HUDSON RIVER ECOSYSTEM STUDIES

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

Progress Report for 1976

Prepared by

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for

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

Purchase Order Number 8-0248-325

July 1978

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FOREWORD

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

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

This progress report to Con Edison documents the results of research carried out by the New York University Medical Center Laboratory for Environmental Studies during 1976.

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

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SUMMARY

This report summarizes the progress of studies conducted in 1976 to determine the effects of pump entrainment by the Indian Point nuclear power station on Hudson River organisms. As in the four previous years' of study, emphasis was placed on the potential effects of entrainment on organisms passing through the plant's condenser cooling system.

In 1976 the Indian Point station included three completed units (Unit 1, Unit 2 and Unit 3). Unit 1 was inoperative the entire year. Unit 2 was functional, but because of scheduled and unscheduled plant shutdowns for maintenance and repairs it operated sporadically during the year. None of this operational time occurred during the "striped bass season" from May through July. Unit 3 was operational with at least three circulator pumps for the entire sampling season. However, some samples (those for May 18 and 25) were not taken at the Unit 3 intake because the intake structures were obstructed by the deployment of a wave-deflector.

River population sampling for all planktonic forms except phytoplankton was carried out in 1976 as in 1971 through 1975. Comparisons of abundance and physiology of river populations will be limited to the years 1971, 1972, and 1974 through 1976 because during the 1973 sampling

season, Units 1 and 2 were off-line much of the time. The basic sampling program during 1976 focused on spatial and temporal distribution of organisms entrained in the Unit 3 intakes.

As Unit 2 was inoperative for the major portion of the sample year, studies were limited to entrainment at Unit 3. In addition, the in-plant studies were modified to include the collection of river samples along a north-south station parallel to the plant intakes simultaneous with each plant sample. It was hoped that this sampling regime would provide a better estimate of river populations susceptible to entrainment. The velocity-reduction cones employed on all sampling nets in the plant during 1974 and 1975 were removed because they were considered ineffective in reducing net mortalities by not reducing the velocity of water flow across the net surface. The cones were replaced with flow-meters in order to obtain better volume estimates during sample collection.

POPULATION STUDIES

The river biota population studies conducted in 1976 were designed to: 1)measure the temporal and spatial distribution of species susceptible to entrainment by the Indian Point facility; and 2) determine whether observed damage to entrained organisms adversely affected populations of those organisms in the river. The results of population studies completed in previous years are presented in our preceding

progress reports (New York University Medical Center, 1973, 1975, 1976a).

Microzooplankton River Populations

River microzooplankton populations were dominated in 1976 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 *Keratella cochlearis* and the protozoans *Centropyxis* sp. and *Carchesium* sp.

The species list of microzooplankton observed in river samples collected from 1971 through 1976 has shown little change from year to year. The yearly appearance of the most frequently occurring copepods and cladocerans (*A. tonsa*, *E. affinis*, *B. longirostris* and *D. brachyurum*) was consistent for all years. The most common rotifer in 1971 was *Brachionus angularis*, while in 1974 and 1975 it was *Nothalca accuminata*. In 1976 *Keratella cochlearis* was the dominant species. Two protozoa *Centropyxis* sp. and *Difflugia* sp. were the dominant species throughout 1971-1975. In 1976 *Centropyxis* sp. and *Carchesium* sp. were the protozoa most frequently observed. However, because of periodic blooms in 1976, the phytoflagel-

lates Ceratium hirudinella and Eudorina sp. were the most abundant protozoa.

The abundance of dominant and subdominant forms, as well as less common species, varied significantly with season and was correlated with the seasonal progression of temperature in the river and varying salinity in the vicinity of the Indian Point plant. 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 greatest in the late spring and summer months (June, July and August), reaching concentrations of more than 200 organisms per liter in late August. Copepods accounted for the majority of microzooplankters collected throughout the year and reflected, in general, microzooplankton abundance in this sector of the Hudson River.

A comparison of microzooplankton data collected in 1976 with those from studies done in 1971-1975 shows the magnitude of peak abundances and seasonal patterns of abundance to be similar. Also, the species composition as well as dominant species within and among years have remained essentially unchanged. There are no indications in our data to suggest that river populations of microzooplankton have been affected by the operation of the Indian Point power station.

Macrozooplankton River Populations

A total of 27 macroinvertebrate groups were identified from 1976 samples; this includes two taxa of invertebrates not previously seen in our samples from the vicinity of Indian Point, the isopod Cassidinidea lunifrons and a number of trichopteran nymphs. Nonetheless, this species inventory resembles closely those for the preceding study years, 1971-1975. Through all the years of this study, macrozooplankton samples have been dominated by three taxa of macroinvertebrates, Gammarus spp. (mostly G. daiberi), Monoculodes edwardsi and Neomysis americana. Because of the relatively high numbers of Chaoborus spp. seen in the 1976 samples, they are being considered as one of the dominant taxa for the year. Together these forms accounted for nearly 60% of the total macrozooplankton collected in daylight as well as nighttime samples.

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

Indian Point. Basically, it may be stated that discrete epibenthic species having similar roles in the macrozooplankton community do not overlap extensively in salt preference or tolerance, and replace one another as hydrologic factors related to salt intrusion vary at specific locations.

Total abundances of macrozooplankton were highest in late summer and occurred in lower numbers in mid to late fall. There was noticeable diurnal variation; macrozooplankton abundances in 1976 were much greater at night than during the day and much greater towards the bottom than near the surface. This confirms the patterns observed in 1971 through 1975.

Studies of macrozooplankton populations in the Hudson River in the vicinity of Indian Point from 1971 through 1976 show the populations to be rather constant. There is little to suggest that the river's populations of macrozooplankton have been affected by the operation of the Indian Point power plant. Although a large number of Neomysis may be killed from passage through the cooling system of the power plant, we do not believe that their population in the river is impacted. Neomysis is transitory and is at the northern fringe of their distribution when observed at the Indian Point area.

Ichthyoplankton River Populations

Of the more than 50 species of fish known to occur in the mid-portion of the Hudson River--i.e., from the Tappan

Zee Bridge to Cementon--life stages of 22 species were found in the 1976 ichthyoplankton collection. Of these 22 species, 18 have been collected each year from 1971 to the present. The species composition and the overall abundance of the ichthyoplankton in the river were similar to that found in 1971 through 1975.

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

The abundance of striped bass life-history stages from river samples was compared to the abundance in the power plant. With the exception of eggs, which were higher in the plant, the abundances of the other life-history stages of striped bass collected at night in the river were equal to or higher in number than that collected in the plant. This result has been observed in all of the previous years' studies.

Physical/Chemical Data

Physical/chemical data from 1972 to 1976 were analyzed and compared to identify trends of change in various parameters throughout the study period. Mean air temperatures in 1976

were measurably higher than in 1974, but were similar to those in 1973 and 1975. Water temperature and dissolved oxygen profiles were generally similar for 1972, 1974, 1975 and 1976. The maximum mean water temperature recorded in 1976 of 26.0°C (78.8°F) was slightly less than the 26.8°C (80.2°F) recorded in 1974, but it was similar to those recorded for 1973 and 1975 and greater than that recorded in 1972.

Secchi disc readings, used as an index of water clarity, were not substantially different from those recorded in 1972, 1974 and 1975, varying without trend from 1.1 to 4.4 ft. No secchi disc readings were taken in 1971 or 1973. The salinity profile for 1976 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 the present appear to be in the time of earliest salt intrusion at Indian Point and in the magnitude of the salinity increase. Measurements of pH in the Indian Point vicinity ranged from 7.2 to 7.6; this has shown little change over the previous years' sampling efforts.

In-plant Studies

The in-plant studies were limited to abundance sampling for macrozooplankton and ichthyoplankton. As there was no apparent effect from the operation of the Indian Point

facility on river phytoplankton and river microzooplankton (New York University Medical Center, 1975, 1976a), these organisms were deleted from further consideration. Initially, the in-plant studies were to be a comparison of entrainment (e.g., numbers of organisms entrained and the effects of entrainment on organism survival) between Unit 2 and Unit 3. Unit 2 was down almost all of 1976, therefore all efforts were directed to the Unit 3 intakes and to the discharge canal station at D-2 for cross-plant survival of entrained organisms. With Unit 2 down, cooling water from the Unit 3 discharge flowed primarily down one side of the discharge canal only, completely by-passing the sampling rigs emplaced within the center of the discharge canal. Sampling procedure was modified to sample from the side of the discharge canal within the flow with nets suspended from the railing on the discharge canal platform. However, current flow was of such intensity (often at 3 ft/sec or greater) that it was impossible to collect any but surface samples. No cross-plant viability or latent mortality studies were done as there would be few viable organisms in the samples. It would be impossible to differentiate mortality resulting from cross-plant effects from collection damage. O'Connor and Schaffer (1977) have demonstrated in a test flume that, at collection velocities exceeding 1.5 ft/sec, net collection alone may account for the majority of latent mortalities in pre-juvenile striped bass.

It is difficult to generalize as to the potential impact of the operation of the Indian Point power station on riverine populations of striped bass from plant abundances. Although five to six years of plant abundance data have been accumulated to date, operating conditions were never the same from one year to the next. However, data derived from river samples taken in the vicinity of Indian Point show that the populations of pre-juvenile striped bass life stages have changed little since this work began in 1971.

1. INTRODUCTION

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

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

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

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

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

1.1 ORGANISMS SUBJECT TO ENTRAINMENT

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

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

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

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

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

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

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

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

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

1.2 THE INDIAN POINT FACILITY

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

placed in operation in October 1962 and taken out of operation in October 1974, uses 318,000 gallons of water per minute (gpm) at maximum flow (708 cfs); Unit 2, which went operational in 1974, and Unit 3, which became operational in 1976, requires 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).

Each of the three units has a separate shoreline intake structure for withdrawal of water from the Hudson River (Figure 1-1). There are four rectangular intake openings at Unit 1 and six each at Units 2 and 3. The openings extend 26 feet (8.0 m) below mean low water (MLW) at Unit 1 and 27 feet (8.2 m) below MLW at Units 2 and 3. The approximate relationship of the intake openings to the river cross-section at Indian point is shown in Figure 1-2. The water from all three units flows through a single discharge canal, and is returned to the river through a series of submerged discharge ports in a 250-foot (76.2 m) length of the canal wall near the downstream end of the canal (Figure 1-1).

1.2.1 Passage Times

The total time required for water to pass from the intakes through a given unit, and then through the discharge canal to the discharge ports depends on the individual and combined operational flow rates of the three units (Table 1-1).

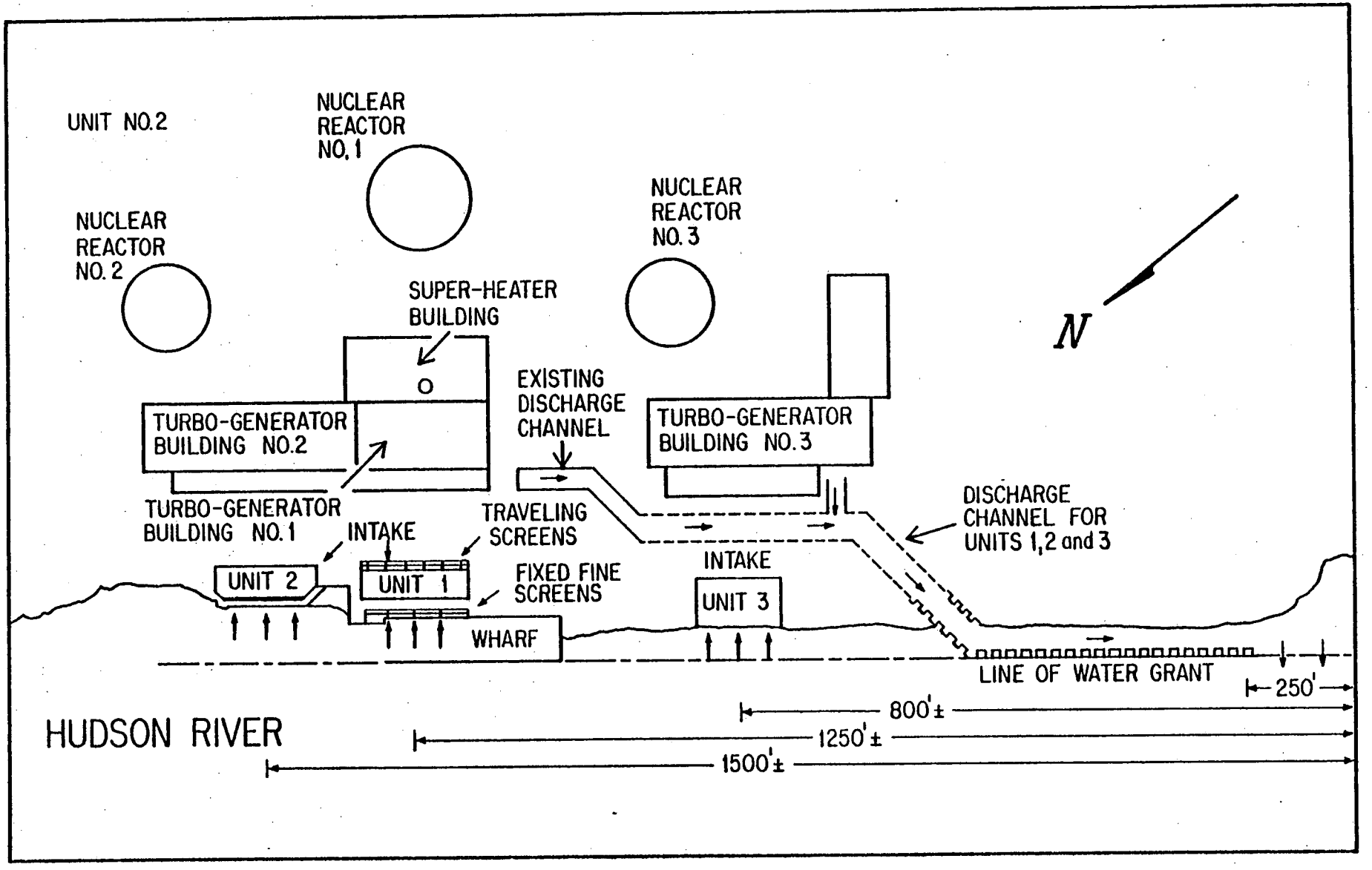

Figure 1-1. Schematic diagram of Indian Point nuclear generating facility.

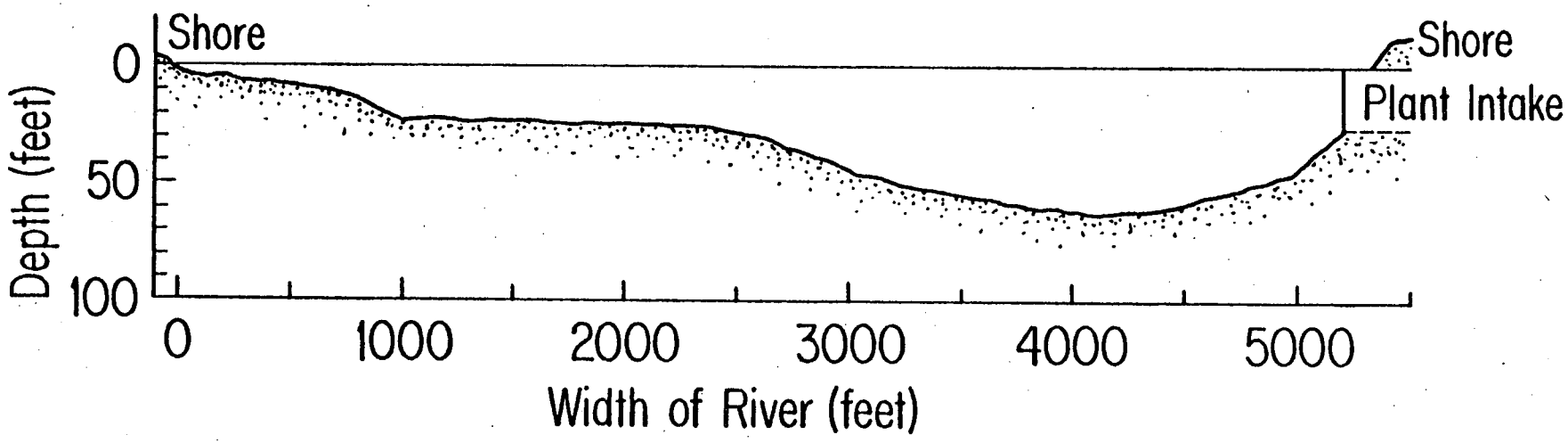

Figure 1-2. Cross section of Hudson River at Indian Point plant intake. For clarity, vertical scale has been expanded by a ratio of 10:1. Data from the U.S. Geological Survey Peekskill (N.Y.) Quadrangle, 1957.

At full flow, the total time for passage is estimated to range from a minimum of 5.2 minutes for Unit 3, during simultaneous operation of all three units, up to 33.2 minutes for Unit 1 operating alone.

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

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

The exposure times of organisms entrained in the cooling-water plume at Indian Point, from entrainment until they reach near-ambient river water conditions (i.e. ambient plus 4 F (2.2 C isotherm), are not precisely known but are not expected to exceed a few hours. The 4° F isotherm example was selected as a result of New York State's thermal criteria for effluents as regarding the cross-sectional area and surface width of the receiving waters (New York State Department of Environmental Conservation, 1973, 1975). The time

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. Source: Consolidated Edison Electric Company of New York.

		INDIVIDUAL UNITS- Single Operation			INDIVIDUAL UNITS- Simultaneous Operation			
	A. FULL FLOW	1	2	3	1	2	3	MEAN
	INTAKE TO CONDENSER	1.16	1.52	1.52	1.16	1.52	1.52	1.46
TIME - MINUTES	CONDENSER TRANSIT	0.08	0.14	0.14	0.08	0.14	0.14	0.13
	CONDENSER TO EFFLUENT	31.99	11.19	7.11	5.96	6.84	3.54	5.30
	TOTAL	33.23	12.85	8.77	7.20	8.50	5.20	6.90
ΔT - °F	CONDENSER RISE (1)	12.6°	15.9°	17.2°	12.6°	15.9°	17.2°	15.9°
	CONDENSER + SERVICE WATER	12.0°	15.6°	16.8°				15.5°
	B. REDUCED FLOW							
	INTAKE TO CONDENSER	1.93	2.53	2.53	1.93	2.53	2.53	2.44
TIME - MINUTES	CONDENSER TRANSIT	0.14	0.23	0.23	0.14	0.23	0.23	0.22
	CONDENSER TO EFFLUENT	53.32	18.65	11.85	9.93	11.40	5.90	8.83
	TOTAL	55.39	21.41	14.61	12.00	14.16	8.66	11.49
ΔT -	CONDENSER (2)	21.0°	26.2°	28.8°	21.0°	26.2°	28.8°	26.6°
°F	CONDENSER + SERVICE WATER	18.6°	25.1	27.6°				25.1°

(1) River Temperature 60°F
(2) River Temperature 40°F

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, 15.9 F for Unit 2, 17.2 F for Unit 3, and 15.9 F for the combination of all three units (Table 1-1). The amount of time organisms will be exposed to these maximum temperature elevations depends on which unit withdraws the organisms from the river, and on the individual and combined flow rates of water through the units. Very little temperature reduction occurs as the water passes from the condensers to the discharge ports, except when the units are operating at substantially unequal ΔT's (New York University Medical Center, 1975, 1976a). Under such circumstances the higher ΔT output will be diluted by the lower during passage down the discharge canal. Calculated exposure times (i.e. from the condenser to the discharge ports) for full-flow operation range from 5.20 minutes for Unit 3, during simultaneous operation of all three units, to 32.23 minutes for Unit 1 operating alone (Table 1-1).

The ΔT encountered by pump-entrained organisms increases in the winter, when cooling water circulation is reduced to 60% of full flow. The maximum temperature rise at 60% design flow is expected to range from 21.0 to 28.8 F. Calculated exposure times also increase with the reduced flows. The relationships of ΔT to calculated exposure time for individual and combined-unit operation at 60% flow are given in Table 1-1.

