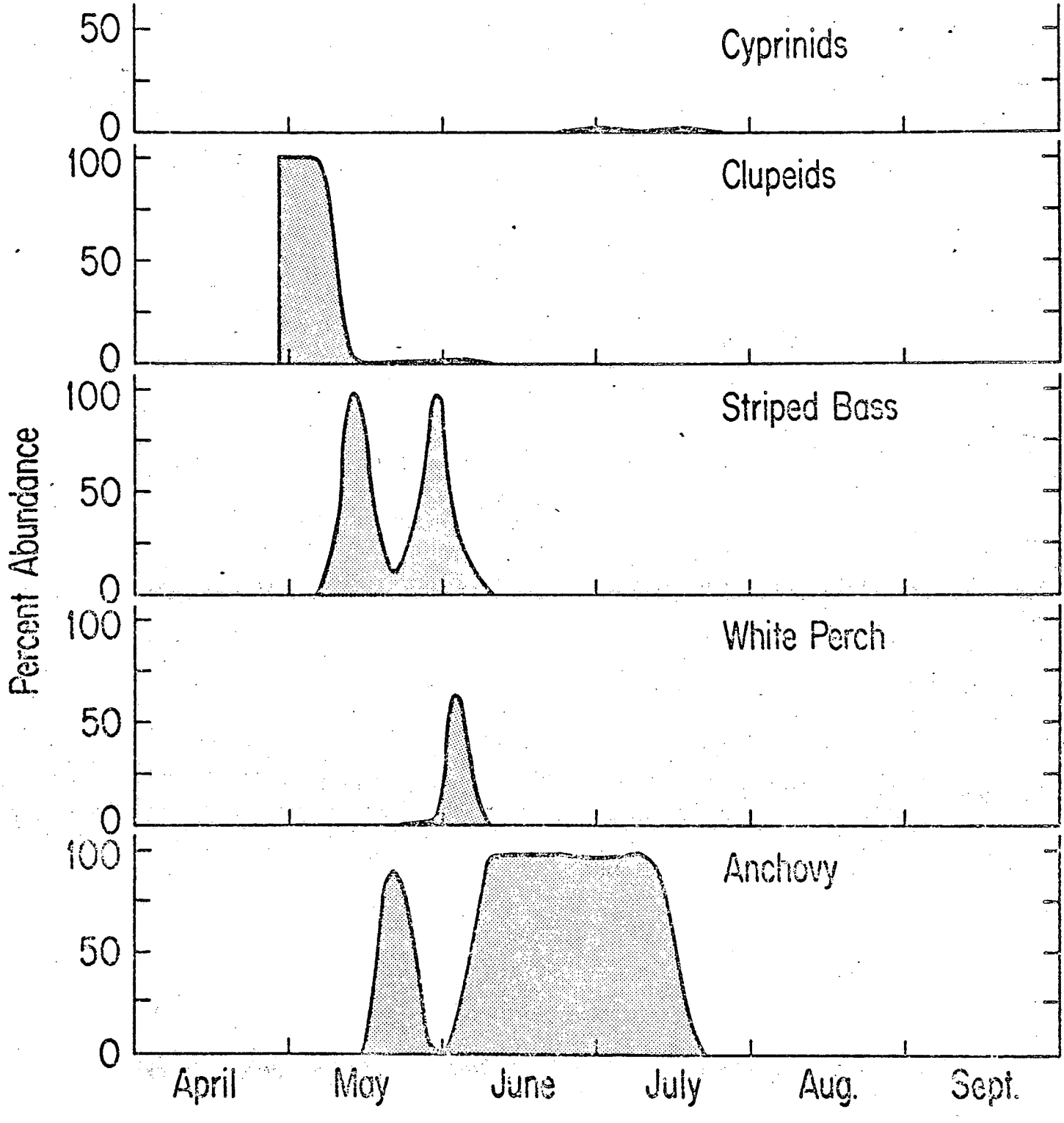

Figure 7-2. Seasonal occurrence and percent abundance for fish eggs by species, 1975. The values shown are percent of total fish eggs in the samples analyzed.

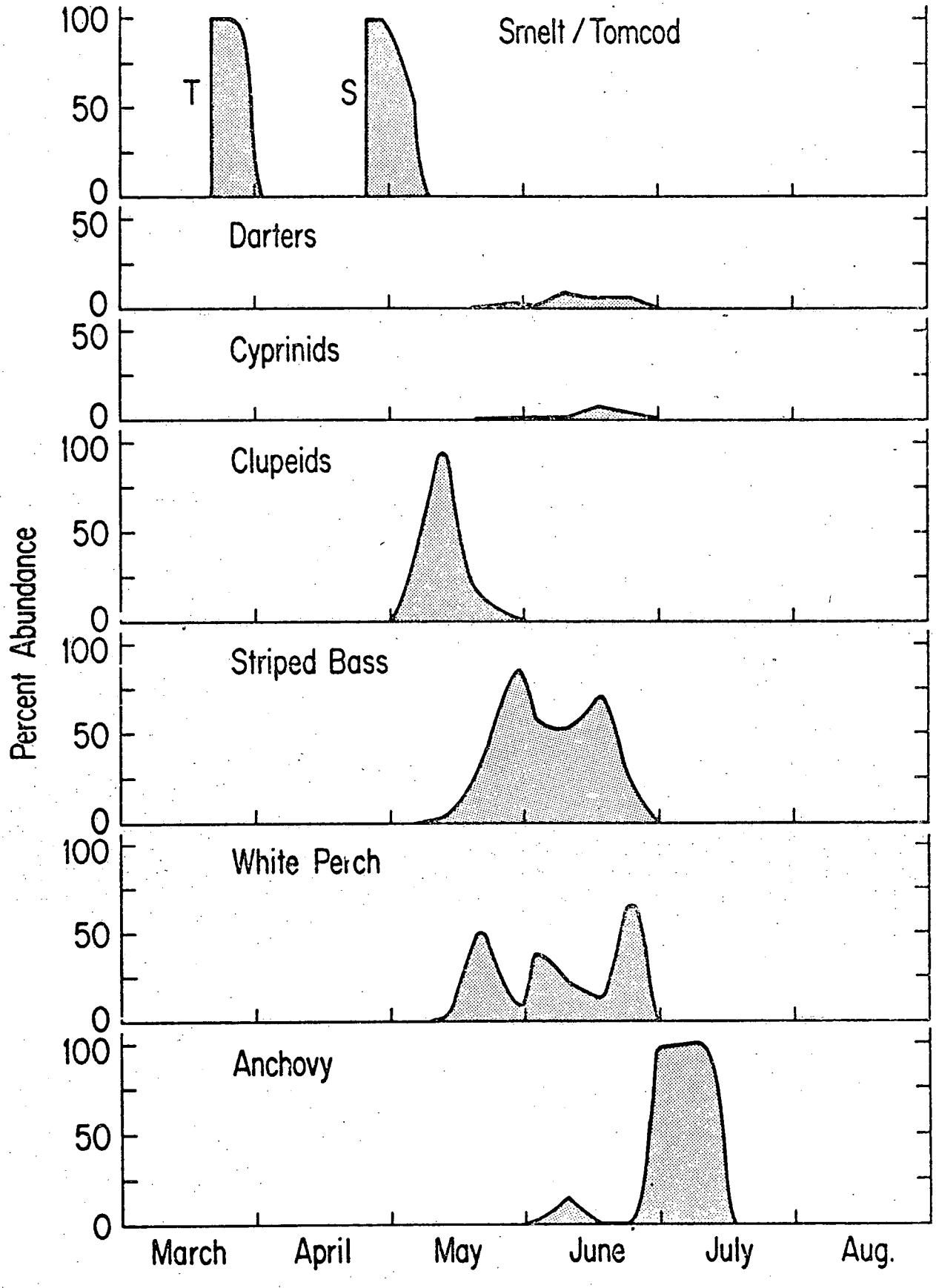

Figure 7-3. Seasonal occurrence and percent abundance for yolk-sac larvae by species, 1975; the values shown are percent of total yolk-sac larvae in the samples analyzed.

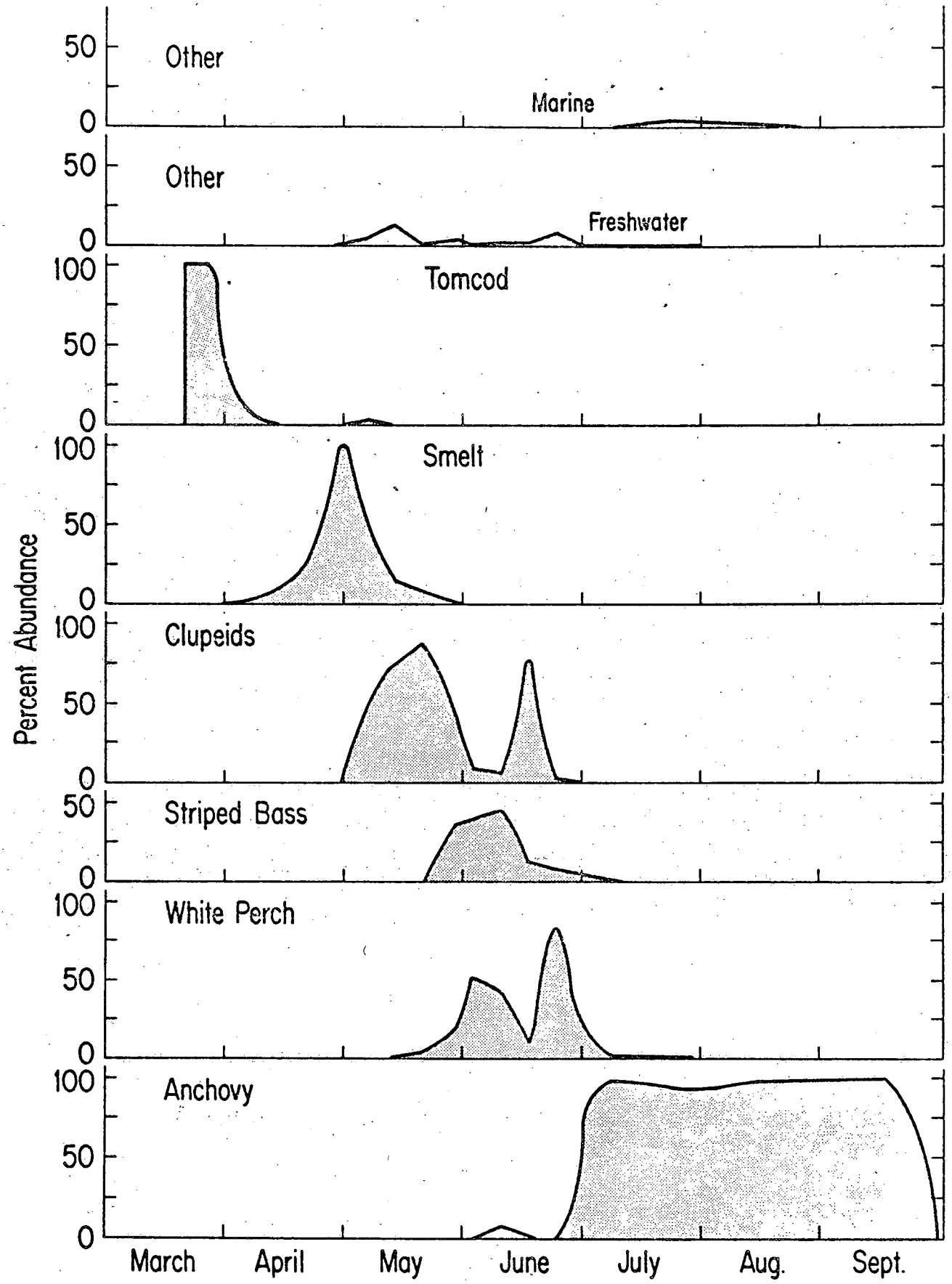

Figure 7-4. Seasonal occurrence and percent abundance for larvae by species, 1975; the values shown are percent of total larvae in the samples analyzed.

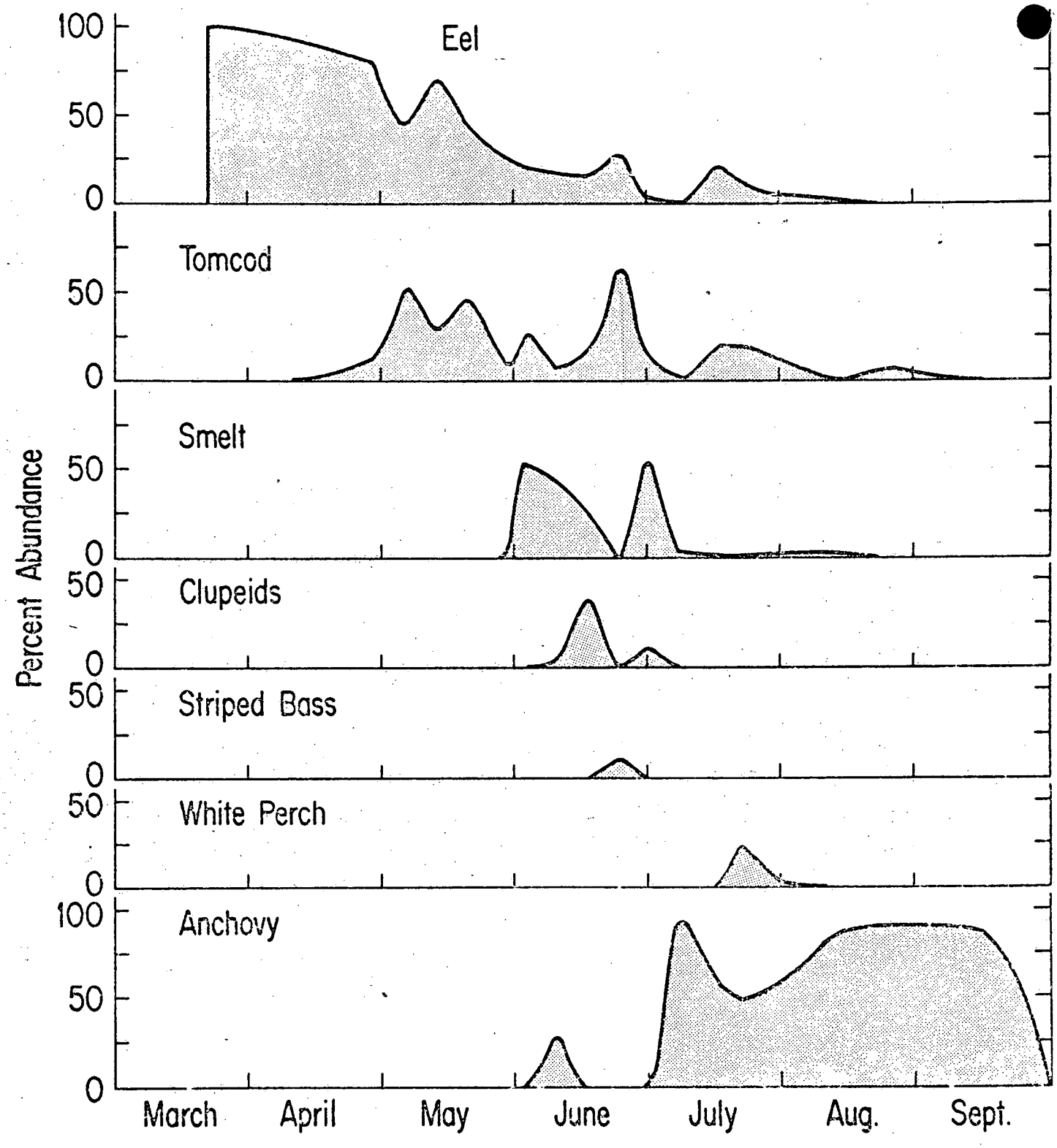

Figure 7-5. Seasonal occurrence and percent abundance for juveniles by species, 1975; the values shown are percent of total juveniles in the samples analyzed.

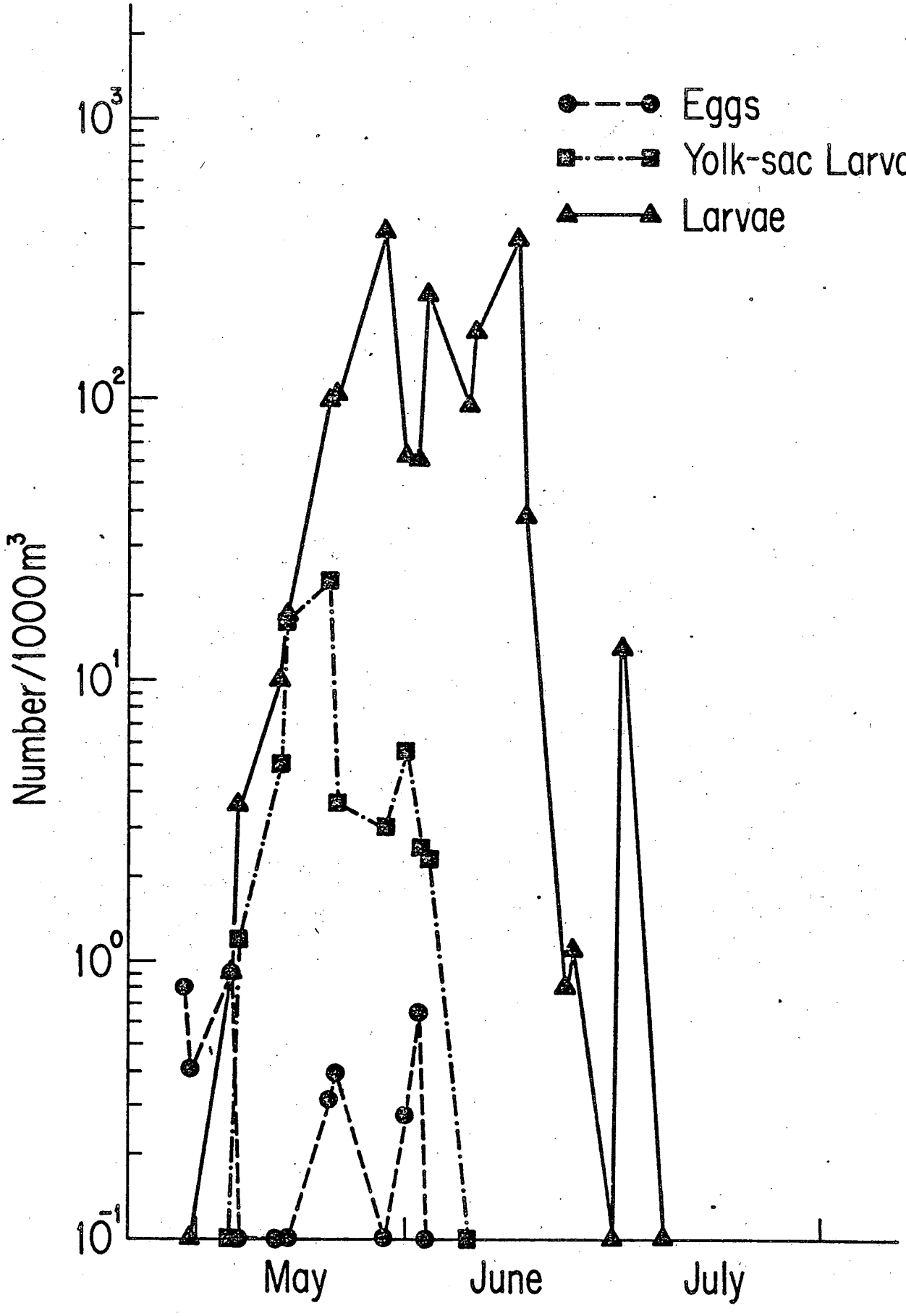

Figure 7-6. Mean abundance (day and night combined) of clupeid life stages collected in river tows, 1975.

