HUDSON RIVER ECOSYSTEM STUDIES

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

Progress Report for 1974

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

for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
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FOREWORD

The research reported herein is part of the larger program of studies of the Hudson estuary ecosystem begun by Consolidated 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, Consolidated 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 known water uses and quality in 1974 and in the future.

This progress report to Consolidated Edison Company of New York, Inc. documents the results of research carried out by the New York University Medical Center Laboratory for Environmental Studies during 1974. In addition, it includes results of certain earlier studies for which data analyses could not be completed in time for the 1973 progress report.

In the past year, the results of the New York University research program and those of Lawler, Matusky and Skelly Engineers and Texas Instruments, Inc. have contributed to the understanding of the impact of power plants and other water uses on the Hudson ecosystem. As the full potential of the waters of the Hudson River as a resource is realized, there is developing an understanding of the natural system and its possible degradation. More and more present and prospective water users appreciate this fact each year; there has occurred since the last progress report (1973) the undertaking of site-specific sampling at a number of Hudson River sites not studied previously.* As these data are incorporated into the results of system-wide and site-specific studies, the potential for a scientifically based management of the Hudson River as a resource becomes more of a reality.

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 is expected to result 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

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* e.g. Site-specific sampling at Albany, N.Y., Lloyd, N.Y., Poughkeepsie and in New York Harbor. In addition, the National Commission on Water Quality has funded a basin-wide assessment of Hudson River Water Quality.

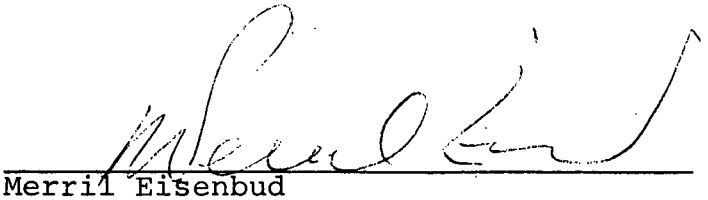
report, other than the introduction, and the chapter on physical/chemical studies, is organized according to the major biological groups studied. There is a chapter on each group, the first part of which is devoted to studies of natural river populations and the second to studies of entrainment effects 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. 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 present report for 1974 studies includes additional chapters, Chapter 8 and 9, covering integrative studies, which include the results of plume entrainment studies initiated in 1974 and the results of river-wide longitudinal studies made in 1973 and 1974.

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.

Joseph M. O'Connor, Ph.D.	Program Director, (15 Jan 1975)
Gerald J. Lauer, Ph.D.	Program Director, (through 1974)
William T. Waller, Ph.D.	Ass't Program Director, (through 1974)
Guy R. Lanza, Ph.D.	Ass't Program Director, (through 1974)
C.C. Lee, Ph.D.	Ass't Program Director, (April 1975)
Theo. J. Kneip, Ph.D.	Chemical Analyses
McDonald E. Wrenn, Ph.D.	Technical Advisor
Herny I. Hirshfield, Ph.D.	Technical Advisor
George Pack, Ph.D.	Technical Advisor
Ronald Heffner, M.A.	Phytoplankton Studies Leader
Patricia C. Storm, B.S. (Ph.D.)	Phytoplankton Entrainment
Wayne Meeks, B.S. (M.S.)	Zooplankton Studies Leader
Lois Zubarik, M.S. (Ph.D.)	Microzooplankton Entrainment
Thomas Ginn, M.S. (Ph.D.)	Microzooplankton Entrainment
Dale Bath, M.S.	Ichthyoplankton Studies Leader
Judith Lefkowitz, M.A.	Biostatistician
Gilbert Tauber, B.A.	Editor
Jeffrey Clock, B.S.	Research Assistant
Karen Eichorn	Research Assistant
James Currie	Research Assistant
Cindy Griffin	Research Assistant
Garry Griffin	Research Assistant
Kammy Griffin	Research Assistant
Jose Hernandez	Research Assistant
Kathy (Kneip) Borner	Research Assistant
Garrett McCarey	Research Assistant
Mark Palmieri	Research Assistant
Cathy Re´	Research Assistant
Tom Rippolon	Research Assistant
Steven Schaffer	Research Assistant
Al Wiedow	Research Assistant
Brenda Hunter	Key Punch Operator
Eleanor Clemm	Secretary
Eleanor Cordisco	Secretary
Julie Cordisco	Secretary

Part-time and summer research assistants: Richard Antonelli, Debbie Barth, Wayne Barth, Robert Carlo, Arthur Cordisco, Ellen Goodenough, Danny Kneip, Larry Kneip, Stephanie Kneip, Carol Tiedermann, D. Roy Wittrup, Yolanda Ziegler.



Merril Eisenbud
Laboratory Director

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SUMMARY

This report summarizes the progress of studies conducted in 1974 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 conducted in 1974.

In 1974 the Indian Point station included two completed units (Unit 1 and Unit 2) and one unit under construction (Unit 3). Units 1 and 2 were neither on line simultaneously, nor operating at full rated capacity for most of the sampling season.

River population sampling for all planktonic forms was carried out in 1974 as in 1971 and 1972. Comparisons of abundance and physiology of river populations were limited to the years 1971, 1972, and 1974 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 which will be completed soon.

Laboratory thermal tolerance studies in 1974 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 1974 studies were critical to the entrainment study program for several reasons. The predictive value of laboratory thermal tolerance studies conducted at Indian Point in 1973 could not be verified during 1973, due to the fact that neither unit was generating power. Consequently, in-plant studies were transferred to the Lovett station. The Lovett station results were encouraging in that they verified the laboratory data, although at a station having ΔT, transit time and flows different from Indian Point. The 1974 in-plant viability studies at Indian Point confirm the results of laboratory simulation for the Indian Point station.

Occasional two-unit operation at Indian Point during 1974 produced ΔT's near the allowable maximum, enabling 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. A full-scale plume study is included in the work scope for 1975.

In-plant entrainment studies conducted in 1974 incorporated a new concept in sampling procedure: 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 1974 were designed to: (1) measure the temporal and spatial distribution of species potentially subject 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 in previous years were included in our preceding progress reports.

Phytoplankton River Populations

Studies conducted in 1974 utilized whole-water samples exclusively. Phytoplankton abundances observed in 1974 were similar to those observed in 1972 with maximum abundances occurring in early summer. However, the distribution by algal groups differed between 1972 and 1974. In 1974, a greater proportion of the algal groups differed between 1972 and 1974. In 1974, a greater proportion of the algae were diatoms (Bacillariophyceae) as compared to 1972. Nevertheless, the seasonal succession of algal groups and the relative timing of their appearance in phytoplankton samples were similar during the two years. In addition, there was observed for the first time, a significant difference in green algae abundance among stations, due primarily to large concentrations of green algae at a single station (G) in July. 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.

Phytoplankton data based upon whole-water samples provided a better estimate of total phytoplankton standing stock than data based upon net collection methods (New York University, 1973). However, the primitive state of taxonomy of many nannoplankters makes species analysis of whole-water phytoplankton samples impractical.

Supplemental measurements for chlorophyll a content in phytoplankton and sub-surface light measurements were taken in the Indian Point vicinity from May through December, 1974. Chlorophyll a, used herein as an estimate of phytoplankton standing stock, varied with no particular trend or pattern, by season and by station. Although there was some correlation of chlorophyll a with cell numbers, it was insufficient for predictive purposes.

Microzooplankton River Populations

River microzooplankton populations were dominated in 1974 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 rotifer Nothalca sp., and shelled amoebae of the genera Centropyxis and Difflugia.

Comparisons of the microzooplankton species observed during 1971 and 1974 sampling periods revealed that the dominant species were similar. The most frequently occurring copepods and cladocera (A. tonsa, E. affinis, B. longirostris and D. brachyurum) were identifical for both years. Two protozoa, Centropyxis sp. and Difflugia sp. were the dominant species during both sampling periods. In 1971 the most common rotifer was Brachionus angularis; however, in 1974 the predominant rotifer was N. accuminata.

The abundance of dominant and sub-dominant forms, as well as less common species, varied significantly with season and was correlated with the seasonal progression of temperature in the river, and the 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 summer months, reaching concentrations of more than 200 organisms per liter in August. 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 two instances, differences among stations were observed: 1) copepod nauplii were more abundant at station F than at station B; and 2) adult Eurytemora affinis distribution data indicated a station effect, but specific differences could not be detected.

Abundance data for night samples of microzooplankton indicated a station effect. As for the daytime samples, specific differences, for the most part, were not detectable.

Nevertheless, the results show that based upon the abundance of species and total numbers, as well as seasonal distribution patterns from 1971-1974, microzooplankton in the river have not been affected by the operation of the Indian Point station.

Macrozooplankton River Populations

A total of 25 macroinvertebrate groups were identified from 1974 samples, two more than were observed in 1972, and four more than in 1971. In all three years macrozooplankton samples were dominated by three taxa, Gammarus spp. (mostly G. tigrinus), Monoculodes edwardsi and Neomysis americana. These forms accounted for 67% of the total macrozooplankton collected during the daylight hours, and 66% 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, the propostional representation of Gammarus, Monoculodes and Neomysis in 1974 samples is less than that observed in 1971 (87%) and 1972 (97%).

The seasonal occurrences of Neomysis americana at Indian Point were found to coincide with salinity pulses in the river. The occurrence of other species, including Monoculodes 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 self 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 May; numbers decreased in June, gradually increased through late September and, except for low numbers in October, were high through December. Macrozooplankton abundances in 1974 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 and 1972. The stations (A, B, C, E) where macrozooplankton abundances differed significantly from other stations in 1974 were not the same as those that were different in 1971 (B, G, F) or in 1972 (A, D). On the basis of three years of study, operation of the Indian Point plant appear 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 estuary--i.e., from the Tappan Zee Bridge to Cementon--life stages of 21 species were found in the 1974 ichthyoplankton collections. Of these 21 species, 18

have been collected each year from 1971 to the present. The species composition of the ichthyoplankton was similar to that found in 1971, 1972 and 1973.

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. 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 possible 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. This is a statistically significant difference that has been observed for the second consecutive year.

There exists no simple explanation for the over abundance of eggs in the plant, although we suspect that some of these differences may simply be results of the different sampling methodologies employed in plant and river sampling. At present, there is insufficient information to permit selection of one set of numbers over the other (plant or river). They may both be correct and that such comparisons are not valid under these circumstances.

PHYSICAL-CHEMICAL DATA

Physical-chemical data from 1972, 1973 and 1974 were analyzed and compared to identify trends of change in various parameters throughout the study period. The trend toward higher mean air temperatures noted in the previous progress report was not maintained in 1974. Water temperature and dissolved oxygen profiles were generally similar for 1972, 1973 and 1974. Maximum mean water temperature recorded in 1974 of 26.8°C (80.2°F) was less than the 27.6°C (81.7°F) recorded in 1973. Values for 1973 and 1974 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 1.4 to 3.2 ft. No secchi disc readings were taken in 1971 or 1973. The 1974 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 1974 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 7.0 to 7.5, 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.

Assuming transit times of entrained organisms are comparable to calculated times for water passage through the plant, the organisms will be exposed for as long as 33.3 minutes at a ΔT of 9.1°C (16.4°F) during full-flow operation.

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

Laboratory thermal tolerance and intake-discharge canal studies of the phytoplankton community in the Indian Point vicinity were continued in 1974. 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 rather than a specific response to some threshold maximum

temperature. Final temperatures (ΔT + ambient temperature) above 30°C (86°F) generally resulted in inhibition of phytoplankton productivity. Temperatures below 30°C produced variable results which may be related to a number of other factors (e.g., physiological state of the algal sample, species composition, availability of nutrients in the enclosed sample, presence or absence of chemical inhibitors, etc.) not examined. Generally, the imposition of rated ΔT for the Indian Point station on algal populations existent at river temperatures below 18°C (64.4°F) caused either no effect or stimulation; populations present at temperatures above 18°C generally were inhibited by ΔT's similar to that for rated plant operation.

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 1972. Copepods were the most abundant forms; the four major species were Eurytemora affinis, Acartia tonsa, Diacyclops biscuspidatus and Halicyclops 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; approximately 90 to 100% of these organisms were captured alive in discharge samples. Calanoid copepods (E. affinis and A. tonsa) were more sensitive, generally showing survival of 50 to 85% in the discharge-canal samples.

Our studies show that there was little to no effect of plant entrainment on the viability of certain microzooplankton species. There appears to be some damage to the copepod E. affinis if the final temperature (ambient water temperature + ΔT) during plant passage rises above 26.7°C (80°F). However, this condition would probably 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) show 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 90%. The impact of this on the Neomysis population in the river is not known. This is believed to be minimal, as the occurrence of Neomysis at Indian Point is irregular and is dependent upon the location and movement of the salt front within the Hudson River estuary.

Supplementary thermal tolerance experiments with Gammarus spp. conducted in 1974 showed that adult females were able to tolerate 30-minute laboratory exposures to a ΔT of $11^{\circ}C$ ($19.8^{\circ}F$) at an ambient water temperature of $26^{\circ}C$ ($78.8^{\circ}F$). 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. Not enough different life stages of the plankton have been examined, and the conditions to which the test organisms were exposed were more extreme than those of normal plant operation.

Ichthyoplankton

Ichthyoplankton studies conducted in 1974 did not include laboratory studies of thermal tolerance. Thus, estimates of ichthyoplankton viability and latent mortality reflect the synergistic effects of thermal and/or chemcial 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 show 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 indicates that the time/temperature exposure of life stages of striped bass at the Indian Point plant is cumulative and that the additional time of exposure

to warm water between station D-1 and D-2 increases the probability of death. A significant increase in the proportion of stunned and dead larvae was noted between D-2 and the discharge-port stations (DP-3 and DP-8), but so few organisms were collected at these stations that conclusions must be treated with care.

If one assumes and accepts the initial idea 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.

Living striped bass eggs and live and stunned striped bass yolk-sac larvae, larvae and juveniles 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.

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 in water that is pumped through the cooling systems of a power plant. Only organisms small enough to pass through the mesh of the intake screens are subject to pumped entrainment. In plume entrainment, organisms are brought into the cooling-water plume by turbulent mixing of effluent cooling water with receiving water.

During the first 3 years of the scheduled 5-year research program the emphasis has been on effects of pumped entrainment, although much of the information obtained is also relevant to plume entrainment. Preliminary studies of plume entrainment were begun in the fourth year.

Pump-entrained organisms are exposed to potential stresses that include abrupt changes in temperature, pressure, mechanical buffeting, velocity shear forces, and chemicals introduced by the plant. Plume-entrained organisms are exposed to elevated temperature, discharged chemical residuals, and velocity shear forces; but these potential stresses are reduced as dilution progresses. The potential stresses on organisms entrained by the Indian Point plant are described in greater detail in the following pages.

1.1 ORGANISMS SUBJECT TO ENTRAINMENT

Organism groups potentially subject to entrainment include planktonic 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, minerals, and water into complex organic matter (including more algae cells) that contributes to the food supply for the other trophic levels in the ecosystem. For this reason, the phytoplankton are often referred to as 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 freely in the water. Zooplankton "graze" on the phytoplankton, bacteria, other zooplankton, and detritus. They are in turn eaten by larger invertebrates and fish. Zooplankton also include a "non-consuming" segment comprised of eggs and non-actively feeding life stages of the consumer group.

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 are 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 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, spend restricted portions of their life histories 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.* Their probability of 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 en-

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* 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.

trainment 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 where they are in the river and in the water column relative to the location of the cooling-water intake and the discharge plume.

1.2 THE INDIAN POINT FACILITY*

The Indian Point facility will soon be comprised of three nuclear-fueled electric generating units with a combined capacity of 2103 MWe. 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; Unit 2, which went operational in 1974, and Unit 3 (to be tested in 1975) 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

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* Paraphrased from the Indian Point Unit 3 Environmental Report.

1-1). There are four rectangular intake openings at Unit 1 and six each at Units 2 and 3. The openings extend 26 feet below mean sea level (MSL) at Unit 1 and 27 feet 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 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 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

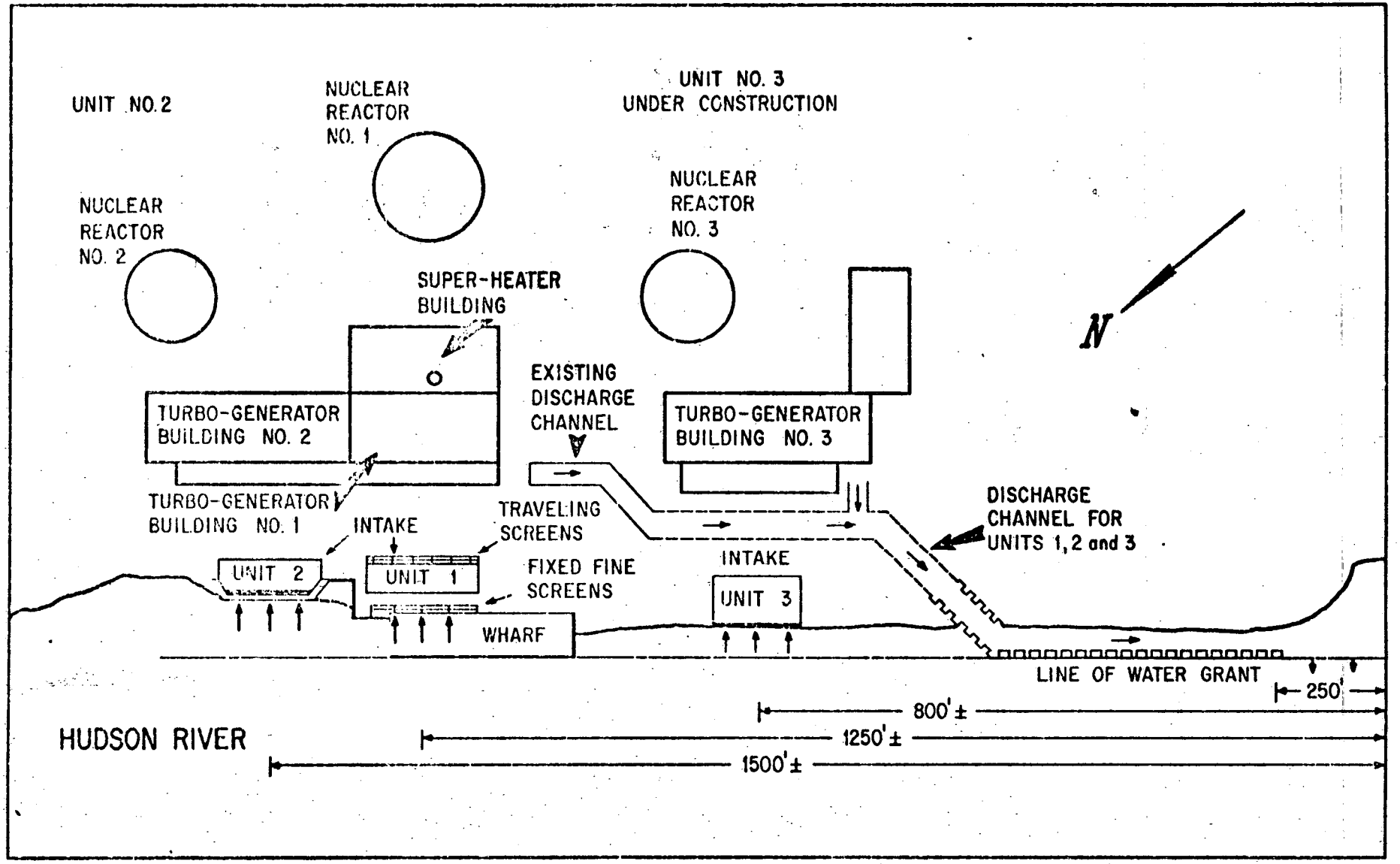


Figure 1-1. Schematic diagram of Indian Point nuclear generating facility.

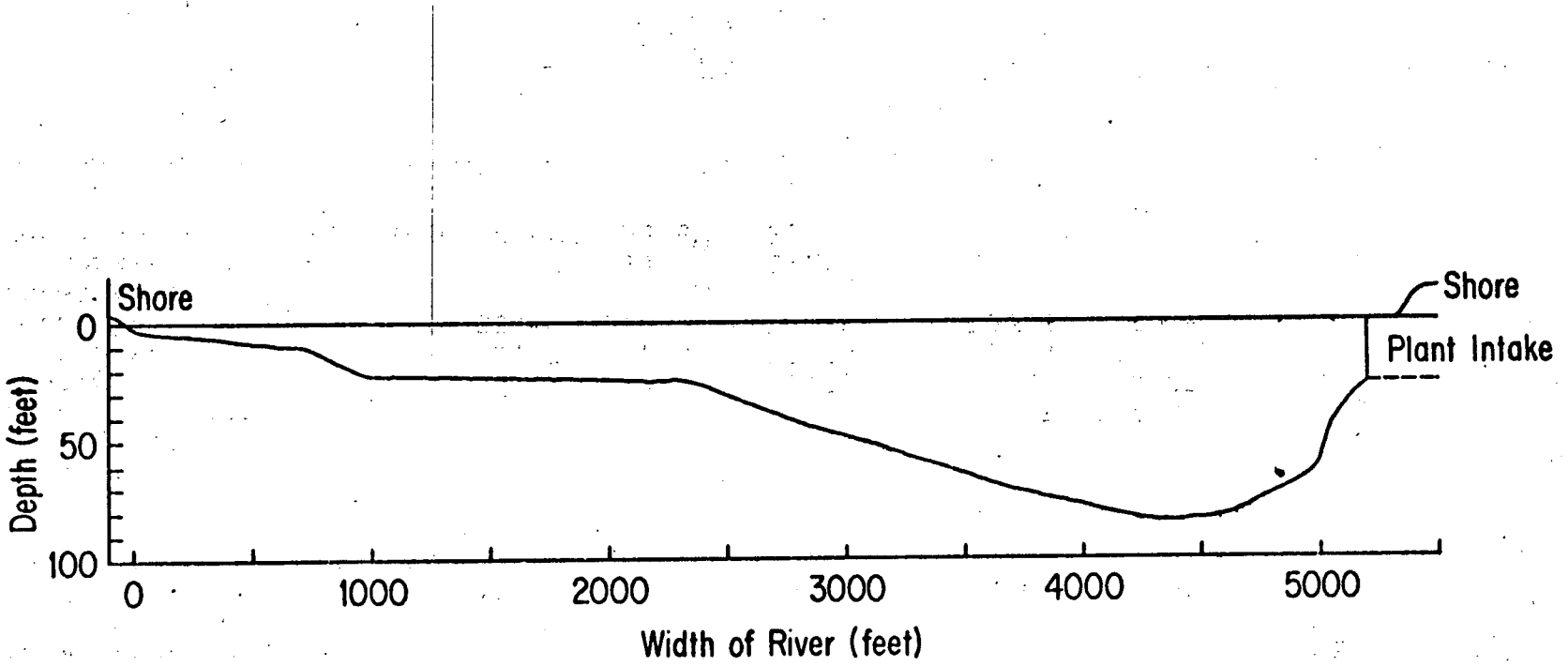


Figure 1-2. Cross section of Hudson River at Indian Point plant intake. For clarity, vertical scale has been expanded by a ratio of 10:1. Data from U.S. Geological Survey Peekskill (N.Y.) Quadrangle, 1957.

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}

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 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 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 is expected as the water passes from the condensers to the discharge ports, except when the units are operating at substantially unequal ΔT's. 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 operated alone (Table 1-1).

The ΔT encountered by pump-entrained organisms will increase in the winter, when cooling water flows are reduced. The maximum temperature rise at 60% of design flow is expected to range from 21 to 27.1°F. Calculated exposure times also increase with the reduced flows. The relationships of temperature rise to calculated exposure times for individual and combined-unit operation at 60% flow are given in the lower part of Table 1-1.

The maximum possible temperature elevation/time-of-exposure 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 drops in hydrostatic pressure. The

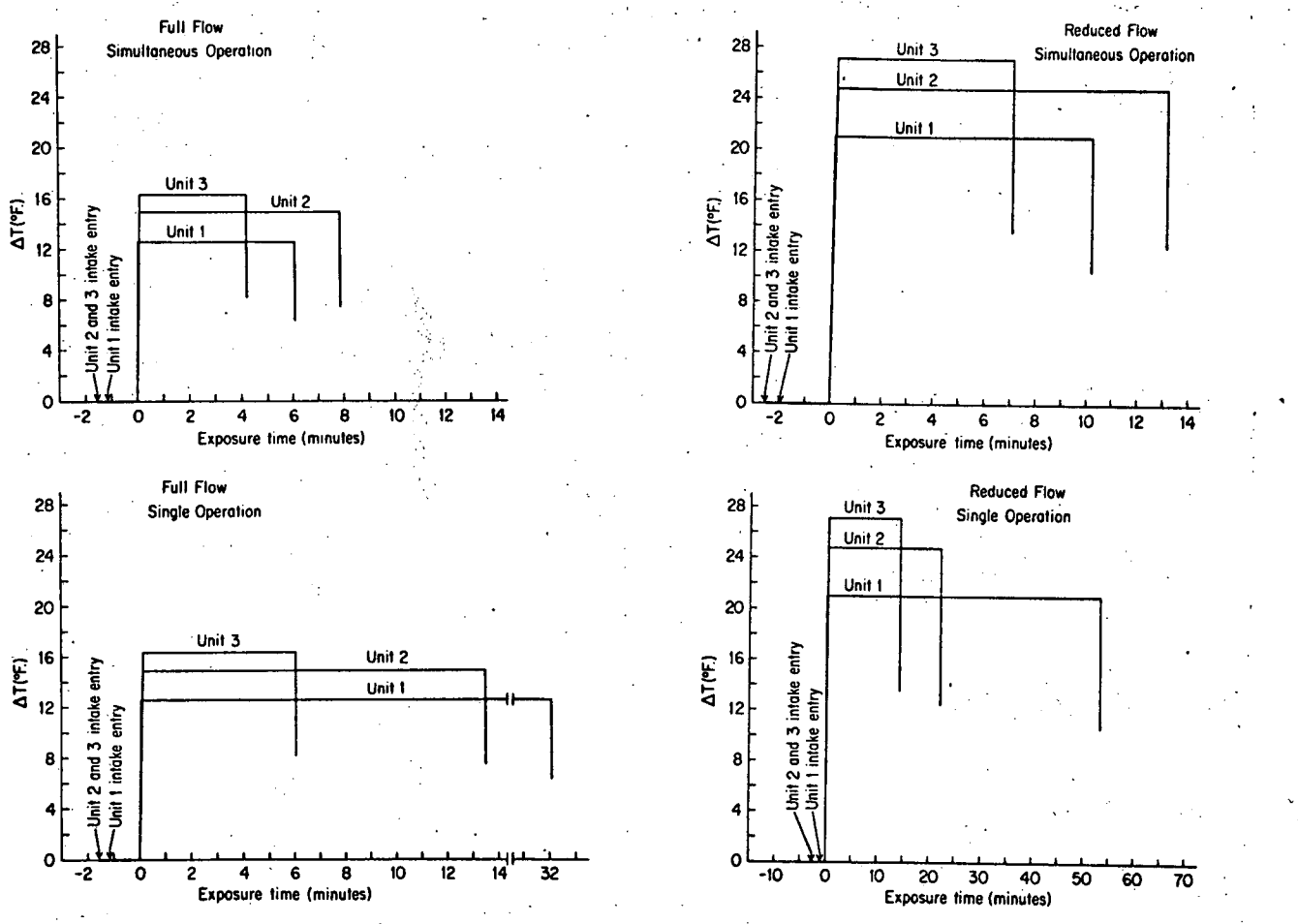


Figure 1-3. Schematic diagrams of temperature elevations and exposure times in the Indian Point condenser cooling system when operating at rated generating capacity.

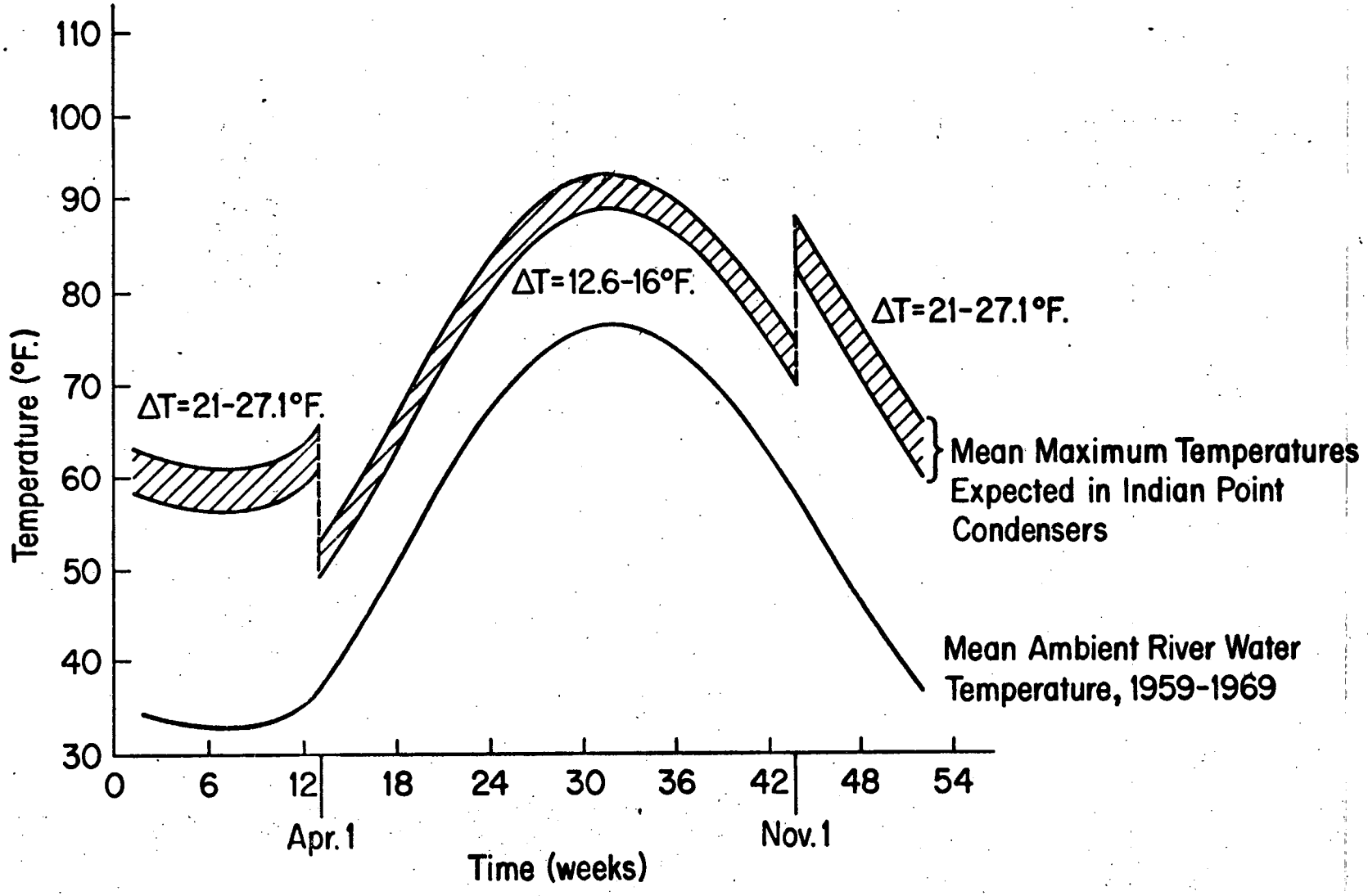


Figure 1-4. Temperatures encountered in Indian Point condensers at proposed cooling water flow rates when plant is operating at rated generating capacity.

degree and rate of such pressure changes depends on the location of the organism in the water column prior to being drawn into the pumps, the design and height 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. The results of ongoing studies conducted by New York University on the effect of pressure changes on entrained Hudson River organisms have shed considerable light on the potentially adverse effects on survival of river organisms exposed to rapid pressure changes.*

1.2.4 Velocity Shear Exposure

Organisms pumped through the Indian Point facility are exposed to rapid decreases and increases 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.

* The effects of changes in hydrostatic pressure on some Hudson River biota, a progress report for 1974 to Consolidated Edison Co. of New York, Inc., 1974. New York University Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies.

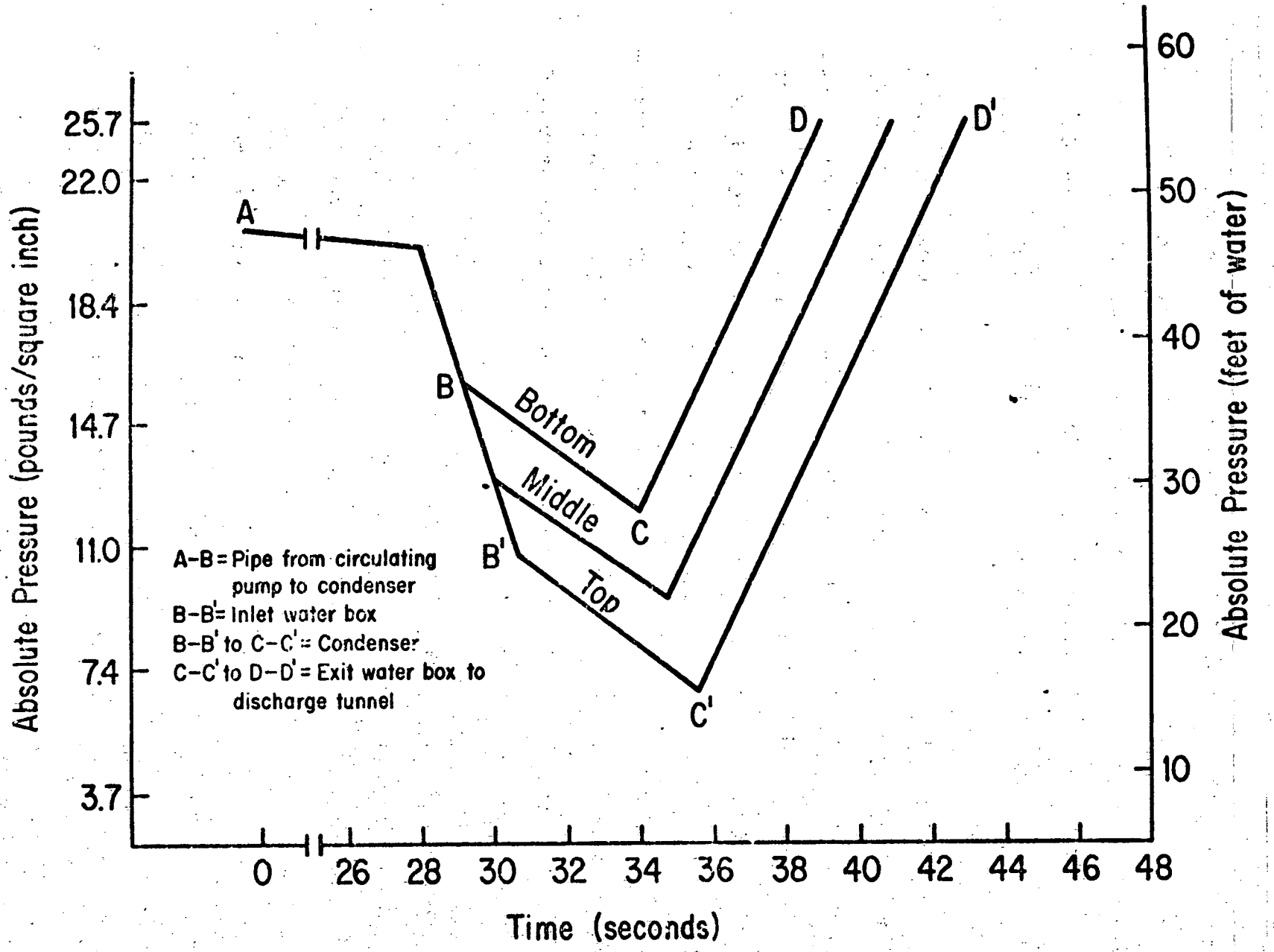


Figure 1-5. Absolute pressure in relation to time from intake to discharge pipe of Indian Point Unit 1 circulating water system.

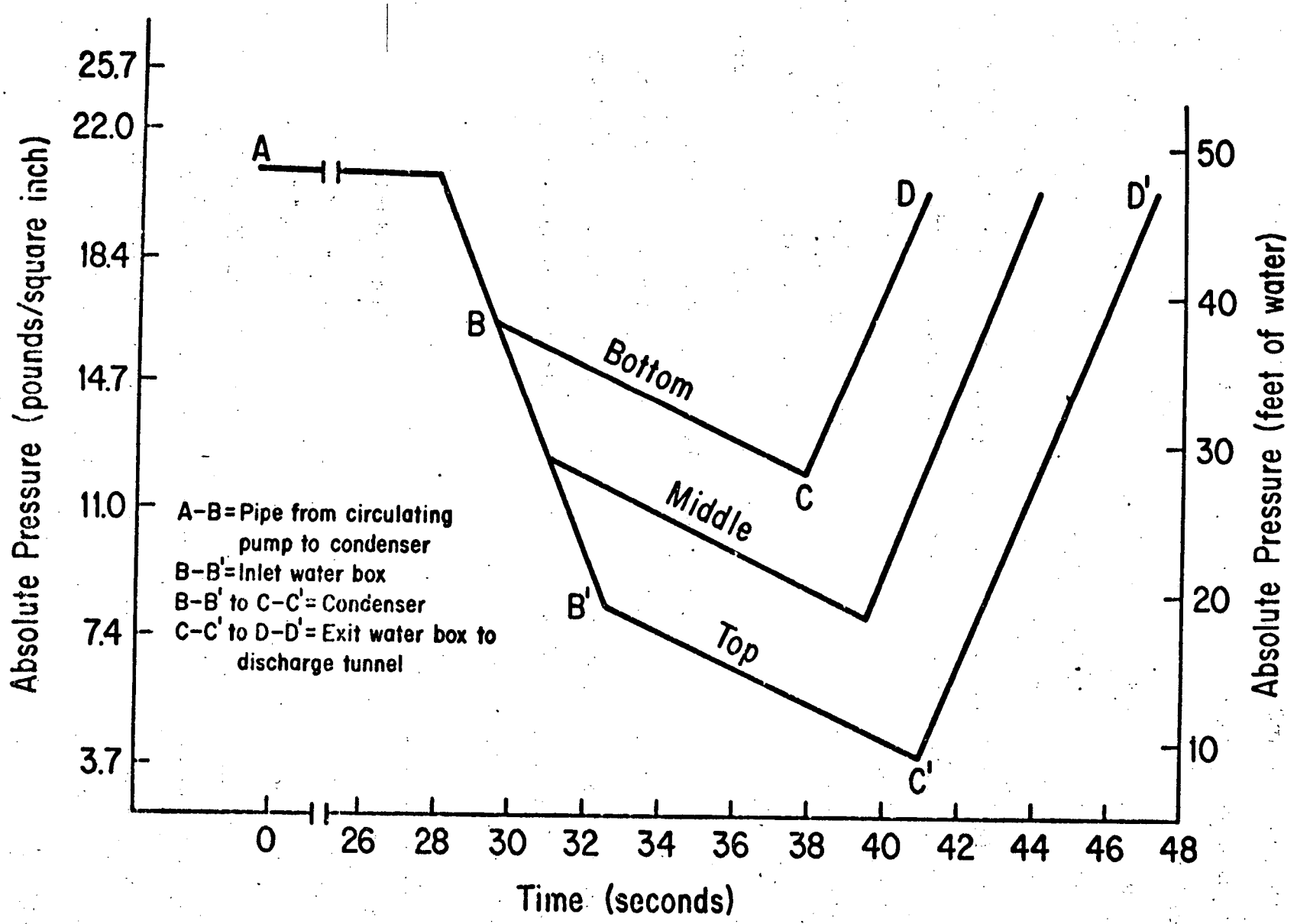


Figure 1-6. Absolute pressure in relation to time from intake to discharge pipe of Indian Point Unit 2 circulating water system.

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 general range of 5.5 to 8.1 fps for Unit 1 and 6.0 to 8.1 fps for Unit 2. Pressures and resultant velocities in Unit 3 are expected to be similar to those in 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. Stressful conditions may occur, however, at interfaces where there exist rapid changes in velocity and where, consequently, an organism may be subject to differentials in velocity and direction of flow on different parts of its body. The biological effects of velocity-related shear forces within the plant have not been studied as an independent stress.

1.2.5 Mechanical Buffeting Exposure

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

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. In the Unit 3 intakes, the traveling screens will be located immediately inside the intake openings, so that the sampling rigs will be positioned between the traveling screens and the pumps.

1.2.6 Chlorine Exposure

The condensers are treated with sodium hypochlorite to remove fouling organisms. Each half of a unit's condensers is chlorinated successively for ½-hour during daylight hours for a total treatment time of 1 hour per unit. This procedure is repeated on alternate days for a maximum of 3 times per week per unit.

The frequency of chlorination is determined by the growth rate of fouling organisms controlled by ambient river water temperature. It is expected that no chlorination will be done when river water temperatures are below 45°F. Further reductions to twice-weekly chlorination during spring and fall may also be possible, if that is enough to control fouling organisms and thereby maintain heat transfer rates in the condensers. Thus, chlorine would be used for not more than 8 months of the year, and, during that period, would be employed no more than 3 times per week. For as much as 5 months out of the 8, it would be used only twice weekly. Table 1-3 shows the annual chlorination schedule used previously for the Indian Point units.

A variety of factors have contributed in recent years to a chlorination schedule considerably less intense than that presented (Table 1-3). To a certain extent, chlorination at the Indian Point station in 1974 was at the request of investigators, since plant management was conducting tests to minimize the frequency of chlorination.

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

Studies of chlorination in the plant discharge canal and plume-entrainment zones were executed to provide as full an assessment of plant impact as possible under all conditions.

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.

1.3 DESIGN OF THE RESEARCH PROGRAM

The initial design of the research program was based on information that was available in late 1970 on the many variables described above. Appropriate changes are made as new information becomes available and as new elements of the Indian Point complex are completed.

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 contained 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 increases or decreases the numbers entrained.

3) Determine to what extent organisms are killed or otherwise adversely affected by entrainment at the Indiar 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 and velocity shear. The latter two stresses can be evaluated only in combination with each other and with pressure, and then only by comparing the conditions of organisms in the intake with those in the discharge canal when the plant is operating at zero ΔT and with no chlorination.

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 <u>in situ</u> experiments wherein organisms (phytoplankton, microzooplankton, 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 examined following this exposure to determine mortality in relation to control conditions.

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 useful for monitoring effects of entrainment and 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-

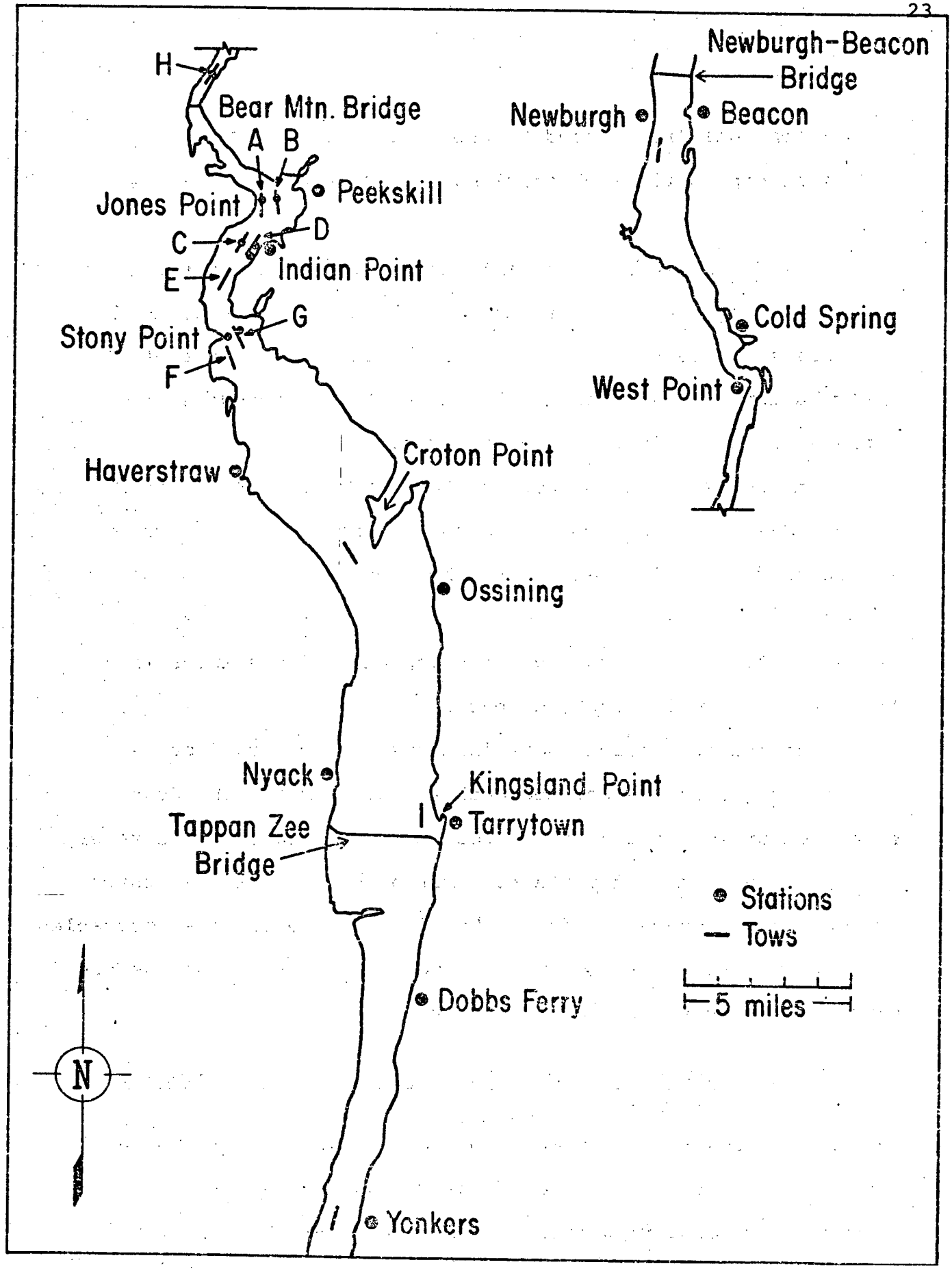


Figure 1-7. New York University Hudson River sampling stations, 1971, 1972 and 1974.

point locations (referenced to the Battery in New 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 the collections were initiated, 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, but the 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 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

Table 1-5. Location and river depth at New York University Hudson River sampling stations, 1971, 1972 and 1974.

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.

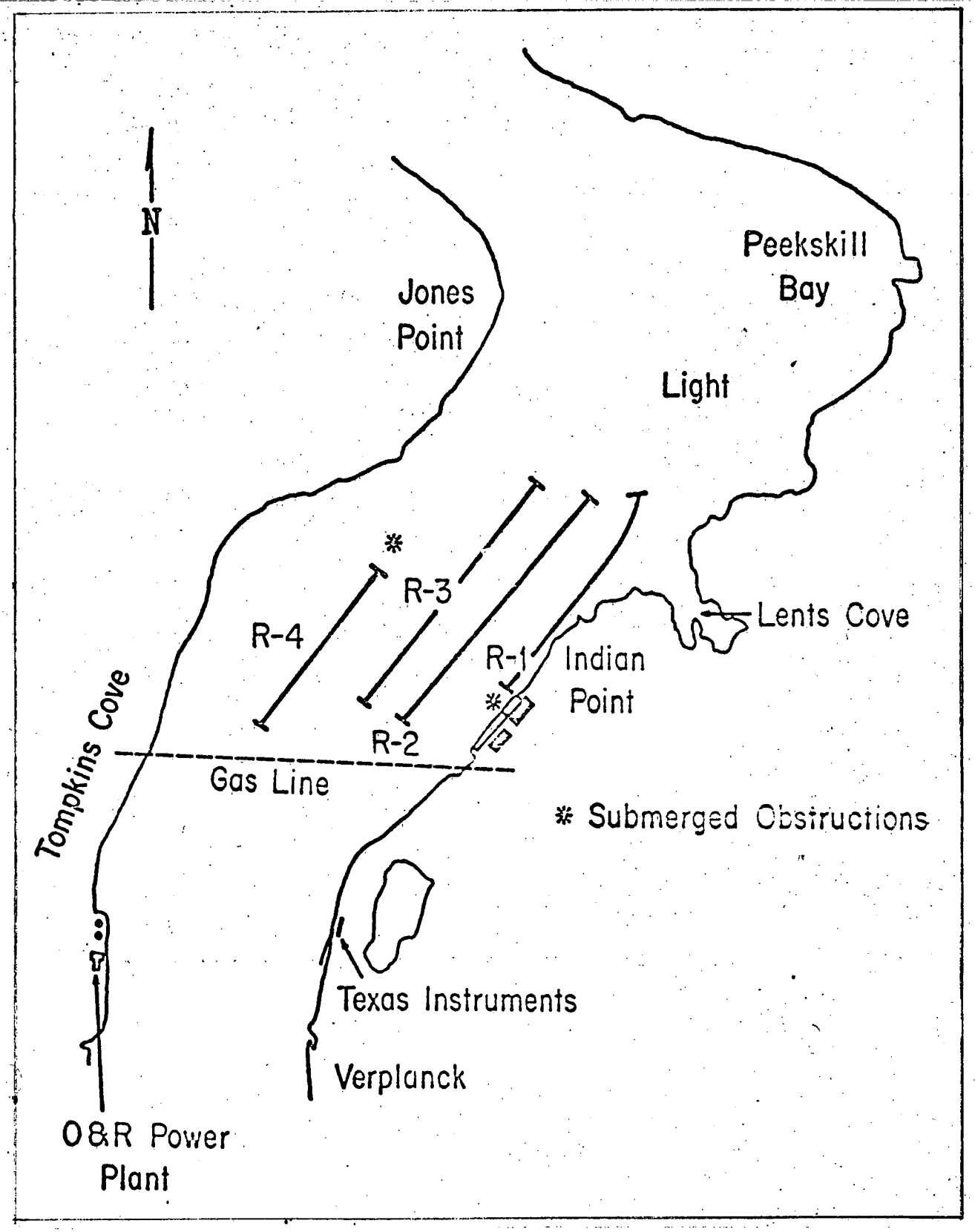


Figure 1-8. New York University Hudson River sampling stations, 1973 and 1974.

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 ath	Approximate epth ontour	Approximate istance 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

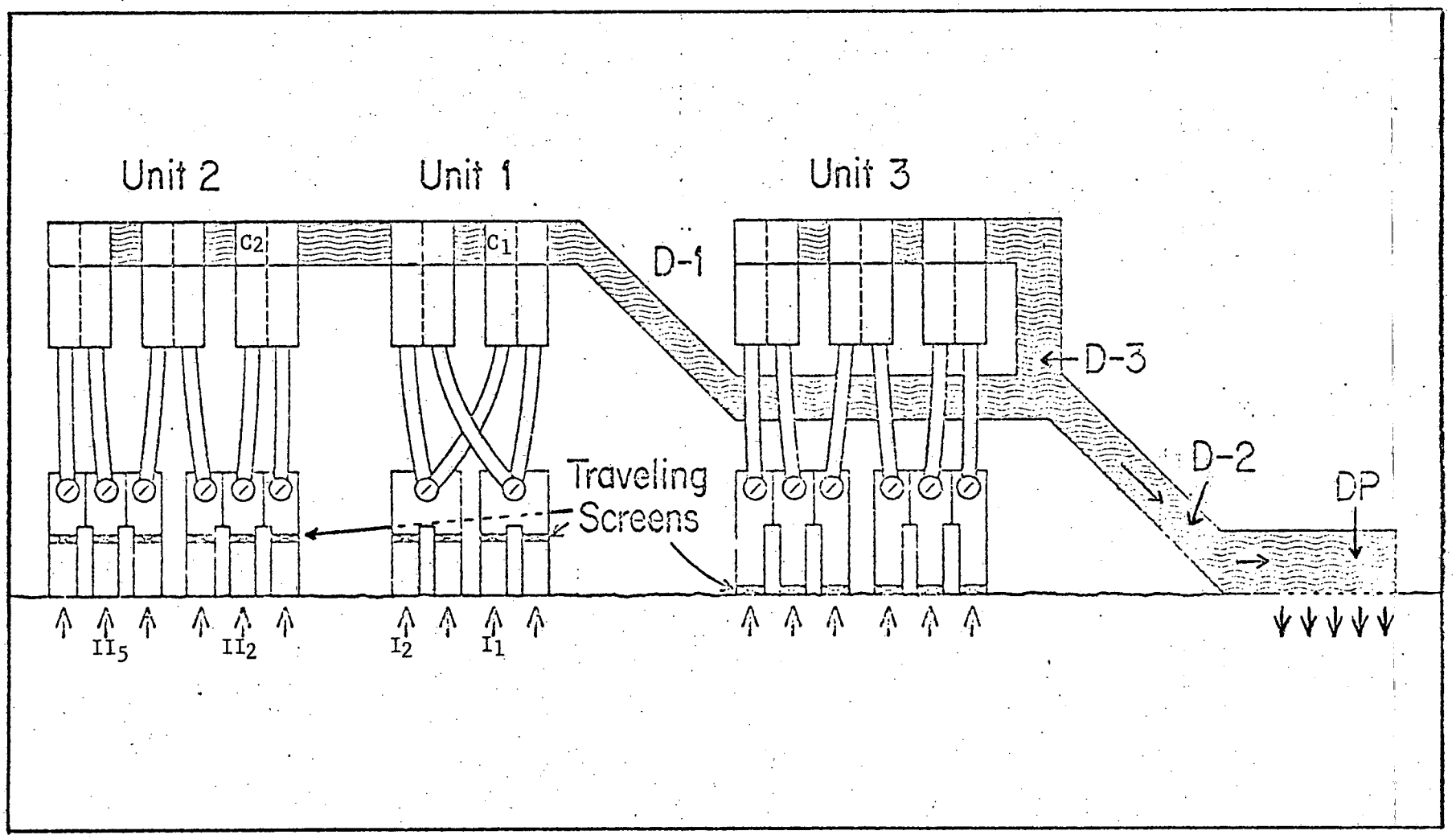


Figure 1-9. Schematic diagram of Indian Point cooling water system showing locations of sampling stations.

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.

Stations C-1, C-2, C-3 and C-4 were small bleeder lines through which very limited amounts of water could be obtained from the condenser water boxes. 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. When Unit 3 is operational station D-3 will be established in the Unit 3 discharge canal just upstream of its confluence with the existing discharge canal used by Unit 1 and 2. Station DP, at the discharge ports, was established in 1973 and sampled throughout 1974. 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, more 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 on 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.

Also in 1974, preliminary studies of the effects of plume entrainment were begun. These studies were undertaken to assess the effects of the thermal discharge plume and/or the chlorinated discharge plume on entrained river organisms. These studies were conducted at stations within the discharge plume, the locations of which varied with the tidal phase (Figure 1-10).

As indicated in Table 1-2, the velocity of the water varies as it moves through the cooling water system. The velocity of the water at a sampling station can affect the collection efficiency of the net as well as the condition of the organisms collected.

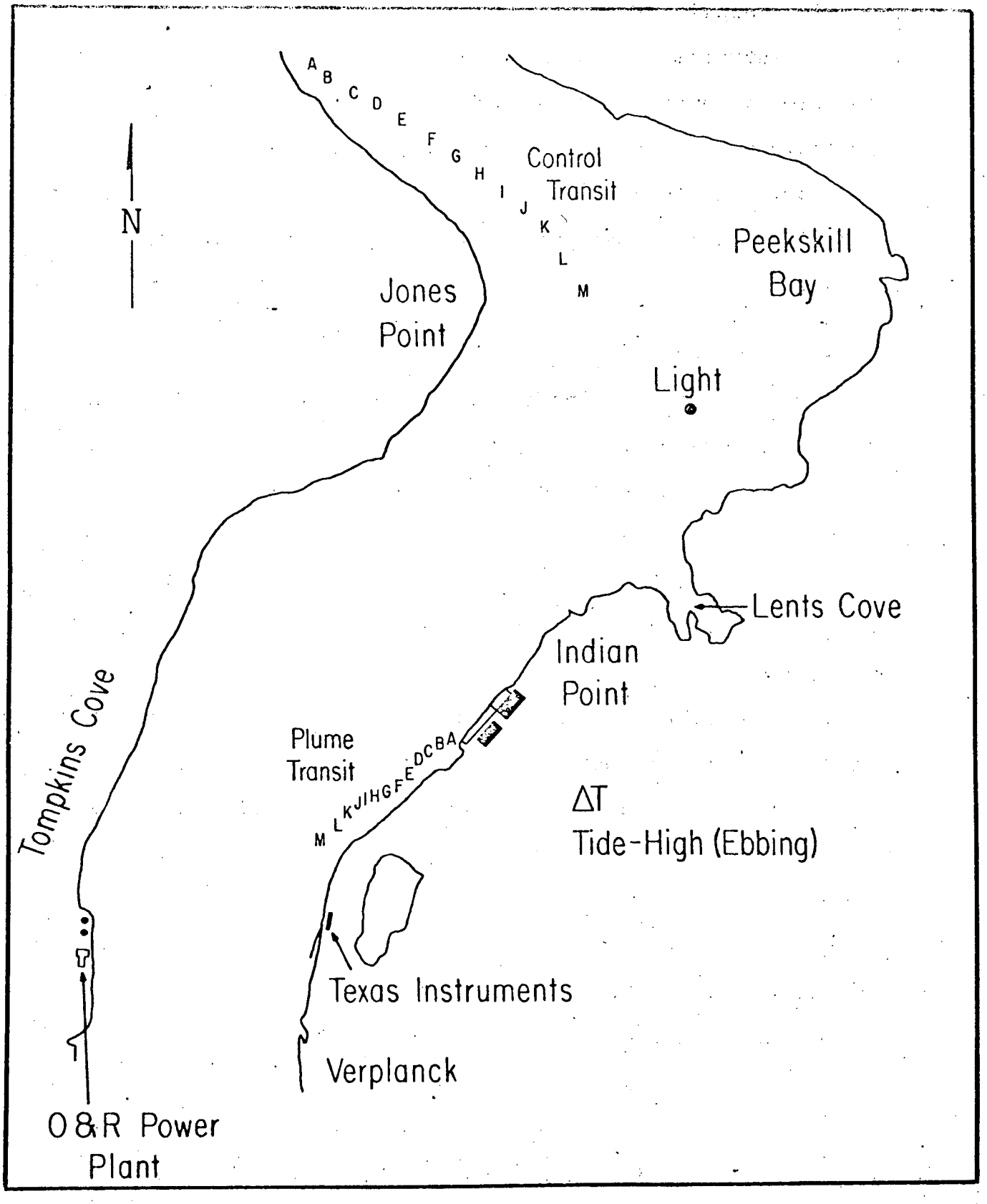


Figure 1-10. Plume transit stations and control transit stations exemplary of station locations for plume studies, September 12, 1974 at Indian Point

Intensive sampling for abundance of fish eggs and larvae during 1973 and entrainment studies during 1974 provided evidence that filtration volumes could be monitored accurately using flow/time calculations. Experiments to be conducted at the Alden Research Laboratories in 1975 hold promise for a precise determination of volume/flow related effects on organism retention in nets and survival.

1.3.2.3 Sampling Gear

Depending on sampling conditions and the kinds of organisms desired, various collection nets were used. The net types and dimensions used in 1971, 1972, 1973 and 1974 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 by 15 cm long, having a sieve window of the same mesh as the net.

Sampling from surface to bottom was needed both at the 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 these organisms in the water column varied markedly as opposed to phytoplankton and microzooplankton, which showed little difference in vertical distribution.

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
			Mesh	Diameter (m)	Length (m)		
Phytoplankton	population, entrainment effects	nannoplankton	10μ	0.12	0.3	brass ring	none
Microzooplankton, all	population, entrainment effects	No. 20 mesh	76μ	0.5	1.9	brass ring	stainless steel
Microzooplankton, large (e.g. adult copepods)	population, entrainment effects	No. 0 mesh	571μ	0.5	1.9	brass ring	stainless steel
Macrozooplankton and Ichthyoplankton	population	No. 0 mesh	571μ	0.5	3.8	PVC cylinder	PVC
Macrozooplankton and Ichthyoplankton	entrainment effects	No. 0 mesh	571μ	0.5	1.9 1.2* or stainless steel	PVC cylinder	PVC
Ichthyoplankton	population	1 mm	1 mm	1.0	3.8	brass ring	PVC
Ichthyoplankton	population	No. 0 mesh Hensen	571μ	1 m	5.7	stainless steel	PVC

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

Sampling rigs capable of simultaneous sampling at three water depths were devised (Figure 1-11), and were installed at each of the intake and discharge-canal sampling stations.

Samples just below the surface were taken by use of nets on tow lines. Samples from intermediate depths down to the bottom of the intakes and discharge canal were taken with nets mounted in the sampling rigs (Figure 1-12). Figure 1-12 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 in Unit 1.

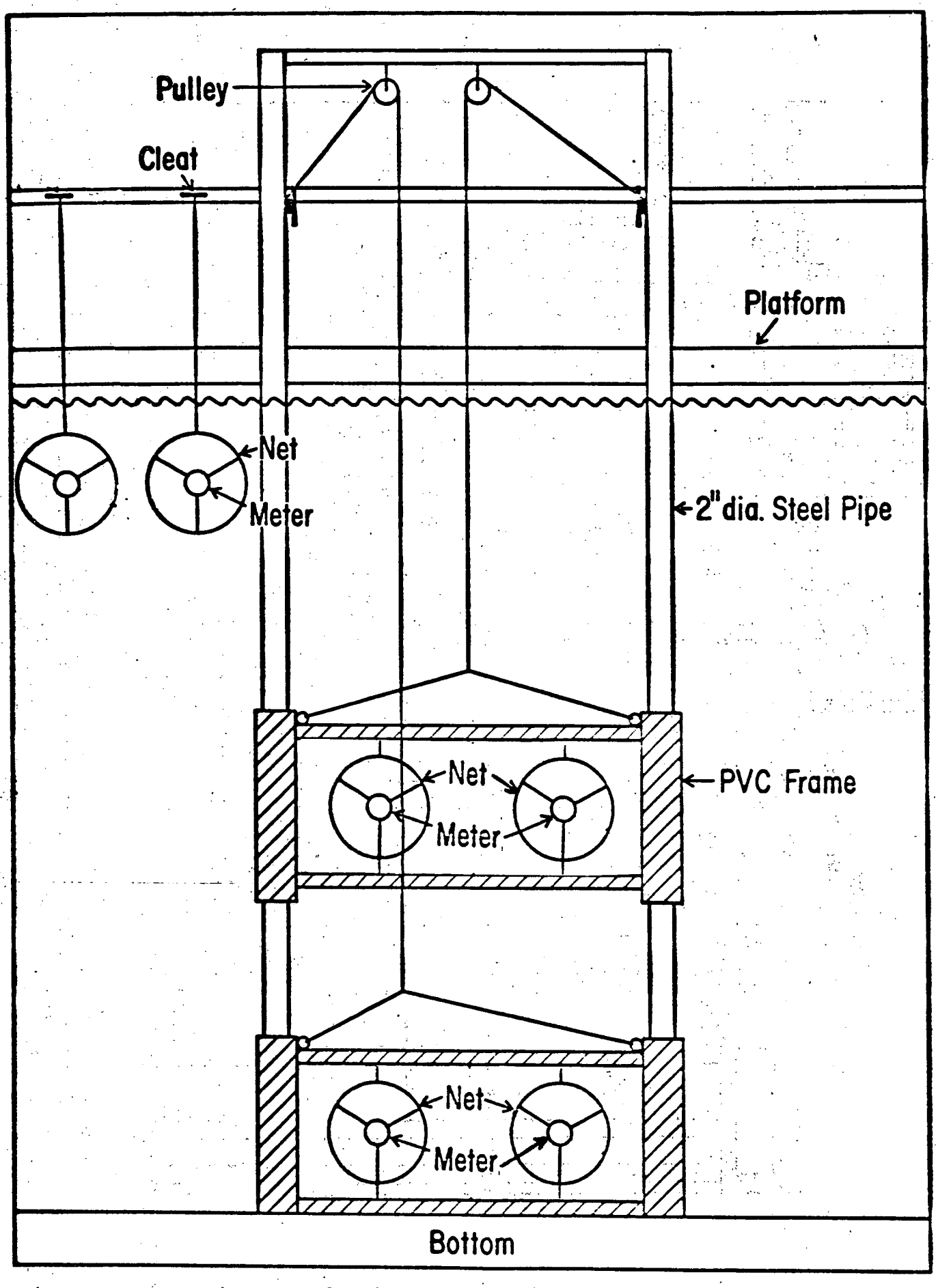


Figure 1-11. Rig used for intake and discharge-canal sampling.

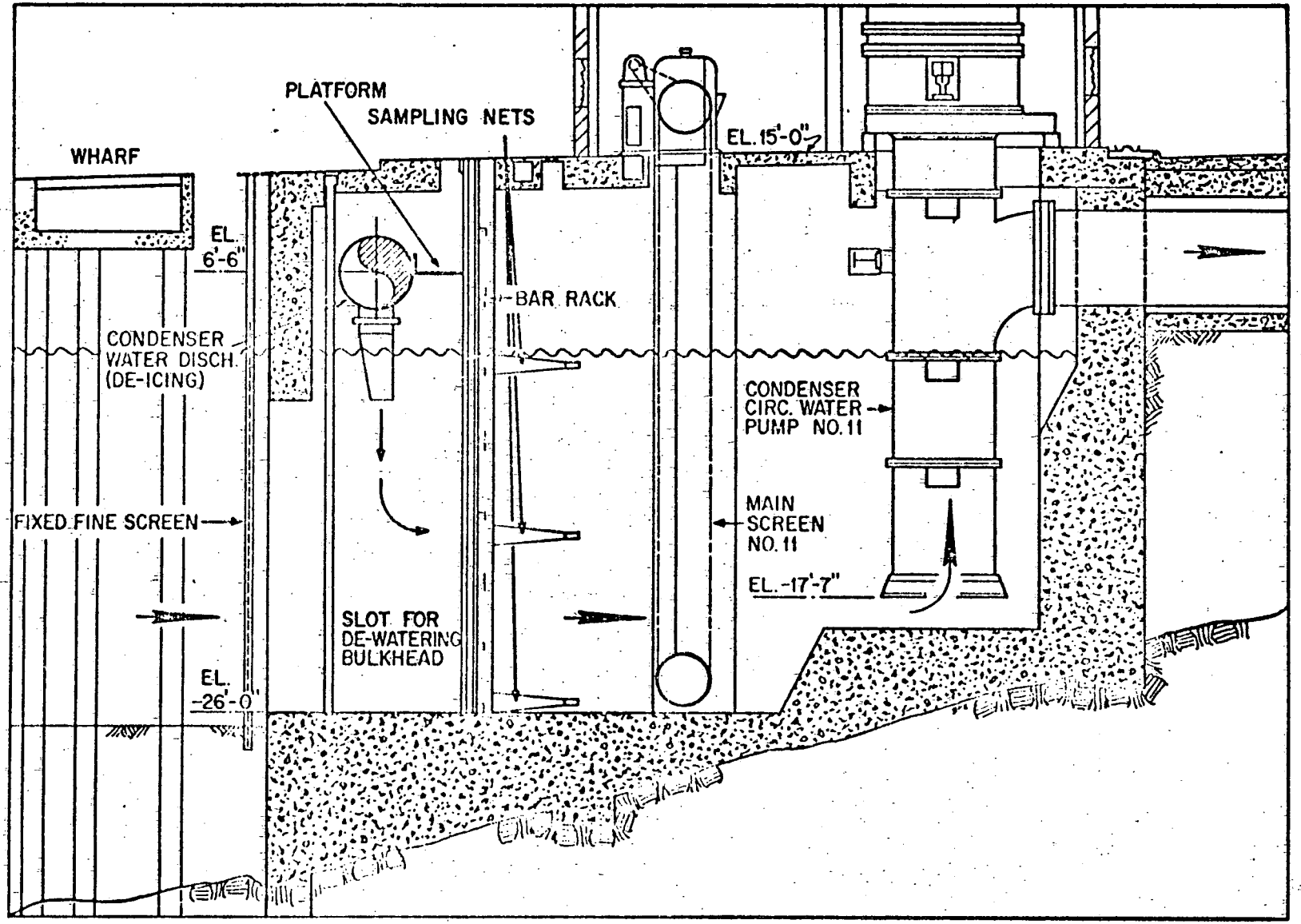


Figure 1-12. Cross-section through Unit 1 forebay showing position of sampling nets. The mouths of the nets are approximately 6 inches behind the bar racks. The configuration of the Unit 2 forebays is similar, but the distance between the bar racks and the traveling screen is greater, permitting the 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) in 1972 and 1974. 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.

Physical and chemical data for 1973 were provided by Texas Instruments, Incorporated (TI). The TI sampling stations used as data sources were selected on the basis of their proximity to New York University sample sites A through G. With the exception of air temperature all of their measurements were done on a Martek Mark II water quality monitoring system. Air temperature was monitored with a meterograph.

2.2 RESULTS AND DISCUSSION

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. These are presented with 95% confidence limits in Figures 2-1 through 2-7.

The observed air temperatures during 1973 and 1974 are shown in Figure 2-1. Air temperatures ranged from 9.1 to 32.3°C (48.4 to 90.1°F) and 12.2 to 30.9°C (54.0 to 87.6°F) for 1973 and 1974, respectively. Except for the month of May and one week in August, mean temperatures were generally higher in 1973 than in 1974; similar differences were observed between 1973 and 1972.

Water temperature and dissolved-oxygen profiles were generally similar for 1972, 1973 and 1974 (Figures 2-2, 2-3 and 2-4). In all 3 years the highest water temperatures and correspondingly lowest dissolved oxygen levels were observed in July and August in association with high air-temperature regimes. Mean water temperatures recorded for 1972 ranged from 3.5 to 25.4°C (38.3 to 77.7°F) and from 4.9 to 27.6°C (40.8 to 81.7°F) in 1973. In 1974 mean water temperatures sampled were from 8.5 to 26.8°C (47.3 to 80.2°F).

Levels of dissolved oxygen in 1974 water samples ranged from 4.8 to 15.8 mg per liter with saturation values from 63.7 to 133.3%. These compare with dissolved oxygen levels of 4.8 to 12.6 mg per liter and saturation figures of 68 to 93%, respectively, for 1972 samples. As stated earlier, dissolved oxygen data indicated generally similar trends at each depth and station for the years 1972-1974. In late July of 1973 and 1974, dissolved oxygen levels were lower by 2.0 to 2.5 mg per liter than any other values for those 2 years. These values indicate either increased oxygen consumption in the study area or intrusion into the area of water containing decreased concentrations of dissolved oxygen. As yet, no explanations for this can be given and no such

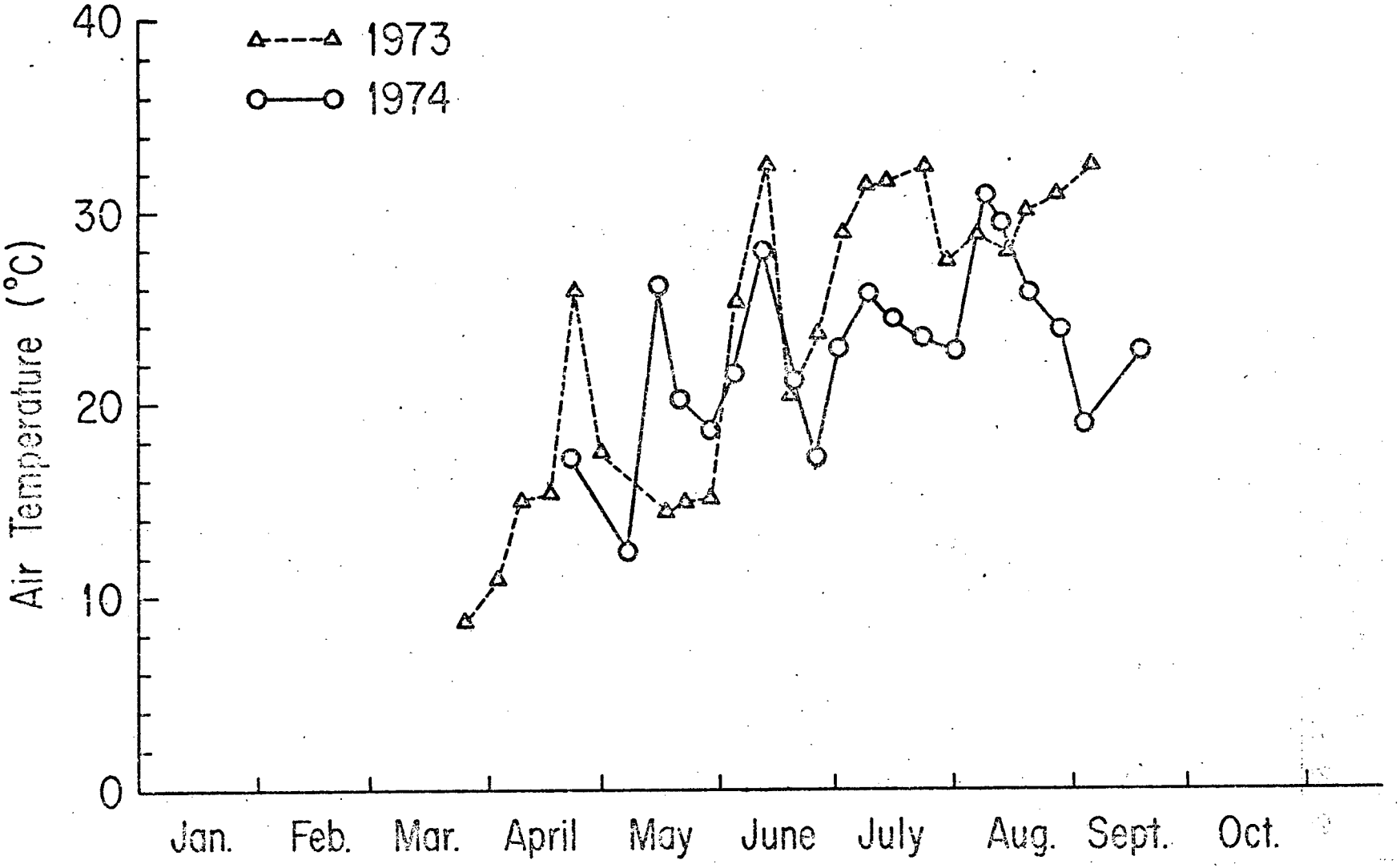


Figure 2-1. Mean daytime air temperatures in the vicinity of Indian Point in 1973 and 1974.

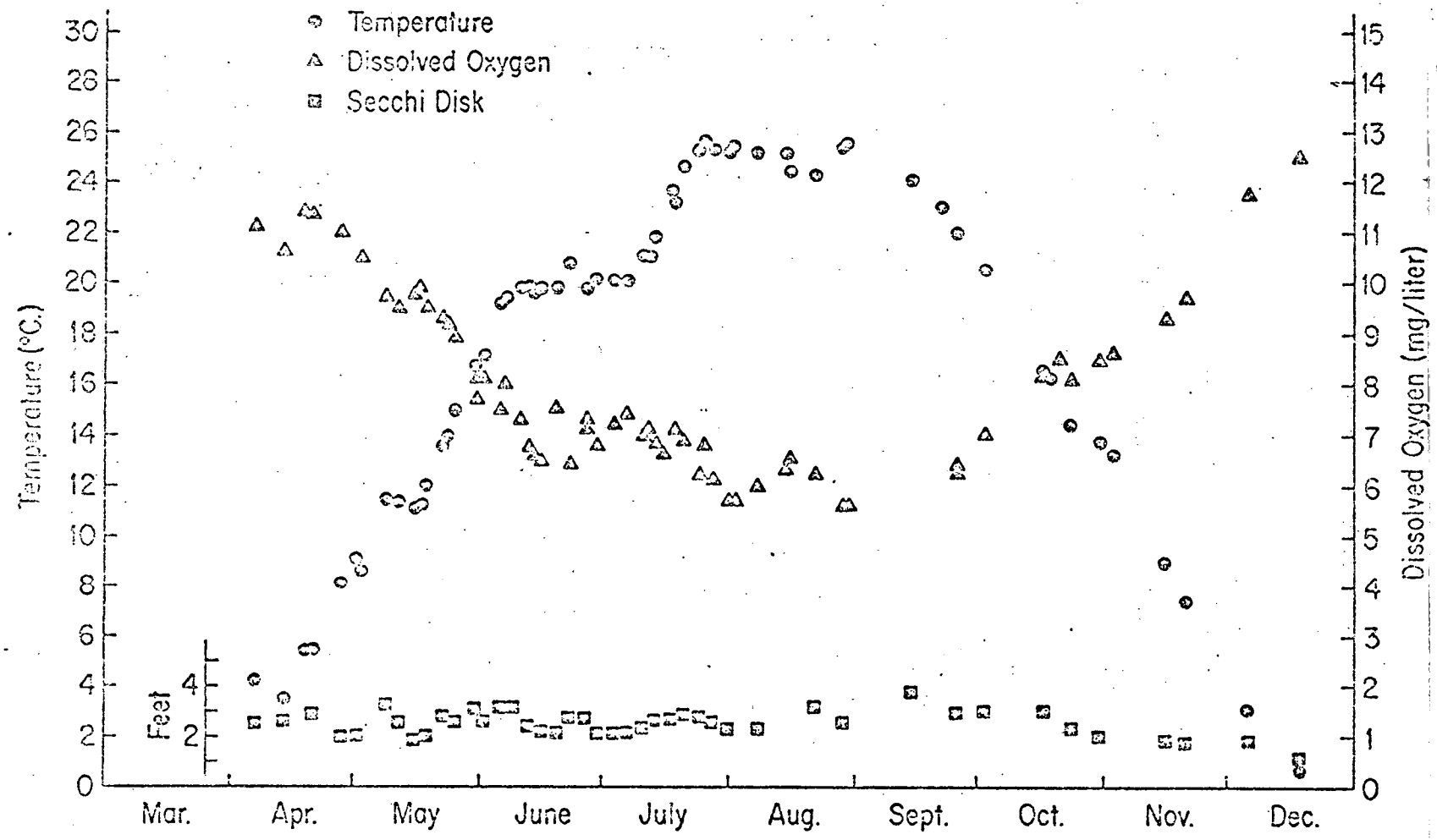


Figure 2-2. Water temperature, dissolved oxygen and Secchi-disk profiles for the Hudson River in the vicinity of Indian Point, 1972. The values shown are mean day and night surface, mid-depth, and bottom values for all stations on each sampling date.