The maximum possible time/temperature combinations encountered by organisms during passage through the Indian Point facility are shown diagramatically in Figure 1-3. Figure 1-4 shows the mean maximum ambient 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. This information and recent data collected by Consolidated Edison in 1974, 1975 and 1976 (Dames and Moore and Con Ed, 1974-75, 1976; Con Ed, 1977) indicate that the average ambient temperature in the vicinity of Indian Point did not exceed 78.9° F. Maximum temperatures in the condensers will exceed those shown in Figure 1-4 only when the intake water temperature exceeds the mean values plotted.

1.2.3 Pressure Exposure

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

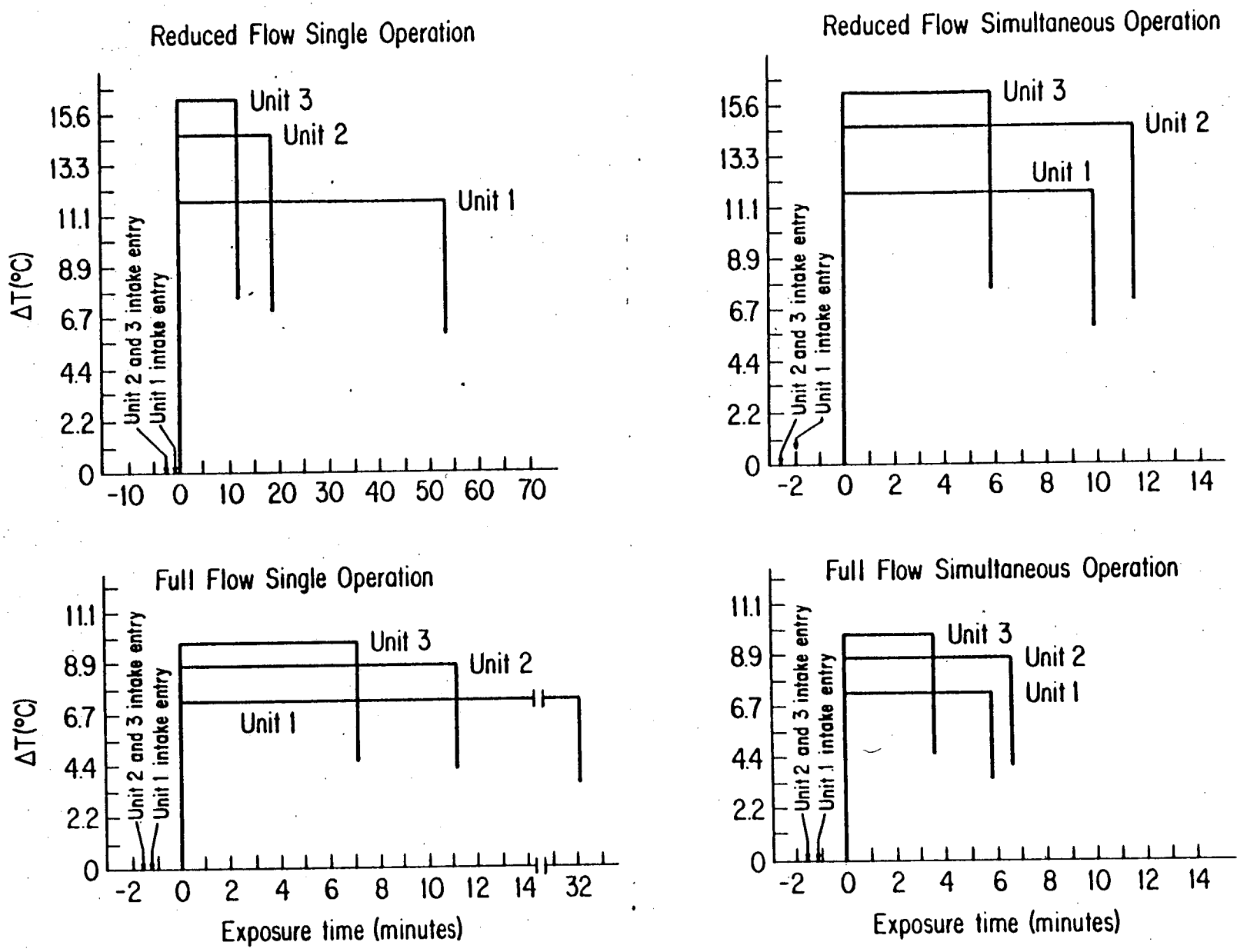

Figure 1-3. Schematic diagrams of temperature elevations and exposure times in the Indian Point condenser cooling system when operating at rated generating capacity.

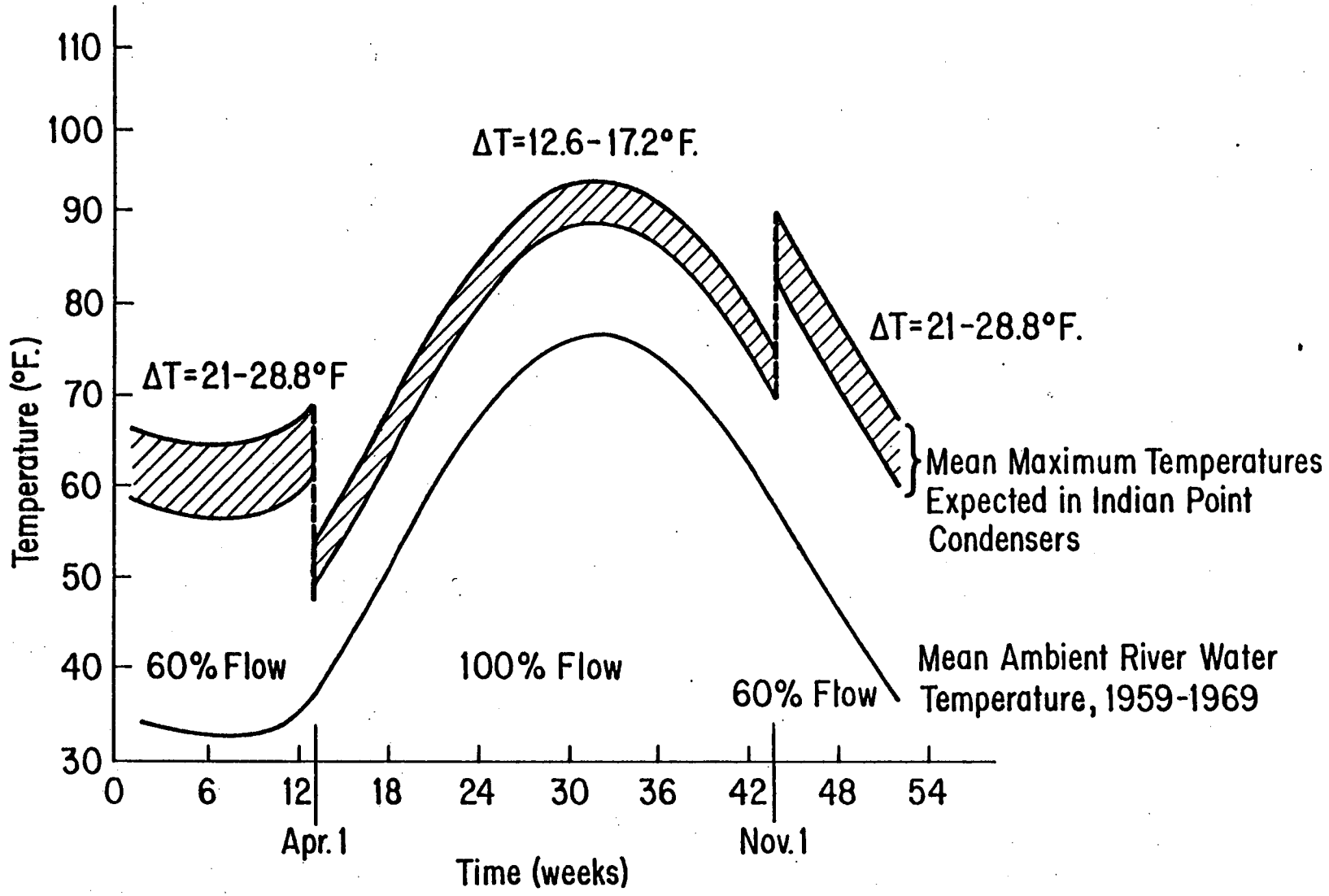

Figure 1-4. Temperatures encountered in Indian Point condensers at proposed cooling water flow rates when plant is operating at rated generating capacity.

pressure. The degree and rate of such pressure changes depend on the location of the organism in the water column prior to being drawn into the pumps, the design and height 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 12.1 to a maximum of 33.3 psia within a 75 second span (Consolidated Edison, 1977). New York University Medical Center (1976b) has reported on the effects of pressure change on entrained Hudson River organiams and discussed the potential adverse effects of pressure on survival of several river organisms, including striped bass.

1.2.4 Velocity Shear Exposure

Organisms pumped through the Indian Point facility are exposed to rapid increases and decreases in velocity. The degree and rate of the velocity change experienced depend on the location of the organism in the water column prior to being drawn into the pumps, the design and diameter of the pipes through which the cooling water passes, surface irregularities within the pipes, and the design and number of

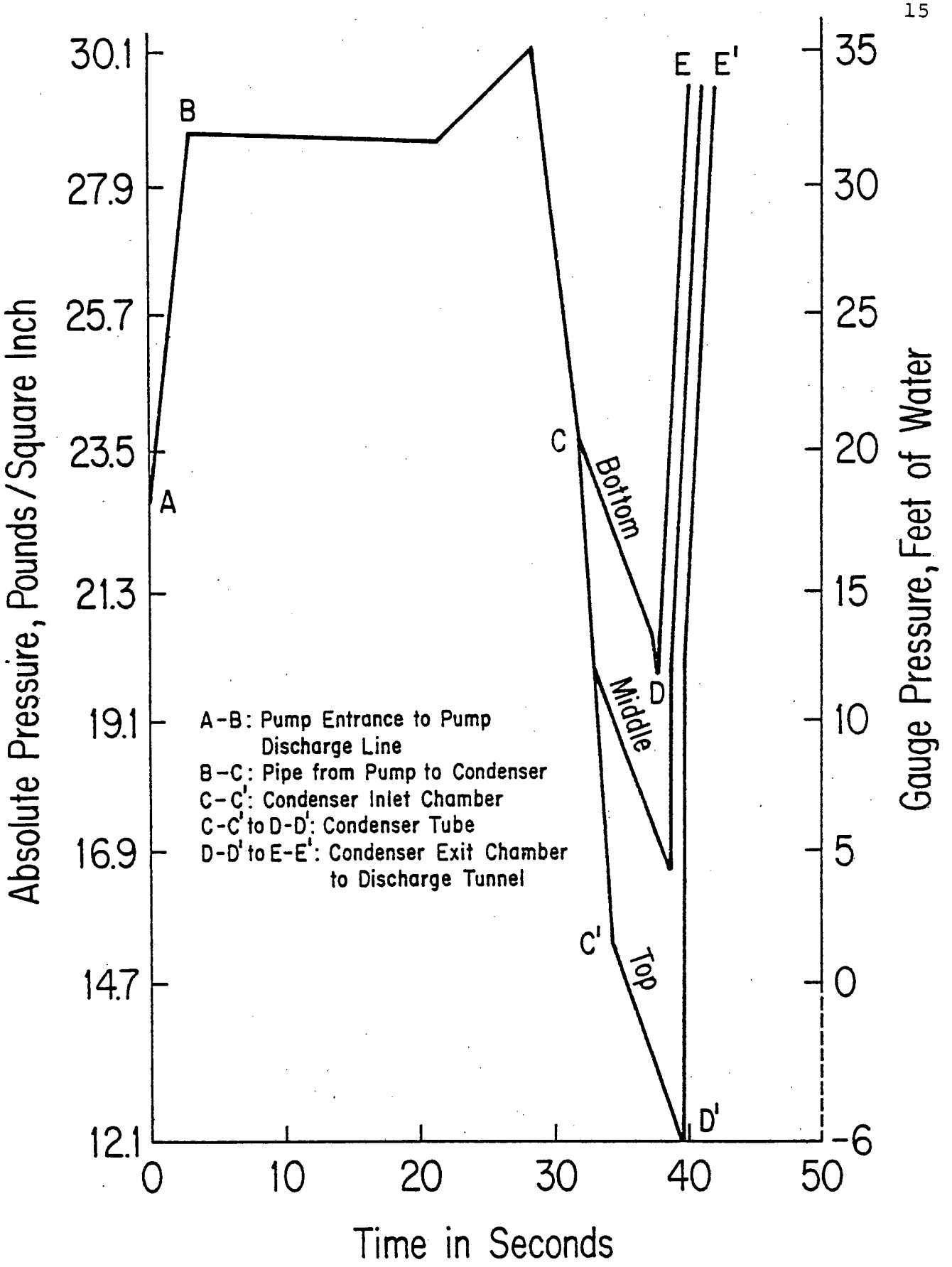

Figure 1-5. Pressure versus time along circulating water system piping with non-winter operating conditions of Indian Point Unit 2 or Unit 3 (no pump recirculation).

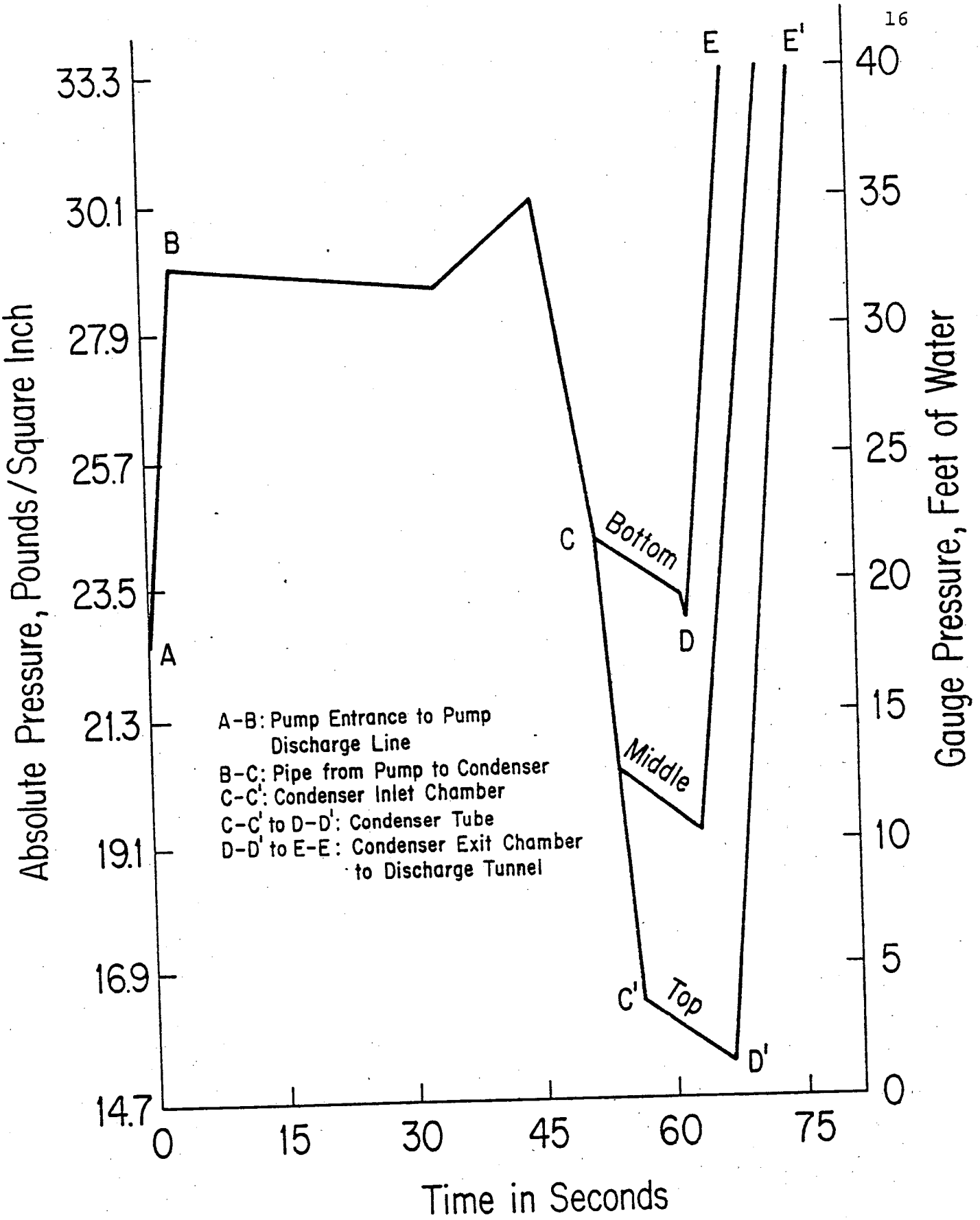

Figure 1-6. Pressure versus time along circulating water system piping with winter operating conditions of Indian Point Unit 2 or Unit 3 (40% pump recirculation).

circulating pumps in operation. Figures 1-5 and 1-6 show the absolute head encountered by organisms entrained in Units 1 and 2, respectively. The resulting velocities within the condenser are in the range of 5.5 to 8.1 feet per second (FPS = 168 to 247 centimeters per second; CPS) for Unit 1 and 6.0 to 8.1 FPS (183 to 247 CPS) for Unit 2. Pressures and velocities in Unit 3 are similar to Unit 2. Table 1-2 shows the estimated cross-sectional flow velocities at other selected points in the Indian Point cooling water system under various operating conditions at 100% design flow.

For most forms, the velocities at which organisms are moved through the system seem to be of little importance in themselves. For example, in two independent studies of the effects of condenser passage and related velocity-induced hydraulic stress Coutant and Kedl, 1974 (see also Kedl and Coutant, 1974) demonstrated that neither ΔT nor velocity-induced stress factors alone or in combination had a significant lethal effect on a variety of entrainable organisms. Tests included striped bass larvae, frog tadpoles and Daphnia. The authors concluded that the condenser was probably not the locus of significant entrainment mortality in power stations. The effects of shear forces within power plants have not been studied as an independent stress, and therefore have not been included in most evaluations of entrainment effects. The results of our studies at Indian Point suggest that shear and/or abrasion do not contribute substantially

Sampling location	Generating units operational						
	1	2	3	1+2	1+3	2+3	1+2+3
Intakes	velocities (feet per second)						
Unit 1	0.57	-	-				
Unit 2	-	0.84	-				
Unit 3	-	-	0.84*				
Discharge canal							
Station D-1	1.03	2.82	-	3.85			
Station D-2	0.79	2.17	2.17	2.97	2.97	4.35	5.14
Station DP	10.0	10.0	10.0	10.0	10.0	10.0	10.0

Table 1-2. Estimated cross-sectional flow velocities (feet per second) at existing sampling points in the Indian Point plant cooling water system when operating at 100% of design flow and at mean tide level in the Hudson River. The numbers decrease by 40% when the system is operating at 60% of design flow. * At Units 1 and 2 the sampling rigs are positioned between the trash bars and the travelling screens within an enclosed bay, as shown in Figure 1-11. The sampling rigs at Unit 3 are positioned in the river in front of the bar racks with no enclosed forebay as at Unit 2. Hence intake samples at Unit 3 may be influenced by normal tidal currents running along the face of the unit.

to mortality of entrained organisms, since little or no deformation of specimens is observed in live samples (New York University Medical Center, 1974).

1.2.5 Mechanical Buffeting Exposure

Mechanical buffeting that organisms experience during passage through the Indian Point facility cooling water 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 (New York University Medical Center, 1974).

1.3 DESIGN OF THE RESEARCH PROGRAM

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

1.3.1 Objectives

The specific objectives of the research program are to:

1) Determine the species composition, abundance, and temporal and spatial distribution of organisms in the Hudson River that are subject to entrainment by the Indian Point plant.

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

3) Determine to what extent organisms are affected by entrainment at the Indian Point plant. This is done by comparing the conditions of organisms collected in the plant's intake bays with those collected in the discharge canal.