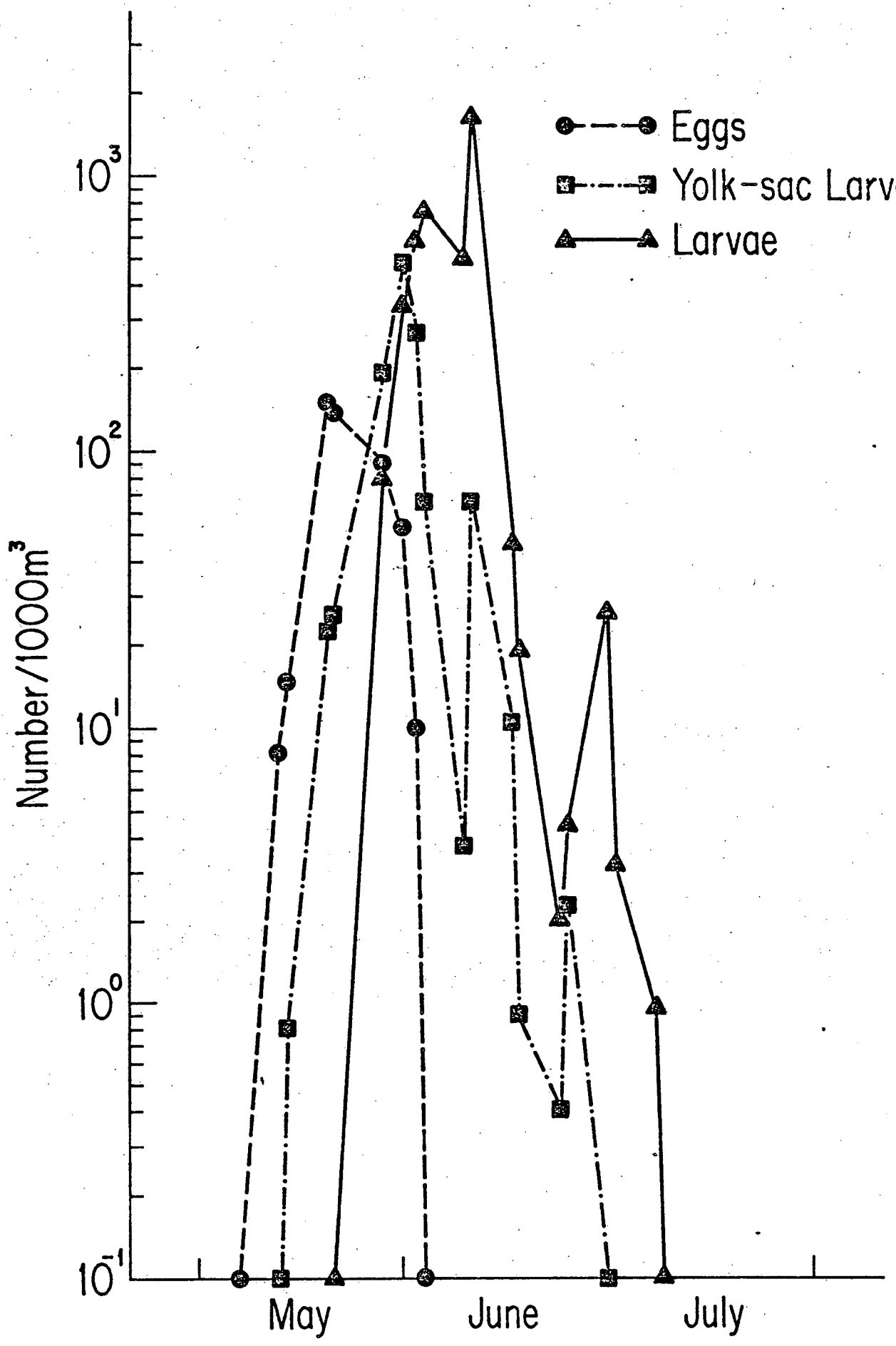

Figure 7-7. Mean abundance (day and night combined) of striped bass life stages collected in river tows, 1975.

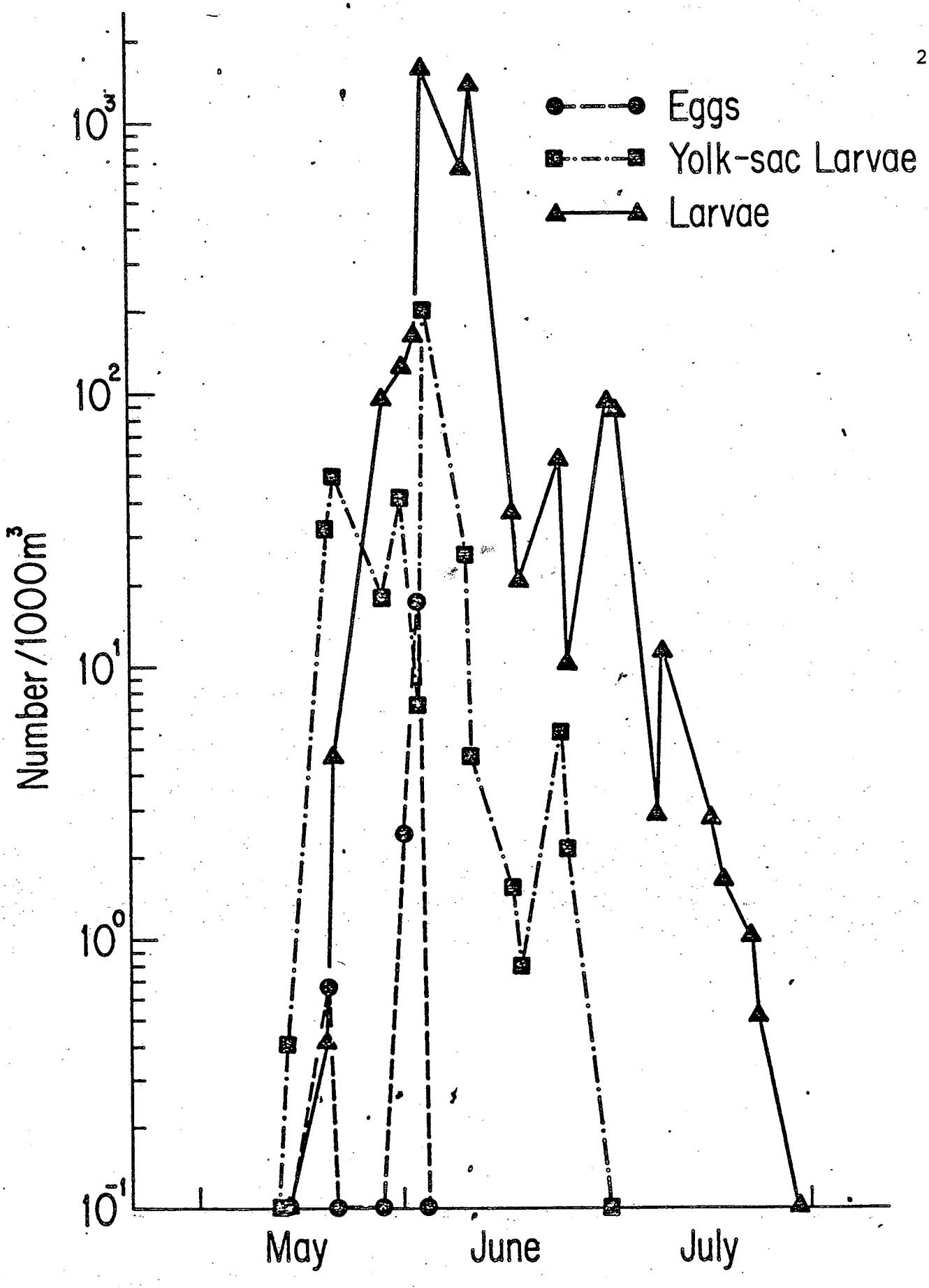

Figure 7-8. Mean abundance (day and night combined) of White perch life stages in river tows, 1975.

until June 9, and had a concentration of 795 eggs/1000 m^3. During this time the salinity varied from 0.0 to 2.0 ppt. However, once the salinity values in the river near Indian Point stabilized at 2.0 ppt or greater (from the end of June through July), anchovy eggs were present in all samples collected; peak abundance (14,000/1000 m^3) occurred on July 8 (Figure 7-9).

The abundance of yolk-sac larvae of each species collected reflect earlier patterns of egg distribution. In most instances, the curves for yolk-sac larvae were displaced to the right of those for the egg and showed indications of having been derived from the previous egg populations; an example of this is seen in striped bass (Figure 7-7).

In our samples, the first yolk-sac larvae to occur in the Indian Point region were those of the tomcod (Microgadus tomcod), Figure 7-3. Next were the yolk-sac larva of rainbow smelt (Osmerous mordax). This is the first time rainbow smelt yolk-sac larvae have been observed in samples from Indian Point. These larvae were collected from April 28 to May 6; peak abundance (7/1000 m^3) occurred on April 28.

Clupeid yolk-sac larvae were first observed in the samples from May 6 and were present through June 9. Peak abundance (23/1000 m^3) occurred on May 19 (Figure 7-6).

Striped bass yolk-sac larvae were first observed on May 13 and were not seen after June 24. Peak abundance (482/1000 m^3) occurred on May 30 (Figure 7-7).

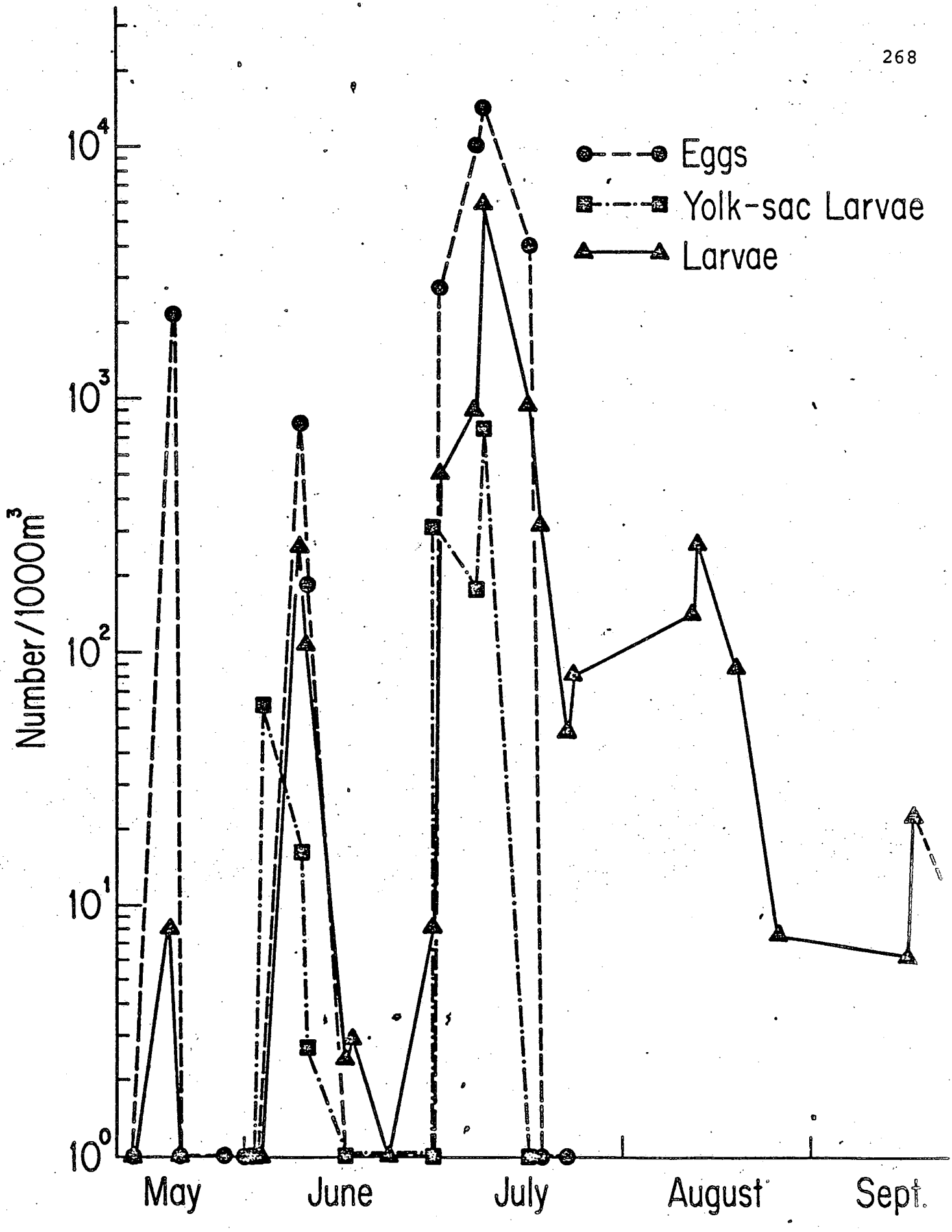

Figure 7-9.. Mean abundance (day and night combined) of anchovy life stages collected in river tows, 1975.

White perch yolk-sac larvae occurred simultaneously with striped bass (May 13) and were observed in the samples until June 24. Peak abundance (200/1000 m^3) for white perch occurred on June 3 (Figure 7-8).

The occurrence of the anchovy yolk-sac larvae followed closely the peak egg abundance during June and July (Figure 7-9). Peak yolk-sac larval periods occurred on June 9 (16/1000 m^3) and on July 8 (760/1000 m^3).

Other yolk-sac larvae seen in our collections were those of a darter (Etheostoma) and two cyprinids (one being a Notropis sp.). Darters occurred from May 20 through June 23; peak abundance (19/1000 m^3) occurred on May 27. The cyprinids occurred from May 20 to June 23, with a peak abundance of 7/1000 m^3 on May 27 (Figure 7-3).

As in 1974, 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 1 until the end of October. Incidental species occurring at this time were the Atlantic silversides (Menidia spp.), weakfish (Cynoscion regalis) and the American sole or hogchoker (Trinectes maculatus). These species are not shown individually in Figures 7-2 to 7-5, but are shown as separate groups under the headings of "other marine" or "other freshwater" species.

Tomcod larvae were first encountered in samples collected on March 26 (14/1000 m^3) and again on May 6 (1.0/1000 m^3). Our data show tomcod larvae to be the dominant species in the river adjacent to Indian Point in late winter and early spring (Figure 7-4).

Rainbow smelt larvae occurred in our samples from April 28 to June 17. Although peak abundance (14/1000 m^3) was not until May 20, rainbow smelt were the dominant larvae in our samples for the latter part of April (Figure 7-4).

Clupeid larvae appeared in the samples on May 5 and were present until July 1 (Figure 7-6). Peak abundance (396/1000 m^3) was recorded on May 27; a second peak (372/1000 m^3) occurred on June 16.

Striped bass larvae occurred in the samples from May 27 to July 7, and showed a peak abundance of approximately 1,638/1000 m^3 on June 10 (Figure 7-7). Striped bass larvae dominated samples throughout this period.

White perch larvae occurred approximately one week earlier than striped bass (May 19) and were present until July 22. Peak abundance (1,550/1000 m^3) was recorded on June 3, and coincided with the abundance peak for striped bass larvae (Figure 7-8).

Anchovy larvae first appeared in the collections on May 19, with an abundance of 1.0/1000 m^3. After this date they were not encountered until June 9 when their abundance reached approximately 260/1000 m^3. Anchovies were occasion-

ally present, but did not remain in the Indian Point region in great numbers until after July 1. Anchovy larvae dominated in our samples from the second week in July until the end of September (Figure 7-4). Peak abundance for this species occurred on July 8 with 5,800/1000 m^3 (Figure 7-9). This is one species whose abundance and dominance occurred simultaneously with the intrusion of salinity into the Indian Point region.

Juvenile life stages for the various species found in our collections are represented in Figure 7-5; all of these are characteristic of brackish and marine habitats. The dominant species was the anchovy; its occurrence was preceded by the American eel, (Anguilla rostrata), and the Atlantic tomcod. Eels were seen in our collections until the end of summer. Tomcod abundance varied in the collections throughout the season. Variations in the numbers of anchovy juveniles, were definitely related to salinity concentrations. Juvenile striped bass and white perch again were not present in large numbers in our collections, but their times of occurrence coincided with those of previous years (New York University Medical Center, 1974, 1976a).

Overall the species composition of the ichthyoplankton collected in 1975 is similar to that found for previous years (Table 7-3). Also, the distribution for the striped bass and white perch with depth is similar to that seen in previous years. Depth profiles, when compared with data

Table 7-3. 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	-	+	-	-	+
Crevalle jack	+	-	-	-	-
Menhaden	+	-	-	-	-
Weakfish	+	+	+	+	+
Sturgeon	+	+	-	-	+
Centrarchid	+	+	+	+	+
Silver perch	-	+	-	-	-
White catfish	-	+	+	+	+
Stickleback	-	+	-	-	-
Gobi	-	-	+	+	-
Windowpane flounder	-	-	-	-	+

from 1971 to 1975, indicate that these larvae have definite diel changes in depth. They are more abundant near the bottom during the day and move up towards mid-depth and the surface at night, generally with an increased abundance (Figures 7-10 through 7-13). As stated in previous reports, the eggs and yolk-sac larvae of striped bass and white perch did not exhibit any diel change, but were distributed near the bottom (Figures 7-14 through 7-19). Although white perch and striped bass juveniles were more mobile, they were more abundant in the mid-to lower-depths.

The distribution of clupeid eggs and yolk-sac larvae with depth is towards the bottom. One exception was in 1974, when more eggs were collected at the surface during the night (Figure 7-20 and 7-21). Clupeid larvae showed no depth preference from one year to another and were distributed throughout the water column. As an example, during 1972 and 1975, larvae were distributed towards the surface for day samples, while larvae in night samples were distributed throughout the water column; higher numbers were found at the surface and/or near the bottom (Figures 7-22 and 7-23). The distribution patterns for the other years appeared to be the opposite of those in 1972 and 1975.

As yet, we have no explanations for these observed differences in the vertical distribution of clupeid larvae from 1971 through 1975. One possibility is that preference for a certain level is species specific, since three different

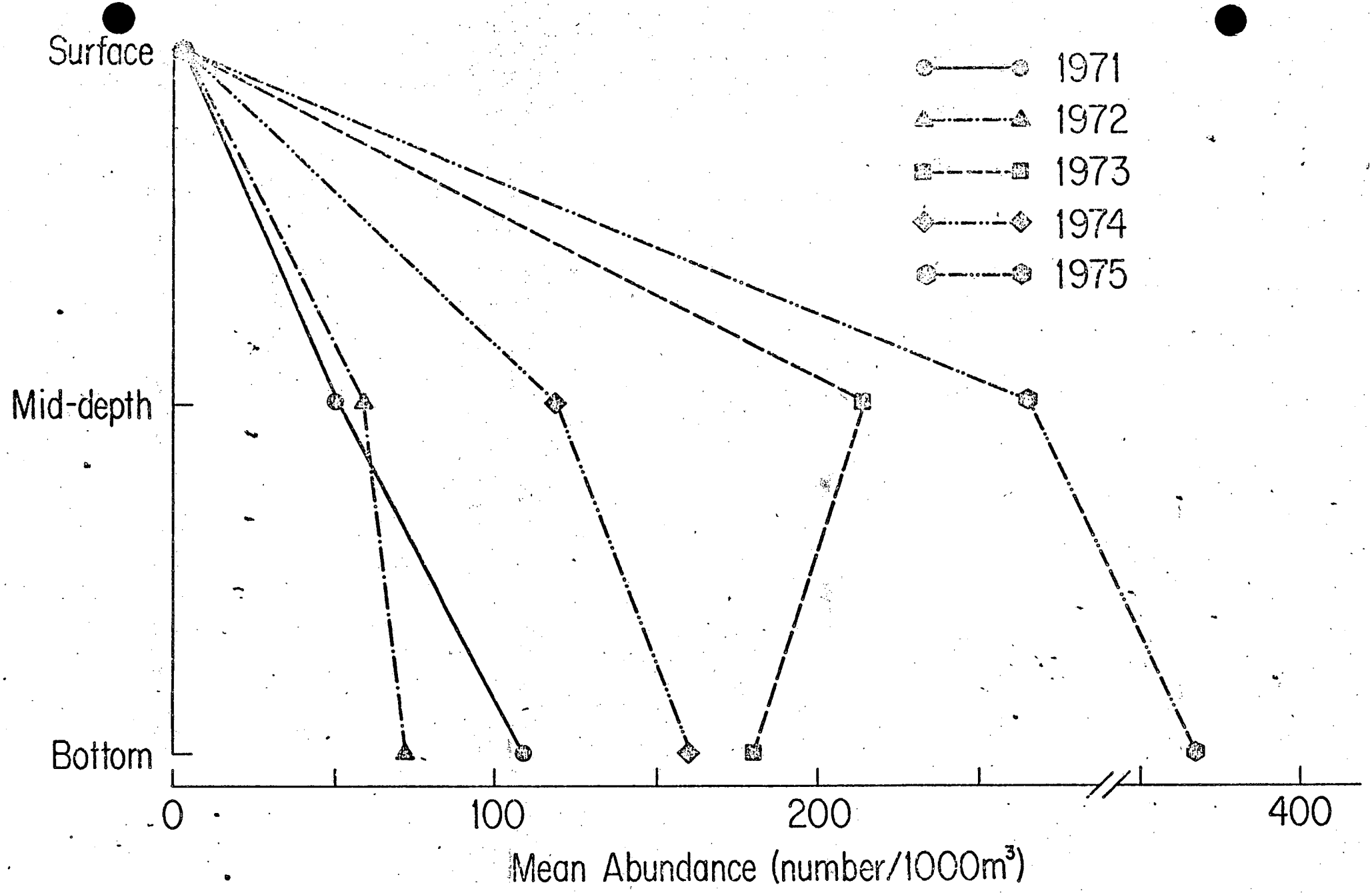

Figure 7-10. Daytime pattern of vertical distribution for striped bass larvae collected in river tows from 1971 to 1975.