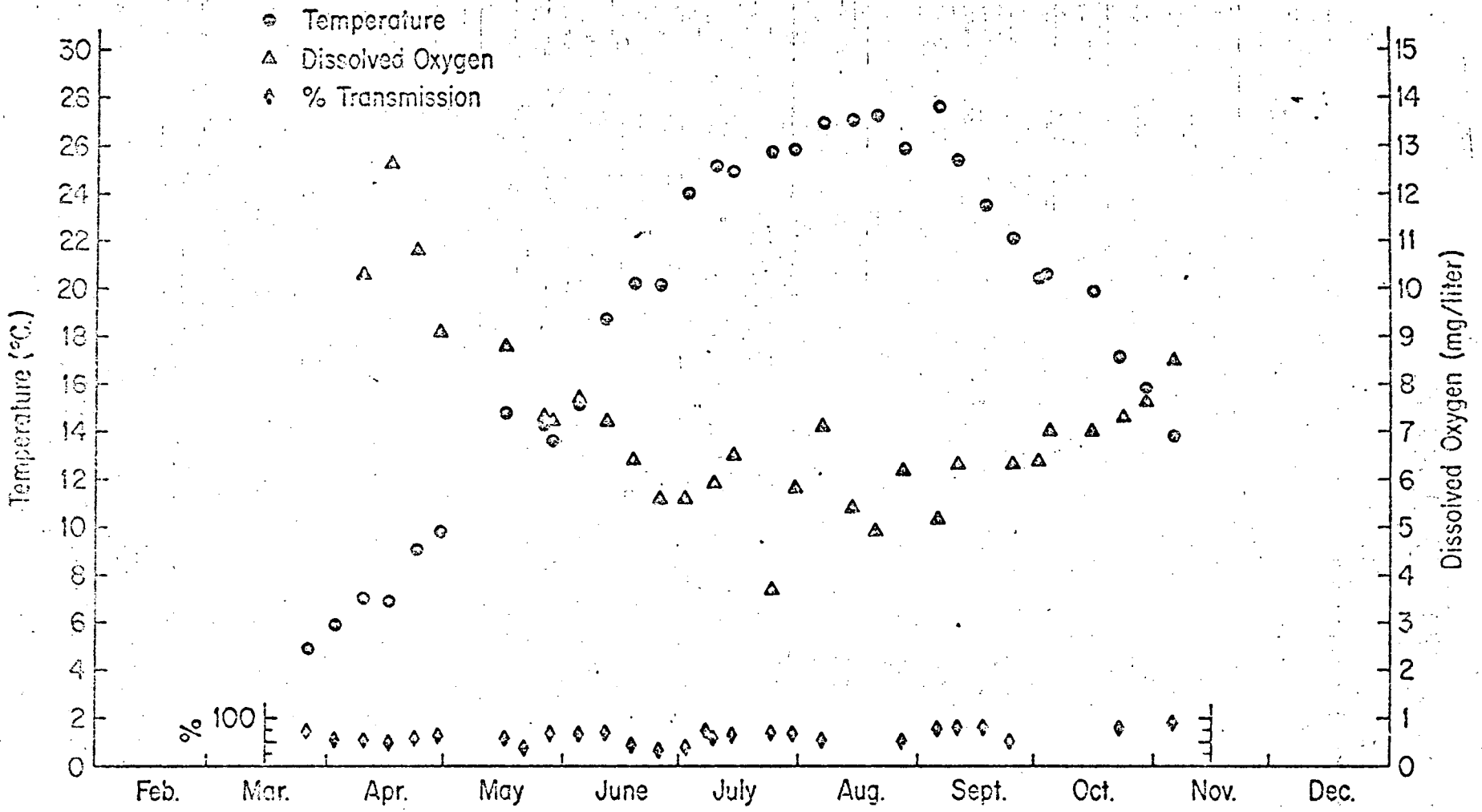


Figure 2-3. Water temperature, dissolved oxygen, and percent transmission (light) profiles for the Hudson River in the vicinity of Indian Point, 1973. The values shown are mean day and night surface, mid-depth, and bottom values for all stations on each sampling date.

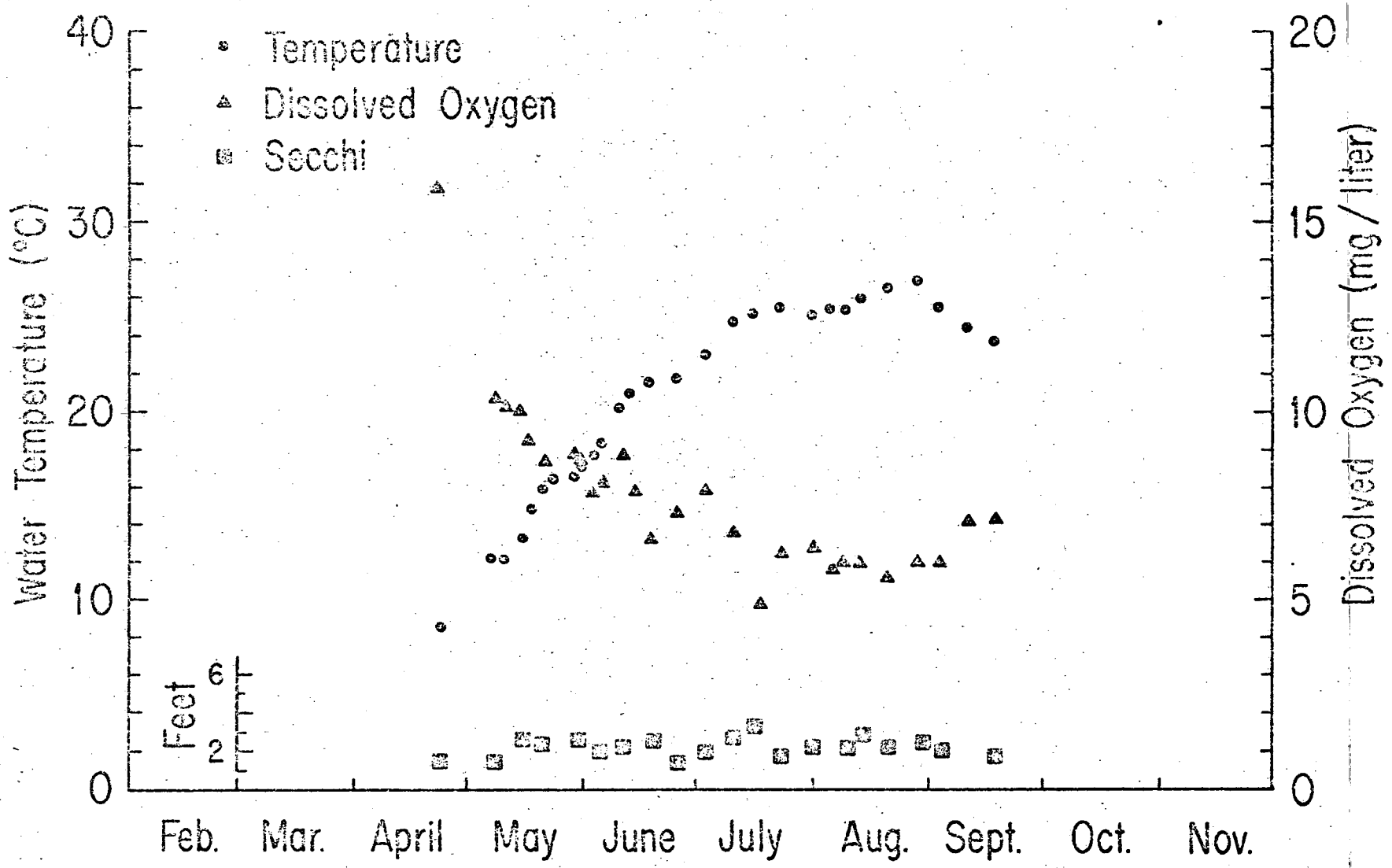


Figure 2-4. Water temperature, dissolved oxygen and Secchi-disc profiles for the Hudson River in the vicinity of Indian Point, 1974. The values shown are mean day and night surface, mid-depth and bottom values for all stations on each sampling date.

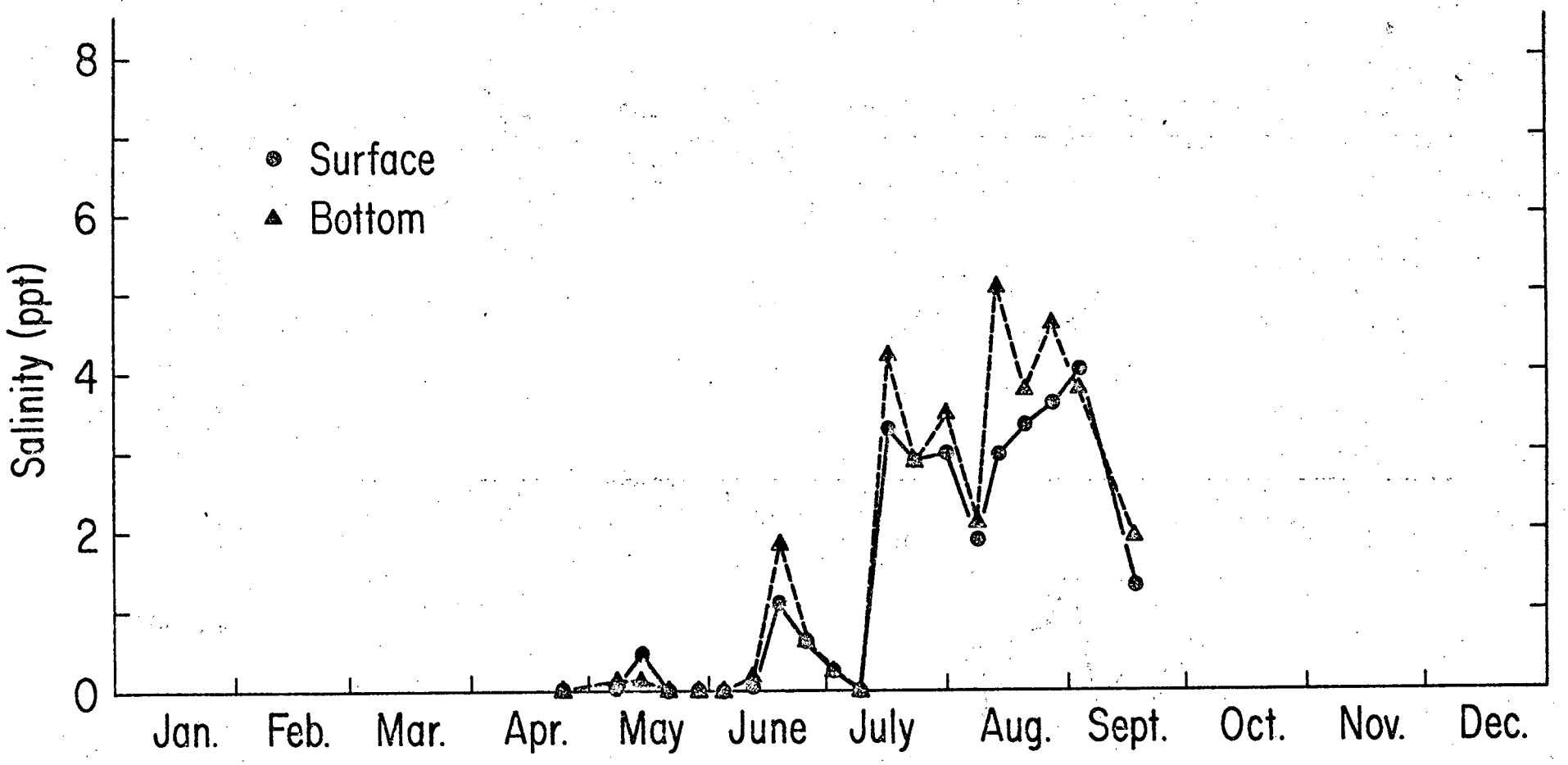


Figure 2-6. Salinity profiles for the Hudson River in the vicinity of Indian Point, 1974. The values shown are mean day surface and bottom values for all stations on each date.

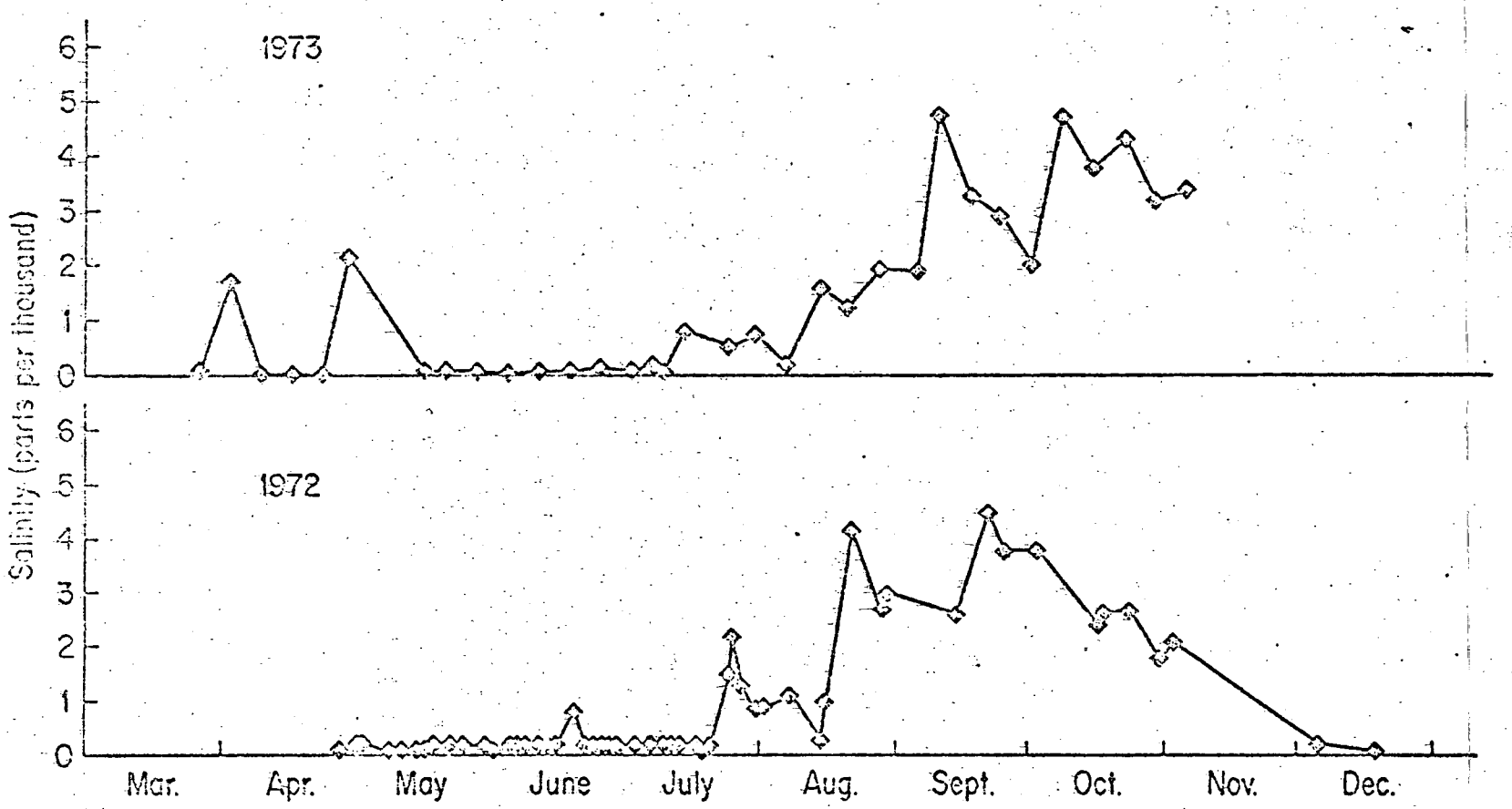


Figure 2-7. Salinity profiles for the Hudson River in the vicinity of Indian Point, 1972 and 1973. The values shown for 1972 are mean day and night surface, mid-depth, and bottom values for all stations on each date. The values shown for 1973 are means for all three depths and for all stations on each date, but based on daytime values only.

results were seen in 1972. However, such occurrences of low oxygen levels in water from Hudson River stations around the Indian Point power plant should be carefully investigated during the 1975 program.

Secchi-disc readings give a rough index of water clarity; low readings are indicative of turbid conditions. Mean Secchi-disc readings in 1974 ranged from 1.4 to 3.2 feet (Figure 2-4) without any trends, and were not substantially different from readings taken in 1972; none were taken for 1973. In view of other results presented in this volume, Secchi-disc results indicate that the water in this study area was well mixed and the cause for the low readings was suspended detritus.

Comparisons of mean pH measurements for 1972, 1973 and 1974 (Figure 2-5) show that water adjacent to Indian Point has a stable pH, ranging from 7.0 to 7.5, although pH was more variable in 1973. No explanations are evident for the 1973 variations nor for stable pH in 1972 and 1974. However, pH was determined by a different method in 1973 than in 1972 and 1974 which may underlie this slight discrepancy.

In 1974, mean salinity profiles in the Indian Point area began increasing in mid-July (Figure 2-6). A maximum mean level of 4.45 parts per thousand salinity was reached in late September, followed by a gradual decline towards pre-saltwater-intrusion levels of below 0.2 parts per thousand. The 1974 seasonal salinity profile followed a general trend similar to that noted in profiles for 1972 and 1973 (Figure 2-7). Major differences among the salinity profiles for the 3 years appear to be in the time of salt intrusion and in the magnitude of the pulses. The

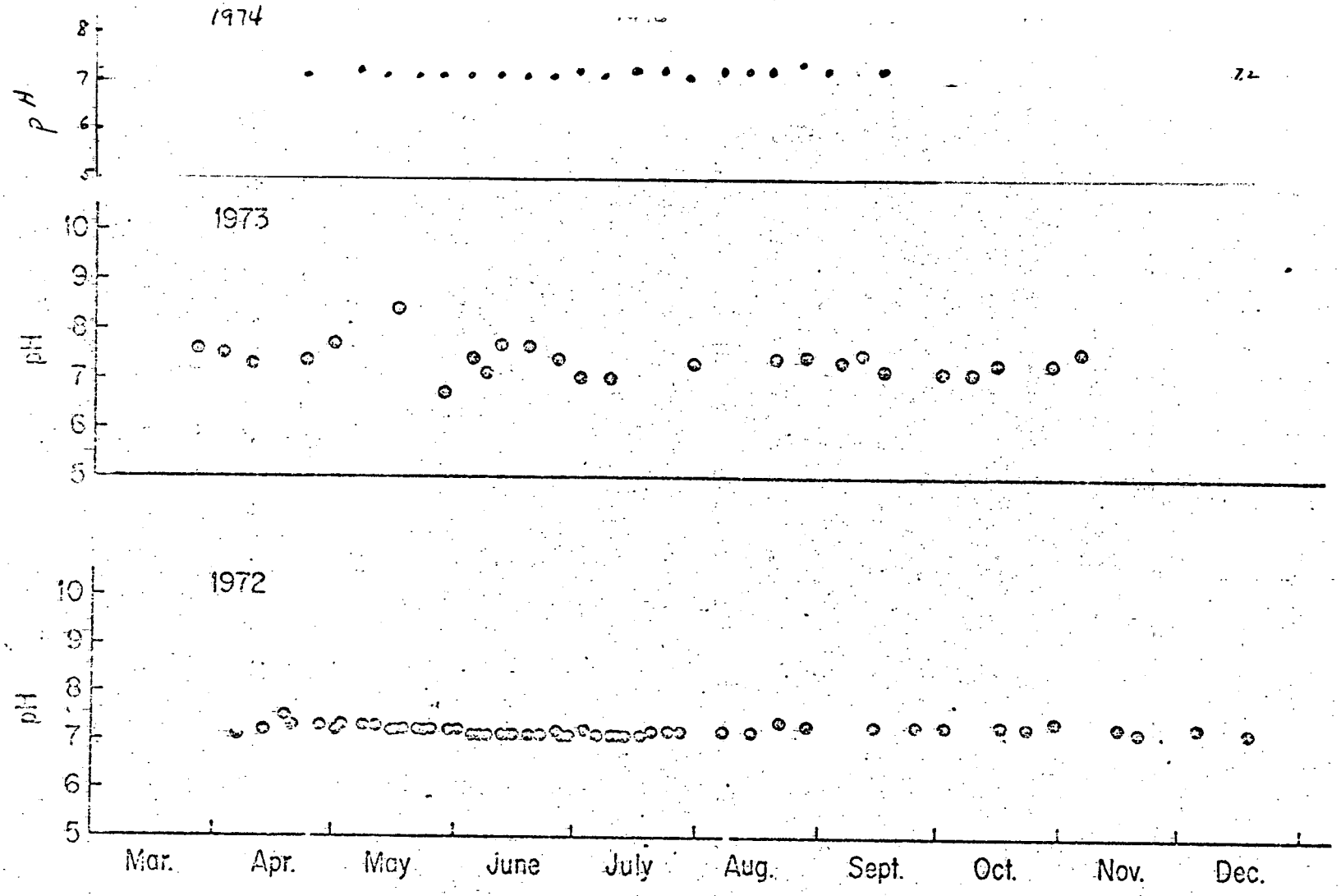


Figure 2-5. pH profiles for the Hudson River in the vicinity of Indian Point, 1972, 1973, and 1974. Values shown for 1972 are mean day and night surface, values for all stations on each date. Values shown for 1973 and 1974 are means of daytime surface, mid-depth, and bottom values for all stations on each date.

salinity profile for 1973 contained a pulse to 2.5‰ salinity in late April-early May; a slight pulse, to 0.5‰ salinity, was observed in mid-May of 1974 and none was apparent in 1972. Another pulse, to 2.0‰ salinity, had appeared approximately 1 month earlier, in late March-early April 1973; however, no data exist for comparison with the equivalent periods in 1972 and 1974.

3. BACTERIA

No bacteriological studies were done in 1974. 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.

4. PHYTOPLANKTON

4.1 PHYTOPLANTKON RIVER POPULATION STUDIES

4.1.1 Methods

Samples for phytoplankton population studies were collected weekly during the spring and summer and monthly during the fall. At each of the sampling sites A through G (Figure 1-7), a submersible pump was lowered to a depth of 20 feet and allowed to pump until all water trapped in the hose during its descent had been flushed. As the pump was raised toward the surface, whole water samples were collected. The pump was held at each 2-foot depth interval for about 1.5 minutes to insure hose flushing; a 90-ml whole-water sample from each depth was preserved immediately with an acid Lugol's solution. Once each month at each station a duplicate whole water sample was collected for chlorophyll analysis.

Photometer readings were taken on each chlorophyll sampling date to delineate the euphotic zone and levels of incident solar radiation (see section 4.2 and 8.2 for description of instrumentation and techniques).

Upon returning to the laboratory, and after being thoroughly mixed, various aliquots of the samples were passed through gridded filters (pore size 1.2μ). The aliquot size utilized was determined by the concentration of organisms and debris within each sample that could be analyzed effectively and efficiently. Determination of this concentration was done immediately after filtration by microscopic examination at 100× magnification.

After filtration, the filters were air dried at room temperature for at least 4 hours to prevent "clouding" in the mounting medium, cut to fit a standard 1 × 3 inch microscope slide, cleared, and fixed with Permount.

The phytoplankton on the filters were identified and counted with a microscope at a magnification of 1250 to 1560×. In the case of diatoms and other forms which occur as individual cells and as colonies, each cell was counted as a unit. Colonial and filamentous green and blue-green algae were counted as a single unit; any colony or filament occupying the entire microscopic field was counted as two units. Only those cells, colonies, or filaments which appeared to have normal chromatophores or, in the case of blue-greens, coloration were counted.

The majority of phytoplankton organisms observed were identified to the species level; however, the identity of a few forms was uncertain (Table 4-1). Although many of the unidentified forms were believed to be in the divisions Chlorophyta and Bacillariophyta, they were not assigned any divisional status because of distortion of distinguishing characteristics resulting from routine slide preparation.

The usual practice was to count and identify approximately 300 units per slide. Enumeration of more than 300 units per slide does not significantly increase the sensitivity of the population analysis. The number of phytoplanktonic organisms per liter (X) was calculated by the following formula (NYU, 1973).

$$X = \frac{(C)}{(F)(P)}$$

Where:

C = specimens counted
F = fraction of filter counted
P = portion of sample filtered

4.1.2. Results and Discussion

The abundance and mean values of abundance of phytoplankton per liter are shown in Tables 4-2 to 4-7 and Figure 4-1. Analyses of variance were performed on the abundances of all phytoplankton, diatoms and green algae. The differences among dates were significant ($\alpha = 0.5$) as observed in data from previous years. Significant differences among stations were indicated for total phytoplankton and green algal abundance. To determine which stations were significantly different, the Scheffé test ($\alpha < 0.10$) (Scheffé, 1959) was applied. The results of this test indicated that, for green algae, algae were more abundant at Station F than at Station A. Specific station differences were not indicated by the Scheffé test for total algal abundance.

The percent composition (mean values) of the microflora by algal groups is depicted in Figure 4-2 and shown in Tables 4-8 to 4-13. Diatoms and green algae (including unidentifiable forms) were the dominant organisms throughout the investigation. Other forms represented only a minor portion of the microflora during the year.

Microfloral species observed at each station are listed in Table 4-1. One hundred-nine phytoplankton forms were observed at Station D (located in front of the plant intakes) while 108 forms were observed at Station E (at the discharge plume); 82 of these occurred at both D and E. One hundred-twenty-two, 102, 103

Table 4-1. Assigned frequency of occurrence for phytoplankton species collected at Stations A through G in 1974. The numbers shown are the numbers of collection dates in which the species were found at each station.

Species	Stations A	B	C	D	E	F	G	Total
Bacillariophyta								
Achnanthes								
exigua Grun.	0	0	0	1	0	0	0	1
lanceolata (Breb.) Grun.	1	1	0	1	0	1	0	4
linearis var. curta H.L. Sm.	0	0	0	0	0	1	1	2
minutissima Kuetz.	1	1	1	0	1	0	0	4
sp.	0	0	0	0	2	0	0	2
Amphiprora								
paludosa W. Sm.	1	0	0	0	1	1	0	3
paludosa var. subsalina Cleve.	0	0	0	0	0	0	1	1
Amphora								
ovalis Kuetz.	0	1	0	0	0	0	0	1
ovalis var. pediculus Kuetz.	0	0	0	0	1	0	0	1
Asterionella								
bleakleyi W. Sm.	0	0	0	0	1	1	0	2
formosa Hass.	10	11	6	9	8	10	8	62
Cocconeis								
placentula Ehr.	1	3	1	0	0	2	0	7
placentula var. euglypta Ehr.	0	2	0	0	1	0	1	4
Coscinodiscus								
excentricus Ehr.	15	9	7	9	10	9	10	69
lineatus Ehr.	0	1	0	1	3	1	1	7
perferatus type	12	14	14	12	13	14	11	90
rothii (Ehr.) Grun.	1	1	3	1	1	1	1	9
sublineatus Grun.	0	0	0	0	1	0	0	1
sp. a.	0	0	4	1	3	1	3	12
sp. b.	0	0	0	0	1	1	0	2
Cyclotella								
bodanica Eulenst.	0	1	0	0	0	0	0	1
comta (Ehr.) Kuetz.	0	0	0	0	0	0	1	1
glomerata Bachm.	22	22	22	22	22	22	22	154
kuetzingiana Thw.	11	12	10	12	10	11	10	76
meneghiniana Kuetz.	19	18	19	16	19	18	18	127
stelligera Cl. & Grun.	4	3	4	4	5	8	5	33
striata (Kuetz.) Grun.	2	2	1	3	3	4	2	17
sp.	6	6	4	4	3	3	1	27

Table 4-1.(cont.)

Species	Stations A	B	C	D	E	F	G	Total
Cymbella								
affinis Keutz.	0	0	0	0	0	1	0	1
sinuata Greg.	0	0	0	0	0	0	1	1
ventricosa Kuetz.	2	1	0	0	0	0	0	3
Diatoma								
tenue Ag.	0	2	1	1	0	0	0	4
vulgare Bory.	1	1	1	1	0	1	0	5
Diploneis								
puella (Schum.) Cl.	1	1	0	0	0	0	0	2
Eunotia sp.	0	0	0	0	0	0	1	1
Fragilaria								
brevistriata Grun.	0	0	0	2	0	0	0	2
construens (Ehr.) Grun.	2	1	2	0	2	0	1	8
construens var. venter (Ehr.) Grun.	1	0	0	1	2	0	1	5
crotonensis Kitton	3	0	1	0	3	1	2	10
leptostauron (Ehr.) Hust.	0	0	0	1	1	1	1	4
vaucheriae (Kuetz.) Peters.	1	0	0	1	0	0	0	2
sp.	1	0	2	1	0	0	1	5
Gomphonema								
olivaceum (Lyng.) Kuetz.	0	0	1	0	1	0	0	2
parvulum Kuetz.	1	1	1	0	1	1	0	5
sp.	0	0	0	1	0	0	0	1
Gyrosigma								
attenuatum (Kuetz.) Rabh.	0	0	1	0	0	0	0	1
spencerii (Quek.) Griff. & Henfr.	1	1	0	2	1	1	0	6
strigilis (W. Sm.) Cl.	0	1	0	0	0	0	0	1
Melosira								
ambigua (Grun.) Muell.	9	9	6	5	9	8	8	54
ambigua var.	2	2	2	0	0	0	0	6
distans var. alpigena Grun.	12	11	10	13	12	12	13	83
granulata (Ehr.) Ralfs.	0	0	5	3	5	2	2	17
granulata var. angustissima Muell.	1	0	0	0	1	0	0	2
italica (Ehr.) Kuetz.	2	2	3	1	2	2	2	14
varians Ag.	1	2	0	1	1	1	0	6
sp. (auxospore)	4	0	1	2	2	2	2	13

Table 4-1. (cont.)

Species	Station A	B	C	D	E	F	G	Total
Meridion								
circulare (Greg.) Ag.	0	0	0	0	0	1	0	1
Navicula								
capitata Ehr.	15	13	10	10	11	11	10	80
cryptocephala Kuetz.	2	4	2	1	1	2	0	12
decussis Oestr.	0	0	0	1	1	0	0	2
lanceolata (Ag.) Kuetz.	1	0	0	1	2	1	0	5
notha Wallace	1	0	0	0	0	0	0	1
peregrina (Ehr.) Kuetz.	2	0	1	0	1	1	0	5
rhynchocephala Kuetz.	3	3	1	1	0	1	1	10
rhynchocephala var. germainii (Wall.) Patr.	5	6	4	5	5	5	3	33
salinarum var. intermedia (Grun.) Cl.	0	1	1	0	0	0	0	2
symmetrica Patr.	0	0	0	1	0	0	0	1
tripunctata var. schizonemoides (V.H.) Patr.	1	0	0	0	0	0	1	2
viridula Kuetz.	0	1	0	0	0	0	0	1
viridula var. avenacea (Breb. ex Grun.) V.H.	3	1	1	1	0	1	0	7
Nitzschia								
accomodata Hust.	5	10	8	4	6	5	5	43
acicularis W. Sm.	3	3	2	3	2	4	6	23
amphibia Grun.	1	0	2	0	1	0	1	5
angustata (W. Sm.) Grun.	0	1	0	0	1	1	1	4
apiculata (Greg.) Grun.	1	0	0	0	1	0	0	2
bremensis Hust.	0	1	0	0	0	0	0	1
capitellata Hust.	3	4	3	2	3	1	2	18
closterium (Ehr.) W. Sm.	0	0	0	0	0	1	1	2
dissipata (Kuetz.) Grun.	2	1	0	2	1	0	1	7
filiformis (W. Sm.) Hust.	1	0	0	0	0	0	0	1
fonticola Grun.	10	9	10	12	12	11	10	74
frustulum Kuetz.	1	0	1	0	0	0	0	2
holsatica Hust.	4	6	2	4	3	4	3	26
hungarica Grun.	0	0	0	1	0	0	0	1
kuetzingiana Hilse	3	5	3	5	5	3	4	28
microcephala Grun.	4	0	0	0	1	0	1	6
palea (Kuetz.) W. Sm.	10	7	7	8	4	3	8	47
parvula Levis	0	0	1	1	0	0	0	2
romana Grun.	4	1	0	2	2	0	1	10
sigma (Kuetz.) W. Sm.	5	3	5	5	4	4	2	28
stegnii	0	1	0	0	0	0	1	2
tryblionella Hantz.	5	8	7	5	5	6	5	41
tryblionella var. debilis (Arn.) A. Mayer	5	9	6	7	7	4	7	45
tryblionella var. levidensis (W. Sm.) Grun.	2	1	0	1	3	2	2	11
tryblionella var. victoriae Grun.	0	0	1	1	3	1	1	7
sp. 1	2	3	3	3	3	4	4	22
sp.	12	14	14	15	10	12	12	89

Table 4-1. (Cont.)

Species	Station A	B	C	D	E	F	G	Total
Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh.	1	0	0	0	0	0	0	1
Skeletonema costatum (Grev.) Cl.	0	0	0	1	0	0	0	1
Stephanodiscus								
astraea (Ehr.) Grun.	8	8	5	8	10	6	6	51
hantzschia Grun.	1	1	1	1	0	0	0	4
niagarae Ehr.	2	0	1	0	1	0	0	4
sp.	1	0	1	2	0	0	0	4
Surirella								
biseriata var. constricta. Grun.	0	0	1	1	0	0	0	2
ovalis Breb.	3	1	1	1	1	1	1	9
ovalis var. minor?	2	0	1	2	1	2	0	8
ovata Kuetz.	6	8	7	7	6	6	10	50
ovata var. crumena (Breb.) V.H.	1	1	0	0	0	0	0	2
Robusta Ehr.	0	0	1	0	0	0	0	1
sp.	0	0	0	1	0	1	0	2
Synedra								
acus Kuetz.	0	0	1	0	0	0	0	1
filiformis Grun.	0	1	0	0	0	0	0	1
parasitica var. subconstricta Grun.	0	0	0	1	0	0	0	1
pulchella Ralfs. ex. Kuetz.	1	2	0	0	0	1	1	5
rumpens Kuetz.	2	1	2	2	3	0	0	10
ulna (Nitz.) Ehr.	2	3	1	1	2	0	0	9
ulna var. longissima (W. Sm.) Brun.	2	1	2	0	0	2	1	8
sp.	1	2	2	2	1	2	2	12
Tabellaria fenestrata (Lyngb.) Kuetz.	2	2	1	1	2	1	0	9
Thalassiosira								
fluviatilis Hust.	2	2	2	1	3	5	5	20
sp.	0	0	0	0	1	0	0	1
Thalassionema								
nitzschioides Grun.	2	0	1	0	1	0	1	5
unidentified form	2	2	1	4	4	1	1	15
Chrysophyta								
Dinobryon	10	10	11	10	10	10	10	71
Mallomonas	1	0	0	0	0	0	0	1

Table 4-1. (cont.)

Species	Station A	B	C	D	E	F	G	Total
Synura	0	0	0	0	1	0	0	1
Euglenophyta								
Euglenoids	8	6	7	7	4	4	6	42
Pandorina	0	0	1	0	0	0	1	2
Flagellate colonies	1	0	0	1	2	0	1	5
Phacus longicauda (Ehr.) Dujardin	2	0	1	1	3	0	0	7
Chlorophyta								
Actinastrum hantzschii Lagerh.	4	3	3	2	4	3	4	23
Ankistrodesmus falcatus (Corda) Ralfs.	4	6	1	2	2	2	0	17
Characium	0	1	0	1	0	1	1	4
Closteriopsis longissima Lemm.	4	1	1	0	3	1	1	11
Closterium	1	0	0	1	2	0	0	4
Crucigenia fenestrata Schmidle	1	0	0	0	0	0	0	1
tetrapedia (Kirch.) West & West	10	11	10	8	8	5	7	59
Kirchneriella obesa (W. West) Schmidle	1	0	0	0	0	0	0	1
Micractinium pusillum Fres.	0	1	1	0	1	0	1	4
sp.	1	0	0	2	1	1	2	7
Pediastrum biradiatum Meyen	9	7	9	9	7	5	3	49
boryanum (Turp.) Mene.	1	0	0	0	0	0	0	1
duplex Meyen	9	8	10	7	9	6	7	56
simplex (Meyen) Lemm.	3	3	3	4	2	0	0	15
tetras (Ehr.) Ralfs.	1	3	1	0	0	1	1	7
Quadrigula lacustris (Chod.) G.M. Smith	1	0	0	0	0	0	0	1

Table 4-1. (cont.)

Species	Station A	B	C	D	E	F	G	Total
Scenedesmus								
abundans (Kirch.) Chodat.	3	2	0	1	1	2	1	10
acuminatus (Lag.) Chodat.	2	2	2	1	2	1	2	12
acutus Meyen	1	1	1	0	0	1	2	6
arcuatus Lemm.	1	0	1	0	1	0	0	3
aristatus Chod.	1	0	0	1	0	0	0	2
bernardi G.M. Smith	1	1	1	0	3	2	1	9
bijuga (Turp.) Lager	3	1	2	1	1	1	0	9
dimorphus (Turp.) Kuetz.	5	5	4	4	3	3	4	28
opoliensis P. Richter	0	0	0	1	0	0	0	1
quadricauda (Turp.) Breb.	21	19	19	21	18	21	18	137
sp.	14	15	17	16	16	12	17	107
Schroederia								
sp.	1	0	0	4	0	0	0	5
Selenastrum								
gracile Reinsch	0	1	1	1	0	1	1	5
Staurastrum	1	0	0	0	0	1	0	2
Tetraedron								
caudatum (Corda) Hansgirg	1	1	0	1	1	0	1	5
hastatum (Reinsch) Hansgirg	0	0	1	1	1	0	0	3
trigonum var. gracile (Reinsch) DeToni	4	3	3	1	1	3	1	16
Treubaria								
setigerum (Archer.) G.M. Smith	0	0	0	1	0	0	0	1
Cyanophyta								
Anabaena								
circinalis Raben.	0	0	0	1	0	0	0	1
sp.	1	0	0	0	0	0	1	2
trichomes	6	6	5	7	5	5	3	37
blue-green colony	3	4	8	6	7	8	4	40
Miscellaneous								
Gonyaulax, Gymnodinium, and/or Peridinium	2	0	1	2	0	2	2	9

Table 4-1. (cont.)

Species	Station A	B	C	D	E	F	G	Total
Miscellaneous (cont.)								
unidentified form	16	11	14	11	15	14	14	95
unidentified coccoid	22	22	21	22	21	22	22	152
unidentified colony > 10 cells	15	15	14	15	14	13	15	101
unidentified colony of 8 cells	16	14	14	14	11	11	14	94
unidentified colony of 4 cells	17	18	16	17	17	19	19	123
unidentified filaments	17	17	16	14	15	14	14	107

Table 4-2. Total and mean numbers of total phytoplankton (thousands) per liter in whole-river-water collections at stations A through G, with analysis of variance, 1974.

Dates	A	B	C	D	E	F	G	Mean
4/23/74	613	689	742	536	560	574	610	618
5/7/74	564	610	540	479	686	481	644	572
5/14/74	1252	1610	1685	1507	1553	1262	1747	1517
5/21/74	3456	3045	2422	3690	3045	1860	3106	2946
5/28/74	1755	1863	2440	1900	2564	5540	3366	2775
6/4/74	684	797	855	1095	1024	8177	1197	9242
6/11/74	3183	3183	5025	3355	5232	5852	5656	4498
6/18/74	4032	5555	564	533	746	1462	1489	822
7/2/74	942	940	1018	748	1053	908	851	923
7/9/74	834	608	1022	1111	937	1690	4320	1503
7/16/74	424	1394	547	608	740	995	239	706
7/23/74	1017	1096	2130	2265	1933	6300	603	2192
7/30/74	1545	1174	1286	865	1087	1459	1466	1269
8/6/74	867	919	909	1000	1060	543	1232	933
8/15/74	413	645	566	733	733	686	666	635
8/20/74	1006	1136	573	864	692	1162	1459	985
8/27/74	823	688	770	1003	902	1764	1127	1011
9/3/74	232	230	262	228	259	1146	1014	482
9/17/74	556	780	843	846	895	764	865	793
10/15/74	689	808	603	290	158	288	277	445
11/12/74	1054	1524	1701	1518	1450	1441	1417	1443
12/17/74	296	269	201	196	234	218	226	234
Mean	1028	1116	1214	1153	1252	1692	1526	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.3657	6	0.0609	2.2895*
Dates	13.2097	21	0.6290	23.6466**
Error	3.3572	126	0.0266	

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

Table 4-3. Total and mean numbers of diatoms (thousands) per liter in whole-river-water collections at stations A through G, with analysis of Variance, 1974.

	Stations							
Dates	A	B	C	D	E	F	G	Mean
4/23/74	487	599	610	432	457	481	502	510
5/7/74	438	518	441	378	596	380	545	471
5/14/74	973	1256	1297	1070	1028	925	1458	1144
5/21/74	3147	2670	2113	3431	2602	1590	2999	2651
5/28/74	1611	1755	2275	1710	2378	4789	2538	2436
6/4/74	601	681	667	998	931	672	1062	802
6/11/74	2970	2963	4911	3176	4632	5491	5418	4223
6/18/74	289	417	322	338	600	958	945	553
7/2/74	521	517	590	465	563	379	401	491
7/9/74	319	190	212	182	459	238	917	360
7/16/74	250	1017	277	291	313	386	74	372
7/23/74	308	343	652	658	568	2363	224	731
7/30/74	506	491	544	365	455	788	814	566
8/6/74	410	440	437	474	531	259	602	450
8/15/74	126	281	177	227	263	235	320	224
8/20/74	594	740	393	623	447	802	1024	661
8/27/74	528	362	433	618	613	1098	745	628
9/3/74	106	108	119	105	111	396	396	192
9/17/74	225	393	422	431	377	494	392	395
10/15/74	265	290	181	67	83	65	76	147
11/12/74	608	1103	1171	1071	1127	719	876	953
12/17/74	241	197	134	120	113	171	156	162
Mean	707	785	835	783	875	1076	1022	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.2843	6	0.0474	1.5144
Dates	21.9629	21	1.0459	33.4153**
Error	3.9393	126	.0313	

** P < 0.01

Table 4-4. Total and mean numbers of green algae (thousands) per liter in whole-river-water collection at stations A through G, with analysis of variance, 1974.

Dates	Stations A	B	C	D	E	F	G	Mean
4/23/74	120	88	133	101	97	90	97	104
5/7/74	124	92	97	99	86	99	99	99
5/14/74	279	354	388	438	520	337	289	372
5/21/74	303	367	292	248	442	270	107	290
5/28/74	145	107	165	190	186	751	827	339
6/4/74	83	117	187	93	93	146	129	121
6/11/74	213	220	114	179	560	362	238	275
6/18/74	90	137	241	190	146	504	545	265
7/2/74	421	423	428	283	490	521	445	430
7/9/74	515	418	810	926	475	1452	3403	1143
7/16/74	175	377	268	312	425	606	158	331
7/23/74	628	686	1287	1405	1191	3780	368	133
7/30/74	964	630	698	472	598	619	615	657
8/6/74	440	351	462	351	346	261	510	388
8/15/74	253	370	314	402	407	382	337	352
8/20/74	333	368	171	214	222	296	356	280
8/27/74	252	297	295	371	242	621	346	346
9/3/74	119	111	132	114	143	738	606	280
9/17/74	253	337	384	377	439	238	460	356
10/15/74	319	315	265	214	68	211	193	226
11/12/74	364	322	456	312	272	467	434	375
12/17/74	55	72	63	76	119	47	69	72
Mean	293	298	348	335	346	582	483	

ANOVA

Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Station	0.6022	6	0.1004	2.7283*
Dates	12.3441	21	0.5878	15.9728**
Error	4.6349	126	0.0368	

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

Table 4-5. Total and mean numbers of blue green algae (thousands) per liter in whole-river-water collections at stations A through G, 1974.

Dates	Stations A	B	C	D	E	F	G	Mean
4/23/74	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1
5/7/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/14/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/21/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/28/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/4/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/11/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/18/74	25.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
7/2/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7/9/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7/16/74	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.4
7/23/74	6.8	14.0	11.2	11.2	11.2	11.3	0.0	9.4
7/30/74	3.8	11.2	11.2	5.6	22.5	15.0	3.8	10.4
8/6/74	0.0	108.7	0.0	150.7	172.9	8.0	60.2	71.5
8/15/74	9.4	22.6	32.0	67.7	27.0	30.1	9.4	28.3
8/20/74	0.0	0.0	0.0	11.3	0.0	3.8	0.0	2.1
8/27/74	0.0	0.0	5.0	2.8	8.4	0.0	8.4	3.5
9/3/74	0.0	3.0	0.7	0.0	1.1	0.0	0.0	0.7
9/17/74	5.3	6.2	7.4	9.9	0.0	0.0	0.0	4.1
10/15/74	82.8	173.6	116.6	9.0	6.7	11.2	6.7	58.1
11/12/74	67.0	90.9	59.5	104.2	37.2	218.9	66.1	91.9
12/17	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.3
Mean	9.1	19.6	11.2	16.9	13.0	13.7	7.0	

Table 4-6. Total and mean numbers of chrysophytes (thousands) per liter in whole-river-water collection at stations A through G, 1974

Dates	Stations A	B	C	D	E	F	G	Mean
4/23/74	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.05
5/7/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5/14/74	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.59
5/21/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5/28/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6/4/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6/11/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
6/18/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7/2/74	0.0	0.0	0.0	0.0	0.0	7.4	4.9	1.76
7/9/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
7/16	0.0	0.0	1.5	5.0	1.8	0.0	4.5	1.82
7/23/74	65.3	53.4	168.6	174.2	163.0	146.3	11.3	111.71
7/30/74	71.3	41.2	33.8	22.5	11.2	37.5	30.0	35.35
8/6/74	17.3	19.8	9.9	24.7	9.9	14.5	60.2	22.31
8/15/74	23.6	33.8	41.4	33.8	33.8	37.6	0.0	29.14
8/20/74	79.8	28.3	7.5	15.8	22.6	60.0	78.8	41.81
8/27/74	42.5	29.2	37.5	11.2	39.3	40.5	25.3	32.23
9/3/74	6.0	7.5	9.0	7.8	2.2	12.0	9.0	7.64
9/17/74	17.7	16.6	9.9	9.9	12.4	5.0	12.5	11.99
10/15/74	2.1	2.5	2.5	0.0	0.0	0.0	0.0	1.00
11/12/74	12.4	8.3	9.9	19.8	12.4	37.2	33.0	19.00
12/17/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
Mean	15.4	10.9	15.1	14.8	14.2	18.1	12.2	

Table 4-7. Total and mean numbers of euglenoids (thousands) per liter in whole-river-water collections at stations A through G, 1974.

Dates	Stations A	B	C	D	E	F	G	Mean
4/23/74	4.9	2.2	0.0	2.2	6.8	2.2	11.3	4.2
5/7/74	1.9	0.0	2.3	2.2	4.5	2.2	0.0	1.9
5/14/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5/21/74	5.6	7.5	16.9	11.3	0.0	0.0	0.0	5.9
5/28/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/4/74	0.0	0.0	0.0	3.2	0.0	0.0	5.6	1.3
6/11/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6/18/74	0.0	2.2	0.0	4.5	0.0	0.0	0.0	1.0
7/2/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7/9/74	0.0	0.0	0.0	2.9	2.6	0.0	0.0	0.8
7/16/74	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.3
7/23/74	9.0	0.0	11.2	16.9	0.0	0.0	0.0	5.3
7/30/74	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.5
8/6/74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8/15/74	1.2	0.0	1.9	1.9	2.2	1.9	0.0	1.3
8/20/74	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.3
8/27/74	0.0	0.0	0.0	0.0	0.0	4.5	2.8	1.0
9/3/74	0.7	0.7	0.7	1.1	1.1	0.0	3.0	1.1
9/17/74	24.8	26.9	19.8	17.4	67.0	27.3	0.0	26.2
10/15/74	20.7	27.3	37.2	0.0	0.0	1.1	1.1	12.5
11/12/74	2.5	0.0	5.0	9.9	0.0	0.0	8.3	3.7
12/17/74	0.0	0.0	1.9	0.0	1.8	0.0	0.0	0.5
Mean	3.2	3.0	4.5	3.3	3.9	1.8	1.7	

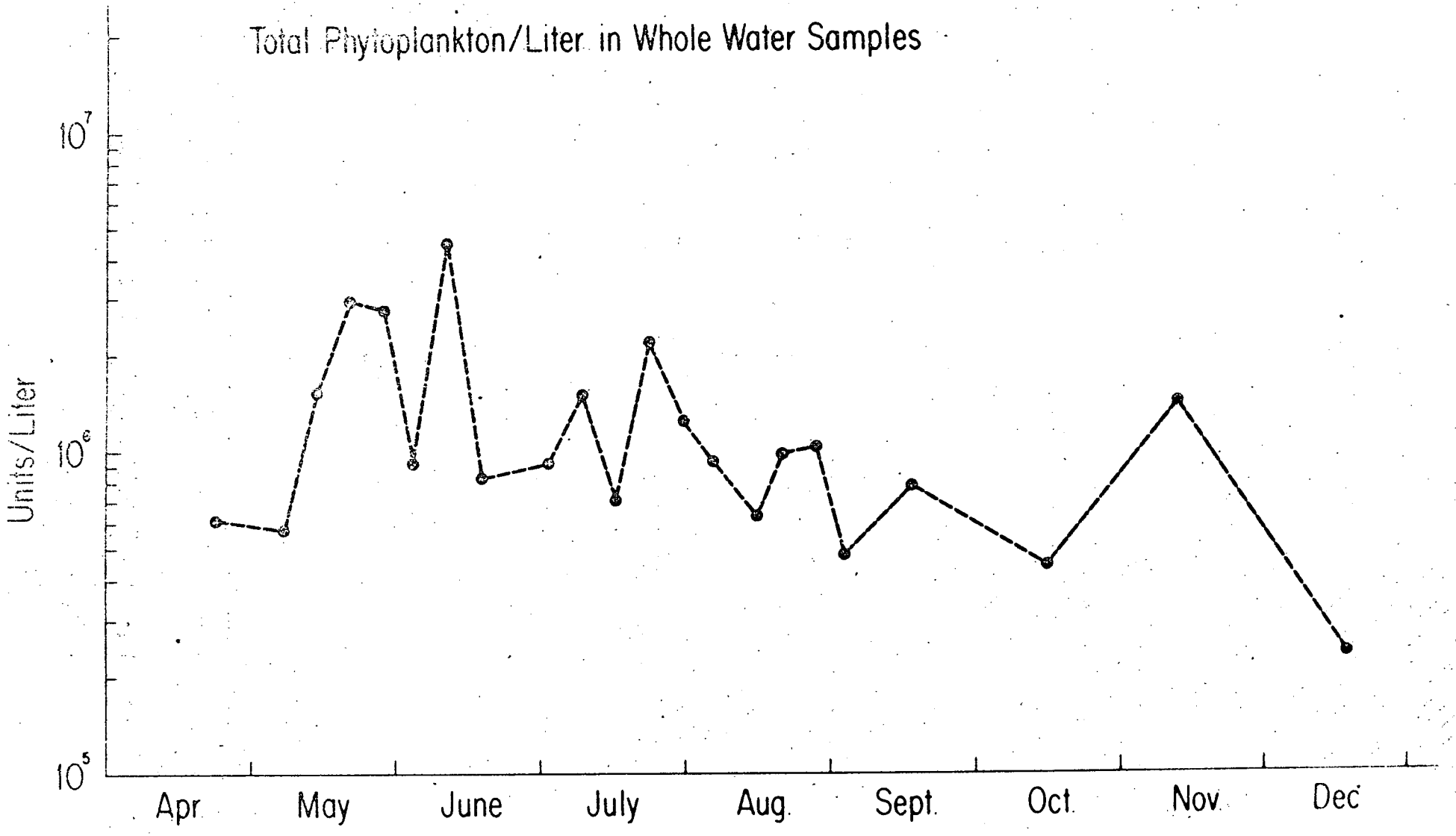


Figure 4-1. Numbers of phytoplankton per liter in whole-water samples from the Hudson River in the vicinity of Indian Point, 1974.

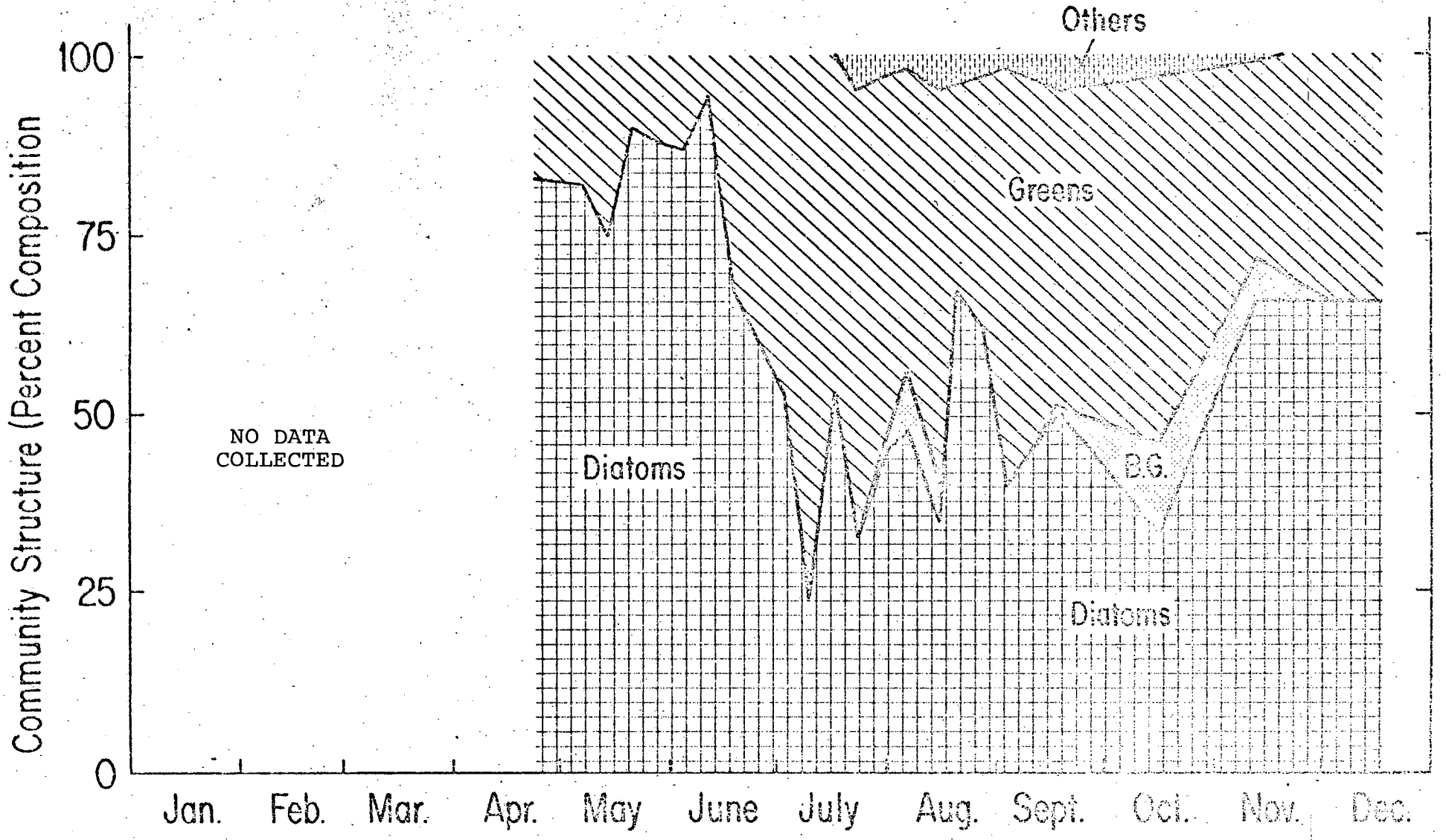


Figure 4-2. Percent composition of phytoplankton in whole-river water collection by algal groups, 1974.

Table 4-8. Percent composition of diatoms in whole-river-water collections at stations A through G, 1974.

Date	Stations A	B	C	D	E	F	G	Percent for date
04/23/74	79	87	82	81	82	84	82	83
05/07/74	78	85	82	79	87	79	85	82
05/14/74	78	78	77	71	66	73	84	75
05/21/74	91	88	87	93	86	86	97	90
05/28/74	92	94	93	90	93	86	75	88
06/04/74	88	85	78	91	91	82	89	87
06/11/74	93	93	98	95	89	94	96	94
06/18/74	72	75	57	64	81	66	63	67
07/20/74	55	55	58	62	54	42	47	53
07/09/74	38	31	21	16	49	14	21	24
07/16/74	59	73	51	48	42	39	31	53
07/23/74	30	31	31	29	29	38	37	33
07/30/74	33	42	42	42	42	54	56	45
08/06/74	47	48	48	47	50	48	49	48
08/15/74	31	34	31	31	36	34	48	35
08/20/74	59	65	69	72	65	69	70	67
08/27/74	64	53	56	62	68	62	66	62
09/03/74	46	47	46	46	43	35	39	40
09/17/74	46	50	50	51	42	65	45	50
10/15/74	38	36	30	23	53	23	28	33
11/12/74	58	72	69	71	78	50	62	66
12/17/74	81	73	67	61	49	78	69	66

Table 4-9. Percent composition of blue-green algae in whole-river-water collections at stations A through G, 1974.

Date	Stations A	B	C	D	E	F	G	Percent for date
04/23/74	0	0	0	0	0	0	0	0
05/07/74	0	0	0	0	0	0	0	0
05/14/74	0	0	0	0	0	0	0	0
05/21/74	0	0	0	0	0	0	0	0
05/28/74	0	0	0	0	0	0	0	0
06/04/74	0	0	0	0	0	0	0	0
06/11/74	0	0	0	0	0	0	0	0
06/18/74	6	0	0	0	0	0	0	0
07/02/74	0	0	0	0	0	0	0	0
07/09/74	0	0	0	0	0	0	0	0
07/16/74	0	0	0	0	0	0	0	0
07/23/74	1	1	1	1	1	0	0	0
07/30/74	0	1	1	1	2	1	0	1
08/06/74	0	12	0	15	16	2	5	8
08/15/74	2	4	6	9	4	4	1	5
08/20/74	0	0	0	1	0	0	0	0
08/27/74	0	0	1	0	1	0	1	0
09/03/74	0	1	0	0	0	0	0	0
09/17/74	1	1	1	1	0	0	0	1
10/15/74	12	22	19	3	4	4	2	13
11/12/74	6	6	4	7	3	15	5	6
12/17/74	0	0	1	0	0	0	0	0

Table 4-10. Percent composition of green algae in whole-river-water collections at stations A through G, 1974

Date	Stations A	B	C	D	E	F	G	Percent for date
04/23/74	20	13	18	19	17	16	16	17
05/07/74	22	15	18	21	13	21	15	17
05/14/74	22	22	23	29	34	27	17	25
05/21/74	9	12	12	7	15	15	3	10
05/28/74	8	6	7	10	7	14	25	12
06/04/74	12	15	22	9	9	18	11	13
06/11/74	7	7	2	5	12	6	4	6
06/18/74	22	25	43	36	20	35	37	32
07/02/74	45	45	42	38	47	58	52	47
07/09/74	62	69	79	83	51	86	79	76
07/16/74	41	27	49	51	57	61	66	47
07/23/74	62	63	60	62	62	60	61	61
07/30/74	62	54	54	55	55	42	42	52
08/06/74	51	38	51	35	33	48	41	42
08/15/74	61	57	56	55	56	56	51	56
08/20/74	33	32	30	25	32	26	24	28
08/27/74	31	43	38	37	27	35	31	34
09/03/74	51	48	50	50	55	64	60	58
09/17/74	46	43	46	45	49	31	53	45
10/15/74	46	39	44	74	43	73	70	51
11/12/74	35	21	27	21	19	32	31	26
12/17/74	19	27	31	39	51	22	31	34

Table 4-11. Percent compostion of chrysophytes in whole-river-water collections at stations A through G, 1974.

	Stations							
Date	A	B	C	D	E	F	G	Percent for date
04/23/74	0	0	0	0	0	0	0	0
05/07/74	0	0	0	0	0	0	0	0
05/14/74	0	0	0	0	0	0	0	0
05/21/74	0	0	0	0	0	0	0	0
05/28/74	0	0	0	0	0	0	0	0
06/04/74	0	0	0	0	0	0	0	0
06/11/74	0	0	0	0	0	0	0	0
06/18/74	0	0	0	0	0	0	0	0
07/02/74	0	0	0	0	0	1	1	0
07/09/74	0	0	0	0	0	0	0	0
07/16/74	0	0	0	1	0	0	2	0
07/23/74	6	5	8	8	8	2	2	5
07/30/74	5	4	3	3	1	3	2	3
08/06/74	2	2	1	3	1	3	5	2
08/15/74	6	5	7	5	5	6	0	5
08/20/74	8	3	1	2	3	5	5	4
08/27/74	5	4	5	1	4	2	2	3
09/03/74	3	3	3	3	1	1	1	2
09/17/74	3	2	1	1	1	1	2	2
10/15/74	0	0	0	0	0	0	0	0
11/12/74	1	1	1	1	1	3	2	1
12/17/74	0	0	0	0	0	0	0	0

Table 4-12. Percent compostion of euglenoids in whole-river-water collections, 1974.

	Stations							
Date	A	B	C	D	E	F	G	Percent for date
04/23/74	1	0	0	0	1	0	2	1
05/07/74	0	0	0	1	1	1	0	0
05/14/74	0	0	0	0	0	0	0	0
05/21/74	0	0	1	0	0	0	0	0
05/28/74	0	0	0	0	0	0	0	0
06/04/74	0	0	0	0	0	0	1	0
06/11/74	0	0	0	0	0	0	0	0
06/18/74	0	0	0	1	0	0	0	0
07/02/74	0	0	0	0	0	0	0	0
07/09/74	0	0	0	0	0	0	0	0
07/16/74	0	0	0	0	0	0	1	0
07/23/74	1	0	1	1	0	0	0	0
07/30/74	0	0	0	0	0	0	0	0
08/06/74	0	0	0	0	0	0	0	0
08/15/74	0	0	0	0	0	0	0	0
08/20/74	0	0	0	0	0	0	0	0
08/27/74	0	0	0	0	0	0	0	0
09/03/74	0	0	0	1	0	0	0	0
09/17/74	5	4	2	2	8	4	0	3
10/15/74	3	3	6	0	0	0	0	3
11/12/74	0	0	0	1	0	0	1	0
12/17/74	0	0	1	0	1	0	0	0

Table 4-13. Percent composition of total phytoplankton for 1974, by station.

	Stations							
Agal Group	A	B	C	D	E	F	G	Mean
Blue greens	0	1	0	1	1	0	0	0
Greens	28	26	28	29	29	34	31	29
Chrysophytes	1	0	1	1	1	1	0	1
Diatoms	68	70	68	67	68	63	66	67
Euglenophytes	0	0	0	0	0	0	0	0

97 and 96 species were observed at river stations A, B, C, F and G, respectively.

The frequency of occurrence for each phytoplankton species, i.e., the number of collection dates on which the species was observed, is shown also in Table 4-1. A species observed at every station on each collection date would have the maximum assigned frequency of 154 (7 stations × 22 collection dates). From Table 4-1, it can be seen that the most common species included Cyclotella glomerata, C. menghiniana, green coccoids, Scenedesmus quadricauda, and four-celled colonies of green algae. Of the 177 forms identified, 52 (29.4%) were common to all seven stations.

Chlorophyll a at the river stations (Table 4-14) ranged from a high of 3.1 mg/m^3 in June, at Station E, to a low of 1.2 mg/m^3 in December, at Station D. Chlorophyll a, often viewed as an estimate of phytoplankton standing crop, showed a gradual increase from May to July, followed by a decline in August through September. Chlorophyll a concentration again increased during October and November (Table 4-14). The autumn increase in chlorophyll a concentrations coincided with increased algal abundances. For the sampling year, regression analysis showed chlorophyll a values to be positively related to algal abundance ($r = 0.597; p < 0.05$) but inadequate as a predictive tool ($r^2 = 0.356$) for purposes of environmental assessment.

Chlorophyll a varied by date and among stations on a given date (Table 4-1); however, station differences exhibited no consistent pattern.

Table 4-14. Summary of results for monthly phytoplankton samples collected at stations A through G, 1974. Number of samples per station was 4 for May, July and August; 3 for June; 2 for September and 1 each for April, November and December.

Date	Station	Chlorophyll a (mg/m^3)	Standard error	Scheffe test	Surface light X 10^{-3} ($cal/cm^2/sec$)	Euphotic zone (cm)	Cell count (X $10^6/l$)
5/07/74	A	2.36	± 0.11	F<G	1.56	5.0	0.56
	B	1.99	0.09		3.27	4.5	0.61
	C	1.92	0.09		2.91	4.3	0.55
	D	1.93	0.10		3.88	4.5	0.48
	E	1.92	0.07		2.27	5.0	0.69
	F	1.85	0.19		2.27	5.1	0.48
	G	2.41	0.04		2.92	5.0	0.64
	MEAN	2.05			2.72		0.57
6/04/74	A	2.58	± 0.08	C<D,E	3.25	5.5	0.68
	B	2.75	0.11	F<D,E	3.25	6.5	0.80
	C	2.14	0.04		3.25	4.5	0.86
	D	3.04	0.02		3.25	3.5	1.09
	E	3.11	0.30		2.74	3.5	1.02
	F	2.16	0.07		2.92	5.5	0.82
	G	2.67	0.08		1.60	6.0	1.19
	MEAN	2.64			2.89		0.92
7/16/74	A	2.63	± 0.13	B>A,C,D,E, F,G	1.46	12.0	0.42
	B	6.28	0.04		N.D.	N.D.	1.39
	C	2.56	0.04		N.D.	N.D.	0.55
	D	2.52	0.09		2.27	10.0	0.61
	E	2.57	0.60		1.54	11.0	0.74
	F	2.05	0.02		3.08	12.0	1.00
	G	1.33	N.D.		4.05	11.5	0.24
	MEAN	2.85			2.48		0.71
8/06/74	A	1.51	± 0.07	N.D.	3.25	8.0	0.87
	B	1.85	0.19		5.18	7.5	0.92
	C	1.83	0.15		3.75	7.5	0.91
	D	1.82	0.26		4.05	7.5	1.00
	E	1.38	0.22		3.08	6.0	1.06
	F	1.90	0.41		3.40	6.5	0.54
	G	1.86	0.23		3.40	5.8	1.23
	MEAN	1.74			3.73		0.93

Table 4-14 (Cont.)

Date	Station	Chlorophyll a (mg/m^3)	Standard error	Scheffe test	Surface light X 10^{-3} ($cal/cm^2/sec$)	Euphotic zone (cm)	Cell count (X $10^6/l$)
9/17/74	A	1.38	± 0.21	N.D	1.77	5.0	0.56
	B	1.41	0.18		2.74	6.5	0.78
	C	1.42	0.10		3.25	6.0	0.84
	D	1.39	0.07		3.00	6.0	0.85
	E	1.58	0.43		3.08	4.0	0.90
	F	1.43	0.11		3.88	6.0	0.76
	G	1.97	0.03		3.40	8.0	0.87
	MEAN	1.51			2.96		0.79
10/15/74	A	2.37	± 0.30	N.D.	0.10	9.0	0.69
	B	2.03	0.11		0.29	7.0	0.81
	C	2.21	0.09		0.16	8.0	0.60
	D	2.08	0.18		0.16	6.0	0.29
	E	2.52	0.03		0.11	6.0	0.16
	F	1.97	0.10		0.10	5.0	0.29
	G	2.35	0.05		0.08	7.5	0.28
	MEAN	2.22			0.14		0.45
11/12/75	A	2.58	± 0.13	B> C,F,G	N.D.	N.D.	1.65
	B	2.86	0.04	A> C,F,G	"	"	1.52
	C	1.95	0.16	E> C,F,G	"	"	1.70
	D	2.35	0.10	D> G	"	"	1.52
	E	2.53	0.16		"	"	1.45
	F	1.89	0.08		"	"	1.44
	G	1.66	0.03		"	"	1.42
	MEAN	2.26					1.44
12/17/74	A	1.65	± 0.08	N.D.	0.78	4.0	0.30
	B	1.22	0.12		0.86	5.0	0.30
	C	1.43	0.14		0.63	4.5	0.20
	D	1.19	0.08		0.58	4.5	0.20
	E	1.48	0.16		0.54	4.8	0.23
	F	1.46	0.11		0.63	5.0	0.22
	G	1.30	0.08		0.78	4.5	0.23
	MEAN	1.39			0.69		0.23

Mean chlorophyll a values, mean phytoplankton abundance, and incident-light values are compared in Figure 4-3. The maximum depth of the euphotic zone occurred in July; the depth of the euphotic zone remained in excess of 5.0 feet during the summer and fall (July through October, Table 4-14).

The numbers of species of various groups of organisms within a river are usually fairly consistent from one river to another (Patrick, 1961). The species and abundances may be totally different depending on the inherent water quality and type and amount of pollution associated with each river. The abundances of Hudson River phytoplankton and the species comprising the phytoplankton community indicate that at Indian Point, as well as at other sampling sites from Lloyd to Haverstraw, the Hudson River is a rather typical Atlantic coastal estuary, supporting a highly productive microflora and showing few blooms of noxious algal forms (QLM, 1974; LMS, 1975a, 1975b). Comparison with other estuaries (e.g. Flemer et al., 1971; Carpenter, 1972) shows a great similarity of species, standing crop and abundance.

Whole-water phytoplankton abundance in 1974 was similar to that recorded in 1972, showing maximum abundance in the early summer ($> 10^6$ cells/liter), and declining to values slightly less than 10^6 cells/liter in late summer and early fall. In both years, November samples were in excess of 10^6 cells/liter at a time coincident with the late-fall diatom pulse. The results of 1974 river phytoplankton studies coincide closely with results obtained in other studies of the same region of the river

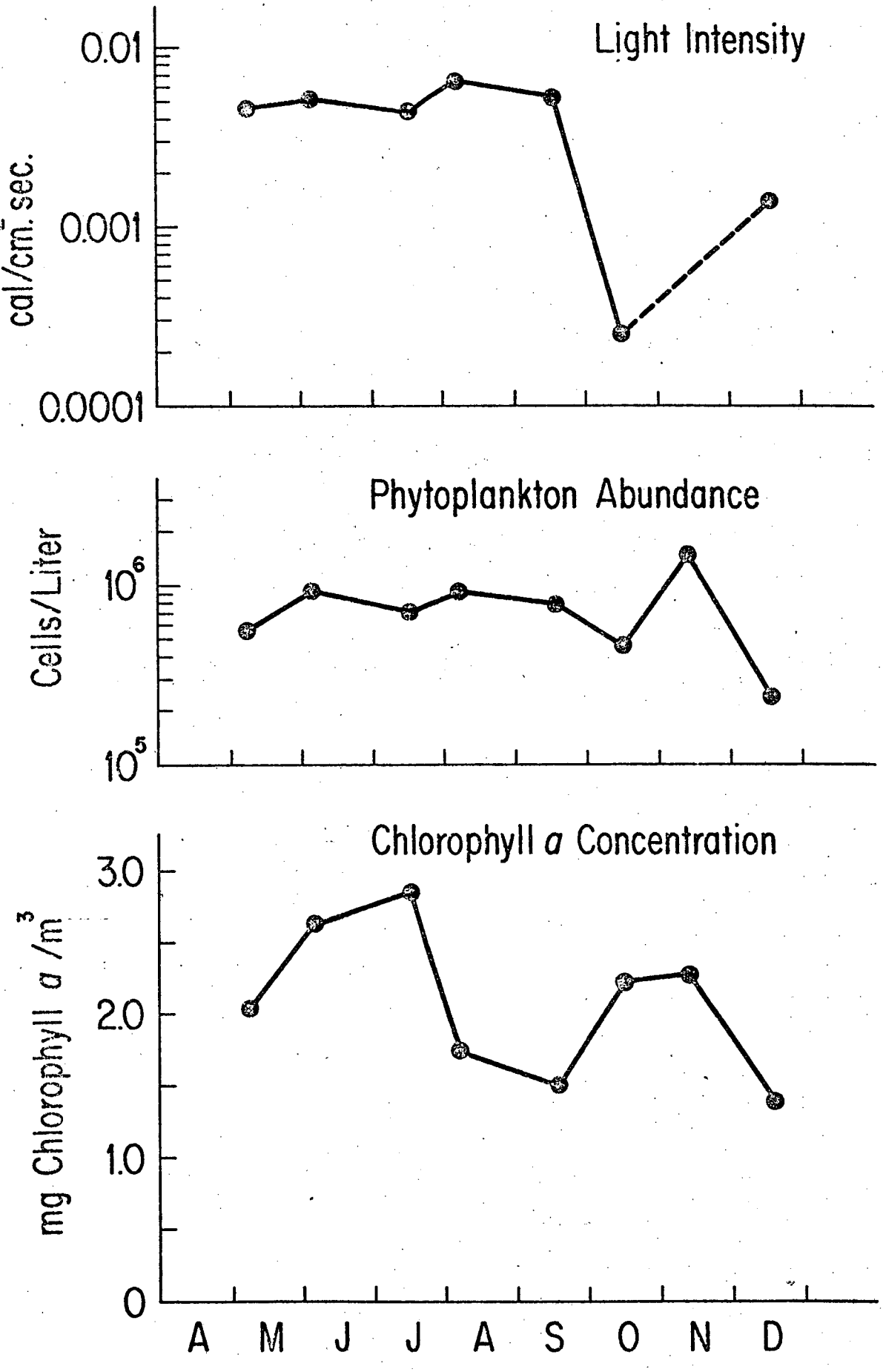


Figure 4-3. Light intensity (cal/cm^2/sec), mean phytoplankton abundance and mean chlorophyll a (mgchla/m^3) for monthly samples collected at Stations A through G, 1974.

in 1973 and 1974 (LMS, 1974; LMS, 1975, in press).

There has been much discussion in the past as to the environmental factors which determine phytoplankton abundance; the major factors being nutrients, light, temperature and grazing (Raymont, 1963; Hutchinson, 1967). Physical/chemical studies generally do not provide evidence of any specific factor or factors which may be associated with the summer-early fall decline in phytoplankton abundance (LMS, 1974; T.I., 1974). Examination of phytoplankton-abundance data in relation to microzooplankton abundance (Section 5 of this report) demonstrates that the summer decrease in phytoplankton may be the result of intensive grazing, primarily by microcrustaceans.

The proportional representation of the various algal groups (greens, diatoms, blue-greens and "other") differed somewhat between 1972 and 1974, in that the contribution of diatoms to the community remained relatively high throughout 1974 (Figure 4-2). in 1972 diatoms contributed as little as 5% to the community during the month of August.

The proportional representation of diatoms and green algae differed between years; however, the succession of algal forms in whole-water samples remained consistent with previous years (New York University, 1973; 1974). Spring samples were dominated by diatoms (Figure 4-2), followed by an increased proportion of greens in the summer and an increase in blue-greens in the fall.

The precise pattern of algal succession in estuaries, generally viewed as a constant, has had to be re-evaluated by present

investigators since recognition of the importance of nannoplankton in photosynthetically-based systems (Yentcsh and Ryther, 1967; Kalff, 1969; Hutchinson, 1967; New York University, 1974). Whole-water analysis, first undertaken on the Hudson River in 1972 and 1973, has demonstrated profound differences between net-plankton data and whole-water data with respect to abundance, species diversity, and proportional representation by groups (New York University, 1974; QLM, 1974). Two major points should be made: first, from an ecological perspective, whole-water sampling is more meaningful to an assessment of water-body function and; second, the taxonomy of classic patterns of species succession may need to be revised.

4.2 ENTRAINMENT EFFECTS STUDIES

4.2.1 Intake and Discharge-Canal Studies

4.2.1.1 Methods

Phytoplankton samples for entrainment studies were collected at the plant intakes, condenser waterboxes, discharge canal and thermal plume during normal plant operation and during times of plant chlorination (Figure 1-9). Samples from the river, away from immediate influences of the Indian Point power plant were used as controls and were compared to intake and discharge-canal samples. Other comparisons were made between the intake and condenser samples, intake and discharge-canal samples, intake and plume samples and discharge-canal and plume samples. Collection procedures are as described previously in Section 4.1. After collection the samples were transported to the Indian Point laboratory for testing; aliquots were removed for species enumeration and for the estimation of photosynthetic activity and chlorophyll a content.

Photosynthesis was estimated by measuring the ^{14}C-uptake of phytoplankton using the light-and-dark-bottle comparison technique (Strickland and Parsons, 1972). During the months of April, May and June six 300-ml samples were placed in standard BOD bottles and spiked with approximately 10 microcurries ^{14}C as $NaH^{14}CO_3$. Carbonate alkalinity and pH were determined for each aliquot. Four light bottles and two dark bottles were incubated for 4 hours in water baths supplied with flowing river water; illuminance at approximately 600 foot-candles was supplied by a bank of daylight fluorescent lights suspended above the water bath. After

July 9 the number of samples taken for ^{14}C studies was reduced to two, one light bottle and one dark bottle. A portion of each sample collected was retained for 24 hours at ambient river temperature prior to incubation with ^{14}C in order to test for possible recovery and/or possible latent effects as a result of plant passage.

After 4 hours, 50-ml samples were removed from the BOD bottles and filtered (0.45μ Millipore filters). One 50-ml aliquot was taken from each bottle, but after July 9, four 50-ml replicate samples were removed from each of the light and dark bottles.

Filters were placed in vials containing 20 ml of previously prepared scintillation "cocktails" consisting of toluene, triton-X and permafluor. ^{14}C-uptake was counted on a liquid scintillation counter. Photosynthesis was computed using the following formula from Saunders, et al., 1962:

$$P \text{ (mg carbon/m}^3\text{/hr)} = \frac{r}{R} \quad \frac{\text{Total volume}}{\text{Volume filtered}} \quad \frac{1}{N} \quad C \quad 10^3$$

r = disintegrations/min of sample
R = disintegrations/min of total microcuries added
N = incubation time
f = isotope correction factor
C = alkalinity × correction factor

Four 50-ml samples were filtered through Whatman GF/C (glass-fiber filters) for chlorophyll a content; 1 ml of $MgCO_3$ (1% w/v) was added a buffer. After filtration the samples were homogenized in 90% acetone and fluorescence was determined with a Turner Model-111 fluorometer. Chlorophyll a was computed using

the formula below (Strickland and Parsons, 1972):

$$\text{Chlorophyll } \underline{a} \text{ (mg/m}^3\text{)} = F_D \frac{\tau}{\tau-1} (R_B - R_A)$$

F_D = fluorometer door correction factor = 0.0016
τ = ratio of chlorophyll/phaeophytin = 2.15
R_B = first reading on fluorometer before acidification
R_A = second reading on fluorometer after acidification

A 250-ml aliquot was removed from each sample and preserved with Lugol's iodine solution. A 50 or 100-ml subsample was removed and filtered through a 1.2μ filter. The filter was then mounted on a microscope slide and the phytoplankton enumerated and identified, (See Methods in Section 4.1 of this report.)

All data were analyzed using a one-way analysis of variance ($\alpha = .05$) and a Scheffé test for comparison of means.