4) 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 and 4. Seven stations, designated A through G, are used in basic sampling design (Figure 1-7 and Table 1-3). Stations A and B, north of Indian Point, and stations F and G, south of Indian Point, provide information on the types and quantities of planktonic organisms entering and leaving the vicinity of the Indian Point facility. Stations C and D provide the same types of information on planktonic organisms passing in front of the Indian Point cooling-water intake bays. They are also used for monitoring effects of entrainment and the

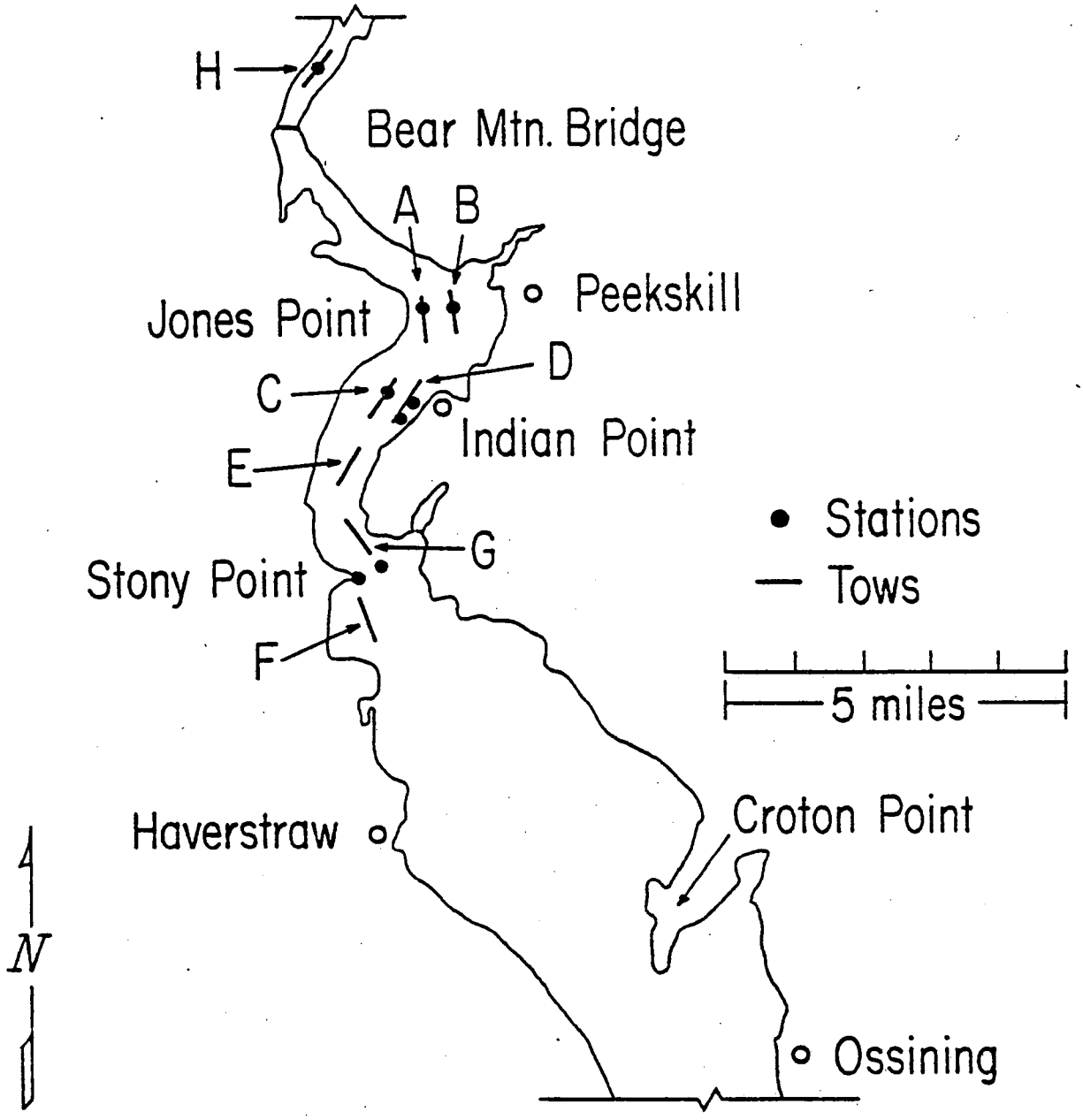

Figure 1-7. New York University Hudson River sampling stations, 1976.

Table 1-3. Location and river depth at New York University Hudson River sampling stations, 1976.

General Location	Letter Designation	River mile-point	River depth (ft)
Jones Point	A	42.7	50
Peekskill Bay	B	42.7	50
Reserve Fleet	C	41.7	50
Indian Point	D	41.7	50
Power-line Crossing	E	41.0	50
Stony Point	F	39.0	50
Montrose Point	G	39.0	50

effects of plant discharges on river populations. Station E is within the thermal plume, close to the discharge ports.

In addition, the 1976 river program was modified to include the collection of river samples from an added station (D-S), located in front of and parallel to the plant intakes (similar to Station D of the seven standard river stations). However, this station was sampled simultaneously with each plant sample. It was hoped that this sampling regime would provide a better estimate of river populations for plant/river comparisons of entrainment than that derived from the seven river stations, from which samples are collected only once during the day and once at night each week during the sampling period. The intent was to sample from three stations on a east-west transect across the river in front of the plant intakes (Figure 1-8) simultaneously with the collection of plant samples. As the numbers of boats required to perform this effort were unavailable until late in the year, only the eastern-most station was sampled.

1.3.2.2 Stations Used in Studies of Pumped Entrainment Effects

Figure 1-9 shows the locations of the proposed sampling stations at the Indian Point plant. The effects of pumped entrainment were determined by comparing data from stations D-1, D-2 with data from the intake stations II-5 and III-5 (the number after the hyphen refers to the specific location of the sampling rig at the intakes or the discharge canal).

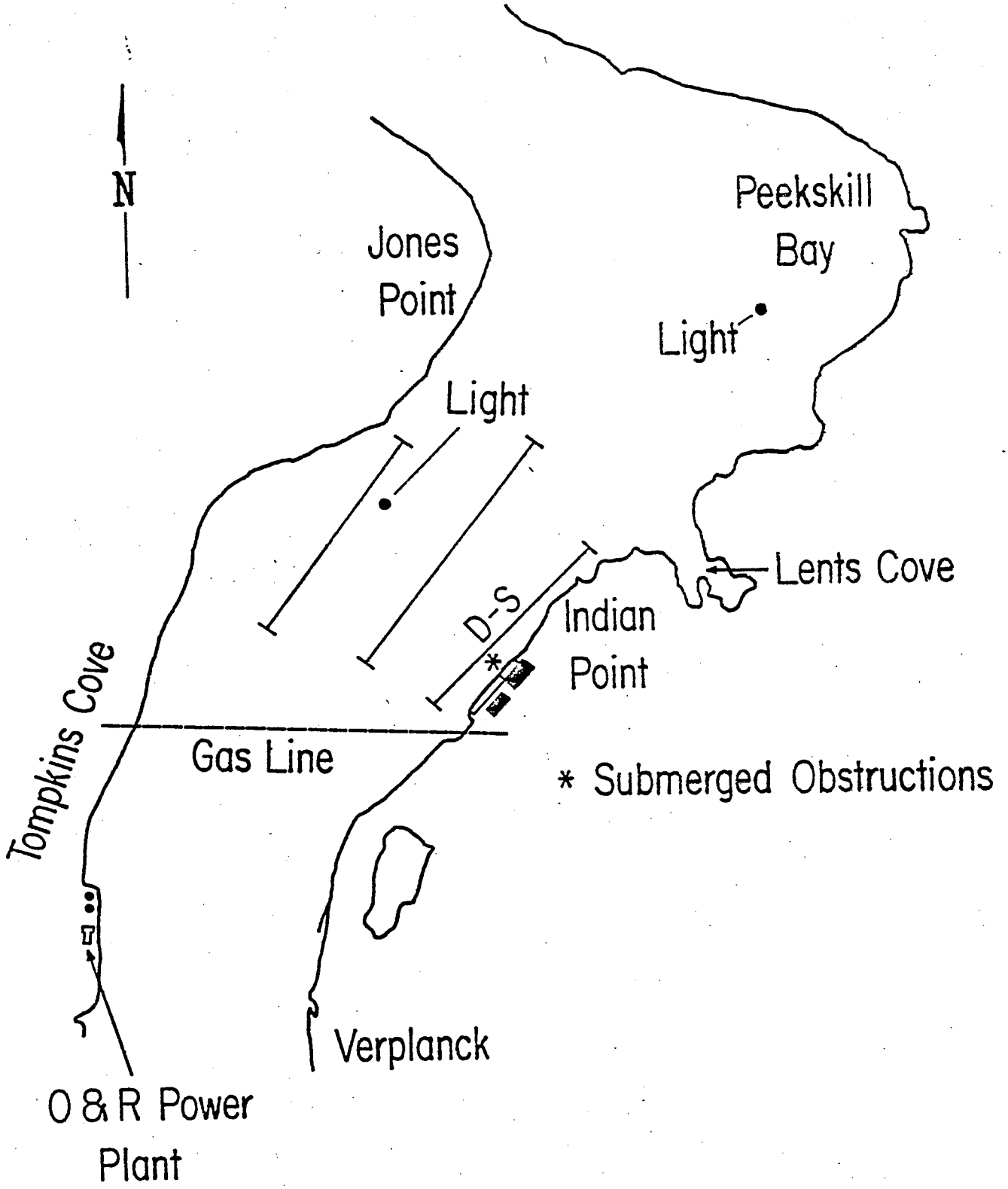

Figure 1-8. Location of proposed transect sampling stations for simultaneous plant/river samples. Only station D-S was sampled in 1976.

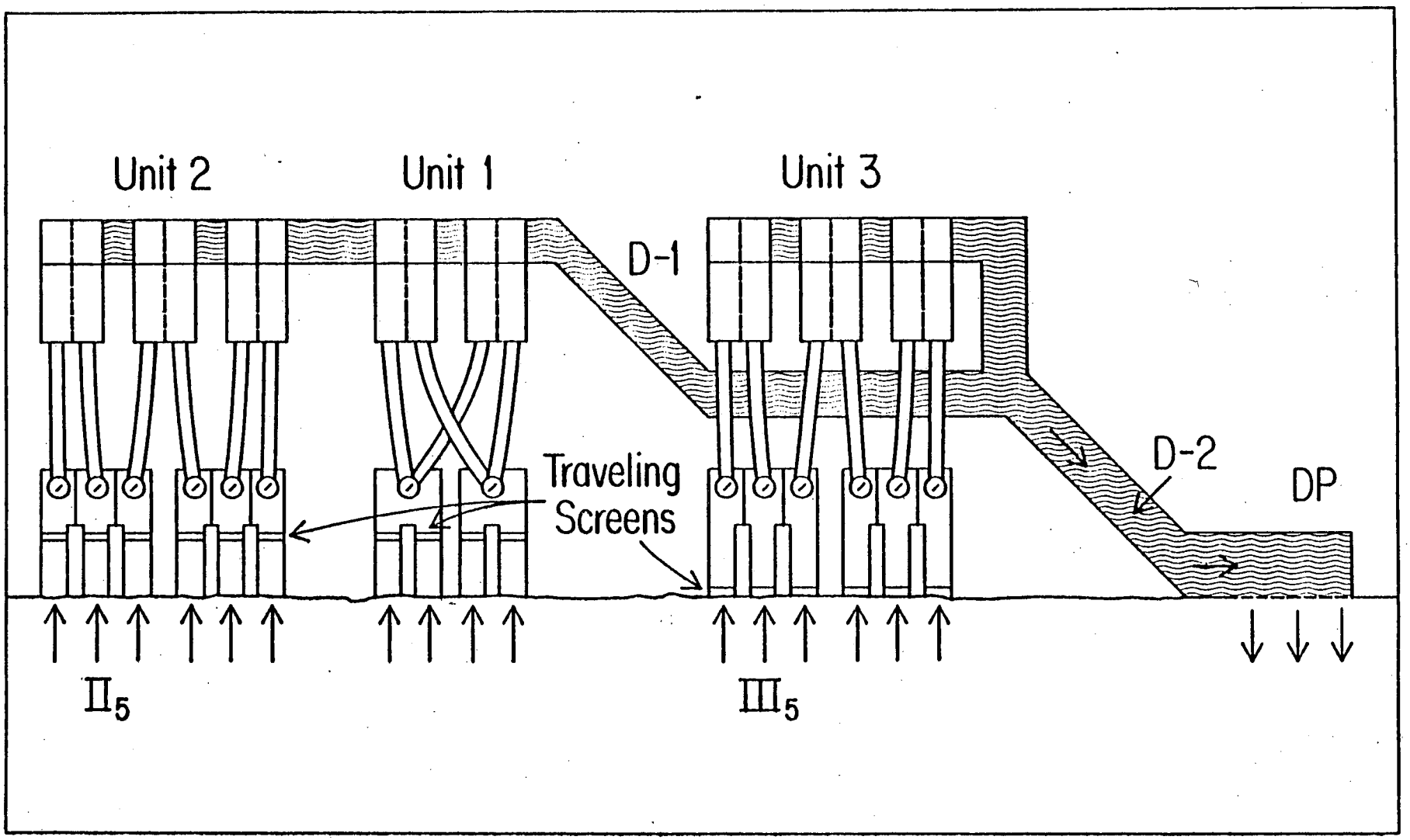

Figure 1-9. Schematic diagram of Indian Point cooling water system showing locations of sampling stations.

However, as Unit 2 was down for most of the year, entrainment sampling was confined to III-5, D-2 and the river simultaneous station.

1.3.2.3 Sampling Gear

Depending on conditions and the kinds of organisms to be sampled, various collection nets were used. These are shown in Table 1-4.

Water passing through each net was recorded by either a TSK digital flowmeter or a General Oceanics digital flowmeter mounted in the net mouth. All nets were provided with cod-end buckets, 5 cm in diameter and 10 cm long, with a seive window of the same mesh as the net.

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

Sampling rigs capable of simultaneous sampling at three water depths were devised (Figures 1-10 and 1-11), and were installed at the Unit 2 intakes and at D-1 and D-2 stations. Such a sampling rig was not constructed for Unit 3 in time for the 1976 study. Instead, samples at this station were collected with nets suspended from a boat anchored near the

Table 1-4. Nets used in sampling for river-population and entrainment-effects studies. SS = stainless steel, PVC = polyvinyl chloride.

Biological group	Study	Net Type	Net dimensions			Net-opening retainer	Bucket
			Mesh	Diameter (m)	Length (m)		
Microzooplankton, all	population, entrainment	No. 20 mesh	76μ	0.5	1.9	brass ring	SS
Macrozooplankton and Ichthyoplankton	population	No. 0 mesh	571μ	0.5	3.8	brass ring	PVC
Macrozooplankton and Ichthyoplankton	entrainment	No. 0 mesh	571μ	0.5	1.9* 1.2	SS ring	PVC

* 1.9-meter nets were used in Unit 3 intakes and in the discharge canal; the 1.2-meter nets were used in Unit 2 intakes where space limitations precluded the use of the longer nets.

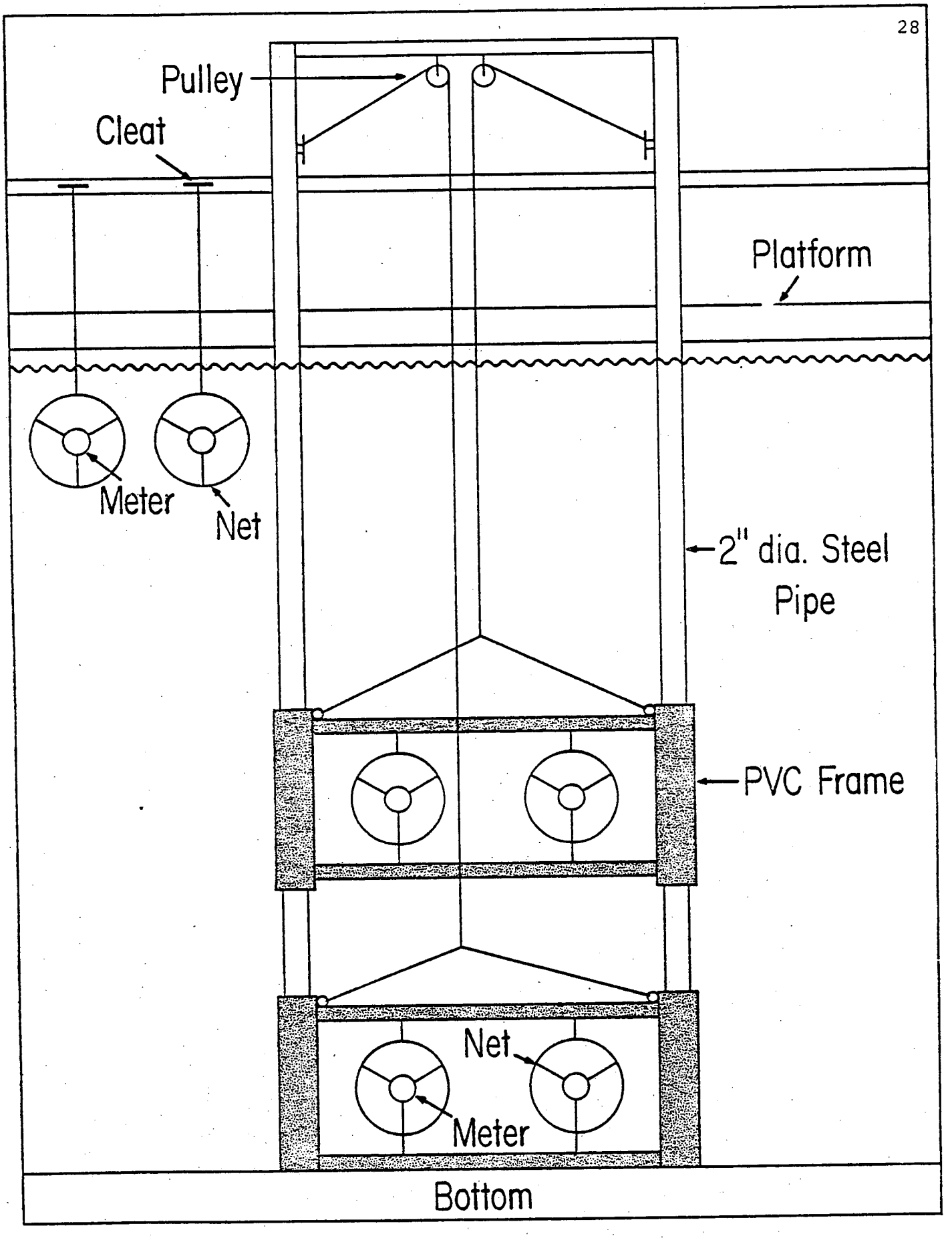

Figure 1-10. Rig used for intake and discharge-canal sampling.