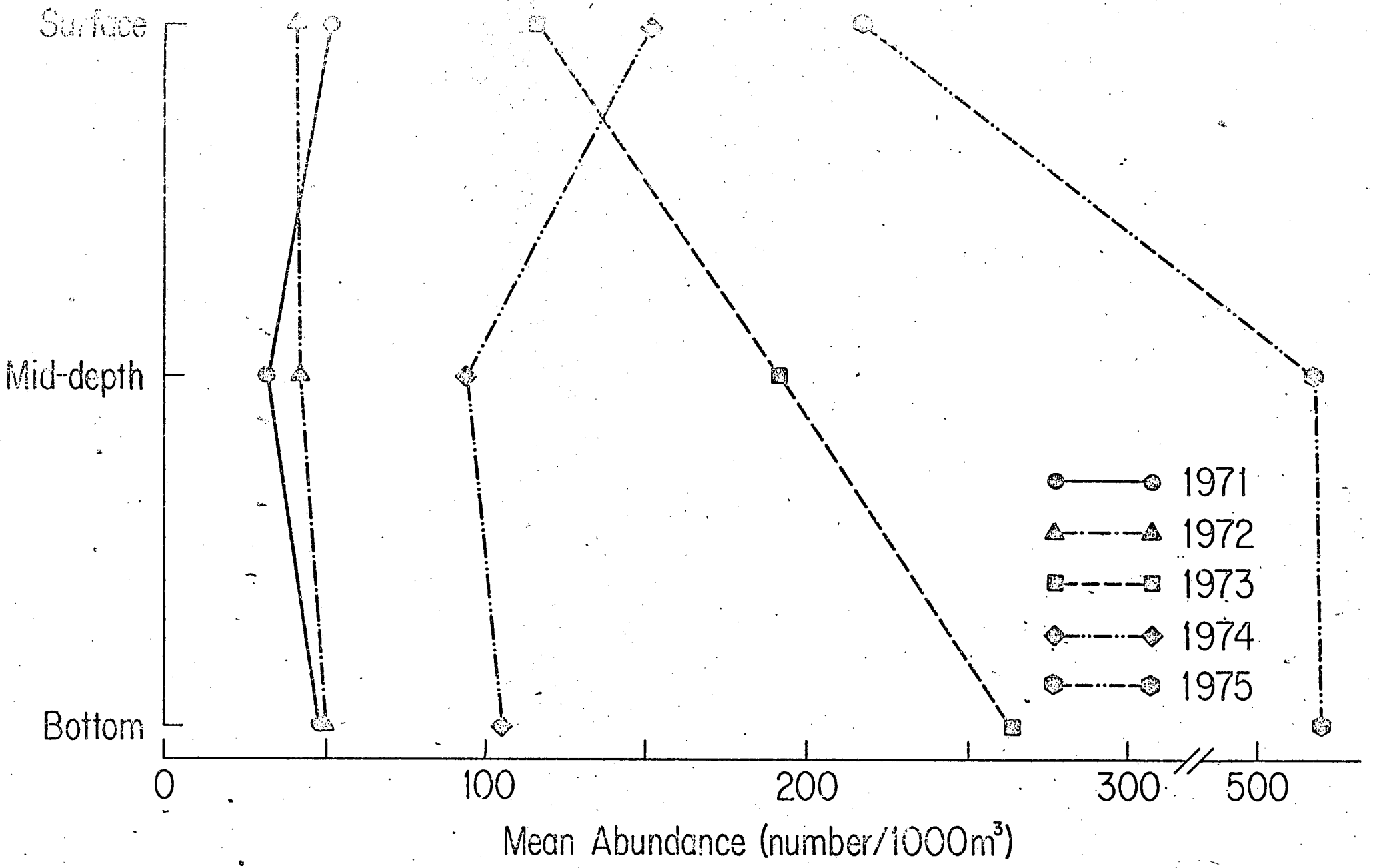

Figure 7-11. Nighttime pattern of vertical distribution for striped bass larvae collected in river tows from 1971 to 1975.

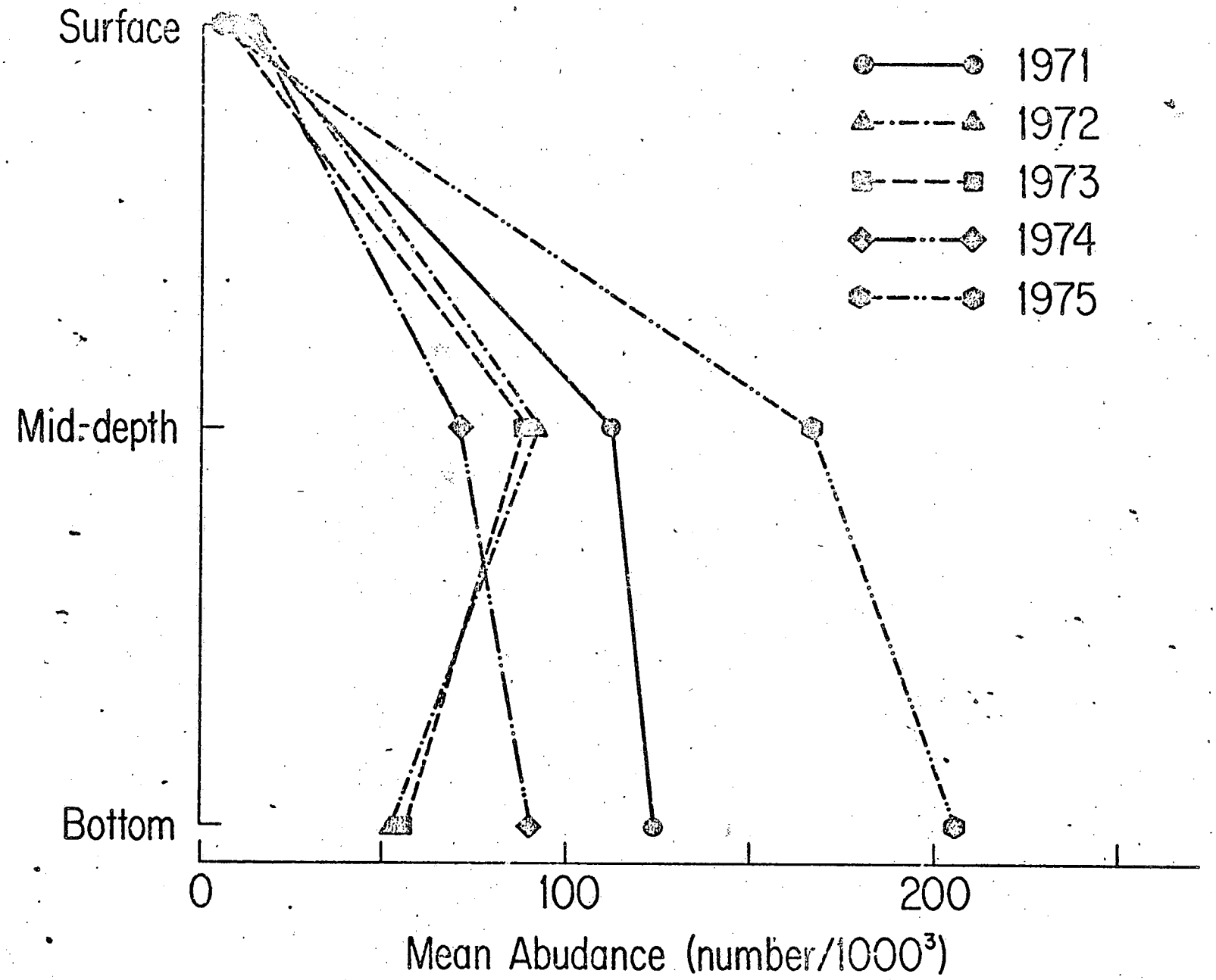

Figure 7-12. Daytime pattern of vertical distribution for white perch larvae collected in river tows from 1971 to 1975.

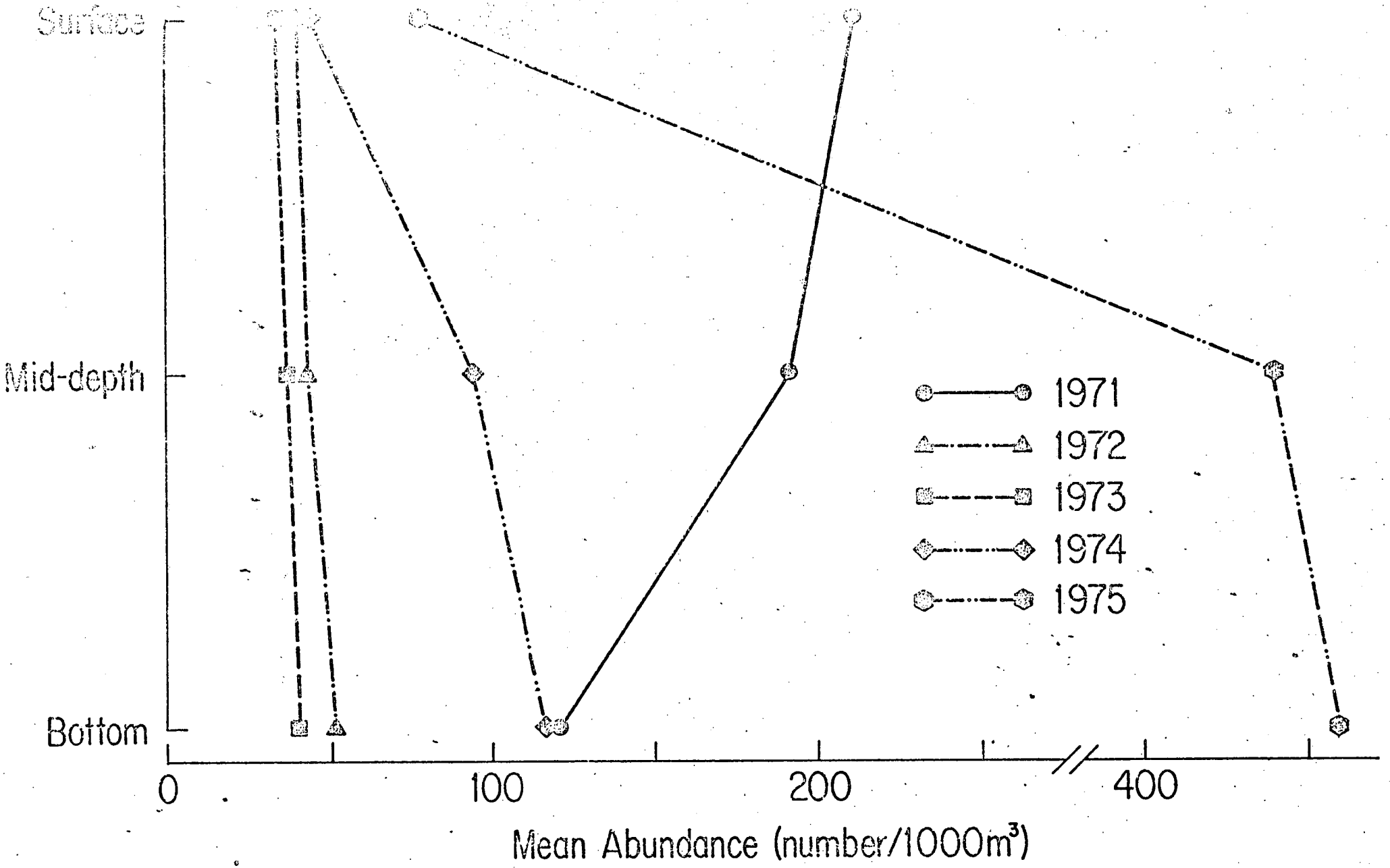

Figure 7-13. Nighttime pattern of vertical distribution for white perch larvae collected in river tows from 1971 to 1975.

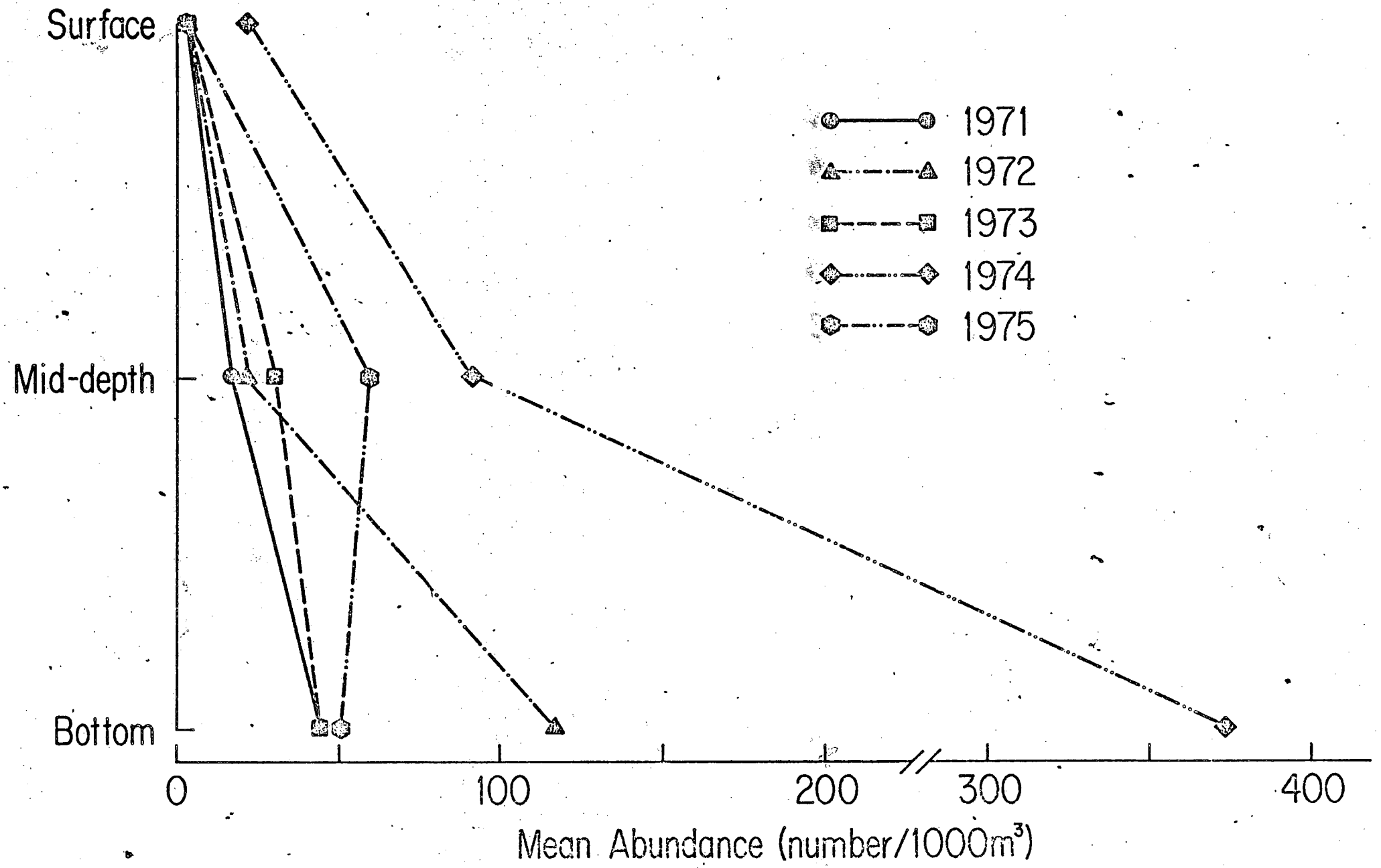

Figure 7-14. Daytime pattern of vertical distribution for striped bass eggs collected in river tows from 1971 to 1975.

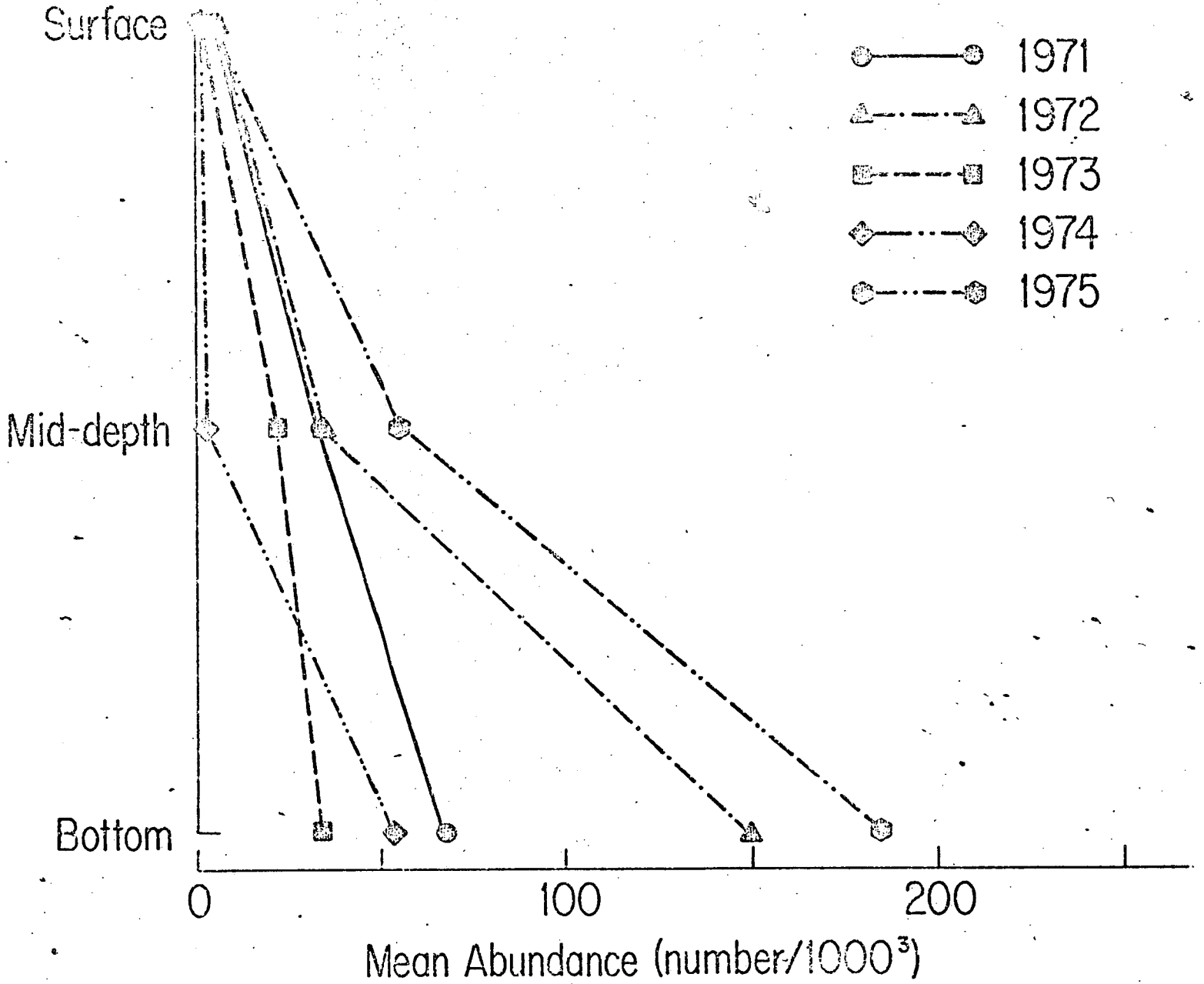

Figure 7-15. Nighttime pattern of vertical distribution for striped bass eggs collected in river tows from 1971 to 1975.

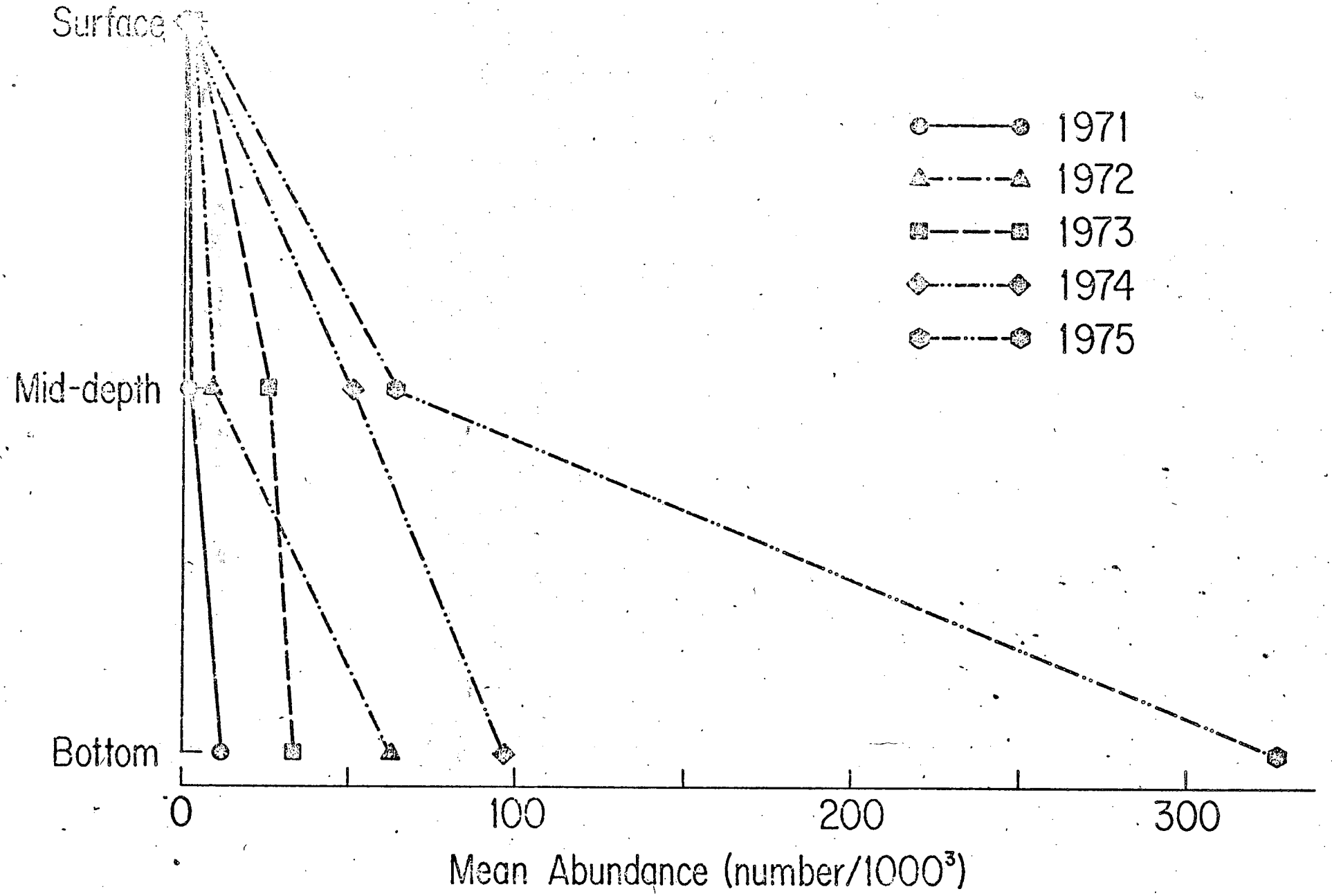

Figure 7-16. Daytime pattern of vertical distribution for striped bass yolk-sac larvae collected in river tows from 1971 to 1975.