4.2.1.2 Results and Discussion

Table 4-15 and Figures 4-4 and 4-5 show the comparative effects of plant passage on phytoplankton from substantially different ambient temperatures, as reflected in photosynthetic activity (estimated from ^{14}C-uptake chlorophyll *a* content, and algal abundance. The parameters analyzed varied by season as river ambient temperatures varied from 8.2°C (46.8°F) in spring to a summer maximum of 26.1°C (79.0°F). By December, river temperature had decreased to 10.5°C (50.9°F). During this period, plant-imposed ΔT varied, ranging from a low of 1.5°C (2.7°F) on June 6 to 24.0°C (43.2°F) on December 18 (see Table 4-15 and Figures 4-4 and 4-5). The mean temperature rise at Unit 2 was 8.2°C (14.6°F); ΔT at Unit 1 varied from 5.0°C (9.0°F) to 6.8°C (12.2°F).

Table 4-15. Summary of results for plant effects on entrained phytoplankton. C_1 and C_2 = Unit 1 and Unit 2 condensers, I and II = Unit 1 and Unit 2 intakes, D = Discharge Canal, P = Plume, R = River. [1]Error for all groups from 8 determinations. [2]Error for all groups from 4 determinations.

Date	Station	Temp. (°C)	Cell counts (X 10^6/l)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Chlorophyll a (mg/m^3)	Standard[2] error	Scheffe test	Photosynthetic activity (mg C/mg Chl a/m^3/hr)
4/16/74	I	8.2	0.44	6.38	± 0.75	D < I,II,C_1,	0.70			9.11
	C_1	15.0	0.48	4.76	0.46	C_2,D,P,R	0.75			6.35
	II	8.2	0.40	6.81	0.57		0.72			9.46
	C_2	18.0	0.44	4.04	0.51		0.74			5.46
	D	18.0	0.46	3.95	1.02		0.68			5.80
	P	12.5	0.47	4.62	0.89		0.70			6.60
	R	7.5	0.46	5.36	0.87		0.65			8.25
4/17/74	I	8.2	0.43	1.44	2.75	P > I,II,C_1,	0.77			1.87
	C_1	8.2	0.52	1.88	2.28	C_2,D	0.84			2.24
	II	8.2	0.36	2.21	2.06	R > I,II,C_1	0.79			2.80
	C_2	8.2	0.41	4.54	0.83	C_2 > I	0.75			6.05
	D	8.2	0.44	3.12	0.80		1.19			2.62
	P	8.2	0.41	6.17	0.49		0.88			7.01
	R	8.2	0.41	5.87	1.05		0.79			5.59
5/21/74	I	16.0	4.71	82.15	±14.84	P< I,II,C_1,	4.47	± 0.11	R< C_2,P,D	18.37
	C_1	21.0	5.27	68.76	1.62	C_2,D,P,R	4.46	0.10		15.41
	II	16.0	4.41	76.87	2.66		4.28	0.14		17.96
	C_2	17.5	5.91	68.34	5.09		4.68	0.22		14.60
	D	18.8	3.92	78.18	3.42		4.88	0.08		16.02
	P	17.2	3.39	9.97	1.98		4.63	0.15		2.15
	R	15.0	3.60	64.39	2.24		3.83	0.16		16.81
5/22/74	I	16.0	4.34	111.67	9.13	P< I,II,C_1,	6.64	0.21	P< I,II	16.81
	C_1	16.0	3.93	102.26	9.25	C_2,D,P,R	7.25	0.55		14.10
	II	16.0	6.57	112.74	5.47	C_2 < I,II,C_1,R	6.62	0.31		17.03
	C_2	16.0	4.93	70.81	4.79	D < I,II	5.09	0.23		13.91
	D	16.0	3.56	79.69	3.58		6.14	0.05		12.98
	P	16.0	1.58	11.22	0.68		3.81	0.13		2.94
	R	16.0	4.39	97.97	2.00		6.28	0.75		15.60

Table 4-15. (Cont.)

Date	Station	Temp. (°C)	Cell counts (X 10^6/l)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Chlorophyll *a* (mg/m^3)	Standard[2] error	Scheffe test	Photosynthetic activity (mg C/mg Chl *a*/m^3/hr)
6/6/74	I	19.5	2.56	45.65	± 1.63	II> I,C_1,C_2,	5.24	± 0.51	II > I,D,P,R	8.71
	C_1	24.9	2.64	44.26	2.52	D,P,R	6.08	0.09	D < C_1	7.28
	II	20.0	1.59	79.06	3.59	R< I,II,C_1,	6.44	0.09	P < C_1	12.28
	C_2	26.0	2.28	44.56	2.03	C_2,D	5.34	0.20	R < I,II,C_1,C_2	8.34
	D	25.0	1.54	52.50	1.95		4.57	0.20		11.49
	P	22.0	2.74	39.95	3.50		4.56	0.19		8.76
	R	22.0	3.01	34.90	0.87		3.78	0.19		9.23
6/7/74	I	19.5	2.65	50.46	2.35		6.23	0.47		8.10
	C_1	19.5	2.86	73.15	2.20		6.73	1.00		10.87
	II	19.5	3.01	62.49	1.07		6.35	0.54		9.84
	C_2	19.5	2.87	73.25	3.57		6.50	0.27		11.27
	D	19.5	3.47	54.59	2.74		5.87	0.28		9.30
	P	19.5	2.55	48.24	3.16		6.37	0.39		7.57
	R	19.5	4.33	43.20	0.65		5.22	0.42		8.28
7/9/74	II	24.5	1.06	44.48	± 0.79	P <II,C ,D,R	3.34	± 0.28	P < II	13.22
	C_2	32.0	0.64	41.92	1.84	R >D	3.15	0.21		13.31
	D	31.4	0.59	40.97	0.47		3.02	0.09		13.57
	P	26.9	0.77	25.67	1.68		2.43	0.22		10.56
	R	24.5	0.79	46.95	1.48		2.72	0.10		17.26
7/10/74	II	24.5	0.99	43.65	1.40	P <II,C_2,D,R	2.99	0.16		14.60
	C_2	24.5	0.68	33.07	1.52	R >II,C_2,D,P	2.66	0.11		12.43
	D	24.5	0.92	39.70	2.09	II> C_2,P	2.77	0.11		14.33
	P	24.5	1.01	17.20	4.40	D >C_2	2.43	0.17		7.08
	R	24.5	0.50	58.47	1.17		2.79	0.21		20.96

Table 4-15. (Cont.)

Date	Station	Temp. (°C)	Cell counts (X 10^6/l)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Chlorophyll *a* (mg/m^3)	Standard[2] error	Scheffe test	Phtotsynthetic activity (mg C/mg Chl *a*/m^3/hr)
8/20/74	I	25.7	0.94	18.34	± 1.98	C_2 >I,II,C_1,	1.32	± 0.19	N.D.	13.89
	C_1	32.0	0.78	21.94	1.57	D,P	1.60	0.12		13.71
	II	26.1	1.10	18.30	3.45		1.24	0.12		14.76
	C_2	33.9	0.85	27.69	0.73		1.61	0.16		17.20
	D	33.6	0.68	18.74	1.74		1.24	0.03		15.11
	P	31.5	0.84	19.23	0.70		1.48	0.28		12.99
	R	26.2	0.55	22.85	0.82		1.55	0.23		14.74
8/21/74	I	25.7	1.03	21.92	3.16	D >I,II,C_1,	1.31	0.14	D > I,II	16.73
	C_1	25.7	1.17	24.56	1.67	C_2,P	2.24	0.07	R > I,II	10.96
	II	25.7	2.13	19.00	2.50	R >I,II	1.56	0.14	C_2 > I,II	12.18
	C_2	25.7	1.52	23.82	0.99	C_2>II	2.48	0.08	P > I,II	9.60
	D	25.7	1.43	28.73	1.68		3.06	0.13		9.39
	P	25.7	1.55	22.26	1.83		2.42	0.09		9.20
	R	25.7	1.45	26.64	0.40		3.00	0.21		8.88
9/26/74	I	21.8	0.71	26.70	± 5.62	N.D.	2.13	± 0.08	I > C_2,D,P,R	12.54
	C_1	26.2	0.55	22.00	1.37		1.82	0.14		12.09
	II	22.0	0.83	23.61	3.17		1.81	0.08		13.04
	C_2	28.2	0.68	25.01	2.99		1.75	0.04		14.29
	D	26.5	0.77	19.61	1.13		1.54	0.04		12.73
	P	27.0	1.33	22.42	2.91		1.49	0.02		15.05
	R	21.2	1.31	17.96	2.56		1.76	0.07		10.20
9/27/74	I	21.8	0.81	45.21	1.89	I >C_1,C_2,D,P	3.18	0.10	C_2>D,P	14.21
	C_1	21.8	0.98	27.37	1.72	II >C_1,D,P	2.40	0.11		11.40
	II	21.8	0.59	38.82	3.04		2.39	0.18		19.24
	C_2	21.8	1.10	33.81	2.18		3.86	0.97		8.76
	D	21.8	0.58	24.52	5.65		1.95	0.07		12.57
	P	21.8	0.70	29.44	3.03		1.93	0.09		15.25
	R	21.8	1.00	36.45	1.04		2.46	0.08		14.82

Table 4-15. (Cont.)

Date	Station	Temp. (°C)	Cell counts (X 10^6/l)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Chlorophyll *a* (mg/m^3)	Standard[2] error	Scheffe test	Photosynthetic activity (mg C/mg Chl *a*/m^3/hr)
10/4/74	I	18.2	1.32	14.20	± 3.37	I > II,C_1,C_2, D	4.03	± 0.40	I > II,C_2,D,P,R	3.52
	C_1	18.2	1.30	4.13	2.97		3.35	0.11	C_1 < D,P,R	1.23
	II	18.2	1.41	33.85	1.90		3.04	0.10	C_2 > P,R	1.29
	C_2	18.2	0.56	3.21	2.32		3.10	0.09	P< I,II,C_1,C_2	1.03
	D	18.2	1.31	3.25	3.64		2.47	0.14		1.32
	P	18.2	0.39	10.68	5.24		2.37	0.10		4.51
	R	18.2	0.51	8.54	2.15		2.35	0.04		3.63
10/24174	I	14.9	0.62	32.88	3.53	C_1 >C_2,P,R	3.55	0.04	C_1 < I,C_2,D,P,R	9.26
	C_1	20.9	0.59	23.42	3.02		1.66	0.37		14.11
	II	15.0	0.63	32.07	1.47		2.69	0.28		11.92
	C_2	24.1	0.59	40.41	2.51		3.61	0.14		11.19
	D	23.5	0.72	33.08	1.31		3.28	0.13		10.09
	P	17.0	0.58	37.99	2.28		3.15	0.14		12.06
	R	15.0	0.71	40.99	5.04		3.17	0.17		12.93
10/25/74	I	14.9	1.05	33.21	2.35	II >I,C_1,C_2, D,P,R	3.83	0.17	N.D.	8.67
	C_1	14.9	0.83	37.20	1.84		3.91	0.15		9.51
	II	14.9	1.12	54.06	3.20	I <C_2	4.23	0.16		12.78
	C_2	14.9	0.88	42.56	1.32		3.77	0.10		11.29
	D	14.9	1.04	36.57	1.69		3.80	0.04		9.62
	P	14.9	1.14	41.85	1.05		4.19	0.04		9.99
	R	14.9	0.79	34.39	2.40		3.41	0.15		10.09
11/20/74	II	10.5	3.24	53.44	2.14	P >II,C_2,D,R	8.10	0.15	N.D.	6.60
	C_2	22.0	5.25	66.01	1.83	R >C_2,D	8.86	0.08		7.45
	D	20.6	5.01	61.24	1.77	II< C_2,D	7.83	0.45		7.82
	P	17.2	3.69	80.61	2.05		8.34	0.16		9.67
	R	10.5	3.37	53.30	0.62		7.69	0.57		6.93
11/21/74	II	10.5	5.95	35.65	2.30	II< C_2,D,P,R	9.41	0.27	C_2 > II,D,P,R	3.79
	C_2	10.5	7.68	53.32	1.81		11.36	0.16		4.69
	D	10.5	5.37	53.78	1.81		9.14	0.21		5.88
	P	10.5	4.54	57.53	1.22		9.69	0.11		5.93
	R	10.5	5.77	53.63	1.00		8.62	0.44		6.22

Table 4-15. (Cont.)

Date	Station	Temp. (°C)	Cell counts (X 10^6/l)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Chlorophyll *a* (mg/m^3)	Standard[2] error	Scheffe test	Phtotosynthetic activity (mg C/mg Chl *a*/m^3/hr)
12/18/74	I	3.0	0.26	2.08	± 0.05	II >I,C_1,C_2, D,P,R	1.05	± 0.31	D< P	1.98
	C_1	3.0	0.15	2.02	0.11		0.89	0.08		2.27
	II	3.0	0.26	4.11	0.57		1.03	0.12		3.99
	C_2	27.0	0.33	1.44	0.09		0.95	0.08		1.51
	D	16.0	2.41	1.84	0.07		0.62	0.05		2.97
	P	8.0	0.63	2.20	0.46		1.40	0.09		1.57
	R	3.0	0.18	1.59	0.04		0.70	0.09		2.27
12/19/74	I	3.0	0.21	1.82	0.29	II >I,C_2,D, P,R	3.03	0.76	I> II,C_2,D,P,R	0.60
	C_1	3.0	0.26	3.06	0.10		2.46	0.21	C_1>R	1.24
	II	3.0	0.16	3.21	0.07	C_1> I, C_2,D,P, R	0.98	0.74		3.28
	C_2	3.0	0.44	1.08	0.03		0.73	0.03		1.48
	D	3.0	0.18	2.05	0.19	D >C_2	1.34	0.35		1.53
	P	3.0	0.31	1.63	0.15	R >C_2	2.26	0.29		0.72
	R	3.0	0.13	1.87	0.09	C2< II,I,C1, D,P,R	0.66	0.06		2.83

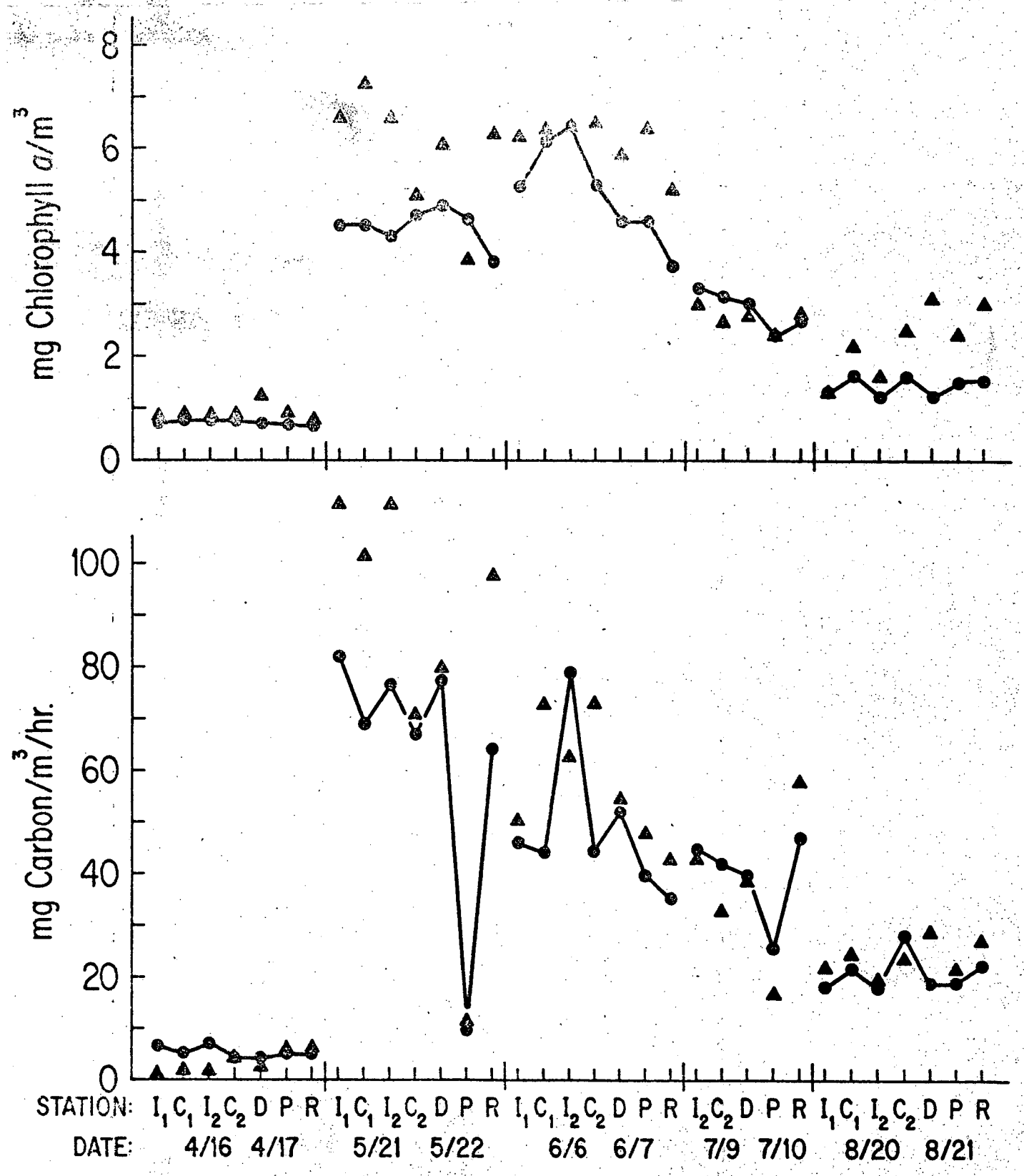


Figure 4-4. Effect of passage through Indian Point condensers on photosynthesis and chlorophyll values (mgC/mg Chl a/m^3/hr), 1974.

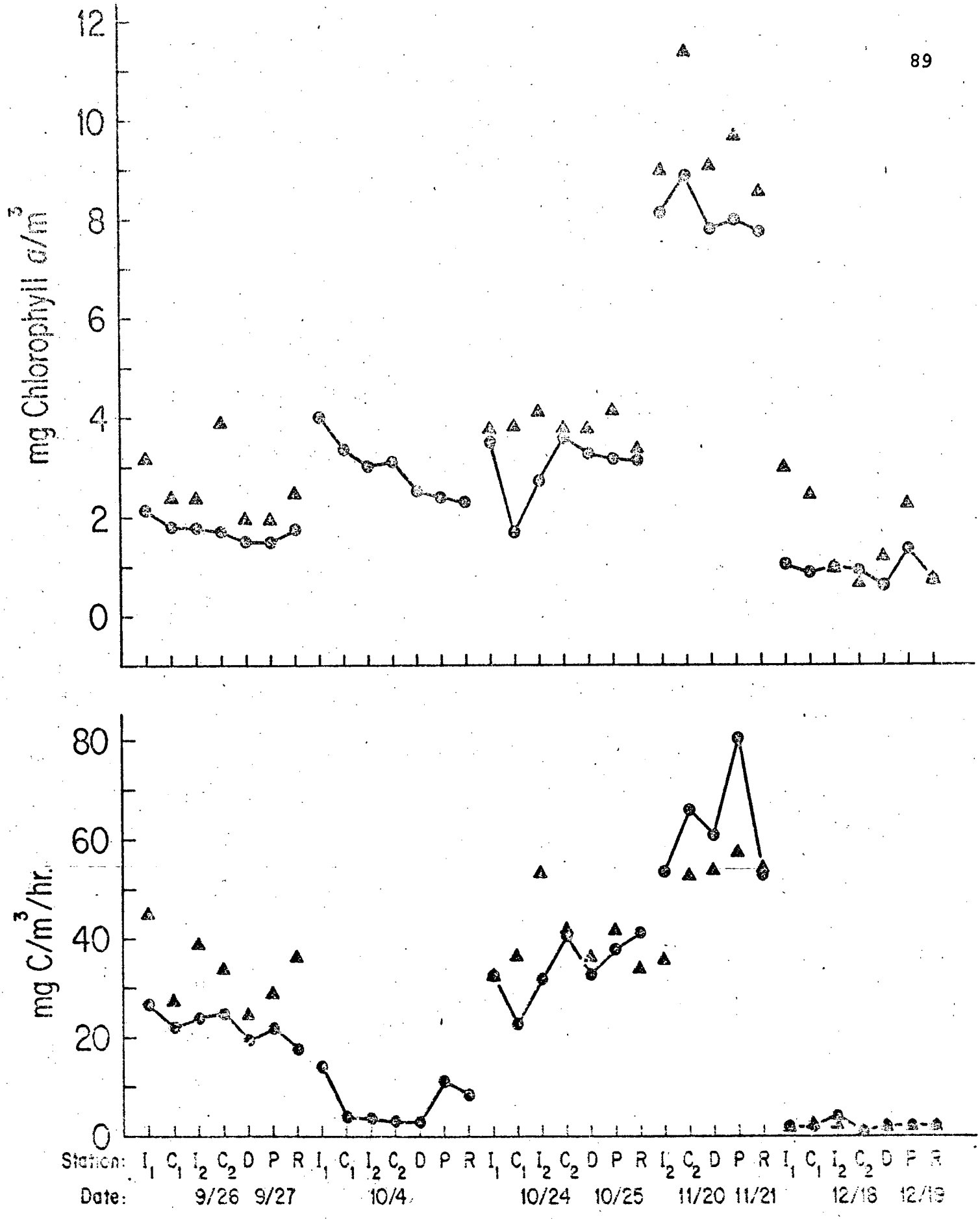


Figure 4-4 (cont.)

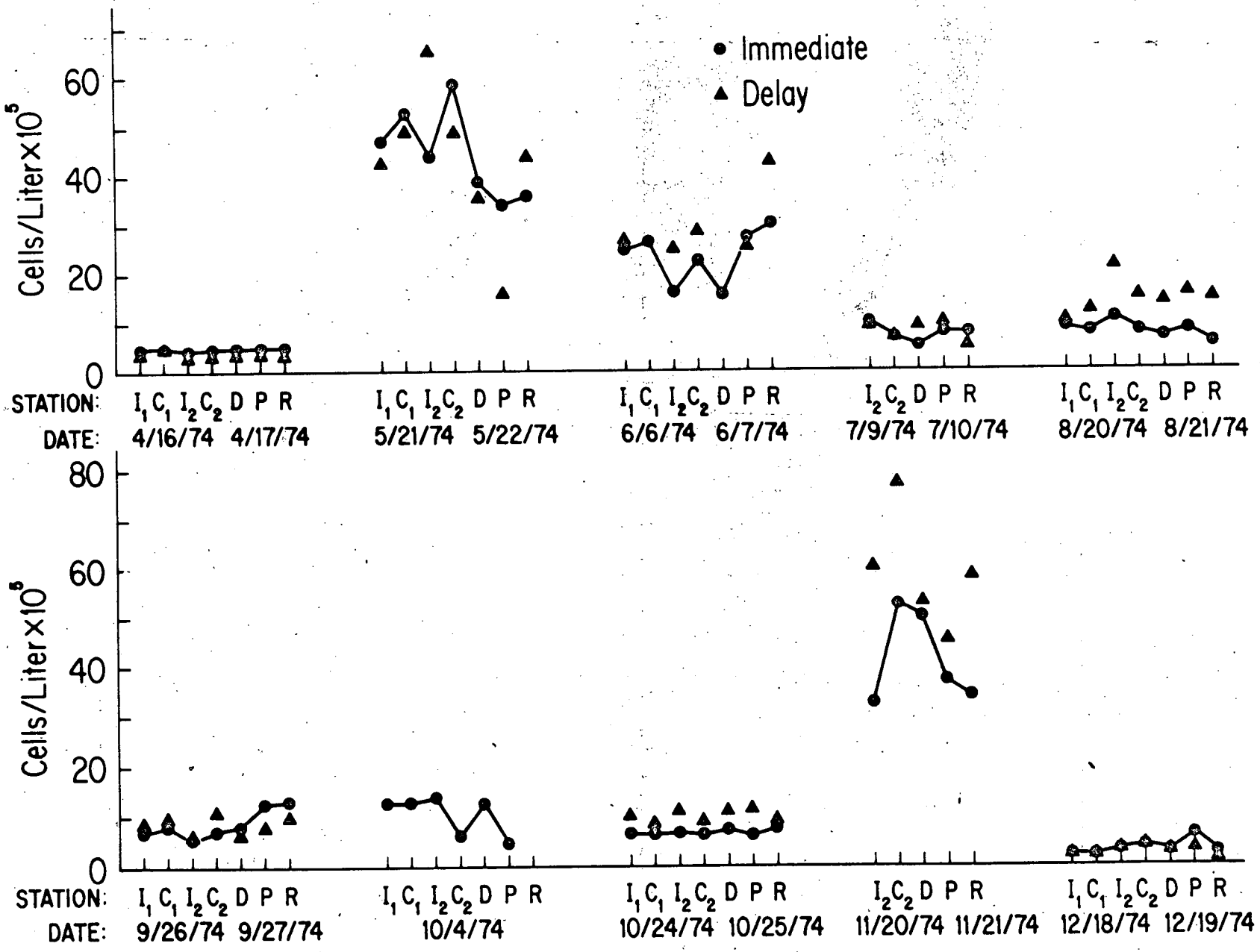


Figure 4-5. Phytoplankton abundance (cells/liter) after passage through condensers and discharge canal of the Indian Point power plant, 1974.

The results obtained in this section varied considerably depending upon the comparisons being made. Generally, they show that during normal power generation procedures, the Indian Point power plant had minimal impact upon the phytoplankton entrained into its cooling water flow. Analyses of photosynthetic activity, chlorophyll content and cell abundance for entrained populations show little to no change among river, intake and discharge-canal samples. At times it appeared that photosynthesis in condenser waterbox samples was inhibited by a ΔT when compared to river and intake samples. However, this inhibition was not permanent, as discharge-canal samples did not reflect this trend. There were indications of algal stimulation as a result of temperature exposure, but this, too, was not consistent.

The results obtained from whole-water samples maintained for 24 hours prior to the determination of cell numbers, photosynthetic activity and chlorophyll a content remain unclear. A general decrease in photosynthetic activity is indicated, and in many samples, a decrease in cell numbers as well as chlorophyll a content. In other cases, increased activity and higher cell numbers and chlorophyll a content were observed after the 24-hour holding period. Whether these decreases are due to confinement, grazing by zooplankton, competition or the effects of entrainment; or whether the increases are attributable to algal recovery and/or stimulation because of plant effects, cannot be determined from the present results.

Samples examined in October and November during condenser chlorination showed that chlorination had a definite inhibitory effect on phytoplankton photosynthesis (Table 4-16), suppressing

Table 4-16. Effects of plant passage on photosynthesis, chlorophyll a and phytoplankton abundance. C_1 and C_2 = Unit 1 and Unit 2 condensers, I and II = Unit 1 and Unit 2 intakes, D = Discharge Canal, P = Plume, R = River. [1]Error for all groups from 8 determinations. [2]Error for all groups from 4 determinations. *Indicates samples exposed to chlorination.

Date	Station	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Photosynthetic activity[3] (mg C/mg Chl a/m^3/hr)
10/24	I	32.88	± 3.53	$C_1 < C_2PR$	9.24
	C_1	23.42	3.02		14.71
	II	32.07	1.47		11.92
	C_2	40.41	2.51		11.19
	D	33.08	1.31		10.09
	P	37.99	2.28		12.06
	R	40.99	5.04		12.93
	C_2*	-2.58	± 2.73	$C_1D_1 < I_1C_1I_2C_2DPRP_1$	negative
	D*	-1.74	2.73		negative
	P*	36.25	2.05		12.72
10/25 (Delay)	I	33.21	± 2.35		8.67
	C_1	37.20	± 1.84	$I_2 > I_1C_1C_2DPR$	9.51
	II	54.06	3.20	$I_1 < C_2$	12.78
	C_2	42.56	1.32		11.29
	D	36.57	1.69		9.62
	P	41.85	1.05		9.99
	R	34.39	2.40		10.09
	C_2*	-2.53	3.76	$C_1D_1P_1 < I_1I_2C_1C_2DPR$	negative
	D*	0.25	1.86		0.10
	P*	20.64	20.75		5.59

Table 4-16. (Cont.)

Date	Station	Chlorophyll a (mg/m^3)	Standard[2] error	Scheffe test	Temp. (°C)	Cells/l	Chlorine residual
10/24	I	3.55	± 0.04	$C_1 < I_1 C_2 DPR$	14.9	6.23×10^5	
	C_1	1.66	0.37		20.9	5.94×10^5	
	II	2.69	0.28		15.0	6.30×10^5	
	C_2	3.61	0.14		24.1	5.87×10^5	
	D	3.28	0.13		23.5	7.18×10^5	
	P	3.15	0.14		17.0	5.83×10^5	
	R	3.17	0.17		15.0	7.07×10^5	
	C_2*	2.37	± 0.04	$C1 < I_1 C_2$	23.4	5.98×10^5	0.43
	D*	2.89	± 0.12		23.0	8.11×10^5	0.18
	P*	2.85	± 0.11		16.5	1.36×10^6	0.0
10/25 (Delay)	I	3.83	± 0.17	N.D.	14.9	1.05×10^6	
	C_1	3.91	0.15		14.9	8.32×10^5	
	II	4.23	0.16		14.9	1.12×10^6	
	C_2	3.77	0.10		14.9	8.82×10^5	
	D	3.80	0.04		14.9	1.04×10^6	
	P	4.19	0.04		14.9	1.14×10^6	
	R	3.41	0.15		14.9	7.92×10^5	
	C_2*	1.63	0.10	$C1 < I_1 I_2 C_1 C_2 DPRP1$	14.9	6.42×10^5	
	D*	2.44	0.06	$D1 < I_1 I_2 C_1 C_2 DPRP1$	14.9	6.59×10^5	
	P*	3.69	0.13		14.9	1.32×10^6	

Table 4-16. (Cont.)

Date	Station	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Scheffe test	Photosynthetic activity (mg C/mg Chl a/m^3/hr)
10/31	I	21.08	± 0.42	N.D.	10.10
	C_1	20.24	3.06		9.87
	II	27.40	1.08		15.22
	C_2	31.77	3.44		10.45
	D	20.45	2.97		9.34
	P	17.18	4.23		10.34
	C_2*	-4.58	11.60	$C_1 < I_1 I_2 C_1 C_2 DP$	negative
	D*	8.07	3.80	$D1 < I_2 C_2$	4.75
	P*	14.92	5.87	$P1 < C_2$	10.51
11/01	I	32.42	± 4.24	N.D.	24.19
(Delay)	C_1	38.20	1.93		18.37
	II	38.41	3.73		10.13
	C_2	30.48	3.61		11.08
	D	32.67	3.28		14.65
	P	30.68	1.34		16.76
	C_2*	-4.50	7.91	$C1D1P1 < I_1 I_2 C_1 C_2 DP$	negative
	D*	6.04	1.66		5.75
	P*	12.76	4.80		7.87

Table 4-16. (Cont.)

Date	Station	Chlorophyll a (mg/m^3)	Standard[2] error	Scheffe test	Temp. (°C)	Cells/l	Chlorine residual
10/31	I	2.07	± 0.10		14.0	9.97×10^5	
	C_1	2.05	0.15	$C_2 > I_2P$	20.9	1.30×10^6	
	II	1.80	0.10		15.0	1.47×10^5	
	C_2	3.04	0.24		24.1	1.71×10^6	
	D	2.19	0.15		22.0	7.44×10^5	
	P	1.57	0.17		16.5	1.096×10^5	
	C_2*	1.47	0.16	$C_1D_1P_1 < C$	24.0	8.04×10^5	0.40
	D*	1.70	0.14		23.0	5.31×10^5	0.20
	P*	1.42	0.54		16.7	7.84×10^5	0.07
11/01 (Delay)	I	1.34	0.26	$I_2 < I_1C_1DP$	14.0	1.04×10^6	
	C_1	2.08	0.18		14.0	1.25×10^6	
	II	3.79	0.63		14.0	1.95×10^6	
	C_2	2.75	0.10		14.0	1.32×10^6	
	D	2.23	0.07		14.0	1.65×10^6	
	P	1.83	0.11		14.0	1.47×10^6	
	C_2*	0.91	0.09	$C_1 < I_2C_2$	14.0	1.00×10^6	
	D*	1.05	0.18	$D_1 < I_2C_2$	14.0	6.398×10^5	
	P*	1.62	0.15	$P_1 < I_2$	14.0	1.32×10^6	

activity to negative values with no evidence of recovery. Chlorination superimposed upon a ΔT completely inhibited photosynthesis as evidenced by decreasing values from intake to plume. However, as the generation time for phytoplankton is rather short and condenser chlorination is only intermittent, this impact is not expected to cause significant change in river populations (See also Section 8 of this report, on Plume Entrainment.)

Finally, the tolerance of entrained phytoplankton to potential stresses, such as abrupt temperature rises and other effects of entrainment, is complicated by the patchy distribution and seasonal and annual variability of the species composition of the phytoplankton. 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 significantly different than that of a community dominated by green and blue-green algae in late summer at the same ambient temperature.

4.2.2 Laboratory Thermal Tolerance Studies

4.2.2.1 Methods

Phytoplankton from whole-water samples collected immediately in front of the intake at Indian Point Unit 1 were used in thermal tolerance studies. One 4-liter sample was collected each sampling period; aliquots were removed for algal identification and enumeration and for the determination of photosynthetic rate and chlorophyll a content.

Essentially two different studies were conducted in 1974. During the period January to April experiments were conducted to

determine the upper thermal tolerance limits of phytoplankton. From May through December, experiments were oriented specifically to the thermal-exposure regimes experienced in pump entrainment.

The effects of thermal shock were tested with ΔT's ranging from 20 to 34°C (36 to 61.2°F). A 1000-ml aliquot was heated to the test temperature (time duration 1-2 min) on a hot plate. The sample was maintained at the test temperature for 60 min., then cooled to river temperature by immersion in an ice bath for approximately 45 min. Aliquots were removed for algal enumeration and determinations of photosynthesis and chlorophyll a content following procedures outlined in Section 4.2.1.1 of this report.

Laboratory studies simulating pump entrainment employed a slightly different test procedure that permitted a more rapid attainment of ΔT and test temperature and a more rapid return to ambient temperature. In this procedure, 100-ml aliquots in 250-ml flasks were heated to the test temperature in boiling water (30-45 sec). Except for the experiments on May 24, which were run with a ΔT of 13°C (23.4°F), all tests were run with a ΔT of 8°C (14.4°F). Samples were held at the test temperature for the prescribed exposure time (6 min, 33 min and 60 min) in thermostatically-controlled water baths. Fifty-ml aliquots in 250-ml flasks were cooled in a crushed-ice bath (60-120 sec). Aliquots for algal enumeration, photosynthesis and chlorophyll a determinations were removed and treated according to the procedures referred to above. This rapid cooling process, initiated on April 24, provided a comparison for the long-term cooling process used on April 10 using the duration of time at the test

temperature as the main effect. Scheffés test (α - 0.10) was used for comparison of means of the treatment groups.

4.2.2.2 Results and Discussion

The results of these experiments are shown in Table 4-17 and Figures 4-6 and 4-7. In general, they indicate that the response of phytoplankton to thermal stresses were varied and were dependent upon population composition and time-temperature exposure relationships. Essentially two different sets of experiments were run. One set was run with high ΔT's (20-34^{o}C or 36-63.2^{o}F) for 60 min and the other was run with a ΔT of 8^{o}C (14.4^{o}F) at exposure times of 6, 33 and 60 min, conditions closer to those obtaining during normal power plant operation. The varied responses to these experimental conditions are discussed separately below.

Experiments on algal response to ΔT's of 20-34^{o}C for 60 min were run with natural populations at ambient temperatures of 0.9-9.5^{o}C (33.6-49.1^{o}F) from January to April. The results show that a 60-min exposure at these ΔT's was inhibitory to photosyntehsis with little change in chlorophyll *a* content or cell numbers. Whether this was a function of the long exposure time or a function of the high-temperature shock is not known. However, in three instances from March to April, different ΔT's were used (Table 4-17) while exposure time was kept constant at 60 min. Although all of the ΔT's tested were inhibitory to photosynthetic activity, the higher ΔT values were generally associated with the greater decreases.

Table 4-17. Summary of results for 1974 laboratory thermal tolerance studies of photosynthesis, chlorophyll and phytoplankton composition. [1]Error for all groups from 8 determinations, [2]Error for all groups from 4 determinations, *Indicates statistically significant variations.

Date	Sample	Temp. (°C)	Exposure (minutes)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Chlorophyll a (mg/m^3)	Standard[2] error	Photosynthetic activity (mg C/mg Chl a/m^3/hr)
1/10/74	Control	0.9		0.12	± 0.49	2.34	± 0.36	0.05
		35.0	60	-0.69	0.56	———	———	negative
1/12/74	Control	0.9		1.03	0.38	1.56	± 0.34	0.66
		32.2	60	0.45	0.19	3.92*	0.45	0.11
3/27/74	Control	6.5		1.16	0.47	———	———	———
		32.0	60	0.38	0.39	———	———	———
		38.0	60	0.43	0.36	———	———	———
4/10/74	Control	5.5		4.63	0.41	1.18	0.08	3.92
		32.0	60	1.19*	0.17	1.20	0.24	0.99
		38.0	60	0.52*	0.33	0.96	———	0.54
4/24/74	Control	9.5		4.50	0.58	1.20	0.05	3.75
		29.5	60	3.25*	0.26	1.02*	0.02	3.19
		32.0	60	1.45*	0.34	1.07	0.12	1.36
5/24/74	Control	16.5		95.08	3.79	5.79	0.09	16.42
		24.5	6	91.93	7.60	5.22	0.05	17.61
		24.5	33	96.21	2.75	5.47	0.04	17.59
		24.5	60	91.96	4.59	5.00	0.09	18.39
6/05/74	Control	18.0		1.28	1.14	2.57	0.08	0.50
		26.3	6	1.37	1.52	2.18	0.10	0.63
		26.3	33	1.88	1.32	2.46	0.11	0.76
		26.3	60	11.10*	0.40	2.13	0.09	5.21

Table 4-17. (Cont.)

Date	Sample	Temp. (°C)	Exposure (minutes)	^{14}C-Uptake (mg C/m^3/hr)	Standard[1] error	Chlorophyll *a* (mg/m^3)	Standard[2] error	Photosynthetic activity (mg C/mg Chl *a*/m^3/hr)
7/03/74	Control	23.2		57.19	± 1.40	3.94	± 0.27	14.51
		31.7	6	47.20*	1.56	3.47	0.23	13.60
		31.7	33	49.93*	1.32	3.40	0.30	14.69
		31.7	60	47.81*	1.10	3.78	0.27	12.65
9/05/74	Control	24.4		16.19	2.43	1.15	0.04	14.08
		32.4	6	14.91	1.28	1.31	0.09	11.38
		32.4	33	15.59	2.65	1.41	0.04	11.06
		32.4	60	15.71	0.52	1.30	0.15	12.08
9/20/74	Control	24.0		38.88	1.93	2.16	0.10	18.00
		32.0	6	32.27*	3.11	2.16	0.14	14.94
		32.0	33	34.90	1.51	1.81	0.05	19.28
		32.0	60	32.59*	1.93	1.90	0.06	17.15
10/14/74	Control	17.8		29.98	5.07	2.75	0.12	10.90
		25.8	6	26.67	2.56	2.17	0.19	12.29
		25.8	33	21.54*	4.29	2.56	0.28	10.24
		25.8	60	16.96*	1.60	2.66	0.16	6.38
11/13/74	Control	13.0		12.98	1.14	2.71	0.14	4.79
		21.0	6	16.22	0.92	3.00	0.16	5.41
		21.0	33	25.49*	1.27	2.49	0.12	10.24
		21.0	60	10.84	1.28	2.86	0.32	3.79
12/10/74	Control	5.0		11.83	3.68	2.10	0.08	5.63
		13.0	6	5.61*	4.30	1.83	0.12	3.07
		13.0	33	4.48*	3.49	2.04	0.77	2.20
		13.0	60	7.61*	1.95	1.64	0.10	4.64

Table 4-17. (Cont.)

Date	Sample	Cells/l	Percent composition of phytoplankton				
			Diatoms	Greens	Blue-greens	Chrysophytes	Euglenophytes
1/10/74	Control						
1/12/74	Control	6.19×10^4					
3/27/74	Control						
4/10/74	Control	1.72×10^5	48.7	51.3			
		2.56×10^5	91.4	8.6			
		3.04×10^5	56.4	43.6			
4/24/74	Control	1.40×10^6	83.1	22.1			
		7.78×10^5	92.1	7.95			
		4.20×10^5	81.1	18.95			
5/24/74	Control	4.53×10^3	92.1	7.9			
		9.55×10^6	92.4	7.6			
		1.42×10^7	89.8	10.2			
6/5/74	Control	1.83×10^6	80.2	19.8			
		7.08×10^5	76.3	23.1			
		1.07×10^6	89.2	10.8			

Table 4-17. (Cont.)

Date	Sample	Cells/1	Percent composition of phytoplankton				
			Diatoms	Greens	Blue-greens	Chrysophytes	Euglenophytes
7/3/74	Control	6.99×10^5	60.8	39.2			
		8.49×10^5	65.6	34.4			
		7.69×10^5	62.5	33.1	4.4		
		7.696×10^5	71.3	28.2	0.6		
9/5/74	Control	8.26×10^5	34.6	58.9	5.5	0.81	0.3
		9.36×10^5	35.096	60.6	1.9	1.9	0.5
		6.19×10^5	18.6	68.6	11.4	0.0	1.4
9/20/74	Control						
		4.42×10^5	28.0	65.0	6.0		
		3.72×10^5	26.2	69.1	3.6	1.2	
		8.93×10^5	21.8	68.3	7.9	1.98	0.00
10/14/74	Control	3.41×10^5	32.5	54.6	12.99		
		3.67×10^5	31.3	49.4	19.3		
		3.23×10^5	38.4	52.1	9.6		
		5.93×10^5	29.1	64.9	5.2		0.7
11/13/74	Control	1.32×10^6	44.7	43.0	10.6	1.7	
		2.60×10^6	54.3	34.6	9.3	1.7	
		1.11×10^6	34.8	45.8	17.0	2.4	
		1.17×10^6	35.8	50.4	11.5	2.3	
12/10/74	Control	8.46×10^5	72.3	22.3	5.3		
		3.74×10^5	61.5	36.1	2.4		
		3.83×10^5	42.4	56.5	1.2		
		3.96×10^5	59.0	40.9			

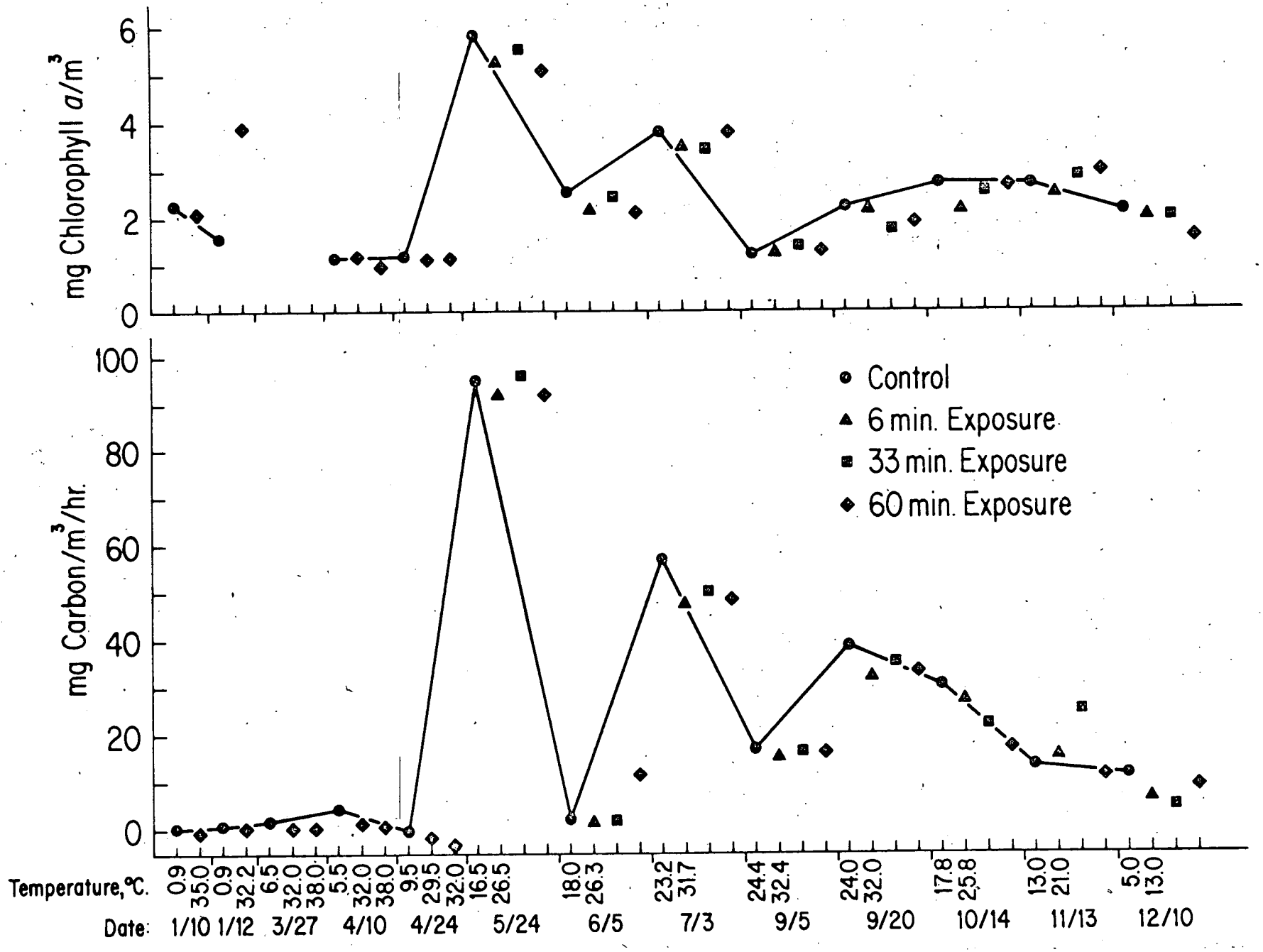


Figure 4-6. Effect of temperature increases on photosynthesis (mg C/m^3/hr) and chlorophyll a levels (mg Chl a/m^3) in laboratory thermal-tolerance studies.

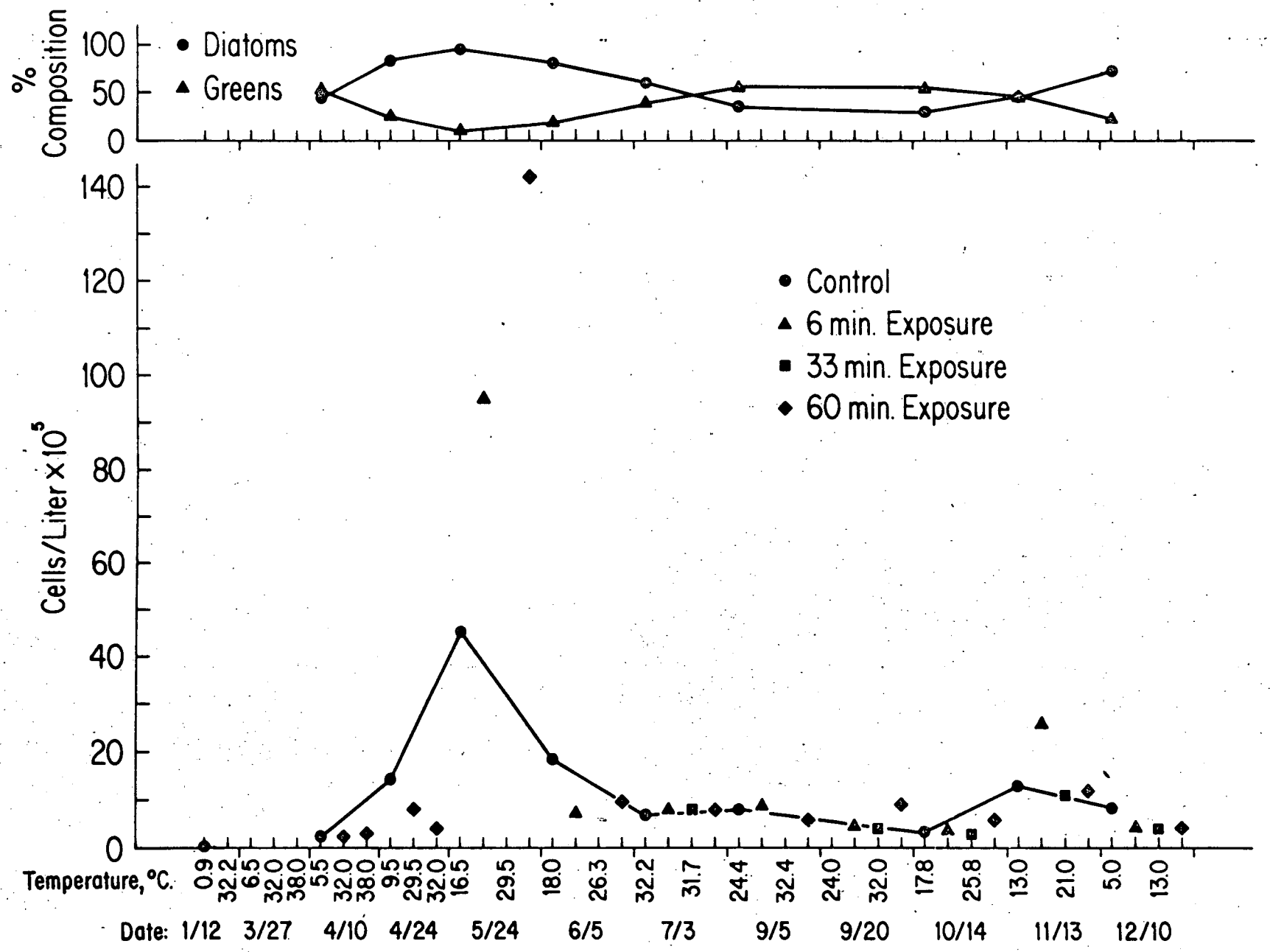


Figure 4-7. Effect of temperature increases on phytoplankton abundances in laboratory thermal-tolerance studies.

From May until December, tests of thermal tolerance were all run at a ΔT of $8^{o}C$, and were tested over three exposure times (6, 33 and 60 min). The results were grouped into three headings based upon the final temperature (ΔT + ambient temperature).

Tests having a final temperature of 13-21^{o}C (55.4-69.8^{o}F) showed variable results. Experiments conducted on November 13 showed increased photosynthetic activity with exposure time up to 33 min, but decreasing after the 60-min exposure. Photosynthetic activity for experiments run on December 10 decreased with time to 33 min and increased after the 60-min exposure.

Tests run with a final temperature of 22-30^{o}C (71.6-86.0^{o}F) were varied also. Spring populations of May 24 and June 5 (having approximately 80-90% diatoms and 10-20% green algae) showed increased photosynthetic activity with time, even after 60 min. However, runs made on October 14 showed increased activity with time up to 33 min only, and declined after the 60-min exposure; these results were similar to those of November 13, described above. A check into the composition of the algal populations for these samples showed that they were similar to each other (30-40% diatoms and 50-60% greens) but were different from the populations of May 24 and June 5.

Tests having a final temperature above 30^{o}C (86.0^{o}F) indicated a general decrease in photosynthetic activity with exposure; this was readily observed after only a 6 min exposure. We are unable to explain the apparent increase in activity noted in the 33 min exposures for July 3 and September 20, as the results for both the 6 min and 60 min exposures were decreased when com-

pared to the controls.

The ambient temperature in the river and the phytoplankton community existing at that temperature affected, profoundly, the outcome of thermal assays. Final temperatures in excess of 30°C (86°F) appear generally to be inhibitory to phytoplankton. Temperatures below 30°C produced conflicting results which, under close scrutiny, may be related to a number of other factors (e.g. specific composition of the algal population, physiological state of the algal samples when collected, availability of nutrients in the enclosed sample, the presence or absence of soluble chemical inhibitors, etc.) which were not considered in these tests.

Field studies of entrainment effects at the Indian Point power plant disclosed a range of effects (from no effect, to stimulation and inhibition) when ambient temperatures were below 20°C (64.4°F). With certain qualifications, these results conform closely to those of Warinner and Brehmer (1971) and Morgan and Stross (1969) for estimating the impact of cooling water entrainment on estuarine phytoplankton. They determined that for plankton populations in the Chesapeake Bay and tributaries, 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.

In the present study, the combination of parameters examined provides data in addition to photosynthetic rates only, and allows more critical examination of laboratory and field results. On

several occasions, laboratory thermal testing resulted in chlorophyll a and carbon-uptake data which were in conflict. Further, comparison of laboratory results and field entrainment studies showed conflicts, none of which fit a single, general explanation.

Entrainment results generally showed a reduction in chlorophyll a in the discharge canal when ambient temperature was above 18°C (64.4°F). Laboratory tests fail to confirm this as being due to temperature alone. Generally, reductions in ^{14}C-uptake were not paralleled by decreases in chlorophyll a. Since carbon fixation is a function of the lamellar structure of chloroplasts in eukaryotic algae (which dominated in most collections) rather than the integrity of the chlorophyll a molecule per se, it is fully possible that, in laboratory thermal tolerance tests, photosynthetic activity may reflect thermal shock more rapidly, and to a greater degree, than analysis for chlorophyll a. The mechanical stresses imposed upon phytoplankters in the course of plant passage may be of sufficient magnitude to degrade more rapidly the chlorophyll a molecule, leading to the results seen in Table 4-17.

Studies of thermal-shock effects on phytoplankton in 1974 utilized techniques more realistic than used in previous years. Comparison of 1973 and 1974 results showed that reductions in photosynthetic rate and, on occasion, chlorophyll a concentrations occurred at lower final temperatures in 1974 than in 1973. Since the abundance and forms of algae in the 2 years were similar, and all experimental procedures except for the method of heating and cooling remained similar, we conclude that the imposition of

instantaneous ΔT on the phytoplankton had more of an effect than slow heating and cooling.

Nonetheless, 1974 studies confirmed that the effects of entrainment of phytoplankton in the cooling water at Indian Point were minimal and would have, of themselves, little or no effect on populations and primary productivity in the river.

5. MICROZOOPLANKTON

5.1 RIVER POPULATION STUDIES

5.1.1 Methods

Microzooplankton were collected at least once every 2 weeks during day and night sampling periods at each of the seven Hudson River stations (Figure 1-8). The sampling procedure consisted of drawing a 9 #20-mesh conical plankton net, 0.5 m in diameter, vertically through 10 m of water. The sample was then washed into a jar and preserved in 10% formalin.

Replicate 1 ml-aliquots were removed from each sample and placed in Sedgwick-Rafter cells for enumeration and identification of organisms. The average number of organisms in the two aliquots was used in calculating the concentration of organisms in the river by 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 by flowmeter
C = volume factor for flowmeter
(R)(C) = volume of water filtered by net

Microzooplankton data were analyzed by a two-way factorial analysis of variance (ANOVA). Numbers per liter were transformed logarithmically for variance stabilization prior to analysis. Where ANOVA indicated significant differences between stations, a Scheffé test ($\alpha < 0.10$) was performed to locate the differences.

One observation is missing from the night samples. The missing value was estimated, and the proper adjustments were conducted on the degrees of freedom and sums of squares (Ostle, 1963).

5.1.2 Results and Discussion

The predominant microzooplankton taxa collected in 1974 were the classes Crustacea and Rotifera and the phylum Protozoa (Table 5-1). The Crustacea, primarily copepods and cladocera, were the most abundant constituents of the microzooplankton populations sampled near Indian Point.

The seasonal abundances of total microzooplankton, Crustacea and Rotifera are presented in Figures 5-1, 5-2 and 5-3; abundance by major taxa is presented in Tables 5-2 through 5-9. There were no differences between day and night abundances for these three groups.

During the April to December sampling period, total microzooplankton abundances were highest from June through August (Figure 5-1). Total abundances declined during September and October, but increased during November. Copepod abundances during day and night sampling periods (Figures 5-4 and 5-5) paralleled seasonal changes in the total microzooplankton abundances. Maximum copepod reproduction most likely occurred during the summer and fall months, as indicated by the increased numbers of nauplii present during these periods.

Eurytemora affinis and Acartia tonsa were the most abundant adult copepods observed during the sampling period (Figures 5-6

Table 5-1. Microzooplankton Species List

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

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

Ostracoda (no further identification)

Cirripedia
  Nauplii

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

Table 5-1 (cont.)

Protozoa
Plasmodroma
Mastigophora
Arcella sp.
Centropyxis sp.
Ceratium hirundinella (Muller)
Coelastrum sp.
Difflugia sp.
Dinobryon sp.
Errerella sp.
Eudorina sp.
Euglypha sp.
Pandorina sp.
Pleodorina sp.
Voluox sp.

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

Suctorid
Metacineta sp.
Staurophrys sp.

Miscellaneous
Gastropod veliger
Pelecypod veliger
Annelid larvae
Nematode
Tardigrade

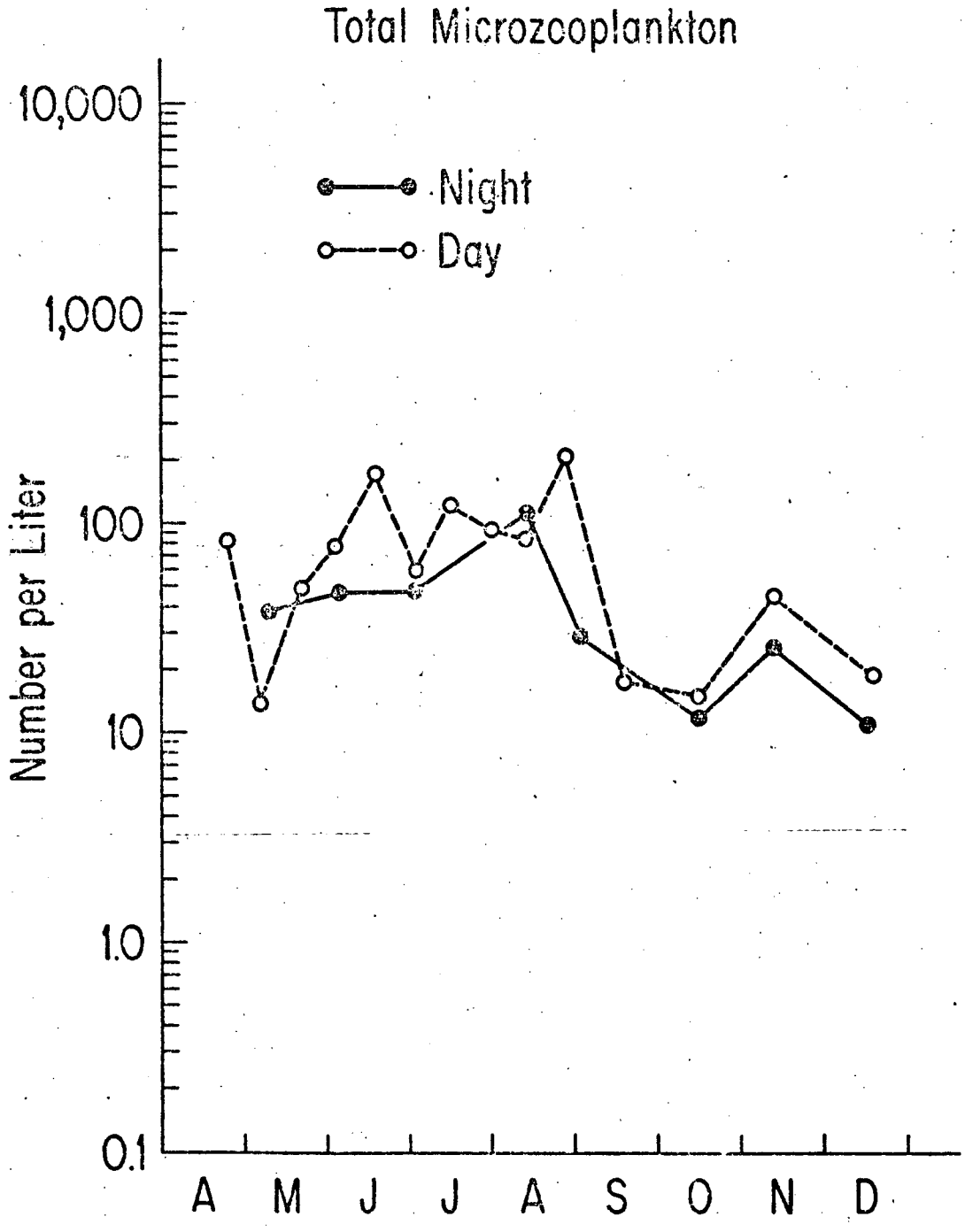


Figure 5-1. Day and night abundances of total microzooplankton, 1974.

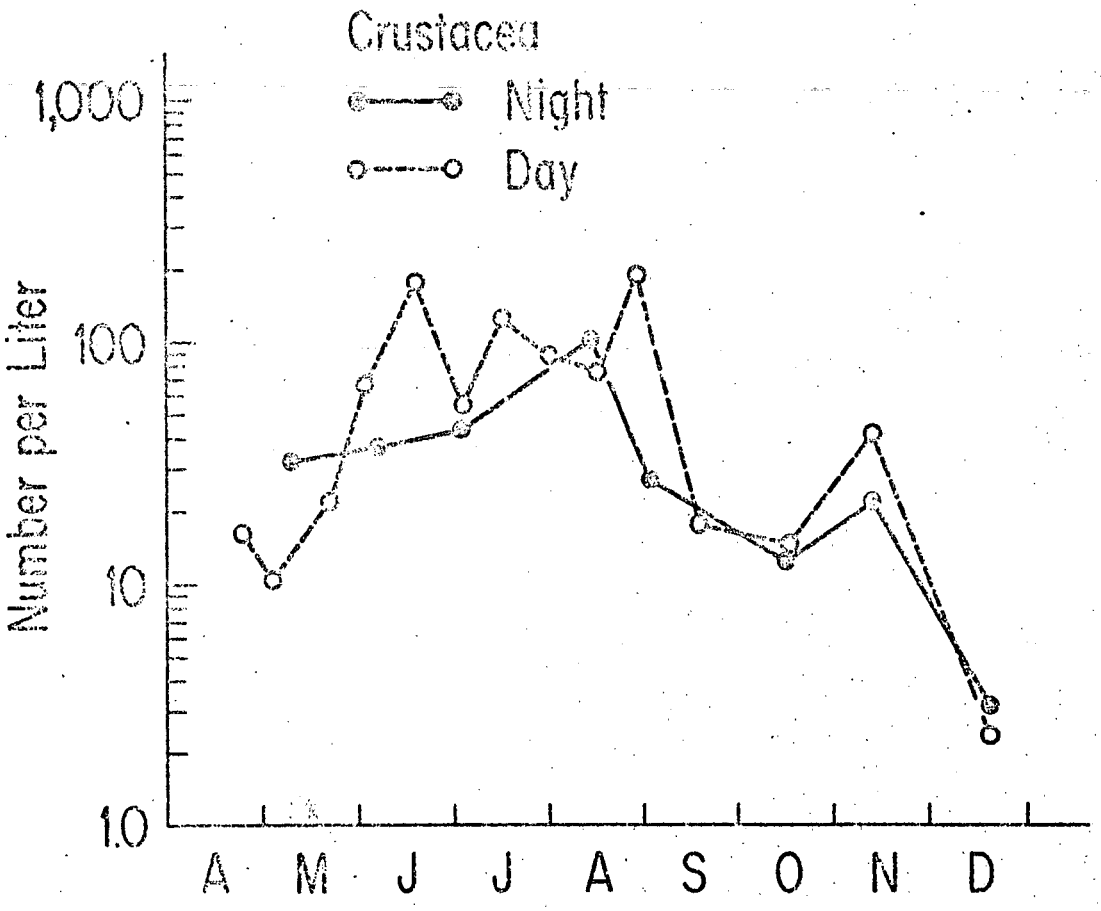


Figure 5-2. Day and night abundances of total Crustacea, 1974.

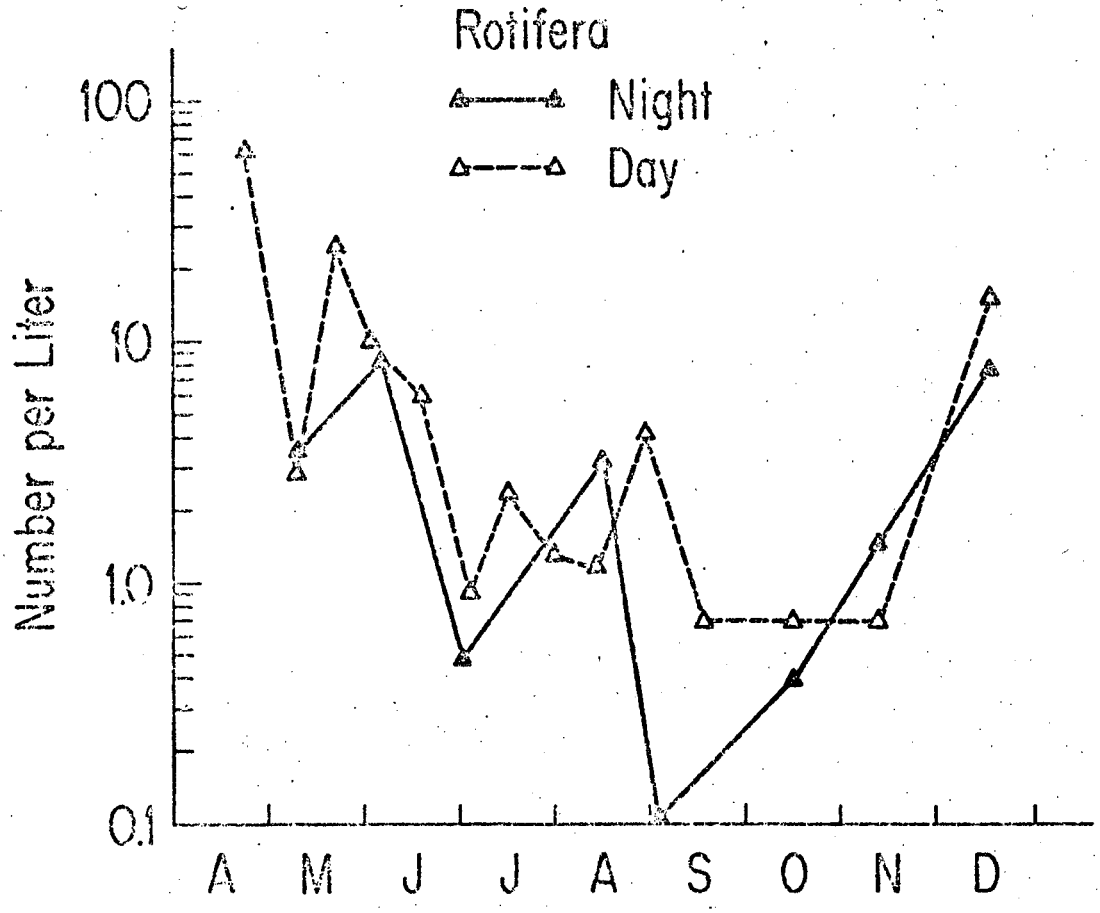


Figure 5-3. Day and night abundances of total Rotifers, 1974.

Table 5-2. Day and night abundances of total microzooplankton, 1974.

Date	A	B	C	D	E	F	G	Mean
				Day				
				Station				
04/23/74	21.4	18.2	40.6	24.9	430.6	21.2	21.6	82.6
05/07/74	8.7	17.2	8.1	10.1	17.1	21.6	16.6	14.2
05/21/74	57.0	45.0	74.4	41.1	34.4	54.7	34.5	48.7
06/02/74	56.2	6.3	38.4	96.4	157.5	121.7	56.7	76.2
06/18/74	155.0	181.8	180.7	112.9	134.4	351.5	212.2	189.8
07/02/74	31.6	66.4	40.0	77.0	61.7	82.5	30.9	55.7
07/16/74	73.9	360.0	116.3	66.5	66.5	158.1	123.2	137.8
07/30/74	54.5	41.3	166.4	95.6	103.8	124.3	63.8	92.8
08/13/74	41.8	44.6	41.5	47.0	93.0	272.8	52.0	84.7
08/27/74	51.4	48.7	58.2	53.2	48.7	176.4	985.1	203.1
09/17/74	19.9	19.3	20.9	17.9	13.3	16.2	22.9	18.6
10/15/74	16.4	9.0	17.3	20.7	10.3	30.9	0.6	15.0
11/12/74	20.9	15.6	24.4	10.1	13.2	15.3	211.7	44.5
12/17/74	28.6	22.0	25.7	18.4	13.2	19.2	7.8	19.3
				Night				
05/08/74	9.0	75.3	10.2	5.0	15.5	9.9	133.4	36.9
06/05/74	35.7	44.9	52.1	56.5	44.3	38.7	44.0	45.2
07/02/74	36.8	46.2	46.1	39.5	31.6	33.6	84.1	45.4
08/13/74	157.2	92.2	105.1	112.6	43.2	121.2	180.2	116.0
09/03/74	21.1	20.4	14.0	1.4	9.0	101.7	26.9	27.8
10/15/74	9.4	10.4	25.0	14.8	9.8	9.0	13.7	13.2
11/12/74	14.7	13.9	19.7	9.1	18.2	24.8	78.6	25.6
12/17/74	15.7	15.6	6.6	14.2	10.5	5.6	-*	11.4

* Indicates missing samples

Table 5-3. Day and night abundances of Crustacea, 1974.

Date	A	B	C	D	E	F	G	Mean
				Day				
				Station				
04/23/74	3.7	4.7	7.6	5.5	77.9	5.8	7.5	16.1
05/07/74	7.1	13.6	5.2	7.7	12.2	17.9	10.5	10.6
05/21/74	17.5	26.3	32.5	27.4	25.7	19.9	17.7	23.8
06/02/74	46.7	5.3	31.1	76.9	139.3	113.6	45.5	65.5
06/18/74	149.7	176.8	173.1	109.9	127.4	342.4	204.7	183.4
07/02/74	31.6	64.0	39.1	73.3	60.3	81.4	30.2	54.3
07/16/74	70.9	354.8	112.5	62.4	63.3	144.4	109.4	131.1
07/30/74	52.3	37.1	148.2	91.5	99.4	115.7	57.0	85.9
08/13/74	39.4	42.6	39.2	39.7	82.9	254.1	46.2	77.7
08/27/74	50.0	48.1	57.4	50.2	47.6	173.1	957.5	197.7
09/17/74	19.1	17.2	19.8	16.9	12.5	16.0	22.9	17.8
10/15/74	15.1	8.7	16.2	18.7	9.6	30.0	0.6	14.1
11/12/74	20.0	14.3	22.6	8.2	11.9	13.6	208.0	42.7
12/17/74	2.7	2.1	2.4	3.2	2.2	2.5	2.3	2.5
				Night				
05/08/74	8.1	64.5	7.5	4.7	12.8	8.3	119.0	32.1
06/05/74	29.0	37.3	41.8	46.3	38.9	27.6	34.5	36.5
07/02/74	35.3	45.2	45.4	38.8	30.5	33.4	83.5	44.6
08/13/74	124.3	81.5	92.8	91.6	34.7	108.4	172.7	100.9
09/03/74	21.0	20.4	14.0	1.3	8.4	100.9	25.2	27.3
10/15/74	8.4	10.0	23.7	13.6	9.3	8.9	12.5	12.4
11/12/74	12.4	12.0	18.8	8.2	16.0	21.0	72.2	22.9
12/17/74	4.1	3.7	1.6	4.6	3.3	1.9	-*	3.2

* Indicates missing samples

Table 5-4. Day and night abundances of copepod nauplii, 1974.

Date	A	B	C	D	E	F	G	Mean
				Day				
				Station				
04/23/74	1.9	3.1	5.6	2.8	47.5	4.0	5.2	10.0
05/07/74	2.4	5.1	2.8	3.4	5.9	7.7	6.0	4.7
05/21/74	12.3	18.1	18.6	7.2	6.5	13.8	8.0	12.1
06/02/74	18.7	1.5	15.9	34.5	72.3	89.9	25.4	36.9
06/18/74	56.1	0.0	64.3	53.8	31.0	267.7	98.6	81.6
07/02/74	6.2	27.1	12.3	14.3	12.4	61.1	15.5	21.3
07/16/74	55.0	335.0	97.6	45.0	38.4	120.4	88.4	111.4
07/30/74	32.7	10.9	108.0	71.4	67.7	63.2	41.6	56.5
08/13/74	10.9	21.9	17.8	21.3	31.5	142.8	16.2	37.5
08/27/74	18.0	32.8	30.3	15.9	27.1	125.7	652.1	128.9
09/17/74	3.0	7.0	7.3	6.7	5.0	3.1	4.3	5.2
10/15/74	12.9	3.4	4.1	16.8	7.6	24.6	0.5	10.0
11/12/74	8.4	9.5	14.8	1.5	4.1	10.3	185.3	33.4
12/17/74	2.3	1.5	1.9	2.3	1.5	2.0	1.1	1.8
				Night				
05/08/74	2.4	14.2	3.0	1.8	4.3	3.5	28.7	8.3
06/05/74	12.5	18.1	27.6	27.4	15.3	15.8	21.4	19.7
07/02/74	7.3	12.4	23.7	8.6	14.2	10.0	12.4	12.6
08/13/74	44.8	28.9	39.0	30.7	11.8	66.7	85.5	43.9
09/03/74	11.1	9.7	7.1	0.1	1.6	54.8	10.5	13.6
10/15/74	1.6	2.3	8.3	8.4	4.0	3.3	3.7	4.5
11/12/74	5.9	2.2	2.3	2.2	3.9	8.2	18.8	6.2
12/17/74	3.0	2.6	1.0	3.3	1.7	1.4	-*	2.2

* Indicates missing samples

Table 5-5. Day and night abundances of copepodids, 1974.

Day

Station

Date	A	B	C	D	E	F	G	Mean
04/23/74	1.8	1.5	1.6	1.7	26.4	1.3	2.0	5.2
05/07/74	3.4	6.7	1.8	3.1	3.2	5.4	3.0	3.8
05/21/74	3.5	6.9	11.7	12.7	12.5	4.8	7.8	8.5
06/02/74	18.2	1.8	10.2	32.5	42.1	12.8	11.9	18.5
06/18/74	53.5	86.1	53.2	38.4	46.9	41.1	63.8	54.7
07/02/74	19.9	28.3	19.9	44.9	37.9	16.9	11.7	25.6
07/16/74	9.4	11.5	7.8	9.4	7.6	11.5	12.4	9.9
07/30/74	6.9	11.1	13.9	6.8	13.6	27.5	5.9	12.3
08/13/74	7.0	6.6	6.8	7.5	19.9	63.7	15.2	18.1
08/27/74	14.9	7.9	16.9	14.5	7.2	31.5	192.6	40.8
09/17/74	8.5	5.9	5.4	5.9	4.5	6.9	12.1	7.0
10/15/74	1.8	4.5	7.2	1.3	1.7	4.6	0.0	3.0
11/12/74	6.3	3.9	5.8	4.8	6.7	2.5	20.5	7.2
12/17/74	0.4	0.5	0.3	0.3	0.4	0.3	1.2	0.5
				Night				
05/08/74	5.1	43.0	3.4	2.7	5.9	2.5	73.1	19.4
06/05/74	11.1	10.5	9.1	13.1	17.2	6.7	6.8	10.7
07/02/74	15.1	20.8	13.6	21.6	9.8	12.3	53.9	21.0
08/13/74	34.1	25.0	25.6	25.3	11.5	20.4	34.4	25.2
09/03/74	3.8	3.5	3.7	0.6	2.8	25.6	4.8	6.4
10/15/74	5.9	5.1	11.2	3.7	2.7	2.3	3.3	4.9
11/12/74	5.3	7.2	8.6	3.6	8.0	4.9	28.6	9.5
12/17/74	0.6	0.3	0.3	0.5	0.7	0.3	-*	0.5

* Indicates missing samples

Table 5-6. Day and night abundances of copepods, 1974.

Day

Station

Date	A	B	C	D	E	F	G	Mean
04/23/74	0.09	0.15	0.32	0.97	3.96	0.35	0.29	0.88
05/07/74	1.09	1.56	0.55	1.08	2.71	4.62	1.39	1.86
05/21/74	0.98	0.79	1.87	7.23	6.39	0.97	1.62	2.84
06/02/74	3.94	0.38	2.80	7.07	21.87	3.36	4.68	6.30
06/18/74	27.06	67.06	23.84	9.47	27.60	22.26	30.38	29.67
07/02/74	4.69	6.47	5.68	12.58	8.08	2.38	2.51	6.06
07/16/74	5.14	5.25	5.69	5.59	14.01	9.58	7.25	7.50
07/30/74	10.98	14.29	22.05	11.27	15.99	18.54	7.20	14.33
08/13/74	15.08	9.49	11.50	6.47	22.22	31.45	12.77	15.57
08/27/74	12.03	5.95	8.63	18.36	11.83	14.11	74.29	20.74
09/17/74	2.08	1.91	1.73	2.39	2.00	4.15	5.46	2.82
10/15/74	0.10	0.35	4.62	0.63	0.21	0.74	0.01	0.95
11/12/74	5.32	0.84	2.07	1.91	1.08	0.75	2.20	2.02
12/17/74	0.00	0.00	0.11	0.14	0.06	0.00	0.07	0.05
				Night				
05/08/74	0.45	7.36	1.04	0.16	2.59	2.18	17.21	4.42
06/05/74	2.48	3.94	1.97	2.31	5.08	1.72	2.06	2.79
07/02/74	11.99	10.70	7.56	8.25	6.00	10.78	16.42	10.24
08/13/74	40.64	21.80	25.64	31.37	8.79	15.44	47.52	27.32
09/03/74	6.17	5.79	2.42	0.58	3.68	18.41	8.88	6.56
10/15/74	0.75	2.36	3.40	1.42	2.02	3.13	5.45	2.65
11/12/74	1.07	2.50	7.96	2.44	4.06	7.86	24.78	7.24
12/17/74	0.09	0.25	0.24	0.09	0.15	0.00	-*	0.14

* Indicates missing samples

Table 5-7. Day and night abundances of rotifera, 1974.