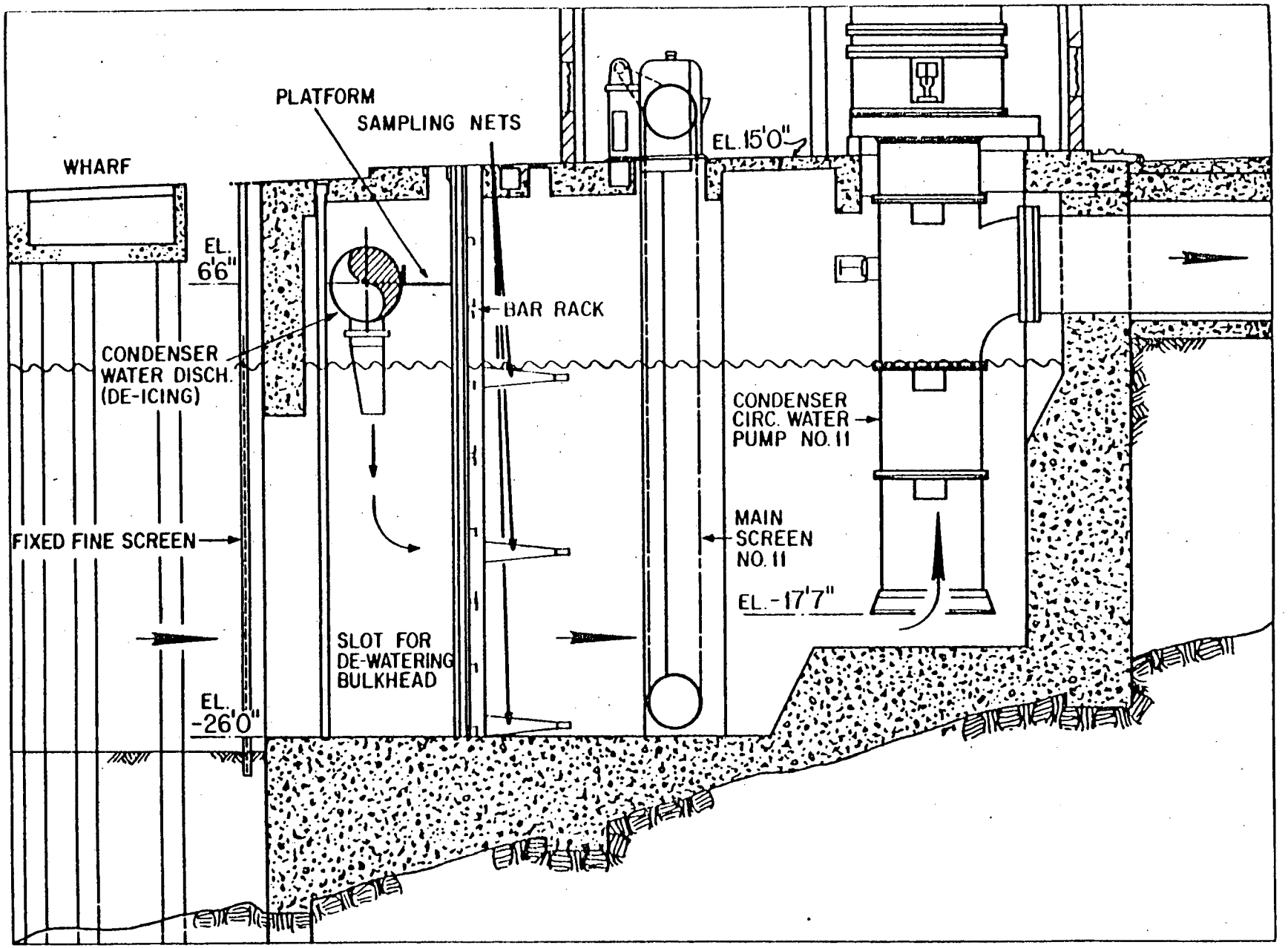

Figure 1-11. Cross-section through Unit 1 forebay showing position of sampling nets. The mouths of the nets are approximately 6 inches behind the bar racks. The configuration of the Unit 2 forebays is similar, but the distance between the bar racks and the travelling screen is greater, permitting the 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.

intake structure (Figure 1-12). This presented the obvious problem of being too far away from our desired position, close to the intake structure itself. The fact that the intake samples at Unit 3 are collected in front of the bar racks in the river, and not within enclosed forebays (as for Units 1 and 2), may affect the estimates of abundance of the organisms drawn into the plant with the cooling water.

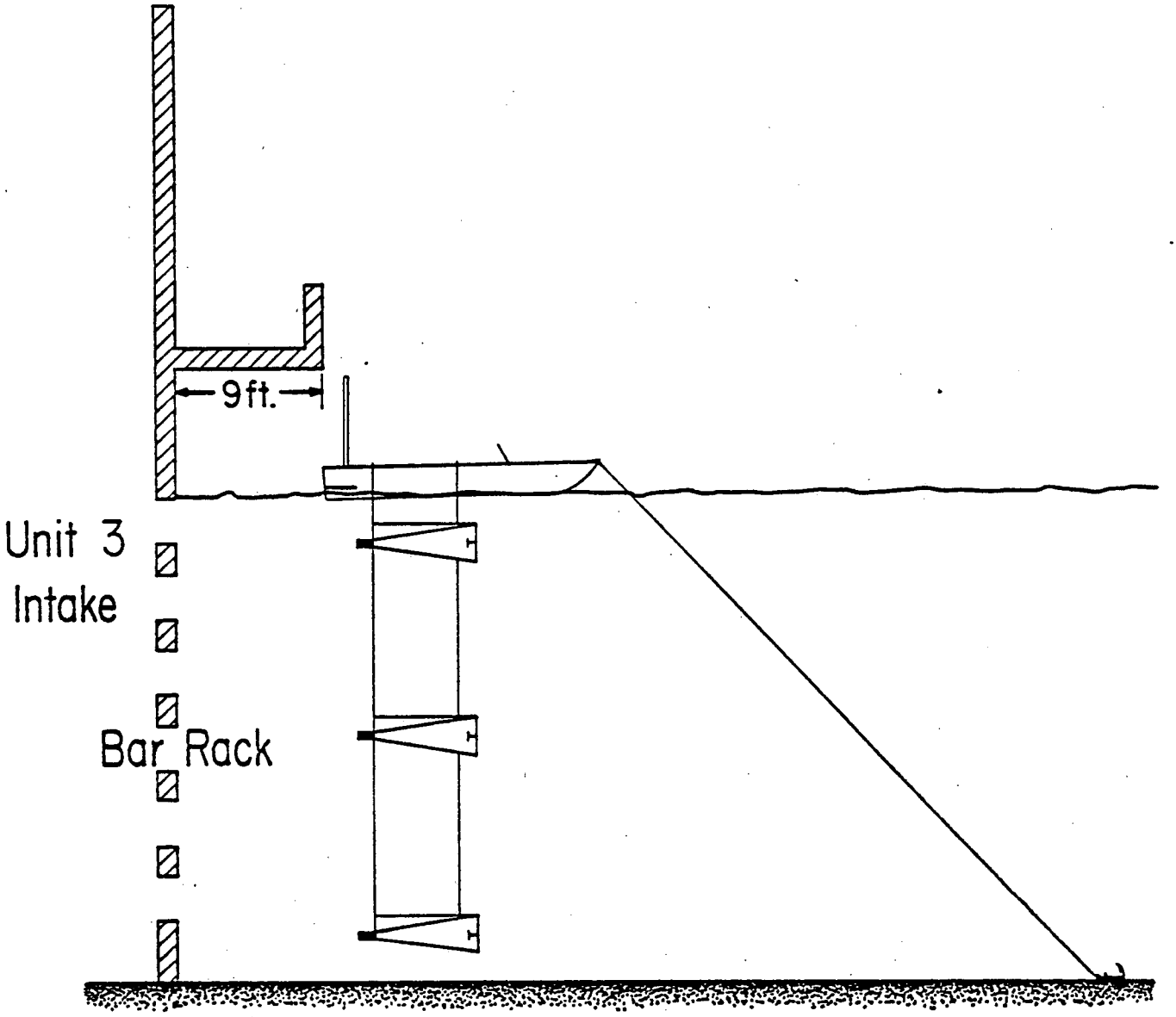

Figure 1-12. Schematic diagram showing sampling set up at a Unit 3 intake station, 1976.

2. PHYSICAL/CHEMICAL STUDIES

2.1 METHODS

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

2.2 RESULTS AND DISCUSSION

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

The observed air temperatures during 1976 ranged from 3.0 to 31.2°C (34.7 to 88.1°F; Figure 2-1). Water tempera-

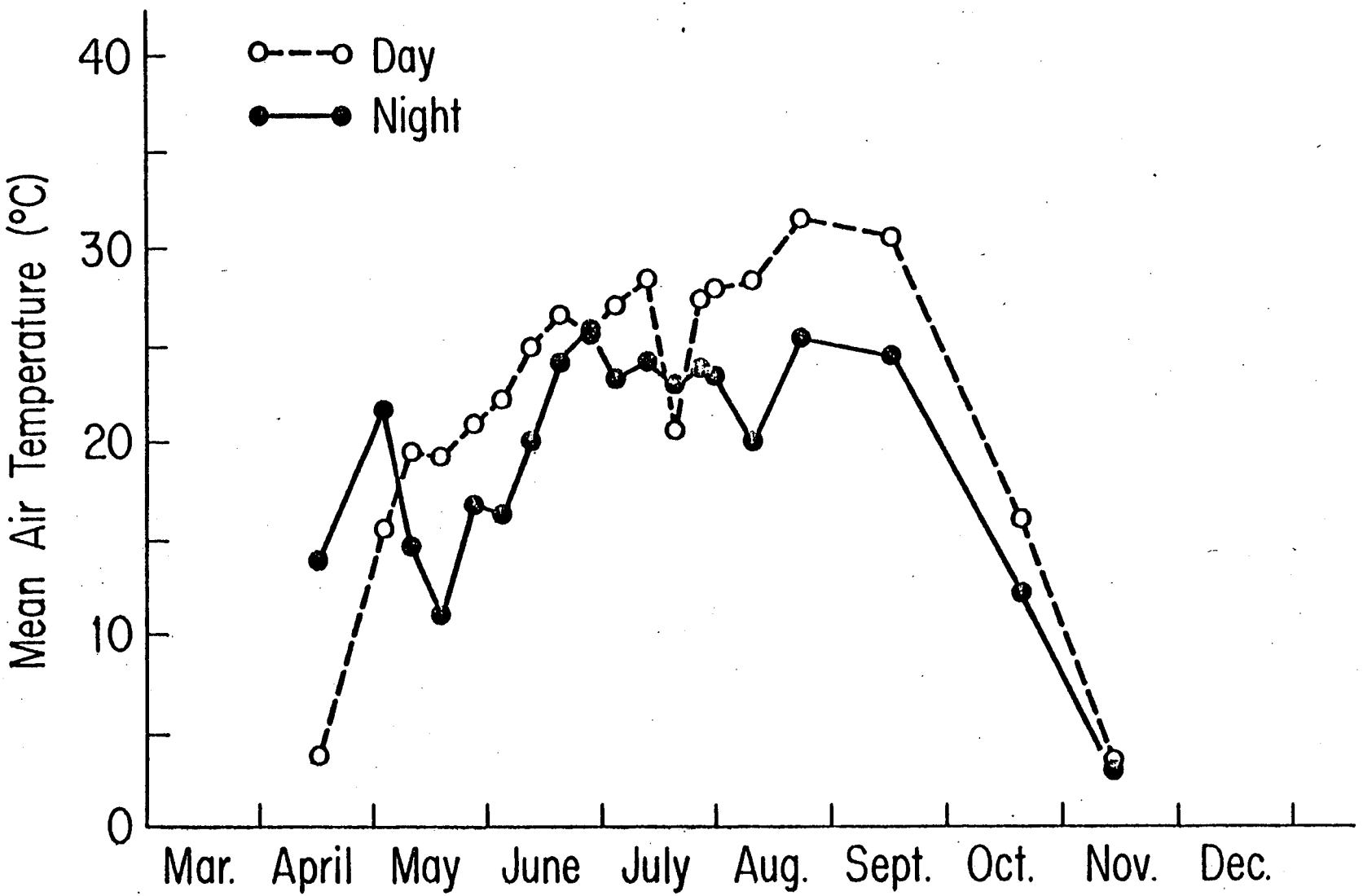

Figure 2-1. Mean day and night air temperature in the vicinity of Indian Point, 1976.

tures were highest in July and August and the dissolved oxygen content was the lowest in July and August (Figures 2-2 and 2-3) maintaining an association with high air-temperature regimes. Mean water temperatures recorded for 1976 ranged from 6.2 to 26.0°C (43.1 to 78.8°F). Dissolved oxygen concentrations which varied inversely with water temperature, ranged from 6.0 to 12.1 mg/ℓ.

Secchi-disc readings give a rough index of water clarity; low readings are indicative of turbid conditions. Mean Secchi-disc readings ranged from 1.1 to 4.4 feet (0.4 to 1.4 m) with no trends, indicating the water in the study area was well mixed (Figure 2-2). The low values result primarily from suspended particulate matter, made up of inorganic suspended matter, suspended detritus and algal cells.

Mean pH values for each date of the study was 7.2 with little variation throughout the Indian Point study area.

The mean salinity in the Indian Point region remained low until late in July (Figure 2-4), at which time the salinity rose sharply to more than 3 parts per thousand (ppt). Prior to the maximum level of 3.7 ppt in late August, the salinity decreased slightly as a result of heavy summer rains. From September to the end of the sampling year, salinity values did not exceed 1 ppt.

The physical measurements (air and water temperatures and salinity) measured at the simultaneous river station (D-S) at the time of plant sampling revealed the same trends as

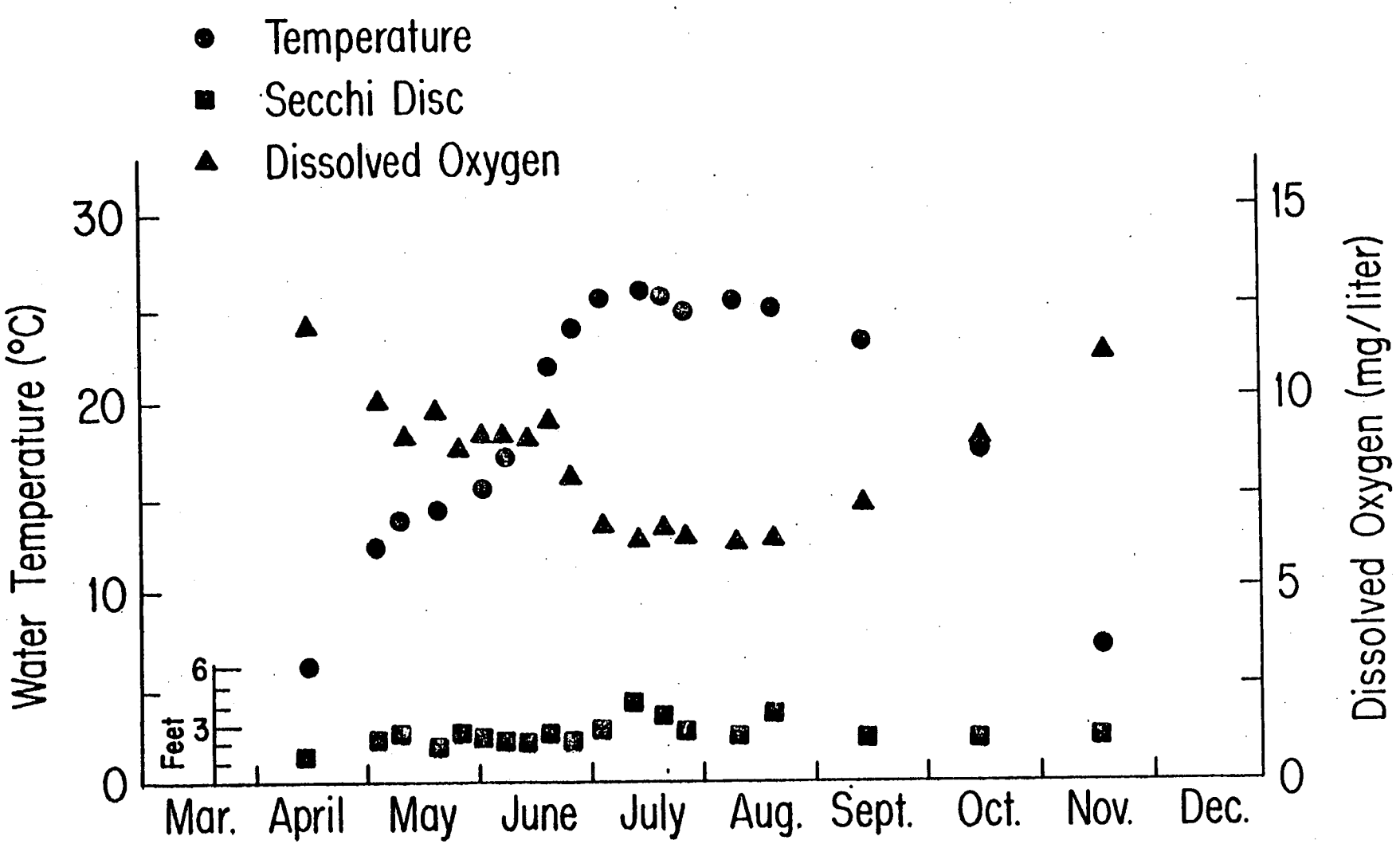

Figure 2-2. Water temperature, dissolved oxygen, secchi disc, profiles for Hudson River in the vicinity of Indian Point, 1976. Values are mean day surface, middle, and bottom for all stations.

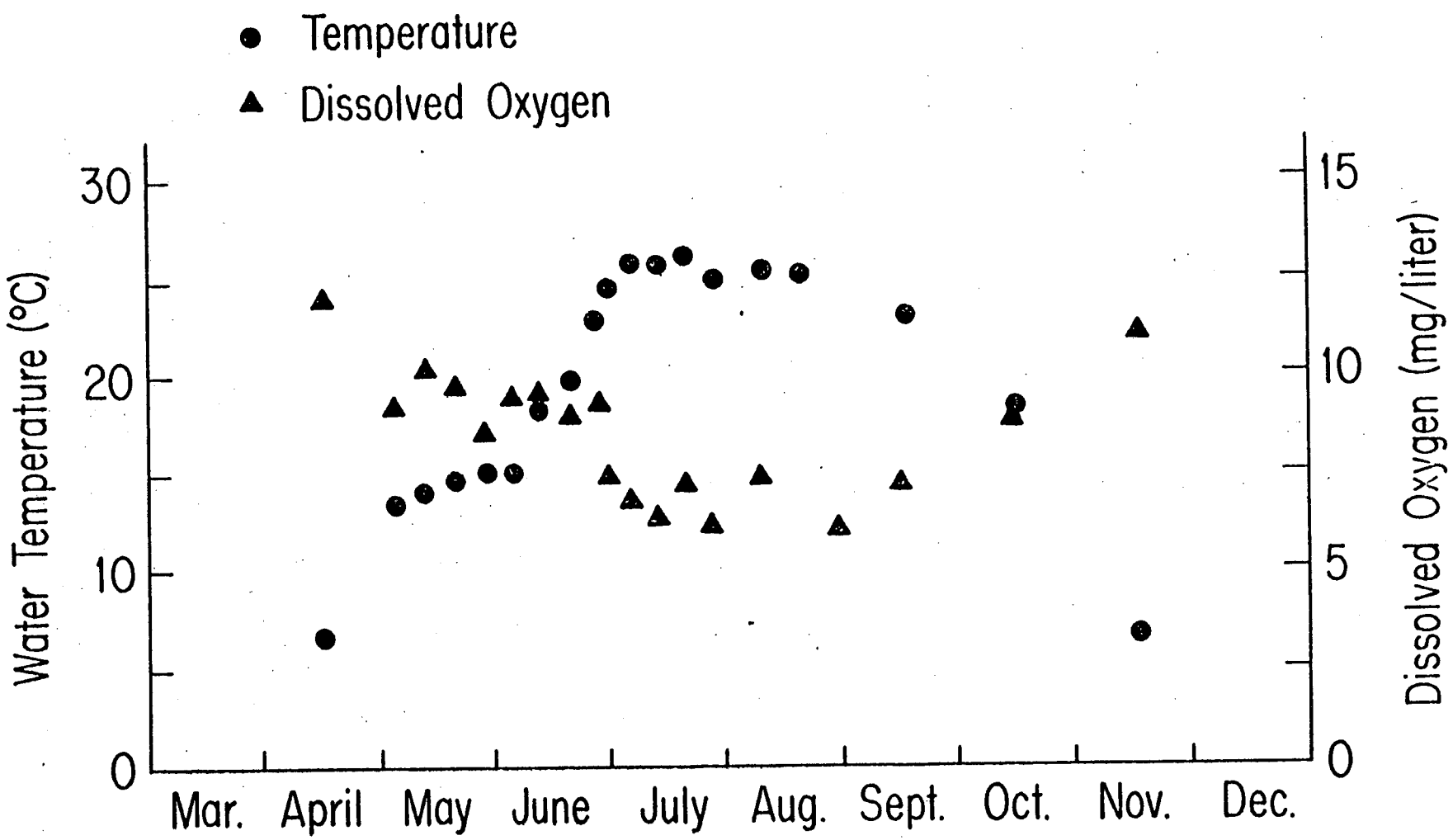

Figure 2-3. Water temperature and dissolved oxygen profiles for Hudson River in the vicinity of Indian Point, 1976. Shown are mean night, surface, middle, and bottom values for all stations.