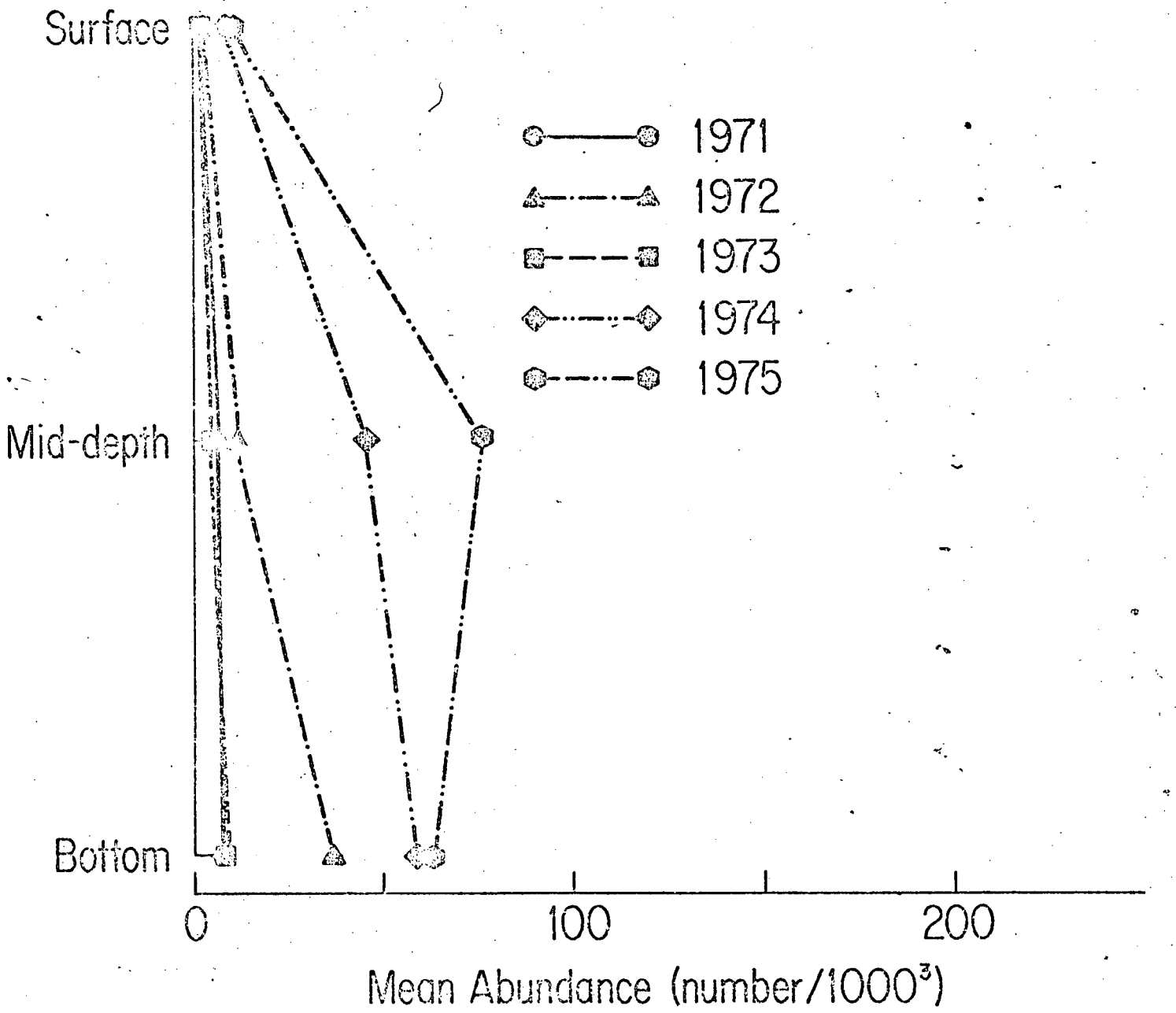

Figure 7-17. Nighttime pattern of vertical distribution for striped bass yolk-sac larvae collected in river tows from 1971 to 1975.

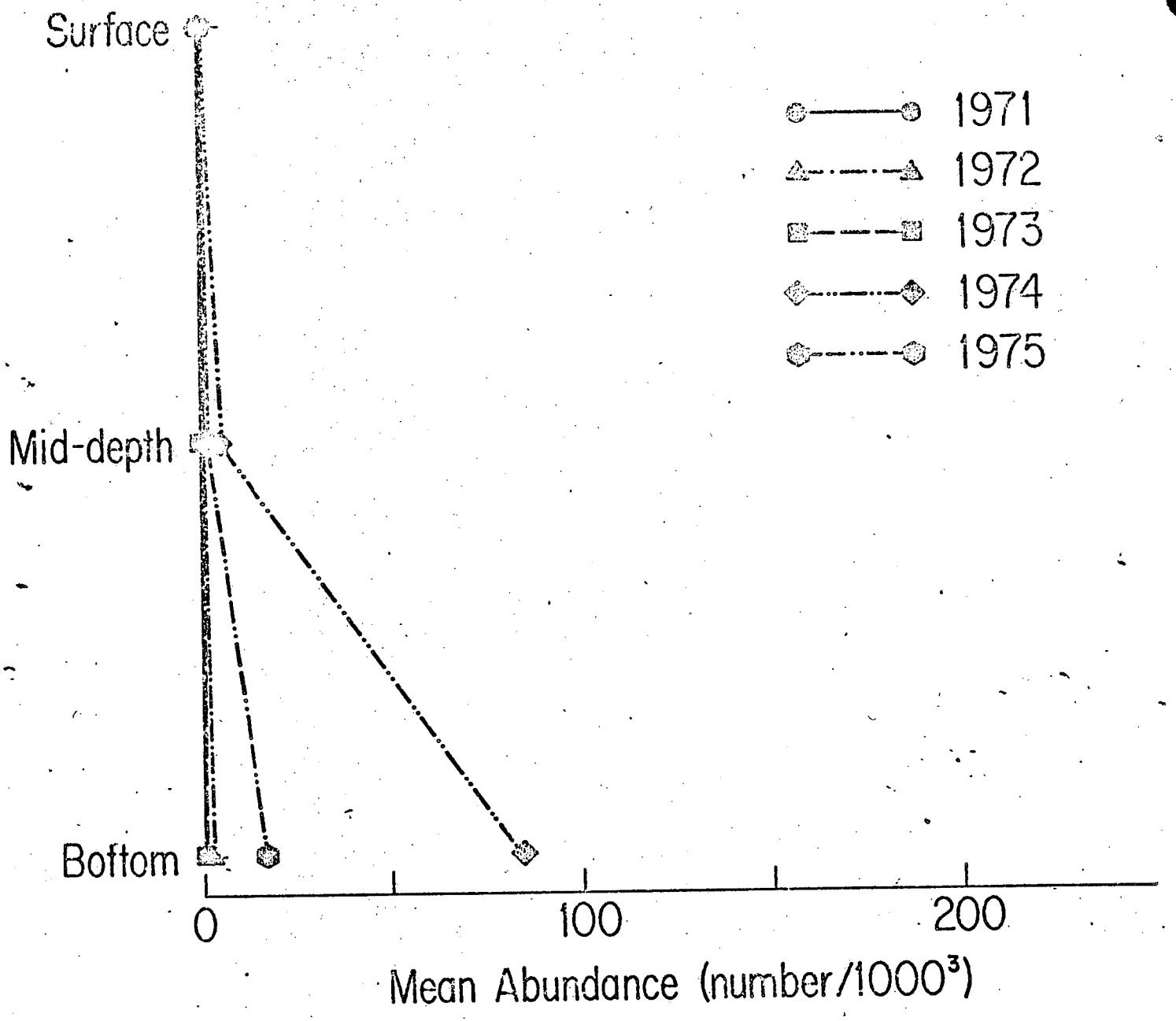

Figure 7-18. Daytime pattern of vertical distribution for white perch eggs collected in river tows from 1971 to 1975.

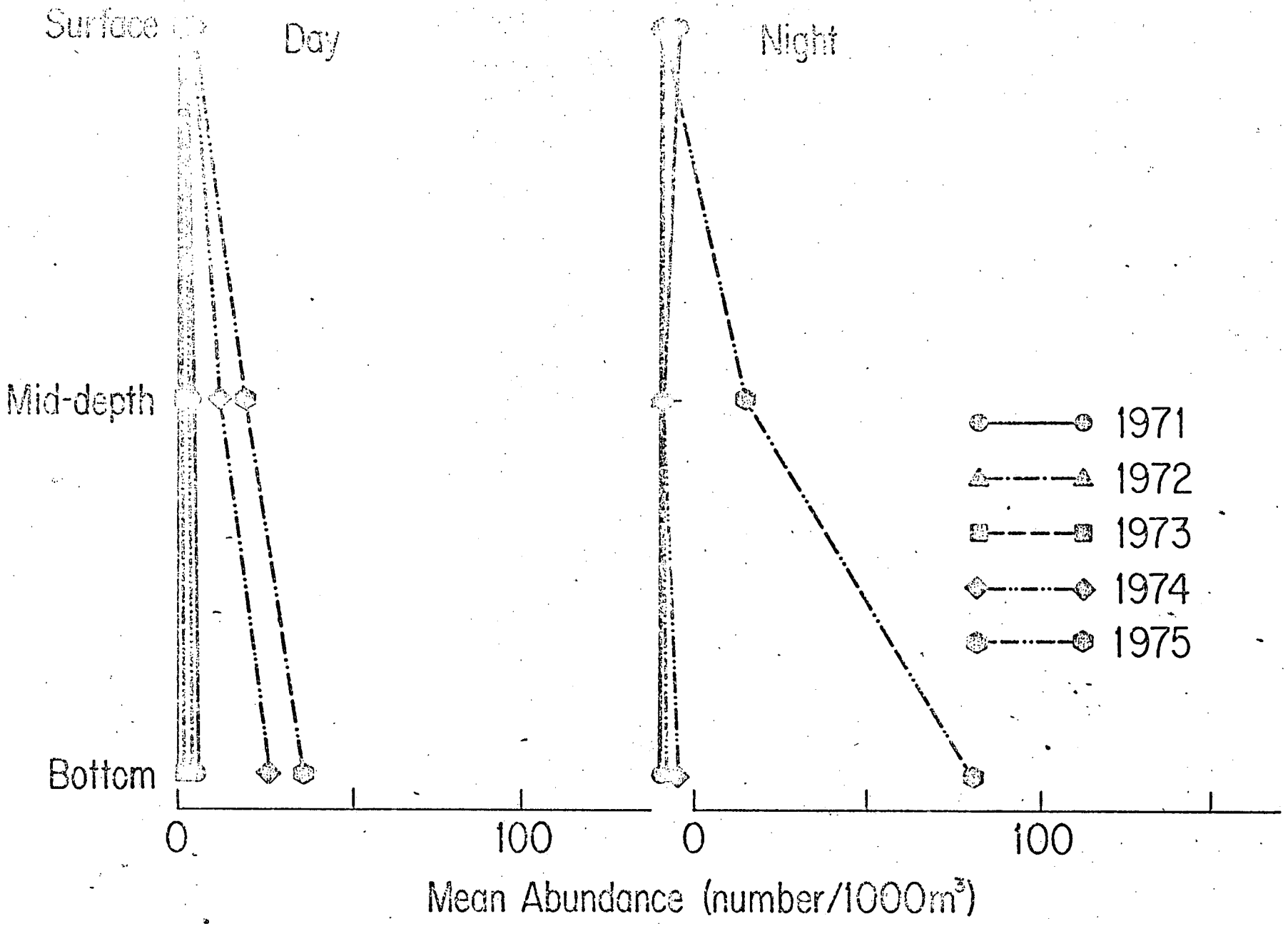

Figure 7-19. Daytime and nighttime patterns of vertical distribution for white perch yolk-sac larvae collected in river tows from 1971 to 1975.

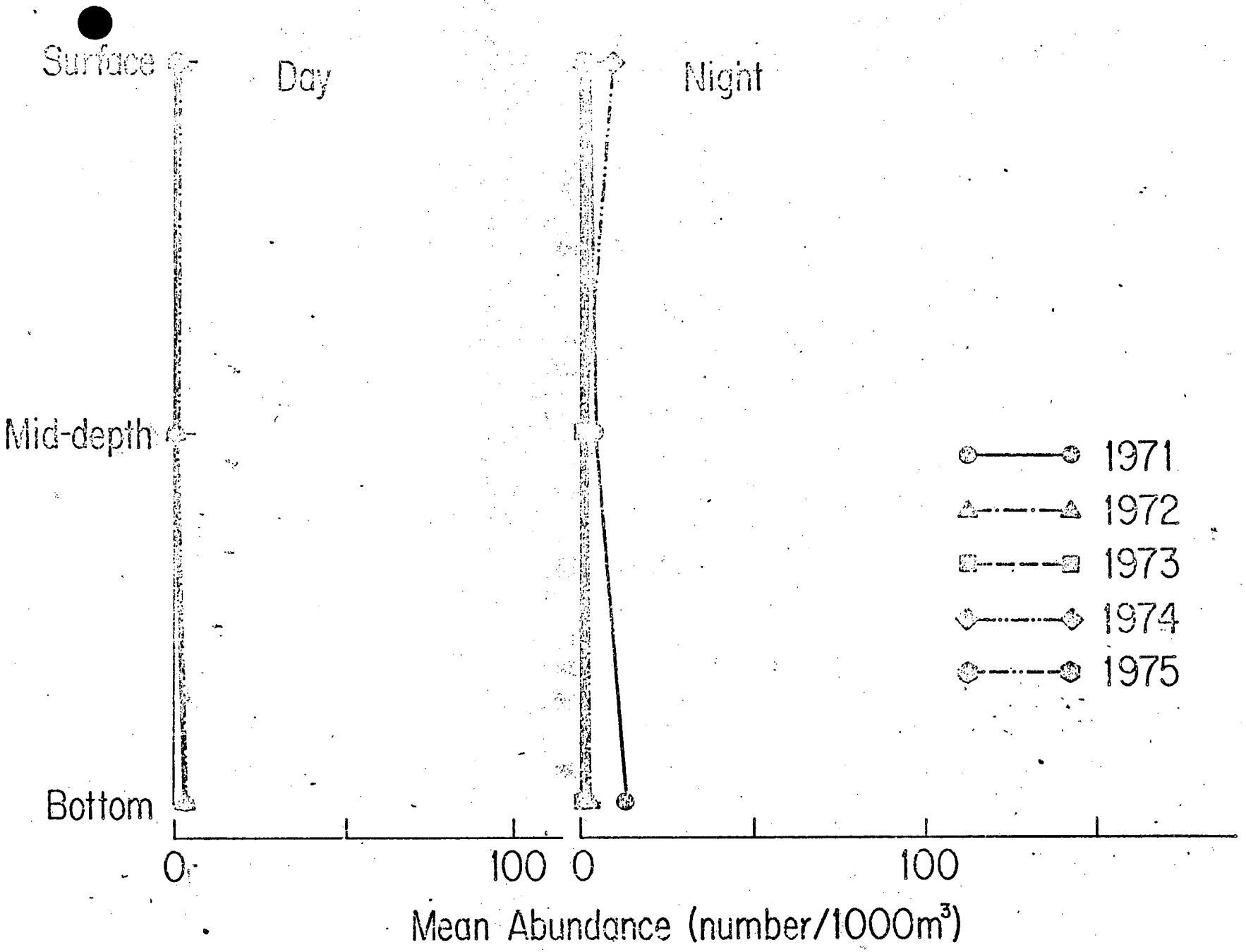

Figure 7-20. Daytime and nighttime patterns of vertical distribution for clupeid eggs collected in river tows from 1971 to 1975.

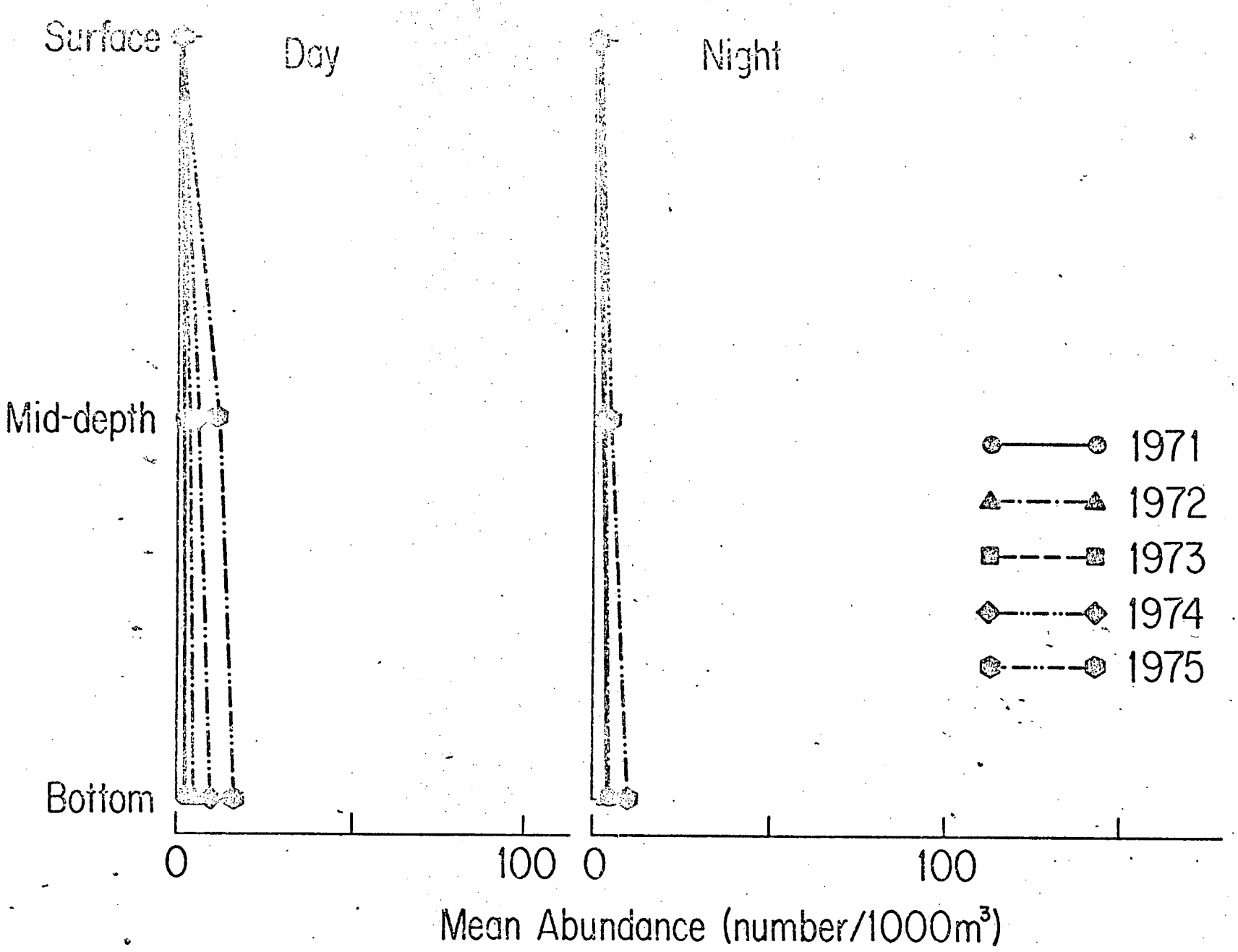

Figure 7-21. Daytime and nighttime patterns of vertical distribution for clupeid yolk-sac larvae collected in river tows from 1971 to 1975.