Day

Station

Date	A	B	C	D	E	F	G	Mean
04/23/74	16.3	13.2	31.5	18.4	327.5	13.9	13.8	62.1
05/07/74	0.8	3.1	2.3	1.9	3.7	3.0	5.0	2.8
05/21/74	38.6	18.5	41.1	13.2	8.3	34.2	15.3	24.2
06/02/74	9.3	1.0	7.2	17.0	16.3	8.2	11.0	10.0
06/18/74	5.0	4.9	7.6	2.6	6.7	8.8	6.6	6.0
07/02/74	0.0	1.9	0.9	1.2	0.6	0.8	0.6	0.9
07/16/74	1.2	2.8	1.6	2.4	0.8	5.2	2.7	2.4
07/30/74	0.9	0.9	2.9	1.4	0.7	1.7	1.3	1.4
08/13/74	1.8	1.5	1.1	1.5	0.5	1.7	0.0	1.2
08/27/74	0.0	0.2	0.7	0.3	0.3	2.5	24.8	4.1
09/17/74	0.6	2.0	0.9	0.5	0.5	0.0	0.0	0.6
10/15/74	1.2	0.1	0.5	1.1	0.1	0.7	0.1	0.6
11/12/74	0.4	1.0	0.6	1.2	0.7	0.0	0.0	0.6
12/17/74	24.8	19.5	22.5	14.4	10.6	16.3	4.9	16.2
				Night				
05/08/74	0.64	7.36	2.45	0.31	2.44	1.66	10.04	3.56
06/05/74	6.49	7.35	10.00	9.53	5.27	10.86	9.05	8.36
07/02/74	0.86	0.53	0.55	0.00	0.80	0.13	0.41	0.47
08/13/74	1.48	0.71	1.28	4.06	0.96	10.19	2.48	3.02
09/03/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/15/74	0.29	0.15	0.47	0.59	0.26	0.12	0.87	0.39
11/12/74	2.04	1.65	0.37	0.46	1.94	1.54	2.56	1.51
12/17/74	11.05	11.08	4.70	8.94	6.71	3.11	-*	7.60

* Indicates missing samples

Table 5-8 . Day and night abundances of protozoa, 1974.

Day

Station

Date	A	B	C	D	E	F	G	Mean
04/23/74	1.28	0.38	1.16	0.97	23.77	1.50	0.29	4.19
05/07/74	0.36	0.56	0.35	0.42	0.90	0.66	0.79	0.58
05/21/74	0.87	0.10	0.82	0.50	0.33	0.58	1.47	0.67
06/02/74	0.10	0.03	0.10	2.43	1.86	0.00	0.18	0.67
06/18/74	0.22	0.00	0.00	0.39	0.22	0.31	0.88	0.29
07/02/74	0.00	0.48	0.00	2.22	0.41	0.24	0.10	0.49
07/16/74	0.17	0.61	0.00	0.00	0.00	0.00	0.00	0.11
07/30/74	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.03
08/13/74	0.00	0.22	0.23	0.63	0.46	3.40	0.74	0.81
08/27/74	0.00	0.00	0.00	0.17	0.00	0.76	0.00	0.13
09/17/74	0.16	0.08	0.12	0.51	0.27	0.18	0.00	0.19
10/15/74	0.00	0.00	0.12	0.75	0.53	0.15	0.00	0.22
11/12/74	0.35	0.21	0.69	0.36	0.48	0.13	1.47	0.53
12/17/74	1.00	0.09	0.63	0.62	0.25	0.22	0.58	0.48
				Night				
05/08/74	0.06	0.00	0.19	0.00	0.29	0.00	4.30	0.69
06/05/74	0.24	0.17	0.30	0.68	0.00	0.23	0.48	0.30
07/02/74	0.29	0.32	0.22	0.37	0.16	0.00	0.20	0.22
08/13/74	15.43	0.00	0.26	0.90	0.16	0.00	0.00	2.39
09/03/74	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.05
10/15/74	0.46	0.15	0.47	0.36	0.13	0.00	0.08	0.24
11/12/74	0.20	0.13	0.31	0.39	0.09	1.85	3.42	0.91
12/17/74	0.51	0.76	0.24	0.45	0.44	0.57	-*	0.49

* Indicates missing samples

Table 5- 9. Day and night abundances of miscellaneous organisms, 1974. The data are for microzooplankters not included in Tables 5-2 through 5-8.

Day

Station

Date	A	B	C	D	E	F	G	Mean
04/23/74	0.09	0.00	0.42	0.00	1.32	0.00	0.00	0.26
05/07/74	0.30	0.00	0.20	0.12	0.34	0.00	0.30	0.18
05/21/74	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01
06/02/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/18/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/02/74	0.00	0.00	0.00	0.25	0.41	0.00	0.00	0.09
07/16/74	1.66	1.82	2.13	1.77	2.40	8.54	11.14	4.21
07/30/74	1.29	3.18	15.24	2.73	3.74	6.87	5.57	5.52
08/13/74	0.60	0.22	0.90	5.22	9.26	13.60	5.16	4.99
08/27/74	1.45	0.36	0.13	2.50	0.87	0.00	2.75	1.15
09/17/74	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.01
10/15/74	0.10	0.21	0.50	0.13	0.11	0.00	0.00	0.15
11/12/74	0.14	0.10	0.55	0.36	0.12	1.64	2.20	0.73
12/17/74	0.09	0.26	0.11	0.14	0.06	0.11	0.00	0.11
				Night				
05/08/74	0.26	3.40	0.09	0.00	0.00	0.00	0.00	0.54
06/05/74	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.03
07/02/74	0.43	0.11	0.00	0.37	0.16	0.13	0.00	0.17
08/13/74	16.02	10.01	10.77	16.02	7.35	2.63	4.97	9.68
09/03/74	0.08	0.00	0.00	0.07	0.22	0.76	1.62	0.39
10/15/74	0.29	0.15	0.38	0.24	0.04	0.00	0.24	0.19
11/12/74	0.05	0.09	0.19	0.07	0.18	0.46	0.43	0.21
12/17/74	0.00	0.08	0.05	0.18	0.07	0.00	-*	0.06

* Indicates missing samples

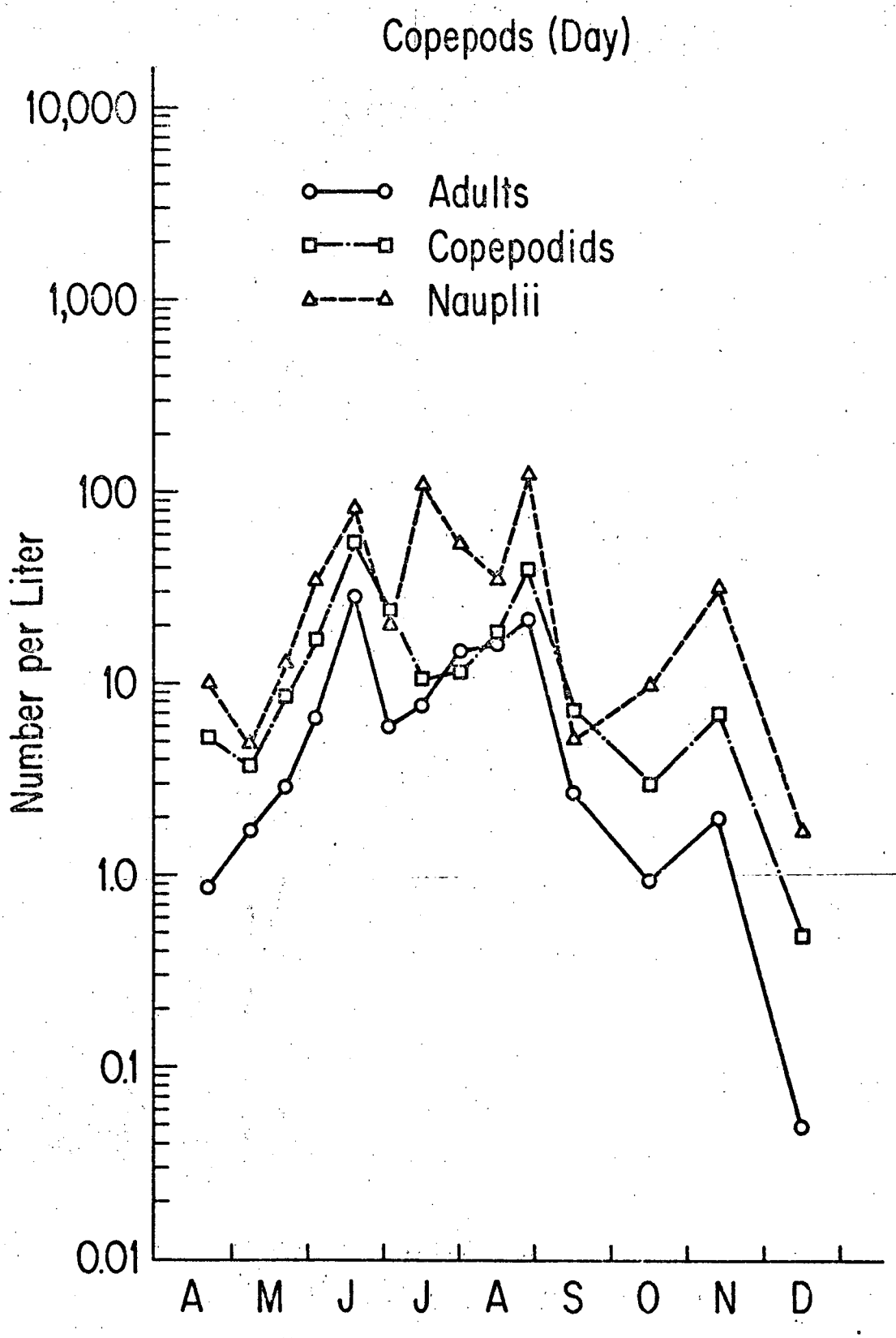


Figure 5-4. Total copepod abundances in day samples, 1974.

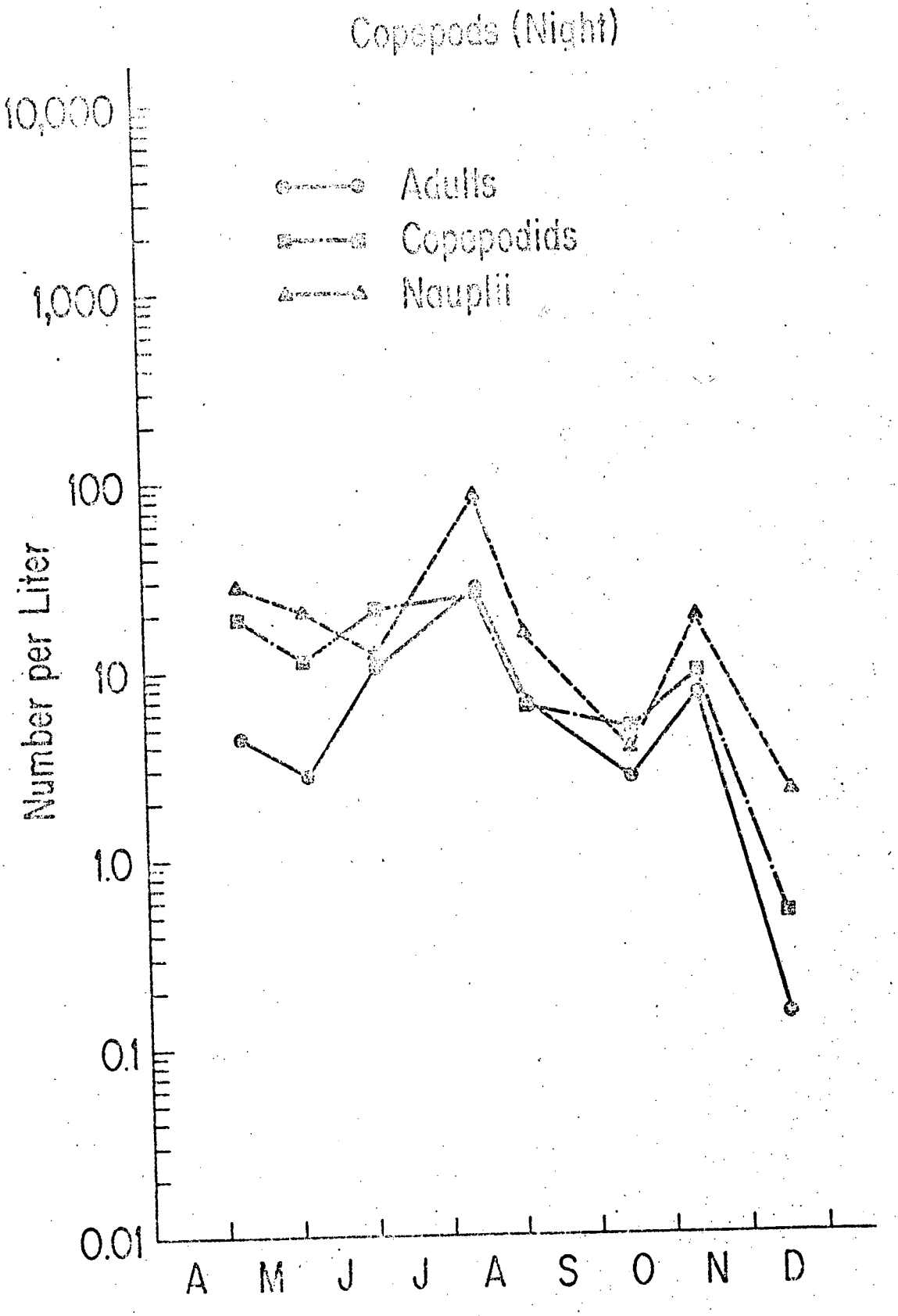


Figure 5-5. Total copepod abundances in night samples, 1974.

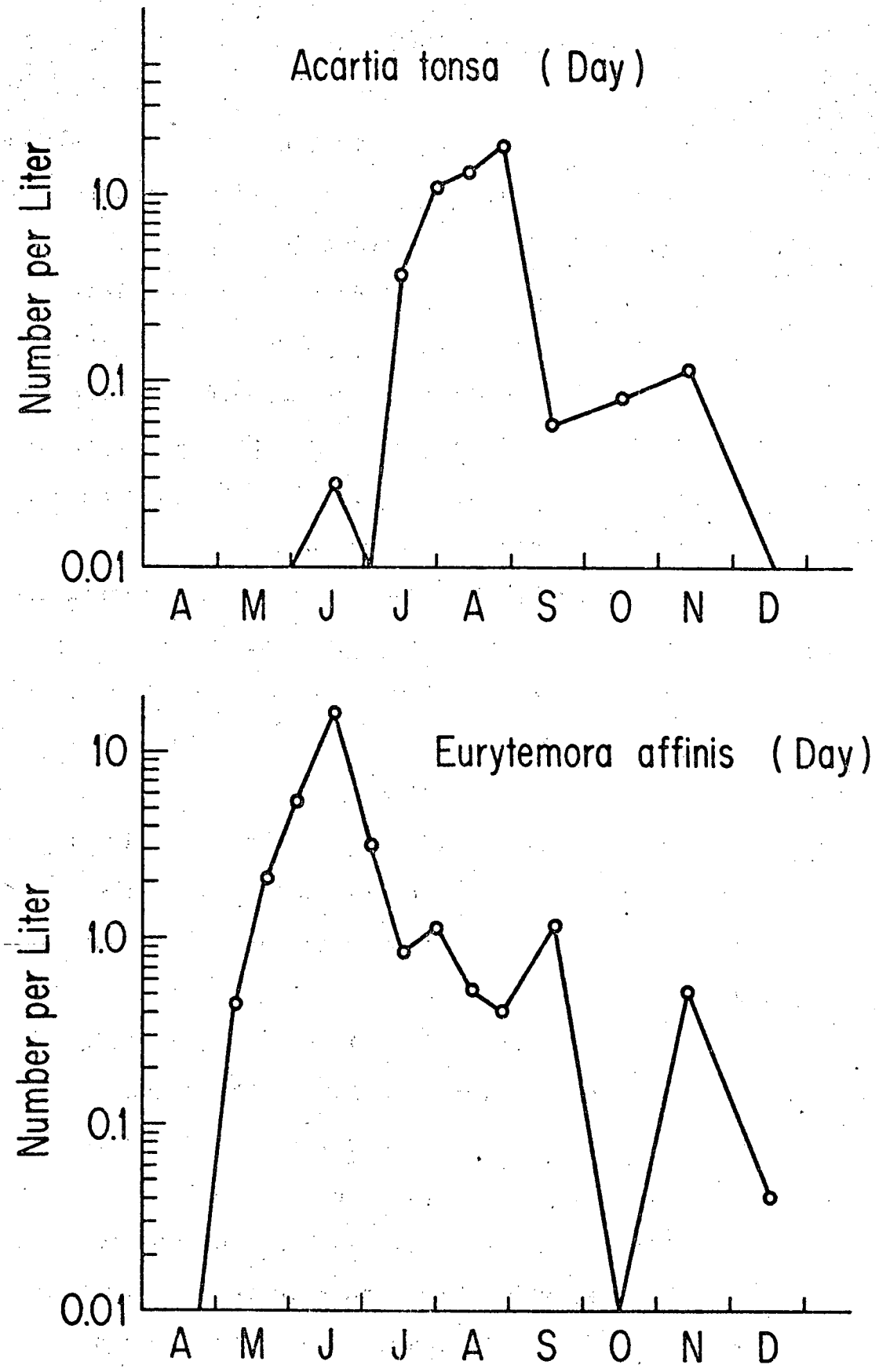


Figure 5-6. Day abundance of calanoid copepods, Acartia tonsa and Eurytemora affinis.

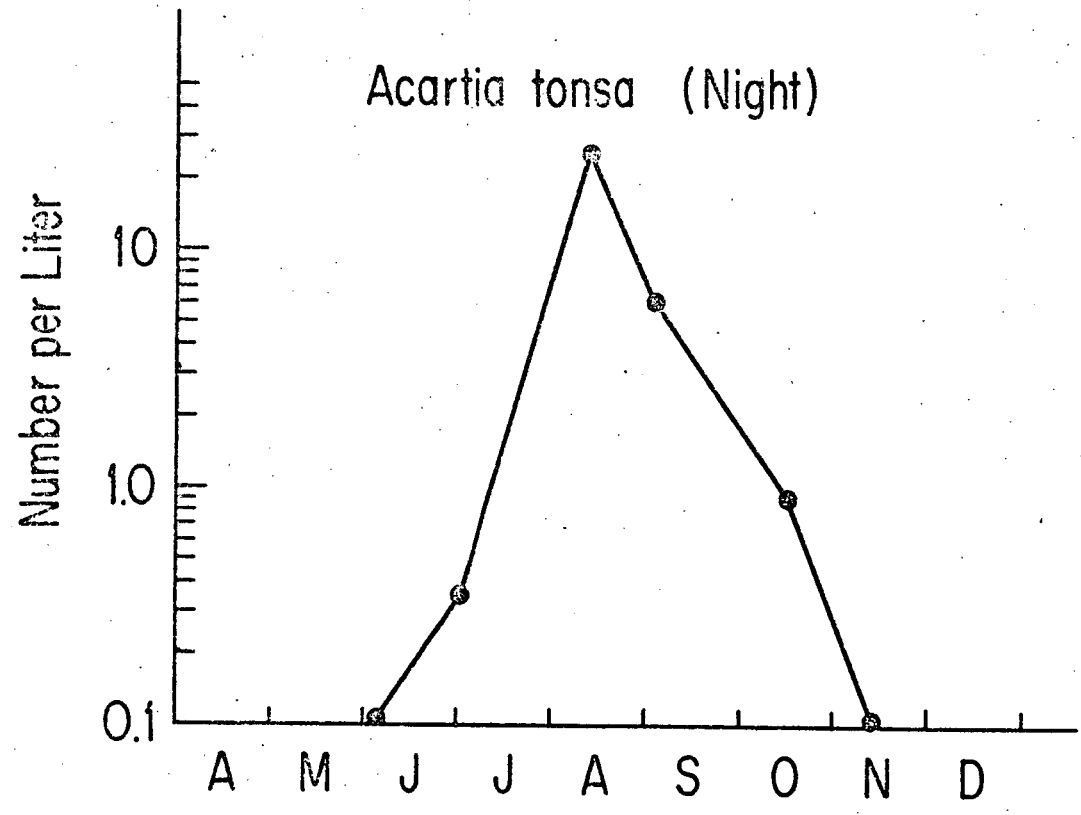
and 5-7). A. tonsa was observed only during the summer and fall. E. affinis occurred throughout the sampling period with peak abundances during late spring and fall. The cyclopoid copepods, Diacyclops bicuspidatus and Halicyclops fosteri, were generally less abundant than the calanoids (Figures 5-8 and 5-9).

The most frequently occurring cladoceran species were Bosmina longirostris and Diaphanosoma brachyurum. D. brachyurum reached peak abundance during July and August and was observed infrequently during the remaining sampling period (Figures 5-10 and 5-11). B. longirostris reached peak abundance during June and occurred throughout the sampling period.

The rotifers reached peak abundance during the spring and fall months (Figure 5-3). Notholca accuminata was the most common species collected, comprising 62% of the total rotifers sampled during the day and 40% of those seen at night.

The protozoans retained by #20-mesh plankton nets are best represented by the shelled amoebae Centropyxis sp. and Difflugia sp. The colonial peritrichs Epistylis and Carchesium sp. are also commonly represented in the protozoan samples (Figure 5-12).

The results of 27 ANOVA on various microzooplankton forms are represented in Tables 5-10 and 5-11; all but five analyses showed no detectable effects of station location on abundance. The analysis of variance for E. affinis sampled during the day indicated a significant station effect, although the Scheffé test was unable to locate the difference. Analyses of copepod nauplii abundance during the day showed Station F to be greater than Station B (Table 5-10). For all samples collected at night,



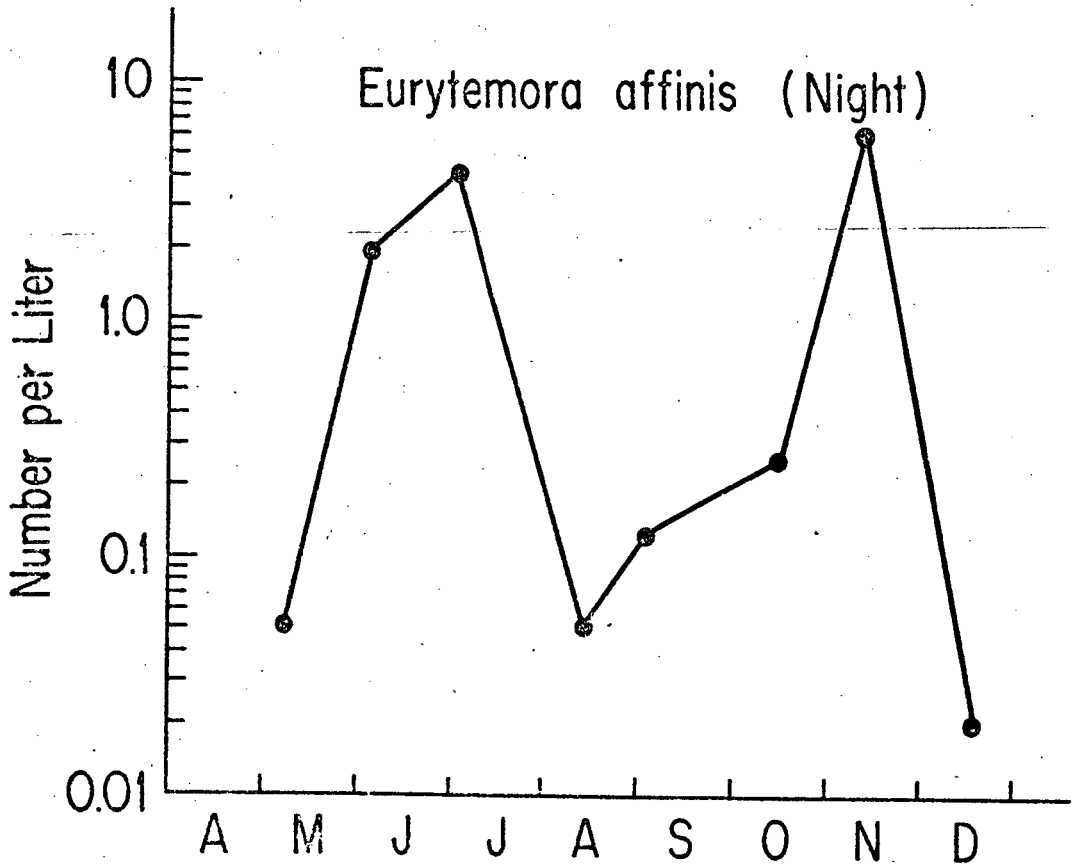
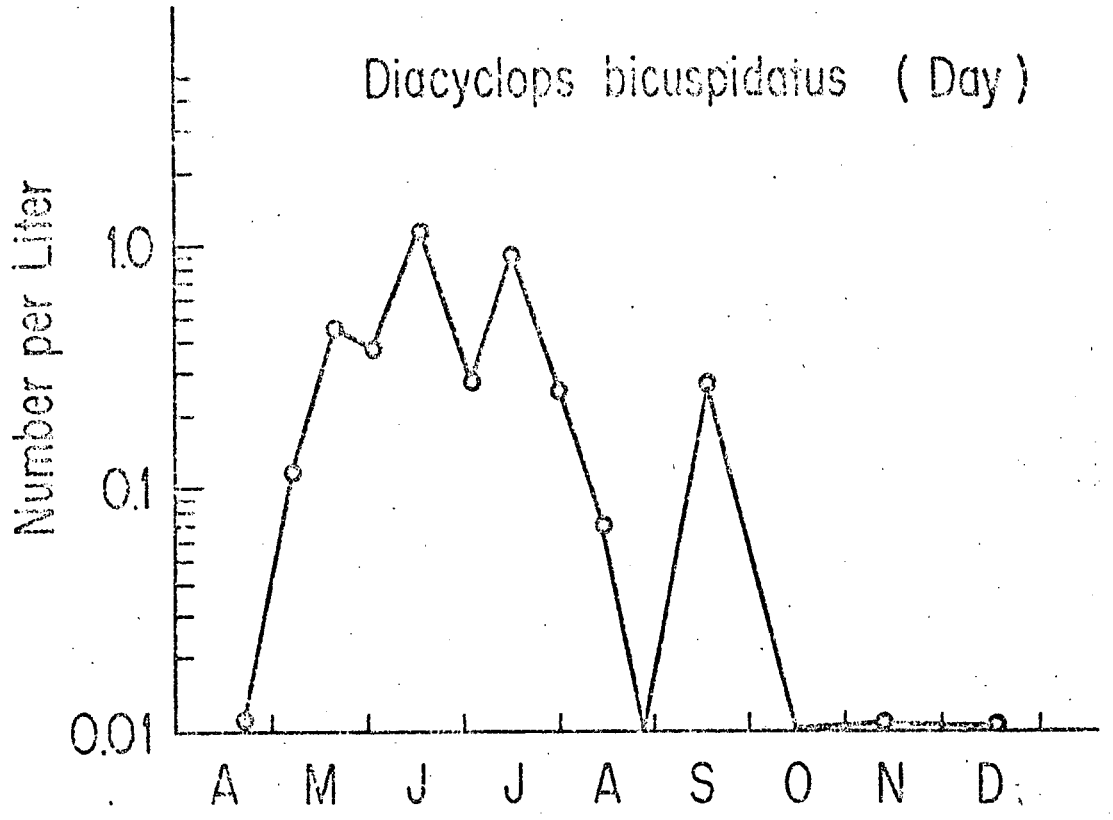


Figure 5-7. Night abundance of calanoid copepods Acartia tonsa and Eurytemora affinis.



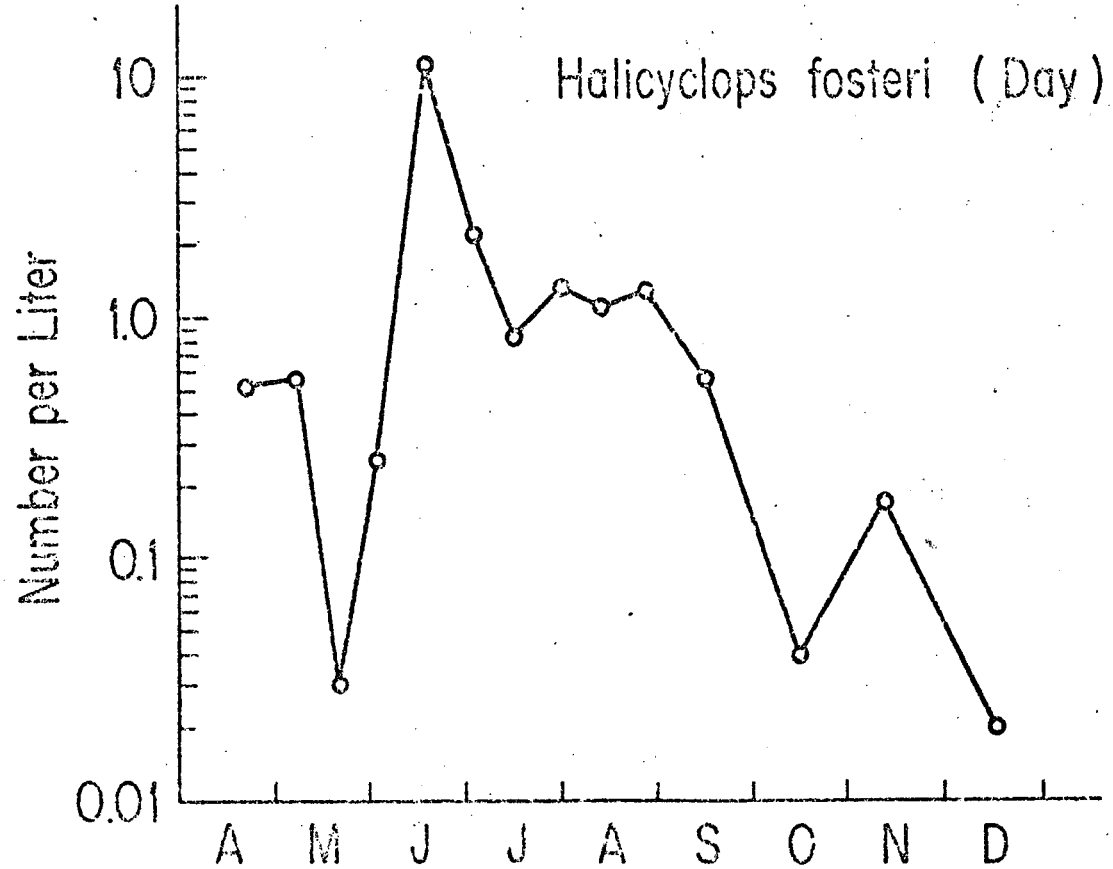
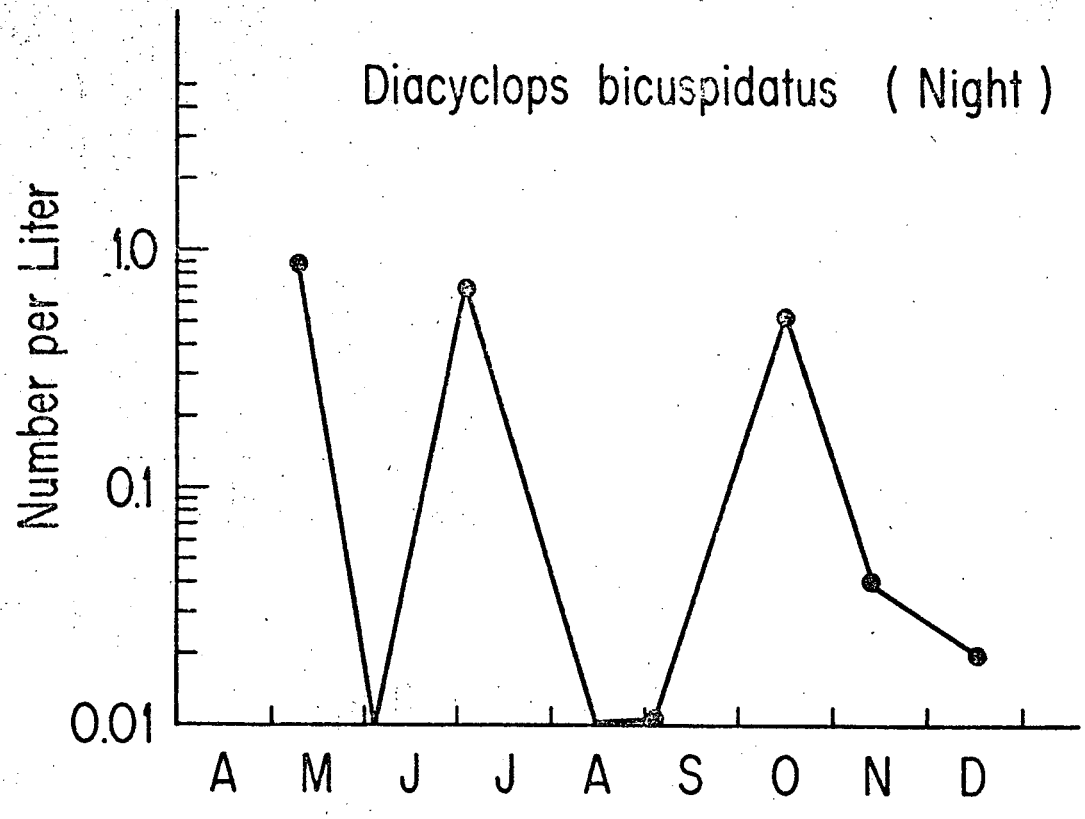


Figure 5-8. Day abundance of cyclopoid copepods Diacyclops bicuspidatus and Halicyclops fosteri.



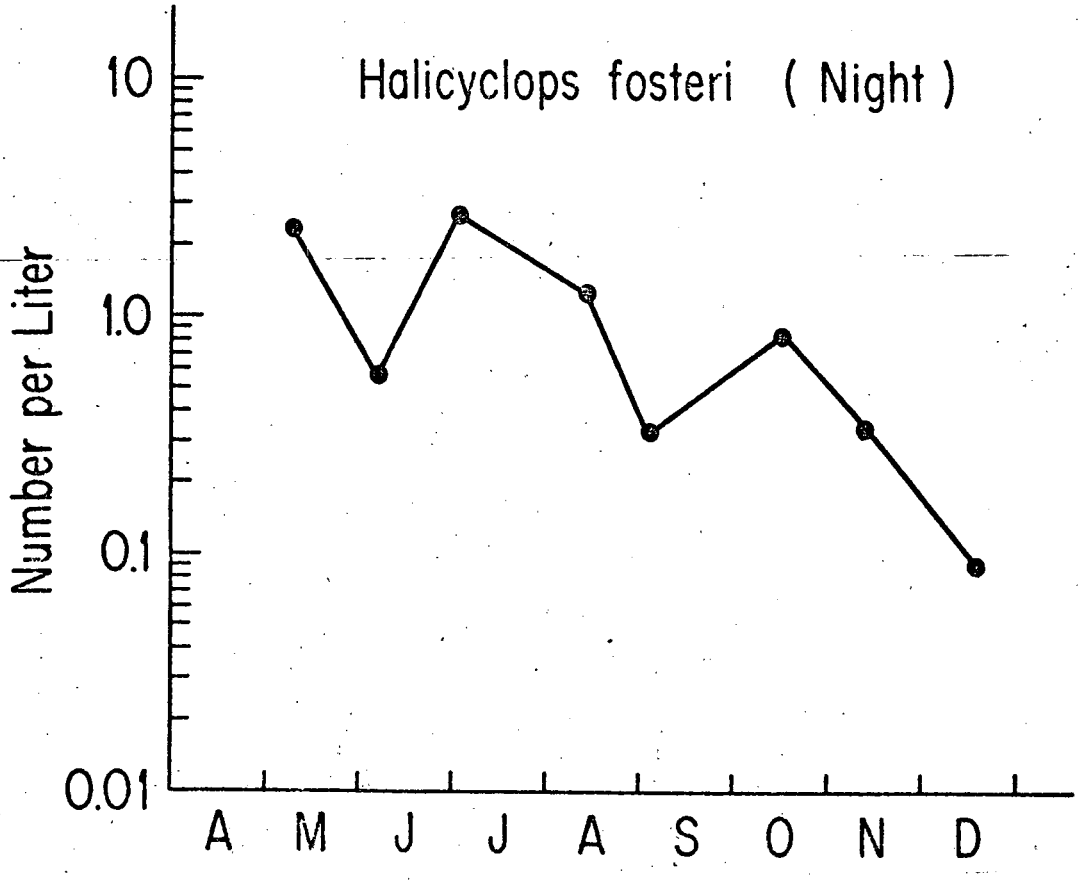


Figure 5-9. Night abundance of cyclopoid copepods Diacyclops bicuspidatus and Halicyclops fosteri.

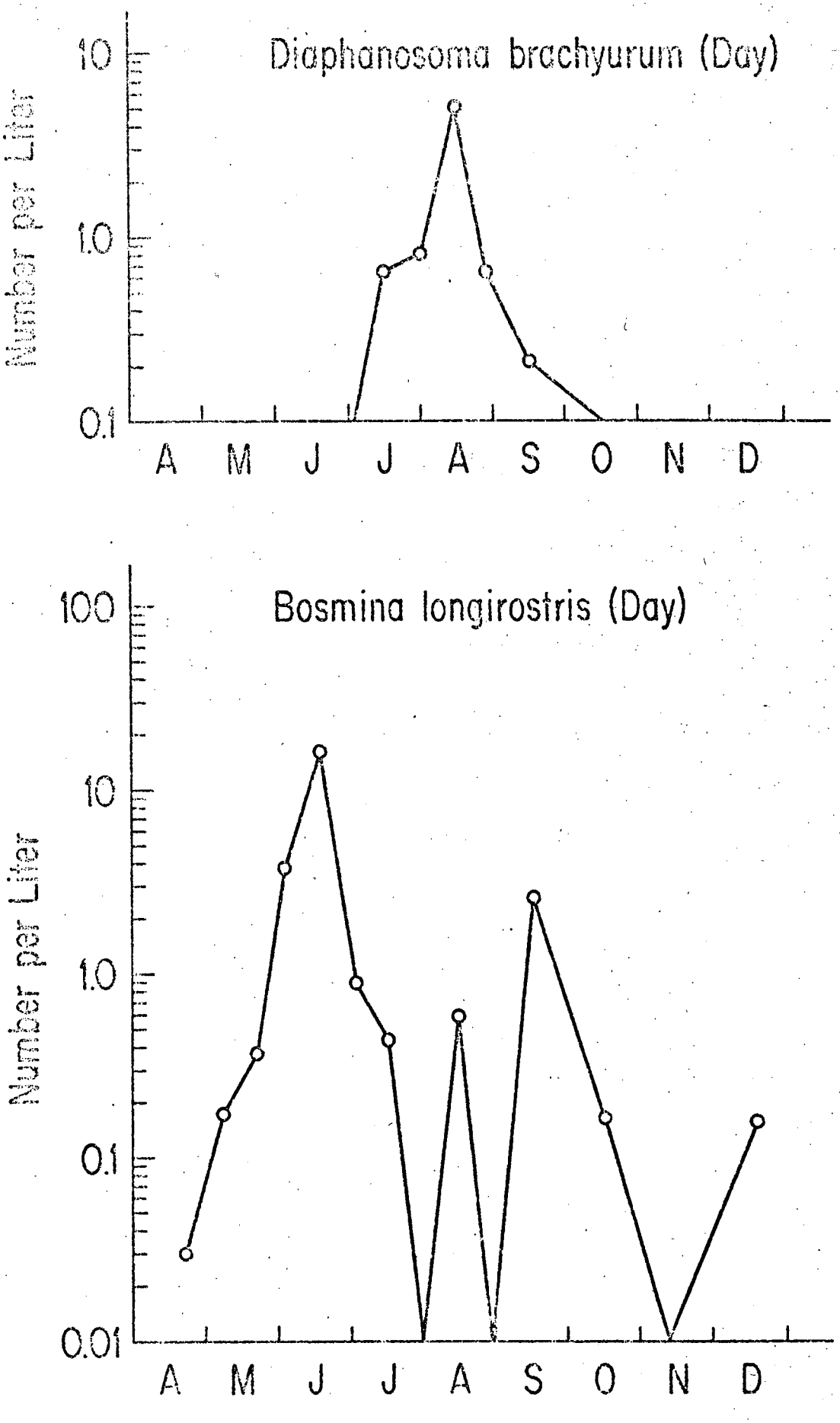
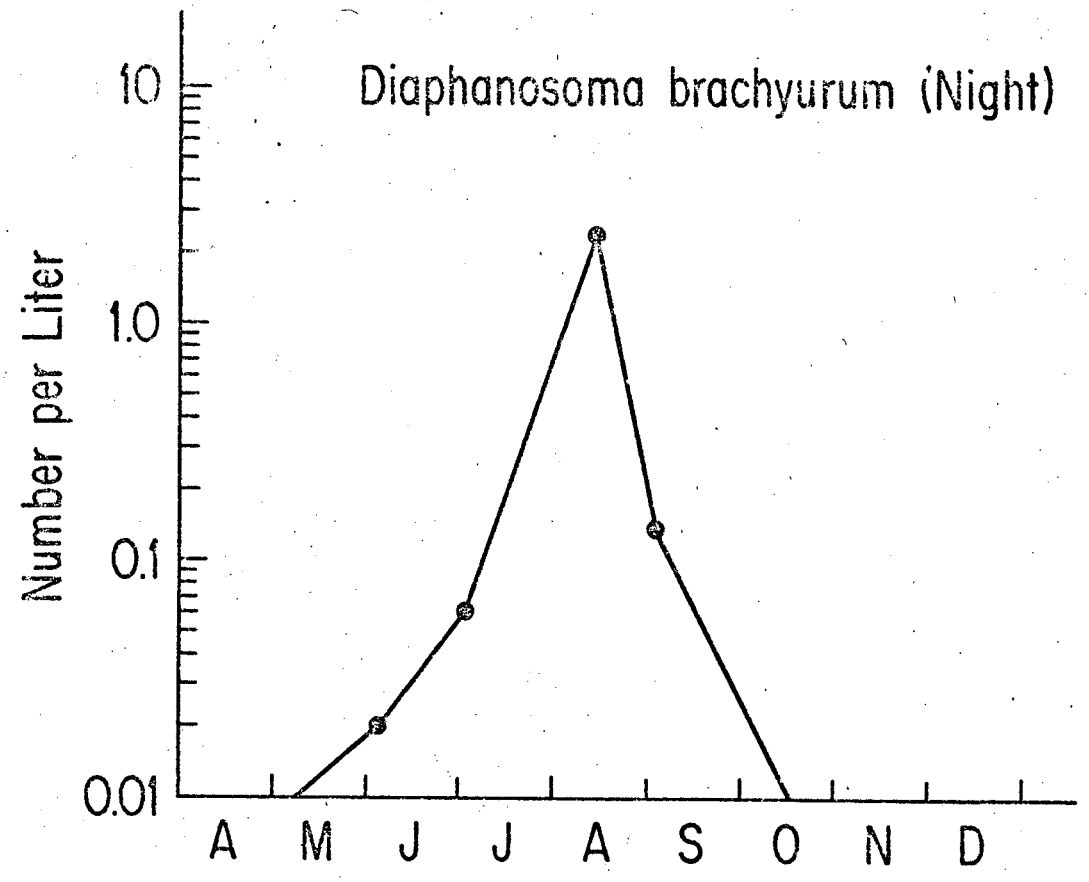


Figure 5-10. Day abundance of cladocerans Diaphanosoma brachyurum and Bosmina longirostris.



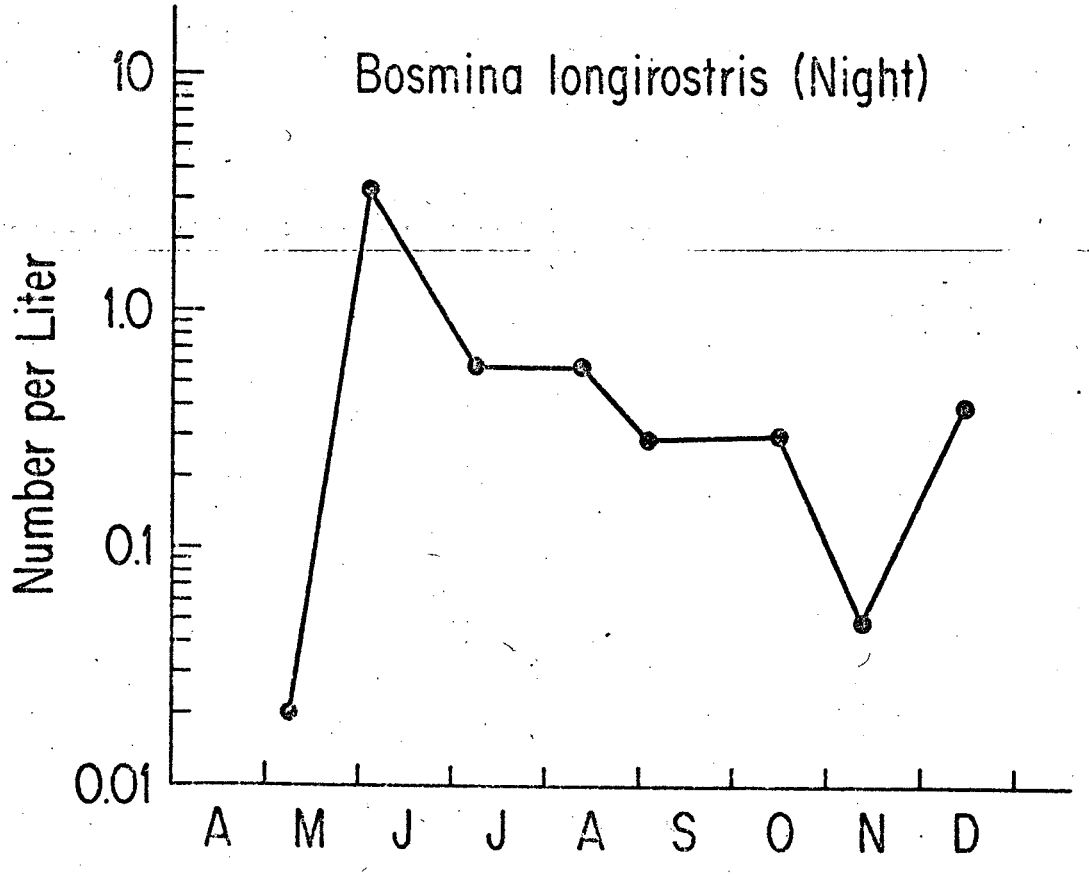


Figure 5-11. Night abundance of cladocerans Diaphanosoma brachyurum and Bosmina longirostris.

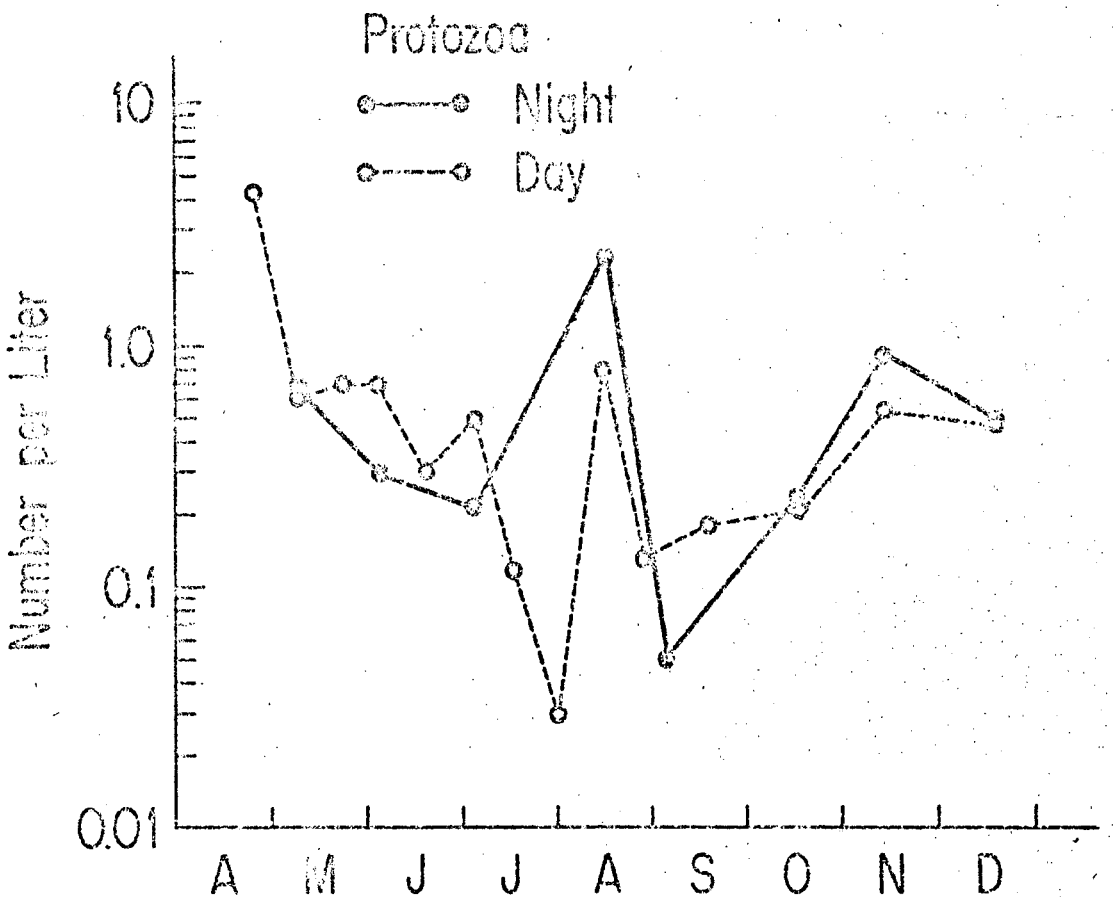


Figure 5-12. Total abundance of Protozoa in day and night samples.

Table 5-10. Results of analyses of variance of day abundances of microzooplankton, 1974.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha < .10$)
Total	1.03	N.S.	---
Copepoda-Adults	1.57	N.S.	---
Copepoda-Copepodids	0.79	N.S.	---
Copepoda-Nauplii	2.37	*	F>B
Eurytemora affinis	2.23	*	N.S.
Acartia tonsa	1.43	N.S.	---
Diacyclops bicuspidatus	1.95	N.S.	---
Halicyclops fosteri	0.80	N.S.	---
Diaphanosoma brachyurum	1.26	N.S.	---
Bosmina longirostris	2.17	N.S.	---
Daphnia pulex	1.06	N.S.	---
Crustacea	1.24	N.S.	---
Rotifera	0.28	N.S.	---
Protozoa	1.66	N.S.	---

* $P < 0.05$

Table 5-11. Results of analyses of variance of night abundances of microzooplankton, 1974.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha < .10$)
Total	2.78	*	G>D
Copepoda-Adults	2.80	*	G>A,C,D,&E
Copepoda-Copepodids	1.81	N.S.	---
Copepoda-Nauplii	1.99	N.S.	---
Eurytemora affinis	1.26	N.S.	---
Acartia tonsa	3.51	*	G>B,C,D&E
Diacyclops bicuspidatus	2.18	N.S.	---
Halicyclops fosteria	1.36	N.S.	---
Diaphanosoma brachyurum	0.90	N.S.	---
Bosmina longirostris	2.06	N.S.	---
Crustacea	2.00	N.S.	---
Rotifera	0.79	N.S.	---
Protozoa	1.03	N.S.	---

* $P < 0.05$

Station G was found to have higher abundances for total microzooplankton, copepod adults and A. tonsa than the other stations (Table 5-11).

Comparisons of the microzooplankton species observed during 1971 and 1974 sampling periods reveal that the dominant species were similar. The most frequently occurring copepods and cladocerans (A. tonsa, E. Affinis, B. longirostris and D. brachyurum) were the same in both years. The two abundant protozoans, Centropyxis sp. and Difflugia sp., were also present during both sampling periods. In 1971, the most common rotifer was Brachionus angularis; however, the predominant rotifer in 1974 was N. accuminata.

It is fair to assume that holoplanktonic organisms in the vicinity of the Indian Point nuclear generating station will be subject to entrainment in the cooling water flow of the power station. River population studies carried out over a period of several years, have had as their objective to determine whether power plant operation has had any qualitative or quantitative impact on river populations.

Comparisons of microzooplankton abundance within sampling years seldom show differences due to factors other than season. The few 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 diversity components and community structure (Pielou, 1975), rather than abundance.

Qualitative comparison of microzooplankton within and between years indicates that the species composition of the plankton has remained essentially the same for the first four years of this study. Where dominant species within taxa have been found to differ (e.g. the dominance of Nothalca over Brachionus in the rotifer population for 1974) 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 started (see e.g. NYU, 1973, 1974; LMS, 1974, 1975).

There exist no data to demonstrate that river populations of microzooplankton have been affected by the operation of the Indian Point station. Near-field data (this report and NYU, 1973, 1974; LMS, 1974) and far-field data (LMS, 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 1971-1974.

5.2 ENTRAINMENT EFFECTS STUDIES

5.2.1 Intake and Discharge-Canal Studies

5.2.1.1 Abundance and Viability

5.2.1.2 Methods

Microzooplankton collected from the Indian Point intake (Stations I-1 and I-2) and discharge (Stations D-1 and D-2) were used in estimating the abundance and viability of entrained microzooplankton. Samples were collected only from surface waters since analysis of previous data showed no depth-related differences and vertical tows in the discharge canal were not possible.

During the first 4 sampling months, March through June, samples were taken using #20-mesh (76μ) nets equipped with TSK flowmeters. In June the flows in the discharge canal were so rapid that it became necessary to discontinue use of the flowmeters and mount velocity reduction cones on the nets to slow the passage of water through the nets to 0.5 fps. The nets were attached to the cones with spring clips and were then mounted on a rigid rack at each of the four stations.

Sampling duration was 3 minutes in all cases. During spring and late fall, when microzooplankton abundance was low and a single 3-minute sample provided insufficient organisms for testing, additional samples were taken.

Two 1-ml samples from each collection were examined immediately after sampling and the number of dead organisms was recorded. The criterion of "death" was lack of motor response upon probing with a pointed instrument. After examination, samples were preserved with formalin. Two subsamples from each sample were counted later

to determine the total number of organisms present. Samples used only for abundance studies were preserved with formalin and counted.

The data were tested for significant differences in abundance using the Kruskal-Wallis non-parametric statistic (Kruskal and Wallis, 1952). Analysis of microzooplankton survival data followed an R × C Contingency Table analysis. Analysis was first done on monthly survival at the intake and discharge stations. When significant differences were found, each date during that month was examined for differences in survival among stations. All significant sets were tested for maximum non-significant subsets by an *a posteriori* simultaneous test procedure.

5.2.1.3 Results

With the exception of two canthocamptid copepods, the species inventories of microzooplankton were the same in 1974 as in 1972; there was no inventory done in 1973 (Table 5-12). The patterns of abundance in Indian Point plant samples followed closely those of the river, with June being the month of peak abundance. The number of copepods exceeded the number of cladocerans by a factor of two, except in September, when 25% of the organisms collected were cladocerans (Table 5-13).

During the late fall, winter and early spring, copepodid stages of the cyclopoid copepod *Diacyclops bicuspidatus* were the dominant organisms present. During the summer months, *Halicyclops fosteri* was the most abundant cyclopoid copepod in the intake and discharge samples; during June, it was the most abundant copepod species in plant and river samples.

Table 5-12. Inventory of microzooplankton collected during Intake and discharge-canal studies.

Species	Presence 1972	1973	1974
Crustacea			
Copepoda			
Acartia tonsa Dana	x	N.S.*	x
Canthocamptid sp. 1	x	"	
Canthocamptid sp. 2	x	"	
Canuella sp.	x	"	x
Diacyclops bicuspidatus	x	"	x
Ectinosoma curticorne	x	"	x
Epischua sp.	x	"	x
Ergasilis sp.	x	"	x
Eurytemora affinis	x	"	x
Halicyclops fosteri	x	"	x
Mesocyclops sp.	x	"	x
Nauplii	x	"	x
Copepodids	x	"	x
Cladocera			
Bosmina longirostris	x	N.S.	x
Chydorid	x	"	x
Daphnia pulex	x	"	x
Diaphanosoma brachyurum	x	"	x
Leptodora kindti	x	"	x
Moina sp.	x	"	x

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

Table 5-13. Abundances of microzooplankton sampled at Indian Point Unit 1 intake stations in 1974, by month. The data shown are mean numbers of organisms, in thousands, collected in 3-minute samples ± standard error (n = number of samples examined). Organisms are collected from approximately 5,400 liters of water in each 3-minute sample.

	Mean numbers of organisms (thousands)					
Month	Micro-crustacea	Calanoid copepods	Cyclopoid copepods	Harpactacoid copepods	Copepods	Cladocerans
March	1.2 ±0.5 n=4	0	0.9 ± 0.5 n=4	0.3 ± 0.1 n=4	1.2 ± 0.5 n=4	.046 ± .045 n=4
April	3.1 ±0.9 n=6	.5 ±0.4 n=6	1.4 ± 0.4 n=6	0.5 ± 0.1 n=6	2.4 ± 0.6 n=6	.017 ± .017 n=6
May	22.77 ±0.08 n=4	15.4 ±8.3 n=5	3.0 ± 1.5 n=5	1.04 ± 0.01 n=5	97.6 ±10.0 n=5	0.3 ± 0.3 n=5
June	184.0 ±0.6 n=2	43.0 ±12.0 n=2	119.2 ± .2 n=2	2.4 ± 0.3 n=2	180.4 ±46.8 n=2	19.3 ± 0.2 n=2
July	45.96 ± .06 n=6	27.5 ± 9.9 n=6	11.0 ± 2.1 n=6	19.2 ±14.2 n=6	31.7 ± 8.3 n=6	1.2 ± 0.2 n=6
Aug	27.0 ±6.0 n=3	21.5 ± 6.3 n=3	0.5 ± 0.3 n=3	4.1 ± 0.6 n=3	26.1 ± 6.2 n=3	0.7 ± 0.2 n=3
Sept	13.1 ±2.2 n=5	7.2 ± 1.9 n=5	1.4 ± 0.6 n=5	0.5 ± 0.1 n=5	9.7 ± 1.8 n=5	3.4 ± 0.8 n=5
Oct	16.8 ±3.0 n=18	3.8 ± 0.8 n=18	9.3 ± 2.2 n=18	2.8 ± 0.8 n=18	16.2 ± 3.0 n=18	0.5 ± 0.2 n=18
Nov	3.3 ±1.7 n=5	0.6 ± 0.4 n=5	1.4 ± 0.7 n=6	0.7 ± 0.4 n=6	2.6 ± 1.4 n=6	0.14 ± 0.07 n=6
Dec	3.1 ±1.2 n=6	0.2 ± 0.2 n=6	2.2 ± 1.0 n=6	0.2 ± 0.1 n=6	2.6 ± 1.1 n=6	0.4 ± 0.1 n=6

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

Acartia tonsa appeared in samples during July and, along with E. affinis was abundant during August. E. affinis and H. fosteri were the most abundant species in September and October.

Harpacticoid copepods were never present in great numbers; the period of greatest abundance was in July and August, when Canuella sp. was present in relatively large numbers.

There were no significant differences in microzooplankton abundance among stations or among sampling periods throughout 1974 (Table 5-14).

The survival of selected groups of microzooplankton in plant-entrained samples collected each month from March through December 1974 is shown in Table 5-15. There was 100% survival of all organisms at all stations during June. Both the river and entrainment abundance data indicate that June is the month of greatest microzooplankton abundance. However, it should be noted that during June, cyclopoid copepods far exceeded calanoid copepods in abundance. During July calanoid copepods suffered heavy mortalities at Station D-2 after exposure to a plant ΔT of 11.6°F (Table 5-15 and 5-16). The difference in survival noted during July and August for total microzooplankton was directly related to deaths of calanoid copepods. In August, microzooplankton survival at the intake stations was significantly higher than at

Table 5-14. Seasonal abundances of microzooplankton at Unit 1 intakes and at discharge-canal stations D-1 and D-2, 1974. The data shown are mean numbers of organisms, in thousands, collected in 3-minute samples ± standard error (n = number of samples examined).

Season	Discharge	Mean numbers of organisms (thousands)		
		Intake	D1	D2
Spring (March-May)	13.0-15.5	5.4 ± 2.1 n=14	11.0 ± 5.4 n=14	----------
Fall (Oct-Dec)	19.5-23.5	7.0 ± 2.7 n=20	20.2 ± 2.7 n=22	10.6 ± 2.0 n=16
Summer (June-Sept)	25.5-36.5	53.7 ±14.3 n=10	68.2 ±24.6 n=12	20.2 ± 3.8 n=10

Table 5-15. Mean percent survival of entrained microzooplankton at Unit 1 intakes (I), discharge-canal stations (D-1, D-2), and discharge port (DP) by month, 1974. Station suffix (cl) indicates chlorination.

Mean % Survival ± S.E.

Month	Micro-rustacea	Calanoid copepods	Cyclopoid copepods	Harpacticoids	Copepods	Cladocerans
March						
I	50.0 ±50.0	0	75.0 ±35.4	100.0	50.0 ±50.1	0
D1	50.0 ±50.0	0	50.0 ±50.0	50.0 ±50.0	66.7 ±33.9	0
D2	N.S.*	N.S.	N.S.	N.S.	N.S.	N.S.
April						
I	94.4 ±3.4	97.5 ± 1.6	94.9 ± 2.8	100.0	95.9 ± 2.2	0
D1	75.0 ± 1.6	57.1 ±60.6	90.6 ± 9.4	58.3 ±36.9	79.9 ± 6.8	1.0
D2	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
May						
I	72.1 ±21.2	63.5 ±26.6	100.0	100.0	72.1 ±21.2	100.0
D1	65.7 ± 2.5	57.0 ± 2.9	100.0	100.0	64.9 ± 4.8	100.0
D2	N.S.	N.S.	N.S.	N.S.		100.0
DP	63.1 ± 4.8	48.8 ±5.5	100.0	100.0	59.6 ± 2.6	100.0
June						
I	100.0	100.0	100.0	100.0	100.0	100.0
D1	100.0	100.0	100.0	100.0	100.0	100.0
D2	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
July						
I	98.2 ±18.0	97.4 ± 2.5	100.0	100.0	98.5 ± 2.1	93.8 ± 6.3
D1	98.6 ± 0.9	100.0	100.0	98.0 ± 2.0	99.7 ± 0.3	62.5 ±37.6
D2	93.1 ± 2.9	89.1 ± 5.4	99.2 ± 0.8	91.1 ± 2.2	93.1 ± 2.5	87.5 ±12.5
Aug.						
I	97.3 ± 0.9	96.9 ± 1.0	100.0	100.0	97.2 ± 0.9	100.0
D1	80.8 ± 2.2	73.3 ± 2.9	100.0	100.0	80.0 ± 2.3	100.0
D2	89.5 ± 1.8	87.5 ± 2.3	0	93.6 ± 3.1	88.9 ± 1.9	100.0

* N.S. No Sample

Table 5-15 (cont.)

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

Table 5-16. Monthly differences in survival of entrained microzooplankton at the intake and discharge stations.

	Micro Crustacea	Calanoids	Cyclopoid	Harpacticoid	Copepods	Clacocera
March	N.S.*	N.S.	N.S.	N.S.	N.S.	N.S.
	(30)**	(1)	(25)	(11)	(29)	(2)
April	N.S.	N.S.	N.S.	S.	N.S.	N.S.
	(198)	(19)	(119)	(37)	(174)	(3)
May	S.***	S.	N.S.	N.S.	S.	N.S.
	(401)	(308)	(62)	(25)	(495)	(6)
June	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	(1897)	(434)	(1245)	(25)	(1704)	(192)
July	S.	S.	N.S.	N.S.	N.S.	N.S.
	(1047)	(619)	(271)	(154)	(1116)	(33)
Aug	S.	S.	N.S.	N.S.	S.	N.S.
	(486)	(430)	(9)	(81)	(470)	(15)
Sept	N.S.	N.S.	S.	N.S.	N.S.	N.S.
	(646)	(88)	(26)	(6)	(120)	(40)
Oct	S.	N.S.	S.	N.S.	S.	N.S.
	(1263)	(290)	(729)	(210)	(1227)	(56)
Nov	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	(74)	(14)	(38)	(19)	(70)	(4)
Dec	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	(95)	(10)	(64)	(7)	(82)	(12)

* N.S. Not Signficant
** (no) Number of Organisms Examined
*** S Significant

either of the discharge stations. During September and October, heavy mortalities among cyclopoid copepods resulted in significant differences among stations; whereas 100% of the cyclopoid copepods collected at Station D-1 survived plant passage, they were all dead at D-2 (Tables 5-15 and 5-16). Since there is little decrease in ΔT from D-1 to D-2 as the cooling water moves down the discharge canal and since these two stations are basically similar, these mortalities reflect a time-temperature synergism affecting the thermal tolerance of these copepods.

Occasionally, significant mortalities among the cladocerans (primarily Bosmina) were observed (e.g., in July and October; Table 5-15). It is believed that these deaths were not caused by plant passage, but by the collection procedure; Bosmina and other cladocerans collected in inlets often become entrapped in the air/water inferface and die. Nevertheless, survival of cladocernas collected from the intake or discharge stations was similar (Table 5-16).

In general, there was 90 to 100% survival of cyclopoid and harpacticoid copepods and cladocerans following plant passage (Table 5-15). Calanoid copepods proved to be the most sensitive to the effects of plant entrainment (Table 5-15). These results are in agreement with other results obtained previously by New York University (NYU, 1973).

Survival of organisms collected at the intakes was generally higher than at the discharge stations, although significant differences between Stations D-1 and D-2 occurred at times. While microzooplankton deaths at the intake stations were probably the result of physical damage from collection and

handling, deaths at the discharge stations were probably the result of additional stresses imposed by the plant, such as pressure stress from pumped entrainment and temperature stress by imposed ΔT as water is passed through the plant.

5.2.2 Latent Effects

5.2.2.1 Methods

Several methods were used for assessing latent effects of entrainment on microzooplankton. Organisms were collected from four different intake and discharge-canal stations. Each sample was mixed so that the organisms were uniformly suspended throughout the sample. Ten 1-ml aliquots were taken with a wide-bore pipette and placed in a 2-ml microcage. Each cage was checked immediately for dead organisms. The cages were then kept in ambient river water and the organisms were observed for mortality after 1-day. It was felt that this method was unsatisfactory because the cage was too small for the numbers of organisms enclosed. To avoid overcrowding, it was decided to pick out individual specimens of the more prevalent species in the sample and place one in each cage. The cages were then kept in flowing river water for the duration of the experiment. In addition to the above type of experiments, 100 ml of uniformly mixed samples were placed in culture jars and were kept in river water until they were observed for latent mortality.

5.2.2.2 Results and Discussion

Latent mortality was assessed using several holding times (Table 5-17). After 1 week (168 hrs) there was less than 10% survival in samples collected from both the intake and discharge

Table 5-17. Latent mortality of entrained microcrustaceans retained at ambient temperature for 1, 4, 6, 24, and 48 hours following capture at Indian Point, (I1=Unit 1 intake; D1 and D2=Discharge canal stations; C1=chlorination; S.E.=standard error for duplicate samples).

Date	Temperature Intake	ΔT	Percent survival ±S.E. 1 hr	4 hrs	6 hrs	24 hrs	48 hrs
04/30							
I1	16°C (60.8°F)	2°C (3.6°F)	80.6 ±2.8				62.5 ±4.2
I1			94.4 ±5.6				74.2 ±7.6
D1			57.4 ±4.4				28.2 19.4
07/31							
I1	25°C (77.0°F)	3°C (5.4°F)	95.5 ± .7	76.9 ±8.0		18.4 ±9.9	
D1			89.5 ±7.5	80.3 ±1.8		72.8 ±4.2	
D2			91.5 ±3.1	47.3 14.0		19.8 16.8	
08/18							
I1	25.2°C (77.4°F)	8.3°C (14.9°F)	98.1 ±1.0		85.7 ±5.0	38.0 ±6.6	
D1			76.5 ±4.5		57.5 ±3.5	31.6 ±1.3	
D2			89.5 ± .6		75.5 ±2.3	41.8 ± .45	
09/26							
I1	21.8°C (71.2°F)	4.7°C (8.5°C)	100.0			72.0 ±1.4	
D1C1			100.0			42.2 27.9	
D2C1			85.7 ±2.5			69.1 19.2	

Table 5-17. (cont)

Date	Temperature Intake	ΔT	Percent survival ±S.E. 1 hr	4 hrs	6 hrs	24 hrs	48 hrs
09/26							
D1			92.8 ±7.2			78.5 ±7.2	
D2			98.6 ±1.4			98.5 ±5.2	
10/24							
I1	14.9°C (58.8°F)	8.6°C (15.5°F)	91.5 ±1.4			74.1 ±2.8	60.8 ±8.4
D1			79.3 ±5.4			63.9 ±1.3	41.5 12.8
D2			88.4 ±2.7			83.2 ±5.4	62.5 ± .35
10/31							
IC1	13.5°C (56.3°F)	9.0°C (16.2°F)	85.4 ±1.4			94.7 ±1.1	
D1C1			75.7 ±2.6			88.2 ±1.25	
D2C1			88.2 ±8.5			84.1 ± .85	

stations. This is in general agreement with 1972 New York University microzooplankton data. Mortality in both the intake and discharge samples after 1 hr was 15-20% less than mortalities after 48 hrs. At the longer holding times the populations tended to become unlike those in the river and the confined populations tended to exhibit presumably abnormal types of behavior and predation such as cannibalism. Also, microalgal populations present in samples kept for periods longer than 24 hrs changed. Green algae tended to increase over diatoms and became dominant, thus affecting the copepods' diet and possibly their ability to survive confinement. It was felt that sample retention times of one day were optimal for observations of latent mortality of entrained microzooplankton.

On two dates (July 31 and August 18) latent mortality was assessed for microzooplankton samples retained for less than 24 hrs. The results were in full agreement with observations made for samples held for 24 hrs (i.e., there was no significant mortality among organisms collected in the discharge canal over those collected in the intakes; Table 5-17). In all cases survival was less after 24 hrs than at the beginning of the observations; the adjusted mean for initial survival was 85.8% (n = 29) and mean 24 hrs survival was 66.0% (n = 29).

The results of latent-effects assessment for Eurytemora affinis held for 24 hrs are shown in Tables 5-18 and 5-19. They indicate that E. affinis may be damaged by temperatures above 80°F, regardless of the ΔT imposed. Temperatures below 80°F had little or no effect even at a 16°F ΔT (Table 5-18), while a

Table 5-18. Latent mortality of Eurytemora affinis retained at ambient temperature for 24 hrs following capture at Indian Point.

Date	Temperature Intake	ΔT	Station	n	% Survival ±S.E.
05/22	15.0°C (59.0°F)	3.5°C (6.3°F)	I1	10	100.0
			I2	10	95.0 ±14.4
			D1	10	99.8 ± 2.0
			D2	10	96.9 ± 9.9
			DP	10	74.6 ±28.8
06/18	21.2°C (70.2°F)	4.5°C (8.1°F)	I1	10	90.0 ±10.0
			I2	9	100.0
			D1	11	70.0 ±15.2
			D2	12	75.0 ±13.1
07/30	25.0°C (77.0°F)	3.8°C (6.8°F)	I1	12	95.1 ± 3.3
			D1	11	35.0 ±15.0
09/26	21.8°C (60.9°F)	4.7°C (8.5°F)	I1	14	100.0
			D1	15	87.5 ± 8.5
			D2	15	92.9 ± 7.1
10/29	13.5°C (56.3°F)	7.0°C (16.3°F)	I1	16	56.2 ±12.0
			D1	16	100.0
			D2	15	93.3 ± 6.7

n= Number of samples

Table 5-19. Latent mortality of Eurytemora affinis held for 24, 36 and 168 hrs following capture at Indian Point on May 29, 1974.

Temperature Intake	Temperature ΔT	Station	n	% Survival ±S.E. 24 hrs	36 hrs	168 hrs
16.5°C (61.7°F	6.8°C (12.2°F)	I1	13	100.0	92.3 ±7.7	13.1 ±8.2
		D1	10	89.6 ±10.0	89.6 ±10.0	20.0 ±13.3
		D2	10	100.0	100.0	12.5 ±12.5

n= Number of samples

final temperature above 80°F with a ΔT of 6.8°F resulted in a 60% decrease in survival (July 30, Table 5-18).

Intake samples obtained on October 29 had unusually high mortalities. On this date there was a considerable oil spill or leakage from a tanker or barge, which was docked at the Indian Point plant. Some of this oily water was collected along with the microzooplankton, and the oil was probably the major cause for the mortalities observed. However, survival of organisms from discharge-station samples in October was high (Table 5-18), thus indicating that mortality in the intake samples was not a widespread phenomenon in the copepod population at that time.

Although May and October tests resulted in D-2 survival slightly less than D-1, survival percentages for E. affinis were, for the most part similar. In June and September, D-2 survival was approximately 5% greater than at D-1. Although no conclusion can be drawn regarding the possibility of population stimulation due to plant passage, the data do demonstrate that time/temperature effects on entrained E. affinis are negligible as the organisms are carried downstream from D-1 to D-2. Insufficient numbers of samples from the downstream limit of the cooling water flow (i.e., station DP) were available for further assessment of time/temperature effects.

The viability of Eurytemora collected from the intakes and from the discharge canal was not significantly different after retention times of 24 and 36 hrs. Although viability was greatly decreased after 168 hrs (Table 5-19), this was probably a confinement effect.

The copepod Acartia tonsa was tested for latent effects resulting from plant entrainment during July and August. Ambient temperature at the time of the experiments was approximately 25°C (77°F); ΔT varied from 3.8°C (6.8°F) to 11.5°C (20.7°F) for July to 8.3°C (14.9°F) for August. The response of Acartia to thermal shock differed substantially among the different dates, and the results are shown in Table 5-20. Latent mortalities were negligible for samples collected on July 16 (ΔT of 11.5°C; final temperature of 97.7°F), and examined after 24 hrs. In August, latent mortalities were high and survival was reduced to 46% in the discharge canal samples (ΔT of 8.3°C or 14.9°F; final temperature 92.3°F, 5.4°F lower than that in July). However, as mortalities in the controls (intake samples) were correspondingly high, and in light of the results of the July samples, ΔT and plant entrainment effects were not the cause of these deaths. The differential between the intake and discharge values was 9.5% but was not significant statistically. This indicates that some common factor present in both samples on that day was responsible for the results observed. Deaths resulting from a salinity change can be ruled out, as the salinity was essentially the same at the time of testing on each of the three dates. Temperature differences can be eliminated by the explanation given above. These deaths could have been caused by an unknown chemical contaminant or contaminants in the river water as evidenced by a layer of foam on the water's surface. The foam was not analyzed at the time as its potential influence was not suspected.

Table 5-20. Latent mortality of Acartia tonsa retained at ambient temperatures for 24 hrs following capture at Indian Point.

Date	Temperature Intake	Temperature ΔT	Station	n	% Survival ±S.E.
07/16	25.0°C (77.0°F)	11.5°C (20.7°F)	I1	10	80.0 ±13.3
			D1	10	80.0 ±13.3
			D2	10	100.0
07/30	25.0°C (77.0°F)	3.8°C (6.8°F)	I1	26	92.3 ± 7.7
			D1	21	92.9 ± 5.2
08/20	25.2°C (77.4°F)	8.3°C (14.9°F)	I1	16	56.2 ±12.8
			D1	16	46.7 ±12.5
			D2	15	46.7 ±27.4

n= Number of samples

All rotifers isolated from intake and discharge station samples were alive after 24 hrs (Table 5-21). Samples from the intakes were used as controls in testing for plant effects upon comparison with the discharge samples. Rotifers held for longer periods of time (36 hrs, 168 hrs) showed almost total mortality with no apparent trend. It would appear, therefore, that maintaining rotifers for periods longer than 24 hrs represented a test of culture technique rather than an assessment of latent entrainment effects.

Based upon our results, we conclude that there were little or no effects of plant entrainment on the viability of certain microzooplankton species in river water used for once-through cooling at Indian Point. However, there appears to be some damage to the copepod Eurytemora affinis if the final temperature (ambient water temperature + ΔT) during plant passage rises above 80°F. This condition would probably be prevalent during midsummer only. But as E. affinis is one of the dominant species of copepods in the river, this could have repercussions on the general food web of the river. At present, we have no information as to the possible magnitude of this effect.

Table 5-21. Latent mortality of rotifers retained for 24, 36, and 168 hrs following capture at Indian Point on May 29, 1974.

Temperature				% Survival ±S.E.		
Intake	ΔT	Station	n	24 hrs	36 hrs	168 hrs
16.5°C (61.7°F)	6.8°C (12.2°F)	I1	10	100.0	100.0	0.0
		D1	10	100.0	95.0 ±5.0	0.0
		D2	11	100.0	30.3 ±11.2	9.1 ±9.0

n= Number of samples

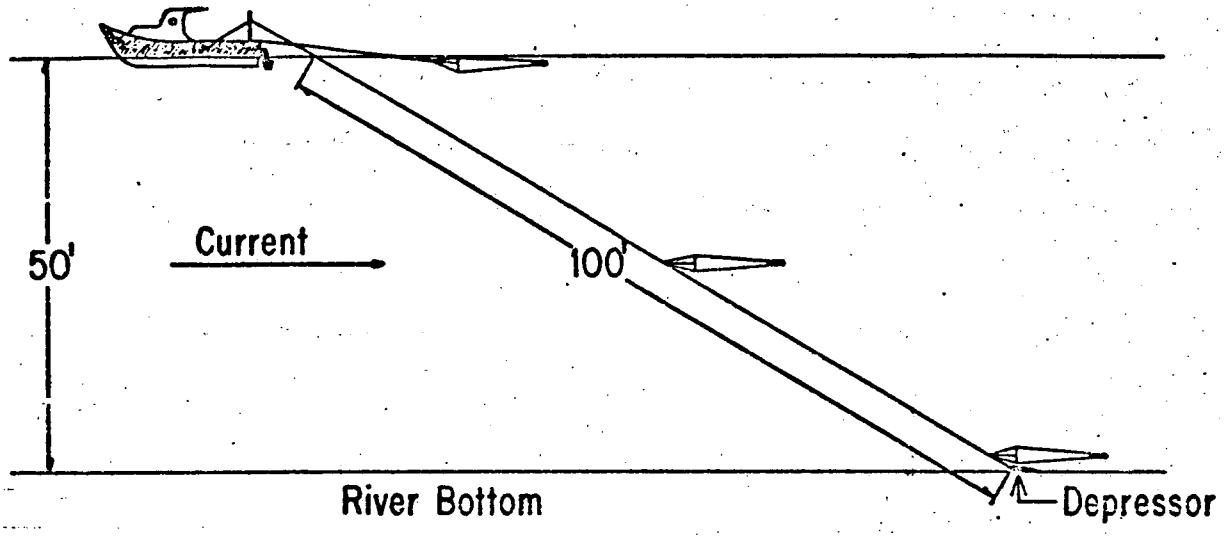


Figure 6-1. Deployment of 0.5-meter plankton nets.

6. MACROZOOPLANKTON

6.1 RIVER POPULATION STUDIES

6.1.1 Methods

In 1974 macrozooplankton and ichthyoplankton were collected simultaneously with plankton nets towed by a 22-foot boat with a 130-hp inboard/outboard motor. The boat had a gantry and davit arm olcated near the stern. A gasoline-powered winch with 250 feet of 1/8-inch stainless steel cable was mounted amidship. The cable, which was attached to a 50-pound net depressor, was routed from the winch through a gantry pulley and then outboard through a davit pulley. The net rig was attached to the towing cable by three bridle lines secured at a common eye to a cable clamp.