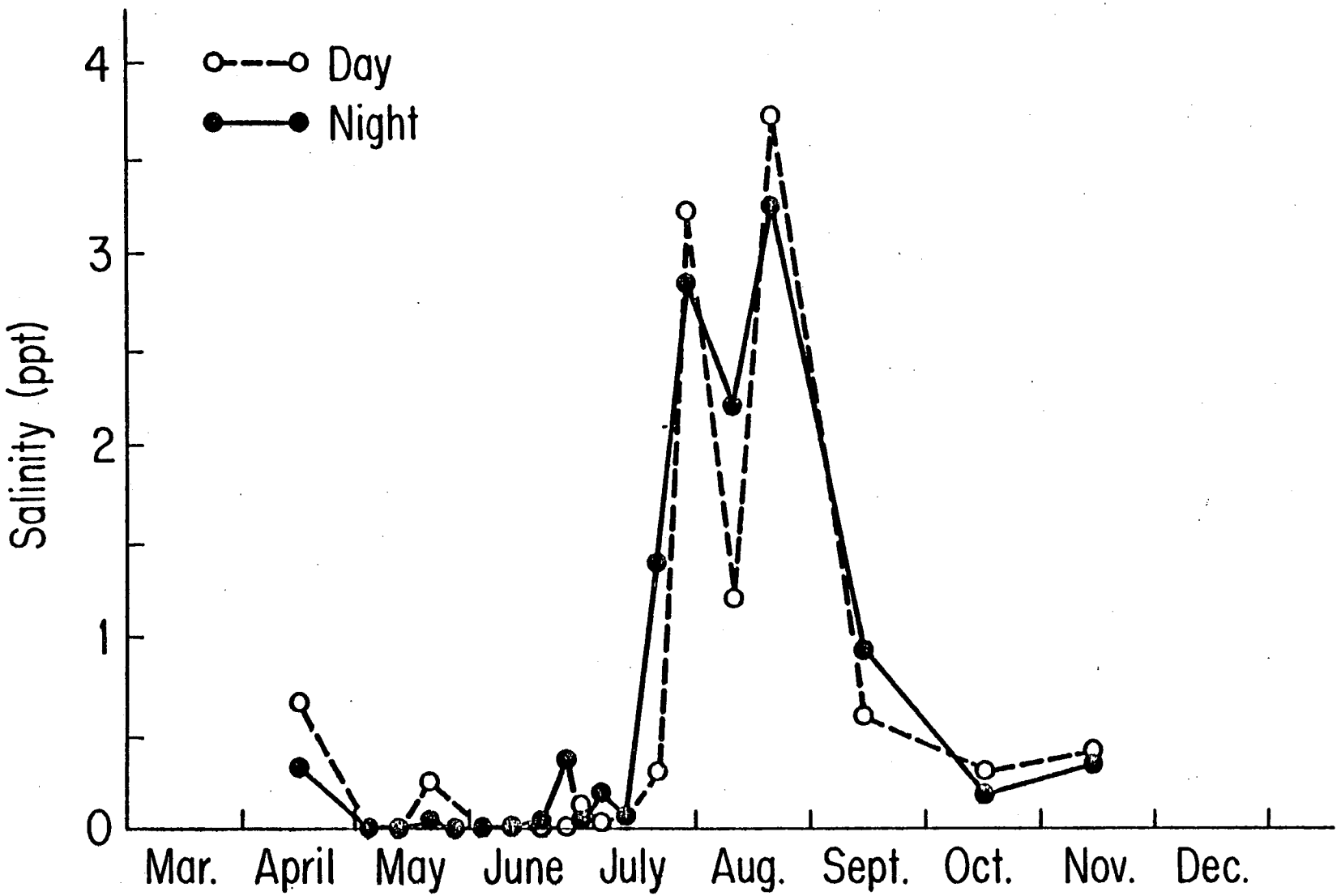

Figure 2-4. Salinity for Hudson River in the vicinity of Indian Point, 1976. Values are mean surface and bottom for all stations on each date.

those of the normal river study (Figure 2-5). The highest mean values for each of these parameters occurred during July and August; lower mean values were during the spring and fall.

A comparison of physical/chemical data from 1972 to 1976 shows that there has been little to no change during the years of this study. This is of utmost importance as these parameters, or the variations thereof, influence the breeding, spawning and migratory behavior of many of the major species of organisms in the aquatic ecosystem (Rowan, 1926; Harrington, 1959; Collins, 1952; Hasler, 1966). To the extent that water temperature is critical for the migratory behavior and spawning of species such as striped bass, white perch, and various clupeid species, the data on Hudson River water temperature in the vicinity of the Indian Point station show that operation of the Indian Point station and nearby power plants has not altered seasonal temperature regimes and, consequently, has not altered temperature as an environmental cue critical to spawning.

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

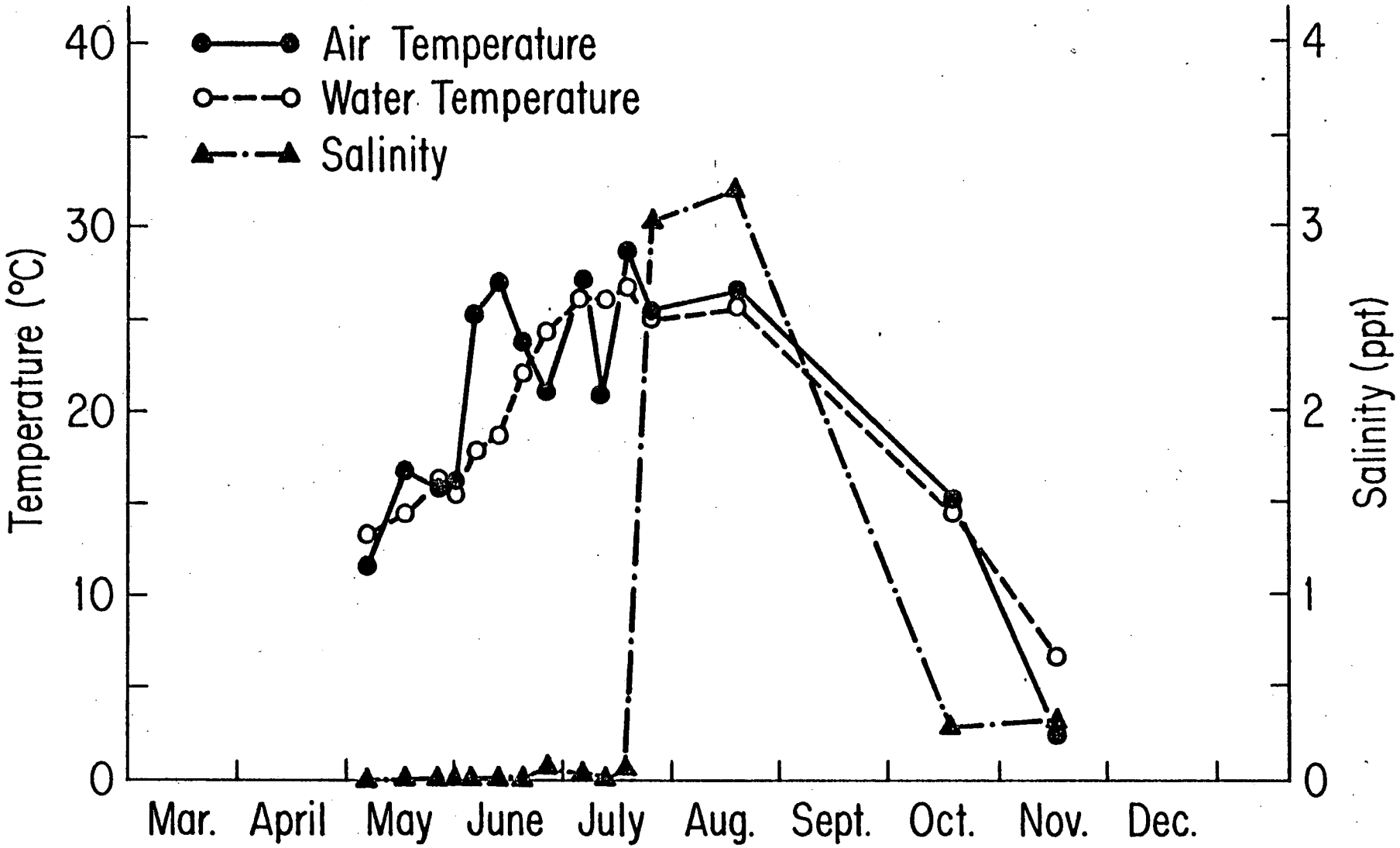

Figure 2-5. Mean air and water temperature and salinity for the simultaneous river sampling, 1976.

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

The more predictable pattern of salinity increase in the late summer and fall also serves an important function, making possible the upstream penetration of marine forms (bluefish, crevalle jack, Neomysis, etc.) to the extensive shoal water nursery grounds of the Tappan Zee, Haverstraw Bay areas and possibly to areas within the influence of the Indian Point station.

3. BACTERIA

Bacteriological studies have been discontinued since 1973. The section designation for bacteria has been included so that the section numbering for each biological group will be consistent throughout this series of progress reports.

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

4. PHYTOPLANKTON

No phytoplankton studies were done in 1976. The section designation for phytoplankton has been included so that the section numbering for each biological group will be consistent throughout this series of progress reports. See studies done for the years 1971-1975 (New York University Medical Center, 1973, 1975, 1976a) for a full report of phytoplankton studies.

5. MICROZOOPLANKTON

5.1 RIVER POPULATION STUDIES

5.1.1 Methods

Day and night microzooplankton samples were collected 15 times during the May through November sampling period at each of the seven Hudson River stations (Figure 1-7). Sample collections were made at two week intervals from the beginning of May through the third week in November. Microzooplankton were collected and preserved following the methods used in previous years (see e.g., New York University Medical Center, 1976a). A No. 20-mesh (76μ) conical plankton net (0.5 meter diameter mouth opening) was drawn vertically through 10 meters of water; the plankton collected was washed into a jar and preserved with 10% formalin.

Replicate 1-mℓ aliquots from each sample were placed in a Sedgwick-Rafter cell; the organisms were identified and enumerated by scanning with a microscope at a magnification of 100× (American Public Health Association, 1971). The concentration of organisms in the river was calculated using the following formula:

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

Where:

A = average of two 1-mℓ counts

V = volume of sample

R = revolutions recorded on flowmeter

C = Volume correction factor for flowmeter and,

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

Microzooplankton data were analyzed by a two-way, factorial analysis of variance (ANOVA) for differences between stations. Where ANOVA indicated significant differences, a Scheffé test ($\alpha = 0.10$) was performed to locate the difference (Sokal and Rohlf, 1969).

5.1.2 Results

The major microzooplankton taxa collected in 1976 were the classes Crustacea and Rotifera and the phylum Protozoa (Table 5-1). The Crustacea, primarily the Copepoda and the Cladocera, were the most abundant constituents of the microzooplankton collected from the Hudson River near Indian Point. The Crustacea accounted for nearly 75% of the microzooplankton observed in samples collected in 1976. The Rotifera and Protozoa constituted 20% and less than 5% respectively.

Mean day and night abundances of total microzooplankton were generally between 10 and 100 organisms per liter (Figure 5-1; Table 5-2). Three peaks of approximately 200 organisms per liter were observed at monthly intervals in late June, late July and late August. Spring and fall abundances were similar.

Table 5-1. Microzooplankton Species List.

Crustacea
  Copepoda
    Acartia tonsa Dana
    Canthocamptid
    Canuella sp.
    Diacyclops bicuspidatus Claus
    Ectinosoma curticorne (Boeck)
    Ergasilus sp.
    Eurytemora affinis (Poppe)
    Halicyclops fosteri M.S. Wilson
    Mesocyclops edax
    Copepodid
    Nauplii

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

Ostracoda (no further identification)

Cirripedia
  Nauplii

Rotifera
    Asplanchna sp.
    Brachionus angularis Grosse
    Brachionus calciflorus Pallas
    Brachionus quadridentata Herman
    Filinia longiseta (Ehrenberg)
    Kellicottia longispina (Kellicott)
    Keratella cochlearis (Grosse)
    Keratella quadrata (Muller)
    Notholca accuminata (Ehrenberg)
    Philodina sp.
    Platyias patulus Ahlstrom
    Pleosoma truncatum (Levander)
    Polyarthra sp.
    Trichocerca sp.
    Miscellaneous rotifer
    Unidentified rotifer #1
    Unidentified rotifer #3

Table 5-1 (cont.)

Protozoa
- Plasmodroma
  - Mastigophora
    - *Ceratium hirudinella* (Muller)
    - *Eudorina* sp.
    - *Pleodorina* sp.
    - *Volvox* sp.
  - Sarcodina
    - *Centropyxis* sp.
    - *Difflugia* sp.
- Ciliophora
  - Ciliata
    - *Carchesium* sp.
    - *Epistylis* sp.

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

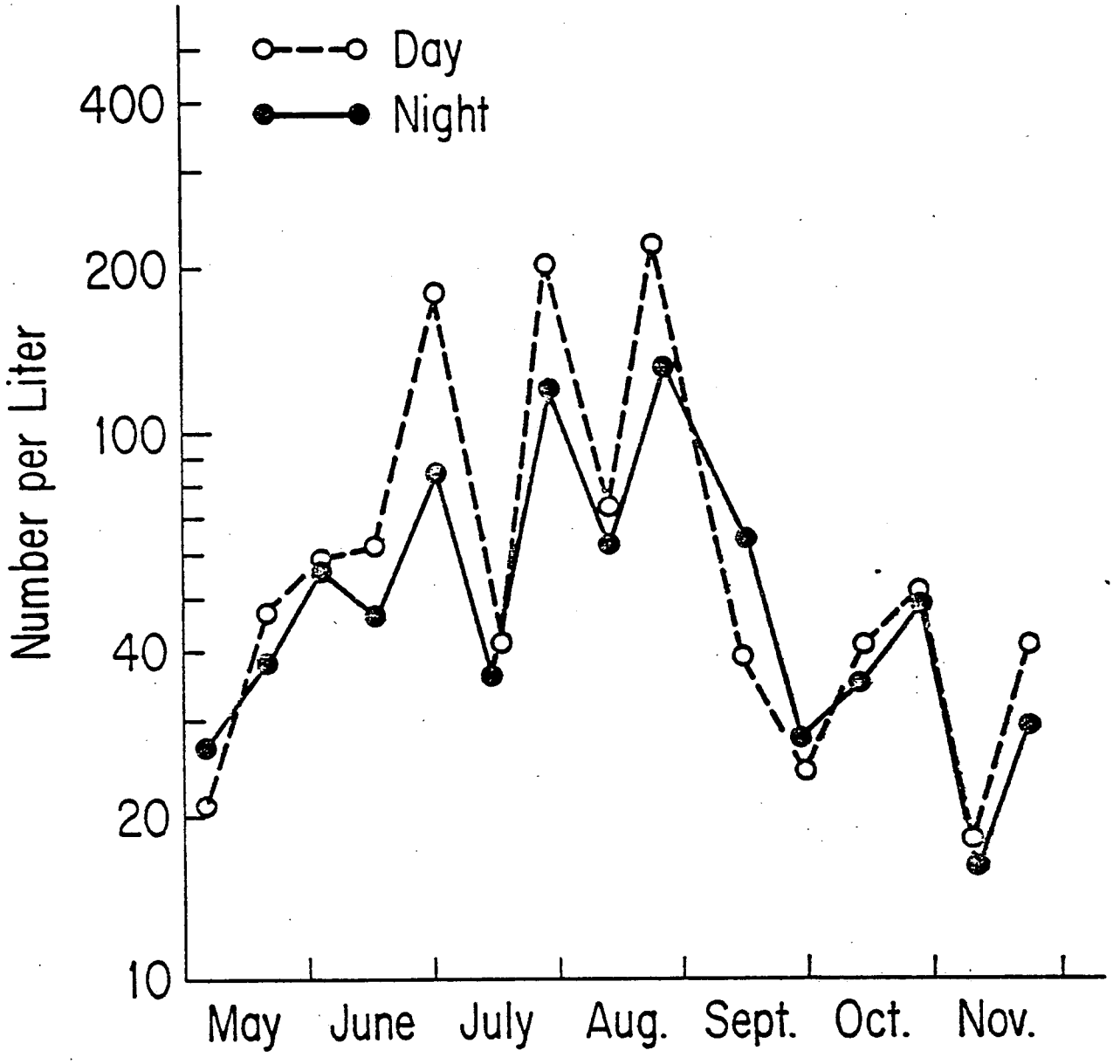

Figure 5-1. Mean day and night abundance of total microzooplankton, 1976.

Table 5-2 . Day and night abundances of total Microzooplankton, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	24.5	25.6	19.2	14.8	22.9	24.5	15.4	21.0
5/20	33.0	51.9	68.1	39.7	34.2	33.1	*	43.4
6/03	107.1	51.7	75.2	37.8	35.8	40.6	*	58.0
6/16	60.2	52.3	48.6	63.2	85.6	58.7	*	61.4
6/29	277.0	138.7	148.3	180.3	244.7	103.7	170.1	180.4
7/15	40.0	28.3	24.8	49.1	56.1	53.1	39.8	41.6
7/27	113.9	121.7	90.3	188.5	94.5	466.4	350.3	203.7
8/12	78.8	148.1	57.9	50.2	55.0	23.7	98.1	73.1
8/23	468.0	106.0	208.3	72.9	112.0	269.9	302.8	220.0
9/14	44.5	38.7	38.2	41.4	34.2	43.0	30.8	38.7
9/29	14.8	23.0	17.7	25.6	25.6	35.9	26.1	24.1
10/13	25.1	41.3	42.2	42.1	44.1	30.3	63.5	41.2
10/26	33.3	67.9	51.1	50.7	52.2	49.9	53.0	51.2
11/09	11.3	18.2	30.3	29.3	19.0	11.3	7.3	18.1
11/22	62.6	37.0	53.8	34.3	34.4	26.1	40.6	41.3

Night

5/05	36.9	27.5	15.6	34.0	18.3	26.2	*	26.4
5/20	30.1	37.3	38.2	27.3	55.6	40.6	*	38.2
6/03	75.3	51.9	84.5	42.2	53.1	29.9	*	56.1
6/16	31.9	47.8	36.9	48.8	75.7	39.1	*	46.7
7/01	45.2	38.9	103.1	145.4	69.5	99.6	92.9	85.0
7/14	28.5	38.8	36.2	35.7	45.9	23.9	44.5	36.2
7/28	88.8	100.5	133.5	116.3	123.4	120.6	159.2	120.3
8/12	45.7	55.1	35.6	53.7	48.4	141.6	54.2	62.0
8/25	117.7	240.1	109.8	109.5	78.0	128.2	150.3	133.4
9/15	46.5	86.7	110.3	50.2	32.5	59.5	61.5	63.9
9/28	34.9	32.0	37.1	17.1	16.9	35.4	20.1	27.6
10/21	15.7	43.4	43.7	37.8	27.2	21.9	52.4	34.6
10/27	26.4	36.7	71.5	58.3	41.7	42.4	67.8	49.3
11/10	17.9	12.5	23.1	8.6	15.4	25.5	10.8	16.2
11/22	33.0	13.1	60.0	23.6	12.3	23.2	39.2	29.2

* sample missing due to loss or breakage

The seasonal pattern and the magnitude of the mean day and night abundances of Crustacea (Figure 5-2, Table 5-3) reflect those of the total microzooplankton. The periods of peak crustacean abundance during the summer months correspond to the periods of maximum copepod reproduction as shown by the large numbers of nauplii observed at that time (Figures 5-3 and 5-4; Tables 5-4 through 5-6).