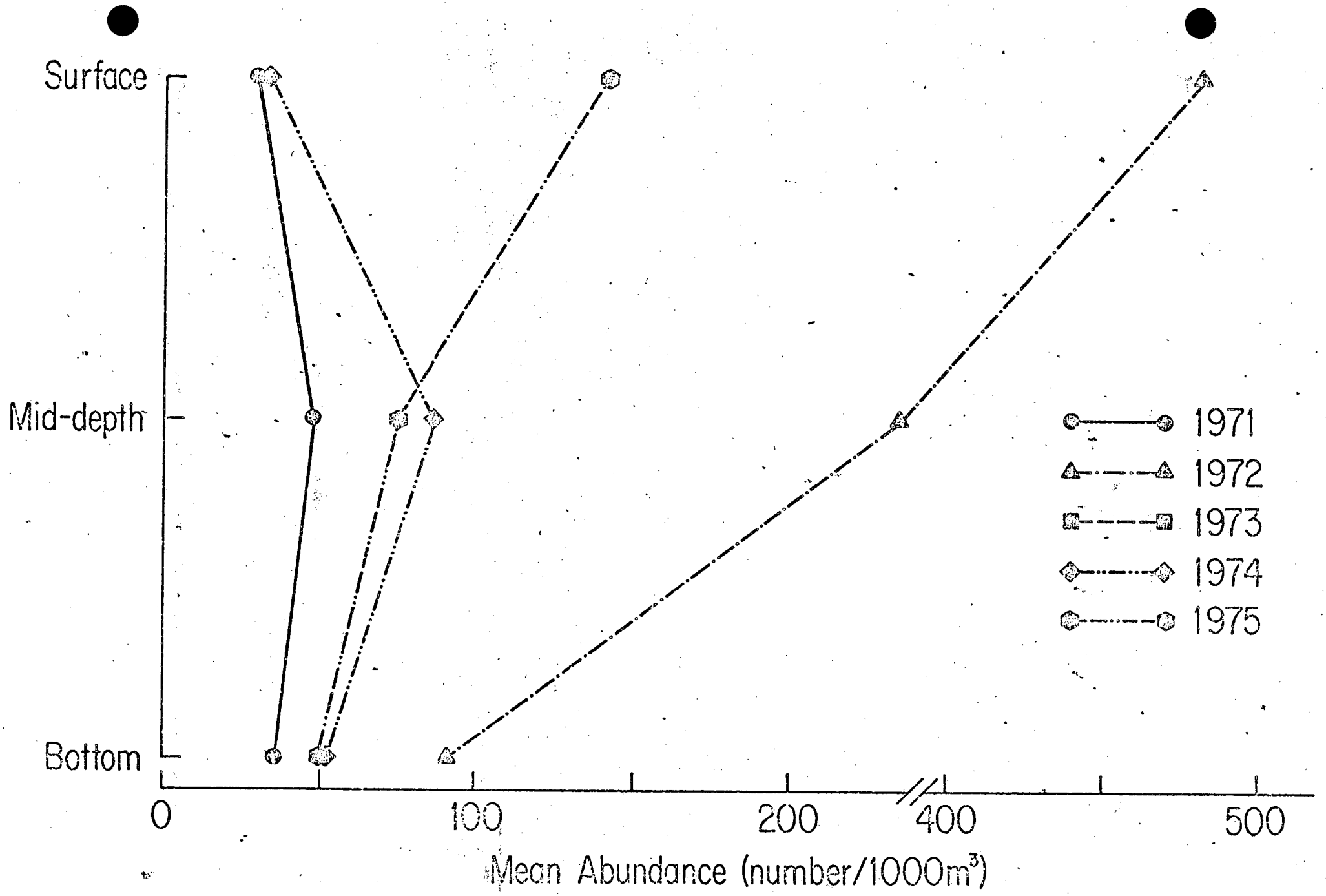

Figure 7-22. Daytime pattern of vertical distribution for clupeid larvae collected in river tows from 1971 to 1975.

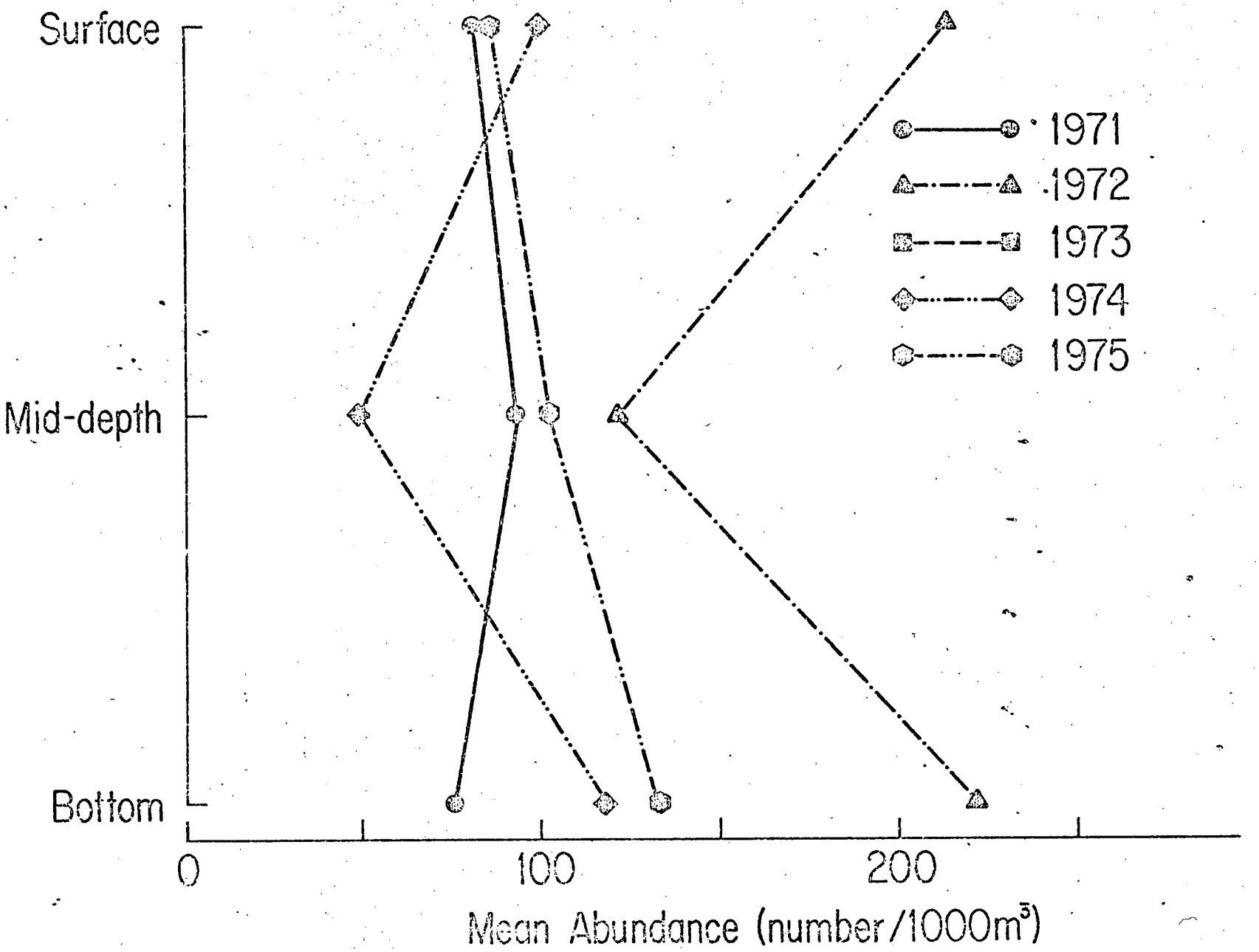

Figure 7-23. Nighttime pattern of vertical distribution for clupeid larvae collected in river tows from 1971 to 1975.

species are included within the grouping of cluepids (Alosa pseudoharengus, A. aestivalis and A. sapidissima). Thus, the vertical distribution of clupeids in the water column during a particular year may be dependent upon the species composition for that year.

Anchovy eggs and yolk-sac larvae were more abundant near the bottom than at the surface during the day and night for 1974 and 1975 (Figures 7-24 through 7-26). There are no egg or yolk-sac larval data for the years prior to 1974 to make further comparisons.

The depth profiles for anchovy larvae are shown in Figures 7-27 and 7-28. It appears that, at times, the larvae were distributed uniformly throughout the water column (1974), but a comparison of data from 1971 to 1975 indicates a general preference of anchovy larvae for the lower strata of the river.

Differences in striped bass abundance at the seven river stations were examined by analysis of variance (ANOVA); separate analyses were done for day and night samples and for each life stage. The factors included in these ANOVA's are station (seven levels; A-G), depth (three levels, surface, middle, and bottom) and date (changed with appearance in the river of a particular life stage). Depth is considered nested within stations and date is crossed with stations (Tables 7-4 through 7-15). Whenever the ANOVA resulted in a significant difference among stations or

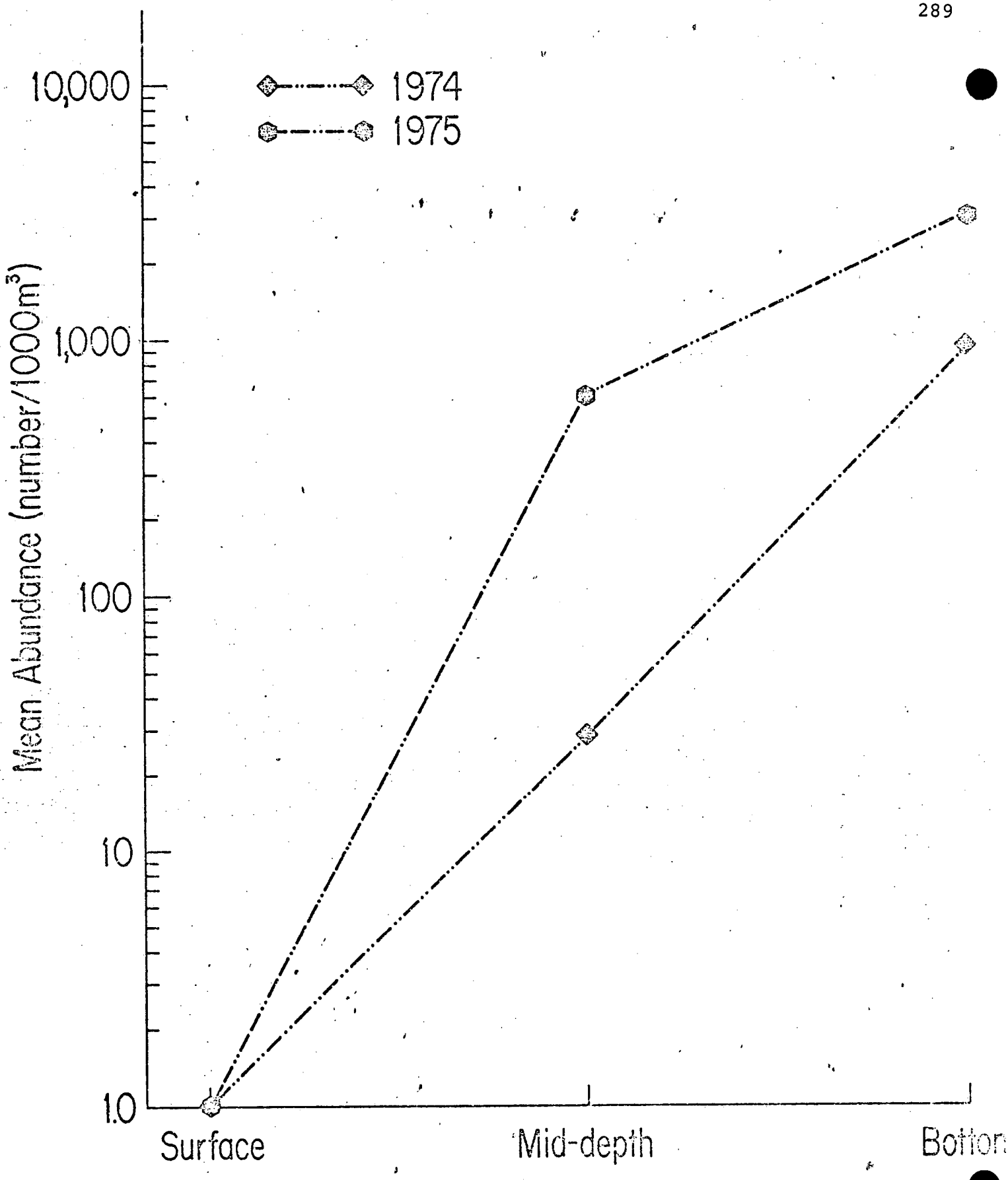

Figure 7-24. Daytime pattern of vertical distribution for anchovy eggs collected in river tows from 1971 to 1975.

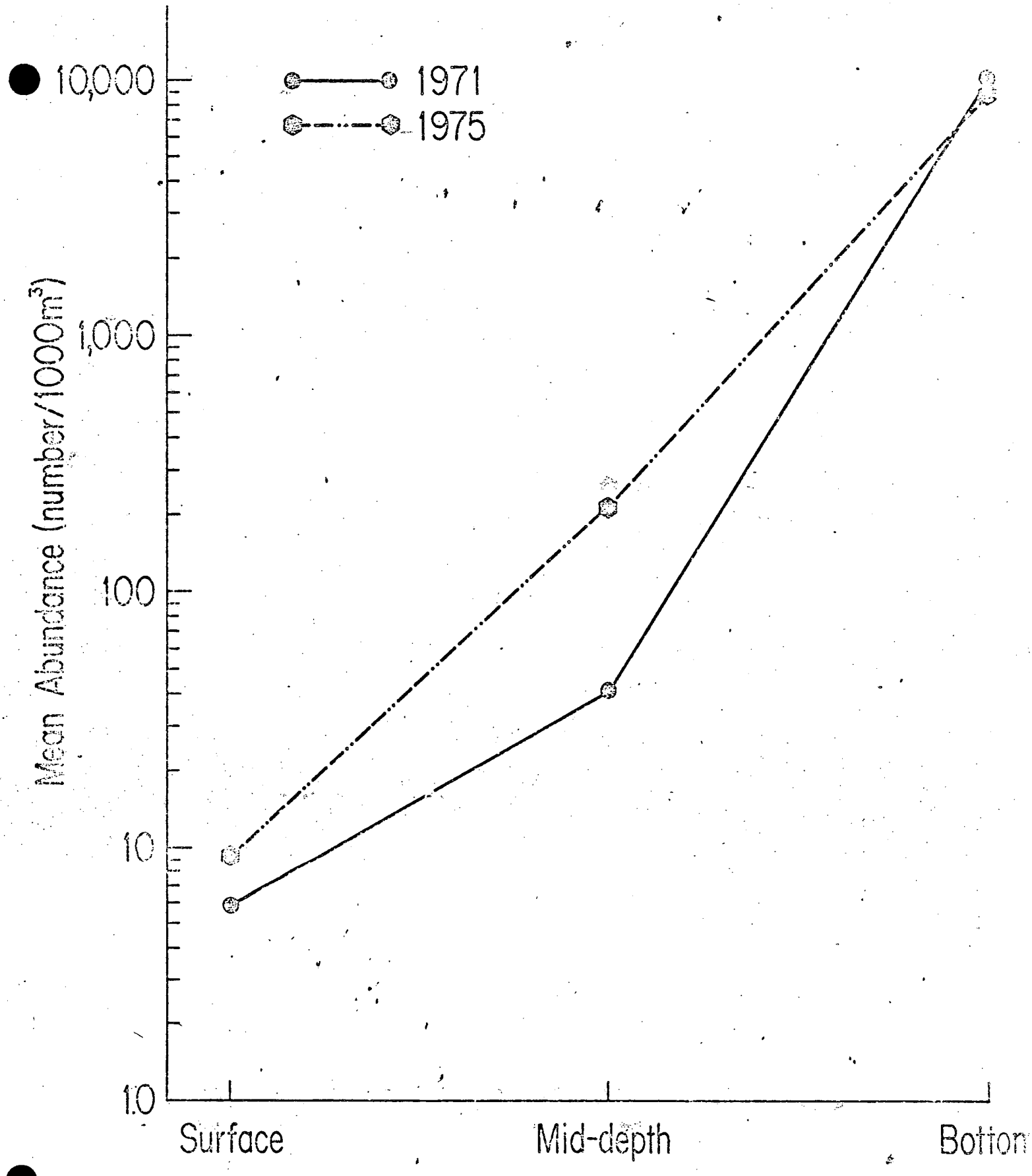

Figure 7-25. Nighttime pattern of vertical distribution for anchovy eggs collected in river tows from 1971 to 1975.

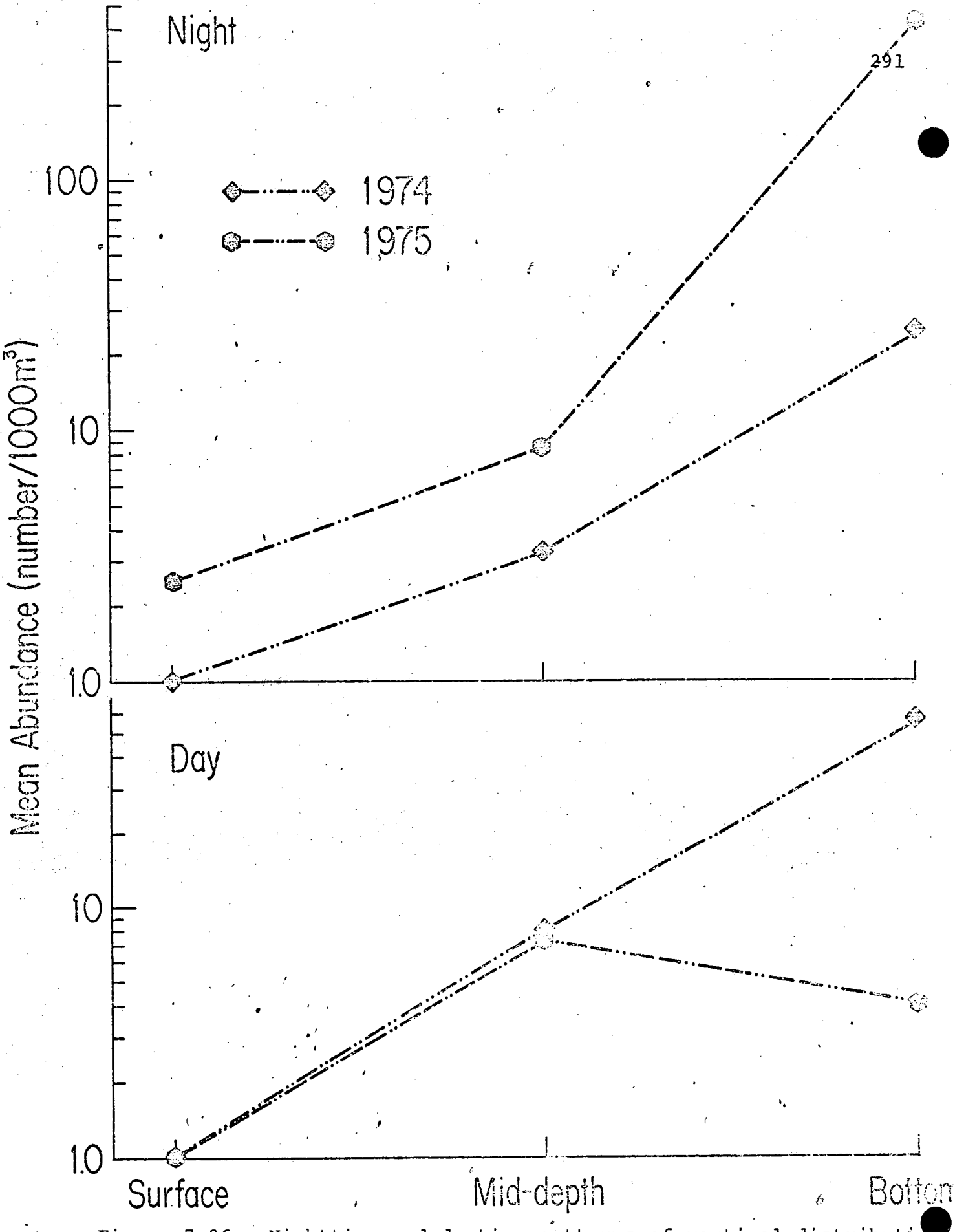

Figure 7-26. Nighttime and daytime patterns of vertical distribution for anchovy yolk-sac larvae collected in river tows from 1974 and 1975.