The #0-mesh plankton nets used were of the standard cylindrical-conical design, 12 feet (3.8 meters) long. The mouth opening was approximately 20 inches (0.5 meter) across. Secured in the mouth opening of each net was a General Oceanic digital flowmeter, Model 1031, from which flow volumes were computed for each tow. As towing began, cable equal to about twice the mean station depth was released from the winch. The "bottom" net was attached to the cable 5 feet above the net depressor. The "mid" net was attached to the mid-point of the cable, 1.5 times the mean station depth. The "surface" net was towed approximately 40 feet astern and was attached to the right side of the boat. The towing speed was adjusted to approximately 2000 RPM's, or so that the surface net remained under the water's surface (Figure 6-1). Each tow lasted 10 minutes and was made against the prevailing current. During slack tide, tows were made upstream against net river flow.

The organisms collected in the tows included both macrozooplankton and ichthyoplankton. All ichthyoplankton were sorted out and analyzed separately for species composition, numerical abundance and life stages (see Section 7).

The macrozooplankton were examined in a glass sorting tray against a black background, and each species was sorted out for counting. When a sample contained a very large number of organisms of a single species, the sample was divided and successively subdivided, using a Folsom plankton splitter to obtain a representative subsample in which the number of organisms was small enough to be counted individually. That number was then multiplied by the appropriate divisor of the original sample to obtain the number in the whole sample.

6.1.2 Results and Discussion

6.1.2.1 Species Composition

A total of 574 macrozooplankton samples were collected and analyzed in 1974. These included 314 samples taken during the daylight hours from April 23 through December 17, and 260 samples taken at night from May 8 through December 18.

A total of 25 invertebrate groups were identified from 1974 samples (Table 6-1). This total was two more than the inventory for 1972 and included four taxa not previously identified in samples from the vicinity of Indian Point: the copepod Caligus, the branchyuran Argulus, the isopod Cirolana and Ctenophores. Missing from 1974 collections were gastropods and bivalve molluscs, both of which may have been included in 1971-72 macrozooplankton samples erroneously due to bottom nets sampling surficial sediments.

Table 6-1. Macrozooplankton taxa in Indian Point collections, 1971, 1972 and 1974.

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

Numerical abundances were determined for 12 of the 25 taxa collected in 1974. The remaining taxa were not counted either because they were difficult to sample accurately (e.g. jellyfish medusae and Ctenophora), or because they were not considered part of the plankton community (e.g Argulus, Caligus, Cirolana, Cumacea, and some of the insects). Decapod larvae were not enumerated because they were generally too small to be retained in the 571μ-mesh nets.

As in previous years, the macrozooplankton community was dominated by three taxa, Gammarus spp. (mostly G. tigrinus), Monoculodes edwardsi, and Neomysis americana. Together these species accounted for 67% of the total daytime macrozooplankton catch (Table 6-2) and 66% of the total nighttime catch. On a station-by-station basis Gammarus, Monoculodes and Neomysis accounted for between 53% and 87% of the total macrozooplankton daytime catch, and between 60 and 71% of the nighttime catch.

The proportional representation of the three dominant forms at Stations A through I varied (Table 6-3). Gammarus was dominant at four stations (A, D, G, I) during the daytime, while Neomysis dominated at B, C, E, and G. Nighttime samples showed that, except for Station G, the dominant form was Gammarus. Of the three dominant forms, Monoculodes was the least abundant. The major sub-dominant forms collected during 1974 were the phantom midge Chaoborus and other dipteran and tendipid insects.

Day-Versus Night Comparisons

Macrozooplankton abundance was significantly greater during the night than during the day (Tables 6-4 and 6-5); total macro-

Table 6-2. Percent composition of macrozooplankton species collected in the vicinity of Indian Point, 1974.

Species	Percent of total	
	Day collections	Night collections
Gammarus spp.	26.3	31.9
Neomysis americana	8.5	10.5
Monoculodes edwardsi	32.3	23.2
"others"	32.2	34.4

Table 6-3. Total Macrozooplankton river abundance and abundance by major groups in day night collections, 1974. Data shown are mean numbers caught per 1000 m^3 by station ±95% confidence intervals.

	Stations							
Day	A	B	C	D	E	F	G	I
Total	11088 ±5741 *n=45	10038 ±5943 n=42	12431 ±5943 n=42	6766 ±5806 n=44	7392 ±5741 n=45	16054 ±5806 n=44	5696 ±5741 n=45	320 ±14557 n=7
Gammarus	4463 ±2582 n=45	1843 ±2673 n=42	1882 ±2673 n=42	2589 ±2612 n=44	1559 ±2582 n=45	4411 ±2612 n=44	1385 ±2582 n=45	249 ±6548 n=7
Monoculodes	841 ± 550 n=45	855 ± 569 n=42	1554 ± 569 n=42	518 ± 556 n=44	563 ± 550 n=45	1119 ± 556 n=44	542 ± 550 n=45	3 ±1395 n=7
Neomysis	1986 ±2770 n=36	2646 ±2893 n=33	5056 ±2893 n=33	2084 ±2809 n=35	3518 ±2770 n=36	6007 ±2809 n=35	1194 ±2770 n=36	26 ±7432 n=5
Night								
Total	24459 ±9975 n=37	25742 ±9843 n=38	26524 ±10113 n=36	19398 ±9975 n=37	29684 ±9843 n=38	27527 ±9716 n=39	18445 ±10256 n=35	
Gammarus	6863 ±4915 n=37	8685 ±4850 n=38	9060 ±4983 n=36	5954 ±4915 n=37	10097 ±4850 n=38	9536 ±4788 n=39	4500 ±5054 n=35	
Monoculodes	3545 ± 880 n=37	3192 ± 869 n=38	2570 ± 892 n=36	2075 ± 880 n=37	2327 ± 869 n=38	2508 ± 857 n=39	1914 ± 905 n=35	
Neomysis	6943 ±2151 n=25	3521 ±2109 n=26	4413 ±2195 n=24	4071 ±2109 n=26	7661 ±2069 n=27	7380 ±2069 n=27	5779 ±2109 n=26	

*n=Number of samples in which the particular species was observed.

Table 6-4. Macrozooplankton abundance in pooled river samples, 1974. Data are mean numbers caught per 1000m^3 with 95% confidence intervals.

Day	Mean	95%C.I.	n
Total	9675	±2410	314
Gammarus	2546	± 978	314
Monoculodes	830	± 22	314
Neomysis	3127	±1053	249
Night			
Total	24627	±3763	260
Gammarus	7858	±1854	260
Monoculodes	2596	± 332	260
Neomysis	5709	± 799	181

* n=Number of samples in which species was observed.

Table 6-5. Comparison of macrozooplankton abundance in day and night river sampling.

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

zooplankton nighttime catches exceeded daytime catches by a factor of 2.6 (Tables 6-3 and 6-4). Abundance of Gammarus spp. was greatest in nighttime samples, exceeding daytime samples by a factor of 3. Gammarus spp. were present in each of the 314 daytime and 260 nighttime samples; they represented 26% of all macrozooplankton collected in the daytime, and 32% of all macrozooplankton collected at night.

Although Neomysis americana was present in 79% of the daytime samples taken, it was only 32% of the total macrozooplankton collected during the day. At night, Neomysis accounted for 23% of the total macrozooplankton collected. Day versus night differences in Neomysis abundance (Table 6-3 and 6-4) were less than that for Gammarus spp. or Monoculodes edwardsi, differing by a factor of 1.8 during the sampling period.

The amphipod Monoculodes edwardsi was present in all river samples taken in the vicinity of the Indian Point power plant. Abundance at night was significantly greater than during the day (Table 6-4); numbers differed between night and day by a factor of 3.1. The proportion of Monoculodes to total macrozooplankton in daytime and nighttime samples was 9% and 11%, respectively (Tables 6-3 and 6-4).

6.1.2.2 Depth Distribution of Macrozooplankton

Distribution of macrozooplankton in river samples showed the greatest abundance of organisms at the bottom of the water column. Since the depths of sampling stations differed (see Section 1), "bottom" samples were from different depths at different stations. Samples from "bottom" strata yielded 98%

of the macrozooplankton in daytime samples, and 49% of the macrozooplankton in nighttime samples.

The relative abundance of macrozooplankton at various depths differed significantly between day and night samples (Table 6-6, Figure 6-2). Surface and mid-depth abundances at night were greater than in the day by a factor of approximately 10. Nighttime bottom samples were about 53% greater than daytime bottom samples. Populations of macrozooplankton vulnerable 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; LMS, 1975) identify the surficial bottom deposits of the River as an important habitat for the many species collected regularly in macrozooplankton nets. As none of the plankton gear employed in the River samples this habitat, except erroneously, it must be assumed that the increased abundance of macrozooplankton at night is due to the emergence of epibenthic forms from the sediments to assume a nocturnal, planktonic mode of existence.

The distribution of the major macrozooplankton components (Gammarus, Neomysis, Monoculodes) during the day was similar (Figures 6-3, 6-4 and 6-5). Approximately 0.2% of the totals for each group occurred in surface samples, while 68 to 92% occurred in the bottom samples. Neomysis had the sharpest distribution of profile with depth; more than 92% of the Neomysis recorded were from the bottom strata.

Table 6-6. Macrozooplankton river abundance in mean numbers caught per $1000m^3$ by depth ±95% confidence intervals for total macrozooplankton and dominant groups.

Day	Surface	Middle	Bottom
Total	147 ±3813 *n=102	3405 ±3832 n=101	24136 ±3656 n=111
Gammarus	21 ±1715 n=102	1323 ±1724 n=101	5980 ±1644 n=111
Monoculodes	7 ± 365 n=102	980 ± 367 n=101	2115 ± 350 n=111
Neomysis	2 ±1846 n= 81	668 ±1858 n= 80	8239 ±1771 n= 88
Night			
Total	4712 ±6432 n= 89	33144 ±6396 n= 90	37045 ±6742 n= 81
Gammarus	772 ±3169 n= 89	11776 ±3152 n= 90	11297 ±3322 n= 81
Monoculodes	395 ± 568 n= 89	3046 ± 564 n= 90	4514 ± 595 n= 81
Neomysis	2642 ±1366 n= 62	5891 ±1355 n= 63	8898 ±1437 n= 56

*n= Number of samples in which the particular species was observed.

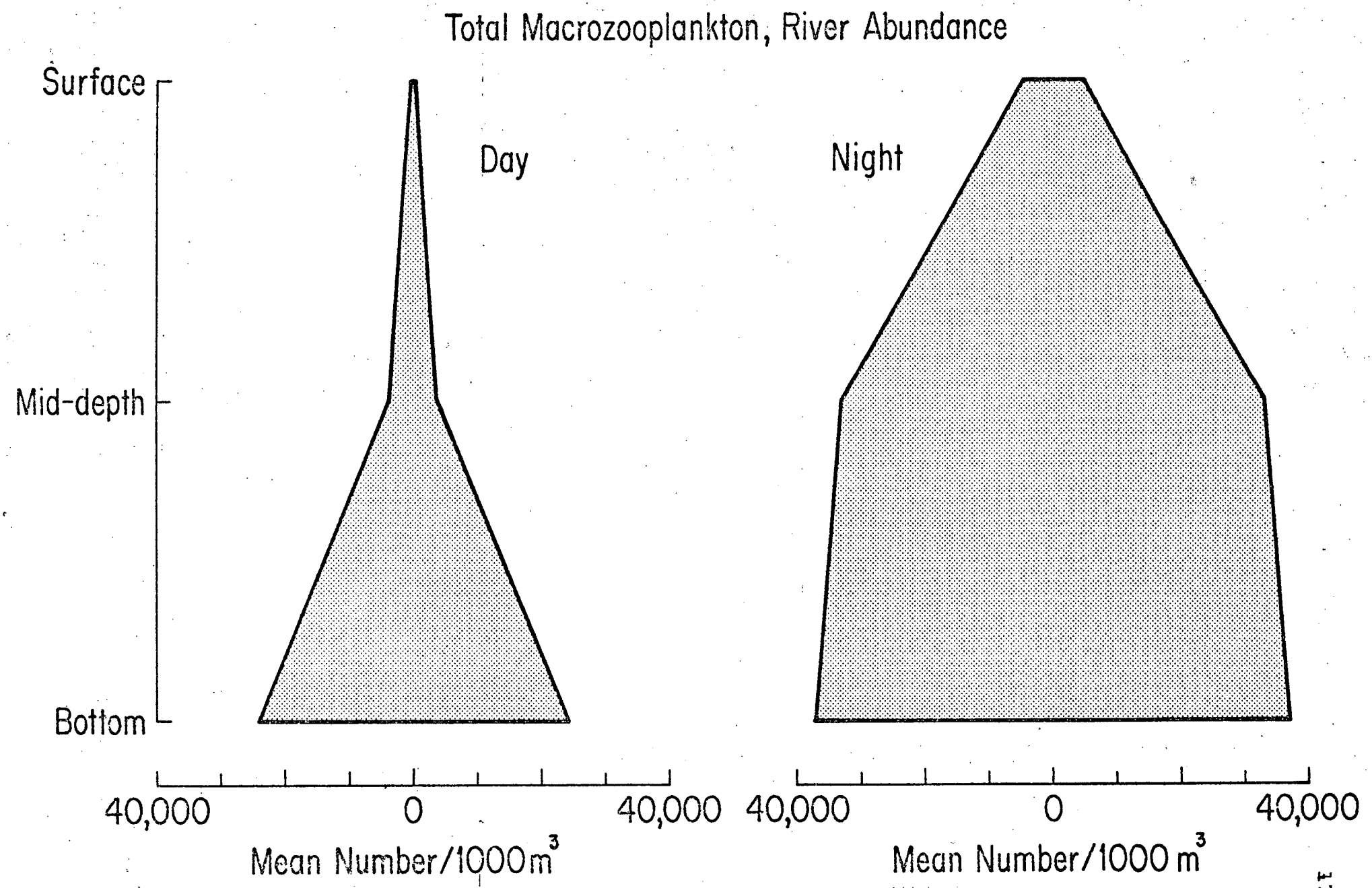


Figure 6-2. Depth distribution for total macrozooplankton in day and night samples in the Hudson River at Indian Point, 1974.

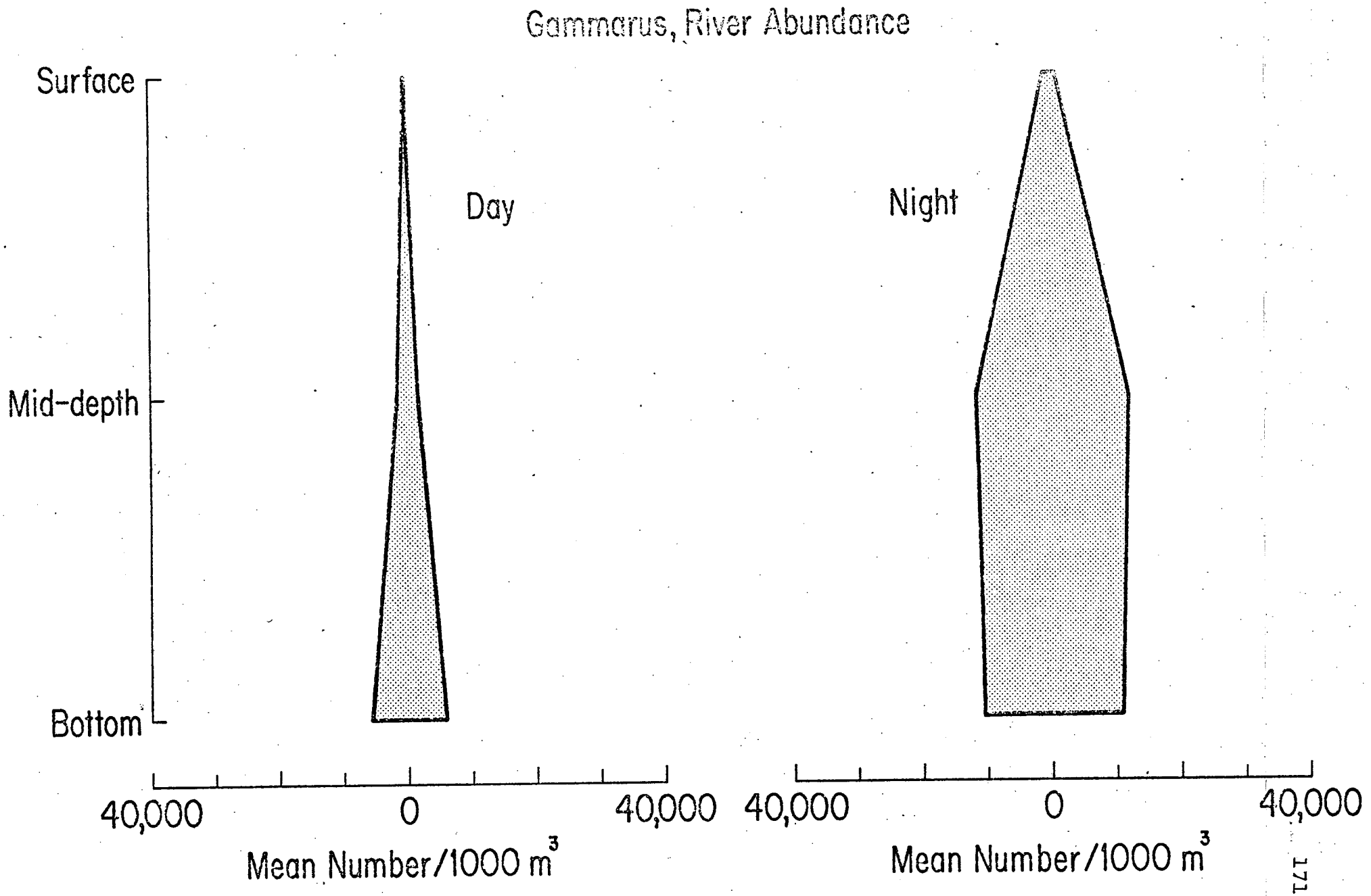


Figure 6-3. Depth distribution for Gammarus spp. in day and night samples in the Hudson River at Indian Point, 1974.

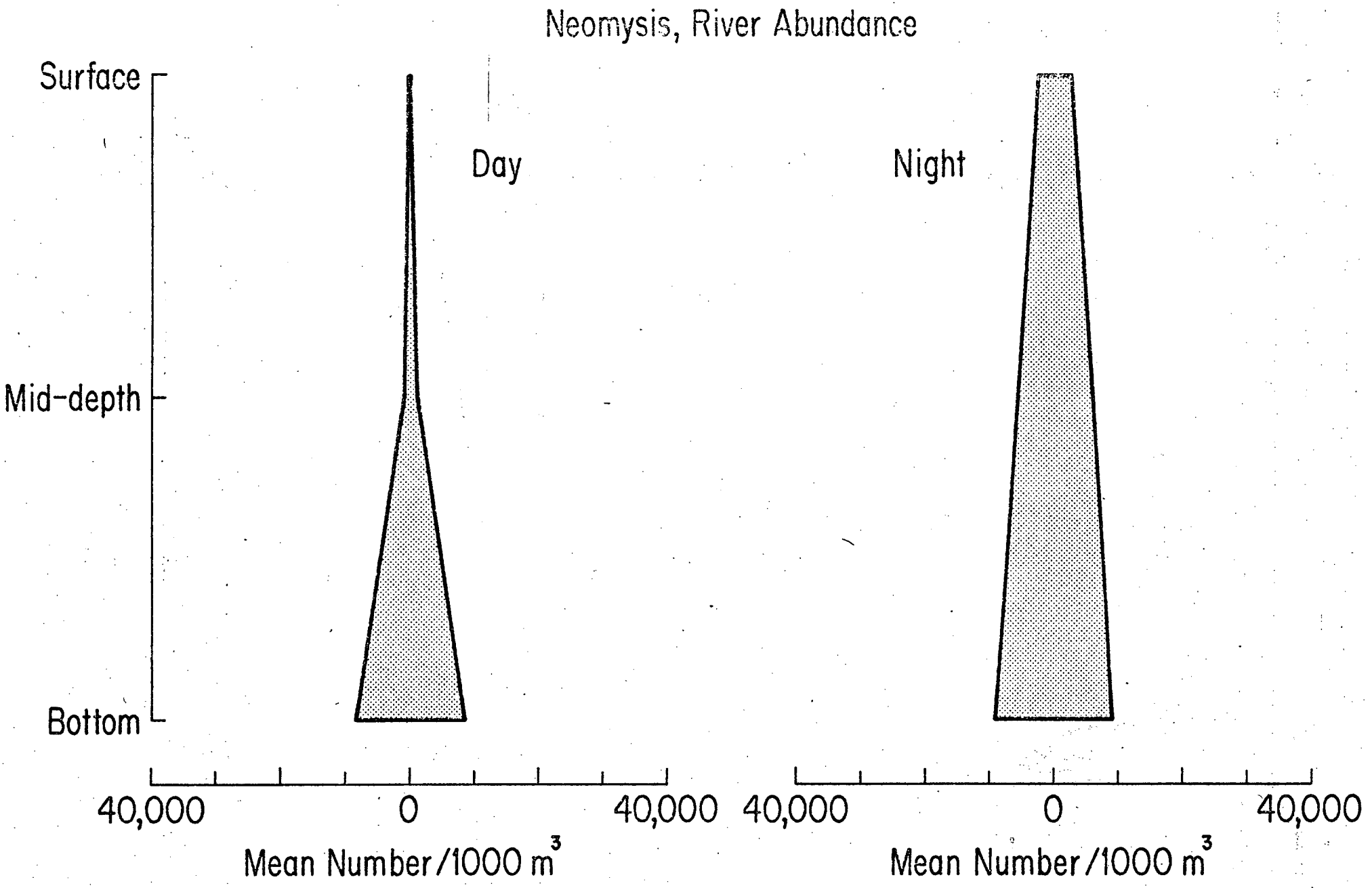


Figure 6-4. Depth distribution for Neomysis americana in day and night samples in the Hudson River at Indian Point, 1974.

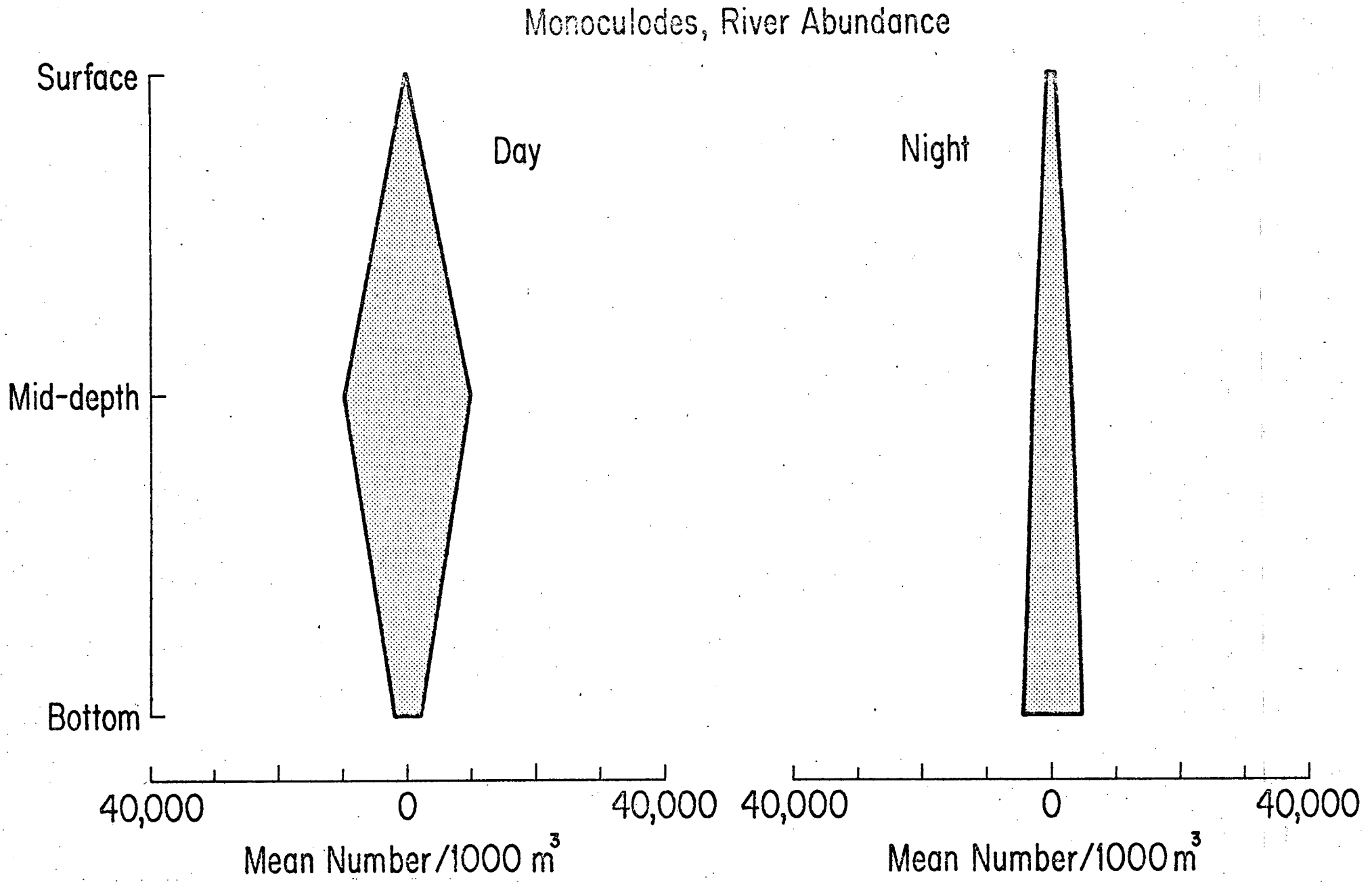


Figure 6-5. Depth distribution for Monoculodes edwardsi in day and night samples in the Hudson River at Indian Point, 1974.

Depth distribution was more even for nighttime samples of the dominant forms. For Gammarus spp. the nighttime abundance at mid-depth and in bottom samples exceeded that of the surface, but did not differ from one another (Table 6-6; Figure 6-3). Monoculodes and Neomysis showed significant differences among all strata with a gradient of increasing abundance from bottom to surface (Table 6-6; Figures 6-4, 6-5). The greatest differences in depth distribution between day and night occurred for Neomysis, whose surface abundance increased by > 10^3 between day and night, and mid-depth abundances increased by a factor of about 10. Abundance in surface and mid-depth samples for all three dominant forms increased by at least a factor of 10 between day and night.

6.1.2.3 Seasonal Abundance

Abundance of macrozooplankton varied significantly with season (Tables 6-7 and 6-8; Figures 6-6 and 6-7). Total abundance for daytime samples ranged from a mean of 3,021 organisms per 1000m^3 (October 15) to 26,128 organisms per 1000m^3 (May 28). Nighttime abundance was greater overall, ranging between 6,480 organisms per 1000m^3 (June 25) to 108,868 organisms per 1000m^3 (May 24). In general, the pattern of macrozooplankton abundance was similar for daytime and nighttime samples, showing a major peak of abundance in late May and smaller peaks in the mid-summer period and in November (Figures 6-6 and 6-7). Daytime values were more variable than those from night samples in the spring-early summer period. Given the pronounced tendency toward diel vertical migration in the macrozooplankton as a whole, the variability in daytime samples could be attributed to differences

Table 6-7. Daytime abundance of individual macrozooplankton taxa by date for all stations, 1974.

Date	Number of Samples	Abundance (mean number per 1000m^3) Crangon	Chaoborus	Cyathura	Chiridotea	Edotea	Oligochaetae
4/23	21	0	46	0	92	0	873
5/07	21	0	57	0	1	1	1401
5/14	22	0	21	0	9	4	81
5/21	17	0	23	2	3	0	84
5/28	22	0	94	2	188	13	119
6/11	20	0	98	1	88	0	62
6/25	22	0	74	10	66	0	25
7/09	22	0	868	5	40	0	86
7/23	21	10	1100	11	6	0	277
8/08	21	28	2390	65	24	3	2297
8/20	22	40	419	9	15	28	12
9/03	21	23	277	6	8	13	38
10/15	21	1	52	0	11	28	33
11/12	20	5	27	0	0	3	398
12/17	21	0	64	3	4	0	1690

Table 6-7 (cont.)

Abundance (mean numbers per $1000m^3$)

Date	Number of samples	Polychaetae	Chironomid	Corophuim	Insect Pupae	Insect Adult	Leptocheirus
4/23	21	1108	21	0	6	10	0
5/07	21	414	5	0	90	0	0
5/14	22	380	11	0	248	1	0
5/21	17	74	6	0	17	4	0
5/28	22	3034	39	3	68	1	0
6/11	20	384	9	0	70	30	0
6/25	22	161	4	0	162	3	0
7/09	22	14	148	0	159	5	0
7/23	21	62	57	0	1075	0	4
8/08	21	60	95	41	114	1	113
8/20	22	3	2	211	186	0	47
9/03	21	19	3	50	6	1	35
10/15	21	26	3	10	0	1	1
11/12	20	9	9	0	1	0	0
12/17	21	66	15	0	0	0	2

Table 6-8. Nighttime abundance of individual macrozooplankton taxa by date for all stations, 1974.

Date	Number of samples	Abundance (mean number per 1000m^3) Crangon	Chaoborus	Cyathura	Chiridotea	Edotea	Oligochaetae
5/08	21	0	128	21	9	3	3406
5/14	21	0	241	2	11	1	25
5/29	21	0	424	2	72	0	1138
6/13	21	0	190	41	23	0	73
6/25	17	4	121	15	60	0	1
7/09	21	0	2042	13	415	0	1144
7/23	20	28	2064	11	30	0	10
8/06	21	62	2874	28	21	4	292
8/20	19	71	1211	26	7	6	46
9/03	21	82	470	74	8	53	127
10/15	21	2	209	5	11	40	139
11/12	20	23	321	12	17	6	135
12/17	16	0	27	1	122	0	12

Table 6-8 (cont.)

Date	Number of samples	Abundance (mean numbers per 1000m^3) Polychaetae	Chironomid	Corophium	Insect Pupae	Insect Adult	Leptocheirus
5/08	21	1851	57	0	247	1	0
5/14	21	330	10	0	145	1	0
5/29	21	1130	157	0	177	7	0
6/13	21	228	26	1	246	7	1
6/25	17	71	1	1	159	3	2
7/09	21	93	73	0	331	8	1
7/23	20	21	9	2	1087	5	237
8/06	21	35	5	96	472	12	263
8/20	19	42	13	143	244	8	2891
9/03	21	40	8	28	44	14	6
10/15	21	38	1	13	1	1	23
11/12	20	15	2	5	0	0	0
12/17	16	44	0	0	0	0	0

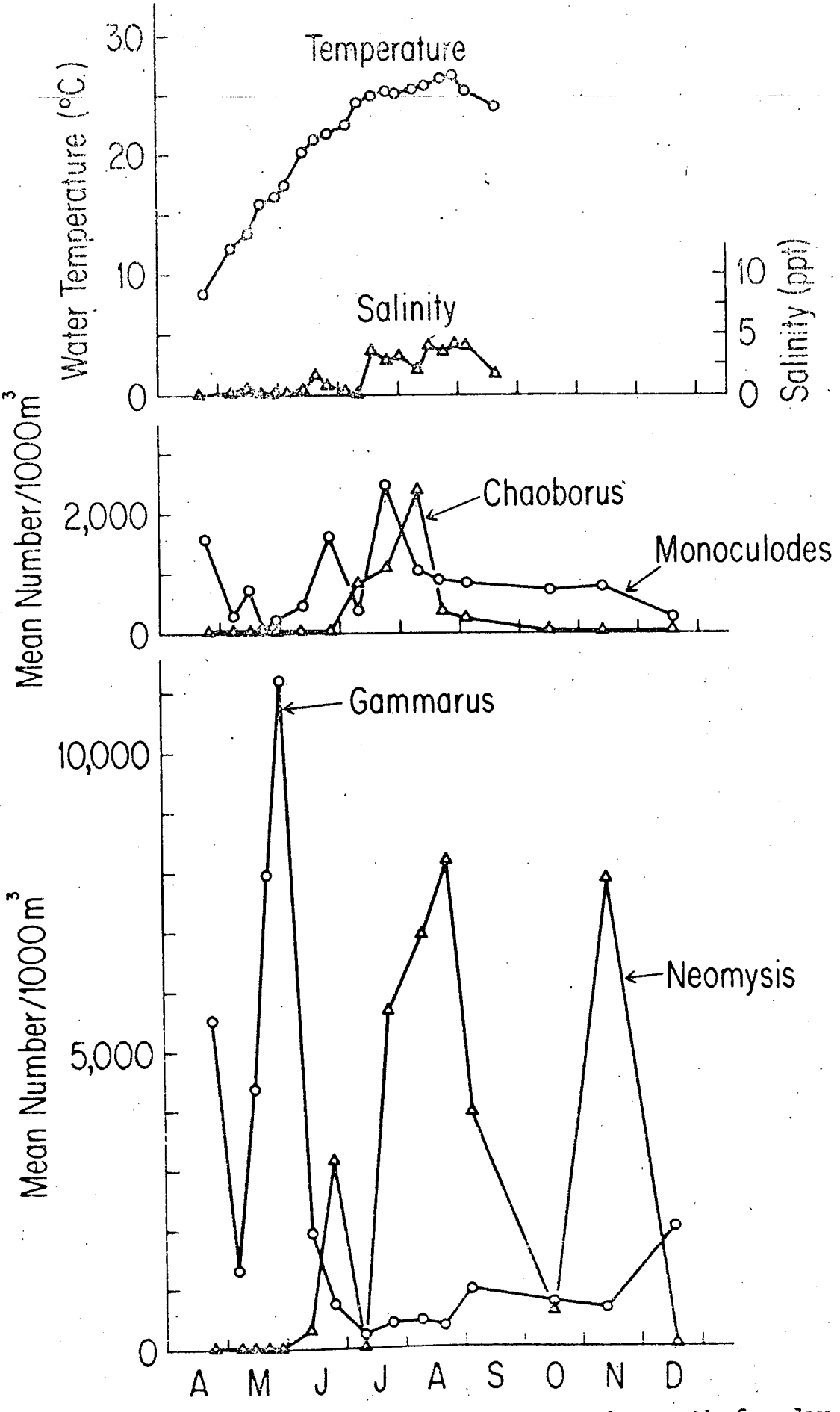


Figure 6-6. Abundance of macrozooplankton by month for daytime samples taken in the Hudson River at Indian Point, 1974.

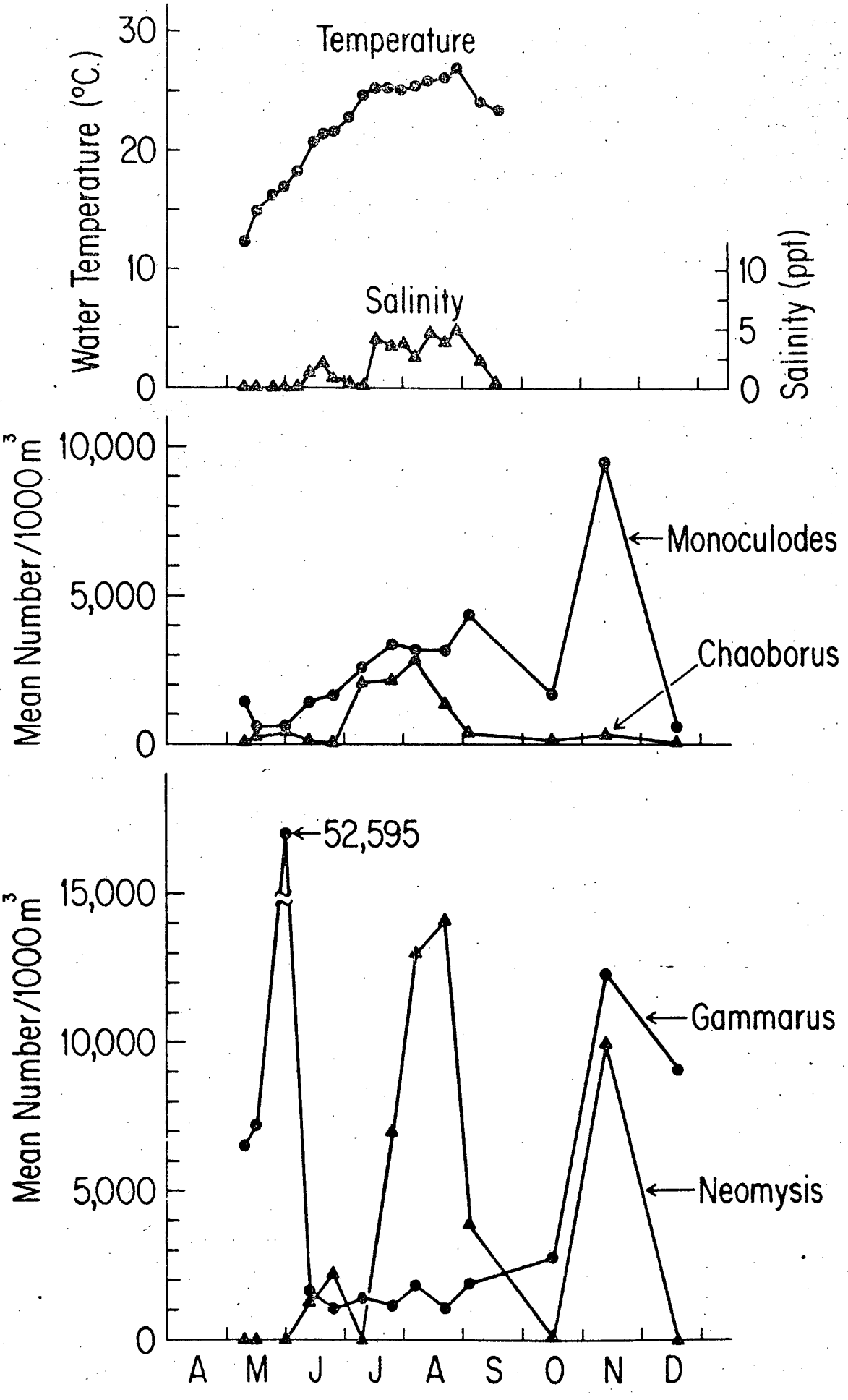


Figure 6-7. Abundance of macrozooplankton by month for night-time samples taken in the Hudson River at Indian Point, 1974.

in cloud cover on the various sampling dates, leading to greater or lesser congregations of the macrozooplankters 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 five daytime sampling dates Gammarus, Neomysis and Monoculodes failed to account for at least half the macrozooplankton collected (Table 6-7). A similar phenomenon occurred in the nighttime collections for four dates (Table 6-8), three of which coincided with daytime samples having lower-than-usual representation of the three major forms.

Throughout May there occurred an abundance of oligochaete and polychaete worms in daytime and nighttime samples. Daytime and nighttime samples in July were dominated by Chaoborus sp., oligochaete worms and insect pupae. Daytime samples taken in December were dominated by oligochaete worms (Tables 6-7 and 6-8).

The abundance and proportional representation of the various macrozooplankton taxa on a seasonal basis are attributable directly to two factors; salt intrusion in the vicinity of Indian Point and 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 fresh-water periods, the amphipod Gammarus spp. and annelid worms (Oligochaeta and Polychaeta) became dominant (Figures 6-6 and 6-7).

In the mid-summer period Chaoborus sp. and other juvenile insect forms were abundant (Tables 6-7 and 6-8) primarily as aquatic stages preparing to metamorphose to a terrestrial life.

Analysis of total macrozooplankton data by ANOVA revealed significant differences in numbers by station, by depth and by date (Tables 6-9, 6-10, 6-11 and 6-12). For night samples of total macrozooplankton, Neomysis and Monoculodes there occurred a significant interaction of station and date, substantiating the seasonal relationship of Monoculodes and Neomysis with salinity intrusion (Tables 6-13 and 6-14).

It is fair to assume that holoplanktonic organisms in the vicinity of the Indian Point nuclear generating station 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 whether power plant operation has any qualitative or quantitative impact on river populations.

Comparisons of macrozooplankton abundance within sampling years seldom show differences due to factors other than season; the few 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

Table 6-9. Differences in macrozooplankton river abundance among stations 1974. Letters refer to the respective river station locations.

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

[1] The analysis of variance resulted in a difference among stations. However, the Scheffe´ test ($\alpha < .10$) did not show any difference among stations for meaningful contrasts.

Table 6-10. Differences in macrozooplankton river abundance among depths 1974. 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	mid>sur; bot>sur; bot>mid
Night	
Total	mid>sur; bot>sur; bot>mid
Gammarus	mid>sur; bot>sur
Monoculodes	mid>sur; bot>sur; bot>mid
Neomysis	mid>sur; bot>sur; bot>mid

Table 6-11. Analysis of variance for all species of macrozooplankton collected during the day in 1974, 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	Sample means	F-Value
A	7	3.7822	.5403	4.11*
B/A	14	68.7013	4.9072	37.35*
C	14	5.5588	.3971	3.02*
AxC	89	10.9813	.1234	0.94
Error	189	24.8308	.1314	
Total	313	113.8544		

Contrast among Stations	Scheffé test[1] ($\log_{10}$ (catch/m^3 +1) Critical value	Contrast value
A vs I	.5110	.5268
B vs I	.5135	.5148
C vs I	.5135	.5641

[1] only significant contrasts are shown here

Table 6-12. Analysis of variance for all species of macrozooplankton collected at night in 1974, 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	Sample means	F-value
A	6	2.4020	.4003	5.01*
B/A	14	33.3729	2.3838	29.83*
C	12	18.2202	1.5183	19.00*
AxC	71	8.1792	.1152	1.44*
Error	156	12.4651		
Total	259	74.6394		

Contrast among Stations	Scheffé test[1] ($\log_{10}$ (catch/m^3 +1) Critical value	Contrast value
A vs G	.2172	.2973
B vs G	.2158	.2182
E vs G	.2158	.3039
E vs (F andG)	.3679	.4835
(A and B) vs (F and G)	.3021	.3912

[1] Only significant contrasts are shown here

Table 6-13. Analysis of variance for Monoculodes collected at night during 1974 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	Sample means	F-value
A	6	.3631	.0605	1.30
B/A	14	10.8956	.7783	16.77*
C	12	9.4982	.7915	17.06*
AxC	71	5.3753	.0757	1.63
Error	156	7.2393	.0464	
Total	259	33.3715		

Table 6-14. Analysis of variance for Neomysis collected at night in 1974 and listed as the $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date. Asterisk(*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Sample means	F-value
A	6	1.0413	.1735	3.20*
B/A	14	5.3303	.3807	7.02*
C	8	26.8435	3.3554	61.84*
AxC	48	5.3400	.1113	2.05*
Error	104	5.6428	.0543	
Total	180	44.1979		

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 to 1974).

There exist no data to demonstrate that river populations of macrozooplankton have been affected by the operation of the Indian Point station. Near-field data (this report and NYU, 1973, 1974; LMS, 1974) and far-field data (LMS, 1974) indicate essentially similar patterns in seasonal variability of species composition, species number, abundance and area of distribution of macrozooplankton in the Hudson River from Indian Point to Haverstraw Bay for the years between 1971 and 1974.

6.2 ENTRAINMENT EFFECTS STUDIES

6.2.1 Temperature-Tolerance Studies

No temperature-tolerance experiments on macroinvertebrates were planned for 1974. Two experiments were conducted, however, to supplement the existing temperature tolerance information on the amphipod Gammarus spp.

6.2.1.1 Methods

Condenser-outlet temperature measurements taken during 1974 at Indian Point Unit 2 revealed the possibility of temperature differentials among condensers. Entrained organisms could therefore be exposed to a range of short term ΔT's, depending on condenser location, followed by a longer term, relatively constant temperature exposure in the discharge canal. An experiment was designed to simulate this potential situation. It supplements the data on the temperature tolerance of Gammarus presented in previous reports in this series (NYU, 1973, 1974).

Gammarus spp. were initially exposed to theoretical condenser temperatures of 10°C, 12°C, and 14°C (18, 21.6, 25.2°F) for 20 seconds. The organisms were subsequently exposed to an 8.3°C (14.9°F) ΔT for 5 and 30 minutes to simulate discharge-canal transit. The experimental design is not an attempt to simulate actual thermal conditions measured at Indian Point. The exposure factors were arbitrarily derived to simulate severe condenser-temperature deviations.

Test organisms were collected from the Indian Point intakes and were maintained in ambient-temperature water baths for at least

48 hours prior to experimentation. Before thermal testing, the organisms were sorted into 125-ml polymethylpentene containers with bottoms of 571μ-mesh nylon netting. To obtain thermal exposures of desired temperature and duration, test containers with Gammarus spp. were immersed in constant-temperature water baths filled with aerated Hudson River water. Temperature was monitored continuously with a thermister telethermometer. At the end of the initial 20-second exposure, the test containers were immediately transferred to a second water bath for periods of 5 or 30 minutes. Following the second exposure, the test groups were transferred to an ambient water table, resulting in an instantaneous drop to ambient temperature. Control groups were placed in the test containers and maintained continuously at ambient temperature.

In 1973, ovigerous female Gammarus spp. were subjected to 5 and 60-minute exposures to an 8.3°C (14.9°F) ΔT at an ambient temperature of 26.0°C (78.8°F) and examined for subsequent release of young. To supplement these data, female Gammarus spp. were subjected to 5 and 30-minute exposures to an 11.0°C (19.8°F) ΔT at an ambient temperature of 26.0°C, as it was found that exposure to 11°C ΔT for 60 minutes was lethal for Gammarus (Ginn et al., 1974). The exposure time was shortened to 30 minutes as it was sufficient to show differential treatment effects. Ovigerous females were first isolated into groups of approximately the same size and then randomly sorted into test groups composed of 10 individuals. After thermal exposure the test organisms were maintained individually in culture dishes containing 200 ml of Hudson

River water at ambient temperature. All of the young were released by the female Gammarus spp. and counted within 6 days after exposure.

6.2.1.2 Results and Discussion

Gammarus spp. exposed to temperatures as high as 39.9°C (103.8°F) for 20 seconds followed by 30-minute exposures to 33.4°C (92.1°F) displayed no reductions in immediate or 5-day survival (Table 6-15). These data exemplify the importance of exposure time in determining thermal tolerances, since 5-minute exposures to temperatures near 40°C (104°F) result in 100% mortality of Gammarus spp. (Ginn et al., 1974). Upon immersion in the 20-second water bath at exposure temperatures of 12 and 14°C (21.6 and 25.2°F) above ambient, the test organisms displayed almost instantaneous loss of orientation followed by immobility. Normal activity of test organisms was resumed within 30 minutes after return to ambient temperature.

The numbers of young produced by ovigerous female Gammarus spp. exposed to 11.0°C (19.8°F) ΔT during a summer ambient temperature (26°C; 78.8°F) are shown in Table 6-16. The numbers of young released by females exposed for 5 minutes were not different from those of the controls, but those exposed for 30 minutes released fewer young. The 10 females exposed for 30 minutes produced only three young during the 10-day observation period following the test exposure. In 1973, eggs and/or young contained in the marsupium of the female Gammarus were found to tolerate an 8.3°C (14.9°F) ΔT for periods up to 30 minutes without a reduction in survival (Ginn, et al., 1974). However, as the upper lethal

Table 6-15. Survival of Gammarus sp. exposed to 20-second ΔT's of 10, 12, and 14°C followed by an 8.3°C ΔT at an ambient temperature of 25.9°C.

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

Table 6-16. Young produced by ovigerous female Gammarus spp. exposed to an 11.0°C ΔT at an ambient temperature of 26.0°C.

	Exposure time		
	0 (control)	5 minute	30 minute
	20	7	0
	15	7	0
	27	23	0
	9	22	0
	26	25	0
	14	10	0
	6	9	0
	3	13	2
	7	12	0
	16	25	1
$\bar{X}$	14.30	15.30	0.30
95% C.I.	8.40-20.20	9.89-20.71	0-0.78

time-temperature combination is approached at an 11.0°C ΔT for 30 minutes (26.0°C ambient) there is a significant reduction of young released.

The importance of these data for assessing plant impact on river populations of macrozooplankton is not yet known. Not enough different life stages of the plankton have been examined, and the conditions to which the test organisms were exposed were more extreme than those of normal plant operation. However, the results presented here indicate that developing young (for Gammarus only) are more sensitive to thermal shock than adults, thus resulting in some loss.

Accepting the fact that there might be losses to the macrozooplankton as a result of reproductive and developmental inhibition following plant entrainment, it remains to be concluded whether this inhibition would have measurable impact on population at Indian Point and in the river as a whole. The data indicated essentially similar patterns of Gammarus (and other species) abundance and distribution during the period 1971-1974 at Indian Point and nearby areas. The lack of observable population shifts over a 4-year period indicates that, for macrozooplankters the effects of entrainment are so small as to be unnoticeable in the population, or so rapidly compensated for that they are not detectable as anomalies in established patterns of abundance or spatial and temporal distribution.

6.2.2 Intake and Discharge-Canal Studies

6.2.2.1 Viability

6.2.2.2 Methods

Macrozooplankton samples for viability analyses were collected at the Indian Point intake and discharge stations from May 7 to November 12, 1974. During this period, a total of 142 samples were examined on 14 sampling dates. The total numbers of major macrozooplankton species examined are presented in Table 6-17. The intake and discharge temperatures measured at the time of collection on each date are listed in Table 6-18.

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

Collected organisms were classified as alive, stunned, or dead. Stunned organisms were alive, but displayed reduced locomotor activity and little response to probing stimuli. Any dead or stunned organisms were immediately enumerated and removed from the sample. The collection was then preserved in 10% formalin and the remaining organisms (alive) were counted later. All samples used for viability analysis were examined within 3 hours after collection.

Table 6-17. Numbers of macrozooplankton examined for viability during 1974 entrainment studies. The specimens were contained in a total of 142 samples collected on 14 dates.

Species	Number of organisms	
	Examined	Maintained for 5-day latent survival analysis
Gammarus spp.	16824	2192
Neomysis americana	7384	416
Monoculodes edwardsi	2555	623
Chaoborus sp.	1795	120
Leptocheirus plumulosus	124	83

Table 6-18 . 1974 macrozooplankton sampling dates and temperature data.

Date	Ambient temperature (°C)	ΔT (°C)
5-7	13.1	9.1
5-30	17.5	7.0
6-13	20.5	8.7
6-18	20.5	5.5
6-25	21.8	5.4
6-27	22.0	7.2
7-2	23.3	5.7
7-9	24.9	8.4
8-15	26.0	7.0*
8-20	25.9	8.1
9-17	23.2	7.7
9-19	24.0	6.9*
10-15	16.6	8.5
11-12	13.0	10.1

* Chlorination

Representatives of the three major macrozooplankton species (Gammarus spp., Neomysis americana and Monoculodes edwardsi) were removed from the samples and maintained in the laboratory for latent-survival analysis. Limited numbers of Chaoborus sp. and Leptocheirus plumulosus were also examined for latent survival. The organisms were removed from the entrainment sample and placed into battery jars (20 per jar) containing 800 ml of Hudson River water. All groups were held for 5 days after collection at ambient 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.

The aquatic plant Myriophyllum sp. and assorted green algae served as substrate and food in all experiments involving culturing of Gammarus spp. and M. edwardsi. The amphipod's diet was also supplemented with finely ground commercial fish food and presoaked maple leaves. N. americana were fed only finely ground fish food.

Analysis of all initial macrozooplankton survival was conducted by the Kruskal-Wallis test, a nonparametric analogue of the single-classification analysis of variance. 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 R × C 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.

6.2.2.3 Results and Discussion

The initial survival of Gammarus spp. collected at Indian Point during spring and fall ambient temperatures (13.0-17.5°C; 55.4-63.5°F) is presented in Table 6-19. Mean percentages alive at the intake, D-1 and D-2 were 96.5%, 94.5% and 95.6% respectively. Statistical analyses of all three viability classifications revealed no differences in initial survival among the three collection stations. Mean survivals of Gammarus spp. collected during the summer (ambient 20.5-24.9°C; 68.9-76.8°F) also exceeded 90% at each of the collection stations (Table 6-20). Entrained Gammarus spp. examined during the summer also displayed no significant reductions in discharge-canal survival when compared with intake survival.

During the summer study period, the mean ΔT of the eight sampling dates was 7.1°C (12.8°F). Based on previous temperature-tolerance experiments (Lauer et al., 1974), a 7.1°C ΔT for periods up to 60 minutes would not result in measurable mortalities of Gammarus spp. due to temperature alone.

Gammarus spp. collected in the discharge canal during periods of condenser chlorination displayed reduced survival when compared with intake samples (Table 6-21). The percentages of all three viability classifications at discharge stations D-1 and D-2 were significantly different ($P < 0.01$) from the corresponding percentages at the intakes (Table 6-22). The survivals at stations D-1 and D-2 were not distinguishable. The reduction in the per-

Table 6-19. Viability of Gammarus spp. collected at the Indian Point intake and discharge stations during the periods of May 7-30 and October 10-November 12, 1974. Ambient temperatures were 13.0 to 17.5°C; ΔTs were 7.0 to 10.1°C.

Station	Condition (percent)		
	Alive	Stunned	Dead
Intake	96.5 95.3-97.7*	1.1 0.6-1.6	2.4 1.3-3.5
D-1	94.5 91.6-97.5	2.6 0- 5.3	2.8 0.8-4.9
D-2	95.6 94.1-97.1	1.2 0.4-1.9	3.2 2.0-4.4

* 95% Confidence Interval

Table 6-20. Viability of Gammarus spp. collected at the Indian Point intake and discharge stations during the period of June 13 to September 17, 1974. Ambient temperatures were 20.5 to 24.9°C, ΔTs were 5.4 to 8.7°C.

Station	Condition (percent)		
	Alive	Stunned	Dead
Intake	94.7 92.2-97.2*	1.5 0.5-2.5	3.8 1.7-5.9
D-1	93.5 90.9-96.0	2.4 1.0-3.8	4.2 2.5-5.9
D-2	94.4 92.6-96.2	1.2 0.3-2.1	4.4 3.0-5.8

* 95% Confidence Interval

Table 6-21 . Viability of Gammarus spp. collected at the Indian Point intake and discharge stations during condenser chlorination on August 15 and September 19, 1974. Ambient temperatures were 24.0 to 26.0°C, ΔT were 6.9 to 7.0°C.

Station	Condition (percent)		
	Alive	Stunned	Dead
Intake	96.0 91.7-100.0*	1.6 0 - 3.8	2.4 0.6-5.4
D-1	66.1 57.1 -75.1	19.9 9.4-30.5	13.9 6.7-21.1
D-2	71.2 65.1 -77.2	12.6 5.7-19.5	16.2 6.9-25.6

* 95% Confidence Interval

Table 6-22. A posteriori comparisons of intake and discharge-canal survival of Gammarus spp. collected during condenser chlorination.

Viability classification	Station comparisons	"U" statistic
Alive	Intake vs D-1	35**
	Intake vs D-2	42**
	D-1 vs D-2	21 N.S.
Stunned	Intake vs D-1	35**
	Intake vs D-2	42**
	D-1 vs D-2	22.5 N.S.
Dead	Intake vs D-1	34**
	Intake vs D-2	39**
	D-1 vs D-2	17 N.S.

N.S.- Not statistically significant at $\alpha=0.05$
** $P < 0.01$

centages of alive Gammarus spp. at Stations D-1 and D-2 was accompanied by a corresponding increase in both the stunned and dead categories. The 95% confidence interval for the reduction of alive Gammarus at Station D-1 when compared to intake survival is 22.3 to 37.5%.

Stunned Gammarus spp. collected in the discharge canal during chlorination displayed increased mortality rates when compared with alive organisms collected from both the intake and discharge stations (Table 6-23). Approximately 50% of the stunned organisms died within 24 hours. During the same period there were negligible mortalities of Gammarus classified as alive.

Monoculodes edwardsi were collected in sufficient numbers for viability analysis from June 13 to November 12, 1974. There were no detectable differences in survival between intake and discharge canal collections (Table 6-24).

The results of 16 latent mortality experiments on the three amphipod species (Gammarus, M. edwardsi, and Leptocheirus plumulosus) and the dipteran Chaoborus sp. are presented in Table 6-25. There were no differences between the 5-day survival rates of organisms collected at the plant intakes and those collected at the three discharge canal stations. In one instance, on June 25, the latent survival of Gammarus spp. at Station D-1 was lower than the latent survival at Station D-2. In all other cases, there were no differences in survival among the discharge canal stations.

Although the 1974 survival data for N. americana varied considerably with date, (i.e. with ΔT) the combined results produced sufficiently large sample sizes for statistical analysis. The

Table 6-23. Latent survival of Gammarus spp. collected at Indian Point during condenser chlorination.

Station	Viability classification	No.	Survival (Percent) initial	1 day	5 day
Intake	Alive	99	100	94.9	85.9
D-1	Alive	100	100	97.0	91.0
D-2	Alive	60	100	100.0	91.7
D-P	Alive	100	100	98.0	89.0
D-1, D-2 & D-P	Stunned	130	100	50.8	40.0

Table 6-24. Viability of Monoculodes edwardsi collected at the Indian Point intake and discharge stations during the period of June 13 to November 12, 1974. Ambient temperatures were 13.0 to 24.9°C; ΔTs were 5.4 to 10.1°C.

	Condition (percent)		
Station	Alive	Stunned	Dead
Intake	92.2 88.3-96.1*	1.5 0-3.1	6.3 2.4-10.2
D-1	91.0 87.3-94.7	2.0 0.8-3.3	6.9 3.3-10.5
D-2	88.8 80.4-97.2	1.9 0-4.2	9.3 12.-17.4

* 95% Confidence Interval

Table 6-25. Latent survival of Gammarus spp., Monoculodes edwardsi, Chaoborus sp., and Leptocheirus plumulosus collected at the Indian Point intake and discharge stations. Maximum non-significant subsets of survival 5 days after collection are underlined. (n= number of samples analyzed.)

Date	Species	n	Stations
May 7	Gammarus spp.	300	I D-1 D-2
May 30	Gammarus spp.	240	I D-2
June 13	Monoculodes edwardsi	63	I D-1
June 18	Monoculodes edwardsi	118	I D-1
June 25	Gammarus spp.	136	I D-1 D-2
June 25	Monoculodes edwardsi	95	I D-1 D-2
June 27	Gammarus spp.	120	I D-1 D-2
June 27	Monoculodes edwardsi	107	I D-1 D-2
July 2	Gammarus spp.	350	I D-1 D-2 D-P
July 9	Gammarus spp.	151	I D-1 D-2
July 9	Monoculodes edwardsi	120	I D-1 D-2
July 9	Chaoborus sp.	120	I D-1 D-2
September 17	Gammarus spp.	170	I D-2 D-P
September 17	Leptocheirus plumulosus	83	I D-2 D-P
October 15	Gammarus spp.	236	I D-1 D-2 D-P
November 12	Monoculodes edwardsi	120	I D-1 D-2

mean percent alive at Station D-1 reached a maximum of 67.3% on June 18 when the operating ΔT was 5.5°C (9.9°F) at an ambient temperature of 20.5°C (68.9°F). The intake survival on June 18 was 82.7%. On August 20, however, the percent alive at Station D-1 was only 7.8% at a ΔT of 8.1°C (14.6°F) above an ambient temperature of 25.9°C (78.6°F). This represents a substantial mortality since the intake survival on August 20 was 96.3%. The high observed mortality is predictable at discharge temperatures near 34°C (93.2°F) based on laboratory bioassays (Lauer et al., 1974).

N. americana survival revealed a significant ($P < 0.01$) effect of collection station on percent alive, stunned and dead (Table 6-26). The overall mean percentages of alive Neomysis americana collected at the intakes and Station D-1 were 82.0% and 44.3%, respectively. The 95% confidence interval on the difference between the survival at intakes and D-1 is 21.8% to 53.6%. A posteriori comparisons of survival at the three collection stations reveals a significant difference between the intake and Stations D-1 and D-2 for all three viability classifications (Table 6-27). Stations D-1 and D-2 were not different from each other, however. Alive N. americana maintained for latent-survival analysis displayed no significant differences in 1 or 5-day mortalities of intake or discharge-canal collections (Table 6-28). N. americana classified as stunned had significantly higher mortality rates during the 5-day retention period than organisms classified as alive.

The night chlorination on August 15 allowed the examination of the response of N. americana during a period of high abundance

Table 6-26. Viability of Neomysis americana collected at the Indian Point intake and discharge stations during the period of June 18 to November 11, 1974. Ambient temperatures were 13.0 to 25.9°C; ΔTs were 5.4 to 10.1°C.

	Condition (percent)		
Station	Alive	Stunned	Dead
Intake	82.0 72.0-92.0*	2.2 0.6-3.8	15.8 6.2-25.3
D-1	44.3 31.4-57.2	15.1 7.2-23.0	40.5 28.5-52.6
D-2	46.1 25.6-66.6	10.4 1.3-19.6	43.4 20.7-66.2

* 95% Confidence Interval

Table 6-27. *A posteriori* comparisons of intake and discharge canal survival of *Neomysis americana* using the Mann-Whitney U-test.

Viability classificiation	Station comparisons	"U" statistic
Alive	Intake vs D-1	153.0**
	Intake vs D-2	96.5**
	D-1 vs D-2	63.0 N.S.
Stunned	Intake vs D-1	154.0**
	Intake vs D-2	91.5**
	D-1 vs D-2	80.5 N.S.
Dead	Intake vs D-1	139.5**
	Intake vs D-2	87.5*
	D-1 vs D-2	74.5 N.S.

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

Table 6-28. Latent survival of Neomysis americana collected at the Indian Point intake and discharge stations on August 20 and November 11, 1974. (n=number of samples analyzed.)

Station	Viability classification	No.	Survival (percent) Initial	1-day	5-day
Intake	Alive	102	100	92.2	75.5
D-1	Alive	98	100	91.8	80.6
D-2	Alive	79	100	87.3	70.9
D-1	Stunned	65	100	53.8	23.1
D-2	Stunned	32	100	34.4	15.6

of the organisms. Although only a few samples could be examined, the large numbers of organisms per sample resulted in quite accurate estimates of entrainment survival. The combined effects of chlorine and a potentially lethal discharge temperature of 33.0°C (91.4°F) resulted in an extremely low survival of N. americana in the Indian Point discharge canal. The percentage alive at Station D-1 was 0.8% compared to an intake survival of 86.7% (Table 6-29).

The results of these viability assessments based on intake and discharge-canal samples of some of the dominant macrozooplankton species (Gammarus, Monoculodes, Leptocheirus, Chaoborus) show that at the rated ΔT for Unit 2 of 8.3°C (14.9°F) and an ambient temperature of 20 to 25°C (68 to 77°F), entrainment into the cooling-water flow of the Indian Point plant had little or no effect on survival. With respect to Gammarus, further support for this can be found in Section 6.2.1 (Temperature Tolerance Studies) which shows that adult females were able to tolerate 30-minute laboratory exposures to a ΔT of 11°C (19.8°F) at an ambient temperature of 26°C (78.8°F). On the other hand, Neomysis americana exposed to the plant conditions described above suffered mortalities upwards of 90%. The impact of this on the Neomysis population in the river is not known, but it is believed to be minimal. Neomysis occurrence during the other times of the year would depend on the salinity distribution in the Hudson River estuary.

All macrozooplankton organisms entrained during periods of condenser chlorination can be expected to experience some added

Table 6-29. Survival of Neomysis americana collected during condenser chlorination on August 15, 1974. The ambient temperature was 26.0°C with a ΔT of 7.0°C. (n=number of individuals examined.)

		Condition (percent)		
Station	n	Alive	Stunned	Dead
Intake	886	86.7	1.8	11.5
D-1	666	0.8	1.9	97.3
D-2	686	1.9	1.2	96.9
D-P	1712	0.3	0.2	99.5

lethal effects (Tables 6-22 to 6-24 and 6-29). However, the results shown are for nighttime chlorination, as the daytime abundance of macrozooplankton is too low to provide meaningful data. The absolute mortality of zooplankton from daytime chlorination, which is the normal procedure, will be far less than for the experimental nighttime chlorination reported here. Therefore, normal chlorination procedures employed at the power plant are not expected to have much impact upon river macrozooplankton.

7. ICHTHYOPLANKTON

7.1 RIVER POPULATION STUDIES

7.1.1 Methods

Ichthyoplankton was generally collected in the 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 1-8), were then sorted for separate detailed analyses. The methods and gear used are described in Section 6-1.

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 "tows" for abundance in the Indian Point generating plant. This type of sampling was done each week through the end of 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, 571μ-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).

Fish eggs and larvae of all species were sorted from the samples, identified to species when possible and enumerated. The data were analyzed by appropriate statistical techniques to determine the similarity and significant differences in temporal

and spatial occurrence of fish eggs and larvae in the river in front of the Indian Point plant, relative to abundance entering the plant intake.

7.1.2 Results and Discussion

A total of 922 ichthyoplankton samples were collected from the Hudson River in 1974. The species and life stages identified in these collections are listed in Table 7-1. A total of 21 species were observed, of which 18 species have been caught continuously since 1971. The life stages and relative abundance by season of fish species taken in these samples are shown in Table 7-2. Seasonal comparisons show that the life stages of the bay anchovy (Anchoa mitchilli) are the most abundant. Following the bay anchovy in relative abundance, in descending order, are the various life stages of the striped bass (Morone saxatilis); white perch (M. americana) and clupeids of the Alosa spp.

The seasonal distribution for fish species sampled during 1974 and their occurrence relative to water temperature and salinity at Indian Point are shown in Figure 7-1. Although there was some overlap, the occurrence of the various species examined appears to be dependent on temperature and salinity rather than time (calendar date) dependent. The frequencies of occurrence of the most abundant species are shown in Figures 7-2 to 7-5. According to these data, striped bass eggs are the first to occur in the Indian Point region when the salinity is less than 3 parts per thousand (ppt). They are followed by the clupeids, white perch, anchovies and cyprinids. The influx of salt water into the Indian

Table 7-1. Ichthyoplankton species and life stages in the river population samples, 1974. (YSL = yolk-sac larvae; Juv = juveniles; Older = older fish).

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)					
Alosa aestivalis (blueback herring)		X	X	X	
Alosa pseudoharengus (alewife)	X	X	X	X	
Alosa sapidissima (American shad)		X	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		X
_____ sp.	X	X	X		
Percidae (perches)					
Etheostoma olmstedi (tessellated darter)		X	X		
Perca flavescens (yellow perch)			X		
Sciaenidae (drums)					
Cynoscion regalis (weakfish)			X	X	

Table 7-1 (cont.)

Species	Eggs	YSL	Larvae	Juv.	Older
Atherinidae (silversides)					
Menidia sp.			X	X	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
Ictaluridae (freshwater catfishes)					
Ictalurus catus (white catfish)					X
Gobiidae (gobies)					
Gobiosoma bosci (naked goby)			X		
Pomatomidae (bluefishes)					
Pomatomus saltatrix (bluefish)					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 and 1974. (1).

Species	Egg			Yolk-sac larvae			Larvae			Juveniles		
	1971	1972	1974	1971	1972	1974	1971	1972	1974	1971	1972	1974
Anchovy	----	----	95.9	----	----	16.3	51.2	30.8	69.8	99.8	57.4	68.7
Clupeids*	7.2	1.1	+	16.6	6.8	3.9	10.7	47.8	7.9	+	3.4	1.4
Striped bass	92.7	87.2	3.1	55.6	65.6	54.8	14.3	7.1	12.2	+	7.3	0.4
White perch	+	0.8	0.5	22.2	6.6	22.7	21.8	8.0	9.4	+	30.1	0.1
Tomcod	----	----	----	----	13.1	----	----	5.2	----	+	----	9.6
Darter	----	----	----	4.0	4.9	1.7	0.1	0.4	0.1	----	+	----
Cyprinids**	----	+	0.5	1.6	1.9	0.6	+	0.4	0.2	----	+	+
Hogchoker	----	10.9	----	----	0.1	0.1	+	0.3	0.1	+	1.7	2.0
Yellow perch	----	----	----	----	+	----	+	0.8	+	----	----	----
Weakfish	----	----	----	----	----	----	----	+	0.1	----	+	2.7
Smelt	----	----	----	----	----	----	1.2	----	0.1	+	+	2.7
Silversides	----	----	----	----	----	----	0.2	+	0.1	----	----	0.2
American eel	----	----	----	----	----	----	----	----	----	+	+	12.9
Pipefish	----	----	----	----	----	----	----	----	+	+	+	0.4
Centrarchid	----	----	----	----	+	----	----	+	+	----	----	----
Gobi sp.	----	----	----	----	----	----	----	----	+	----	----	----
Atlantic sturgeon	----	----	----	----	----	----	----	+	----	----	----	----

(1)- Data for 1973 was not available for all species.

\+ indicates less than 0.1 percent.

* The clupeids included alewife, blueback herring, and shad. The eggs are presumed to be alewife because of time of occurence and size. The shad are presumed to be present in larval and juvenile stages, but not as yolk-sac-larvae due to the size of shad (9 to 10mm) for 1971 and 1972. For 1974, shad were present only as yolk-sac larvae (fish) in the catch, with no larvae.

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

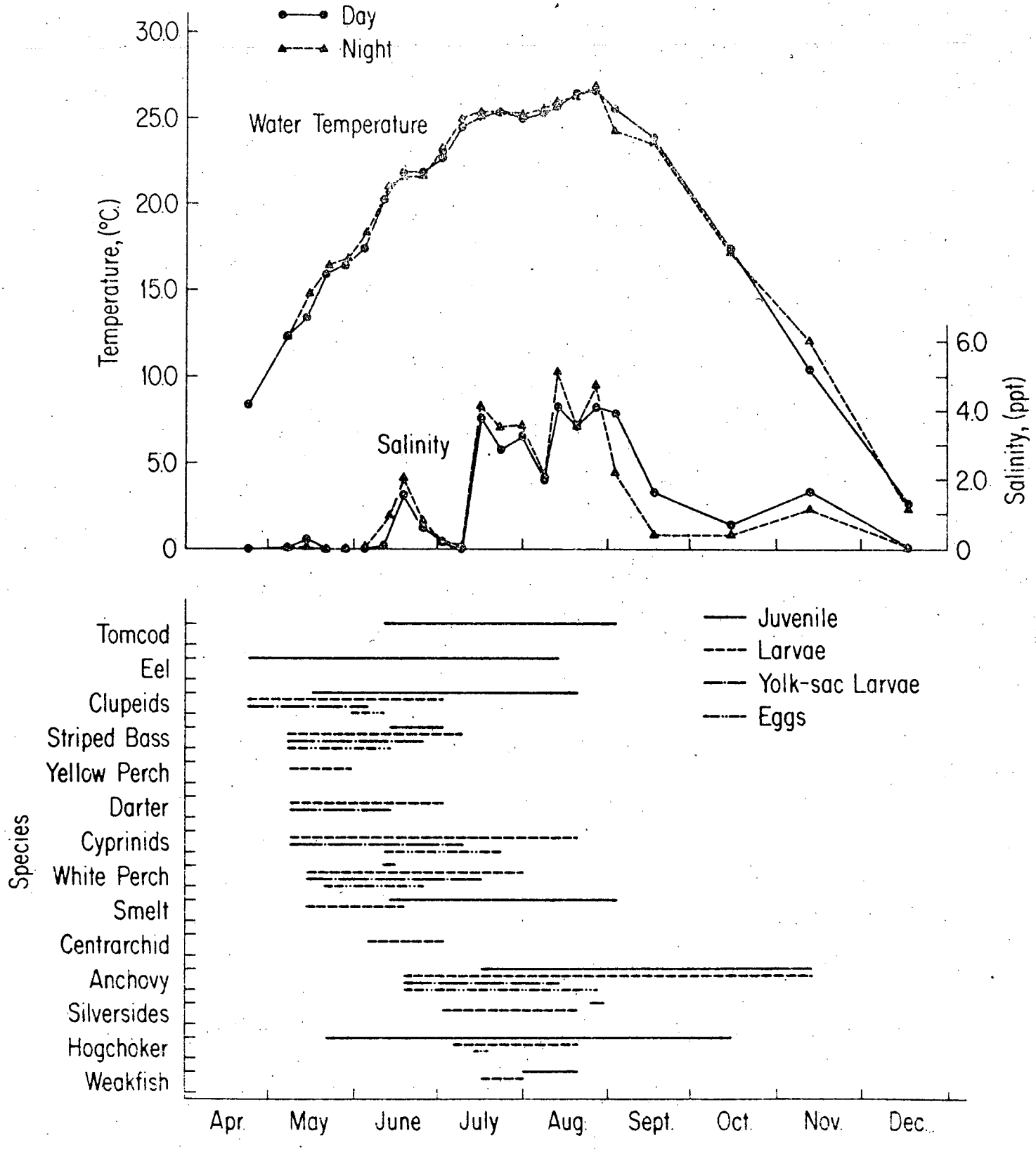


Figure 7-1. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1974.

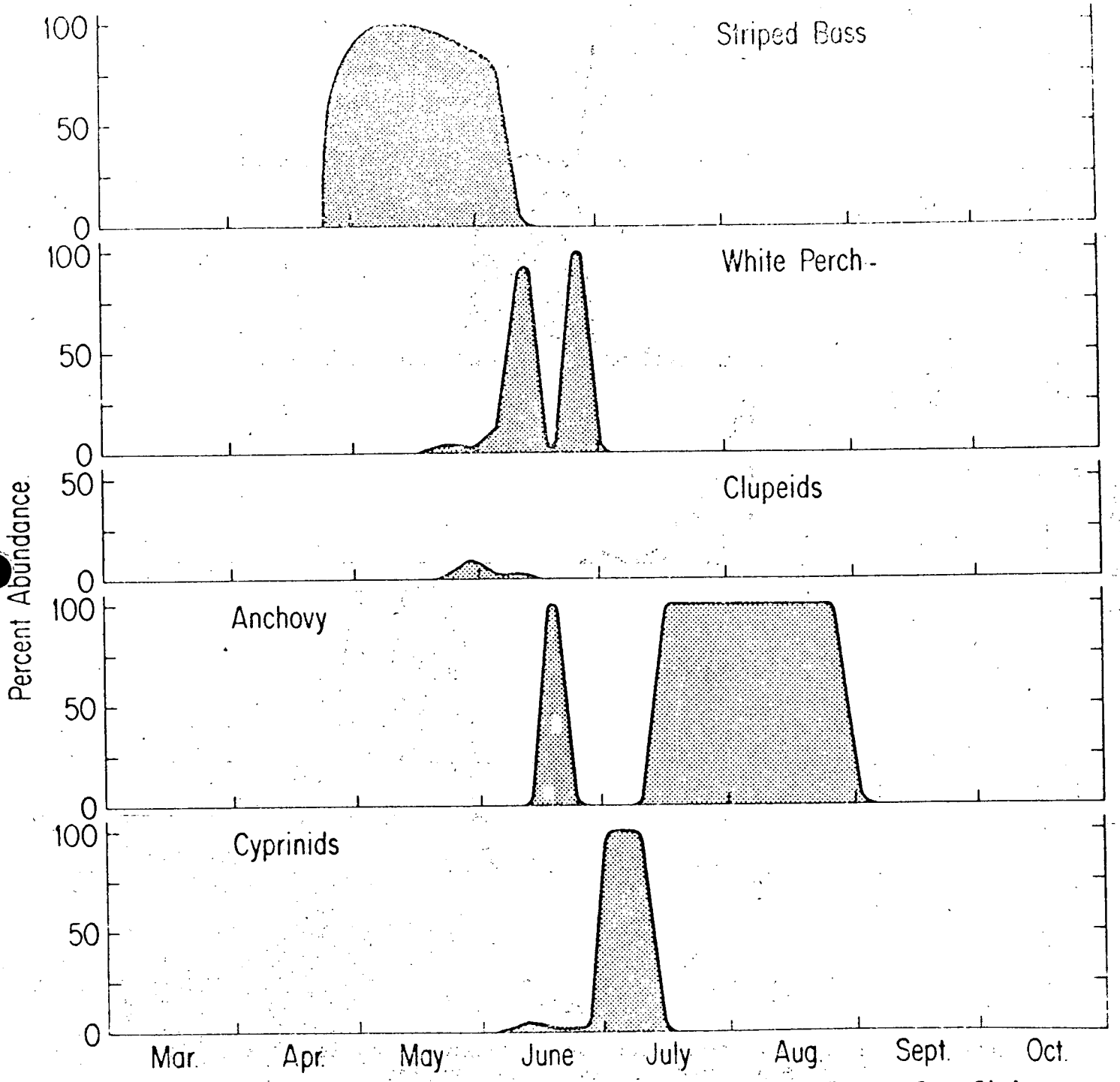


Figure 7-2. Seasonal occurrence and percent abundance for fish eggs by species, 1974; values shown are percent of total fish eggs in the samples analyzed.

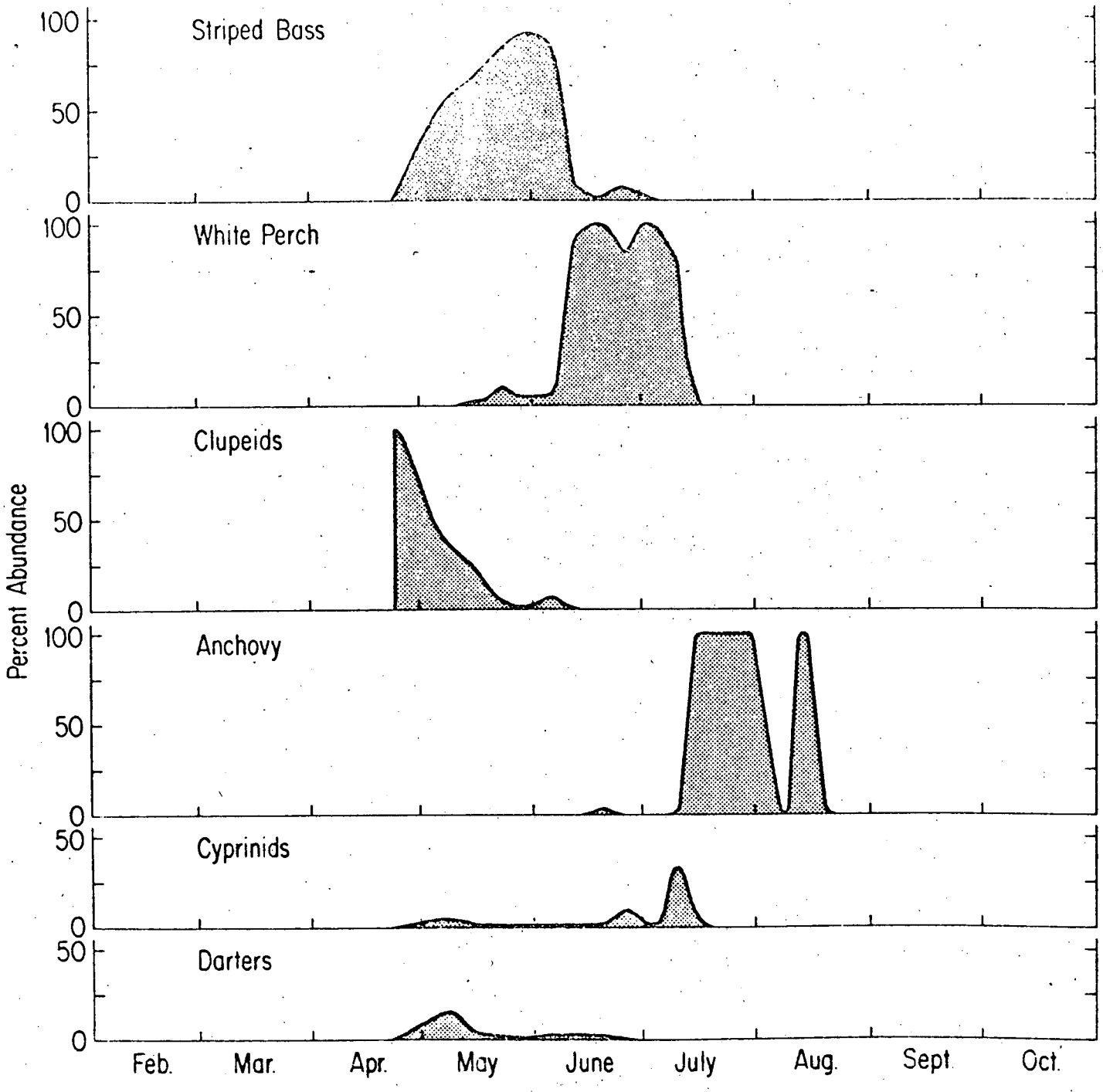


Figure 7-3. Seasonal occurrence and percent abundance for yolk-sac larvae by species, 1974; values shown are percent of total yolk-sac larvae in the samples analyzed.