Peak mean abundances of Rotifera of approximately 30 organisms per liter occurred on May 20, June 16 and October 26 (Figure 5-5; Table 5-7). Intermediate rotifer abundances (1-10 organisms/liter) were observed in July, August and early September and decreased to a low concentration value of 0.2 rotifers per liter in the September 28 night sample (Figure 5-5; Table 5-7). Intermediate abundances were also observed in November.

The most abundant rotifers observed in 1976 samples were Keratella cochlearis and an unidentified rotifer.

Mean day and night abundances of Protozoa in the Hudson River ranged from 0.3 to 16.0 organisms per liter (Figure 5-6; Table 5-8). During the remainder of the sampling period protozoan mean abundances ranged from 0.7 to 3.0 organisms per liter with the exceptions of a 0.4 organism/liter value on July 27 and the higher value observed on August 12 (Figure 5-6; Table 5-8).

The most frequently observed protozoan species were the shelled amoeba Centropyxis sp., and the colonial peritrich,

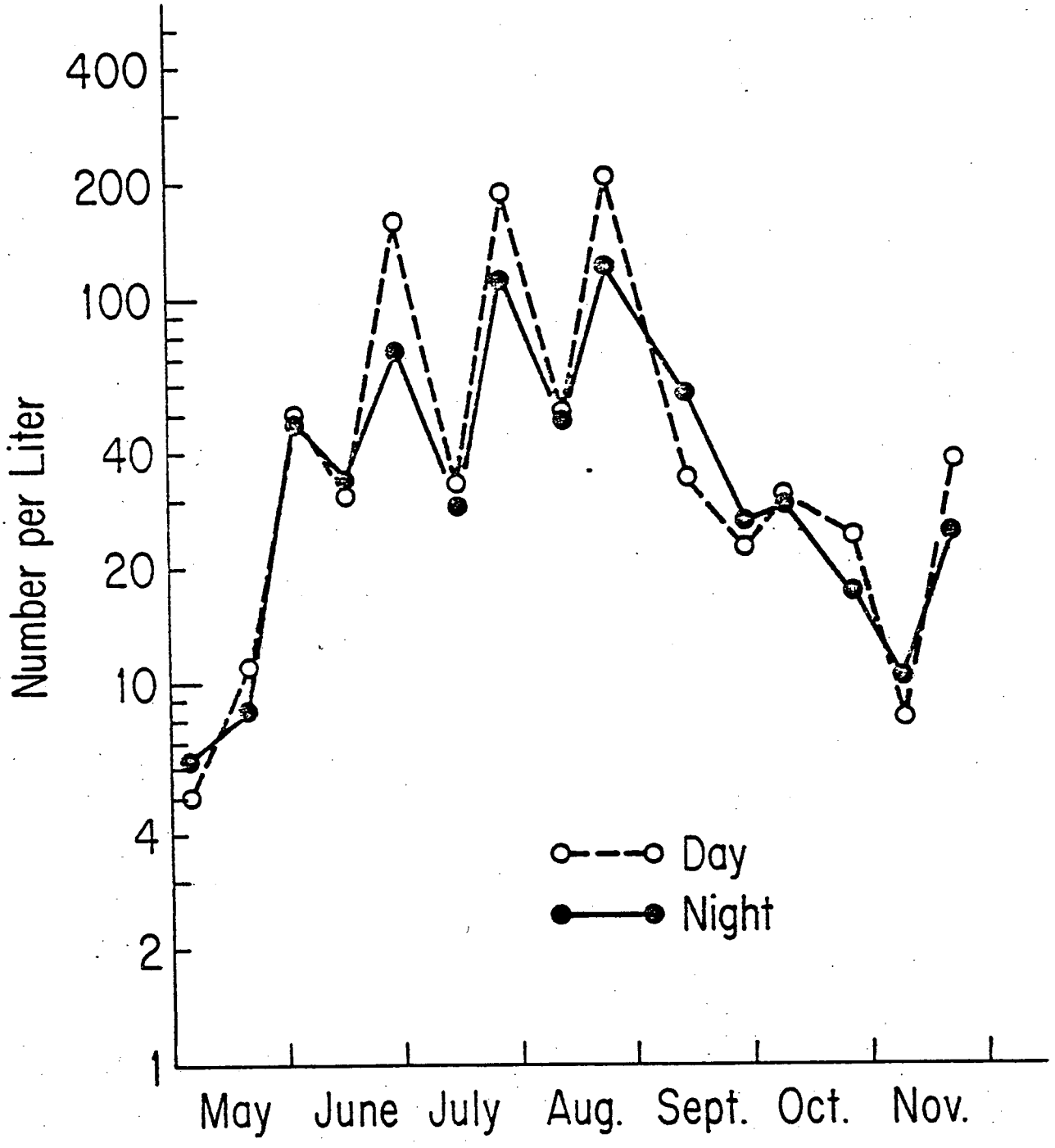

Figure 5-2. Mean day and night abundance of Crustacea, 1976.

Table 5-3. Day and night abundances of Crustacea, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	4.20	4.88	6.31	3.88	6.57	4.98	4.12	5.0
5/20	10.16	8.90	22.07	5.29	11.53	8.24	*	11.0
6/03	98.87	41.24	65.95	32.62	30.01	33.73	*	50.4
6/16	33.44	28.72	24.57	26.38	42.81	31.64	*	31.3
6/29	250.68	123.02	128.36	159.35	212.07	86.39	153.77	159.1
7/15	33.23	22.70	23.32	41.17	39.72	40.56	33.42	33.4
7/27	95.19	105.21	79.87	178.56	73.31	453.33	327.40	187.6
8/12	51.96	112.44	39.28	36.71	34.99	12.35	65.12	50.4
8/23	446.26	98.71	195.80	59.82	101.31	257.98	280.89	205.8
9/14	37.49	31.55	32.25	38.45	31.36	41.43	25.01	33.9
9/29	12.42	21.79	16.09	22.70	24.42	34.59	25.02	22.4
10/13	21.33	30.37	32.29	36.78	37.88	16.68	35.78	30.2
10/26	19.01	26.40	16.35	38.12	31.66	11.35	23.61	23.8
11/09	4.26	6.26	14.41	10.33	9.73	5.71	5.28	8.0
11/22	57.26	32.15	49.74	31.66	31.76	24.29	39.14	38.0

Night

5/05	8.6	7.1	3.6	7.1	4.3	6.4	*	6.2
5/20	8.8	7.7	5.7	5.8	10.8	12.0	*	8.5
6/03	6.56	46.5	74.4	38.3	45.3	22.4	*	48.8
6/16	23.3	32.2	27.7	36.3	54.5	26.8	*	33.5
7/01	40.1	33.1	93.3	119.2	60.5	82.7	82.0	73.0
7/14	22.2	32.3	24.9	27.0	36.2	18.5	41.1	28.9
7/28	85.7	97.2	122.3	111.3	115.9	112.5	140.3	112.2
8/12	31.2	39.5	26.6	40.3	39.9	123.4	41.5	48.9
8/25	113.6	205.5	105.4	93.0	68.7	108.0	146.6	120.1
9/15	35.3	83.3	101.4	40.7	30.9	57.4	50.0	57.0
9/28	33.7	31.4	36.3	14.7	15.7	33.0	19.4	26.3
10/12	14.5	36.5	37.2	29.8	21.8	16.1	46.8	29.0
10/27	15.4	11.3	20.0	12.4	10.7	9.6	40.8	17.2
11/10	12.8	4.7	17.2	5.3	8.9	17.1	6.6	10.4
11/22	31.1	9.9	49.4	16.5	10.6	21.3	32.9	24.5

* samples missing due to loss or breakage

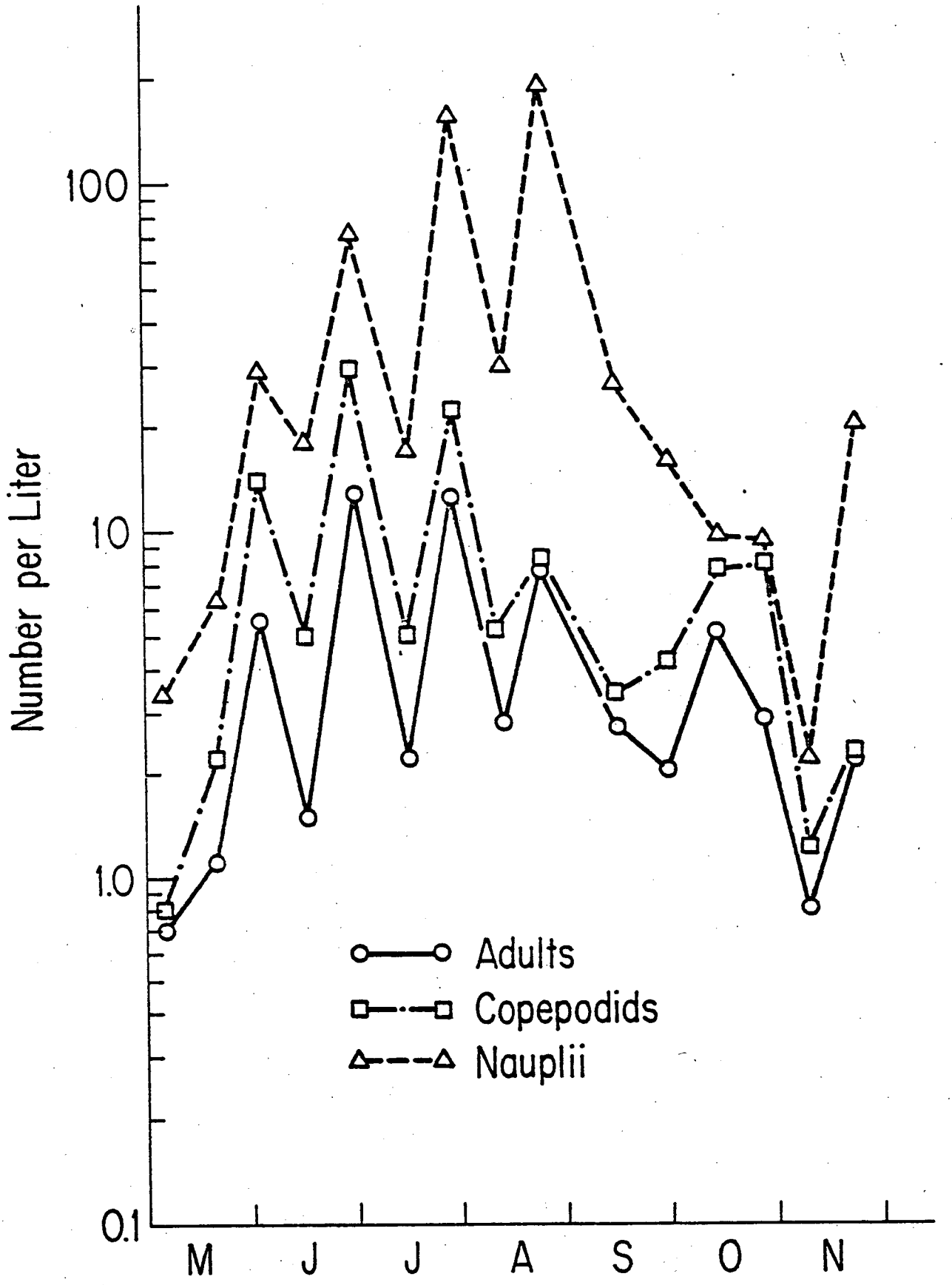

Figure 5-3. Mean day abundance of total Copepoda, 1976.

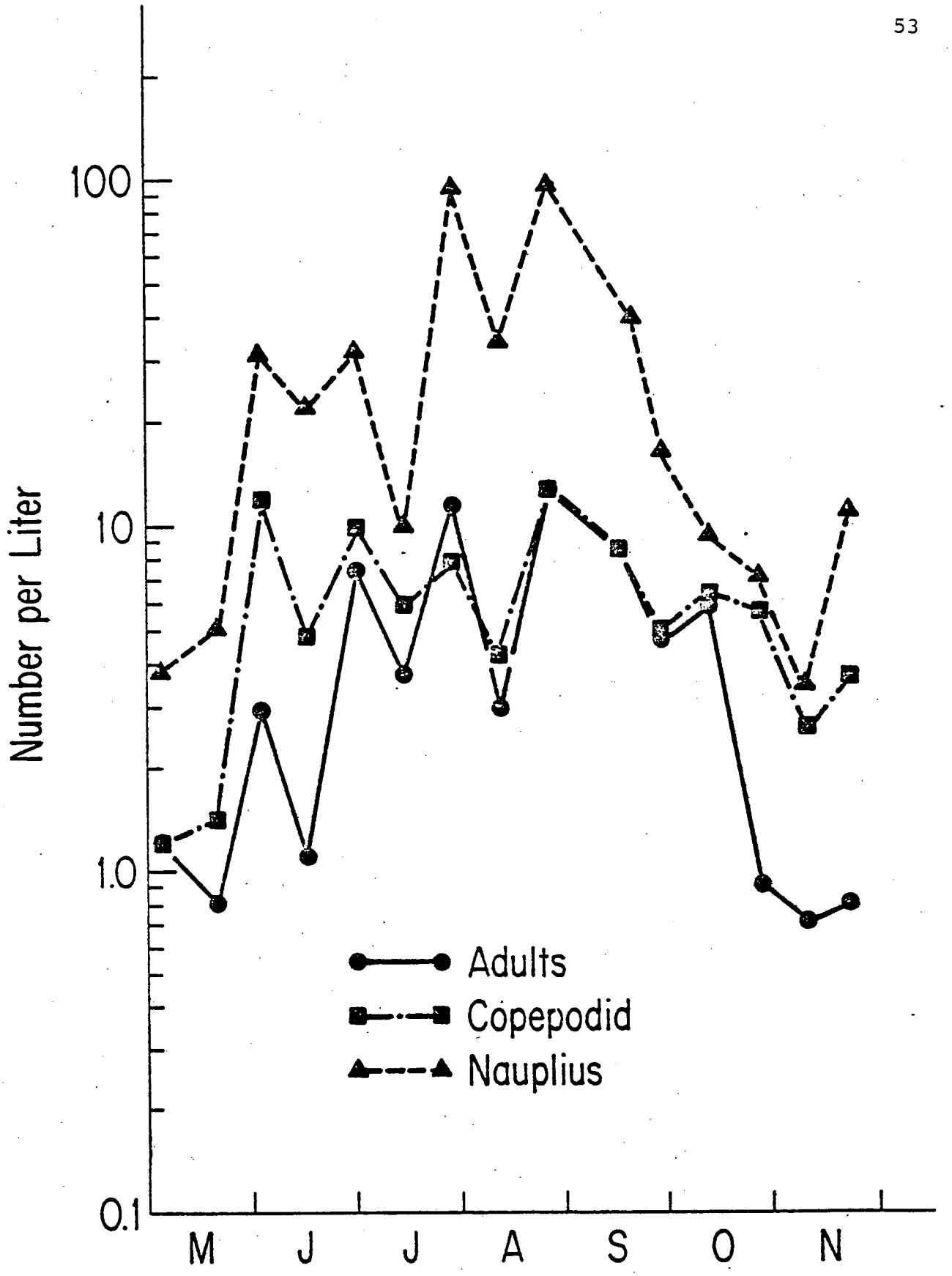

Figure 5-4. Mean night abundance of total Copepoda, 1976.

Table 5-4. Day and night abundances of Copepoda, Nauplii, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	2.72	3.40	3.49	2.56	5.05	4.80	1.94	3.4
5/20	5.76	5.29	9.66	3.48	7.40	6.15	*	6.3
6/03	40.07	28.27	35.13	21.07	21.44	26.44	*	28.7
6/16	21.37	15.73	13.65	13.28	22.38	21.04	*	17.9
6/29	104.45	62.87	50.66	63.38	95.07	58.12	72.01	72.4
7/15	16.05	10.69	6.43	29.53	23.64	22.94	11.57	17.3
7/27	18.24	59.13	46.23	167.23	59.26	441.00	302.47	156.2
8/12	43.10	61.98	13.68	8.84	23.68	4.17	51.45	29.6
8/23	436.36	86.13	181.67	23.97	81.16	255.40	254.12	188.4
9/14	32.22	22.43	12.87	36.51	29.89	34.30	15.66	26.3
9/29	6.52	13.80	9.38	18.70	21.89	28.17	13.61	16.0
10/13	10.10	8.44	8.29	5.85	5.87	5.82	22.99	9.6
10/26	13.07	5.50	5.15	13.16	16.16	4.05	9.04	9.4
11/09	1.84	2.24	2.55	2.35	1.03	1.71	3.37	2.2
11/22	25.87	20.04	26.05	8.31	17.15	12.18	31.33	20.1

Night

5/05	5.65	4.58	2.05	4.97	2.22	3.46	*	3.8
5/20	4.00	5.23	4.34	2.67	6.98	7.13	*	5.1
6/03	53.87	30.08	47.68	19.30	19.62	15.46	*	31.0
6/16	13.09	19.16	18.37	23.57	37.54	20.12	*	22.0
7/01	18.38	19.67	26.50	40.94	34.35	45.06	34.71	31.4
7/14	5.29	9.64	9.95	12.49	17.57	8.75	6.06	10.0
7/28	79.59	83.59	97.23	86.19	97.94	93.32	113.21	93.0
8/12	15.85	28.16	15.72	29.68	29.92	97.34	20.63	33.9
8/25	99.89	151.29	87.97	59.38	42.37	92.33	128.80	94.6
9/15	27.79	53.58	86.33	27.78	15.96	25.77	38.93	39.4
9/28	21.68	18.17	22.44	12.01	12.27	13.77	14.69	16.4
10/12	5.41	14.45	15.68	6.69	4.77	5.16	13.70	9.4
10/27	7.70	5.88	8.88	3.28	4.29	6.21	13.61	7.1
11/10	4.38	1.21	7.04	1.65	1.11	6.31	2.21	3.4
11/22	11.17	3.11	21.18	7.24	5.22	10.63	17.41	10.9

* Samples missing due to loss or breakage

Table 5-5. Day and night abundances of Copepodids, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	.59	.57	1.34	.81	1.01	.18	1.33	.8
5/20	1.69	1.44	6.34	.91	2.31	.55	*	2.2
6/03	34.64	8.09	20.44	8.18	6.12	5.92	*	13.9
6/16	4.34	3.87	3.99	5.24	6.95	5.16	*	4.9
6/29	42.69	24.67	24.48	33.92	32.18	17.32	27.67	29.0
7/15	4.29	4.28	5.95	3.88	4.39	4.48	7.71	5.0
7/27	43.15	23.81	23.58	4.99	6.39	6.34	12.87	17.3
8/12	3.35	6.86	6.33	7.07	5.03	3.19	3.62	5.1
8/23	4.29	8.06	8.67	14.95	10.07	1.93	10.71	8.4
9/14	2.38	3.51	7.05	.45	.49	5.04	4.91	3.4
9/29	4.04	4.84	3.71	3.45	1.52	3.46	7.46	4.1
10/13	6.55	7.21	5.12	15.83	12.27	3.37	3.50	7.7
10/26	4.46	6.05	4.26	19.06	11.45	3.65	6.28	7.9
11/09	.72	.60	3.10	.47	1.44	1.43	.56	1.2
11/22	4.24	.31	2.05	3.49	1.23	2.35	2.18	2.3