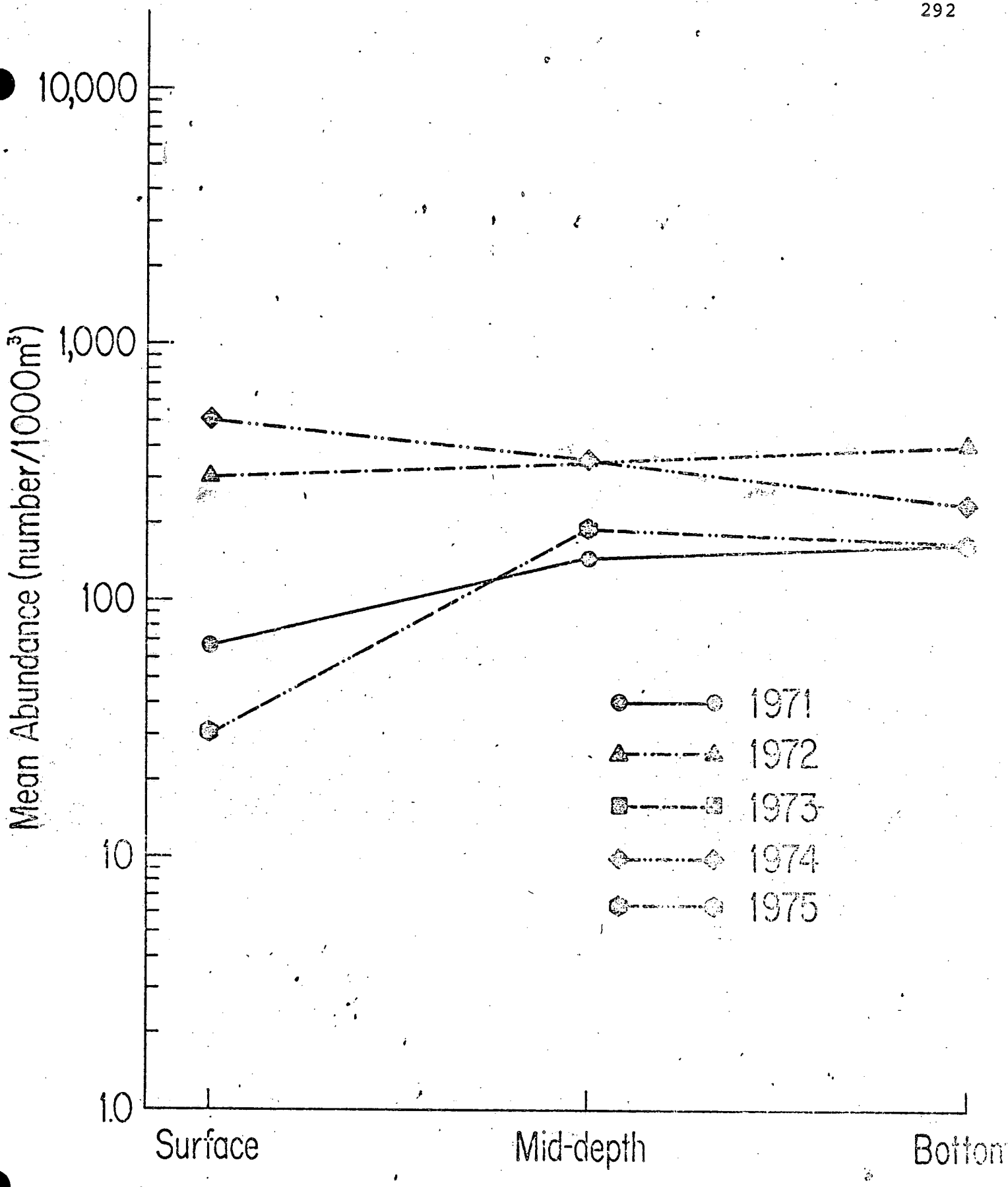

Figure 7-27. Daytime pattern of vertical distribution for anchovy larvae collected in river tows from 1971 to 1975.

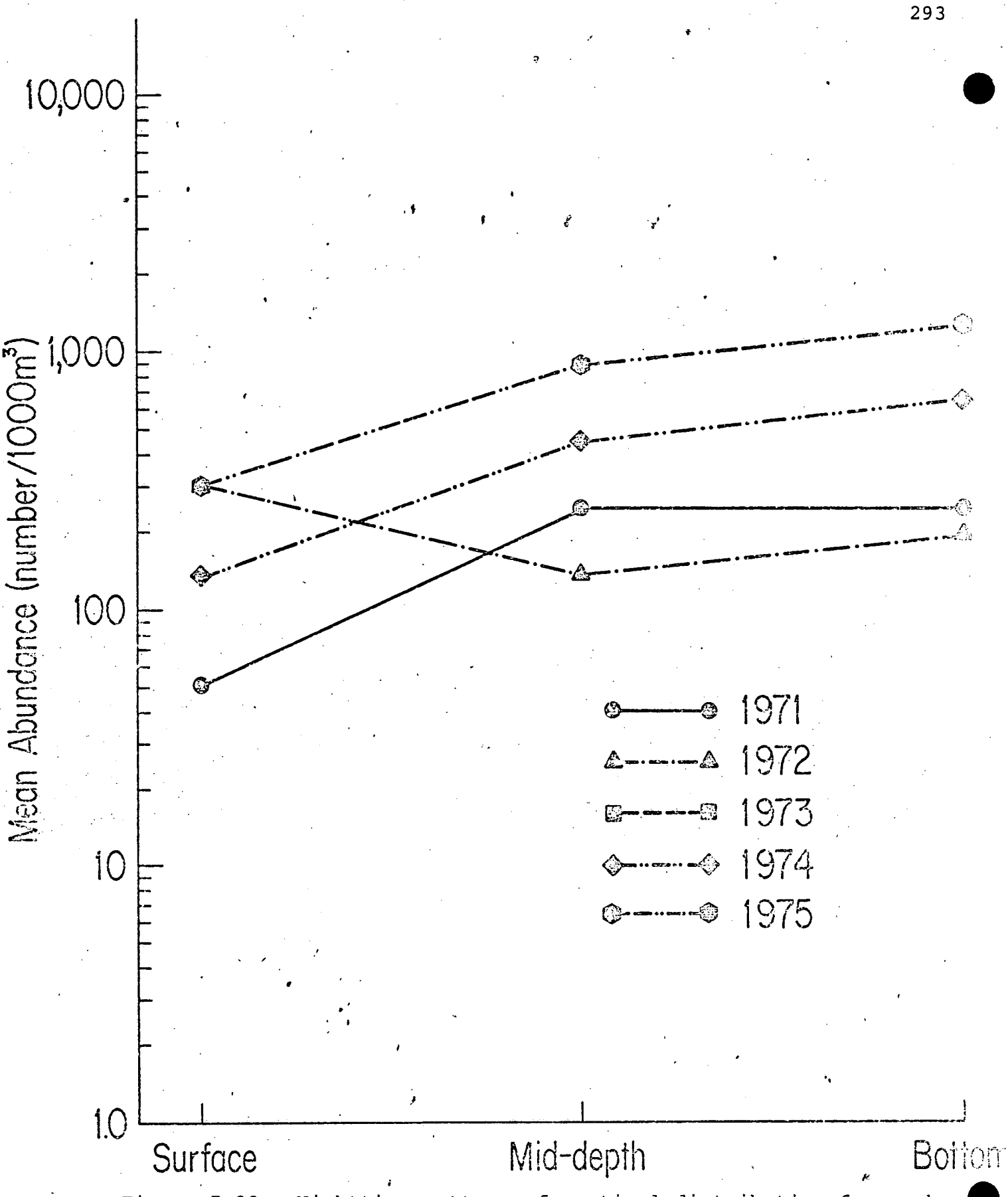

Figure 7-28. Nighttime pattern of vertical distribution for anchovy larvae collected in river tows from 1971 to 1975.

Table 7-4. Day and night striped bass abundance in the Hudson River by station, 1975. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n=number of samples).

	Stations						
Collections	A	B	C	D	E	F	G
Day							
Eggs 5/12-6/16	95±46 n=18	9±46 n=18	72±46 n=18	31±46 n=18	33±46 n=18	8±46 n=18	10±47 n=17
Yolk-sac larvae 5/19-6/23	179±171 n=18	140±171 n=18	351±171 n=18	59±171 n=18	83±171 n=18	80±171 n=18	12±171 n=17
Larvae 5/30-7/7	282±216 n=21	304±216 n=21	294±216 n=21	80±216 n=21	295±216 n=21	196±216 n=21	20±222 n=20
Night							
Eggs 5/13-5/27	121±148 n=9	19±148 n=9	75±148 n=9	26±148 n=9	207±148 n=9	80±148 n=9	39±148 n=9
Yolk-sac larvae 5/13-6/24	92±66 n=20	61±64 n=21	18±64 n=21	98±64 n=21	33±64 n=21	44±64 n=21	54±64 n=21
Larvae 5/27-7/1	515±321 n=16	552±300 n=18	300±300 n=18	635±300 n=18	413±300 n=18	398±300 n=18	181±300 n=18

Table 7-5. Day and night striped bass abundance in the Hudson River by depth, 1975. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n=number of samples).

Collections	Surface	Middle	Bottom
Day			
Eggs 5/12-6/16	1±29 n=42	60±29 n=42	51±29 n=41
Yolk-sac larvae 5/19-6/23	2±107 n=42	64±107 n=42	329±107 n=41
Larvae 5/30-7/7	1±136 n=49	265±136 n=49	371±136 n=48
Night			
Eggs 5/13-5/27	4±88 n=21	55±88 n=21	184±88 n=21
Yolk-sac larvae 5/13-6/24	5±41 n=48	78±41 n=49	87±41 n=49
Larvae 5/27-7/1	214±190 n=41	524±190 n=41	526±188 n42

Table 7-6. Differences in striped bass river abundance among stations in $\log_{10}$ (catch/m^3 + 1).

Collections	Day	Night
Eggs	none*	none
Yolk-sac larvae	none	none
Larvae	none	none

* ANOVA indicated a station difference but Scheffé test did not.

Table 7-7 . Differences in striped bass river abundance among depths in $\log_{10}$ (catch/m^3 + 1).

Life Stage	Day	Night
Eggs	none	none
Yolk-sac larvae	B>S,B>M	none
Larvae	B>S,M>S	none

Table 7-8. Day abundance of striped bass in the vicinity of Indian Point, 1975. Data are mean numbers collected per $1000m^3$ with 95% confidence intervals. (C.I. = confidence intervals; n = number of samples).

	Mean	C.I.	n
Eggs 5/12-6/16	37	±67	125
Yolk-sac larvae 5/19-6/23	130	±61	125
Larvae 5/30-7/7	211	±77	146

Table 7-9. Night abundance of striped bass in the vicinity of Indian Point, 1975. Data are mean numbers collected per $1000m^3$ with 95% confidence intervals. (C.I. = confidence intervals; n = number of samples).

	Mean	C.I.	n
Eggs 5/13-5/27	81	±49	63
Yolk-sac larvae 5/13-6/24	57	±23	146
Larvae 5/27-7/1	422	±107	124

Table 7-10. Analysis of variance for striped bass eggs collected during the day in the river in 1975. (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F= F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
A	6	.0134	.0022	2.3752*
B/A	14	.0188	.0013	1.4302
D	5	.0431	.0086	9.1849*
A X C	30	.0760	.0025	2.7008*
Error	69	.0647	.0009	
Total	124	.2160		

Table 7-11. Analysis of variance for striped bass eggs collected during the night in the river in 1975. (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
A	6	.0204	.0034	1.1109
B/A	14	.0658	.0047	1.5350
C	2	.1066	.0083	2.7044
A X C	12	.0623	.0052	1.6941
Error	28	.0858	.0031	
Total	62	.2509		

Table 7-12. Analysis of variance for striped bass yolk-sac larvae collected during the day in the river in 1975. (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterick (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
A	6	.0508	.0085	1.0688
B/A	14	.2486	.0178	2.2435*
C	5	.2926	.0585	7.3940*
A X C	30	.1270	.0042	.5350
Error	69	.5462	.0079	
Total	124	1.2652		

Table 7-13. Analysis of variance for striped bass yolk-sac larvae collected during the night in the river in 1975. (A = stations; B = depth; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, α <0.05, for the test).

Source	DF	SS	MS	F
A	6	.0106	.0018	.9473
B/A	14	.0468	.0033	1.7632
C	6	.1014	.0169	8.9158*
A X C	36	.0699	.0019	1.0247
Error	83	.1574	.0019	
Total	145	.3863		

Table 7-14. Analysis of variance for striped bass larvae collected during the day in the river in 1975. (A = Stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
A	6	.1057	.0176	1.5157
B/A	14	.3528	.0252	2.1681*
C	6	.5784	.0964	8.2935*
A X C	36	.2667	.0074	.6374
Error	83	.9648	.0116	
Total	145	2.2685		

Table 7-15. Analysis of variance for striped bass larvae collected during the night in the river in 1975. (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
A	6	.1005	.0167	1.7902
B/A	14	.1615	.0115	1.2327
C	5	2.6357	.5271	56.3462*
A X C	30	.1787	.0060	.6366
Error	68	.6362	.0094	
Total	123	3.7125		

depth, a Scheffé test ($\alpha \leq 0.10$) was done to find the difference.

Except in one case (nighttime abundance of eggs), there were significant differences in abundance among dates for the daytime and nighttime analysis of eggs, yolk-sac larvae, and larvae (Tables 7-10 through 7-15). Abundance differences at the various stations were detected by ANOVA only in one instance; daytime abundance of eggs. However, a Scheffé test did not reveal a significant difference (Tables 7-4 and 7-6). Therefore one might assume, as in 1974, that there was no significant differences in abundance at the various river stations. Significant differences with depth were found in two instances. Daytime abundances of yolk-sac larvae were greater in the bottom samples than either the surface or mid samples. Daytime larvae abundance in mid and bottom samples was greater than for surface samples (Tables 7-5 and 7-7). The one instance of significant station/date interaction (daytime egg abundance) was probably not real because, as stated previously, the ANOVA in this instance showed a station effect but the Scheffé test did not.

ANOVA was not applied to the abundances of juveniles because insufficient numbers were caught.

Observed differences in abundance among dates for the different life stages of striped bass are not unexpected for the same reasons mentioned in 1974 (New York University Medical Center, 1976a).

The dates included in the daytime analysis of eggs are from May 12 to June 16, for yolk-sac larvae from May 19 to June 23; for larvae from May 30 to July 7. The dates included in the nighttime analysis of eggs are from May 13 to May 27; for yolk-sac larvae, from May 13 to June 24 and for larvae from May 27 to July 1.

As in 1974 a "t" test (Natrella, 1963) was carried out to test for differences between mean day and mean night abundances for each life stage. Variance was assumed to be unequal. The results are shown in Table 7-16. As in 1974 (New York University Medical Center, 1976a) larval abundance was greater at night than during the day (Tables 7-14 and 7-15). This difference may be the result of daytime net avoidance by larvae and juvenile fish, or to diel migration.

Table 7-16. Differences in striped bass river abundance in $\log_{10}$ (catch/m^3 + 1) between day and night samples, 1975.

Eggs	none
Yolk-sac larvae	none
Larvae	night>day

7.2 ENTRAINMENT EFFECTS STUDIES

The overall objective of the ichthyoplankton entrainment studies was to determine how these organisms are affected by pumped entrainment through the Indian Point plant. This determination was made by comparing the viability, or condition, of organisms sampled in the discharge canal with the condition of those collected at the intake sampling stations, which served as controls.

7.2.1 Viability Assessments

The experiment was designed to evaluate differences in latent mortality of striped bass sampled from the intake and discharge stations at Indian Point in 1975 and to compare latent effects among study years (1973 through 1975). It is essential to note that the data from 1973 were obtained primarily from Unit 1 which was operating without a ΔT. 1974 data were from Units 1 and 2; 1975 data are from Unit 2 only.

7.2.1.1 Methods

Alive striped bass were collected (May 13-July 15) from intake and discharge samples using the procedures described in Section 7.2 of the 1974 Progress Report (New York University Medical Center, 1976a). The fish were identified immediately in samples and classified as alive or stunned. They were then placed in aerated 100 mℓ jars labelled as to station,

depth, date and time of sample, and placed in an ambient-temperature water bath. Dead organisms were removed from the jars when they appeared. The experiment was terminated after 72 hours and all remaining specimens were preserved for later examination.

7.2.1.2 Results

A total of 603 live striped bass eggs were collected in 1975 from intake stations II-2 and II-5 and from the Indian Point discharge canal (Table 7-17 and 7-18). One-hundred-sixty five eggs hatched successfully. The success of hatching was equal ($\sim$ 27%) for total numbers of eggs collected from the intakes and discharges (Table 7-19). Differences in hatching success occurred between the two intake stations. Eggs collected at station II-2 had a hatching success of 20.7%, while eggs collected from station II-5 had a hatching success of 42.3%.

In the 72-h following collection, the survival of striped bass eggs taken at II-5 was less than for those taken at II-2 (Figure 7-29). Survival was similar between sample groups during the first 24-h. Significant differences did exist between II-2 and II-5 after 48 and 72-h.

Egg survival in samples taken at intake and discharge stations was compared independently for stations II-2 vs. discharge and station II-5 vs. discharge ($\alpha = 0.05$; Table 7-20). In neither case was there any difference in survival

Table 7-17. Initial abundance of live, stunned and dead striped bass eggs, yolk-sac larvae, larvae and juveniles collected during plant entrainment sampling in 1975. (II-2, II-5 = Intake, D-1, D-2 = Discharge-canal stations, DP3 = Discharge port station).

	Alive	Stunned	Dead	Total
Eggs				
II-2	168		188	356
II-5	368		391	759
D-1	40		91	131
D-2	23		119	142
DP3	4		28	32
Total	603		817	1420
Yolk-sac larvae				
II-2	9	4	28	41
II-5	8	2	59	69
D-1	0	0	14	14
D-2	0	0	10	10
DP3	0	0	9	9
Total	17	6	120	143
Larvae				
II-2	277	64	153	494
II-5	361	95	440	896
D-1	106	16	255	377
D-2	5	4	53	62
DP3	0	2	27	29
Total	749	181	928	1858
Juveniles				
II-2	5	0	5	10
II-5	9	0	4	13
D-1	0	0	5	5
D-2	2	0	2	4
DP3	1	0	0	1
Total	17	0	16	33

Table 7-18. Initial viability of striped bass with 95% confidence intervals. Data are mean percentages for sampling stations (II-2, II-5 = Unit 2 Intakes; D-1, D-2 = discharge-canal samples; n = number of samples with the depths pooled).

Life stage and station	% Alive	% Stunned	% Dead	n
Eggs				
II-2	34.7±14.2	---	66.3±14.2	19
II-5	39.3±11.7	---	60.7±11.7	24
D-1	25.8±15.0	---	74.2±15.0	10
D-2	19.7±14.4	---	80.3±14.4	17
Yolk-sac Larvae				
II-2	21.8±18.7	12.5±13.6	65.7±22.8	18
II-5	11.1± 2.9	6.2±11.7	82.7±16.2	18
D-1	0±0	0±0	100±0	9
D-2	0±0	0±0	100±0	5
Larvae				
II-2	58.9±15.2	16.4± 9.6	24.7±12.8	19
II-5	33.5±10.7	14.4± 6.9	52.1±13.8	23
D-1	17.5± 8.7	11.6±12.2	70.9±12.4	19
D-2	2.8± 7.0	5.3± 8.4	91.8±14.2	7

Table 7-19. Number and percentage of Striped bass eggs hatching from total of live eggs collected at Indian Point plant.

Station	Total live eggs collected	Total eggs hatched	Percentage of egg hatched
Intake	536	147	27.4
Discharge	67	18	26.9
Intake (II-2)	168	71	42.3
Intake (II-5)	368	76	20.7

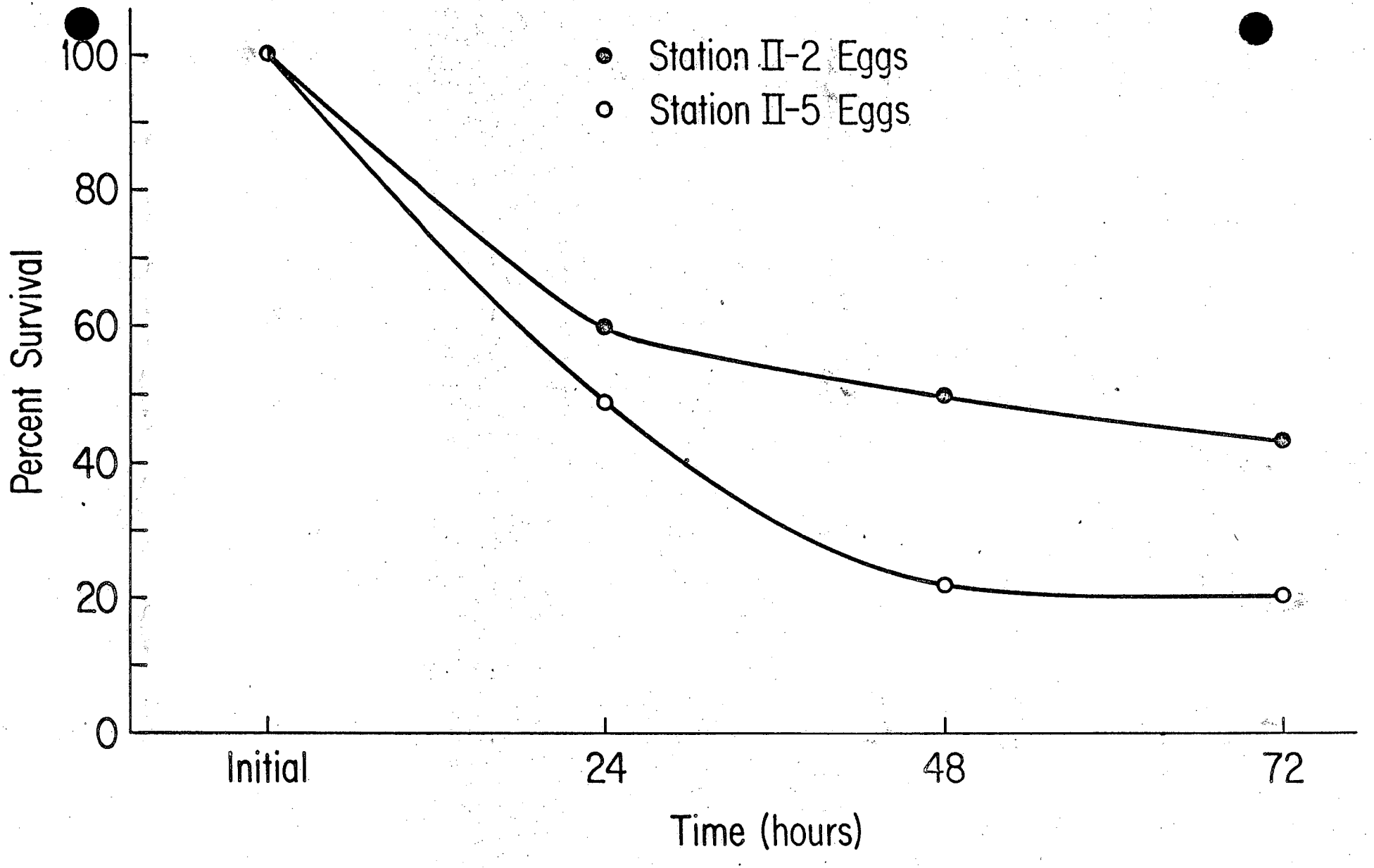

Figure 7-29. Survival curves for live striped bass eggs collected from two Indian Point intake stations in 1975 and held for 72 hours at ambient river temperature.