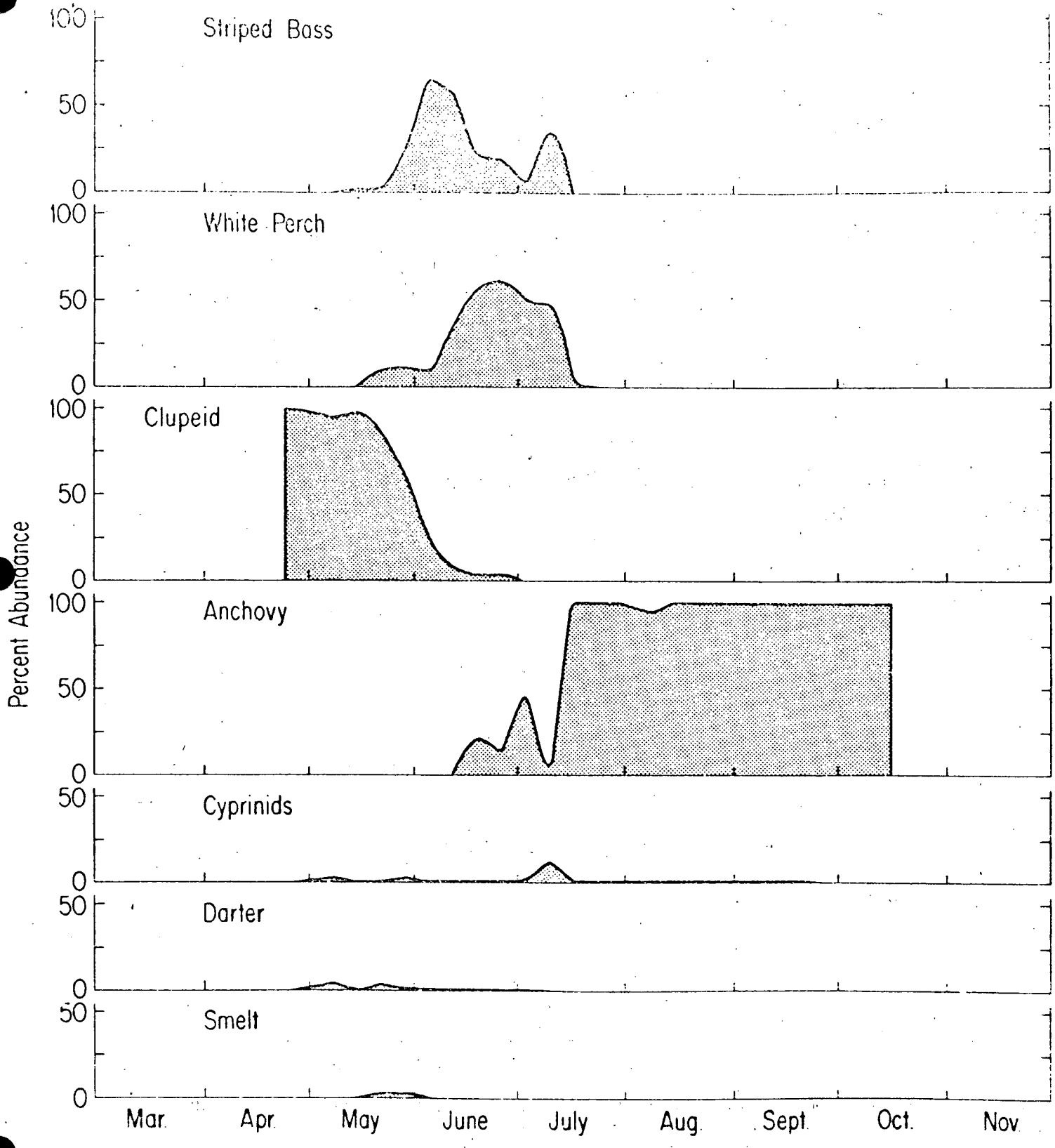


Figure 7-4. Seasonal occurrence and percent abundance for larvae by species, 1974; values shown are percent of total larvae in the samples analyzed.

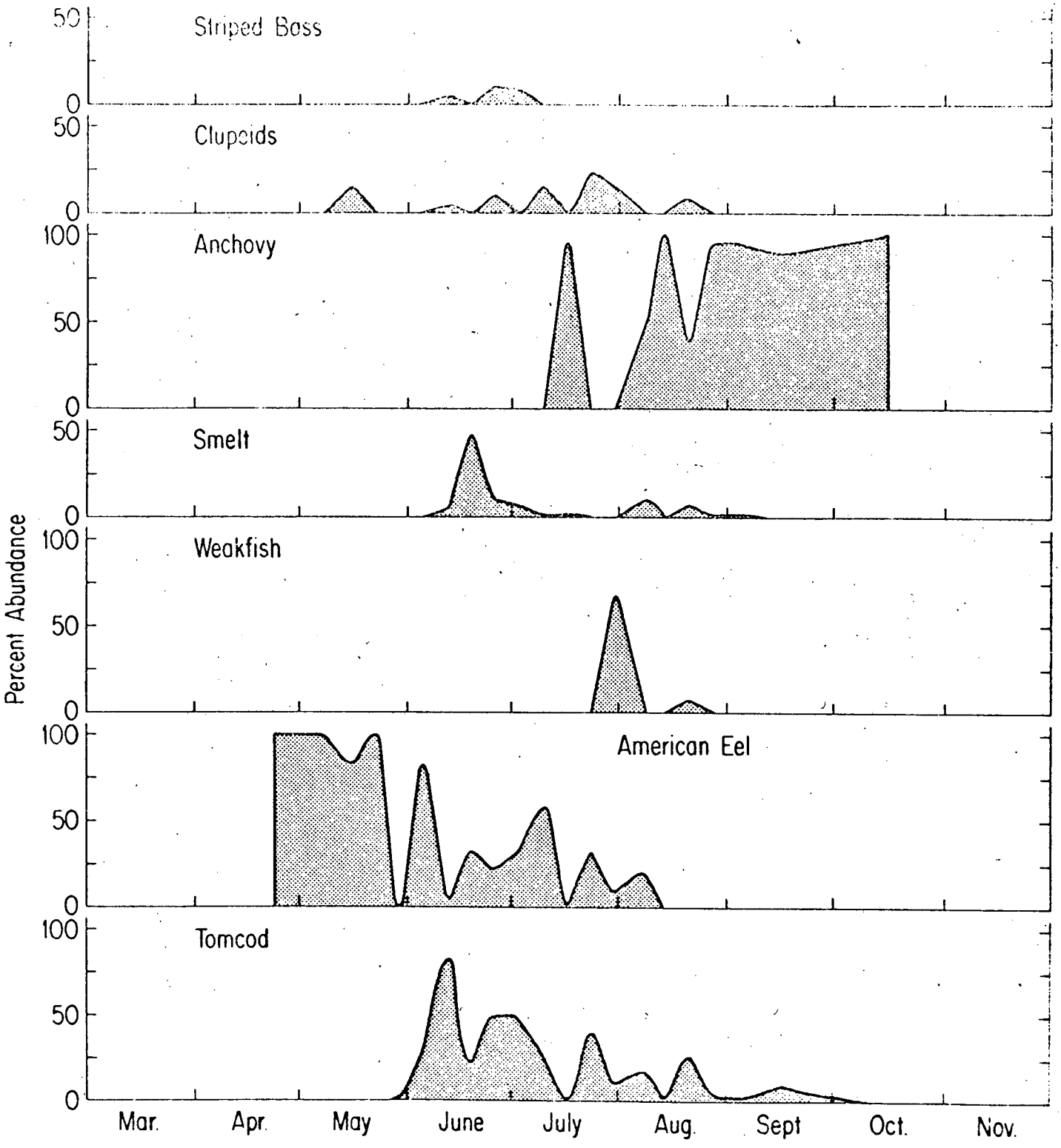


Figure 7-5. Seasonal occurrence and percent abundance for juveniles by species, 1974; values shown are percent of total juveniles in the samples analyzed.

Point region was first noted on June 18; this intrusion correlated with an increased abundance of anchovy eggs and a decreased abundance of white perch eggs. However, as salinity levels returned to pre-intrusion levels at the end of June and the beginning of July, anchovy egg production declined while white perch eggs increased to pre-salt water levels. During this period of fresh water in early July, cyprinid eggs were also present in large numbers. Bay anchovy eggs became the dominant egg species as salinity values in the waters adjacent to Indian Point rose towards maximum (Figures 7-1 and 7-2). All of this suggests a strong response to changes in salinity.

The abundance of yolk-sac larvae of each species collected follows closely the curves established for its egg abundance. In most instances, the curves for yolk-sac larvae were displaced to the right of those for the eggs and thus show indications of having been derived from the previous peak egg abundance; an example of this is seen in striped bass (Figure 7-3). As white perch eggs are adhesive and demersal, they were not represented quantitatively in the collections; the eggs that were collected were usually those that were water hardened without prior attachment. Consequently, there appeared to be more white perch yolk-sac larvae than eggs. The clupeids were the only species that showed little resemblance between egg and yolk-sac larvae abundances. The fact that clupeids are represented by three species in the Indian Point region may contribute to this discrepancy. The peak occurrence of clupeid eggs in our collections appeared on May 28, but maximum abundance for clupeid yolk-sac larvae had been observed prior to

this date. Possible explanations for this occurrence include spawning by two different species (alewife, Alosa pseudoharengus, and blueback herring, A. aestivalis), or spawning by just one species (alewife) outside the Indian Point region with a sequenced influx of the newly hatched yolk-sac larvae into the area (Figure 7-3). The shad (A. sapidissima) in our collection consisted of one yolk-sac larva on May 14. The clupeid yolk-sac larvae peak seen on June 4 was probably derived from the eggs present on May 12 (Figures 7-2 and 7-3).

Larvae collected prior to the salt influx into the Indian Point region were predominantly clupeids, striped bass and white perch. After salt intrusion, the dominant larval species collected was the bay anchovy; this dominance continued from mid-July until the end of October. Incidental species occurring at this time included the Atlantic silversides (Menidia sp.), weakfish (Cynoscion regalis) and the American sole or hogchoker (Trinectes maculatus). Although these species were present from the middle of July to the end of August, their numbers were incidental to the anchovy and thus are not shown in Figures 7-2 to 7-5.

The sequence of occurrence of striped bass and white perch (Figures 7-2 to 7-4) is most striking. There was a definite separation of striped bass and white perch in time,but at a time when eggs and yolk-sac larvae of the two species were most abundant. This serves to indicate that the two species have separate spawning times in the river. During the larval stages however, their occurrence was simultaneous (Figure 7-4).

Only three American shad larvae were collected in May; one on May 7 and the other two on May 28. Their sizes ranged from 15 to 25 mm. At the same time the size range for other clupeid larvae was from 4 to 10 mm.

The 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, and prior to its occurrence, it was the American eel (Anguilla rostrata). The tomcod (Microgadus tomcod) occurred throughout the collecting season. Juvenile striped bass and white perch were not represented in large numbers, as they were probably large enough and mobile enough to actively avoid net capture. Also, juvenile striped bass tend to move into shallow water near shore and hence, were not sampled by our nets.

Overall, the species composition of the ichthyoplankton collected in 1974 is similar to that found for previous years. Also, the distribution for the striped bass and white perch with depth is similar to that seen in previous years. However, this yearly comparison of data revealed an unusually high abundance for striped bass in 1973 (See NYU, 1974, Figures 7-1 to 7-4). Data from 1973 were found to be in error; i.e. higher by an order of magnitude. With the correction of this computational error, mean abundance for striped bass in the river are comparable from 1971 to 1974 (Figures 7-6 to 7-9).

The depth profiles, when compared with data from 1971 on, indicate that larvae have definite diel changes in depth; they

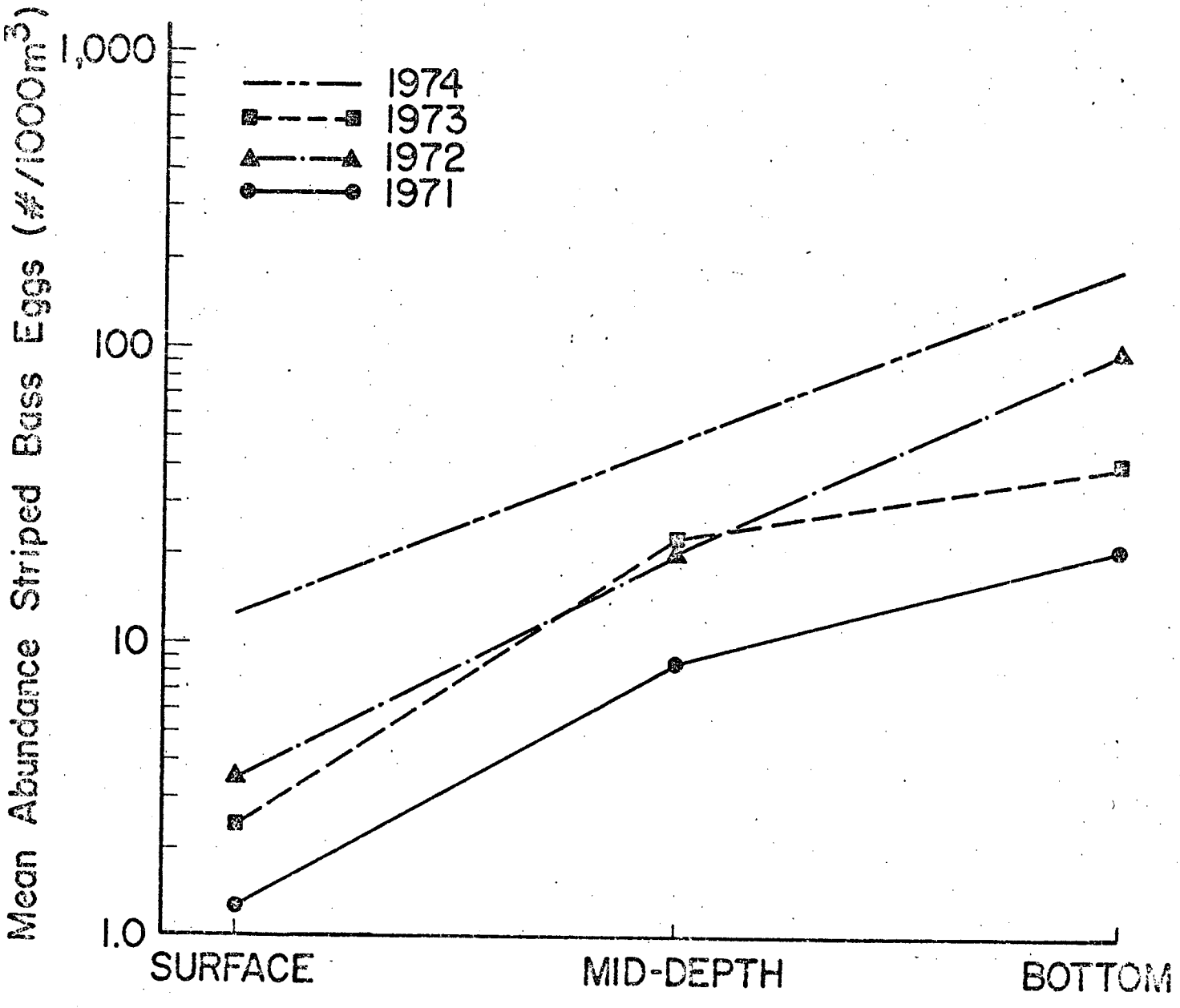


Figure 7-6. Mean abundance (day and night combined) of striped bass eggs collected in river tows from 1971 to 1974.

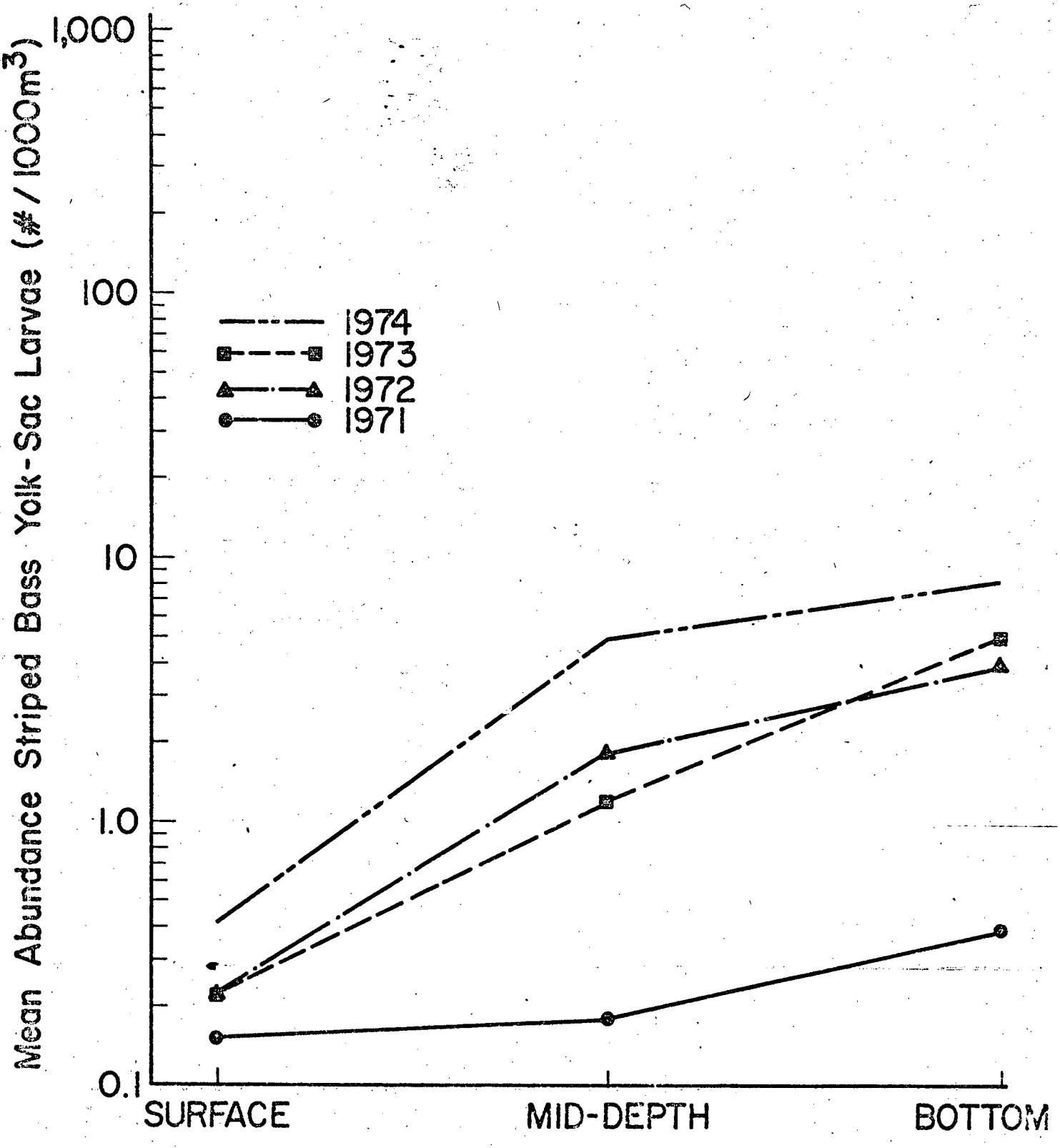


Figure 7-7. Mean abundance (day and night combined) of striped bass yolk-sac larvae collected in river tows from 1971 to 1974.

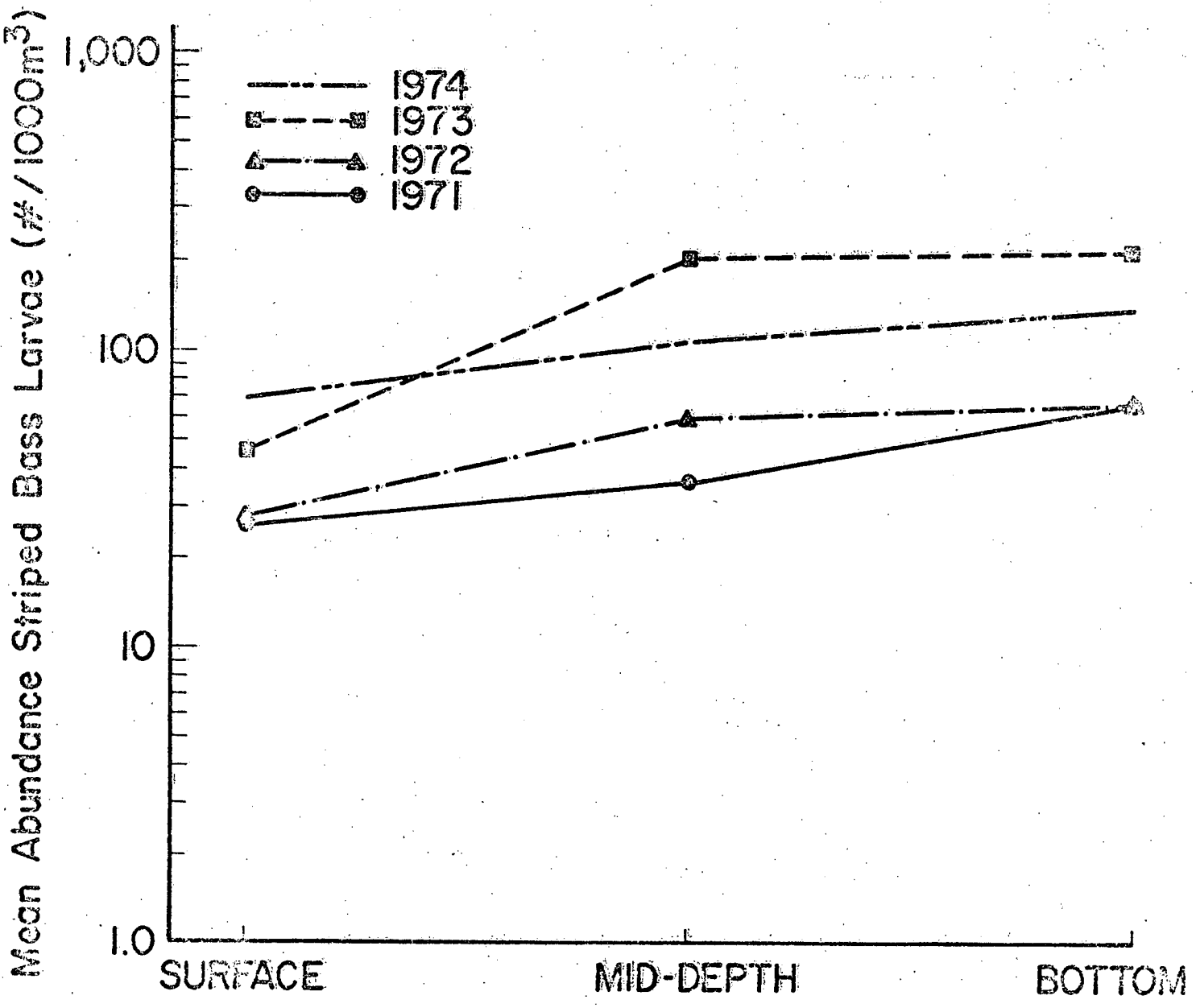


Figure 7-8. Mean abundance (day and night combined) of striped bass larvae collected in river tows from 1971 to 1974.

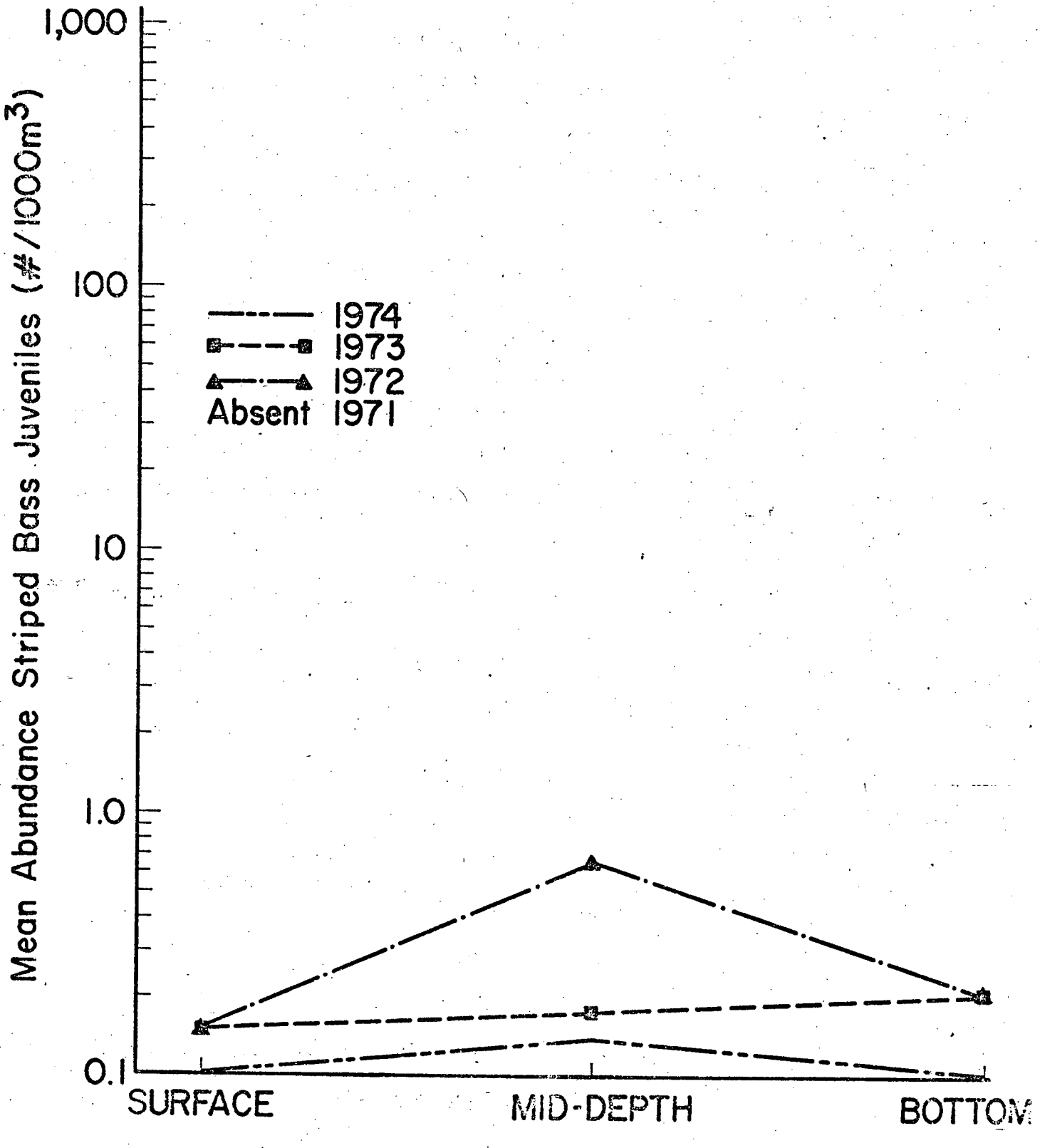


Figure 7-9. Mean abundance (day and night combined) of striped bass juveniles collected in river tows from 1971 to 1974.

are more abundant towards the bottom during the day. Eggs and yolk-sac larvae of these two species did not exhibit a definite diel change but, as stated in past reports, are believed to be more passive and are thus subjected to tidal influences in their distribution. Although white perch and striped bass juveniles were more mobile, they were more abundant in the mid to lower depths (Figures 7-6 to 7-17).

The depth profiles for clupeids during the day showed eggs distributed more towards the surface. The yolk-sac larvae and larvae showed a preference for mid to bottom waters, while the juveniles of this group were distributed more towards intermediate depths (Figure 7-18). This compares favorably with observations made in 1971, but not those of 1972 in which clupeid distribution was more towards the water's surface.

At night, clupeid eggs were more numerous towards the surface, while yolk-sac larvae were evenly distributed throughout the water column, with higher numbers at the surface and bottom. Juveniles preferred bottom waters (Figure 7-19). This pattern resembles that observed for 1972.

The reasons for these observed differences in the vertical distribution of clupeid larvae from 1971 to 1974 are not known. One possibility is that preference for a certain level is species specific, since three different species are included within the grouping of clupeids (Alosa pseudoharengus, A. aestivalis and A. sapidissima). Thus the vertical distribution of clupeids in the water column during a particular year would be dependent upon the species composition for that year.

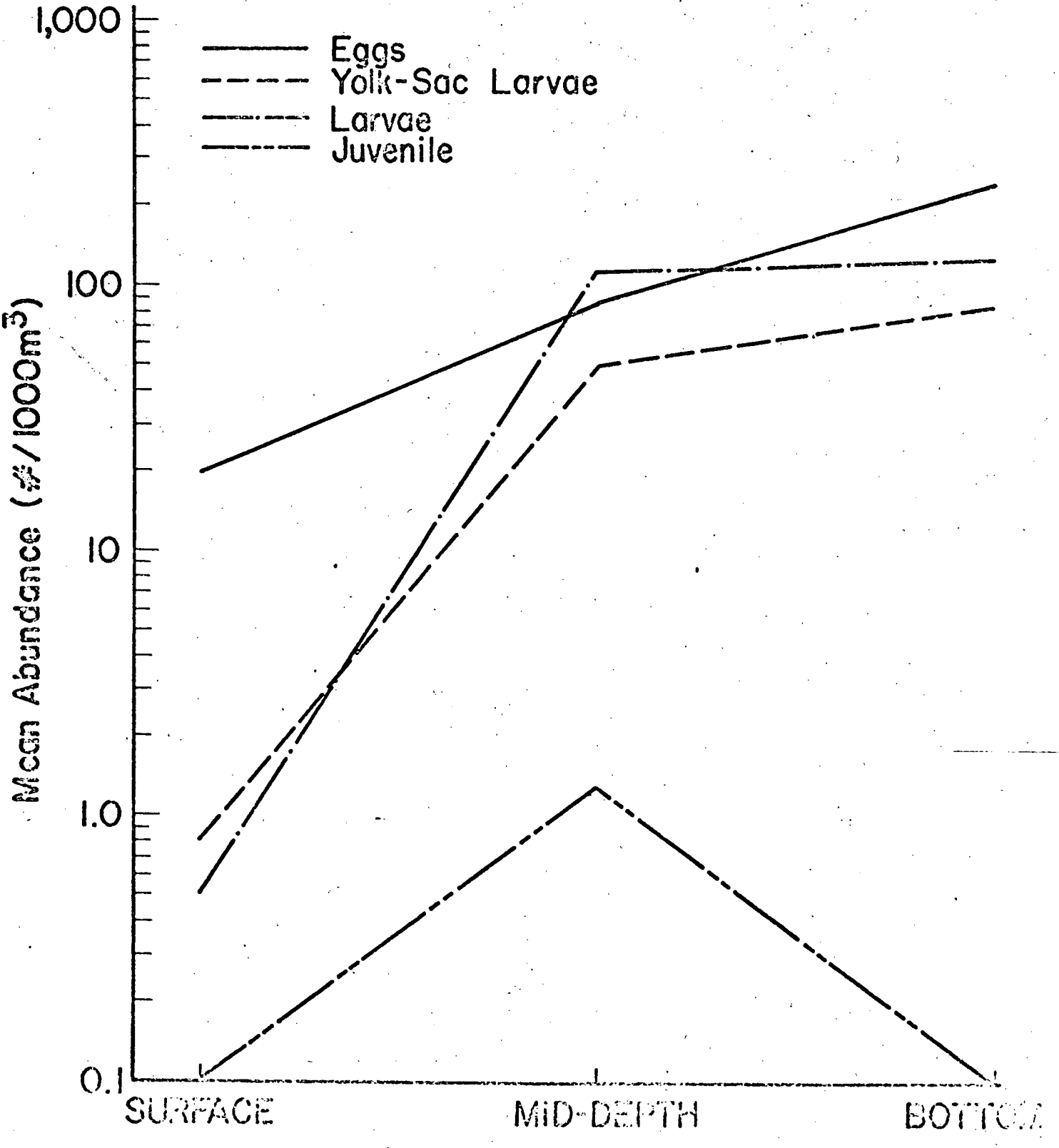


Figure 7-10. Daytime pattern of vertical distribution for striped bass, 1974.

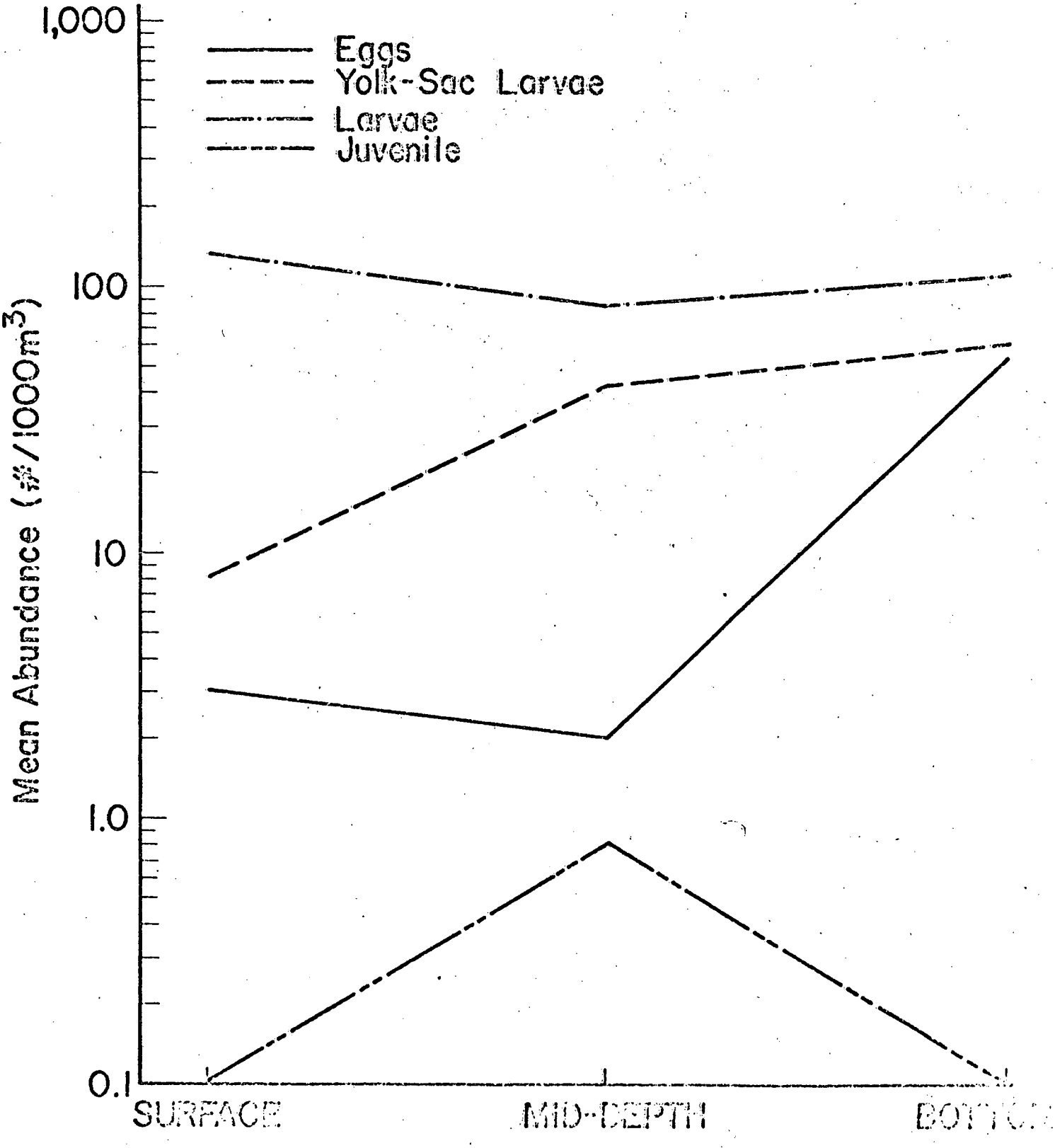


Figure 7-11. Nighttime pattern of vertical distribution for striped bass, 1974.

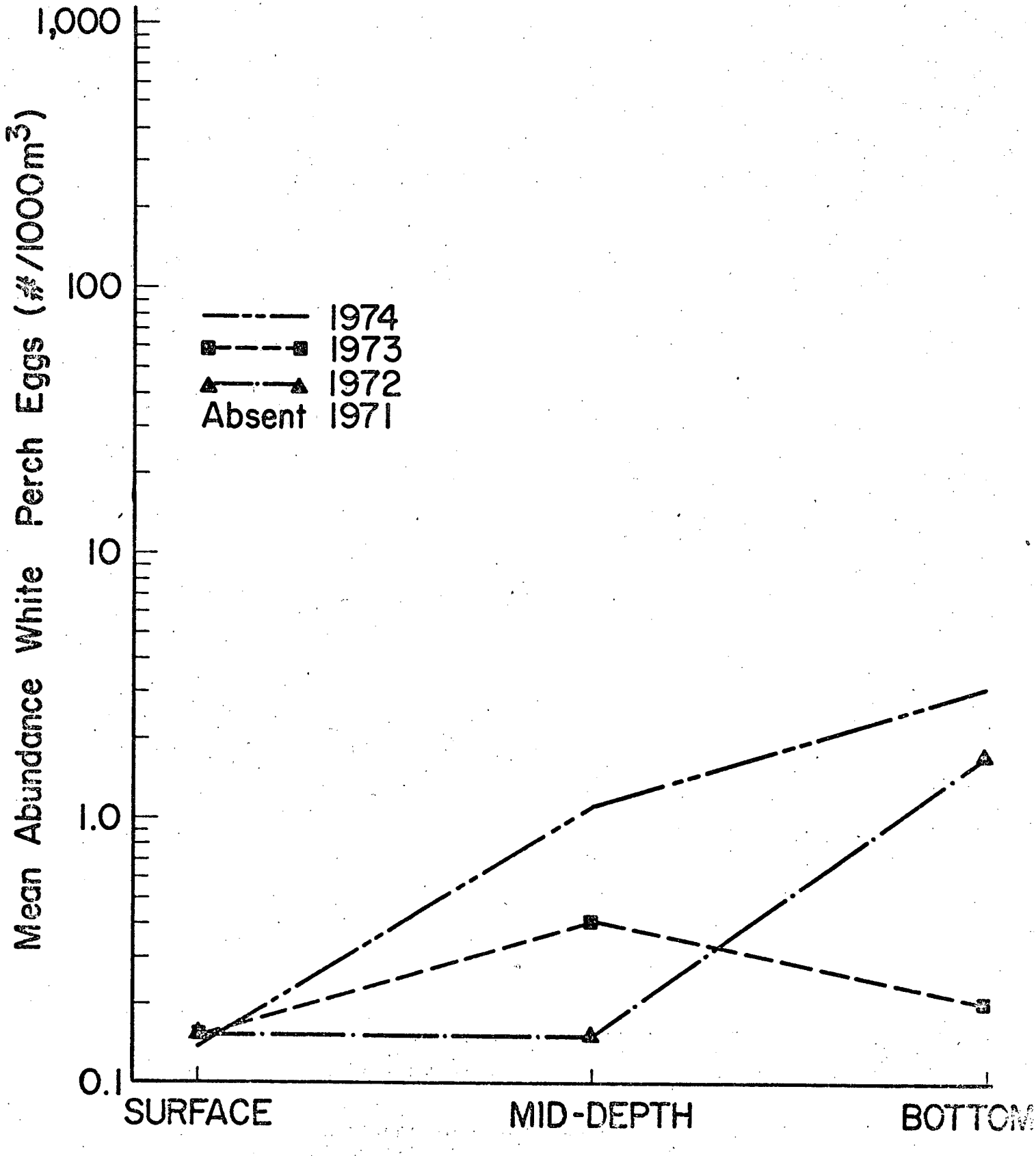


Figure 7-12. Mean abundance (day and night combined) of white perch eggs collected in river tows from 1971 to 1974.

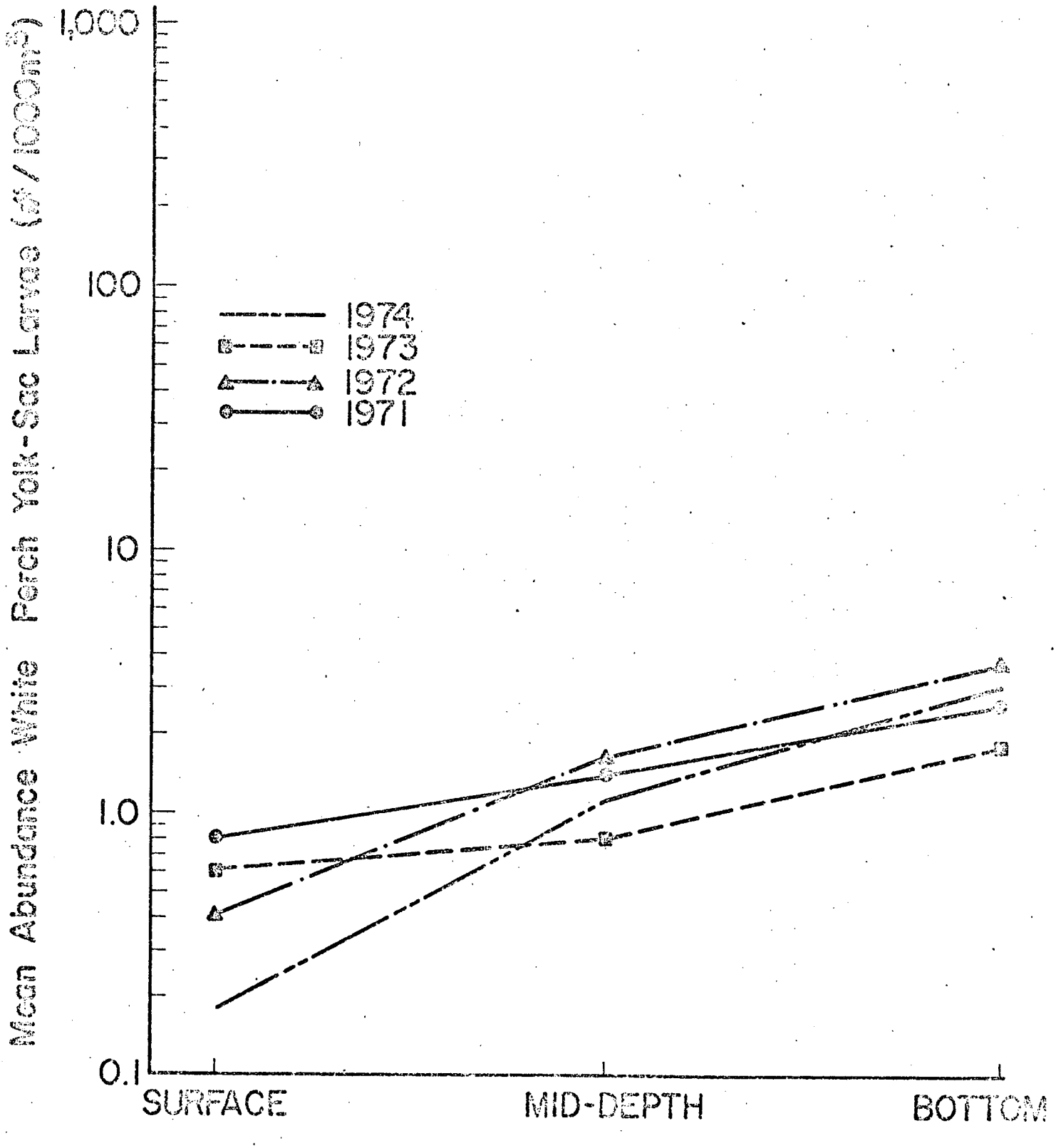


Figure 7-13. Mean abundance (day and night combined) of white perch yolk-sac larvae collected in river tows from 1971 to 1974.

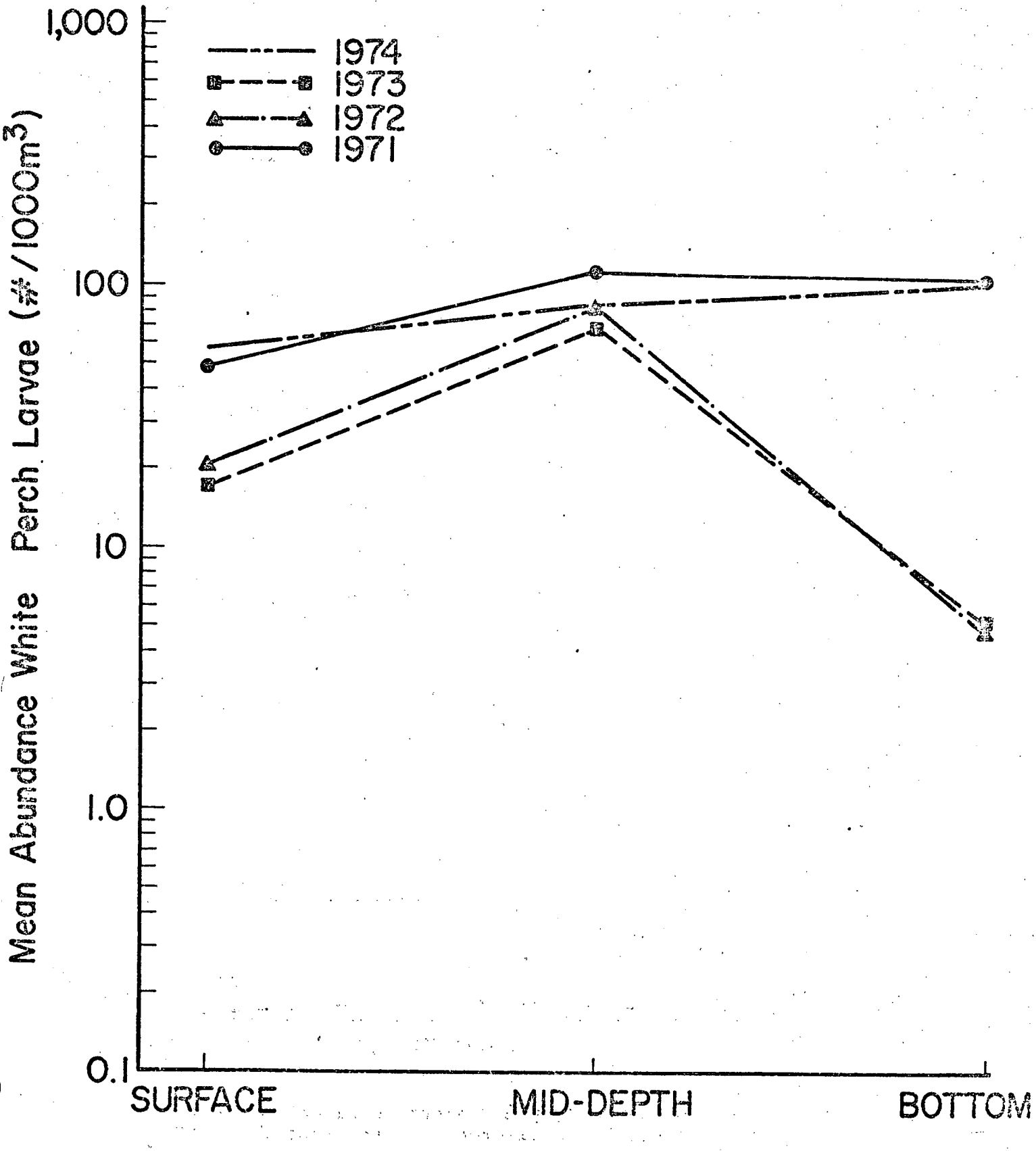


Figure 7-14. Mean abundance (day and night combined) of white perch larvae collected in river tows from 1971 to 1974.

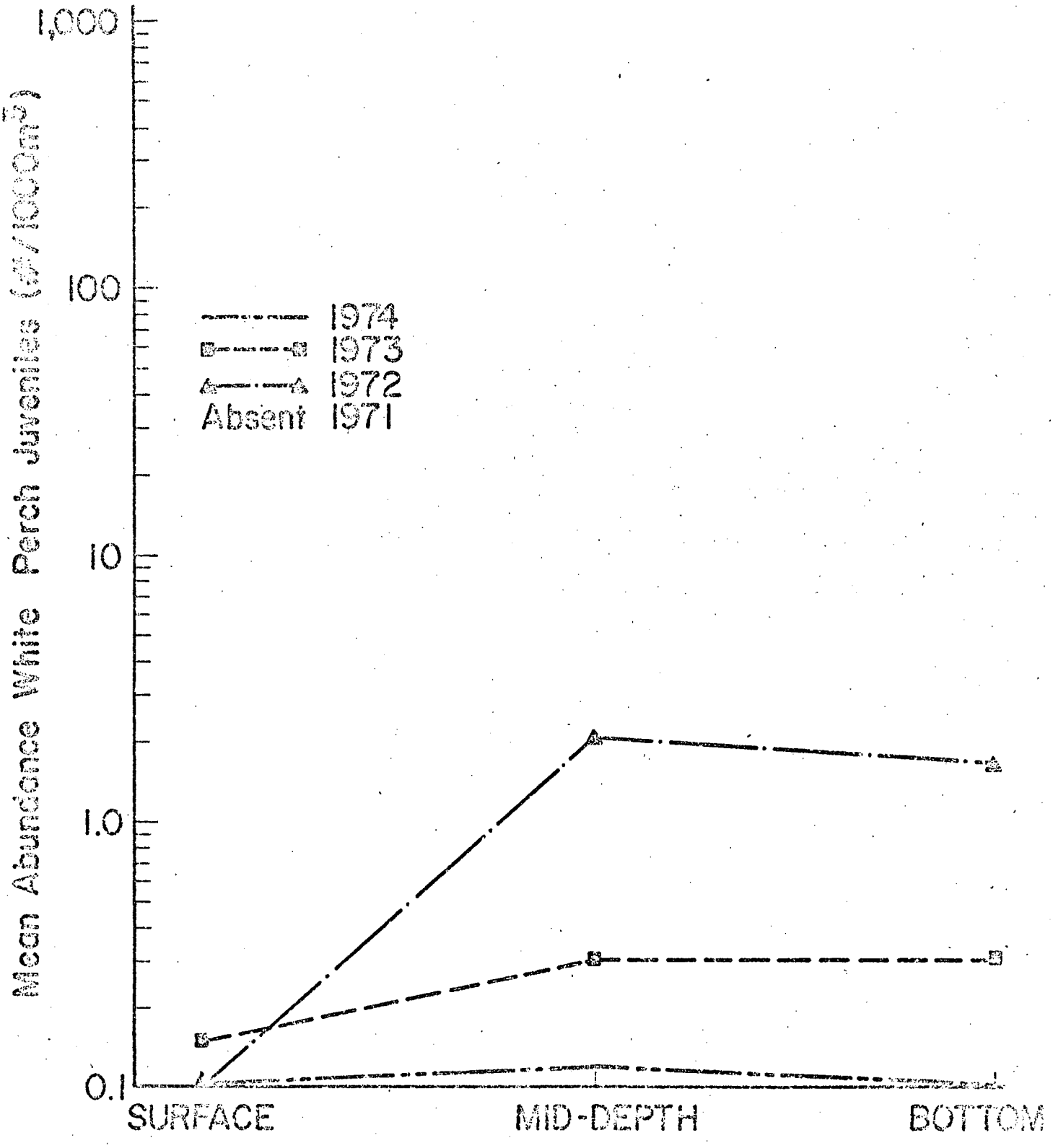


Figure 7-15. Mean abundance (day and night combined) of white perch juveniles collected in river tows from 1971 to 1974.

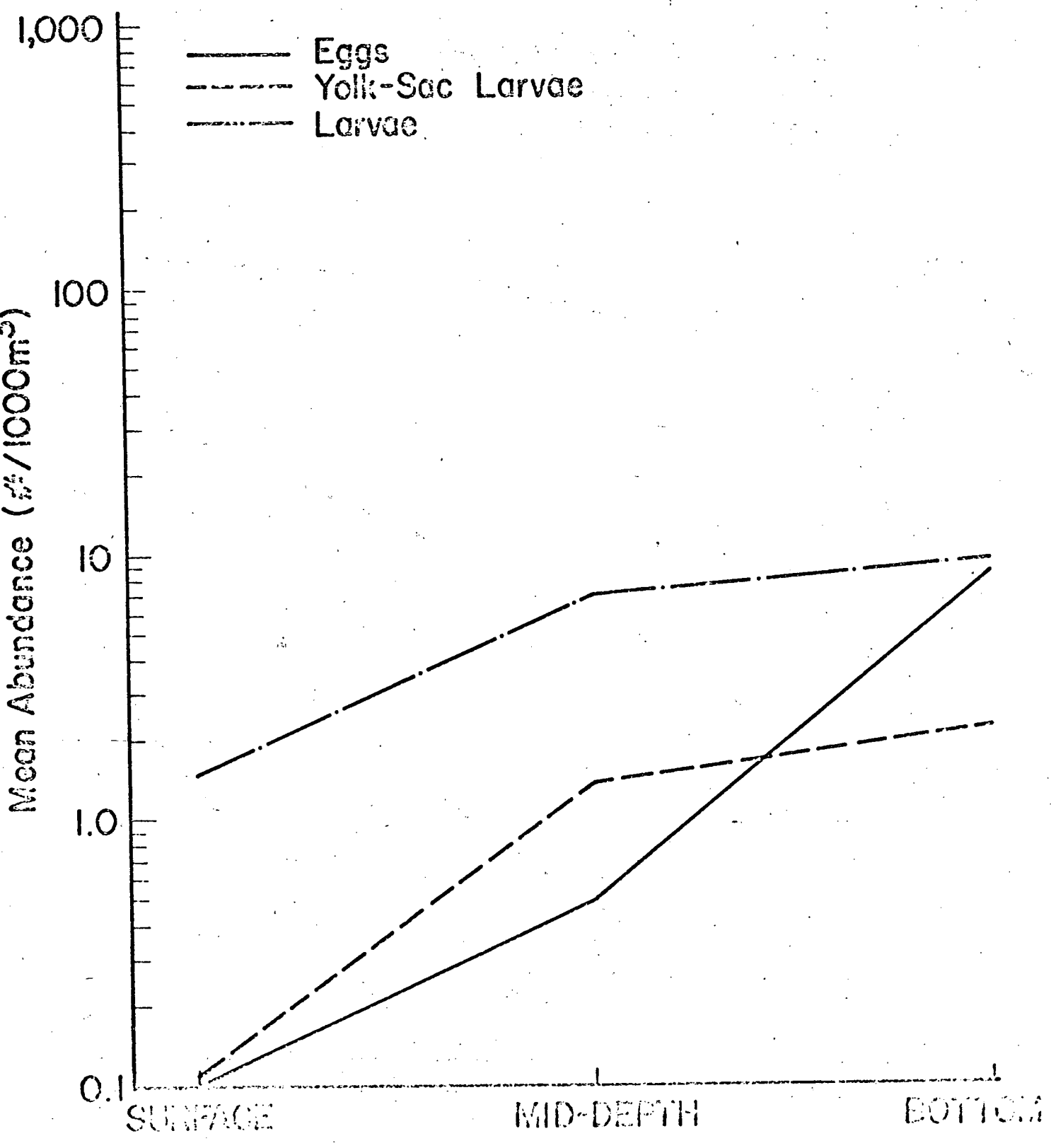


Figure 7-16. Daytime pattern of vertical distribution for white perch, 1974.

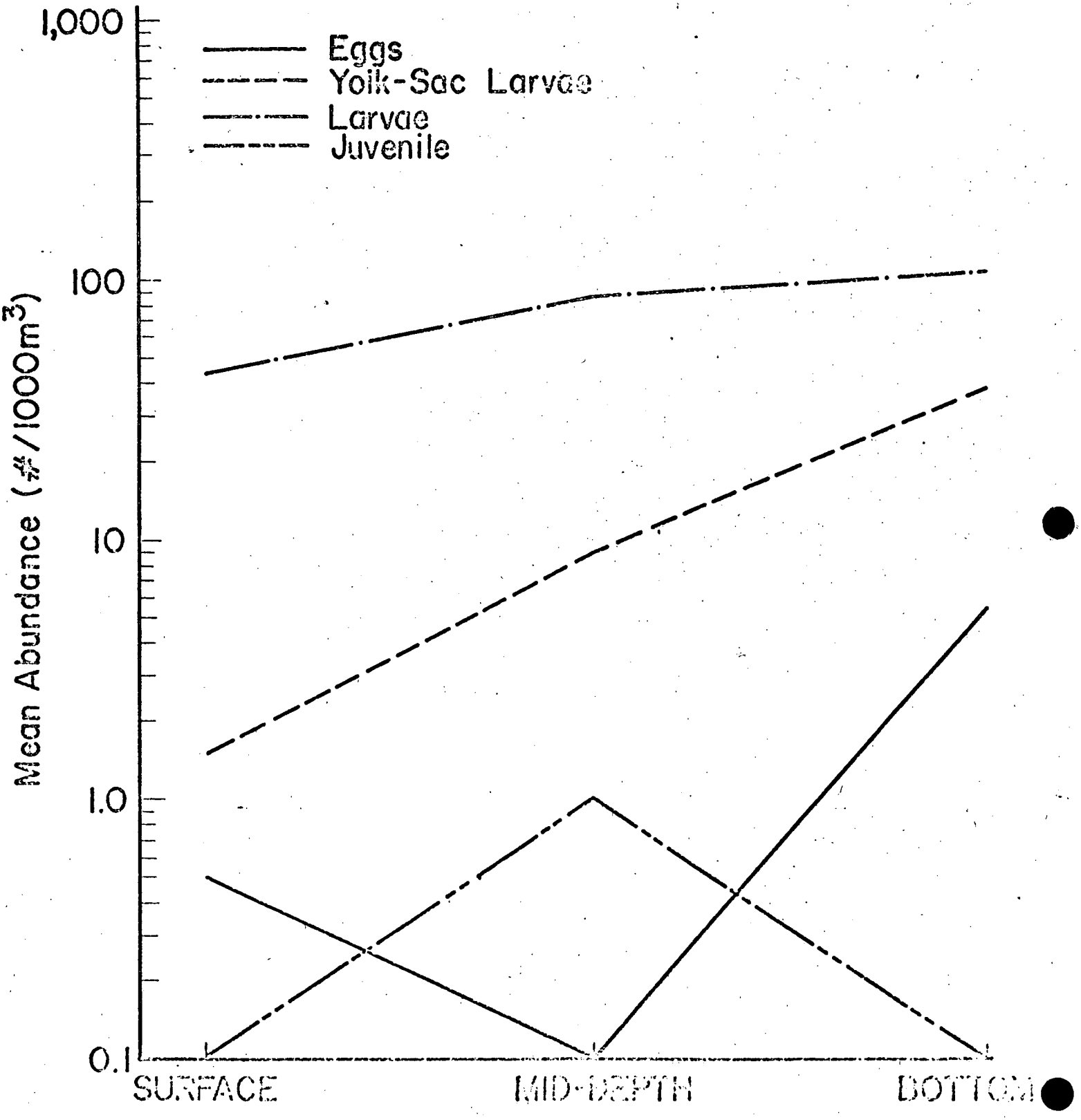


Figure 7-17. Nighttime pattern of vertical distribution for white perch, 1974.

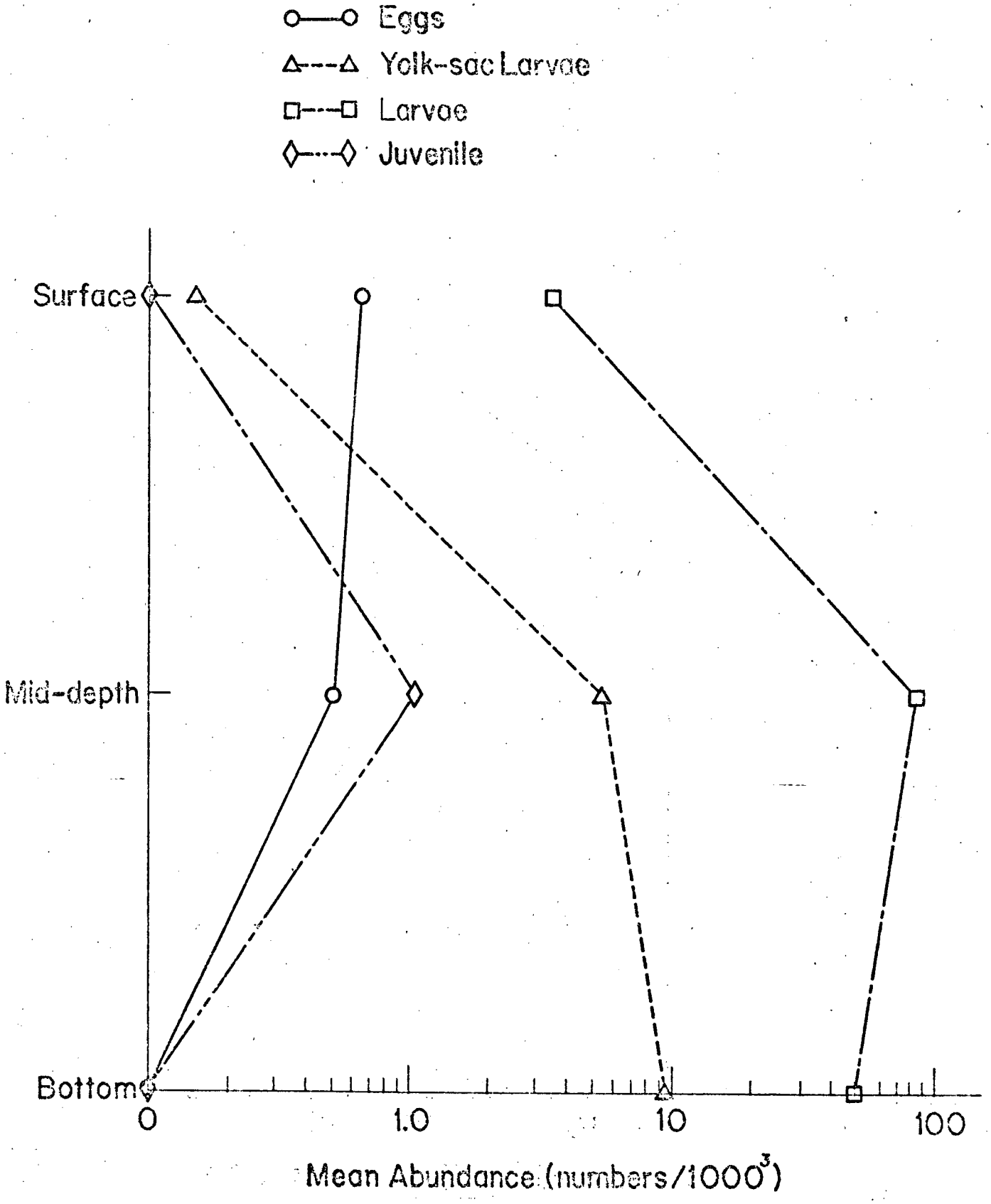


Figure 7-18. Daytime pattern of vertical distribution for clupeids, 1974.

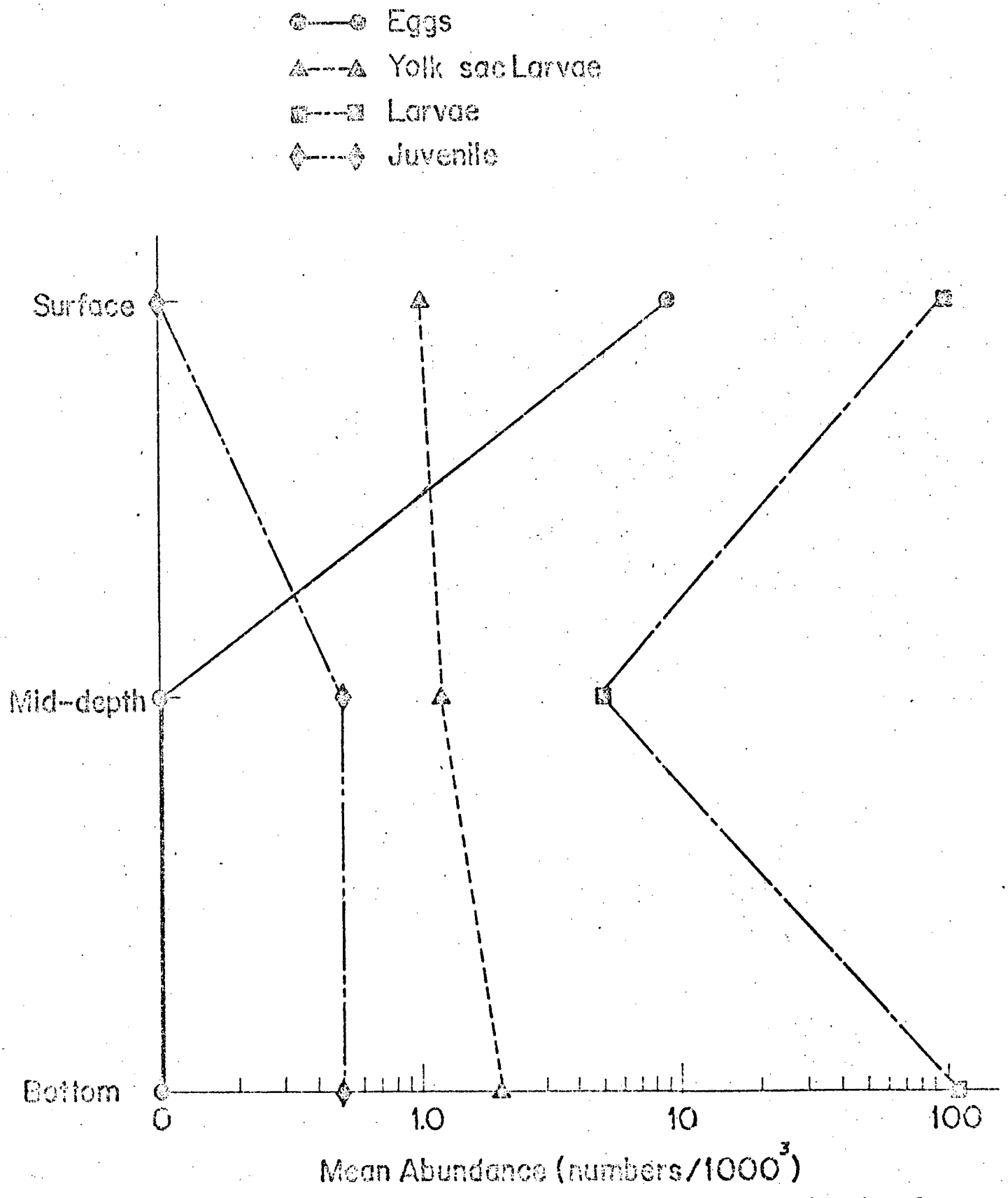


Figure 7-19. Nighttime pattern of vertical distribution for clupeids, 1974.

Anchovy eggs, yolk-sac larvae and juveniles were more abundant near the bottom than at the surface during the day. Anchovy larvae were distributed uniformly within the water column, seeming not to prefer any one depth. During the night the same general pattern was observed as for the day, but with an increase in the numbers of juveniles towards the surface (Figures 7-20 and 7-21). This distribution resembles that observed in previous years.

Analysis of variance was applied to the striped bass abundance data for eight stations in the Hudson River. Separate analyses were done for day and night samples and for each life stage. The factors included in these ANOVA's are station (eight levels, A to G and I), depth (three levels, surface, middle and bottom) and date (varies with life stage). Depth is considered nested within stations and date is crossed with stations (Tables 7-3 to 7-14). Wherever the ANOVA resulted in a significant difference among stations or depth, a Scheffe test ($\alpha \leq 0.10$) was done to find the difference.

There were significant differences in abundance among dates for the daytime analyses of eggs, yolk-sac larvae and larvae (Tables 7-9 to 7-11), but there were no differences among stations. Only larvae showed a significant difference with depth; they were much more abundant in mid and bottom samples than in surface samples (See also Table 7-4). In no case was there interaction between station and date. There were insufficient numbers of striped bass juveniles caught in our samples to perform a valid ANOVA.

Observed differences in abundance among dates for the different life stages of striped bass are not unexpected. As one life stage

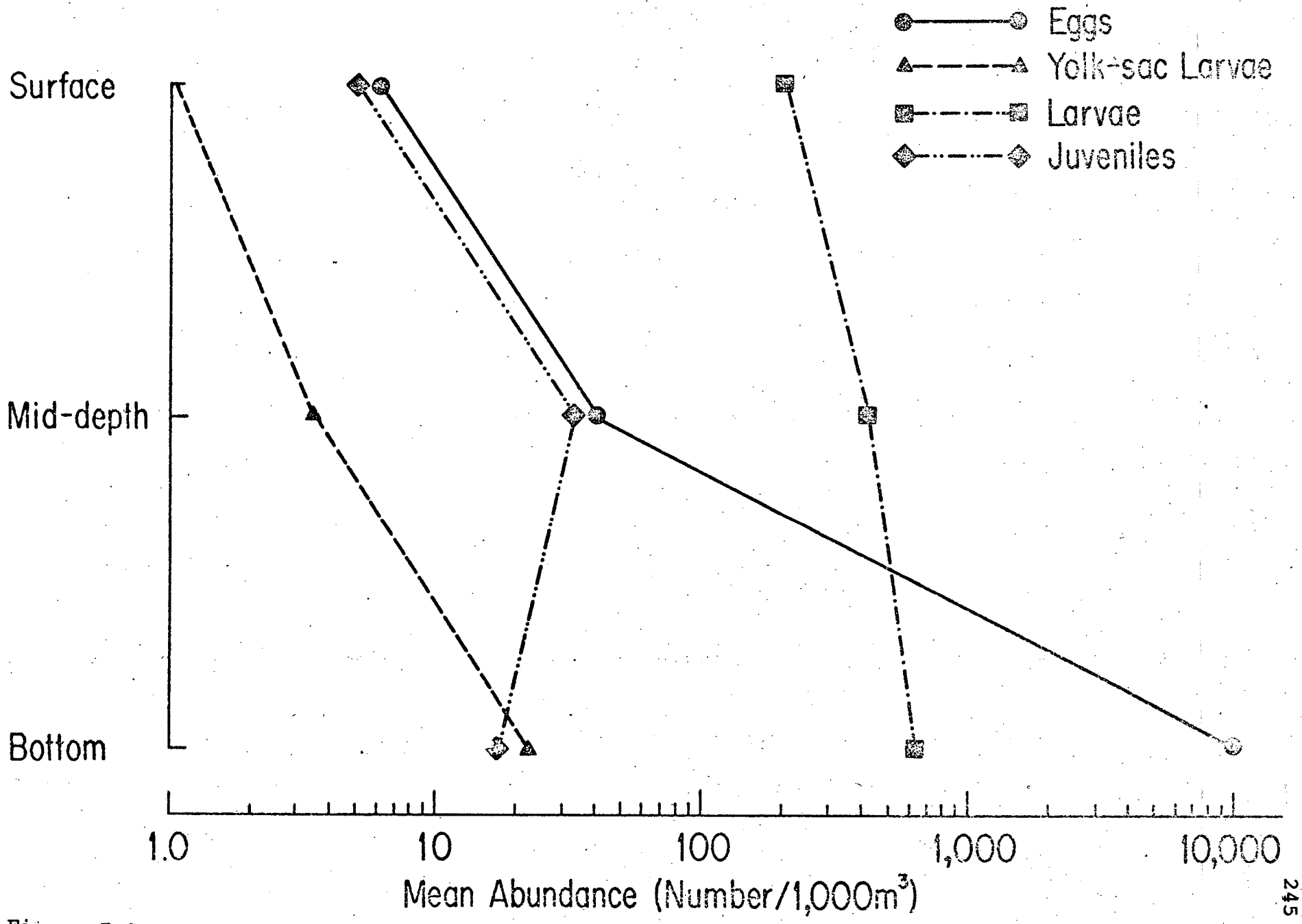


Figure 7-20. Daytime pattern of vertical distribution for anchovy, 1974.

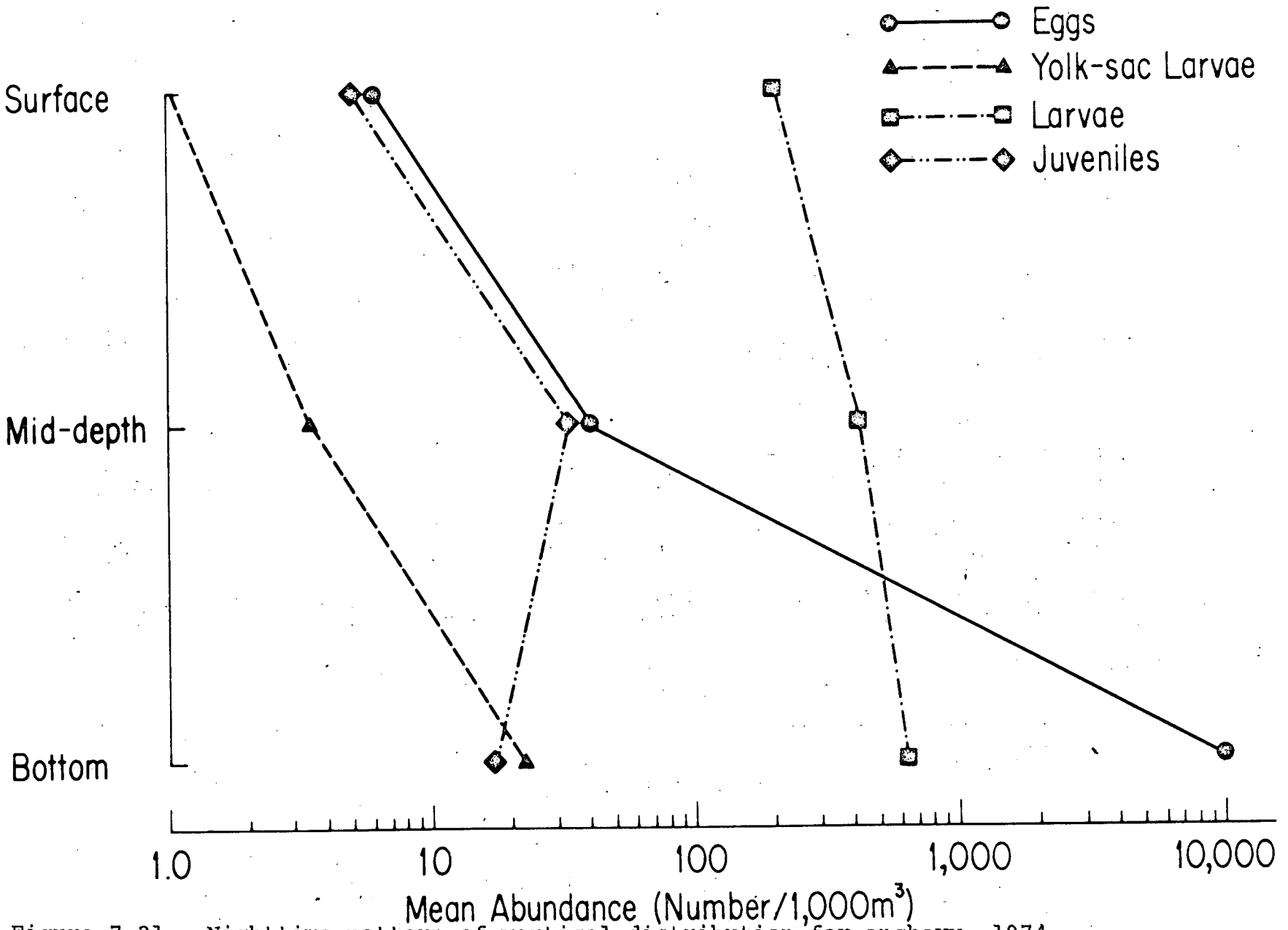


Figure 7-21. Nighttime pattern of vertical distribution for anchovy, 1974.

Table 7-3. Day and night striped bass abundance in the Hudson River by station, 1974. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n = number of samples).

Collections	Stations A	B	C	D	E	F	G	I
Day								
Eggs 5/7-6/11	128±303 n=18	64±332 n=15	143±312 n=17	123±303 n=18	359±303 n=18	264±303 n=18	30±303 n=18	13±643 n=4
Yolk-sac larvae 5/7-6/25	68± 53 n=24	32± 56 n=21	53± 54 n=23	40± 53 n=24	65± 53 n=24	67± 53 n=24	22± 53 n=24	40±105 n=6
Larvae 5/7-7/9	209±102 n=30	67±108 n=27	98±104 n=29	53±102 n=30	30±102 n=30	166±102 n=30	28±102 n=30	104±198 n=8
Juveniles 6/25-7/2	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6
Night								
Eggs 5/8-6/13	32±37 n=15	11± 37 n=15	11± 37 n=15	29± 37 n=15	53± 34 n=18	0± 37 n=15	0± 34 n=18	n=0
Yolk-sac larvae 5/8-6/13	48±32 n=15	43± 32 n=15	60± 32 n=15	33± 32 n=15	36± 29 n=18	35± 32 n=15	18± 29 n=18	n=0
Larvae 5/16-7/9	125±60 n=23	200± 60 n=23	121± 60 n=23	127± 60 n=23	136± 56 n=27	93± 62 n=23	29± 56 n=27	n=0
Juveniles 6/13, 9/17	0± 0 n=6	1± 0 n=6	1± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	0± 0 n=6	n=0

Table 7-4. Day and night striped bass abundance in the Hudson River by depth, 1974. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n = number of samples).