Night

5/05	1.66	1.60	1.02	1.22	.87	.62	*	1.2
5/20	2.95	.56	.17	.70	1.44	2.70	*	1.4
6/03	0.00	11.71	20.55	14.78	18.46	5.31	*	11.8
6/16	5.39	3.22	2.55	3.91	8.16	1.79	*	4.2
7/01	7.90	4.14	14.57	12.14	7.09	11.07	12.35	9.9
7/14	5.88	8.81	5.57	5.17	3.51	4.03	8.09	5.9
7/28	2.55	4.79	5.18	15.50	6.57	8.45	10.61	7.7
8/12	4.83	3.61	5.60	2.95	2.43	5.31	4.58	4.2
8/25	6.43	14.41	5.20	21.46	15.66	11.65	5.30	11.4
9/15	4.37	11.69	8.90	4.09	4.79	19.47	5.65	8.4
9/28	7.85	6.54	5.01	2.40	2.54	7.87	2.00	4.9
10/12	5.95	6.88	8.36	5.35	2.58	3.50	11.81	6.3
10/27	5.10	2.01	6.06	3.03	1.72	2.35	18.69	5.6
11/10	4.05	.87	5.87	1.49	.37	4.44	1.41	2.6
11/22	8.02	.28	7.65	.74	2.41	1.94	4.43	3.6

* samples missing due to loss or breakage

Table 5-6. Day and night abundances of adult Copepods, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	.71	.79	1.34	.51	.51	0.00	.73	.7
5/20	1.36	.96	3.31	.15	.61	.33	*	1.1
6/03	20.60	2.66	7.19	1.35	.77	.55	*	5.5
6/16	.46	.34	.74	2.27	4.35	.84	*	1.5
6/29	13.17	10.23	12.52	19.64	17.06	4.38	12.89	12.8
7/15	3.84	.49	3.22	.65	.73	1.40	4.93	2.2
7/27	33.36	21.12	9.75	4.99	6.90	5.99	5.23	12.5
8/12	.48	2.19	2.51	5.17	.74	4.74	3.42	2.8
8/23	2.64	2.90	3.85	19.56	9.18	.64	14.60	7.6
9/14	1.13	.53	10.57	1.04	.73	1.60	3.51	2.7
9/29	1.09	2.42	2.43	.54	1.01	2.80	3.95	2.0
10/13	.94	2.15	2.56	12.42	14.76	2.45	.46	5.1
10/26	.30	6.88	2.46	4.30	3.03	.81	1.26	2.7
11/09	.13	.89	1.46	1.25	.96	.14	.56	.8
11/22	3.39	1.71	3.55	.48	1.02	4.20	2.41	2.4

Night

5/05	1.33	.92	.51	.77	1.24	2.35	*	1.2
5/20	1.24	.22	.33	.70	1.93	.49	*	.8
6/03	1.58	2.44	3.08	3.56	5.94	.99	*	2.9
6/16	.38	.81	2.04	1.30	1.63	.56	*	1.1
7/01	5.33	3.73	12.98	9.04	3.00	10.28	7.92	7.5
7/14	3.38	5.03	1.73	1.72	1.32	1.67	11.19	3.7
7/28	3.32	8.84	19.93	9.30	10.96	10.70	16.51	11.4
8/12	3.49	2.89	1.99	2.72	1.78	1.77	5.73	2.9
8/25	5.84	36.71	11.00	10.73	8.57	4.03	12.16	12.7
9/15	2.78	17.54	5.42	7.54	9.57	11.10	5.45	8.5
9/28	4.13	6.40	8.72	.30	.42	10.93	1.81	4.7
10/12	2.07	7.57	5.43	6.88	3.77	3.21	11.34	5.8
10/27	.54	.46	1.01	1.01	.43	.43	2.77	.9
11/10	.67	.69	.59	.17	1.48	.93	.40	.7
11/22	.49	.28	.59	1.11	.40	1.30	1.58	.8

* Samples missing due to loss or breakage

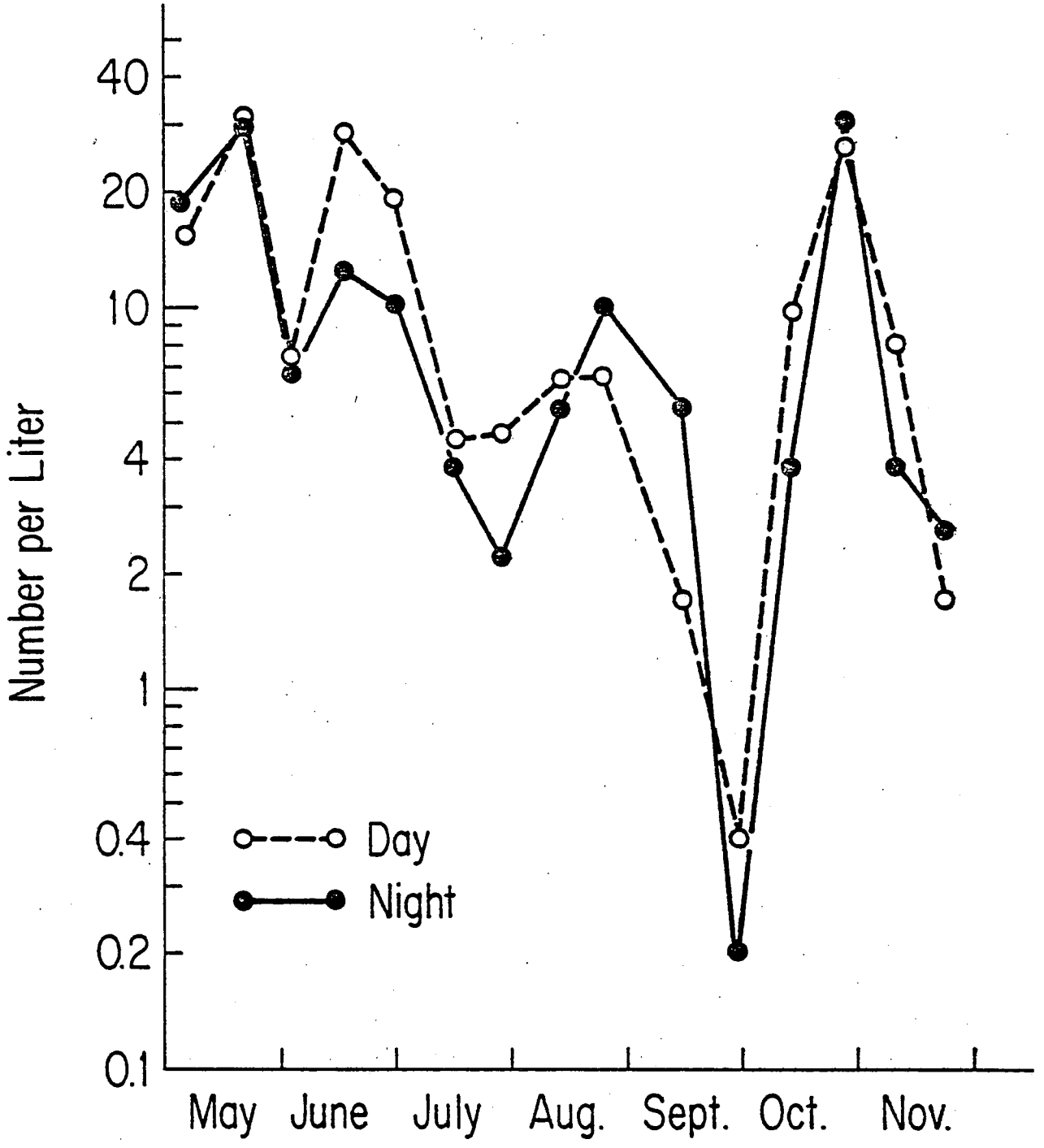

Figure 5-5. Mean day and night abundance of Rotifera, 1976.

Table 5-7. Day and night abundances of Rotifera, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	19.4	20.0	11.9	10.5	15.7	18.0	10.8	15.2
5/20	21.5	42.6	46.1	34.2	21.7	24.5	*	31.8
6/03	7.9	9.9	9.3	4.9	5.4	6.7	*	7.3
6/16	25.2	22.9	23.1	35.3	41.9	24.5	*	28.8
6/29	22.7	14.7	18.5	17.9	28.3	14.9	15.7	19.0
7/15	2.9	2.6	0.0	4.3	9.7	7.6	4.5	4.5
7/27	3.1	3.5	2.2	3.6	0.0	9.2	10.5	4.6
8/12	7.9	11.5	5.6	4.8	5.8	3.4	6.6	6.5
8/23	13.2	3.1	4.2	5.4	4.7	7.7	9.7	6.9
9/14	1.8	1.9	1.4	1.2	1.2	.1	4.2	1.7
9/29	.5	.1	.2	.4	.5	0.0	.9	.4
10/13	2.8	9.7	4.1	4.1	5.0	12.6	25.4	9.7
10/26	12.5	40.7	11.5	11.5	19.2	37.7	28.9	26.3
11/09	6.0	9.8	15.2	15.2	7.0	3.1	1.6	7.8
11/22	2.8	2.0	1.9	1.9	1.5	1.1	.8	1.7

Night

5/05	24.6	20.1	10.8	26.4	13.3	18.4	*	18.9
5/20	21.1	29.5	32.2	21.5	44.3	28.0	*	29.4
6/03	9.5	3.6	9.5	3.6	7.4	6.9	*	6.7
6/16	7.9	15.0	7.8	12.1	19.9	11.8	*	12.4
7/01	4.4	5.4	8.5	19.8	8.5	14.8	10.1	10.2
7/14	3.2	3.4	6.0	3.3	5.1	4.0	1.6	3.8
7/28	1.8	.7	2.0	4.0	1.8	2.8	2.1	2.2
8/12	6.7	5.8	3.3	5.2	4.4	7.1	5.2	5.4
8/25	3.2	30.9	3.1	14.5	5.4	11.7	1.2	10.0
9/15	9.5	1.9	8.5	7.8	1.2	1.0	8.7	5.5
9/28	.2	0.0	.2	.3	.6	0.0	.2	.2
10/12	.5	5.2	4.4	5.7	3.4	4.7	2.8	3.8
10/27	10.3	24.6	49.7	44.5	29.9	30.8	26.3	30.9
11/10	3.2	4.5	3.7	1.8	4.3	5.8	3.4	3.8
11/22	0.0	1.6	7.1	5.2	.4	.6	3.5	2.6

* Sample missing due to loss or breakage

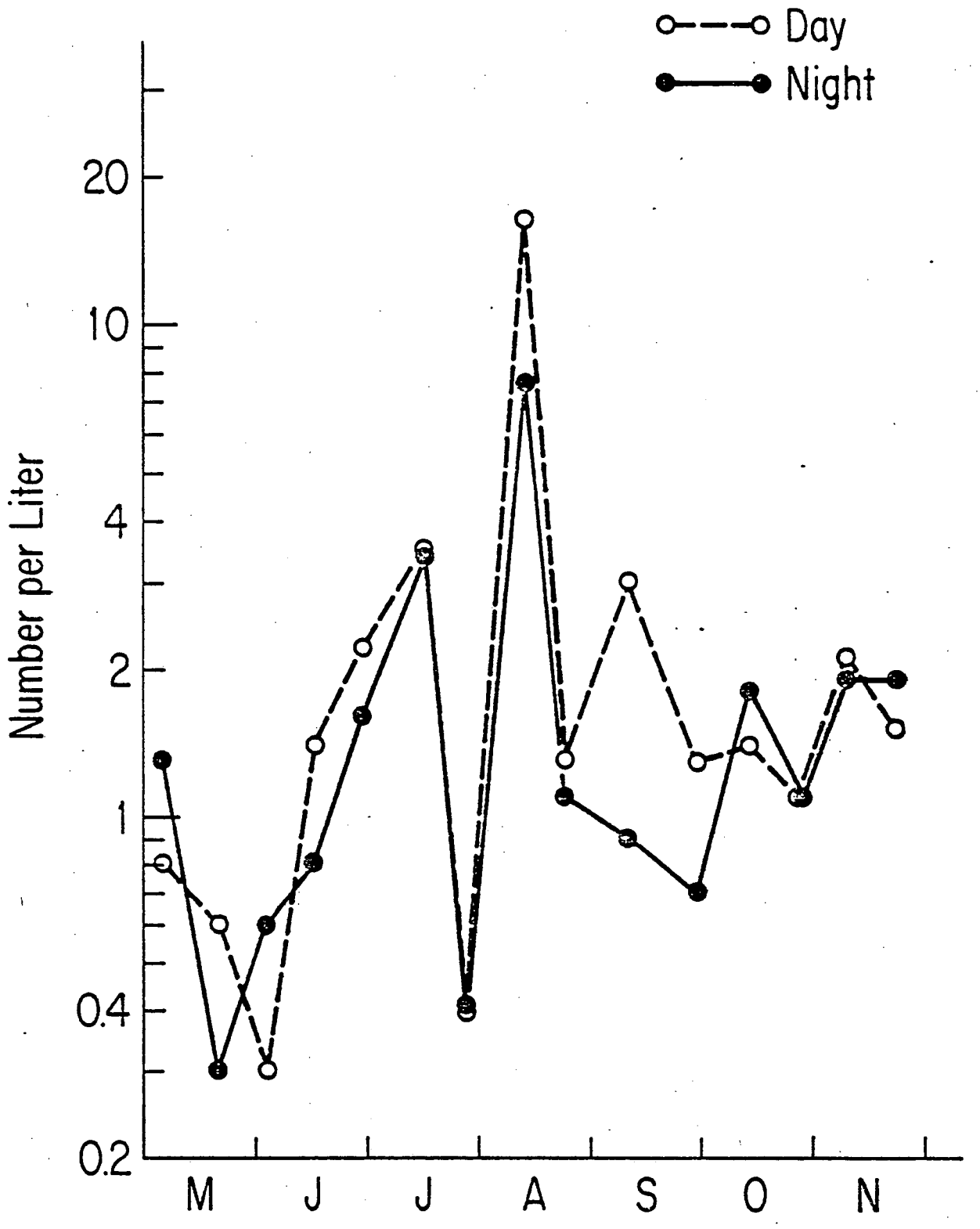

Figure 5-6. Mean day and night abundance of Protozoa, 1976.

Table 5-8. Day and night abundances of Protozoa, 1976. Number per liter.

Day

Station

Date	A	B	C	D	E	F	G	Mean
5/05	.95	.79	.87	.37	.51	1.42	.48	.8
5/20	1.36	.48	0.00	.30	.97	.33	*	.6
6/03	.37	.55	0.00	.22	.46	.14	*	.3
6/16	1.55	.68	.95	1.57	.87	2.51	*	1.4
6/29	3.63	.90	1.42	2.68	3.90	1.99	.63	2.2
7/15	3.84	2.96	1.45	3.45	5.85	5.04	1.93	3.5
7/27	1.33	0.00	0.00	0.00	.51	.35	.40	.4
8/12	18.91	23.86	12.94	8.70	14.11	8.02	25.73	16.0
8/23	2.97	.32	1.60	.77	1.18	.97	1.46	1.3
9/14	5.14	5.26	4.58	1.70	1.59	1.35	1.40	3.0
9/29	1.86	1.09	1.39	2.54	.67	1.15	.22	1.3
10/13	.94	1.23	1.66	1.22	1.24	1.07	2.28	1.4
10/26	1.78	.83	1.34	1.07	1.35	.81	.25	1.1
11/09	1.05	2.09	3.83	3.76	2.26	2.29	.45	2.2
11/22	2.54	2.80	2.05	.60	1.12	.71	.69	1.5

Night

5/05	3.65	.23	1.28	.55	.62	1.36	*	1.3
5/20	.10	.11	.33	0.00	.48	.49	*	.3
6/03	.20	1.79	.62	.27	.33	.53	*	.6
6/16	.77	.64	1.40	.39	1.31	.45	*	.8
7/01	.74	.41	1.32	6.49	.55	1.05	.93	1.6
7/14	3.09	3.14	5.31	5.17	4.39	1.11	1.35	3.4
7/28	0.00	0.00	.80	.31	.88	.19	.29	.4
8/12	7.79	9.87	5.60	8.16	4.04	10.62	7.45	7.6
8/25	.58	1.37	.59	.95	1.48	2.69	.31	1.1
9/15	1.59	1.46	.39	1.29	.40	.96	.20	.9
9/28	.83	.58	.56	2.10	.42	.22	0.00	.7
10/12	.72	1.72	1.88	2.29	1.99	1.17	2.83	1.8
10/27	.72	.62	1.82	1.26	1.14	1.50	.69	1.1
11/10	1.85	2.94	2.15	1.32	1.86	2.57	.80	1.9
11/22	1.94	1.69	3.53	1.11	1.34	1.17	2.85	1.9

* samples missing due to loss or breakage

Carchesium sp. The most abundant protozoans observed during the period of peak protozoan concentrations were the dinoflagellate, Ceratium hirudinella and the colonial phytomonad, Eudorina sp.

The occurrence of the calanoid copepod, Acartia tonsa in the Indian Point vicinity was limited to the summer months (Figure 5-7; Table 5-9). Peak concentrations of A. tonsa were between 5 and 6 per liter. Eurytemora affinis, the other abundant calanoid copepod, occurred from May 20 to the end of the sampling period with the exception of October 12-13 when no E. affinis were observed in either day or night samples (Figure 5-8; Table 5-10). Mean abundance of E. affinis was generally between one and five organisms per liter through the summer and somewhat less than one in the spring and fall (Figure 5-8; Table 5-10). The cyclopoid copepods, Diacyclops bicuspidatus (Figure 5-9; Table 5-11) and Halicyclops fosteri (Figure 5-10; Table 5-12) were observed in either a day or night sample during the entire May through November sampling period. The peak mean abundance of D. bicuspidatus occurred in late June while that of H. fosteri occurred in October. Peak mean abundance values of D. bicuspidatus and H. fosteri were comparable to the peak values for the calanoid copepods, A. tonsa and E. affinis however, cyclopoid abundances were generally lower (between 0.1 and 1.0 organisms per liter) throughout the sampling period.

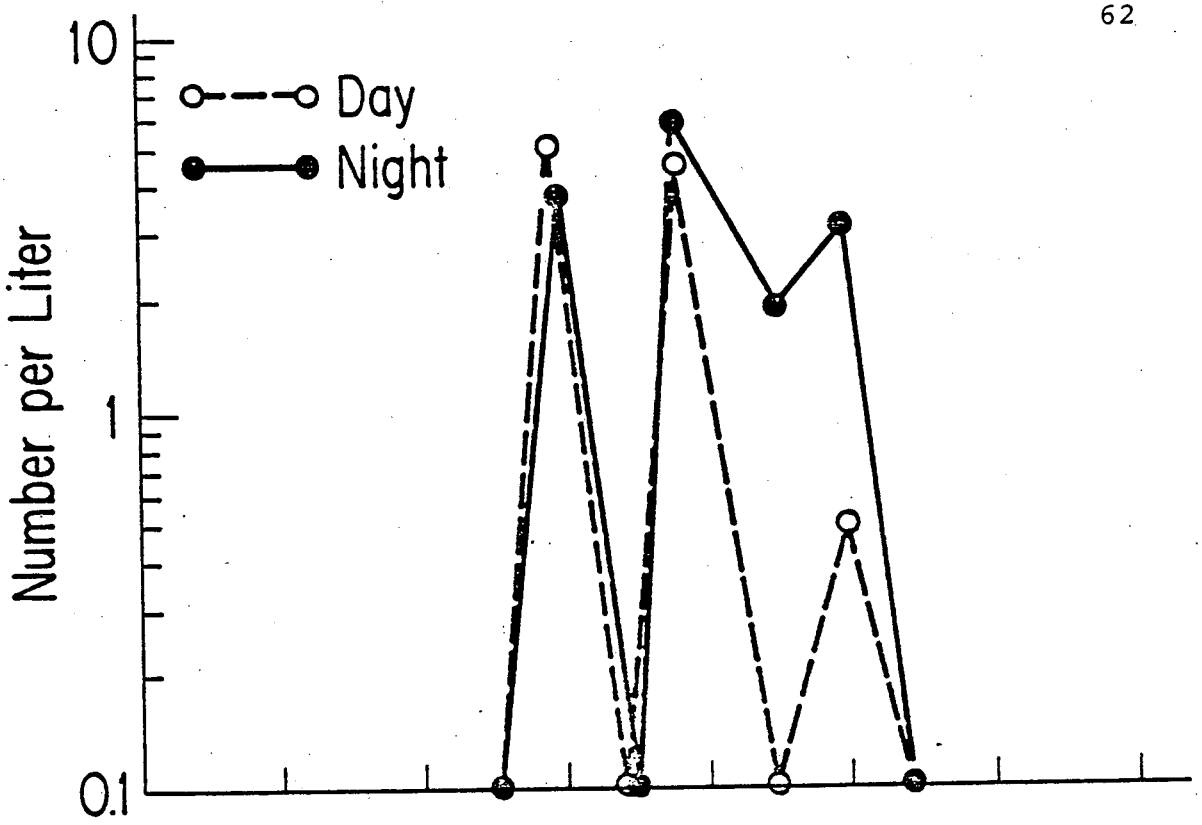

Figure 5-7. Mean day and night abundance of Acartia tonsa, 1976.