Table 7-20. Comparisons of the initial viability of striped bass samples collected during plant entrainment, 1975. The station means being compared are expressed within brackets between the upper and the lower limits of the confidence interval for each comparison at 95% confidence interval (II-2, II-5 = Unit 2 intakes; D-1, D-2 = discharge-canal stations).

Comparison	Difference
Eggs, percent alive[1]	
{II-2 - II-5}	4.4±21.9
{(II-2, II-5) - D-1}	11.5±19.2
{(II-2, II-5) - D-2}	17.6±16.3
{II-2 - D-1}	8.9±21.6
{II-5 - D-1}	13.5±19.9
{II-2 - D-2}	15.0±19.7
{II-5 - D-2}	19.6±17.9
{ D-1 - D-2}	6.1±21.1

[1] The percent dead is the reciprocal of the alive table shown.

Table 7-20 (cont.).

Comparison	Difference
Yolk-sac larvae, percent alive	
{II-2 - II-5}	10.7±21.9
{(II-2, II-5) - D-1}	16.4±21.9
{(II-2, II-5) - D-2}	16.4±29.7
{II-2 - D-1}	21.8±26.1
{II-5 - D-1}	11.1±17.8
{II-2 - D-2}	21.8±26.3
{II-5 - D-2}	11.1±24.3
Yolk-sac larvae, percent stunned	
{II-2 - II-5}	6.3±17.4
{(II-2, II-5) - D-1}	9.4±17.3
{(II-2, II-5) - D-2}	9.4±23.5
{II-2 - D-1}	12.5±19.0
{II-5 - D-1}	6.2±17.4
{II-2 - D-2}	12.5±26.0
{II-5 - D-2}	6.2±22.3
{ D-1 - D-2}	0±0
Yolk-sac larvae, percent dead	
{II-2 - II-5}	16.9±27.1
{II-2, II-5) - D-1}	25.8±27.3
{II-2, II-5) - D-2}	25.8±37.1
{II-2 - D-2}	34.3±31.8
{II-5 - D-1}	17.3±22.7
{II-2 - D-2}	34.3±43.4
{II-5 - D-2}	17.3±30.9
{ D-1 - D-2}	0±0

Table 7-20 (cont.).

Comparison	Difference
Larvae, percent alive	
{II-2 - II-5}	25.4±17.5
{(II-2, II-5) - D-1}	27.5±15.2
{(II-2, II-5) - D-2}	42.1±23.5
{II-2 - D-1}	41.4±16.9
{II-5 - D-1}	16.0±13.7
{II-2 - D-2}	56.0±25.0
{II-5 - D-2}	30.7±19.6
{ D-1 - D-2}	14.6±14.6
Larvae, percent stunned	
{II-2 - II-5}	2.0±11.2
{(II-2, II-5) - D-1}	3.7±11.4
{(II-2, II-5) - D-2}	10.0±13.9
{II-2 - D-1}	4.8±15.1
{II-5 - D-1}	2.8±13.0
{II-2 - D-2}	11.1±16.3
{II-5 - D-2}	9.1±13.1
{ D-1 - D-2}	1.0±11.6
Larvae, percent dead	
{II-2 - II-5}	28.7±18.5
{(II-2, II-5) - D-1}	30.3±17.0
{(II-2, II-5) - D-2}	52.2±25.3
{II-2 - D-1}	46.3±17.3
{II-5 - D-1}	18.9±18.3
{II-2 - D-2}	67.2±22.0
{II-5 - D-2}	39.8±25.7
{ D-1 - D-2}	20.9±21.6

among eggs from intake and discharge stations (Table 7-21). The 72-h survival of eggs in intake and discharge samples is presented (for combined intake samples vs. discharge samples) in Figure 7-30.

Only 17 live yolk-sac larvae were collected at Indian Point in 1975; all were from intake samples (Tables 7-17 and 7-18). No yolk-sac larvae were captured which were classified as "stunned". Eight (47.1%) survived the 72-h holding period (Table 7-22).

Of the 749 live larvae sampled in 1975, 85% (638) were collected in intake samples and 15% in discharge samples. Eighty-eight percent of all stunned larvae were from intake samples, and 10% from the discharge (Tables 7-17 and 7-18). The 72-h survival of larvae initially classified as alive exceeded 40% for both groups (Table 7-22). Among stunned larvae, maximum survival was less than 5% in intake samples and 0 for organisms collected in the discharge (Table 7-22).

The time course of survival among samples of alive and stunned larvae was similar, even though the final values differed. In both cases (Figures 7-31 and 7-32) the greatest decrease in survival occurred in the first 24-h ($\sim$ 45% among larvae classified as alive and from 82% to 100% among larvae classified as stunned). Between 24-h and 72-h the remaining larvae suffered little mortality. Among larvae initially classified as alive the survival of organisms from intake and discharge samples was similar after 72-h (Table 7-22).

Table 7-21. Significant differences in initial survival for three life stages of striped bass among Indian Point plant samples (II-2, II-5 = Unit 2 intake samples; D-1, D-2 = discharge-canal samples.) Using an a posteriori Wilcoxon two sample test.

Life stage	Live	Stunned	Dead
Eggs	None	---	---
Yolk sac Larvae	None	II-2 > D-1** II-2 > D-2** II-5 > D-1** II-5 > D-1**	None
Larvae	II-2 > II-5** II-2 > D-1** II-2 > D-2** II-5 > D-1* II-5 > D-2**	None	II-2 < II-5** II-2 < D-1** II-2 < D-2** II-5 < D-2**

* P<0.05
** P<0.01

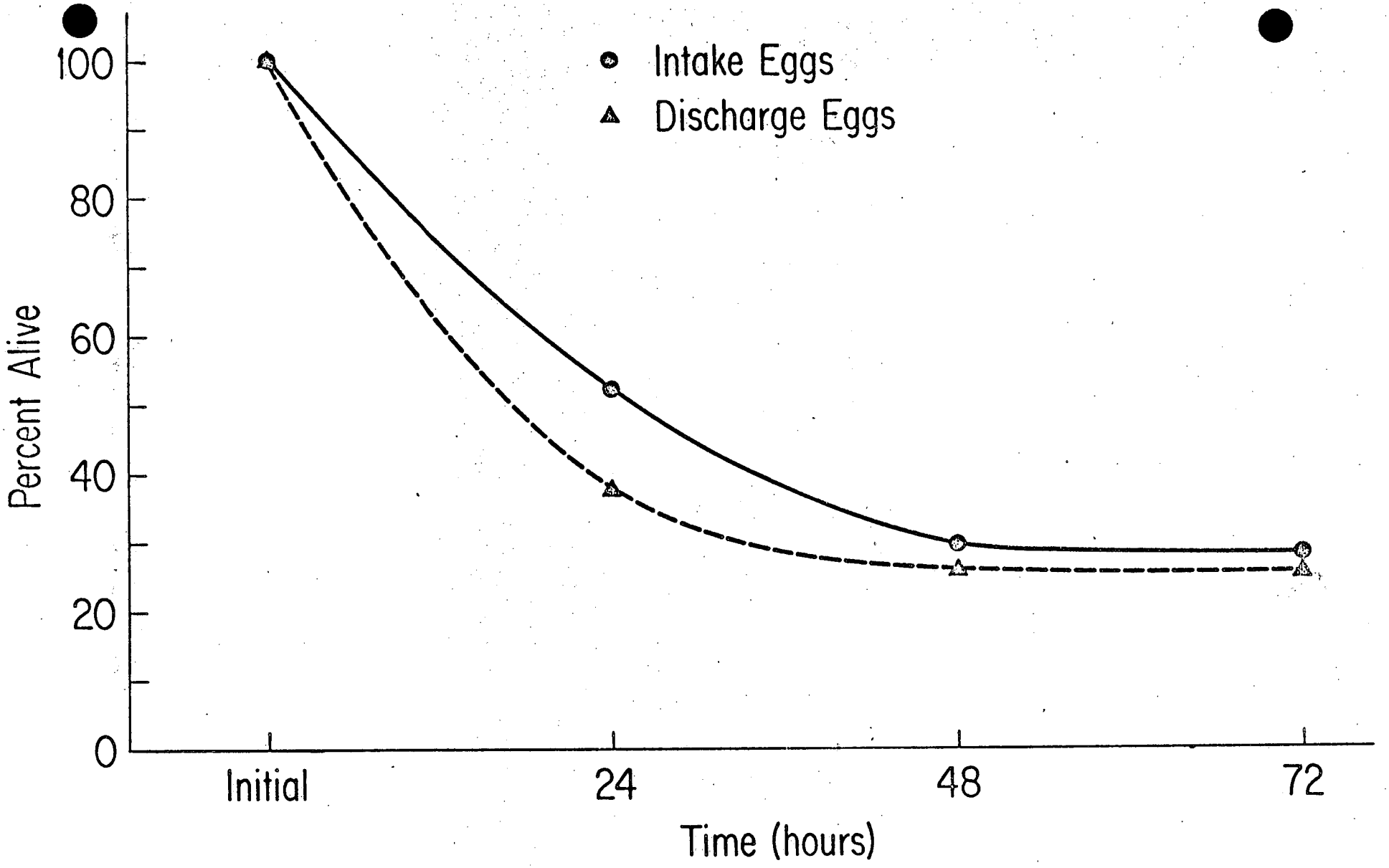

Figure 7-30. Survival curves for live striped bass eggs collected at Indian Point intake and discharge stations in 1975 and held for 72 hours at ambient river temperature.

Table 7-22. Survival of Entrained Striped Bass Yolk-sac larvae, Larvae, and Juveniles after a 3-day holding period.

Life Stage	Source	Initial Condition	Initial N	Number Surviving	% Survival
Yolk-sac L.	Intake	Alive	17	8	47.1
Yolk-sac L.	Discharge	Alive	0	0	0.0
Larvae	Intake	Alive	638	324	50.8
Larvae	Discharge	Alive	111	47	42.2
Larvae	Intake	Stunned	159	7	4.4
Larvae	Discharge	Stunned	22	0	0.0
Juveniles	Intake	Alive	14	13	92.9
Juveniles	Discharge	Alive	3	1	33.3

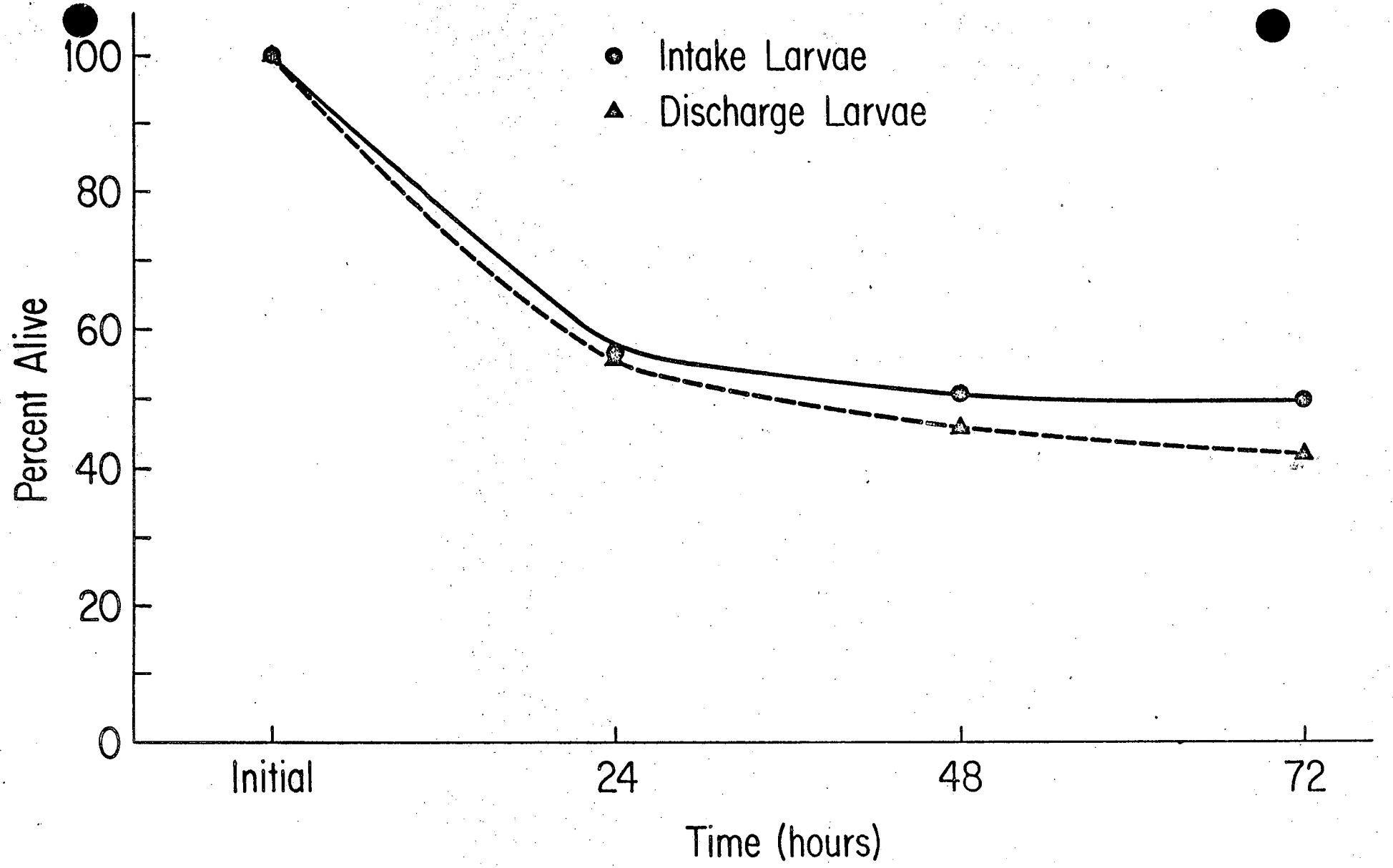

Figure 7-31. Survival curves for live striped bass larvae collected at Indian Point intake and discharge stations in 1975 and held for 72 hours at ambient river temperature.

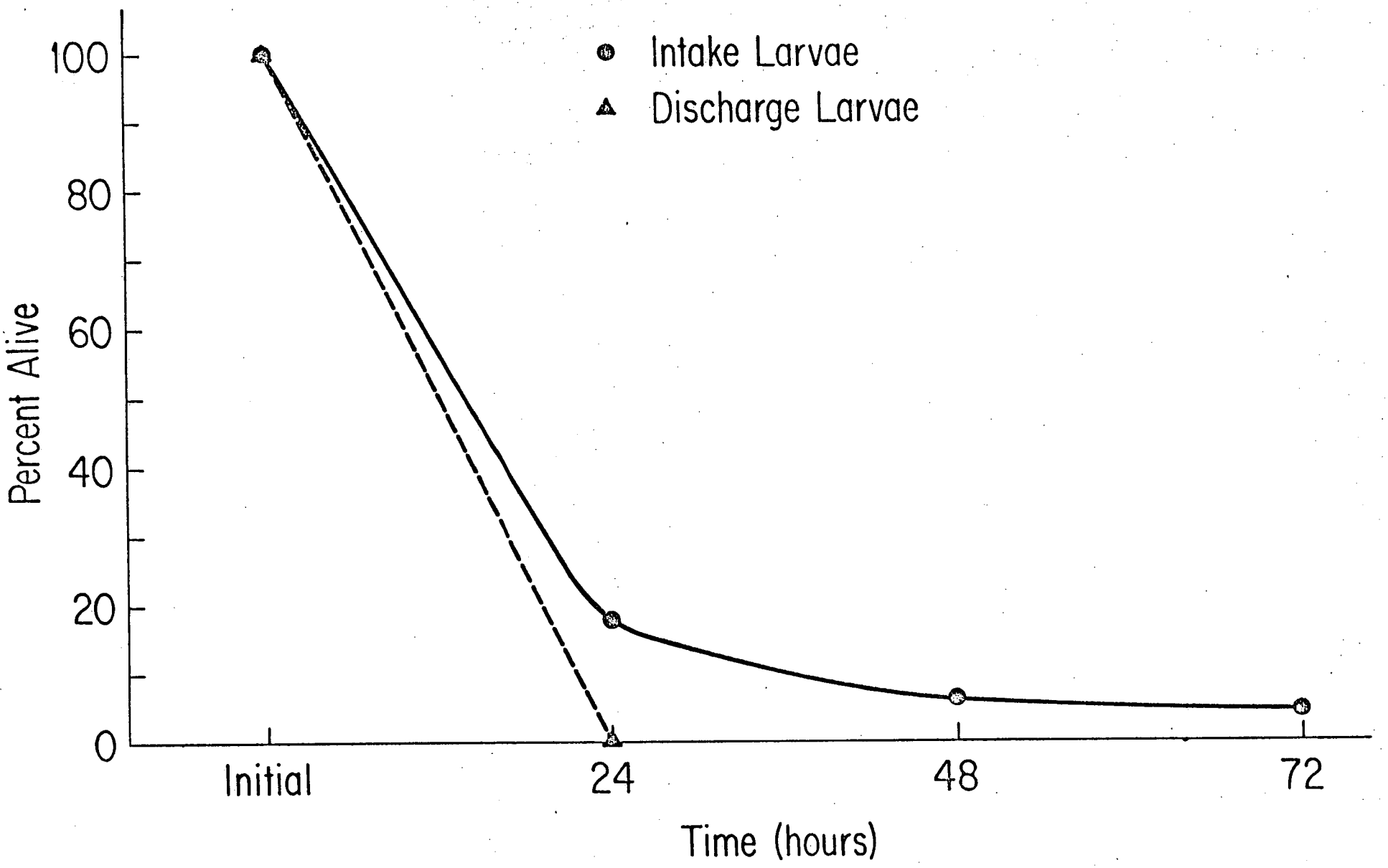

Figure 7-32. Survival curves for stunned striped bass larvae collected at Indian Point intake and discharge stations in 1975 and held for 72 hours at ambient river temperature.

7.2.1.3 Discussion

The pattern of survival among alive and stunned eggs, yolk-sac larvae and larvae in 1975 was similar to the patterns determined in 1973 (New York University Medical Center, 1974) and 1974 (New York University Medical Center, 1976a) in that the majority of mortality occurred during the first 24-h of the holding period. Substantial differences exist among years, however, with regard to overall latent survival data. In general, it is felt that these differences reflect uncontrollable differences in technique among years rather than any differences ascribable to year-to-year differences in plant effect, or year-to-year differences in the hardiness of Hudson River striped bass eggs, yolk-sac larvae and larvae.

Egg survival decreased substantially between 1974 and 1975 (Table 7-23). However, live egg abundance doubled in 1975 as compared to 1974, and the majority of the live eggs were collected in 3 to 4 hours of a single sampling date (May, 1975). Attempts to derive as much information as possible from these collections probably resulted in greater-than-optimum concentrations of eggs in the holding jars, and induced mortality may have been caused either by high O_2 consumption, or by excessive crowding of the eggs. Anticipating the recurrence of this phenomenon, provisions have been made for greater flexibility in holding facilities during the 1976 "egg season."

Table 7-23. Survival of Entrained Striped bass eggs and larvae at the 3 day holding period from 1973-75.

Life-stage	Source	Condition	% Survival 1973	1974	1975
Eggs	Intake	Alive	--	63.9	27.4
Eggs	Discharge	Alive	--	47.5	26.9
Larvae	Intake	Alive	27.2	34.8	50.8
Larvae	Discharge	Alive	36.1	47.8	42.2
Larvae	Intake	Stunned	9.8	4.2	4.4
Larvae	Discharge	Stunned	6.1	2.5	0.0

The survival of larvae initially classified as "alive" has increased since 1973 (Table 7-22). This is probably due as much to gradual improvement of technique among years as to any plant-related factor. The greatest overall increase has been among organisms taken from intake samples. Overall survival of live larvae taken from discharge samples is similar among the years.

A major difficulty in obtaining adequate data on plant-related mortality and the latent effects of plant passage on ichthyoplankton has been an insufficient understanding of the extent to which sampling gear may affect the organisms being sampled. O'Connor and Schaffer (1977 in press; see also New York University Medical Center, 1976c) tested the effects of sampling gear on striped bass eggs, yolk-sac larvae and larvae at different velocities. They demonstrated among 14-day old larvae that the velocity at collection time had a strong influence on 72-h latent mortality. Collections made at 0.5 fps showed 24-h survival about 40% less than control groups. Organisms of the same age collected in nets at 1.5 fps had survival at 24-h reduced by approximately 75% in comparison to controls. These data coincide rather closely with 24-h survival values of larvae observed in 1975, even though net approach velocities for the 1975 conditions could only be approximated at 0.5-0.7 fps at the intake and 0.9-1.7 fps in the discharge canal.