Collections	Surface	Middle	Bottom
Day			
Eggs	21±201	92±203	341±192
5/7-6/11	n=41	n=40	n=45
Yolk-sac larvae	1± 35	52± 35	91± 33
5/7-6/25	n=55	n=54	n=61
Larvae	0± 67	120± 68	155± 64
5/7-7/19	n=69	n=68	n=77
Juveniles	0± 0	1± 0	0± 0
6/25-7/2	n=14	n=14	n=16
Night			
Eggs	3±24	2±24	55±24
5/8-6/13	n=37	n=37	n=37
Yolk-sac larvae	9±21	46±21	59±21
5/8-6/13	n=37	n=37	n=37
Larvae,	152±38	94±38	106±40
5/16-7/9	n=57	n=58	n=53
Juveniles	0±0	1±0	0±0
6/13, 9/17	n=14	n=14	n=14

Table 7-5. Differences in striped bass river abundance among stations in $\log_{10}(\text{catch}/m^3 + 1)$.

Collections	Day	Night
Eggs 5/7-6/11	none	none
Yolk-sac larvae 5/7-6/25	none	none
Larvae 5/7-7/9	none	B>G*
Juveniles ---------	----	----

*Letters refer to river sampling stations.

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

Collections	Day	Night
Eggs 5/7-6/11	none	bot>sur; bot>mid
Yolk-sac larvae 5/7-6/25	none	mid>sur; bot>sur
Larvae 5/7-7/9	mid>sur; bot>sur	none
Juveniles ---------	----	----

Table 7-7. Day abundance of striped bass in the Hudson River, 1974. Data are mean numbers collected per 1000 m^3 with 95% confidence intervals. (S. E. = Standard error; n = number of samples).

Collections	Mean	S.E.	n
Eggs 5/7-6/11	158	± 115	126
Yolk-sac larvae 5/7-6/25	49	± 20	170
Larvae 5/7-7/9	96	± 38	214
Juveniles 6/25-7/2	0	± 0	44

Table 7-8. Night abundance of striped bass in the Hudson River, 1974. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (S. E. = standard error; n = number of samples).

Collections	Mean	S.E.	n
Eggs 5/8-6/13	20	± 14	111
Yolk-sac larvae 5/8-6/13	38	± 12	111
Larvae 5/16-7/9	117	± 22	168
Juveniles 6/13, 9/17	0	± 0	42

Table 7-9. Analysis of variance for striped bass eggs collected during the day in the river in 1974. (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 for the test).

Source	DF	SS	MS	F
A	7	.0321	.0046	.4508
B/A	14	.1492	.0107	1.0482
C	5	.4533	.0907	8.9140*
A X C	32	.3124	.0098	.9600
Error	67	.6814	.0102	
Total	125	1.6284		

Table 7-10. Analysis of variance for striped bass yolk-sac larvae collected during the day in the river in 1974. (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 for the test).

Source	DF	SS	MS	F
A	7	.0048	.0007	.3983
B/A	14	.0372	.0027	1.5605
C	7	.0926	.0132	7.7613*
A X C	46	.0744	.0016	.9496
Error	95	.1619	.0017	
Total	169	.3709		

Table 7-11. Analysis of variance for striped bass larvae collected during the day in the river in 1974. (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 for the test).

Source	DF	SS	MS	F
A	7	.0542	.0077	1.8382
B/A	14	.1329	.0095	2.2544*
C	9	.3304	.0367	8.7171*
A X C	60	.2692	.0045	1.0652
Error	123	.5181	.0042	
Total	213			

Table 7-12. Analysis of variance for striped bass eggs collected during the night in the river in 1974. (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 for the test).

Source	DF	SS	MS	F
A	6	.0051	.0009	1.3099
B/A	14	.0178	.0013	1.9514*
C	5	.0071	.0014	2.1919
A X C	25	.0130	.0005	.0827
Error	60	.0390	.0006	
Total	110	.0820		

Table 7-13. Analysis of variance for striped bass yolk-sac larvae collected during the night in the river in 1974. (A = stations; B = sepths; 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 for the test).

Source	DF	SS	MS	F
A	6	.0022	.0004	.7188
B/A	14	.0142	.0010	1.9648*
C	4	.0301	.0075	14.6131
A X C	19	.0202	.0011	2.0627*
Error	67	.0345	.0005	
Total	110	.1011		

Table 7-14. Analysis of variance for striped bass larvae collected during the night in the river in 1974. (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 for the test).

Source	DF	SS	MS	F
A	6	.0418	.0070	3.4395*
B/A	14	.0351	.0025	1.2366
C	8	.4219	.0527	26.0438
A X C	43	.1560	.0036	1.7922
Error	96	.1944	.0020	
Total	167	.8492		

develops into the next, there will naturally occur a decrease in numbers of one life stage and an increase in numbers of the succeeding life stage (egg to yolk-sac larva to larva to juvenile) with time. The dates included in the analysis of eggs are from May 7 to June 11; for yolk-sac larvae from May 7 to June 11 plus June 18 and 25; for larvae, the same dates as for yolk-sac larvae plus July 2 and 9. Only two juveniles were found, one each on June 25 and July 2.

The analysis of night data showed a significant difference in abundance among stations for striped bass larvae (Tables 7-3 to 7-5 and 7-12 to 7-14). There were significant differences among depths for eggs and yolk-sac larvae (Table 7-6); abundance for the bottom samples was greater than the surface ones. There was insufficient data on striped bass juveniles to perform a valid ANOVA as only two were collected.

A "t" test (Natrella, 1963) was carried out to test for differences between mean day and mean night abundances for each life stage. Variability was unknown and assumed unequal. The results are shown in Table 7-15. Egg abundance was greater during the day than at night, while larval abundance was greater at night than during the day. There was no difference in yolk-sac larval or juvenile abundance for day or night samples (See also Tables 7-7 and 7-8). We are unable to explain these differences, since one would expect similar values at night as well as during the day, although the distribution with depth may vary. However, these data correlate well with previous data (NYU, 1973, 1974) and with Texas Instruments' 1974 river data (T. I., 1975).

Table 7-15. Differences in striped bass river abundance in $\log_{10}(\text{catch}/m^3 + 1)$ between day and night samples, 1974.

Eggs	Day > Night
Yolk-sac larvae	none
Larvae	Night > Day
Juveniles	Night

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. Basically, 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 Short-term Viability Assessments

7.2.1.1 Methods

Ichthyoplankton collected from Indian Point intakes (station I-1, I-2, II-2 and II-5), discharge canal (station D-1 and D-2) and discharge ports (DP-3 and DP-8) were used in estimating the abundance, viability and latent mortality of entrained ichthyoplankton. Our interest here is with the various life stages of striped bass only; life stages of other species found in the collection were classified, enumerated and catalogued, but their data are not considered in this discussion.

Samples were collected weekly from the first week in May through the second week in July; sampling prior to May and after July 15 was on a once-per-month schedule. A ΔT was present throughout the sampling regime.

Ichthyoplankton samples were collected using the sampling system and procedures described for macrozooplankton (Section 1 of this report and the preceeding section on macrozooplankton). Immediately after collection the samples were transported to the on-site laboratory and placed in a water table with flowing river water to await sorting.

Examination of samples to determine alive, stunned and dead fish and eggs was randomized by choosing lots. This procedure was instituted to avoid bias in viability results which may arise from picking samples in the same sequence each time, since the time following net capture may be a factor in survival. As a sample was picked for analysis, the contents of the sample were poured into a shallow glass dish backed with black tape, suspended in flowing river water, and sorted according to the following criteria:

Fish:

Live--swimming vigorously, no orientation problems, behavior normal.

Stunned--swimming erratically, struggling, swimming on side, some twitching but mobile.

Dead--no vital life signs, no body or opercular movements, no response to gentle probing.

Eggs:

Live--chorion complete and clear, oil globule and/or embryo intact.

Dead--chorion ruptured and/or opaque, oil globule and/or embryo ruptured.

One person was assigned the final responsibility of determining the condition of fish or eggs if such a question arose. Following the immediate viability examination, alive eggs and alive and stunned larvae were removed and maintained in the laboratory to be examined for latent mortality (to be described later). The time

required to sort a given set of samples varied depending upon the numbers of stations operational and the number of fish eggs and larvae collected. The sorting time per sample varied from as little as 15 minutes up to 2 hours.

Data on the proportion of individuals in each group were examined by analysis of variance (ANOVA) using mathematical procedures described in Sokal and Rohlf (1969) and Winer (1962). Raw data were first converted to natural logarithmic values to make them suitable for ANOVA. The results of the analyses were then subjected to the Student-Newman-Kuels procedure ($\alpha = 0.05$) to identify any significant differences in sample means within a given series of samples. For each type of analysis, our ultimate concern was the difference between the condition of organisms sampled in the intake and those sampled in the discharge canal. However, in the interest of maximum statistical sensitivity, our first step was to test for significant differences between similar stations. If there were no statistical differences for these samples, the data from those stations were combined to provide a larger body of data and, correspondingly increased sensitivity, for subsequent comparisons.

Abundance values (no./1000 m^3 of water filtered) were used only to determine whether the quantities of each life stage entering the plant at the various intake stations were the same. These same data will be used again for comparison of in-plant abundance with abundance in the river.

7.2.1.2 Results and Discussion

The abundances of striped bass eggs, yolk-sac larvae, larvae and juveniles collected from the entrainment stations were tested to determine whether significant differences existed among stations (Tables 7-16 and 7-17). The number of striped bass eggs collected was greater at station II-2 than station I-1 or I-2, but was nearly equal to their sum. The explanation for this difference may lie in the construction of the intakes themselves. At Unit 1, one circulator pump is divided between two intake forebays (I-1 and I-2), while at Unit 2, a circulator pump having a pumping capacity identical to that in Unit 1 operates through one intake forebay. In essence, samples collected at either I-1 or I-2 approximate half that of Unit 2; egg data for II-2 were considered separately, while those for I-1 and I-2 were lumped. As there existed no significant differences among stations for yolk-sac larvae, larvae or juveniles, intake survival data used in further testing was lumped for all stations (Tables 7-16, 7-17 and 7-18). Significant variations shown in the tables were determined from geometric means, although only the arithmetic values are listed. The numbers of samples and/or organisms collected at II-5 and at the discharge-port stations (DP-3 and DP-8) were insufficient to obtain meaningful conclusions (Table 7-18). Consequently, comparisons involving these stations are not included in this report.

Because the results of contingency table analysis revealed significant differences in the relative mortality of striped bass eggs, all sets of data were tested by *a posteriori* techniques to determine precisely which stations differed from others, and in what manner (Table 7-16).

Table 7-16. Significant differences in initial survival for four life stages of striped bass among Indian Point plant samples, (I-1, I-2 = Unit 1 intake samples; II-2 = Unit 2 intake samples; D-1, D-2 = discharge-canal samples; DP-3, DP-8 = Discharge-port samples).

Life Stage	Dead/Total caught	Stunned/Total caught	Dead/Stunned
Eggs*	(I-1, I-2) > II-2 D-1 > (I-1, I-2) D-2 > (I-1, I-2) D-1 > D-2 D-2 > II-2	------	-----
Yolk-sac larvae	None	None	D-2 > Intakes
Larvae	D-1 > Intakes D-2 > Intakes DP-3 > Intakes DP-8 > Intakes	None	D-1 > Intakes D-2 > Intakes DP-3 > Intakes DP-8 > Intakes
Juveniles	None	D-1 > Intakes	None

*Eggs are not classified as stunned.

Table 7-17. Initial viability of striped bass with 95% confidence intervals. Data are mean percentages for sampling stations. (I-1, I-2 = Unit 1 intake; II-2 = Unit 2 intake; D-1, D-2 = Discharge-canal samples, DP-3, DP-8 = Discharge-port samples; DP = Average discharge-port samples; n = number of samples).

Life stage and Station	% Alive	% Stunned	% Dead	n
Eggs				
I-1, I-2	39±9	-----	61±9	86
II-2	55±11	-----	46±11	49
D-1	19±13	-----	81±13	25
D-2	30±14	-----	70±14	32
DP	7±17	-----	93±17	5
Yolk-sac larvae				
Intakes	8±5	32±9	59±9	93
D-1	9±20	18±27	73±31	11
D-2	0±0	0±0	100±0	17
DP	0±0	0±0	100±0	1
Larvae				
Intakes	26±6	31±6	44±7	149
D-1	10±6	10±5	79±8	74
D-2	9±9	11±9	80±12	39
DP-3	0±0	0±0	100±0	12
DP-8	0±0	0±0	100±0	4
Juveniles				
Intakes	100±0	0±0	0±0	18
D-1	21±25	63±30	17±20	12
D-2	75±69	25±69	0±0	4
DP-3	33±106	33±106	33±106	3

Table 7-18. Initial abundance of live, stunned and dead striped bass eggs, yolk-sac larvae, larvae and juveniles collected during plant entrainment sampling in 1974. (I = Intake station average; I-1, I-2 = Unit 1 intakes; II-2 = Unit 2 intake; D-1, D-2 = Discharge-canal stations; DP-3, DP-8 = Discharge-port stations; DP = Discharge-port station average.

	Eggs		
	Alive	Dead	Total
I-1, I-2	204	260	464
II-2	294	210	504
D-1	30	79	109
D-2	29	89	118
DP	1	7	8
Total	561	646	1207

	Yolk-sac larvae			
	Alive	Stunned	Dead	Total
I	15	54	127	196
D-1	0	2	14	16
D-2	0	0	23	23
DP	0	0	1	1
Total	15	56	163	234

	Larvae			
	Alive	Stunned	Dead	Total
I	141	243	270	654
D-1	22	34	255	311
D-2	3	6	83	92
DP-3	0	0	37	37
DP-8	0	0	20	20
Total	170	283	656	1109

	Juveniles			
	Alive	Stunned	Dead	Total
I	25	0	0	25
D-1	3	9	3	15
D-2	3	1	0	4
DP-3	1	1	1	3
Total	31	11	4	46

The ratio of dead eggs to the total number of eggs collected (i.e., instantaneous mortality) in the intakes was between o.42 and 0.56. No attempt was made to identify "stunned" eggs as there was no simple criterion for identifying a stunned egg. This proportion of dead eggs to the total egg count at the intakes is suggestive of the magnitude of natural mortality of eggs in nature plus the effect of net capture on eggs. Using this number as a baseline estimate, the ratio of dead to total eggs among intakes and other stations was tested for differences. The percentage of dead eggs at station D-1 was approximately 16% greater than I-1 and I-2, and 30% greater than at II-2. Further downstream in the discharge canal, at D-2 there existed a 19% difference in mortality as compared to I-1 and I-2, and a 33% increase in mortality as compared to II-2; absolute differences between station means with 95% confidence intervals are shown in Table 7-19. In both cases the differences between intake and D-2 were greater than between the intake and D-1.

Relatively few yolk-sac larvae were collected at the Indian Point station; yolk-sac larvae catch was only 19% of the egg catch, 21% of the larvae catch and 9% of the total catch for all striped bass life stages (Table 7-18). The proportions of dead yolk-sac larvae to to the total yolk-sac larvae catch were 65, 88 and 100% respectively, at the intakes, D-1 and D-2. The ratio of stunned yolk-sac larvae to their total was 28% at the intakes and 13% at D-1; there were no stunned yolk-sac larvae collected at D-2. As was evident in the eggs, yolk-sac larval mortality increased from

Table 7-19. Comparisons of the initial viability of striped bass samples collected during plant entrainment, 1974. The station means being compared are expressed within brackets between the upper and lower limits of the confidence interval for each comparison at the 95% confidence interval. (I-1, I-2 = Unit 1 intakes; II-2 = Unit 2 intake; D-1, D-2 = Discharge-canal stations; DP = Discharge-port stations; asterisk (*) indicates a significant difference between means).

Comparison					Difference
Eggs, percent alive[1]					
2.6	<	{(I-1, I-2) - II-2}	<	29.6 *	16.1
4.5	<	{(I-1, I-2) - D-1}	<	35.0 *	19.7
-7.5	<	{(I-1, I-2) - D-2}	<	25.4	8.9
14.9	<	{(I-1, I-2) - DP}	<	50.2 *	32.5
19.4	<	{II-2 - D-1}	<	52.5 *	35.8
7.5	<	{II-2 - D-2}	<	42.5 *	25.0
30.3	<	{II-2 - DP }	<	67.0 *	48.6
-8.0	<	{D-1 -D-2}	<	29.6	10.8
-6.6	<	{D-1 - DP}	<	32.2	12.8
3.5	<	{D-2 -DP }	<	43.8 *	23.6

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

Table 7-19. (Cont.)

Comparison			Difference	
Yolk-sac larvae, percent alive				
-19.4 <	{I - D-1}	<	21.7	1.2
2.9 <	{I - D-2}	<	12.9 *	7.9
3.0 <	{I - DP}	<	12.9 *	7.9
-11.2 <	{D-1 - D-2}	<	29.3	9.1
-11.2 <	{D-1 - DP}	<	29.3	9.1
0.0 <	{D-2 -DP}	<	0.0	0.0
Yolk-sac larvae, percent stunned				
-14.0 <	{I - D-1}	<	42.1	14.1
23.3 <	{I - D-2}	<	41.2 *	32.3
23.3 <	{I - DP }	<	41.2 *	32.3
-9.0 <	{D-1 - D-2}	<	45.3	18.2
-9.0 <	{D-1 - DP}	<	45.3	18.2
0.0 <	{D-2 - DP}	<	0.0	0.0
Yolk-sac larvae, percent dead				
-18.1 <	{I - D-1}	<	46.1	13.9
31.8 <	{I - D-2}	<	50.7 *	41.3
31.3 <	{I - DP }	<	50.7 *	41.3
-4.1 <	{D-1 - D-2}	<	58.6	27.3
-4.1 <	{D-1 - DP}	<	58.6	27.3
0.0 <	{D-2 - DP}	<	0.0	0.0

Table 7-19. (Cont.)

Comparison			Difference		
Larvae, percent alive					
7.6	< {I - D-1}	<	23.8 *		15.7
6.1	< {I - D-2}	<	27.5 *		16.8
19.8	< {I - DP-3}	<	31.7 *		25.7
19.8	< {I - DP-8}	<	31.7 *		25.7
-9.4	< {D-1 - D-2}	<	11.7		1.1
4.4	< {D-1 - DP-3}	<	15.8 *		10.1
4.4	< {D-1 - DP-8}	<	15.8 *		10.1
-0.02	< {D-2 - DP-3}	<	18.0		9.0
-0.02	< {D-2 - DP-8}	<	18.0		9.0
0.0	< {DP-3 - DP-8}	<	0.0		0.0
Larvae, percent stunned					
12.2	< {I - D-1}	<	28.1 *		20.2
8.7	< {I - D-2}	<	31.2 *		20.0
24.5	< {I - DP-3}	<	36.8 *		30.7
24.5	< {I - DP-8}	<	36.8 *		30.7
-10.5	< {D-1 - D-2}	<	10.9		0.2
2.7	< {D-1 - DP-3}	<	18.3 *		10.5
2.7	< {D-1 - DP-8}	<	18.3 *		10.5
1.2	< {D-2 - DP-3}	<	20.1 *		10.7
1.2	< {D-2 - DP-8}	<	20.1 *		10.7
0.0	< {DP-3 - DP-8}	<	0.0		0.0
Larvae, percent dead					
25.8	< {I - D-1}	<	45.9 *		35.8
22.8	< {I - D-2}	<	50.7 *		36.7
36.8	< {I - DP-3}	<	50.3 *		56.4
36.8	< {I - DP-8}	<	50.3 *		56.4
-13.4	< {D-1 - D-2}	<	15.2		0.9
71.8	< {D-1 - DP-3}	<	87.1 *		20.6
71.8	< {D-1 - DP-8}	<	87.1 *		20.6
68.1	< {D-2 - DP-3}	<	92.5 *		19.7
68.1	< {D-2 - DP-8}	<	92.5 *		19.7
0.0	< {DP-3 - DP-8}	<	0.0		0.0

intakes to station D-2 in the discharge canal. The numbers of dead yolk-sac larvae at D-1 were 23% greater than at the intakes; at D-2, dead yolk-sac larvae were 35% greater than at the intakes (See Table 7-19 for absolute differences between station means at the 95% confidence interval). Stunned yolk-sac larvae, on the other hand, decreased in numbers from intakes to D-2 (28% at the intakes, 13% at D-1 and 0 at D-2). If we accept the initial idea that the difference in the numbers of dead or stunned individuals between the discharge canal stations 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 there was no observable plant effect upon the numbers of stunned yolk-sac larvae as the number of stunned individuals at the discharge stations was below that at the intakes.

Approximately 22% of the striped bass larvae collected at the Indian Point intakes were alive at capture, 37% were stunned and 41% were dead. Among pre-juvenile stages sampled, larvae appear more resistant to the effects of net capture than either eggs (≃49% dead at collection) or yolk-sac larvae (≃65% dead at collection). Mortality of larvae increased across the plant; there were 41% more dead and an insignificant percentage (13%) more of stunned larvae at D-1 than at the intake stations. There was little change in percentage dead (8%) and stunned (13%) between D-1 and D-2 (See Table 7-19 for absolute differences between station means for viability at the 95% confidence interval). The percentage of stunned individuals at the discharge stations was

less than that at the intakes or that expected as a result of net collection.

For all life stages, the proportion dead increased with distance downstream in the cooling water flow from intake stations through station D-2. This indicates that the time/temperature exposure of life stages of striped bass at the Indian Point plant is cumulative and that the additional time of exposure to warm water between D-1 and D-2 increases the probability of death. A significant increase in the proportion of stunned and dead larvae was noted between D-2 and DP stations, but so few organisms were collected at DP-3 and DP-8 that conclusions must be treated with care.

If the following factors for natural mortality and collection trauma are applied (49% for eggs, 65% for yolk-sac larvae and 41% for larvae), to discharge-canal data for cross-plant viability assessments, values attributable to plant kill of 23 to 26% for eggs, 23 to 35% for yolk-sac larvae and 41 to 49% for larvae are obtained. This assumes that the collection trauma, based on current flow is identical for the intake and discharge stations. This is not entirely true as the current flow in the discharge canal may be one to two times faster than that at the intakes.

7.2.2 Latent Effects

The purpose of the latent-effects experiments was to determine if there were any difference in the hatching success between live striped bass eggs collected from the intakes and those from the discharge canal at the Indian Point power plant, and also to evaluate

whether live and stunned larval and juvenile striped bass collected from the discharge canal suffered greater rates of latent mortality than larvae and juveniles sampled from the intakes.

7.2.2.1 Methods

Living eggs and live and stunned larvae and juveniles from intake and discharge samples (described earlier) were held for at least 72 hours after collection to determine latent mortality. These specimens were collected from the first week in May through the second week in July, and were identified initially during sorting. The condition of each organism (live, stunned, dead) was verified. Alive and stunned organisms were transferred to 700-ml glass jars, each of which was marked with the date, station, time and depth of collection. The glass containers were aerated and kept at ambient river temperature throughout the holding period. Each day the number of live and dead organisms was recorded; dead organisms were removed and preserved in 10% formalin for identification at a later time. At the end of the 72-hour holding period, all remaining living specimens were preserved for identification.

7.2.2.2 Results and Discussion

The number of live eggs collected from intake and discharge canal samples and the numbers of these which hatched are shown in Table 7-20. The number hatched from the discharge canal samples was 16% less than that for the intake samples. However, 2 X 2 contingency table analysis ($\alpha = 0.05$) indicated no significant difference in hatching for samples from these two stations; hatching success was approximately 50% for both.

Table 7-20. 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 eggs hatched
Intake	297	190	63.9
Discharge	61	29	47.5

The numbers of striped bass larvae and juveniles that survived the 3-day holding period after collection, as well as their initial classification as to condition, are given in Table 7-21. Survival curves for striped bass larvae collected from the intake and discharge canal and initially classified as live are shown in Figure 7-22. Approximately 50% of the larvae so classified had died after 24 hours. The percentage increased to 52 and 65% in the discharge canal samples and intake samples, respectively, after 72 hours. Two by two contingency table analysis showed no significant difference in the survival rates of these two groups after 24, 48 or 72 hours ($\alpha = 0.05$). Survival curves for striped bass larvae collected from the intake and discharge canal and initially classified as stunned are shown in Figure 7-23; most of these died during the first 24 hours of the holding period, approximately 70% for those from the intake and 90% for the discharge canal samples. These figures increased to greater than 95% for both groups after 72 hours.

Survival curves for striped bass juveniles collected from intake and discharge canal stations and initially classified as live are shown in Figure 7-24; there was no stunned category. Approximately 15% of the juveniles examined died after 72 hours. Two by two contingency table analysis of these data showed no significant difference between the survival of these two groups after 24, 48 and 72 hours.

These observations suggest that for the three different life stages of striped bass examined (egg, larva and juvenile) stunned

Table 7-21. Survival of entrained striped bass larvae and juveniles after a 3-day holding period.

Life stage	Source	Initial condition	Initial number	Number surviving	Percent survival
Larvae	Intake	alive	152	53	34.8
	Discharge	alive	23	11	47.8
Larvae	Intake	stunned	234	10	4.2
	Discharge	stunned	39	1	2.5
Juveniles	Intake	alive	24	21	87.5
	Discharge	alive	7	6	85.7

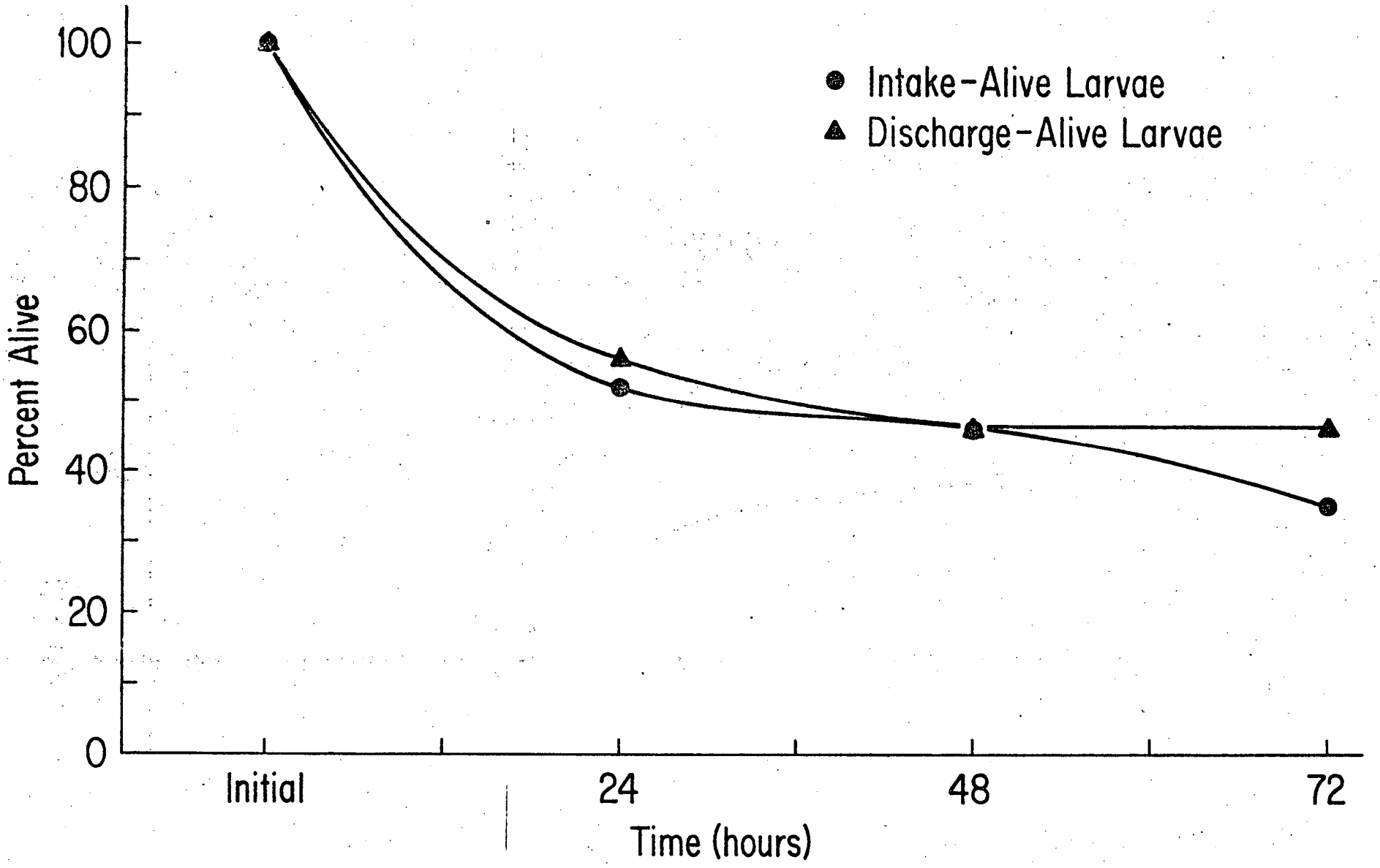


Figure 7-22. Survival curves for live striped bass larvae collected at Indian Point intake and discharge stations in 1974 and held for 72 hours at ambient river temperature.

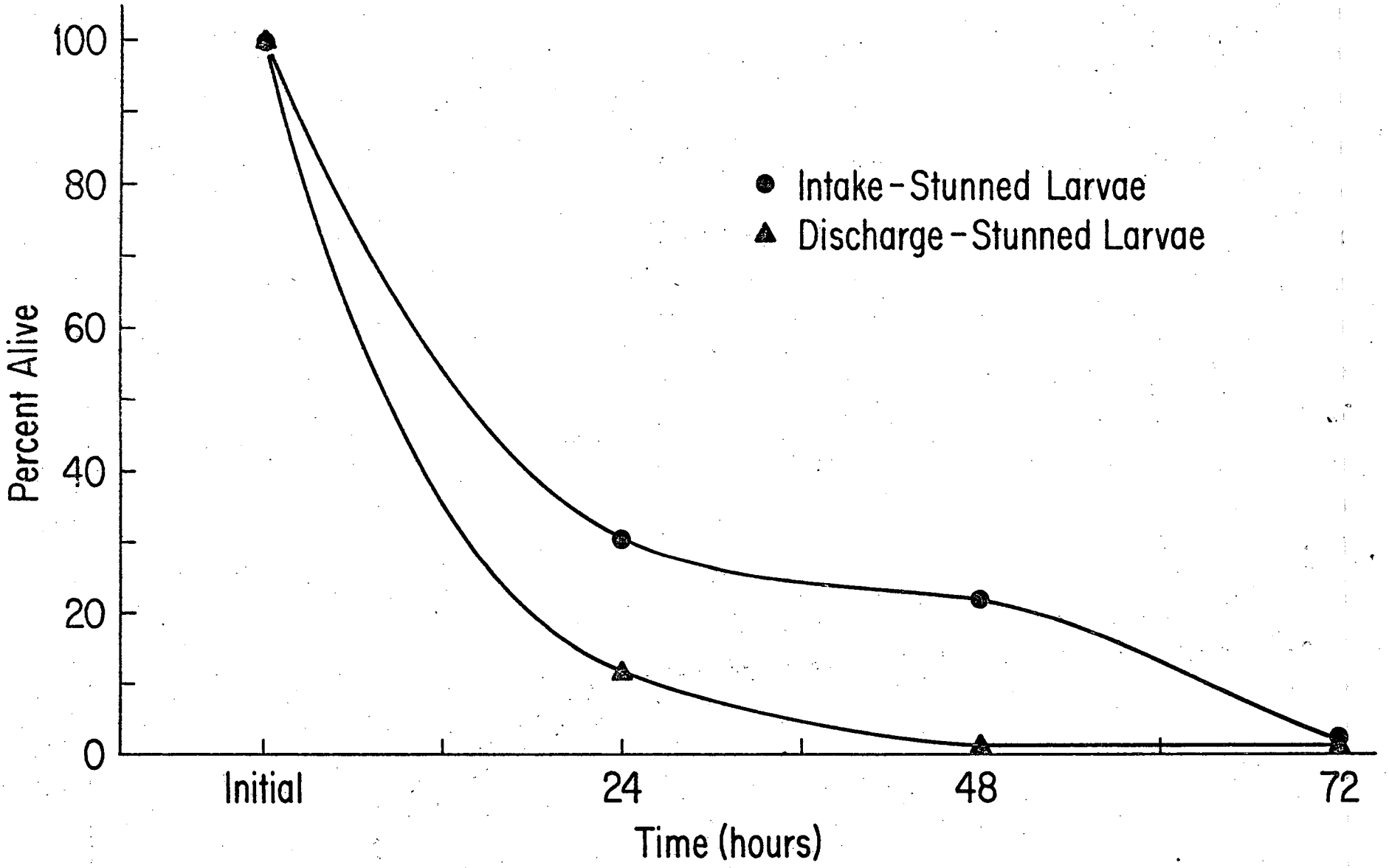


Figure 7-23. Survival curves for stunned striped bass larvae collected at Indian Point intake and discharge stations in 1974 and held for 72 hours at ambient river temperature.

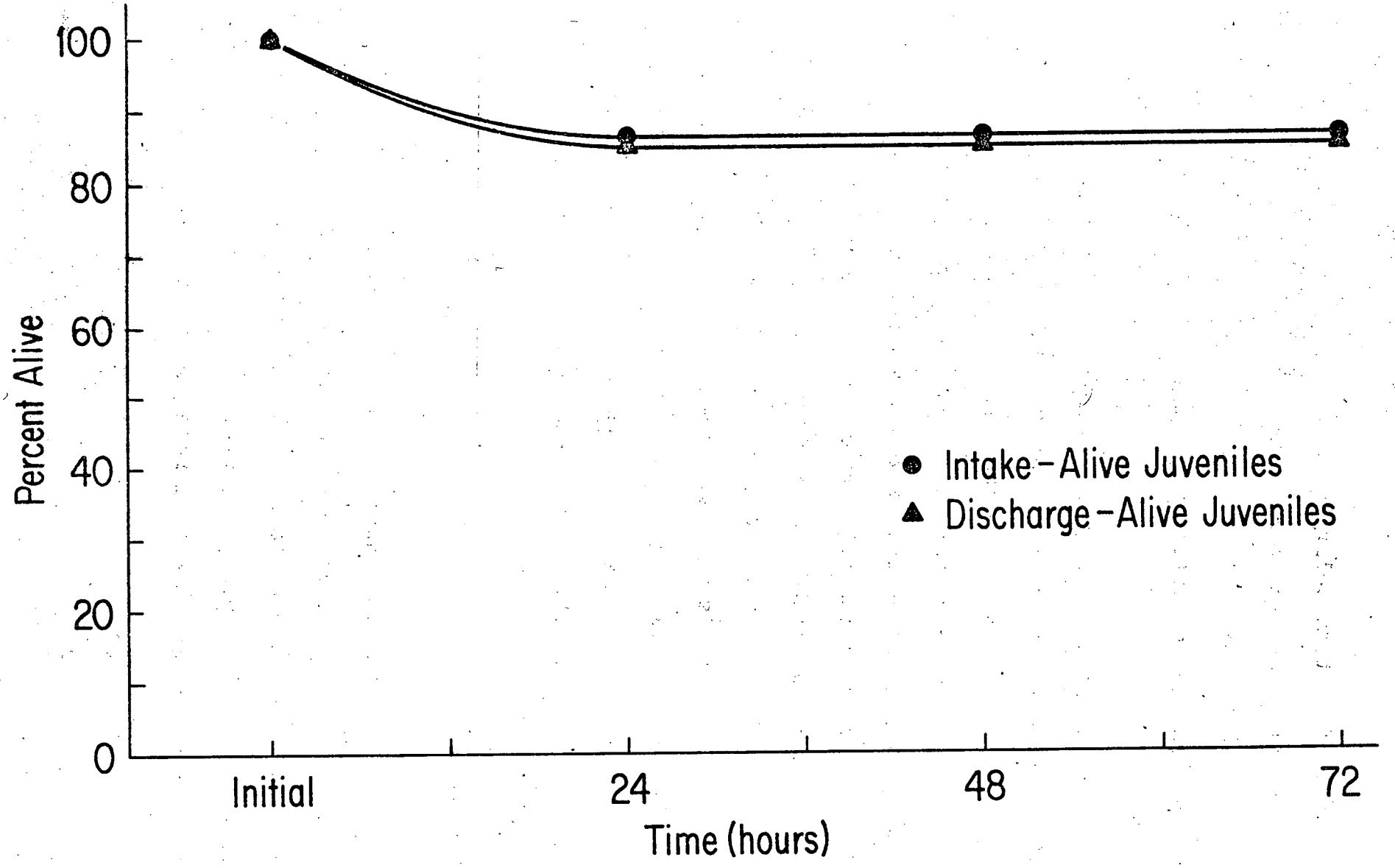


Figure 7-24. Survival curves for live striped bass juveniles collected at Indian Point intake and discharge stations in 1974 and held for 72 hours at ambient river temperature.

larvae had highest latent mortality--greater than 95% after 72 hours--while juveniles were the most hardy, with approximately 15% mortality after 72 hours. Live larvae and eggs were intermediate, with percentages of latent moratality between 50 and 70% after 72 hours.

As there were no controls in which non-stressed organisms (not exposed to net collection trauma or to plant passage) were tested, these results are unable to show what caused the latent mortalities. Also, we have no data on confinement mortality as a result of our holding the various life stages in glass jars. However, if we assume that the collection and confinement trauma are similar for both the intake and discharge canal samples, the difference observed between the two groups of samples should be the plant effect. If this is the case, then plant effect on latent mortality for the various life stages of striped bass was negligible. This may not be entirely true, however, as there were many more live individuals collected from the intakes than from the discharge canal.

7.2.3 Plant Abundance

7.2.3.1 Methods

The abundance of ichthyoplankton in the intakes and discharge canal of the Indian Point facility was determined by weekly sampling throughout May and June, and up to July 15. Sampling prior to May and after July 15 was done once-per-month. Samples were taken using 0.5-m plankton nets with a 571μ 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. Attempts to minimize the trauma associated with net-collections, primarily by the use of velocity-reduction cones on sampling nets and by sampling for short durations, precluded the use of flowmeters to determine the volumes of water filtered. The volumes of water filtered at the intake and discharge stations were 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 (See Table 7-22).

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). The analyses contained in this section are limited to striped bass.

Statistical analysis of the data was by analysis of variance (ANOVA) using $\log_{10}(\text{catch}/m^3 + 1)$ per sample as the numeric input to satisfy the assumptions of a parametric statistic. Where significant differences among main effects and/or interactions were detected ($\alpha = 0.05$), an a posteriori test (Scheffe's test) was employed ($\alpha = 0.10$) to determine precisely where the difference occurred.

7.2.3.2 Results and Discussion

The abundances for the various life stages of striped bass sampled during entrainment sampling are shown in Table 7-23. These were tested by ANOVA to determine differences between stations (Table 7-24) and among stations (Table 7-25). Generally, the mean

Table 7-22. Calculated volumes, in cubic meters, of water filtered through sampling nets during entrainment sampling. Volumes are based upon the percentage of flow produced by circulators and service pumps operational at the time of sampling

	Unit 1 intake		Unit 2 intake		Discharge canal	
Date	Flow (%)	Volume	Flow (%)	Volume	Flow (%)	Volume
5/21	94.5	8.48	82.8	7.43	85.9	7.71
5/23	94.5	8.48	82.8	7.43	85.9	7.71
5/28	94.5	8.48	98.9	8.88	97.7	8.77
5/30	94.5	8.48	98.9	8.88	97.7	8.77
6/4	94.5	8.48	83.3	7.48	86.3	7.75
6/13	94.5	8.48	98.9	8.88	97.7	8.77
6/18	94.4	8.48	98.9	8.88	97.7	8.77
6/25	92.6	8.31	75.4	6.77	80.0	7.18
6/27	83.1	7.46	98.9	8.88	94.6	8.49
6/28	88.5	7.94	95.3	8.56	93.5	8.39
7/2	95.0	8.53	98.9	8.88	97.8	8.78
7/9	6.9	0.62	98.9	8.88	74.2	6.66
7/23	95.0	8.53	98.9	8.88	97.8	8.78
8/20	95.0	8.53	98.9	8.88	97.8	8.78
9/17	95.0	8.53	77.5	6.96	82.2	7.38
10/15	95.0	8.53	82.8	7.43	86.0	7.72
11/12	43.9	3.94	50.0	4.49	48.4	4.34
12/17	52.7	4.73	30.7	2.76	36.6	3.29

Table 7-23. Abundance of striped bass collected at intake and discharge-canal stations, 1974. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n = number os samples; n.s. = not sampled).

Collections	Unit 1 intake		Unit 2 intake		Discharge canal	
	I-1	I-1	II-2	II-5	D-1	D-2
Eggs, 5/21 - 6/4	113±37 n=168	105±44 n=114	210±71 n=131	n.s.	131±38 n=71	83±28 n=132
Yolk-sac larvae 5/21 -6/4	29±9 n=168	37±11 n=114	48±17 n=131	n.s	26±15 n=71	17±11 n=132
Larvae 5/28 - 7/9	46±12 n=270	47±15 n=180	74±16 n=150	19±56 n=12	163±19 n=216	60±19 n=210
Juveniles *	0	0	0	0	0	0

* Only one juvenile was caught during the sampling period, on June 28 in a discharge-canal bottom sample.

Table 7-24. Differences in striped bass plant abundance among stations in $\log_{10}$ (catch/m^3 +1). (N.D. = not determined).

Collections	Unit 1 intake	Unit 2 intake	Discharge canal
Eggs 5/21/74-6/04/74	none	N.D.	D1>D2
Yolk-sac larvae 5/21/74-6/04/74	none	N.D.	none
Larvae 5/28/74-7/09/75	none	none	D1>D2
Juveniles	N.D.	N.D.	N.D.

Table 7-25. Differences in striped bass night abundance among intakes of Units 1 and 2 and discharge canal in $Log_{10}(catch/m^3 +1)$. (I= Unit 1 intake; II= Unit 2 intake; D= Discharge canal.)

Life stage	I vs II	I vs D	II vs D
Eggs	II>I	none	II>D
Yolk-sac larvae	II>I	I>D	II>D
Larvae	II>I	D>I	D>II
Juveniles	----	----	----

abundance of pre-juvenile stages was similar between stations at each intake, although Unit 2 intakes had consistently more of each life stage than Unit 1. Also, more eggs and larvae were found at station D-1 than at station D-2. Except for larvae, for which the discharge canal samples showed the greater abundance, egg and yolk-sac larvae abundances were significantly lower in the discharge canal than in the intakes (Table 7-25).

Other than differences which may result from the inherent patchy distribution of the various life stages in the river, the following are possible explanations for distribution differences observed for entrainment samples.

The explanation for the observed difference in which abundance of pre-juvenile states at the Unit 2 intake was consistently greater than the Unit 1 intake (almost twice as much) may lie in the sampling stations themselves. At Unit 1, one circulator pump is divided between two sampling forebays (I-1 and I-2), while at Unit 2, a circulator pump of the same pumping capacity as that in Unit 1, operates through one intake forebay. In essence, samples collected at either I-1 or I-2 approximate only half those of Unit 2.

The fact that the abundance for various of the life stages decreases between D-1 and D-2 may simply be a culling effect, since D-1 precedes D-2 in the discharge canal. If a given number of organisms or eggs is released into the discharge canal at a point above D-1, and nets at D-1 remove some of them, it follows that there will be fewer to be collected at D-2.

Our analyses show that striped bass larvae were much more

numerous in the discharge canal than in the intakes, while egg abundance was much lower in the discharge canal than in the intakes. These opposing differences will be discussed separately.

Decreased numbers of larvae at intake stations may be the result of net avoidance by the highly motile larvae. Even though large numbers of larvae are brought into the plant, they are able to avoid net capture while in the intake stream of the circulator pumps. However, once the larvae are subjected to a ΔT and mechanical stresses as a result of pumped entrainment during plant passage, they become disoriented and physically disabled to such a point that they become more susceptible to net capture at the discharge stations. This point is substantiated by increased numbers of dead and stunned larvae caught at the discharge canal stations relative to live individuals (See sections 7.2.1 and 7.2.2 on viability). Added support for this belief is the fact that the abundance data for this life stage in the discharge canal and the river are nearly equal (Table 7-26).

The increased numbers of eggs collected at the intakes as compared to the discharge stations may be more difficult to explain, since eggs are passive and move in response to current flow. Culling at the intake nets should not decrease egg counts to produce the differences observed (Table 7-23). Egg rupture and disintegration and net extrusion losses as a result of plant passage should not be a factor, based upon our studies at the flume at Alden (NYU, 1975). Turbulent conditions in the discharge canal should preclude losses due to settling of eggs and thus not sampled at

Table 7-26. Abundance of striped bass collected in the river and at intake and discharge-canal stations, 1974. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n = number of samples).

Collections	Unit 1 intake	Unit 2 intake	Discharge canal	River
Eggs 5/21 - 6/4	113±38 n=282	210±71 n=131	100±23 n=203	20±14 n=111
Yolk-sac larvae 5/21 - 6/4	32±7 n=282	48±17 n=131	20±9 n=203	38±12 n=111
Larvae 5/28 - 7/9	46±9 n=450	70±15 n=162	112±14 n=426	117±22 n=168
Juveniles *	0	0	0	0

*Only one juvenile was caught during the sampling period, on June 28 in a discharge-canal bottom sample.

the discharge stations. Consequently, if there are no reasons to believe that numbers at the discharge canal are underestimated, perhaps those at the intakes may be overestimated. Flow measurements with TSK flowmeters were made at the intake and discharge canal stations and compared with the calculated flows for 1974. These measurements showed that flows at the intakes were under-estimated, and the abundance values therefore overestimated, by nearly one-third. Adjusting for overestimation at the intakes, egg abundances for intake and discharge samples become compatible; this adjustment shows little effect for comparisons of other life stages (Table 7-27).

The depth distribution of all stages was uniform at the Unit 1 intake and in the discharge. At Unit 2, the abundances of eggs and yolk-sac larvae were greatest at the bottom; larvae showed a uniform depth distribution (Tables 7-28 and 7-29). Similar differences may have existed at the Unit 1 intake, since ANOVA indicated a depth effect, but the Scheffe test failed to identify the difference.

Eggs were most abundant in the latter part of May (May 21-23) reaching peak densities of 785 eggs per 1000 m^3 in Unit 2 bottom samples (Table 7-30). The greatest densities of eggs occurred in the bottom samples from both intakes on May 21 at Unit 1 and on May 23 at Unit 2. Overall egg abundance was greatest on May 23 when an average of 338 per 1000 m^3 were collected in intake samples. Egg abundance declined between May 23 and May 28.

Concentrations of yolk-sac larvae at the intakes were greatest

Table 7-27. Adjusted striped bass abundance for plant entrainment samples. Data are mean numbers collected per 1000 m^3 by station with 95% confidence intervals. (n= number of samples used in the calculations.)

Collections	Unit 1 intake	Unit 2 intake	Discharge canal
Eggs 5/21 to 6/04	75 ± 19 n = 282	140 ± 47 n = 131	100 ± 23 n = 203
Yolk-sac larvae 5/21 to 6/04	21 ± 5 n = 282	32 ± 11 n = 131	20 ± 9 n = 203
Larvae 5/28 to 7/09	31 ± 6 n = 450	47 ± 10 n = 162	112 ± 14 n = 426
Juveniles*	0	0	0

*Only one juvenile was caught during the sampling period on June 28 a discharge canal bottom sample.

Table 7-28. Striped bass abundance by depth with 95% confidence intervals for in-plant samples. Data are mean numbers collected per 1000 m^3, (n = number of samples).

Station location and collections	Surface	Middle	Bottom
Unit 1 intake			
Eggs 5/21 - 6/4	129±49 n=94	78±49 n=94	132±49 n=94
Yolk-sac larvae 5/21 - 6/4	36±13 n=94	23±13 n=94	38±13 n=94
Larvae 5/28 - 7/29	56±16 n=150	50±16 n=150	32±16 n=150
Juveniles	0	0	0
Unit 2 intake			
Eggs 5/21 - 6/4	167±123 n=44	140±125 n=43	321±123 n=44
Yolk-sac larvae 5/21 - 6/4	23±29 n=44	41±29 n=43	80±29 n=44
Larvae 5/28 - 7/9	75±26 n=54	58±26 n=54	75±26 n=54
Juveniles	0	0	0
Discharge-canal			
Eggs 5/21 - 6/4	97±39 n=67	105±39 n=68	98±39 n=68
Yolk-sac larvae 5/21 - 6/4	35±15 n=67	19±15 n=68	18±15 n=68
Larvae 5/28 - 7/9	101±23 n=142	121±23 n=142	114±23 n=142
Juveniles	0	0	0

Table 7-29. Differences in striped bass plant abundance among depths in Log_{10} (catch/m^3 +1). (Sur= surface; mid= middle; bot= bottom.)

Collections	Unit 1 intake	Unit 2 intake	Discharge
Eggs 5/21/74-6/04/74	none[1]	Bot>Mid	none
Yolk-sac larvae 5/21/74-6/04/74	none[1]	Bot>Sur	none
Larvae 5/28/74-7/09/74	none	none	none
Juveniles	----	----	----

[1] ANOVA showed significant difference but Scheffe´ test did not.

Table 7-30. Striped bass abundance in mean numbers collected per 1000 m^3 by date and depth with standard errors. (X= mean number; SE= standard error; N= number of samples used in means determination.

Collection and dates		Depth Surface	Middle	Bottom
Eggs, Unit 1 intake				
5/21	x	24	177	530
	SE	112	36	60
	N	10	10	10
5/23	x	407	155	145
	SE	75	25	41
	N	22	22	22
5/28	x	0	25	109
	SE	94	31	51
	N	14	14	14
5/30	x	93	44	59
	SE	72	24	39
	N	24	24	24
6/04	x	29	29	39
	SE	72	24	39
	N	24	24	24
Eggs, Unit 2 intake				
5/21	x	296	242	188
	SE	57	70	204
	N	10	10	10
5/23	x	280	257	785
	SE	52	67	186
	N	12	11	12
5/28	x	79	23	135
	SE	57	70	204
	N	10	10	10
5/30	x	19	47	122
	SE	52	64	186
	N	12	12	12
6/04	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken

Table 7-30 (cont.).

Collection and dates		Depth: Surface	Middle	Bottom
Eggs, discharge				
5/21	x	65	402	324
	SE	65	31	51
	N	10	10	10
5/23	x	354	162	195
	SE	62	29	47
	N	11	12	12
5/28	x	57	23	23
	SE	65	31	51
	N	10	10	10
5/30	x	19	67	38
	SE	60	29	47
	N	12	12	12
6/04	x	48	5	16
	SE	42	20	33
	N	24	24	24
Yolk-sac larvae, Unit 2 intake				
5/21	x	0	59	71
	SE	18	17	22
	N	10	10	10
5/23	x	70	21	11
	SE	12	12	15
	N	22	22	22
5/28	x	0	0	59
	SE	16	15	19
	N	14	14	14
5/30	x	39	25	5
	SE	12	11	14
	N	24	24	24
6/04	x	39	20	69
	SE	12	11	14
	N	24	24	24

Table 7-30 (cont.).

Collection and dates		Depth: Surface	Middle	Bottom
Yolk-sac larvae, Unit 2 intake				
5/21	x	0	67	27
	SE	17	28	41
	N	10	10	10
5/23	x	56	37	101
	SE	16	27	37
	N	12	11	12
5/28	x	23	0	101
	SE	17	28	41
	N	10	10	10
5/30	x	9	56	84
	SE	16	25	37
	N	12	12	12
6/04	x	no samples taken	no samples taken	no samples taken
	SE			
	N			
Yolk-sac larvae, discharge				
5/21	x	13	65	26
	SE	24	15	18
	N	10	10	10
5/23	x	35	11	43
	SE	23	14	17
	N	11	12	12
5/28	x	0	0	23
	SE	24	15	18
	N	10	10	10
5/30	x	10	10	10
	SE	22	14	17
	N	12	12	12
6/04	x	38	16	5
	SE	16	10	12
	N	24	24	24

Table 7-30 (cont.).

Collection and dates		Depth: Surface	Middle	Bottom
Larvae, Unit 1 intake				
5/28	x	0	8	8
	SE	37	24	14
	N	14	14	14
5/30	x	34	5	0
	SE	28	13	11
	N	24	24	24
6/04	x	98	192	138
	SE	28	18	11
	N	24	24	24
6/13	x	324	118	20
	SE	40	26	16
	N	12	12	12
6/18	x	0	20	0
	SE	40	26	16
	N	12	12	12
6/25	x	30	25	20
	SE	28	18	11
	N	24	24	24
6/28	x	21	10	10
	SE	28	18	11
	N	24	24	24
7/02	x	7	15	29
	SE	28	23	13
	N	24	16	16
7/09	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken

Table 7-30 (cont).

Collection and dates		Depth: Surface	Middle	Bottom
Larvae, Unit 2 intake				
5/28	x	11	0	45
	SE	40	23	26
	N	10	10	10
5/30	x	0	9	47
	SE	37	21	24
	N	12	12	12
6/04	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken
6/13	x	188	188	225
	SE	37	21	24
	N	12	12	12
6/18	x	141	19	28
	SE	37	21	24
	N	12	12	12
6/25	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken
6/28	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken
7/02	x	no	no	no
	SE	samples	samples	samples
	N	taken	taken	taken
7/09	x	0	70	0
	SE	45	25	30
	N	8	8	8

Table 7-30 (cont.).

Collection and dates		Depth Surface	Middle	Bottom
Larvae, discharge				
5/28	x	0	11	11
	SE	32	43	57
	N	10	10	10
5/30	x	10	10	0
	SE	29	39	52
	N	12	12	12
6/04	x	323	355	172
	SE	21	28	37
	N	24	24	24
6/13	x	295	428	219
	SE	29	39	52
	N	12	12	12
6/18	x	57	38	105
	SE	29	39	52
	N	12	12	12
6/25	x	17	29	70
	SE	21	28	37
	N	24	24	24
6/28	x	40	74	189
	SE	21	28	37
	N	24	24	24
7/02	x	57	14	100
	SE	25	34	45
	N	16	16	16
7/09	x	0	19	38
	SE	36	48	64
	N	8	8	8

between May 23 and 28; maximum concentrations occurred in bottom samples (Table 7-30).

The distribution of larvae with depth was more even than for egg and yolk-sac larvae. Larvae increased in abundance from May 28 and declined shortly thereafter (Table 7-30). Depth distribution during the period of peak abundance was uniform at Unit 2, but was skewed toward the surface at Unit 1.

7.2.4 Plant and River Comparisons

Comparisons for the abundance of the four life history stages of striped bass in river and plant samples are shown in Table 7-18. With the possible exception of eggs, the mean abundance per 1000 m^3 for the various life stages collected at night at the plant and in river stations adjacent to the plant are generally consistant. Only night comparisons are discussed here because samples at the plant were collected at night only.

Numerically the mean abundance of eggs in river samples was less than those at the plant, differing by a factor of 5 at the Unit 1 intakes and at the discharge canal, and by a factor of approximately 10 at the Unit 2 intakes (Table 7-18); this is confirmed statistically by Table 7-31. Even if the intake data are adjusted (See page 290 of this report) such that cross-plant abundances between the intakes and the discharge canal are consistent, egg abundance in the plant was still 5 to 7 times greater than in the river. Although there are substantial differences between the plant and river samples, there is insufficient information to select one set of numbers (plant or river) over the other; both may valid.

Table 7-31. Differences in striped bass abundance at night among river, Units 1 and 2 intakes, and discharge canal in Log_{10} (catch/m^3 + 1). (R= river, I= Unit 1 intake, II= Unit 2 intake, D= discharge canal.)

Life stage	R vs I	R vs II	R vs D
Eggs	I>R	II>R	D>R
Yolk-sac larvae	none	none	R>D
Larvae	R>I	R>II	none
Juveniles	----	----	----

Because of the uniqueness of the sampling regions as well as the sampling regimes (See section 1 of this report), we suspect that some of these differences may simply result from the sampling methodolgies employed and that the plant is more efficient for egg collection or that the river sampling procedure, as described, is quantitatively inadequate for plant/river comparisons to be made. 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 based on samples collected from seven stations in the river adjacent to Indian Point; each station was sampled once in a sampling period. Whereas, plant sampling was designed to observe the numbers of organisms drawn into the power plant and, subsequently, the effect of plant entrainment on the river biota during plant operation. Samples were collected from a permanent station (Indian Point plant) 6 to 7 times within a sampling period. As striped bass eggs are non-motile and planktonic, their distribution in the river is influenced by tidal and current flows, and they may not be sampled quantitatively by once-over river tows. However, the probability of obtaining more planktonic individuals becomes greater if one merely samples the water passing by for several successive intervals, as is done in plant sampling. Therefore, to expect these two different sampling programs to yield comparable data is too much.

8. PLUME ENTRAINMENT STUDIES

Preliminary laboratory and field studies simulating the effects of discharge-plume entrainment (entrainment in the discharge plume of organisms not previously exposed to plant effects) on representative Hudson River biota were completed in 1974. The research program was structured to develop study approaches with applicability to power plant discharg-plume studies in general. Experimental design focused on producing information of predictive value with emphasis on observing (1) simultaneous exposures of organisms from different trophic levels to the Indian Point thermal plume in the presence and absence of chlorination; and (2) both the "immediate" and latent effects of exposure to the plume.

8.1 SIMULATED PLUME-TRANSIT STUDIES

8.1.1 General Methods and Materials

Field studies involved the exposure of phytoplankton, macrozooplankton and fish to discharge-plume and control areas by attaching submerged containers appropriate for each organism to floating racks (Figure 8-1). Studies were done in the presence and absence of the chlorine (hypochlorite solution) used to defoul the plant's cooling-water lines.

The general procedure herein described was adhered to during the plume-transit experiments. Several passes were made by boat through the Unit 1 and 2 discharge-plume area. Water temperatures were determined with YSI Model 43 telethermometers. When the highest surface ΔT was located, the organism-exposure rack (Figure 8-1) was lowered into the plume. At the same time, a rack was

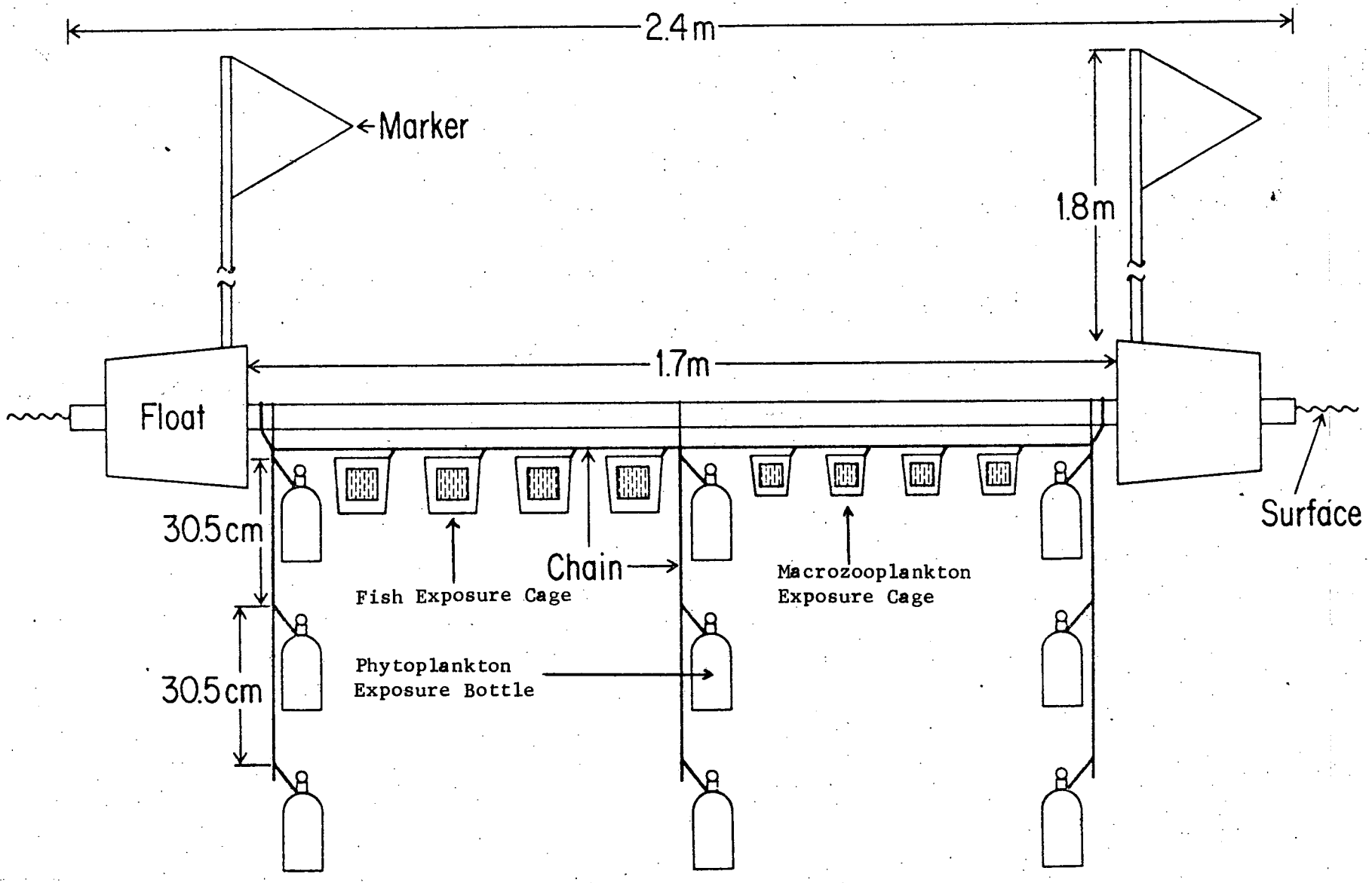


Figure 8-1. Organism exposure rack used in simulated plume entrainment.

placed in a non-plume (control) area of the river. The racks were permitted to drift in the river for 1 hour under the influence of local tidal/current movement. The approximate position of each rack and the water temperature were recorded at 5-minute intervals throughout the transit. Water samples were taken at least three times during each transit period (at the beginning, midpoint and the end) and returned to the laboratory for chlorine analysis using an amperometric titrator. Water temperature and chlorine were also monitored at the plant and in the discharge canal to characterize levels entering the plume.

Organisms were retrieved following simulated plume transit, and immediately returned to the laboratory for short-term mortality examination; others were retained for observations of latent mortality. Studies with phytoplankton are described in section 8.1.2, following.

Summaries of field observations characterizing the simulated plume-transit of the exposure racks are shown in Figures 8-2 to 8-9. All position plots (A-M) were estimates based on shoreline reference points noted at 5-minute intervals during the exposure period. Figures 8-2 to 8-5 represent experiments done in August, while Figures 8-6 to 8-9 show those experiments completed in September. All experiments were run with and without chlorination at Unit 1.

Statistical treatment of data from phytoplankton experiments consisted of one-way analysis of variance and the Scheffé Test for differences between means. Experimental data from macrozooplankton (Gammarus spp.) and fish (Morone saxatilis) were subjected

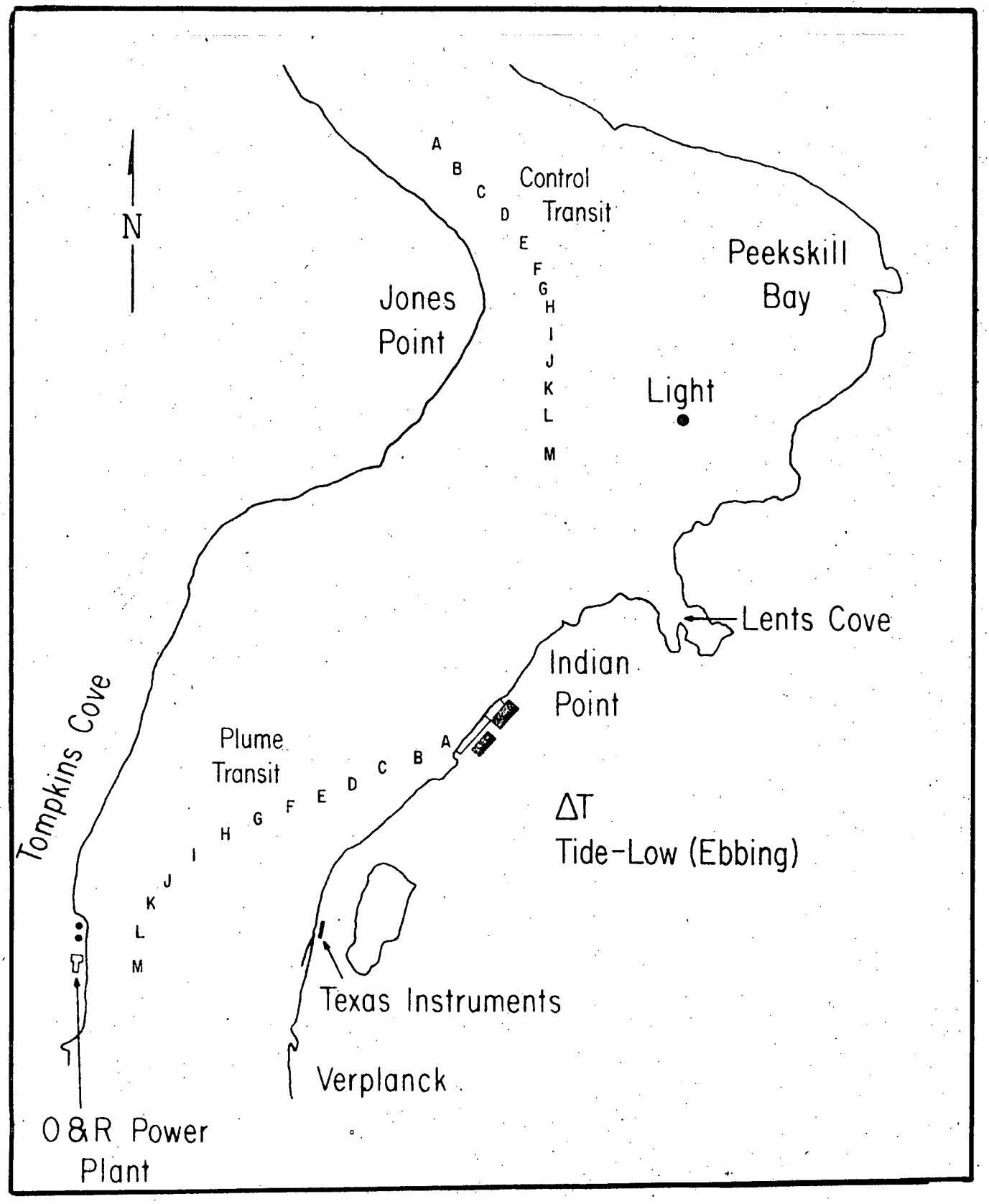


Figure 8-2. Plume transit stations and control transit stations for plume studies at Indian Point in absence of chlorination (8/22/74).

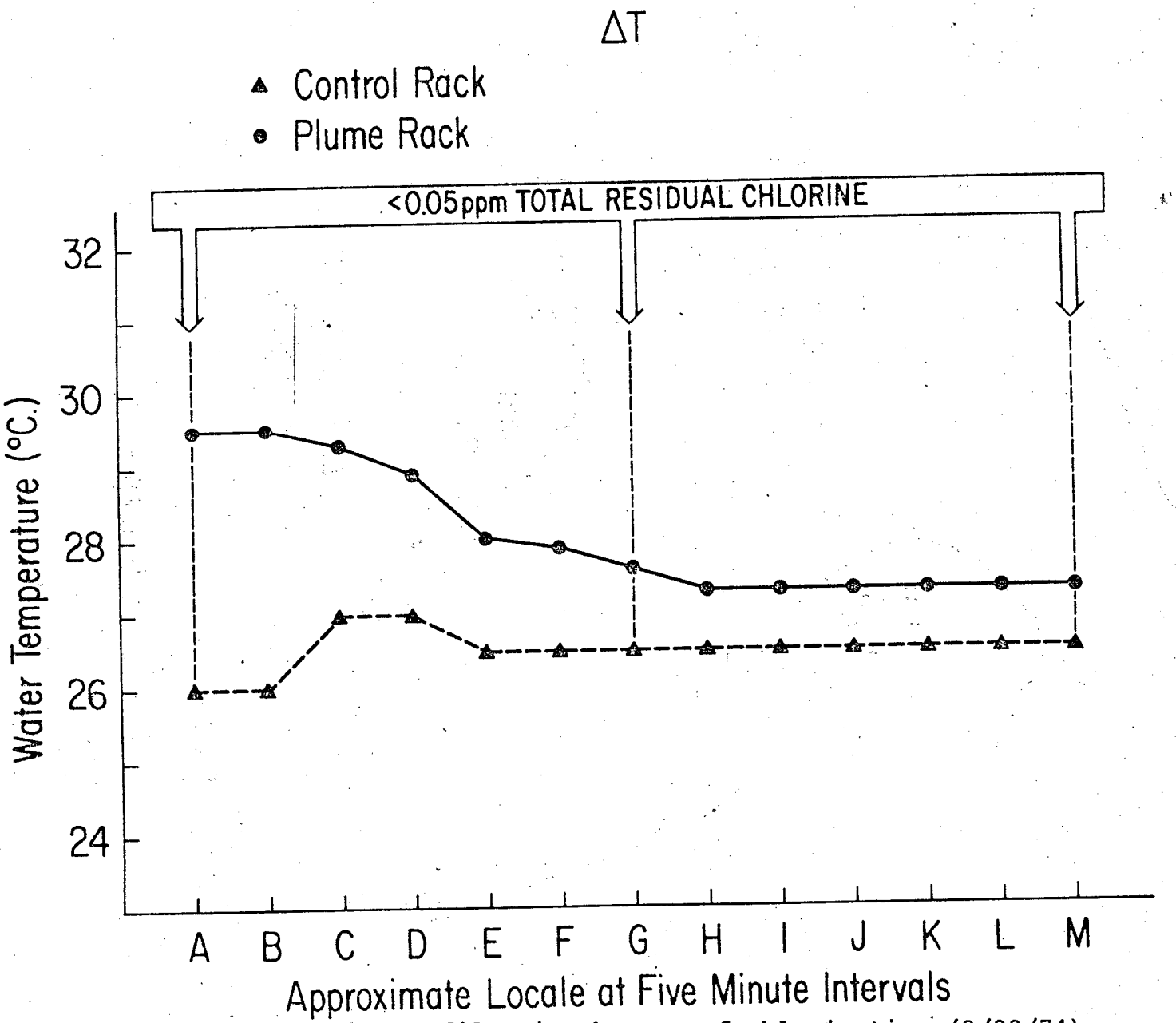


Figure 8-3. Transit-temperature profiles in absence of chlorination (8/22/74).

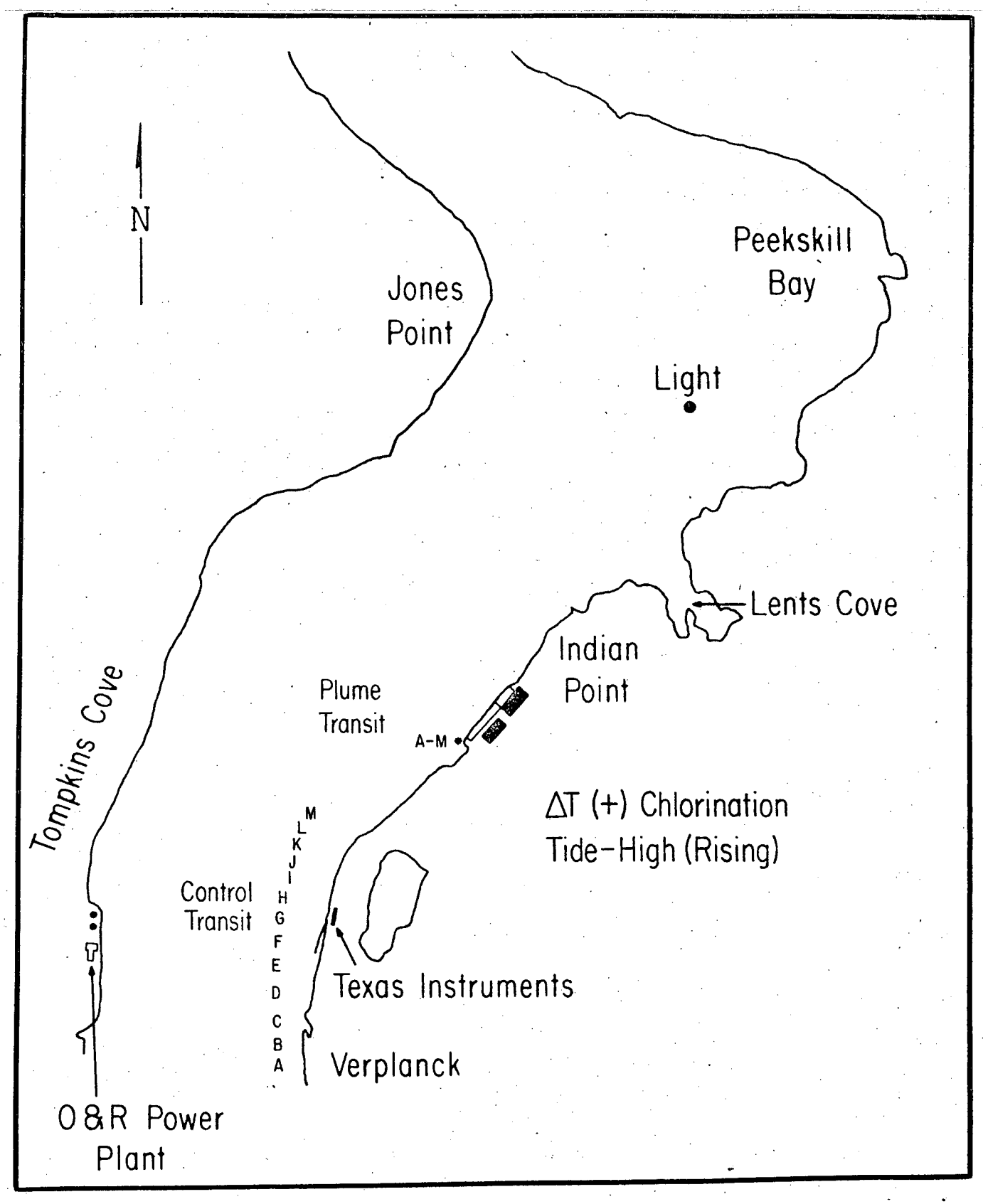


Figure 8-4. Plume transit stations and control transit stations for plume studies at Indian Point in presence of chlorination (9/12/74) (*transit rack moved back and forth in discharge port area).

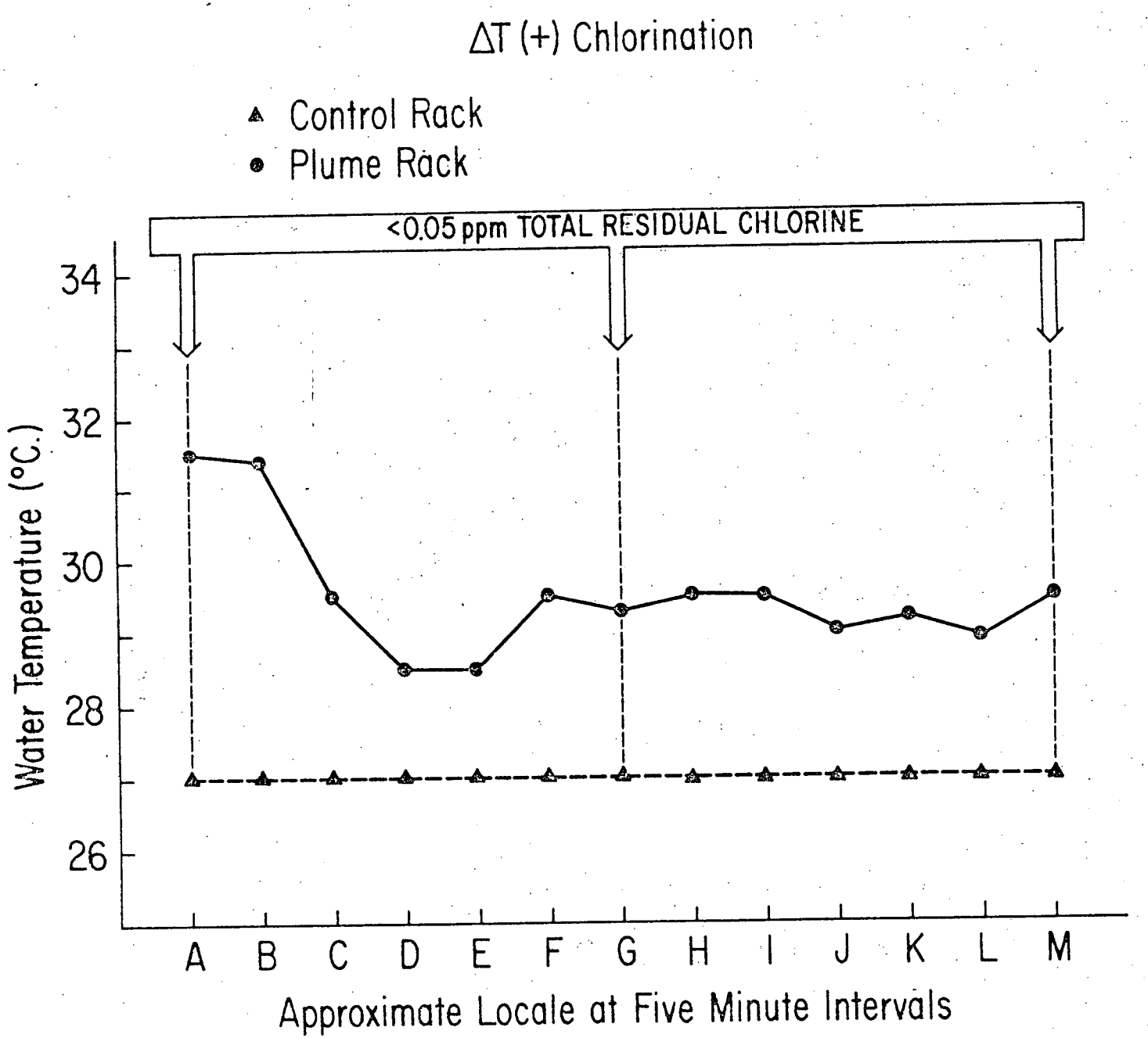


Figure 8-5. Transit-temperature profiles in presence of chlorination (8/22/74) (*transit rack moved back and forth in discharge port area).

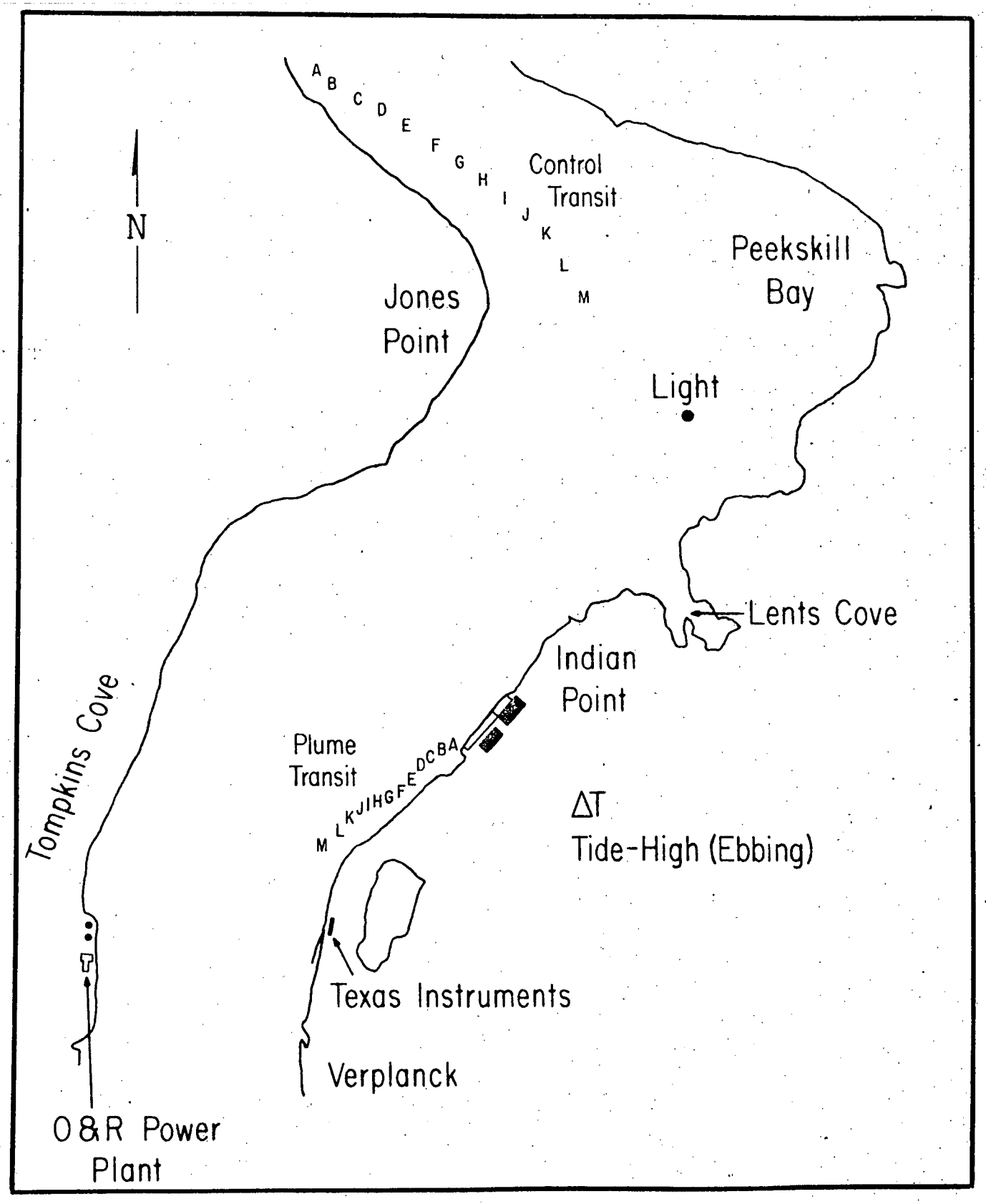


Figure 8-6. Plume transit stations and control transit stations for plume studies at Indian Point in absence of chlorination (9/12/74).

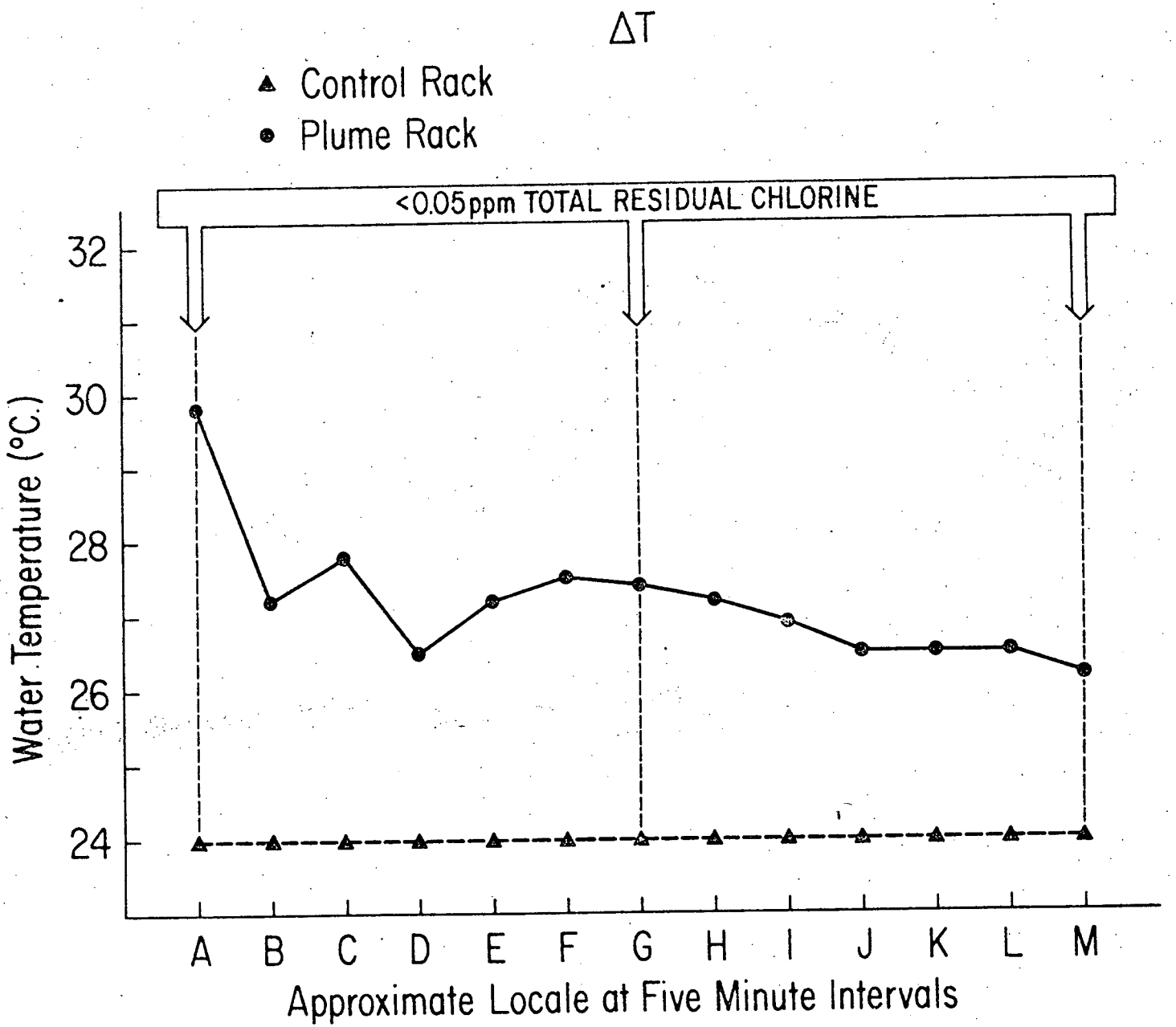


Figure 8-7. Transit-temperature profiles in absence of chlorination (9/12/74).

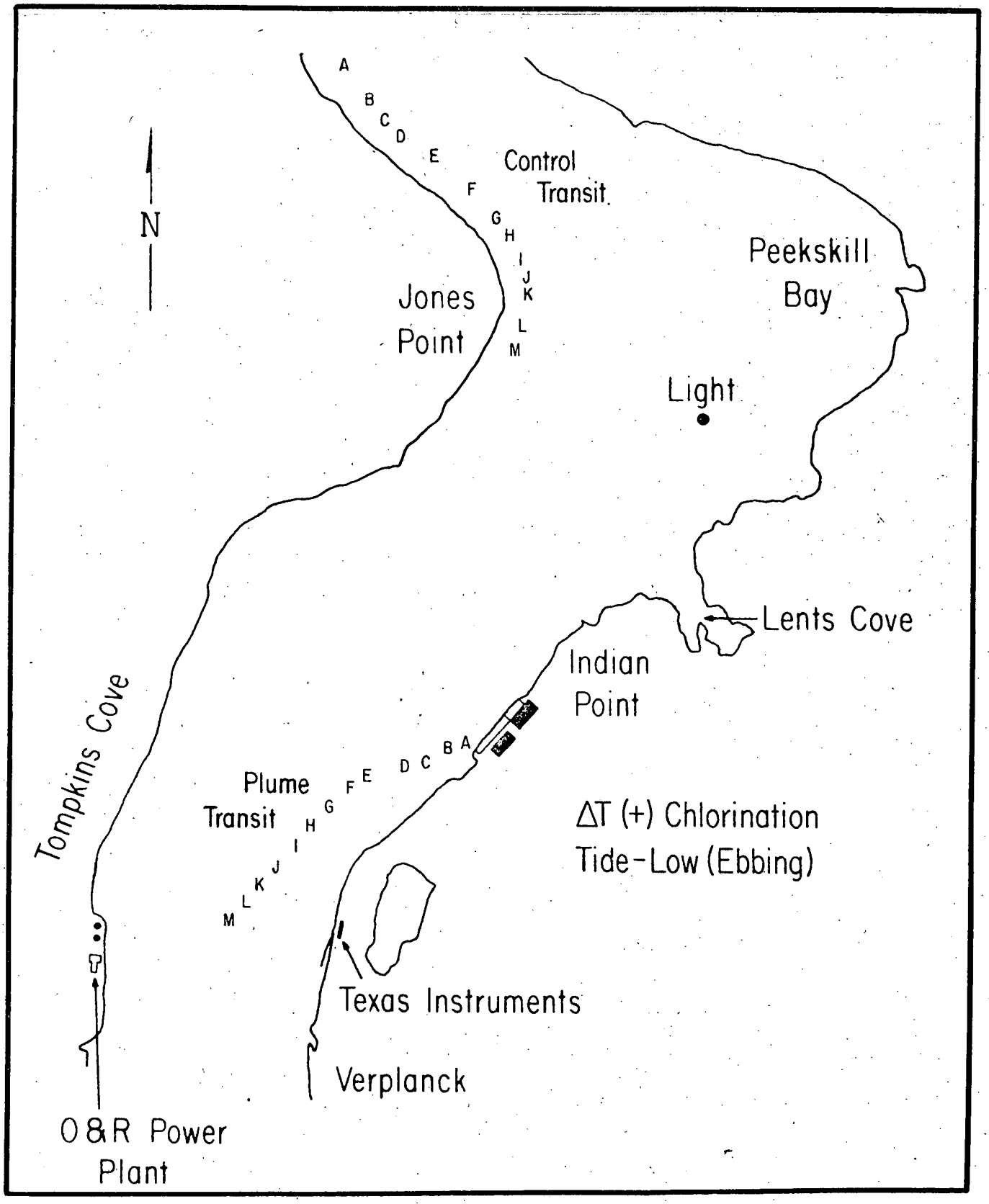


Figure 8-8. Plume transit stations and control transit stations for plume studies at Indian Point in presence of chlorination (9/12/74).

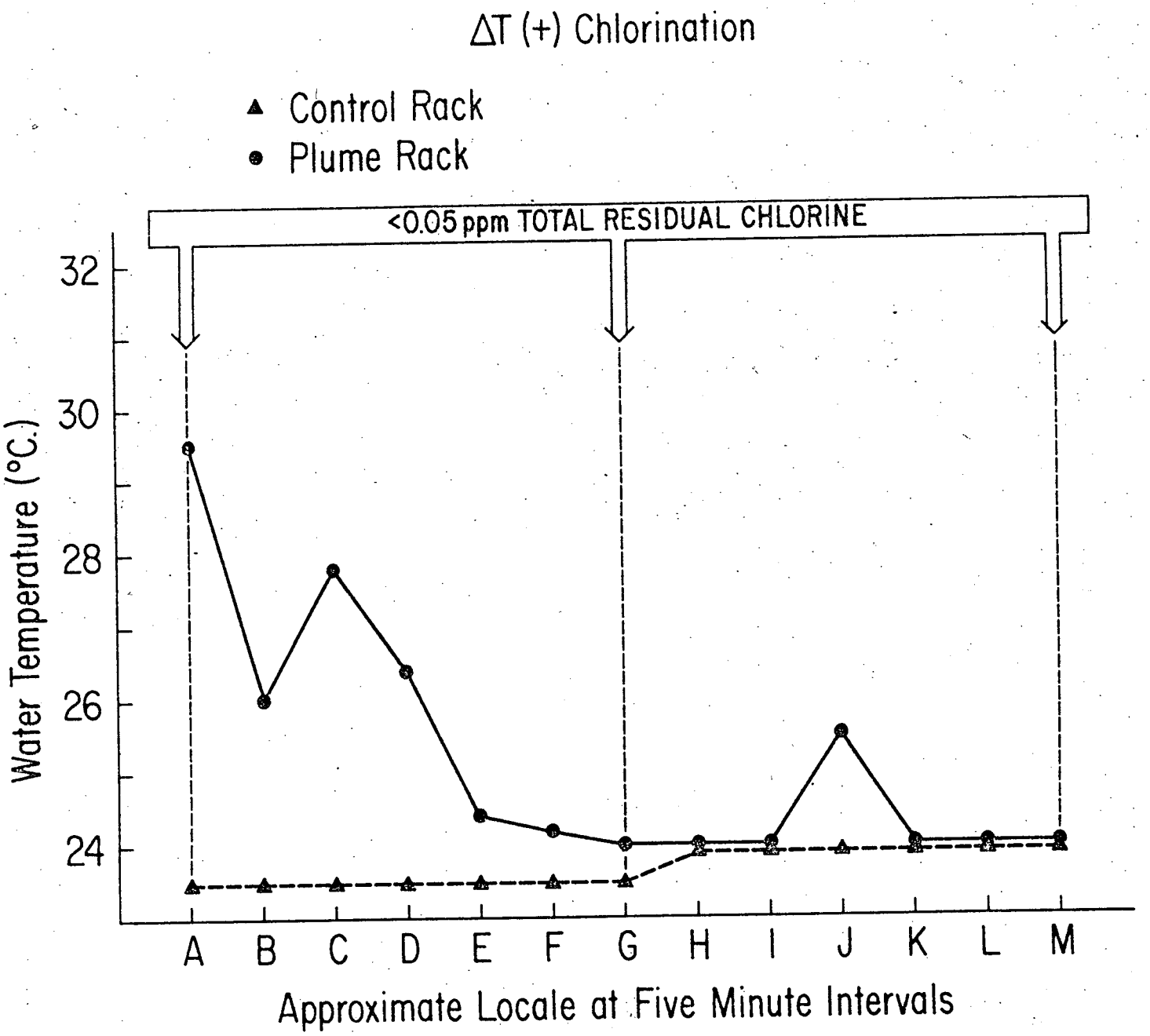


Figure 8-9. Transit-temperature profiles in presence of chlorination (9/12/74).

to R x C Contingency Table Analysis using the G-Test (Scheffe, 1959). If an analysis indicated a significant effect of treatment on survival, an a posteriori simultaneous test procedure was conducted to reveal all non-significant sub-sets of rows and columns.

8.1.2 Phytoplankton

8.1.2.1 Methods and Materials

Studies designed to characterize the effects of discharge-plume entrainment on phytoplankton included measurements of photosynthetic activity as ^{14}C-uptake rate, and of cell chlorophyll a content as an indication of the photosynthetic potential of the algal community.

Phytoplankton assemblages were prepared as follows. Separate 4-liter samples were collected from the river adjacent to the intake structures and from the discharge plume areas. These were used as control and experimental material, respectively. Control samples were collected and incubated 2 hours before each experimental set was collected. Experimental bottles were mixed and aliquoted as (1) three 300-ml light (transparent) productivity bottles; (2) three 300-ml dark (shielded against light with black tape and an outer layer of aluminum foil) productivity bottles; and (3) three 300-ml bottles for chlorophyll a analysis and algal taxonomy. Following the exposure period, each of the latter was divided into four 50-ml sub-samples for chlorophyll a analysis. The remaining 100 ml was used for algal taxonomy. Productivity bottles were spiked with 10 microcuries (μC) of $NaH^{14}CO_3$. Chemical analyses of pH and $CaCO_3$ were also carried out.

Algal identification was limited to the surface samples. During an experiment, triplets consisting of one light bottle, one dark bottle and one chlorophyll a/taxonomy bottle were suspended from the experimental transit rack (Figure 8-1) at each of three depths: 1.27, 91 and 183 cm below the water surface. Following the 1-hour exposure, the bottles were transferred to an identical but stationary incubation rack in ambient-temperature water for the additional time required to complete the 4-hour ^{14}C-uptake incubation. The control rack carried four 300-ml light bottles, one each at 1.27, 91 and 183 cm depth, and one 300-ml bottle at 1.27 cm for surface chlorophyll a and taxonomic examination. Control-rack dark bottles were incubated in a continuous-flow trough receiving river water at ambient temperature.

All productivity bottles were incubated in situ to maximize simulation of light and temperature variations with depth. Temperatures were measured at the surface with a telethermometer and at 91 and 183 cm depth with a weighted temperature-salinometer probe.

At the initiation of each incubation, a set of incident submarine light readings were taken with a Kahl radiometric photometer. Light absorbed by a photocell was measured on a small ammeter and converted to microwatts/ centimeter square ($\mu W/cm^2$) using a set of conversion factors calibrated with the instrument. The $\mu W/cm^2$ are converted to calories per centimeter square per second ($cal/cm^2/sec$) by the following formula taken from the IBP Handbook #12 (1969):

$$\mu W/cm^2 \times \frac{1}{1 \times 10^6} \quad 4.186 = cal/cm^2 \text{ sec.}$$

Light values were used to calculate solar radiation at the water's surface and to fix the depth of the euphotic zone (Table 8-1).

Photosynthesis was measured using the ^{14}C-uptake rate as described by Steeman-Nielsen (1952) and modified by Saunders et al (1962). After incubation samples were brought in to the laboratory. A set of four 50-ml aliquots was taken from each bottle. These were then filtered using a Millipore filter apparatus with 47-mm filters having 0.45μ openings. The vacuum pump was maintained at 15 inches Hg to prevent cell breakage. Each sample was rinsed with filtered river water to remove any non-absorbed radioactivity. Each filter was then placed in a liquid scintillation vial containing 20 ml of cocktail.* Carbon-14 uptake was measured in a liquid scintillator following the procedure of Wang & Willis (1965). Chemical quenching was corrected by using a set of prepared homogenously quenched standards from Amersham Searle Co.

Total carbon was calculated using the table from Saunders et al. (1962) relating pH, alkalinity and temperature. These parameters were then used in the following formula to calculate photosynthesis.

$$P = r \times f \times c \times \frac{1}{N} \times \frac{\text{Total Volume}}{\text{Volume Filtered}} \times 10^3$$

---

* Cocktail consisted of: toluene, triton X and permafluor in ratios of 14.2/7.6/1.0 (volume/volume/volume).

Table 8-1. Summary of experimental results of simulated plume entrainment of phytoplankton, August 22, 1974. Depth of euphotic zone, 1.98 m.

Condition	Depth (cm)	Light intensity ($cal/cm^2/sec$)	Temp. (°C)	Chlorophyll *a* (mg/m^3)	Photosynthetic activity ($mgC/m^3/hr$)	Carbon fixation per unit chlorophyll
Control	1.27	$1.12X10^{-3}$	25.8	1.69	30.27	17.9
	91.00	$1.02X10^{-4}$	25.8	----	6.96	4.1
	183.00	$1.26X10^{-5}$	25.8	----	6.26	3.7
ΔT	1.27	$1.12X10^{-3}$	29.1	1.85	28.00	15.1
	91.00	$1.02X10^{-4}$	28.3	2.07	10.94	5.3
	183.00	$1.26X10^{-5}$	28.2	1.19	1.98	1.7
Control	1.27	$1.12X10^{-3}$	25.8	1.26	25.29	20.0
	91.00	$1.02X10^{-4}$	25.8	----	9.73	7.7
	183.00	$1.26X10^{-5}$	25.8	----	4.65	3.7
ΔT with Chlorination	1.27	$1.12X10^{-3}$	31.3	2.07	22.48	10.9
	91.00	$1.02X10^{-4}$	29.9	2.20	3.69	1.7
	183.00	$1.26X10^{-5}$	30.9	1.83	4.46	2.4

Table 8-1 (Cont).

Condition	Depth (cm)	Light intensity ($cal/cm^2/sec$)	Temp. (^0C)	Chlorophyll a (mg/m^3)	Photosynthetic activity ($mgC/m^3/hr$)	Carbon fixation per unit chlorophyll
Control	1.27	$2.27X10^{-4}$	24.0	1.01	19.55	19.4
	91.00	$2.11X10^{-5}$	24.0	----	5.82	5.8
	183.00	$7.29X10^{-6}$	24.0	----	3.89	3.9
ΔT	1.27	$2.27X10^{-4}$	28.4	1.39	13.67	9.8
	91.00	$2.11X10^{-5}$	28.4	1.22	13.19	10.8
	183.00	$7.29X10^{-6}$	28.4	1.20	1.93	1.6
Control	1.27	$2.27X10^{-4}$	24.0	1.49	28.06	18.8
	91.00	$2.11X10^{-5}$	24.0	----	11.59	7.8
	183.00	$7.29X10^{-6}$	24.0	----	24.47	16.4
ΔT with Chlorination	1.27	$2.27X10^{-4}$	28.4	1.38	15.49	11.2
	91.00	$2.11X10^{-5}$	28.4	1.26	9.68	7.0
	183.00	$7.29X10^{-6}$	28.4	----	0.18	

r = disintegrations/minute of sample
R = disintegrations/minute of ^{14}C added
f = isotope correction factor
C = carbon (mgC/l)
N = incubation time
10^3 = conversion to mgC/m^3

Chlorophyll analysis followed the method of Strickland and Parsons (1972). Each of four 50-ml aliquots was filtered with 1-ml of dilute magnesium carbonate as a buffer using a Millipore appratus and GFC glass filters. After filtration the filters were homogenized in 90% acetone (acetone-water) with a tissue grinder. Following 1 hour to allow complete extraction, samples were centrifuged. The fluorescence of chlorophyll *a* in the supernatant was measured with a Turner Model-111 fluorometer. After the initial fluorescence measurement, the samples were acidified with 4N HCl, held for 5 minutes, and a reading of phaeophytin absorption taken with the fluorometer.

Chlorophyll *a* and phaeophytin *a* were calculated as follows:

$$\text{mg Chl } a/m^3 = F_D \frac{\tau}{\tau-1} (R_B - R_A) \times \frac{\text{Total volume}}{\text{Volume filtered}} \times \frac{\text{ml extract}}{10}$$

$$\text{mg Phaeo-pigment}/m^3 = F_D \frac{\tau}{\tau-1} (R_A - R_B) \times \frac{\text{Total volume}}{\text{Volume filtered}} \times \frac{\text{ml extract}}{10}$$

F_D = door factor, a calibration of the fluorometer using a comparison of readings on a Beckman DB spectrophotometer where:

F_D = Chl *a*/R and = 0.00161

Chl *a* = 11.6 E_{665} - 1.31 E_{645} - 14 E_{630}

E = absorption readings taken at the indicated wavelengths on the spectrophotometer.

R = fluorescent reading of the same sample as above.

τ = ratio of sample before and after acid addition at the time of the above analysis, and = 2.15.

A 250-ml sample for phytoplankton counts and identification was preserved with Lugol's iodine solution.* Upon return to the laboratory, aliquots of 25, 50 or 100 ml were prepared, depending on organism density. Each aliquot was filtered using a 1.2μ, 47-mm gridded filter. After filtration, filters were dried and then mounted on slides with permount. The phytoplankton on the filters were identified and enumerated following the methods described earlier in Section 4 of this report.

8.1.2.2 Results and Discussion

The results of experiments carried out to examine the effects of simulated plume entrainment upon phytoplankton assemblages are summarized in Table 8-1. The results of comparing control and experimental assemblages at each depth are outlined by date in Table 8-2. The vast majority of phytoplankton assemblages exposed to simulated plume transit during August 1974 (Figures 8-2, 8-3, 8-4, 8-5 and Table 8-2) experienced marked decreases in photosynthetic activity. One exception was an increase in ^{14}C-uptake noted in the assemblages exposed to ΔT at 91-cm depth on September 12. These decreases in photosynthetic activity appeared to be the

*Lugol's consisted of: (g/liter distilled water): 40 iodine, 80 potassium iodide, 80 glacial acetic acid, 50 glycerine, and 50 of 95%-ethanol.

Table 8-2. Summary of analysis of observed effects of simulated plume entrainment of phytoplankton. (Plume compared to control at each depth).

Date	Depth (cm.)	Effect of ΔT on photosynthetic activity as mg C/mg Chl a/hr	Effect of ΔT with chlorination on photosynthetic activity as mg C/mg Chl a/hr
8/22/74	1.27	-2.8	-9.1
	91.00	+0.8	-6.0
	183.00	-2.0	-1.3
9/12/74	1.27	-9.6	-7.6
	91.00	+5.0	-0.8
	183.00	-2.3	n.d.*

*n.d.-not determined

result of ΔT alone, with perhaps a slight additive effect from low-level (0.05 ppm) total residual chlorine.

Taxonomic profiles of phytoplankton assemblages are given in Table 8-3. Surface assemblage density values, expressed as cells per liter, and the percent composition of each major algal group indicate that similar phytoplankton communities were present in the control and experimental groups on a given exposure day. The taxonomic profiles of dominant organisms noted in the study assemblages are provided in Table 8-4.

Although these results indicate substantial reduction (from 10 to 78%) in photosynthetic activity in the phytoplankton assemblages exposed to simulated plume conditions (Table 8-2), the results are not conclusive. In examining the methodology of this experiment, it was noted that samples exposed experimentally to plume conditions were collected from areas adjacent to the plant discharge ports. Therefore, the apparent reduction of photosynthetic activity in assemblages exposed to plume conditions were, in all probability, a result of plant entrainment or of plant entrainment compounded by plume entrainment and not a result of plume entrainment alone.

Several factors individually or in concert may help to explain the observed differences in community response between study dates (August and September, 1974). The overall taxonomic structure of the phytoplankton communities studied on both dates was similar in that each was composed of greater than 90% diatoms and green algae. However, if we compared percentages of major algal

Table 8-3. Taxonic profile of surface Phytoplankton assemblages (percent composition).

Date	Assemblage	Cells/liter	Percent of Total Identified				
			Diatoms	Greens	Blue-greens	Chrysophytes	Euglenoids
8/22/74	Control	$1.27X10^6$	70.57	27.66	----	1.77	----
	ΔT	$2.21X10^6$	67.48	31.91	1.42	1.22	----
	Control	$2.32X10^6$	62.52	32.23	4.85	----	----
	ΔT with chlorination	$2.14X10^6$	57.56	37.18	3.15	2.10	----
9/12/74	Control	$7.60X10^5$	33.14	63.61	----	3.25	----
	ΔT	$8.10X10^5$	41.83	55.40	0.55	2.22	----
	Control	$1.03X10^6$	37.12	59.83	0.87	2.18	----
	ΔT with chlorination	$1.01X10^6$	36.61	59.93	1.79	1.79	1.79

Table 8-4. Taxonomic profile of surface Phytoplankton assemblages (dominant organisms).

Date	Assemblage	Percent of total examined		
		Cyclotella glomerata	Coccoids	Other
8/22/74	Control	67.73	22.69	9.57
	ΔT	62.80	19.30	17.88
	Control	59.03	23.88	17.08
	ΔT with chlorination	54.41	25.00	20.58
9/12/74	Control	27.81	36.69	35.50
	ΔT	36.01	28.53	35.46
	Control	31.88	36.68	31.44
	ΔT with chlorination	30.94	28.25	40.81

groups on one date with the same groups on another (e. g., diatoms in August and greens in August with the same groups in September) we note a shift in dominance from diatoms in the August assemblages to greens in the September assemblages (Table 8-3). Diatoms noted on both dates were composed largely of the same species, Cyclotella glomerata. If we compared green algae on both dates, we note that the increase in percent composition of greens in September was not accompanied by a corresponding increase in the dominant group of greens, the coccoids (Table 8-4). The increase observed was probably in species of green algae other than the coccoids, many of which were unidentified; these are listed under the "other" category in Table 8-4. Thus, there exists the possibility that some or all of these "other" species were more sensitive to the stresses encountered during plume entrainment simulations (ΔT and low levels of residual chlorine).

8.1.3 Macrozooplankton

8.1.3.1 Methods and Materials

Gammarus spp. (Gammarus daiberi and G. tigrinus) were selected as the test organisms to be used in the plume entrainment studies as these amphipods were the most abundant macroinvertebrates entrained in the condenser cooling water system at Indian Point. Test organisms were collected at the Unit 1 intake stations and maintained in the laboratory for at least 48 hours prior to experimentation. Microscopic examination of the experimental test groups revealed that they were primarily G. daiberi.

Prior to experimentation, 40 Gammarus spp. were randomly

sorted into each test container (Figure 8-10 and Table 8-5). The containers were polyethylene jars with areas of the sides (63 x 63 mm) and tops (45 x 45 mm) removed and covered with 0.571-mm mesh nylon netting. During the experiment, the test containers were suspended from the floating transit rack (Figure 8-1). The experiment was conducted at three exposure sites:

1) A control area in the Hudson River outside of the detectable influence of the Indian Point thermal plume.

2) A 1-hour drift through the Indian Point plume, starting at the confluence of the discharge jets with the water surface.

3) A 1-hour exposure in the Indian Point discharge canal at station D-2.

Following plume exposure the test organisms were immediately transported to the Indian Point laboratory and examined for viability. Living organisms were then placed into 800-ml battery jars (20 per jar) and maintained at ambient river temperature for 5 days after plume exposure. The aquatic plant Myriophyllum sp. and assorted green algae served as substrate and food for Gammarus spp. The amphipod's diet was also supplemented with finely ground commercial fish food and presoaked maple leaves.

8.1.3.2 Results and Discussion

The survival of Gammarus spp. exposed to the Indian Point discharge plume using the transit rack is summarized in Tables 8-6 and 8-7. There was 100% survival of all test organisms immediately after plume exposure. During normal plant operation on August 22, there were no differences between the 5-day survival rates of organisms exposed in the plume, in the discharge

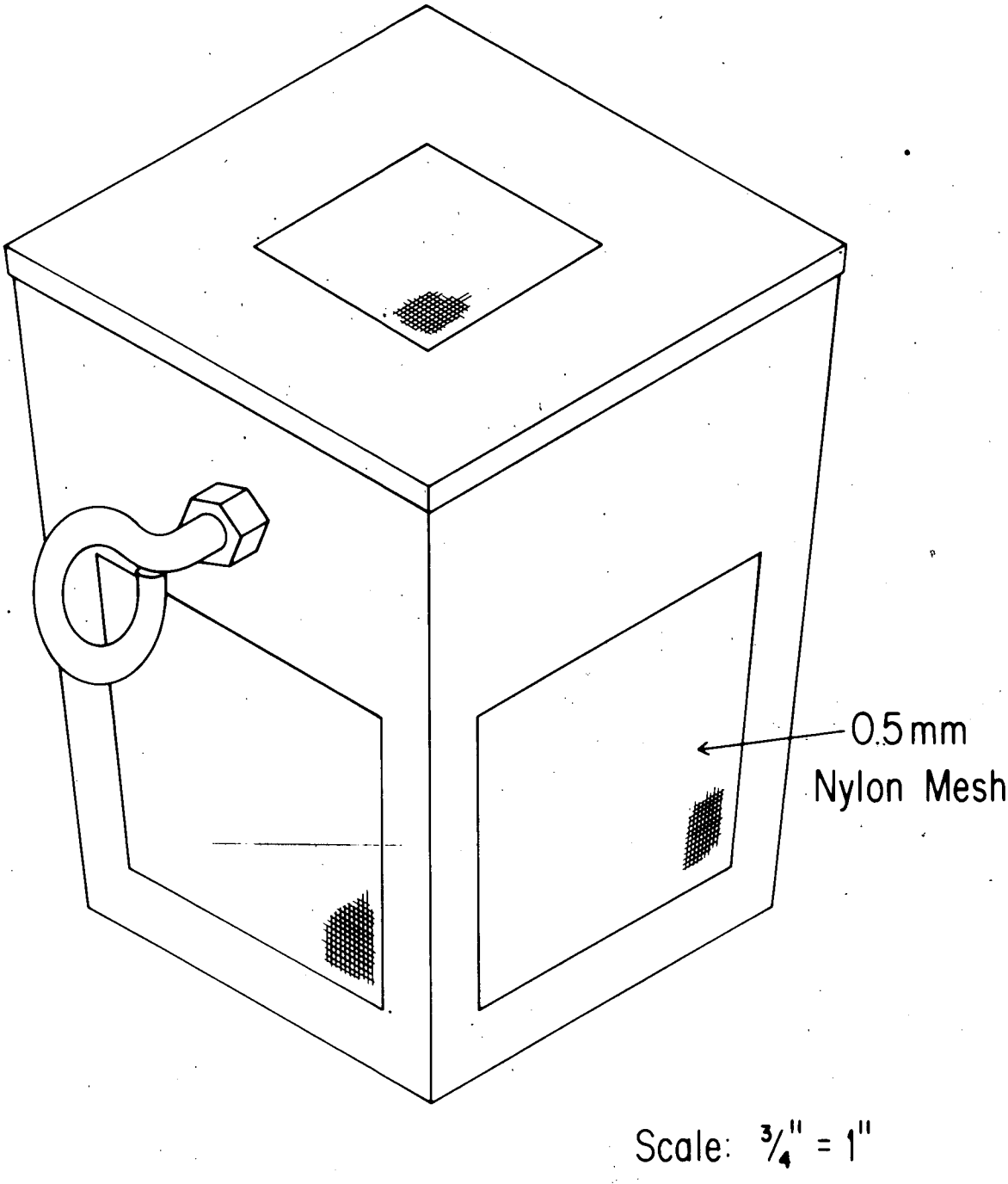


Figure 8-10. Experimental exposure chamber.

Table 8-5. Specifications of organism containers.

Phytoplankton bottle

Height:	13.21 cm.	
Diameter:	5.08 cm.	
Volume:	300.0 ml.	

Macrozooplankton cage

Top:	10.0 cm. square	(approximately 4.50 cm. square 0.571 mm mesh panel)
Sides:	13.5 cm. high	(approximately 6.30 cm. square 0.571 mm mesh panel)
Bottom:	8.5 cm. square	(no mesh)
Volume:	946.0 ml.	

Fish cage

Top:	12.5 cm. square	(approximately 9.00 cm. square 1.0 mm mesh panel)
Sides:	17.0 cm. high	(approsimately 9.00 cm. square 1.0 mm mesh panel)
Bottom:	9.0 cm. square	(no mesh)
Volume:	1.946 liters	

Table 8-6. Survival of Gammarus spp. following 1-hour exposures in the Indian Point discharge canal and discharge plume on August 22, 1974. The ambient temperature was 25.8°C; the discharge temperature was 33.0°C.

Station	Chlorination	n	Percent survival	
			Immediate	5 Day
Control	no	40	100	92.5
Plume	no	40	100	85.0
D-2	no	40	100	92.5
Control	yes*	40	100	87.5
Plume	yes	40	100	90.0
D-2	yes	40	100	65.0

*Control organisms maintained outside of chlorinated plume area.

Table 8-7. Survival of Gammarus spp. following 1-hour exposures in the Indian Point discharge canal and discharge plume on September 12, 1974. The ambient temperature was 24.0°C; the discharge temperature was 32.1°C.

Station	Chlorination	n	Percent survival		
			Immediate	1 Day	5 Day
Control	no	40	100	97.5	77.5
D-2	no	40	100	100.0	87.5
Plume	no	40	100	97.5	75.0
Control	yes*	40	100	100.0	80.0
D-2	yes	40	100	97.5	77.5
Plume	yes	40	100	97.5	67.5

*Control organisms maintained outside of plume area.

canal or maintained outside the plume as controls. Survival rates of Gammarus spp. exposed to the chlorinated plume in the river and at station D-2 on August 22 were not different from the controls. However, there was a reduced survival of organisms exposed at station D-2 when compared with the test group maintained in the plume (Table 8-6).

On September 12 (Table 8-7) there were no detectable differences in latent survival rates between the controls and the experimental groups exposed at D-2 or in the plume, tested before or during chlorination; however due to reduced survival in the controls during this portion of the experiment, the detection of subtle differences in latent mortality was limited.

The results will be discussed together with those for plume experiments with fish in the following section.

8.1.4 Fish

8.1.4.1 Methods and Materials

Experiments on the effects of simulated plume entrainment on juvenile striped bass (Morone saxatilis) included laboratory and field observations. Juvenile fish used in each study were obtained from the Verplanck hatchery (Hatchery Roe Number 26).

All fish were transferred from the Verplanck hatchery and acclimated to holding facilities in the New York University Indian Point laboratory for 72 hours prior to use in an experiment. Pre-experiment holding facilities consisted of 81-liter (56 x 41 x 36 cm) fiberglass flow-through aquaria which received a continuous supply of ambient Hudson River water. Each aquarium was kept in a shallow trough of flowing river water to help

maintain ambient water temperature. Approximately 100 M. saxatilis with an average length of 63 mm (S. E. = 0.30)* were held in each aquarium and fed on Tetramin. Constant aeration provided supplementary oxygen, and the laboratory fluorescent lighting was on automatic photoperiod providing 12 hours light and 12 hours dark per 24-hour cycle.

The same basic procedure was used to prepare fish for all experiments. Each replicate group was isolated from the holding aquaria just prior to exposure by randomly selecting and placing ten fish into a plastic test cage (See Figure 8-10 and Table 8-5) having five panels (top and sides) of 1.0-mm mesh netting. Cages were kept submerged in a 75-l pail half-filled with ambient Hudson River water until the beginning of the experiment. Mesh was ommitted from the cage bottom to allow retention of sufficient water to keep the fish submerged during transfer from the holding pails to the study site.

Field studies simulating the plume entrainment of juvenile striped bass involved the transit of caged fish through the Indian Point discharge plume on the organism exposure rack following the procedures outlined previously (Figure 8-1). Four groups of ten fish each were drifted through the plume for 1 hour in the absence of power plant chlorination, followed by an

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*Lengths were measured after preservation.

equivalent drift with different fish in the presence of chlorination. Separate control rack drifts were done for each experiment, and all drifts were done on the same day to minimize differences in plume configuration (exclusive of tidal change). Transit-rack movement patterns during the experimental period are shown in Figures 8-2 to 8-9.

8.1.4.2 Results and Discussion

Tables 8-8 and 8-9 provide the results of experiments simulating the plume entrainment of M. saxatilis juveniles. No immediate mortality was noted in juvenile fish exposed to plume ΔT alone (Figure 8-6, 8-7; Table 8-8) or plume ΔT with Unit 1 chlorination (Figure 8-8, 8-9; Table 8-9). Observations for latent mortality in groups exposed to plume ΔT and plume ΔT with chlorination indicated one and two dead fish, respectively, 72 hours after exposure. Control groups had 100% survival over the 96-hour period. Statistical examination indicated that the observed differences in mortality between the experimental and control groups were not significant.

Preliminary results from plume transit experiments using species of amphipods and striped bass and subsequent observations for latent mortalities showed that conditions in the Indian Point power plant's discharge plume had little or no impact on the organisms tested. As several groups of organisms were tested and survived with little to no effect as a result of exposure in the plant's discharge canal, it can be concluded that organisms entrained into the discharge plume would be little affected.

Table 8-8. Number of juvenile Morone saxatilis mortalities following exposure to the Indian Point discharge plume.

Replicates	Post-exposure time in hours					Condition total	
	I*	24	48	72	96	Dead	Alive
Control							
1	0	0	0	0	0	0	10
2	0	0	0	0	0	0	10
3	0	0	0	0	0	0	10
4	0	0	0	0	0	0	10
ΔT							
1	0	0	0	0	0	1	9
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0

* Immediately following 1-hour transit exposure.

Table 8-9. Number of juvenile Morone saxatilis mortalites following exposure to the Indian Point discharge plume during Unit 1 chlorination.

Replicates	Post-exposure time in hours					Condition total	
	I*	24	48	72	96	Dead	Alive
Control							
1	0	0	0	0	0	0	10
2	0	0	0	0	0	0	10
3	0	0	0	0	0	0	10
4	0	0	0	0	0	0	10
ΔT with Chlorination							
1	0	0	0	1	0	1	9
2	0	0	0	1	0	1	9
3	0	0	0	0	0	0	10
4	0	0	0	0	0	0	10

*Immediately following 1-hour transit exposure.

8.2 LABORATORY SIMULATIONS OF MICROZOOPLANKTON PLUME ENTRAINMENT

8.2.1 Methods and Materials

Initial experiments designed to test the effectiveness of organism cages in plume transit indicated that the mesh netting required to retain microzooplankton was too fine to permit adequate water exchange to the cage interior. As a result, a laboratory simulation was devised for use in lieu of cage transit through the plume.

Microzooplankton were collected from the power plant intake structures on the morning of an experiment or on the day preceding, with a 0.5-m diameter, #20-mesh (76μ) nylon net. Prior to use in an experiment, the collection debris (including dead organisms) was allowed to settle out of each sample while the organisms were maintained in a continuous-flow water bath maintained at ambient river water temperature.

Microzooplankton were exposed to simulated entrainment by immersing caged organisms in controlled-temperature water baths. Immersion baths consisted of 200-ml dishes (11.0 cm diameter; 3.5 cm high) placed in larger, continuously mixing water baths at a set temperature. All experimental temperatures in the 200-ml baths were recorded.

Immersion cages were made of transparent plastic cylinders (3.0 cm diameter; 2.1 cm high) fitted with 76μ-mesh nylon net bottoms. Organisms were introduced by adding a 10-ml sample aliquot to each cage. Therefore, the number of organisms per cage on a particular date depended upon the density of organisms present. Four replicate cages were prepared for each control

and experimental group.

Simulated exposure to plume ΔT was accomplished by immersing caged organisms in water baths maintained at the maximum ΔT observed in the power plant plume (discharge port area) at the time of the tests. Control cages were simultaneously immersed in water baths at ambient river water temperature. Following the 1-hour immersion, cages were transferred to and held in water baths at ambient river temperature.

Simulated exposure to plume ΔT with chlorination was accomplished as follows. A water sample was collected from the power plant condenser as soon as chlorine residual was detected during hypochlorite application. Chlorinated condenser water was diluted to produced concentrations equal to 50 and 25% of that in the condenser. Two sets of three 200-ml water baths, each containing 100, 50 and 25% of the condenser chlorine concentration, were prepared. One set was placed in a water bath (Magni-Whirl Incubator; Blue M. Co., Blue Island, Illinois) at plume temperature, while the other was placed in a continuous-flow trough receiving river water at ambient temperature. Organisms were exposed to each residual chlorine level in each of the two test temperatures by transferring immersion cages from one water bath to another at 20-minute intervals for 1-hour. Cages were placed in 100% chlorinated condenser water for the initial 20 minutes and transferred to 50 and 25% dilutions for the remaining time. Following exposure, all cages were suspended in a 9.5-liter tank receiving flowing river water at ambient temperature with sup-

plemental aeration. One half of the organisms were observed for immediate effects 1-hour after exposure and the remainder were examined for latent effects 24-hours later.

8.2.2 Results and Discussion

Copepod survival following exposure to consecutive dilutions of Indian Point discharge water is summarized in Tables 8-10 and 8-11. In all cases there were no statistically significant differences between the initial and latent survivals of control groups and test groups exposed to simulated plume temperatures. Test groups exposed to chlorinated samples (both ambient temperature and heated) displayed consistently lower survival rates than organisms maintained at controlled conditions. All Eurytemora affinia exposed to chlorinated water samples at simulated plume temperatures died within 24 hours after exposure (Table 8-12). E. affinis exposed to chlorinated water at ambient temperature had fewer survivals than non-chlorinated controls, although the survival was statistically higher than for the exposures to heated, chlorinated water.

Acartia tonsa exposed to chlorinated water at plume and ambient temperatures died within 24 hours (Table 8-10). Also, significant reductions in the survival of A. tonsa exposed to chlorine were observed within 1 hour after testing (Table 8-11).

These data indicate that combined stresses of temperature and chlorine resulted in higher latent mortalities than chlorine alone, whereas temperature without chlorine treatment did not result in detectable mortalities.

Table 8-10. Immediate survival of copepods exposed to simulated plume bioassays for 1 hour. Ambient temperature was 24.0°C; plume temperature, 29.1°C. Condenser chlorine (total residual) was 0.44 mg/l.

	Percent Survival			
Species	Ambient	Plume	Chlorinated ambient	Chlorinated plume
Eurytemora affinis	99.1 (116)[1]	96.9 (96)	86.4 (81)	74.1 (85)
Acartia tonsa	100.0 (32)	94.8 (39)	34.8 (46)	11.7 (60)

[1]Number of test organisms.

Table 8-11. Latent survival of copepods exposed to simulated plume bioassays for 24 hours. Ambient temperature was 24.0°C; plume temperature, 29.1°C. Condenser chlorine (total residual) was 0.44 mg/l.

Species	Percent Survival			
	Ambient	Plume	Chlorinated ambient	Chlorinated plume
Eurytemora affinis	80.0 (70)[1]	61.4 (57)	30.2 (53)	0.0 (19)
Acartia tonsa	80.0 (30)	85.7 (21)	0.0 (35)	0.0 (23)

[1]Number of test organisms.

Table 8-12. Survival of *Gammarus* spp. and *Leptocheirus plumulosus* following 1-hour exposures at the intake and station D-2 during condenser chlorinations on July 25 and August 1, 1974.

Date	Species	Station	Temp. (°C)	n	Percent Survival Immediate	5 Day
25 July	*Gammarus*	Control	26.2	40	100	90.0
		D-2	33.3	40	100	92.5
1 August	*Gammarus*	Control	25.3	40	100	97.5
		D-2	28.2	40	100	97.5
	Leptocheirus	Control	25.3	30	100	96.7
		D-2	28.2	30	100	93.3

Although these experiments were designed to test the effects of severe temperature (maximum ΔT in discharge plume) and chlorine residuals upon representative microzooplankters, they were, in essence, effects of plant entrainment. Maximum ΔT values are only realized at the discharge port area of the discharge plume, and there only for a very short time (less than 20 minutes, before being diluted by river water. Residual chlorine levels were less than 0.05 ppm and generally below our level of detection within the discharge plume, and the dilutions of 50 to 25% of condenser box levels would probably be much higher than would be experienced by plume entrained organisms. Since only half of a unit's condensers are chlorinated at a time, the chlorine concentration of the cooling water flow is reduced approximately 50% at the confluence of the condenser water boxes. Moreover, further chlorine dilution would result from the cooling water flow from other units prior to the discharge area.

These experiments suggest that copepod representatives of the microzooplankton will probably survive any temperature regime in the Indian Point power plant's discharge plume, and probably even after plant chlorination, as chlorine levels will have dissipated to minimal values prior to its discharge into the river.

8.3 OTHER SIMULATION EXPERIMENTS

Other simulation experiments involved the immersion of caged macrozooplankton in the discharge canal at Station D-2 prior to and during chlorination, and the exposure of juvenile fish to

discharge-canal water taken from Station D-1 to establish critical limits for plume entrainment. These were designed to observe the effects of extreme cases of plume-ΔT simulation, both with and without plant chlorination, upon selected organisms.

8.3.1 Macrozooplankton

8.3.1.1 Methods and Materials

Gammarus spp. and Leptocheirus sp. were used at test organisms for these experiments. The experimental design was basically similar to that described earlier for plume-transit studies with Gammarus. In this case, exposure was in the discharge canal at Station D-2.

After 1 hour of exposure at Station D-2, the test organisms were immediately returned to the Indian Point laboratory and examined for viability. Living organisms were placed into 800-ml battery jars (20 per jar) and maintained at ambient river temperatures for 5 days after exposure.

8.3.1.2 Results and Discussion

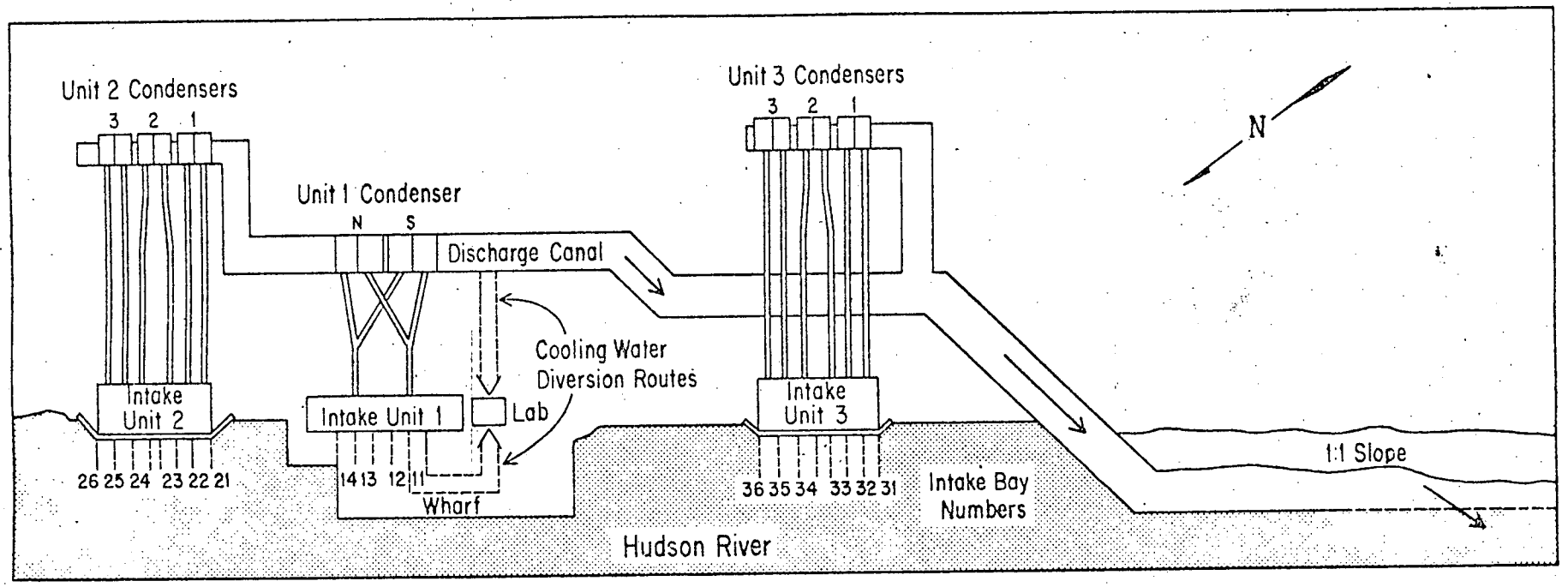
The survival of amphipods exposed to entrainment in the discharge canal at Station D-2 is shown in Table 8-12. On July 25, during operation of Indian Point Units 1 and 2, and with chlorination at Unit 2, there were no detectable differences in the latent survivals of controls and test groups. On August 1, the Unit 1 discharge was diluted by a factor of 50% by the operation of two Unit 2 circulating pumps without ΔT. No effects on 5-day latent survivals of Gammarus and Leptocheirus plumulosus exposed during this period were observed.

These results suggest that if the organisms were able to survive the drastic conditions existing in the discharge canal, the milder conditions in the discharge plume should have little or no effect on river organisms entrained into it.

8.3.2 Fish

8.3.2.1. Methods and Materials

Laboratory experiments involved the exposure of juvenile striped bass to extremely severe conditions of plume ΔT by using heated cooling-water diverted from the plant discharge canal prior to and during chlorine application. It was not possible to immerse test cages in the discharge canal itself, as the water flow in the canal would have impinged the fish against the sides of the test cages. Instead, in these experiments, water was pumped through PVC pipelines from the intake and discharge canal to control and experimental exposure aquaria in the Indian Point wet lab. The aquaria held 37.85 liters (51 X 31 X 27 cm) the discharge water was allowed to enter and overflow the aquarium for 1-hour. Chlorine levels were monitored in all experiments to characterize residual levels during chlorination and to confirm the absence of chlorine when no chlorination was occuring. A schematic of the cooling-water diversion routes and a graphic summary of observed total residual chlorine levels are provided in Figure 8-11. At the conclusion of an experiment, fish were examined for immediate mortality and survivors were retained for 24 hours to permit observation of latent effects. Survivors in each replicate group were placed in separate 37.85-liter glass-covered aquaria filled with filtered Hudson River



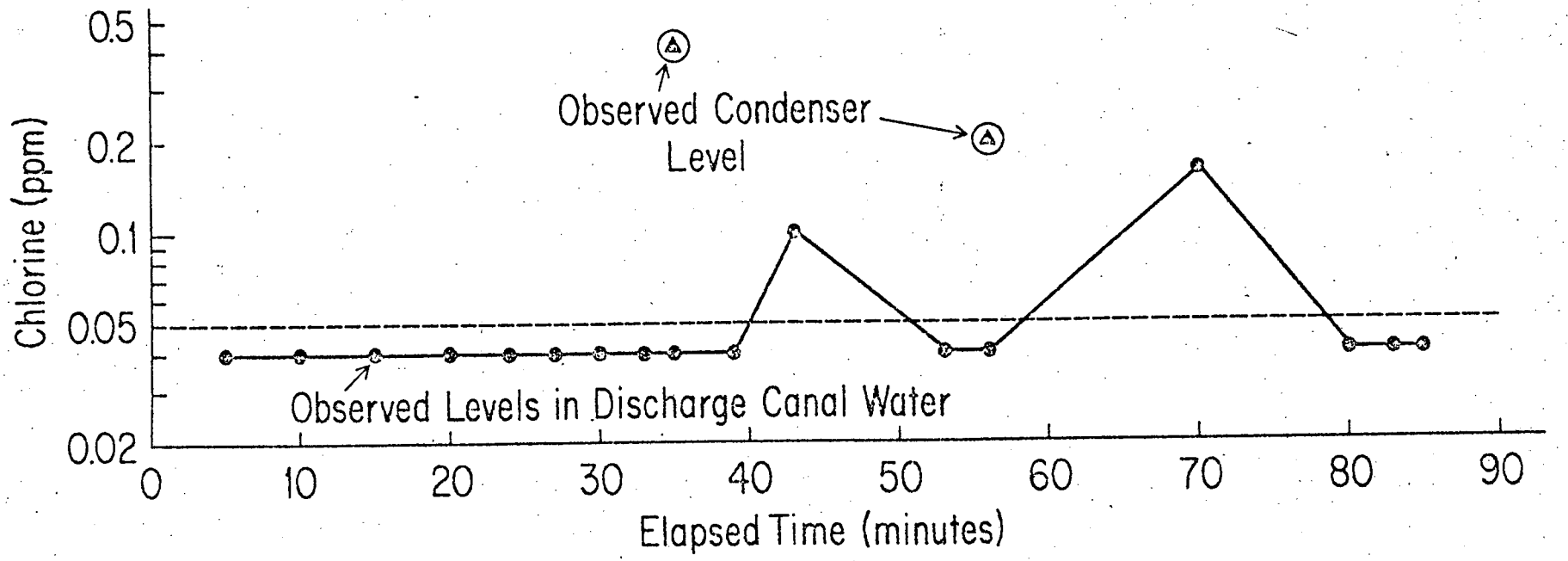


Figure 8-11. Schematic of Indian Point cooling-water diversion routes with observed discharge-canal chlorine levels during "worst possible case" plume entrainment simulation.

water at ambient temperature. All other holding conditions were the same as described for pre-experimental periods.

8.3.2.2. Results and Discussion

Tables 8-13 and 8-14 present the results of the laboratory simulations of "worst possible case" discharge-canal entrainment at the Indian Point station. Immediate mortalities in juvenile fish exposed to simulations of a plume ΔT of 6.8°C (12.2°F) reached 50% in three replicate groups and 60% in the fourth group. Control groups at the ambient river temperature of 24.0°C (75.2°F) had one mortality in one replicate group (10%) and no mortality in the other three groups (Table 8-13).

Observations for latent mortality (24 hours after exposure) indicated no additional deaths in any of the experimental groups. However, there were five additional deaths in the control replicate groups (Table 8-13).

Immediate mortalities of juvenile fish exposed to simulations of a plume ΔT of 6.9°C (12.4°F) and residual chlorine levels attaining 0.16 ppm during Unit 2 chlorination ranged from 20 to 50%. (See Figure 8-11 for measured chlorine levels during the exposure period.) Mortality in the controls was 10%, or one fish per replicate (Table 8-14). Observations for latent mortality (24 hours after exposure) indicated no additional deaths in any experimental group although there was one additional death in the control groups (Table 8-14).

Statistical analyses using 8 X 2 contingency tables showed significant differences, but the G-test on all possible combinations of rows and columns failed to show where the differences

Table 8-13. Number of juvenile Morone saxatilis mortalities following simulated "worst possible case" discharge-plume entrainment ΔT (units 1 and 2) at the Indian Point Nuclear Station.

Replicate	Mortalities		Total	
	Immediate*	24 hours	Dead	Alive
Control				
1	1	2	3	7
2	0	0	0	10
3	0	2	2	8
4	0	1	1	9
ΔT				
1	5	0	5	5
2	5	0	5	5
3	6	0	6	4
4	5	0	5	5

* Immediately following one hour exposure.

Table 8-14. Number of juvenile Morone saxatilis mortalities following simulated "worst possible case" discharge plume entrainment ΔT (units 1 and 2) chlorination at the Indian Point Nuclear Station.

Replicate	Mortalities		Total	
	Immediate*	24 hours	Dead	Alive
Control				
1	1	0	1	9
2	1	1	2	8
3	1	0	1	9
4	1	0	1	9
ΔT with Chlorination				
1	5	0	5	5
2	5	0	5	5
3	4	0	4	6
4	2	0	2	8

* Immediately following one hour exposure.

were. When all control, plume-ΔT, and plume ΔT with chlorination exposure groups were combined to form a 2 x 2 Contingency Table, analysis indicated statistical differences in mortality between all control and experimental groups at immediate and latent observation times.

Contingency table analysis for the numbers dead and numbers alive for immediate and latent observations for each ΔT and ΔT with-chlorination group (8 x 2) from field transit and laboratory simulations showed no significant differences among the eight rows. Additional comparisons made among the control groups, ΔT groups, and ΔT-with-chlorination groups failed to detect any significant differences. Therefore, observed chlorine levels did not appear to add significant mortality to that produced by ΔT. Generally, these results were similar to those found for the macrozooplankton; the discharge plume would have little to no effect on river organisms entrained into it.

8.4 PREFERENCE AND AVOIDANCE STUDIES

8.4.1. Methods and Materials

In conjunction with plume entrainment studies, laboratory studies were conducted to examine the response of Gammarus spp. to heated and chlorinated discharge water in an experimental avoidance chamber (Figure 8-12). The chamber was constructed of 0.64-cm thick plexiglass. Overall dimensions of the chamber were 908 X 451 X 152 mm. The chamber was divided into sections, with a vertical plexiglass sheet separating quadrants 1 and 4. Intake and effluent water were injected into quadrants 1 and 4, respectively, at the rate of 5.45 liters per minute for each source (10.9 l/min total flow). Constant flow was maintained

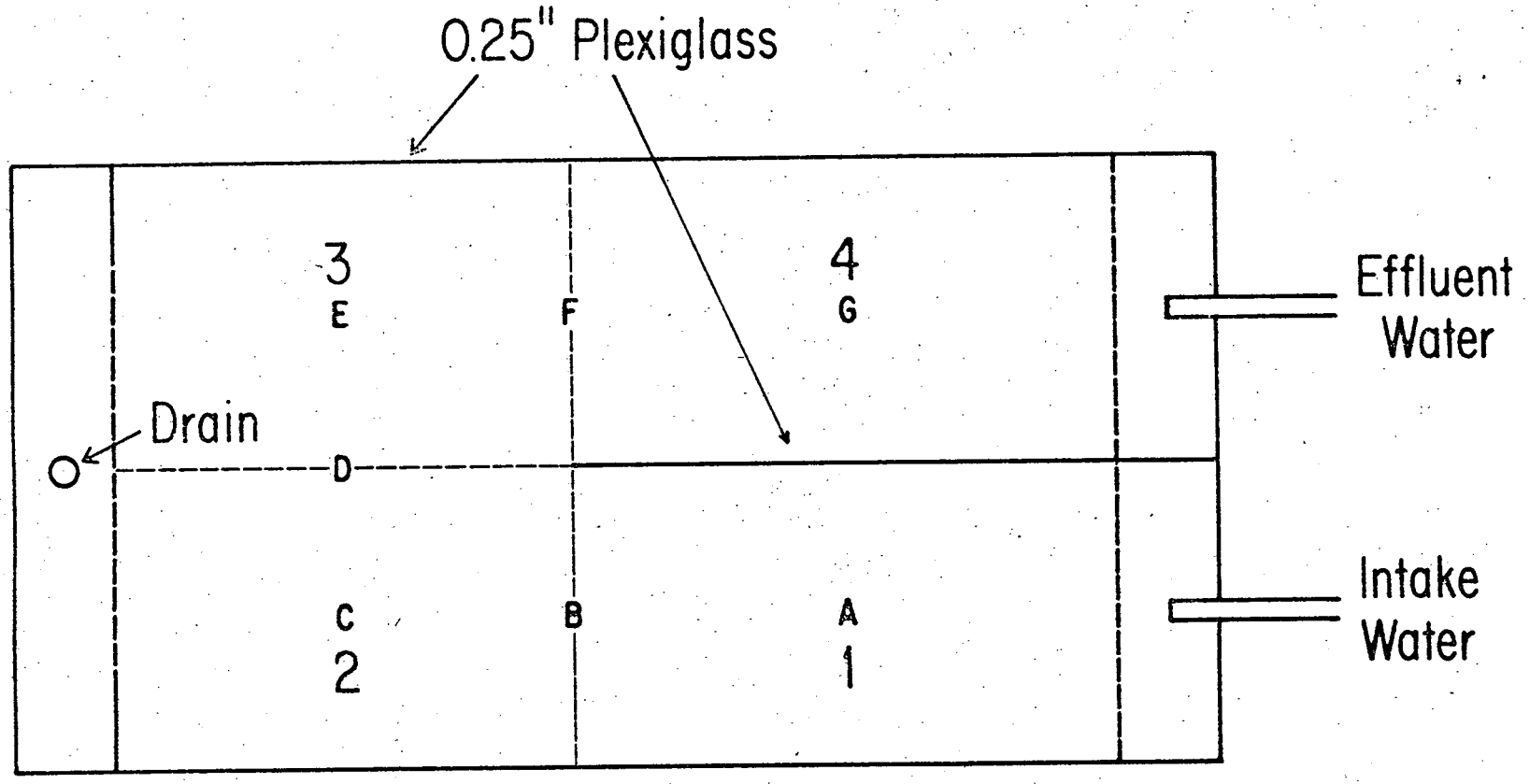


Figure 8-12. Experimental avoidance chamber. Temperatures were measured at points A through G.

by head boxes. Some mixing occurred in quadrants 2 and 3 before the water passed through a 571μ-mesh nylon screen prior to the drain. Dye studies revealed no transfer of water between quadrants 1 and 4.

During operation the water depth in the chamber was 22 mm. Lighting was provided by two 40 W cool-white fluorescent tubes suspended 1.3 m above the chamber.

The experimental procedure consisted of introducing eight Gammarus spp. simultaneously into the centers of quadrants 1 and 4. Counts of the numbers of organisms in each quadrant were then made by two observers, one counting quadrants 1 and 2, the other counting quadrants 3 and 4. Temperature at the mid-depth (11 mm) at points A through G (Figure 8-12) was measured at 5-minute intervals with a YSI thermister telethermometer. Control conditions were established by testing the chamber with Hudson River water introduced into both quadrants 1 and 4 (intake versus intake.)

A total of four experiments were run during a period when ambient river temperatures varied from 15.3 to 16.0°C (59.5 to 60.8°F) and when Indian Point discharge temperatures ranged from 22.1 to 23.2°C (71.8 to 73.7°F). In the two control experiments, Indian Point intake water was introduced into both sides of the chamber (intake-intake). The two avoidance experiments consisted of introducing intake water and heated discharge water and intake water and chlorinated heated discharge water into the two sides of the chamber (intake-discharge).

All of the Gammarus spp. used for temperature and/or chlorine avoidance experiments were maintained in the laboratory and examined for viability 24 hours after exposure.

8.4.2 Results and Discussion

Preliminary temperature avoidance experiments on Gammarus spp. conducted during normal plant operation at Indian Point (without chlorination) are presented in Table 8-15. The relative occurrence of Gammarus differed among quadrants 1 through 4 in both intake-intake and intake-discharge experiments (see Figure 8-12) and there were no apparent differences between intake-intake and intake-discharge experiments in the occurence of Gammarus in quadrants 3 and 4. These distributions of test organisms in the chamber indicated that, for ambient river temperatures of 15.6 to 15.7°C (60.1 to 60.3°F), there was no detectable response of Gammarus to a ΔT of approximately 7.3°C (13.1°F). Response of experimental animals under these conditions was similar to animals tested under control conditions (ambient river water), in that the amphipods moved freely throughout the four quadrants with no particular preference or avoidance.

The results of monitoring temperature and chlorine levels in avoidance experiments simulating plant operation with chlorination are shown in Table 8-16. No residual chlorine (< 0.05 ppm) was seen in the intake samples during the experimental period, while a range of < 0.05 to 0.40 ppm was detected in the discharge water. In these experiments, Gammarus spp. avoided quadrant 4, which received undiluted discharge water (Table 8-17). The numbers of Gammarus counted in quadrant 3 were not reduced when compared with

Table 8-15. Distribution of Gammarus spp. in the experimental temperature avoidance trough. Tests were conducted during periods of no condenser chlorination.

Time (min)	Distribution by quadrants: Intake-Intake 1	2	3	4	Intake-Discharge 1	2	3	4
0	8	-	-	8	8	-	-	8
5	3	7	4	2	4	5	1	6
10	6	2	4	4	5	4	2	5
15	2	8	4	2	6	4	2	4
20	3	4	4	5	5	5	4	2
25	2	5	3	6	3	4	8	1
30	3	8	1	4	2	7	3	4
35	3	6	3	3	0	5	10	1
40	2	5	5	4	0	10	4	2
45	1	5	5	5	1	9	5	1
50	10	5	1	0	0	4	9	3
55	6	6	4	0	0	9	5	2
60	6	6	3	1	0	9	5	2
Mean	3.92	5.58	3.42	3.00	2.17	6.25	4.83	2.75
95% C.I.	±1.64	±1.07	±0.83	±1.27	±1.48	±1.51	±1.82	±1.05

Table 8-16. Temperature and chlorine data collected during temperature avoidance studies.

	Measurement Point								
	Intake headbox								Discharge headbox
	(I Box)	A	B	C	D	E	F	G	(D Box)
$\bar{X}$ Temperature °C									
Intake-Intake	15.6	15.6	15.7	15.8	15.9	15.9	15.9	15.9	15.8
Intake-Discharge (no cl)	15.7	15.7	15.9	16.0	18.8	22.5	22.7	22.8	23.0
Intake-Intake	15.4	15.4	15.6	15.7	15.8	15.8	15.7	15.7	15.7
Intake-Discharge (during cl)	15.3	15.3	15.4	15.6	19.1	21.9	22.1	22.1	22.3

Total chlorine residual mg/l		I Box	D Box
Intake-Intake (2 experiments)	$\bar{X}$	0.0	0.0
	range	0.0	0.0
Intake-Discharge (no cl)	$\bar{X}$	0.0	0.0
	range	0.0	0.0
Intake-Discharge (during cl)	$\bar{X}$	0.0	0.16
	range	0.0	0.03-0.40

Table 8-17. Distribution of Gammarus spp. in the experimental temperature avoidance trough during condenser chlorination.

Time (min)	Distribution by quadrants: Intake-Intake 1	Intake-Intake 2	Intake-Intake 3	Intake-Intake 4	Intake-Chlor. Discharge 1	Intake-Chlor. Discharge 2	Intake-Chlor. Discharge 3	Intake-Chlor. Discharge 4
0	8	-	-	8	8	-	-	8
5	6	5	3	2	8	4	3	1
10	6	5	3	2	4	7	5	0
15	5	2	7	2	6	10	0	0
20	4	5	6	1	6	6	4	0
25	4	6	3	3	6	7	3	0
30	3	7	4	2	-*	-	-	-
35	3	6	6	1	6	9	1	0
40	6	5	4	1	5	6	5	0
45	4	8	2	2	7	6	3	0
50	2	6	3	5	7	6	3	0
55	2	8	4	2	6	6	4	0
60	2	8	6	2	5	8	3	0
Mean	3.92	5.91	4.25	2.08	6.00	6.82	3.09	0.09
95% C.I.	±1.00	±1.10	±1.02	±0.69	±0.74	±1.11	±1.02	±0.20

* missed observation

pre-chlorination experiments. However, all of the test organisms found in quadrant 3 in tests with chlorination were positioned centrally near the drainage screen (see Figure 8-12). Dye studies with the chamber revealed considerable dilution of effluent water near the division between quadrants 2 and 3. Thus it appears that Gammarus spp. were able to detect the presence of chlorinated water entering at quadrant 4 and moved to areas of little or no chlorine content.

No mortalities were noted for any of the test groups during 24 hours of observation after testing.

Based on laboratory studies Gammarus spp. would be expected to actively avoid the residual chlorine concentrations encountered in the Indian Point thermal plume near the discharge ports. It is not known if Gammarus spp. could detect and avoid the much lower chlorine concentrations occurring in the more diluted plume not adjacent to the discharge ports. In situ bioassays indicate, however, that Gammarus spp. are able to pass through the Indian Point thermal plume during chlorination without displaying increases in immediate or latent mortalities.

9. LONGITUDINAL HUDSON RIVER SURVEY

A series of seasonal surveys of the Hudson River estuary from Albany to the Battery was begun in September 1973 and will continue through 1976. The survey was initiated to determine the the temporal and spatial distributions of phytoplankton populations in the estuary and its major tributaries. Physical and chemical data were also collected to determine trends in these parameters and their influence on phytoplankton dynamics.

In 1974 a comparison of samples from selected tributaries and the Hudson River was initiated to determine whether observed river phytoplankton species assemblages are endemic or passive.

The sampling of tributaries was discontinued in 1975; however, sampling of the river stations was expanded to include macrozooplankton and ichthyoplankton, in addition to phytoplankton.

The purpose of the overall longitudinal survey is to obtain a general biological perspective of the Hudson River estuary and to analyze the relationship of the biota sampled at Indian Point to the entire estuarine ecosystem.

9.1 Sampling Stations

Table 9-1 indicates the 30 sampling stations used for river and tributary analysis in 1973 and 1974. Samples collected in 1975 included only river stations R-1 through 6-16. Sampling in the spring, summer and fall of 1974 was begun at a point 1 mile above Troy Dam (Station R-1). The nest station sampled was just below the dam at milepoint 150. All subsequent samples were collected at

Table 9-1. Hudson River and tributary sampling stations.

Tributary location	Station	River location	Mile-point	Station
Mohawk River	T-17	Upper Hudson	151	R-1
		Dam (Troy)	150	R-2
Poeston Kill	T-18		148	
		Albany	140	R-3
Papscanee Creek	T-19		135	
		Coeymans	130	R-4
Stockport Creek	T-20	Stockport Creek	119	R-5
Catskill Creek	T-21		111	
		Inbocht Bay	108	R-6
Esopus Creek	T-22		102	
		Turkey Point	96	R-7
Rondout Creek	T-23		90	
		Port Ewen	89	R-8
		Poughkeepsie	74	R-9
Wappinger Creek	T-24		66	
		Danskammer Pt.	64	R-10
Fishkill Creek	T-25		58	
Moodna Creek	T-26		56	
		Cold Spring	52	R-11
Popolopen Creek	T-27		46	
Peekskill Creek	T-28		45	
		Indian Point	42	R-12
Cedar Pon Creek	T-29		38	
Croton River	T-30		35	
		Scarborough	30	R-13
		Greystone Station	17	R-14
		West 112 th St.	7	R-15
		Battery (40°-42' N.)	0	R-16

intervals of approximately 10 nautical miles to milepoint 0 (Station R-16) at the Battery.

9.2. Methods

Physical and chemical data were obtained from surface-water samples. Physical data collected at each station included water temperature, air temperature, depth and light intensity. The chemical data analyzed at the time of collection included pH, dissolved oxygen, alkalinity (as $CaCO_3$), and salinity.

Water samples were frozen immediately for subsequent analysis of the following dissolved nutrients: nitrite, nitrate, orthophosphate, total phosphate and silicate. Particulate and dissolved concentrations of the following materials were also obtained from frozen samples: Cd, Co, Cu, Ni, Mn, Pb, Fe, Zn and organic carbon.

Biological samples collected during 1973-1974 included phytoplankton, microzooplankton and Chlorophyll a. Phytoplankton was collected by whole-water surface samples and preserved with Lugol's solution. Phytoplankton enumeration and identification was carried out using the gridded-filter technique.

Chlorophyll a was determined in the field by measuring the fluorescence of water passed through a continuous-flow fluorometer. Fluorescence was determined for samples from discrete depths at 5-ft intervals from the surface to the bottom of the water column. Four 50-ml surface-water samples were filtered in the field (Millipore) for laboratory determination of chlorophyll a by the acetone-extraction technique.

Microzooplankton was collected by vertical tows with a #20-mesh (76μ) conical plankton net.

During 1975, macrozooplankton and ichthyoplankton were collected by 10-minute tows taken against the prevailing current. Collection and analysis followed the same procedures as outlined in section 6.1 for macrozooplankton river population studies. A major part of the macrozooplankton studies will concern the analysis of the distribution and life history of Neomysis americana and Gammarus spp.

Data analysis and discussion of the longitudinal river surveys from 1973 to 1975 will be presented in the 1975 annual report. At that time the 3-year data base of physical and chemical studies will be integrated with the biological data to develop an overall description of the Hudson River estuarine ecosystem.

REFERENCES

Abood, K. A., 1974. Circulation in the Hudson River esturary. Ann. N. Y. Acad. Sci., volume 250.

American Public Health Association, 1971. Standard methods for the examination of water and wastewater. 12th. edition, Amer. Public Health Association., New York.

Carpenter, E.J., 1971. Annual phytoplankton cycle of the Cape Fear River esturary, North Carolina. Ches. Science, 12:95.

Flemer, D.A., C. Keefe, D. Hamilton and J. Mihursky, 1971. The effects of thermal loading and water quality on estuarine primary productivity. Ref. 71-6b, Natural Resources Institute, Univ. Md.

Fleminger, A., and R. Clutter, 1965. Avoidance of towed nets by zooplankton. Limnol. and Oceanogr., 10:96.

Ginn, T. C., W. Waller and G. Lauer, 1974. The effects of power plant condenser cooling water entrainment on the amphipod Gammarus sp. Water Res., 8:937.

Hutchinson, G.E., 1967. A treatise on limnology. vol. II-Introduction to lake biology and the limnoplankton. John Wiley and Sons, New York.

Kaliff, J., 1967. Phytoplankton abundance and primary production rates in two artic ponds. Ecology, 48: 558.

Kruskal, W. H. and W. A. Wallis, 1952. A use of ranks in one-criterion variance analysis. Jour. Amer. Stat. Assn., 47: 583.

Lauer, G., W. Waller, D. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko and P. Storm, 1974. Entrainment studies on Hudson River organisms. Proc. 2nd. Entrainment and Intake Screening Workshop, Baltimore, Md., 1973.

Lawler, Matusky and Skelly Engineers, 1974. 1973 Hudson River aquatic ecology studies in the vicinity of Danskammer Point. A report to the Central Hudson Gas and Electric Corp.

----------, 1975a. 1973 Hudson River aquatic exology studies-Bowline Point and Lovett generating stations. A report to Orange and Rockland Utilities.

----------, 1975b. Aquatic ecology of the Cape Fear River estuary, North Carolina. A report to the U. S. Army Engineers, Wilmington District, N. C.

Mann, H. B. and D. R. Whitney, 1947. On a test of whether one of two random variables is stochastically larger than the other . Ann. Math. Stat., 18: 50.

Morgan, R. P. II, and R.G. Stross, 1969. Destruction of phytoplankton in the cooling water supply of a steam-electric station. Ches. Science, 10: 165.

Natrella, M. G., 1963. Experimental statistics. National Bureau of standards Handbook 91, U. S. Dept. Commerce, National Bureau of Standards, Washington, D. C.

New York University, 1973. Effects of entrainment by the Indian Point power plant on Hudson River biota: a progress report for 1971 and 1972 to the Consolidated Edison Co. of New York. New York University Medical Center, New York.

----------, 1974. Effects of entrainment by the Indian Point power plant on Hudson River biota: a progress report for 1973 to the Consolidated Edison Co. of New York. New York University Medical Center, New York.

Ostle, B., 1963. Statistics in research. The Iowa State University Press, Ames, Iowa.

Patrick, R., 1961. A study of the numbers and kinds of species found in rivers in eastern United States. Proc. Acad. Nat. Sci. Philadelphia, 113: 215.

Pielou, E. C., 1975. Ecological diversity. John Wiley and Sons, New York, New York.

Quirk, Lawler and Matusky Engineers, 1974. 1971-1972 Hudson River aquatic ecology studies at Bowline, pre-operational conditions. A report to Orange and Rockland Utilities.

Raymont, J. E. G., 1963. Plankton and productivity in the oceans. Pergamon Press, New York.

Saunders, G., F. Trama and R. Bachman, 1962. Evaluation of a modified ^{14}C- technique for shipboard estimation of photosynthesis in large lakes. Great Lakes Res. Div. Publ. Number 8.

Scheffe, H,. 1959. Analysis of variance. John Wiley and Sons, New York.

Shannon, C. E., 1948. A mathematical theory of communication. Bell System Tech. J., 27: 379-423 and 623-656.

Sokal, R. and J. Rohlf, 1969. Biometry. Freeman Publ. Co., San Francisco, California.

Steeman-Nielsen, E. 1952. Use of radioactive carbon (^{14}C) for measuring organic production in the sea. J. Cons. Int. Explor. Mer., 18: 117.

Strickland, J. and T. Parsons, 1972. A practical handbook of seawater analysis, Bull. 167, Fish. Res. Bd. Canada.

Texas Instruments, Inc. 1974. Hudson River ecology study in the area of Indian Point, volume 7. A report to the Consolidated Edison Co. of New York.

----------. 1975. First annual report for the multiplant impact study of the Hudson River estuary. A report to the Consolidated Edison Co. of New York.

Vollenweider, P. (ed.), 1969. A manual on methods for measuring primary production in aquatic environments. IBP Handbook 12, F. A. Davis Co., Philadelphia, Penn.

Wang, C. and D. Willis, 1965. Radiotracer methodology in biological science. Prentice Hall, Englewood Cliffs.

Warinner, J. E. and M. Brehmer, 1966. The effects of thermal effluents on marine organisms. Air-water Pollut., 10: 277.

Wiebe, P. H. and W. R. Holland, 1968. Plankton patchiness' effects on repeated net tows. Limnol. and Oceanogr., 13: 315.

Wiener, N., 1948. Cybernetics. John Wiley and Sons, New York, New York.

Yentch, C. S. and J. H. Ryther, 1969. Relative significance of the net plankton and nannoplankton in the waters of Vineyard Sound. J. Cons. Int. Explor. Mer., 24: 231.