It may be concluded, therefore, that striped bass ichthyoplankton which survive plant passage (alive or stunned) will experience substantial mortality (ranging from 50% to 100%) over the 72-h following plant passage. However, based upon available experimental data a substantial portion of the latent effect may be induced by sampling gear (New York University Medical Center, 1976c). If all other conditions were equal, then one would be permitted, depending upon known water velocities, to increase latent survival values by some defined value which would reduce substantially the measured latent effects of plant passage on striped bass ichthyoplankton.

7.2.2 Plant Abundance

7.2.2.1 Methods

The abundance of ichthyoplankton in the intakes and discharge canal of the Indian Point facility was determined by weekly sampling from May through July 13. Sampling prior to May and after July 14 was done once-per-month. Samples were taken using 0.5-m plankton nets with a 571 μ-mesh in the net and cod-end bucket.

Abundance determinations were made from the same samples used to estimate ichthyoplankton viability and latent mortality effects. The use of velocity-reduction cones on the sampling nets and sampling for short durations, both intended to minimize the trauma associated with net-collections, precluded the use of flowmeters to determine the volumes of water filtered. The volume filtered at the intake and discharge stations was calculated from cone-opening diameter, pumping rates of circulators and service water pumps, numbers of circulators operating and tidal height at the time of sampling (New York University Medical Center, 1976a; see Table 7-24).

The inventory of ichthyoplankton species and life-history stages captured at the plant intakes and discharge canal was similar to that documented previously (see section 7.1 of this report). The analyses contained in this section are limited to striped bass.

Table 7-24 . Calculated volumes, in cubic meters of water filtered through sampling nets during 1975 entrainment sampling. Volumes are based upon the percentages of flow produced by circulators and service pumps operational at the time of sampling.

	Unit II Intakes		D-1		D-2		DP-3	
Date	Flow (%)	Volume	Flow (%)	Volume	Flow (%)	Volume	Flow (%)	Volume
4/29	82.8	7.43	61.1	5.49	61.1	5.49	61.1	21.9
5/06	74.3	6.67	54.4	4.88	54.4	4.88	54.4	19.5
5/13	82.2	7.38	72.5	6.51	72.9	6.54	72.9	26.2
5/20	82.6	7.42	60.5	5.43	60.5	5.43	60.5	21.7
5/22	82.8	7.43	61.0	5.48	61.0	5.48	61.0	21.9
5/27	83.3	7.48	61.4	5.51	61.4	5.51	61.4	22.0
6/03	98.7	8.86	72.3	6.49	72.3	6.49	72.3	25.9
6/10	98.9	8.88	72.4	6.50	81.4	7.31	81.4	29.2
6/17	99.3	8.91	72.7	6.53	80.6	7.24	80.6	28.9
6/24	99.4	8.92	72.8	6.54	72.8	6.54	72.8	26.1
7/01	99.4	8.92	73.2	6.57	85.4	7.67	85.4	30.7
7/08	99.4	8.92	73.2	6.57	83.1	7.46	83.1	29.8
7/15	98.9	8.88	74.2	6.66	74.2	6.66	74.2	26.6
8/19	98.9	8.88	72.8	6.54	72.8	6.54	72.8	26.1
9/16	98.9	8.88	72.8	6.54	86.0	7.72	86.0	30.9
10/14	82.8	7.43	62.3	5.59	62.3	5.59	62.3	22.4
11/18	82.8	7.43	62.3	5.59	62.3	5.59	62.3	22.4
12/09	84.7	7.60	63.8	5.73	63.8	5.73	63.8	22.9

The data were tested by analysis of variance (ANOVA) using $\log_{10}$ (catch/m^3 + 1) per sample as the numeric input. The log transform was used to satisfy the major assumption of ANOVA, that the variance of the data was homogeneous. Catch per unit effort (CPUE) analysis was compared to the catch per 1000 m^3 as an estimate of the consistency of volumes sampled. CPUE was time-related, expressed simply as the number of organisms caught per 5-min sampling event. The comparison of results derived from abundance (#/1000 m^3) with CPUE was considered critical as a technique for identifying abnormally high or abnormally low flows which may have occurred and otherwise gone undetected, since flowmeters were not being used. The dates and samples selected for comparison are limited to those dates when all stations involved in the comparison were sampled (e.g., if, on any given sampling date for any given reason, 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). This is not to be confused with missing samples in which only one or two samples are missing from a station for that date. Where significant differences among main effects and/or interactions were detected ($\alpha = 0.05$), an a posteriori test (Scheffés test) was employed ($\alpha = 0.10$) to determine precisely where the difference occurred.

7.2.2.2 Results and Discussion

The abundances (in catch per 1000 m^3 and in catch per unit effort) for the various life history stages of striped bass sampled during the 1975 entrainment studies are shown in Tables 7-25 and 7-26. These were tested to determine differences between the intake stations (II-2 and II-5), the discharge stations (D-1, D-2 and DP) and among the intake and discharge stations; the results are shown in Tables 7-27 to 7-29. Generally, the mean abundance of pre-juvenile stages was greater at II-5 than at II-2, greater at the intakes than at the discharge stations, and greater at D-1 than at D-2 or DP. However, statistical differences were observed only for egg and post-yolk-sac larval stages. With the exception of larval abundance between station II-5 and station D-1, in which analysis by catch/1000m^3 showed no difference and analysis by catch/unit effort showed II-5 to be greater than D-1, densities and catch-effort data yielded similar findings.

The abundance of eggs and yolk-sac larvae in the intake was nearly twice as much as that in the discharge canal (Table 7-30); this is comparable to the results observed in 1974 (New York University Medical Center, 1976a). However, as in 1974, there is no reason to believe that the numbers at the discharge canal were underestimated. As our data showed significant differences between different intakes (II-2 and II-5 in 1975 and between Unit 1 and Unit 2 in

Table 7-25. Abundance of striped bass collected at intake and discharge-canal stations, 1975. Data are mean numbers collected per 1000m^3, with 95% confidence intervals. (n=numbers of samples)

	Unit II intakes		Discharge Canal		
Collections	II-2	II-5	D-1	D-2	DP
Eggs, 5/13-6/3	387±14 n=99	732±13 n=116	277±16 n=82	263±16 n=78	25±23 n=34
Yolk-sac larvae, 5/13-6/3	35± 7 n=99	46± 6 n=116	27± 7 n=82	15± 8 n=78	7±11 n=39
Larvae, 5/13-7/15	75± 7 n=194	198± 6 n=211	135± 7 n=180	55± 7 n=167	14±11 n=69

Table 7-26. Abundance of striped bass collected at intake and discharge canal stations, 1975. Data are catch per unit effort with 95% confidence intervals. (n=numbers of samples)

	Unit II intakes		Discharge Canal		
Collections	II-2	II-5	D-1	D-2	DP
Eggs	3.172±.032 n=99	5.836±.029 n=116	1.610±.035 n=82	1.551±.036 n=78	.615±.052 n=39
Yolk-sac larvae	.303±.029 n=99	.388±.027 n=116	.171±.033 n=82	.103±.034 n=78	.205±.024 n=39
Larvae	.665±.022 n=194	1.768±.021 n=211	.883±.023 n=180	.395±.024 n=167	.420±.037 n=69

Table 7-27. Differences in striped bass night abundance between Unit 2 intakes and the discharge canal in Log_{10}(catch/1000m^3 + 1) and in Log_{10} (catch/unit effort + 1).

	Catch per 1000m^3		Catch per unit effort	
	Intake	Discharge	Intake	Discharge
Eggs, 5/13-6/3	573±10 n=215	270±11 n=160	4.609±.022 n=215	1.581±.025 n=160
Yolk-sac larvae, 5/13-6/3	41± 5 n=215	21± 5 n=160	.349±.020 n=215	.138±.023 n=160
Larvae, 5/13-7/15	139± 5 n=405	96± 5 n=347	1.240±.015 n=405	.648±.016 n=347

Table 7-28. Differences in striped bass abundance with adjusted volumes among Unit 2 intakes and discharge-canal stations in $Log_{10}(catch/1000m^3 + 1)$.

Station	Eggs	Yolk-sac Larvae	Larvae
II-2 vs II-5	II-5>II-2	N.S.	II-5>II-2
II-2 vs D-1	N.S.	N.S.	D-1>II-2
II-2 vs D-2	N.S.	N.S.	N.S.
II-2 vs D-P	II-2>D-P	N.S.	II-2>D-P
II-5 vs D-1	II-5>D-1	N.S.	N.S.
II-5 vs D-2	II-5>D-2	N.S.	II-5>D-2
II-5 vs D-P	II-5>D-P	N.S.	II-5>D-P
D-1 vs D-2	N.S.	N.S.	D-1>D-2
D-1 vs D-P	D-1>D-P	N.S.	D-1>D-P
D-2 vs D-P	D-2>D-P	N.S.	N.S.

Table 7-29. Differences in striped bass abundance among Unit II intakes and discharge-canal stations in $\log_{10}$ (catch/unit effort +1).

Station	Eggs	Yolk-sac Larvae	Larvae
II-2 vs II-5	II-5>II-2	N.S.	II-5>II-2
II-2 vs D-1	N.S.	N.S.	D-1>II-2
II-2 vs D-2	N.S.	N.S.	N.S.
II-2 vs D-P	II-2>D-P	N.S.	II-2>D-P
II-5 vs D-1	II-5>D-1	N.S.	II-5>D-1
II-5 vs D-2	II-5>D-2	N.S.	II-5>D-2
II-5 vs D-P	II-5>D-P	N.S.	II-5>D-P
D-1 vs D-2	N.S.	N.S.	D-1>D-2
D-1 vs D-P	D-1>D-P	N.S.	D-1>D-P
D-2 vs D-P	D-2>D-P	N.S.	N.S.

Table 7-30. Striped bass abundance by depth with 95% confidence intervals for in-plant samples. Data are mean numbers collected per $1000m^3$, (n = number of samples).

Station location and collections	Surface	Middle	Bottom
Unit 2 intake			
Eggs 5/13-6/3	221±89 n=96	539±80 n=111	608±67 n=92
Yolk-sac larvae 5/13-6/10	9± 7 n=117	51±12 n=134	45±27 n=115
Larvae 5/13-7/8	147±43 n=174	425±78 n=196	280±35 n=170
Juveniles 6/17-7/8	0 n= 57	5± 7 n=62	6± 8 n=55
Discharge-Canal			
Eggs 5/20-6/3	4±15 n=38	22±21 n=38	22±15 n=38
Yolk-sac larvae 5/20-6/3	22±18 n=64	16±13 n=72	16±14 n=66
Larvae 5/27-7/15	255±40 n=113	208±120 n=117	138±39 n=105
Juveniles 6/17-7/15	0 n=63	0 n=67	5± 8 n=57

1974), this inequality between the intakes and the discharge canal may result simply from the dilution in the discharge canal of one intake having high abundance with one having a low abundance. However, we were unable to sample from all intake bays.

Egg abundance with depth at the Unit 2 intakes was greatest at the mid-depth and bottom, (Tables 7-30 through 7-32) and corresponds with 1974 results. Yolk-sac larvae and larvae were most abundant at the middle depth at the intakes. For all life history stages collected at the Unit 2 intakes, the abundances at the mid-depth and bottom were significantly greater than at the surface. This was not unexpected, for these life stages were most abundant at these same layers in the river.

There was no difference in abundance with depth for eggs and yolk-sac larvae in the discharge canal. Any depth distribution seen at the intakes will have been altered by mixing during plant passage. However, larvae were not evenly distributed in the discharge canal, being more abundant in surface and mid-depth samples (Tables 7-30 through 7-32). The turbulent mixing conditions in the discharge canal make this result somewhat unexpected.

There were too few striped bass juveniles caught in the plant for adequate testing and analysis.

Eggs were most abundant in the latter part of May (May 20 through 27) reaching peak densities of 1,809 eggs per

Table 7-31. Striped bass abundance in mean numbers collected per 1000m^3 by date and depth with 95% confidence intervals. (X = mean number; CI = 95% conficence interval; N = number of samples used in means determinations).

Collection and dates	Surface X	Surface CI	Surface N	Middle X	Middle CI	Middle N	Bottom X	Bottom CI	Bottom N
Eggs, Unit 2 intake									
5/13	79	281	12	52	258	13	239	250	9
5/20	418	235	16	1090	172	26	1809	157	19
5/22	656	235	16	1208	200	20	1270	207	12
5/27	109	171	28	229	165	28	149	126	28
6/03	0		24	9	180	24	0		24
Eggs, Discharge									
5/27	78	26	14	49	37	14	59	26	14
6/03	0		24	6	27	24	0		24
Yolk-sac larvae, Unit 2 intake									
5/13	0		12	0		13	0		9
5/20	8	20	16	31	27	26	92	72	19
5/22	42	20	16	107	31	20	122	94	12
5/27	4	15	28	101	26	28	36	58	28
6/03	5	16	24	33	28	24	42	63	24
6/10	0	17	21	10	29	23	0		23
Yolk-sac larvae, Discharge									
5/20	26	42	14	0	28	18	0		16
5/22	0		12	48	30	16	13	31	12
5/27	0		14	10	32	14	10	28	14
6/03	43	31	24	12	24	24	31	20	24

Table 7-31 (cont.).

Collection and dates	Surface X	Surface CI	Surface N	Middle X	Middle CI	Middle N	Bottom X	Bottom CI	Bottom N
Larvae, Unit 2 intake									
5/13	0		12	10	335	13	0		9
5/20	0		16	0		26	0		19
5/22	7	150	16	6	260	20	9	145	12
5/27	0		28	52	215	28	4	9	28
6/03	56	120	24	477	234	24	514	97	24
6/10	550	129	21	2587	240	23	1199	99	23
6/17	420	110	28	380	215	28	248	9	28
6/24	112	704	3	0		7	84	364	4
7/01	64	262	7	0		8	32	212	7
7/08	0		19	0		19	0		16
Larvae, Discharge									
5/27	0		14	0		14	10	118	14
6/03	337	91	24	265	276	24	313	86	24
6/10	1339	137	12	1109	415	12	474	146	10
6/17	141	58	28	141	253	28	75	79	28
6/24	76	1935	2	80	811	5	0		3
7/01	86	57	7	19	546	8	0		6
7/08	0		18	0		18	0		16
7/15	0		8	16	546	8	0		4
Juveniles, Unit 2 intake									
6/17	0		28	4	10	28	0		28
6/24	0		3	0		7	0		4
7/01	0		7	0		8	0		7
7/08	0		19	12	13	19	21	15	16
Juveniles, Discharge									
6/17	0		7	0		28	5	12	28
6/24	0		8	0		5	0		3
7/01	0		8	0		8	0		6
7/08	0		5	0		18	10	17	16
7/15	0		12	0		8	0		4

Table 7-32. Differences in striped bass abundance among depths in $\log_{10}(\text{catch}/m^3+1)$. (Sur = surface; mid = middle; bot = bottom).

Collections	Unit 2 intake	Discharge
Eggs, 5/13-6/3	Mid>Sur Bot>Sur Mid>Bot	None
Yolk-sac larvae, 5/13-6/10	Mid>Sur Bot>Sur	None
Larvae, 5/13-7/15	Mid>Sur Bot>Sur Mid>Bot	Sur>Bot

1000 m^3 in the Unit 2 bottom samples (Table 7-31) and was consistent with the 1974 results. These abundances were greatest in Unit 2 intake, bottom samples on May 20 and May 22, and more specifically, at the time of slack high tide for these two dates. The lower density or lack of, eggs in the discharge samples may have resulted from dilution as described previously.

Yolk-sac larvae were most abundant at the intakes between May 22 and May 27. Maximum densities of 122 per 1000 m^3 occurred in the intake bottom sample from May 22. The greatest single abundance of yolk-sac larvae in the discharge canal occurred in May 22 mid-depth samples, although the numbers were much less than at the intakes.

Larvae at the Unit 2 intakes were most abundant at the mid-depth on June 10 with 2,587 per 1000 m^3. Also, larvae from the surface samples in the discharge canal were most abundant on this date, with 1,339 per 1000 m^3.

Generally, the peak densities by date for the various life stages of striped bass correspond closely to the results reported for 1974. The mean numbers collected, however, were higher in 1975 than 1974.

7.2.3 Plant and River Comparisons

The abundance of the pre-juvenile life history stages of striped bass in plant and river samples are compared in Table 7-33. The mean abundance of eggs was higher in plant

Table 7-33. Abundance of striped bass collected in the river and at intake and discharge-canal stations, 1975. Data are mean numbers collected per 1000 m^3 with 95% confidence intervals. (n = number of samples).

Collections	Unit II Intake	Discharge canal	River
Eggs, 5/13-5/27	373±56 n=179	340±20 n=90	32±49 n=63
Yolk-sac Larvae, 5/20-6/10	31± 9 n=284	14±11 n=196	99±39 n=83
Larvae, 5/27-7/01	454±51 n=343	257±58 n=263	422±107 n=124

samples (intake and discharge), differing by a factor of approximately 10. This is confirmed statistically in Table 7-34. The comparison of egg abundance between plant and river samples for 1974 was similar; plant samples were higher by a factor of 10. Yolk-sac larvae were more abundant in river samples for both 1974 and 1975. Larval (post-yolk-sac) abundance between plant and river samples, on the other hand, differed in 1974 and 1975. In 1974 larvae in the plant intakes were less abundant than in the river, while in 1975 the plant abundance at the intakes was slightly higher than that in the river.

These data are not directly comparable for several reasons. Basically, the river sampling program was designed to aid in differentiating yearly abundances and changes in river biota as a result of power plant operation, whereas plant sampling was designed to observe the numbers of organisms drawn into the power plant and, subsequently, to assess the effect of plant passage on the survival of the river biota during power generation. River samples are collected once from each of seven "standard" stations in the vicinity of Indian Point on a given sampling date, while plant samples are collected from permanent sites six to seven times within a sampling period (night only). As certain striped bass life stages (e.g., eggs and yolk-sac larvae) are relatively non-motile, their distribution in the river is patchy, being influenced by the spawning site, and by tidal and current

Table 7-34 . Differences in striped bass abundance at night among mid- and bottom river stations, Unit II intakes and discharge canal in $Log_{10}(catch/m^3 + 1)$. (R=river, II=Unit 2 intake, D=Discharge canal) for those dates on which striped bass appeared both in river samples and plant samples.

Life Stage	II vs D	II vs R	D vs R
Eggs, 5/13-5/27	N.S.	II>R	D>R
Yolk-sac Larvae, 5/20-6/10	II>D	R>II	R>D
Larvae, 5/27-7/01	II>D	R>II	R>D

flows, and they may not be sampled quantitatively by once-over river tows. The probability of obtaining more planktonic individuals becomes greater if one samples the water several times at a permanent site at successive intervals than if one samples randomly by once-over tows. This alternative has been proposed for 1976. Also simple comparisons of abundance as shown in Table 7-33 have not considered the vertical distribution of the different life stages in the river (see Table 7-5 of this section). Since the plant intakes draw water from 27 ft. below mean sea level (MSL), and the river bottom in front of the intake structures slopes up from approximately 50 ft. below MSL (Figure 1-2) the organisms recovered in the plant samples are primarily from the middle depth and bottom of the river. If vertical distribution with depth is neglected and abundances are simply averaged for the entire water column, as has been done, abundance comparisons may be affected and result in erroneous conclusions. As an example, contrast the results of Table 7-35 through 7-37 with those of Tables 7-33 to 7-34 which compare the plant abundance of striped bass eggs, yolk-sac larvae and larvae with the abundance of these life stages in the middle and bottom river samples, since these life stages show an affinity for the bottom layers of water in the river (see River Population Studies Section and Figures 7-14 through 7-19 of this report). While it is expected that the plant which draws water from all depths

Table 7-35. Abundance of striped bass collected in the river and at intake and discharge-canal stations, 1975. Data are mean numbers collected per 1000m^3 with 95% confidence intervals. (n=number of samples). River values are adjusted values, using only mid- and bottom-samples.

Collections	Unit II Intake	Discharge Canal	River
Eggs, 5/13-5/27	373±56 n=179	340±20 n=90	119±59 n=42
Yolk-sac Larvae, 5/20-6/10	31± 9 n=284	14±11 n=196	143±50 n=56
Larvae, 5/27-7/01	454±51 n=343	257±58 n=263	524±132 n=83

Table 7-36. Differences in striped bass abundance at night among river, Unit II intakes and discharge canal in L_{10} (catch/m^3+1). (R = river, II = Unit 2 intake, D = discharge canal) for these dates on which striped bass appeared both in river samples and plant samples.

Life Stage	II vs D	II vs R	D vs R
Eggs, 5/13-5/27	N.S.	II>R	D>R
Yolk-sac Larvae, 5/20-6/10	II>D	R>II	R>D
Larvae, 5/27-7/01	II>D	II>R	R>D

Table 7-37. Differences in striped bass abundance at night among mid- and bottom river stations and surface, mid- and bottom plant stations in Log_{10}(catch/m^3 + 1). (R=river, P=plant) for those dates on which striped bass appeared both in river samples and plant samples.

Life Stage	P vs R
Eggs, 5/13-5/27	P>R
Yolk-sac larvae, 5/20-6/10	R>P
Larvae, 5/27-7/01	R>P

and directions in a cone-like fashion will collect more organisms than a once-over river tow, which samples only from discrete depths, the difference for eggs is only 2-3:1, not 10:1 as in Table 7-33. The differences for yolk-sac larvae and larvae are not so evident, since they are mobile and their mobility may allow them to move away from areas within the influence of the plant intake pumps.

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