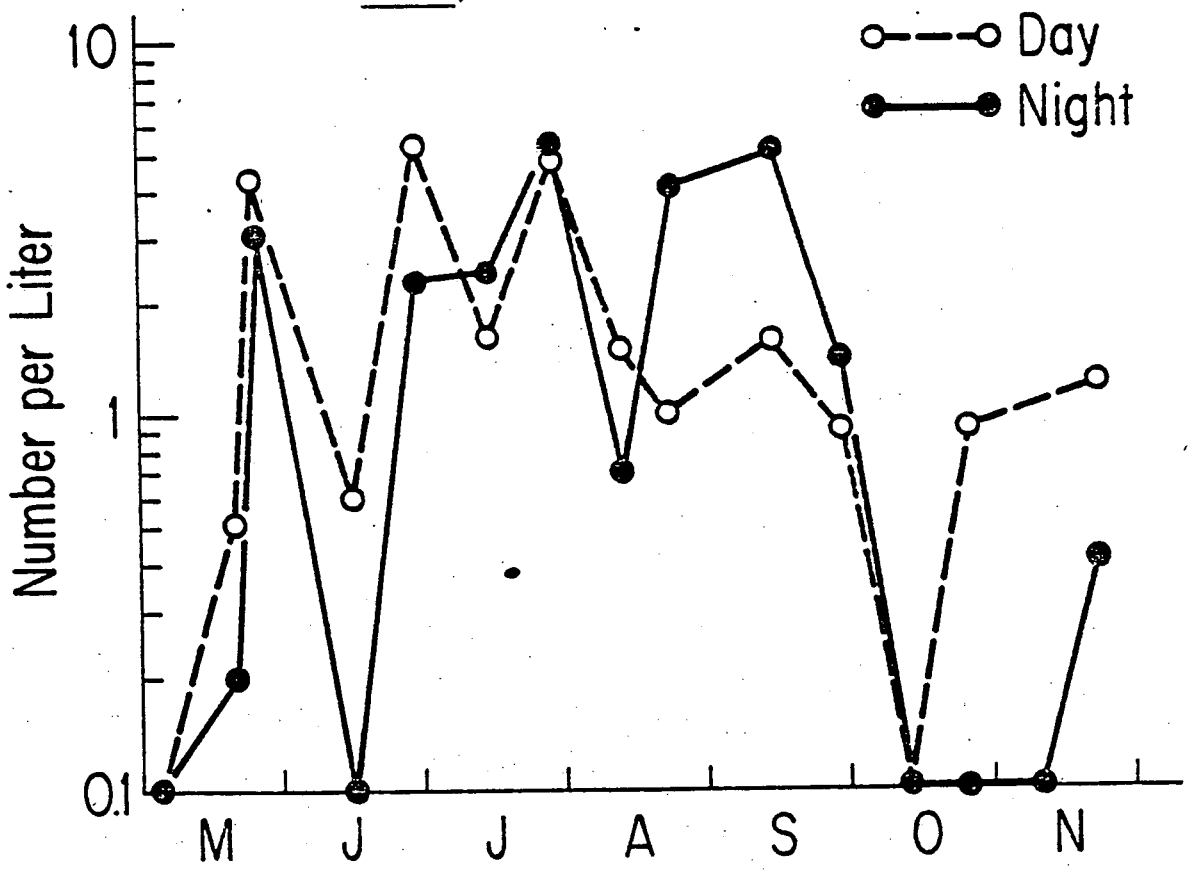

Figure 5-8. Mean day and night abundance of Eurytemora affinis, 1976.

Table 5-9 . Day and night abundances of *Acartia tonsa*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	.06	0.00	0.00	0.00	0.00	0.00	0.00	.0
5/20	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/03	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/16	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7/15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7/27	9.79	9.60	6.92	.91	2.30	3.17	2.82	5.1
8/12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8/23	.66	1.61	1.60	12.08	5.92	.32	9.25	4.5
9/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9/29	0.00	0.00	.12	0.00	0.00	2.64	.66	.5
10/13	0.00	0.00	0.00	0.00	0.00	.31	0.00	.0
10/26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

Night

5/05	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
5/20	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/03	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/16	0.00	0.00	.13	0.00	0.00	0.00	*	.0
7/01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7/28	0.00	1.47	4.78	1.55	3.29	7.32	8.25	3.8
8/12	0.00	0.00	0.00	0.00	0.00	0.44	0.00	.1
8/25	3.21	17.15	4.16	1.91	3.63	2.24	8.73	5.9
9/15	0.00	1.46	1.16	0.65	0.20	5.89	3.63	1.9
9/28	2.48	4.65	6.86	0.00	0.00	7.65	.36	3.1
10/12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10/27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

* samples missing due to loss or breakage

Table 5-10. Day and night abundances of *Eurytemora affinis*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	.06	0.00	.07	0.00	0.00	0.00	0.00	.0
5/20	.17	.48	2.48	0.00	.12	0.00	*	.5
6/03	17.60	2.00	5.43	.45	.15	.28	*	4.3
6/16	.31	.11	.32	.70	1.96	0.00	*	.6
6/29	5.00	5.72	5.69	5.80	6.34	1.39	8.18	5.4
7/15	3.39	.16	1.77	.65	.24	.84	4.28	1.6
7/27	18.24	9.98	2.20	.91	2.30	0.00	.80	4.9
8/12	.24	1.10	1.02	1.63	.17	3.44	2.61	1.5
8/23	0.00	0.00	0.00	3.45	1.78	0.00	1.46	1.0
9/14	.75	.18	6.52	.15	0.00	1.11	2.57	1.6
9/29	.47	1.45	1.16	0.00	.17	.16	2.63	.9
10/13	0.00	.15	0.00	0.00	.18	0.00	0.00	.0
10/26	0.00	3.58	.22	1.34	1.01	.20	.25	.9
11/09	0.00	0.00	.36	.16	.14	0.00	0.00	.1
11/22	0.00	.16	2.58	.24	.31	3.28	1.95	1.2

Night

5/05	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
5/20	.19	0.00	.17	.28	.24	.49	*	.2
6/03	.59	.98	.41	2.46	3.30	.23	*	1.3
6/16	0.00	0.00	.26	0.00	0.00	.22	*	.1
7/01	3.49	1.24	5.03	.85	.55	1.84	3.03	2.3
7/14	3.09	4.19	1.59	.72	.44	1.11	9.43	2.9
7/28	2.81	6.26	10.36	4.34	4.38	2.82	6.19	5.3
8/12	1.34	.24	.18	.68	0.00	0.00	2.29	.7
8/25	2.04	13.72	3.42	6.44	1.65	0.00	1.25	4.1
9/15	1.99	14.13	3.48	3.88	6.38	4.93	1.01	5.1
9/28	1.65	1.45	1.48	.30	.21	3.28	1.27	1.4
10/12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10/27	.09	0.00	.20	0.00	0.00	.21	.23	.1
11/10	.17	0.00	.39	.08	.19	0.00	.20	.1
11/22	.24	.14	.59	.19	.13	.26	.95	.4

* sample missing due to loss or breakage

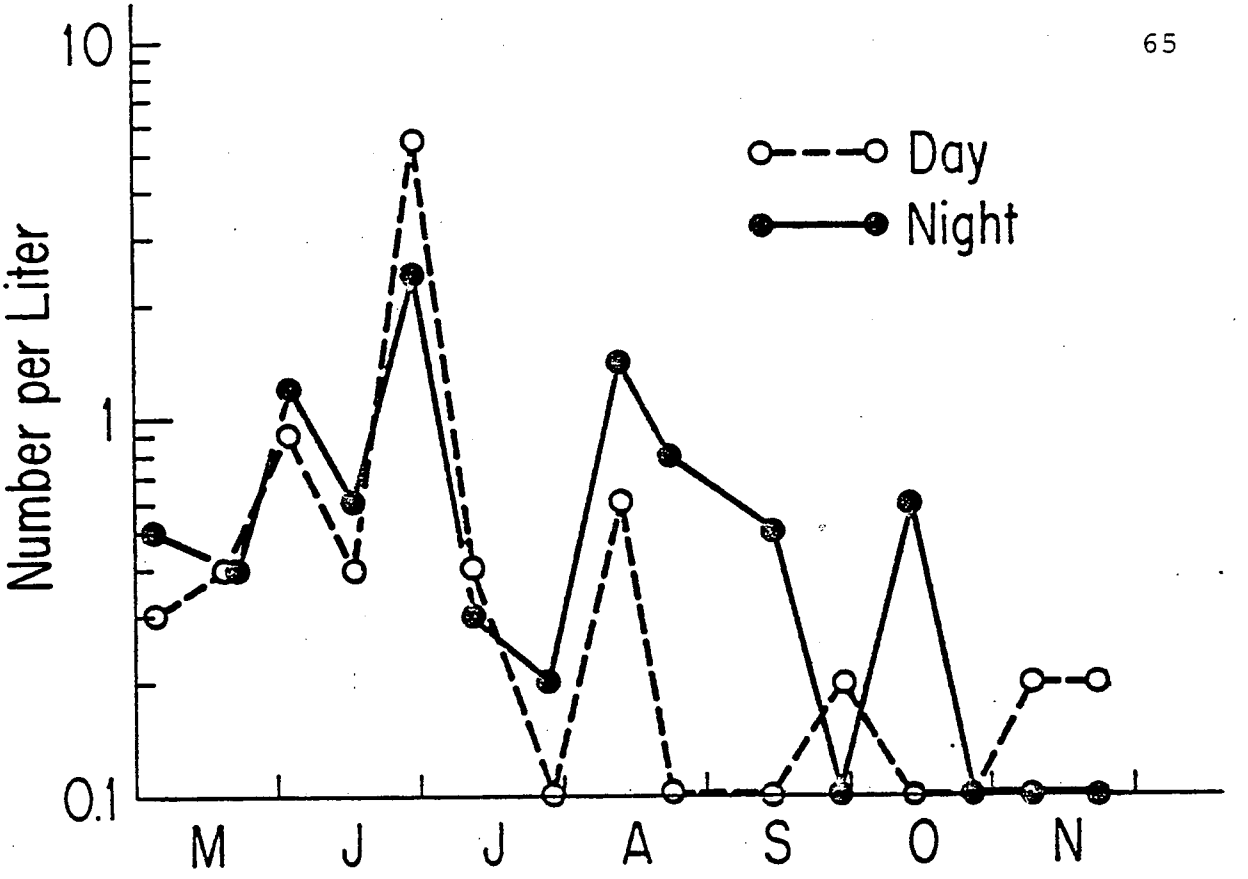

Figure 5-9. Mean day and night abundance of Diacyclops bicuspidatus, 1976.

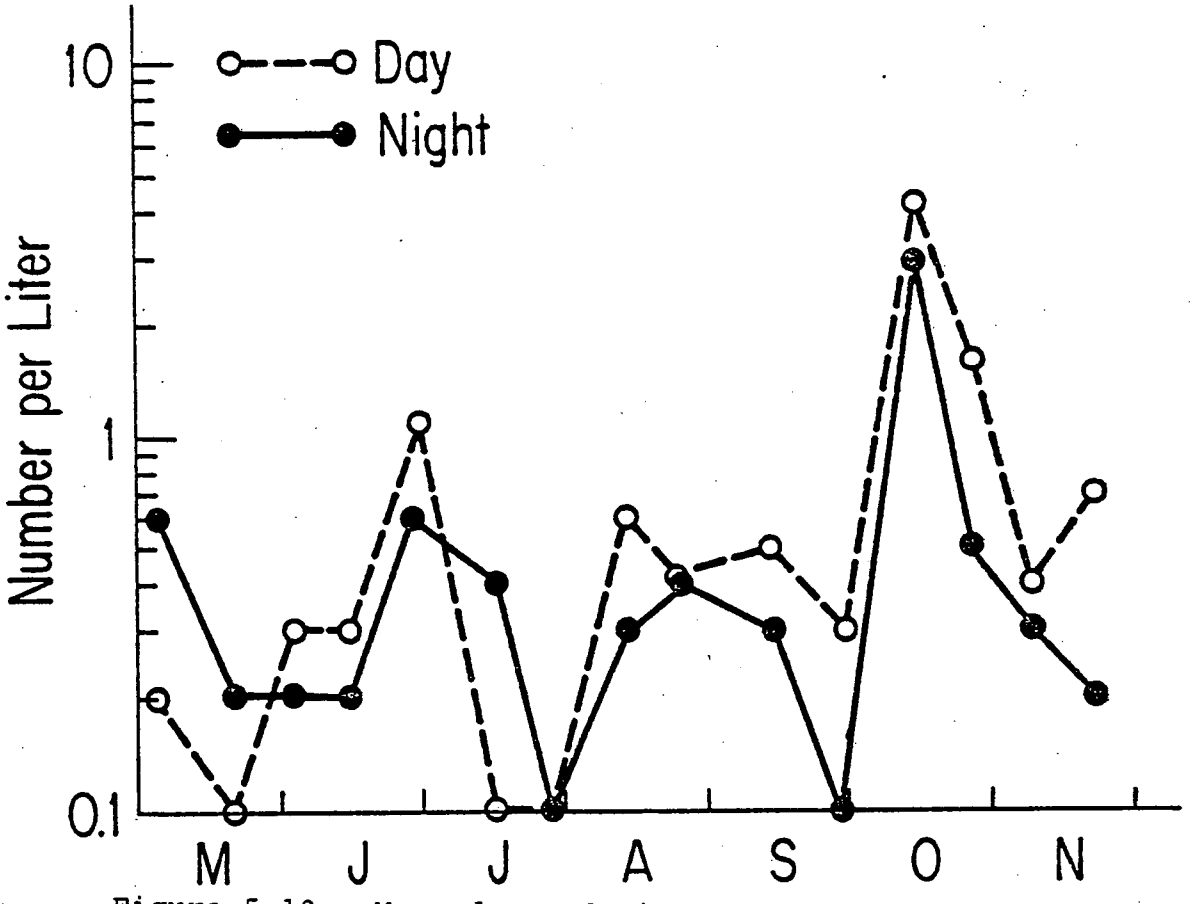

Figure 5-10. Mean day and night abundance of Halicyclops fosteri, 1976

Table 5-11. Day and night abundances of *Diacyclops bicuspidatus*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	.30	.45	.81	.15	.13	0.00	.48	.3
5/20	1.02	0.00	.83	.15	.36	.22	*	.4
6/03	2.43	.44	1.28	.56	.61	.14	*	.9
6/16	0.00	.11	.21	.52	1.30	.42	*	.4
6/29	5.45	3.91	5.12	9.82	8.78	1.99	3.46	5.5
7/15	.45	0.00	1.45	0.00	.24	0.00	.64	.4
7/27	0.00	.38	0.00	0.00	0.00	0.00	0.00	.1
8/12	0.00	.55	.56	2.18	.08	.49	.60	.6
8/23	0.00	.32	0.00	0.00	0.00	0.00	0.00	.0
9/14	0.00	0.00	0.00	.15	0.00	.37	.47	.1
9/29	.16	.24	.58	0.00	0.00	0.00	.22	.2
10/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10/26	0.00	0.00	0.00	.27	0.00	0.00	0.00	.0
11/09	.13	.45	.36	.31	.14	.14	0.00	.2
11/22	.64	.62	.32	0.00	0.00	0.00	0.00	.2

Night

5/05	1.00	.23	.26	.33	.37	.74	*	.5
5/20	.95	0.00	0.00	.28	1.20	0.00	*	.4
6/03	.59	1.14	2.26	.96	2.14	.30	*	1.2
6/16	.19	.64	.89	.52	.98	.34	*	.6
7/01	.92	.62	2.65	5.08	1.91	3.95	1.63	2.4
7/14	0.00	0.00	0.00	0.00	.44	.28	1.08	.3
7/28	0.00	.74	.40	0.00	0.00	0.00	0.00	.2
8/12	1.61	1.68	.90	1.13	.49	1.33	2.01	1.3
8/25	0.00	2.40	1.78	.72	0.00	0.00	.62	.8
9/15	0.00	1.46	.39	.65	.80	.14	0.00	.5
9/28	0.00	0.00	.37	0.00	0.00	0.00	0.00	.1
10/12	0.00	0.00	0.00	0.00	0.00	0.00	4.25	.6
10/27	.27	0.00	.20	.25	.14	0.00	0.00	.1
11/10	0.00	0.00	0.00	0.00	.56	0.00	0.00	.1
11/22	.24	0.00	0.00	.19	0.00	0.00	0.00	.1

* Samples missing due to loss or breakage

Table 5-12. Day and night abundances of *Halicyclops fosteri*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	.12	.23	.34	.22	.13	0.00	.24	.2
5/20	0.00	.48	0.00	0.00	.12	0.00	*	.1
6/03	.56	.22	.48	.34	0.00	.14	*	.3
6/16	.15	.11	.21	.70	.43	.14	*	.3
6/29	.91	.60	1.14	1.79	1.46	.80	.94	1.1
7/15	0.00	.33	0.00	0.00	.24	0.00	0.00	.1
7/27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
8/12	.24	.55	.84	1.22	.41	.74	0.00	.6
8/23	.66	0.00	.32	.38	.89	0.00	.49	.4
9/14	.25	.35	1.59	.45	.73	0.00	.23	.5
9/29	.31	.61	.23	.54	.34	0.00	0.00	.3
10/13	.94	1.38	2.26	11.21	11.20	1.53	.46	4.1
10/26	.30	3.03	2.02	2.42	2.02	.41	1.00	1.6
11/09	0.00	.15	.55	.63	.69	0.00	.56	.4
11/22	2.33	.78	.65	0.00	.61	.57	.23	.7

Night

5/05	.33	.46	.26	.33	.87	1.48	*	.6
5/20	.10	.11	.17	.14	.48	0.00	*	.2
6/03	.20	.16	0.00	.14	.49	.38	*	.2
6/16	0.00	.16	.38	.52	.33	0.00	*	.2
7/01	0.00	.83	1.32	.85	.27	.53	.23	.6
7/14	.15	.84	.13	.72	.44	0.00	.54	.4
7/28	0.00	0.00	.40	.31	0.00	.19	0.00	.1
8/12	.27	.48	.18	0.00	.32	0.00	.57	.3
8/25	.29	0.00	.15	.24	.16	1.34	.31	.4
9/15	0.00	0.00	0.00	1.51	.40	.14	0.00	.3
9/28	0.00	0.00	0.00	0.00	0.00	0.00	.18	.0
10/12	1.26	4.13	1.88	4.01	1.79	2.04	5.20	2.9
10/27	.18	.15	.40	.25	.14	.21	2.08	.5
11/10	.34	.35	.20	.08	.56	.47	.20	.3
11/22	0.00	.14	0.00	.74	.13	.52	0.00	.2

* Samples missing due to loss or breakage

The most abundant Cladocera collected in 1976 were Diaphanosoma brachyurum (Figure 5-11; Table 5-13) and Bosmina longirostris (Figure 5-12; Table 5-14). D. brachyurum occurred only during the summer months at concentrations below one per liter except on July 27 when a peak abundance of 3.7 per liter was observed (Figure 5-11; Table 5-13). Bosmina longirostris (Figure 5-12; Table 5-14) occurred throughout the sampling period generally in concentrations between 1 and 10 organisms per liter. Peak mean abundance of B. longirostris was observed on June 29 at greater than 40 organisms per liter (Figure 5-12; Table 5-14).

The results of 36 ANOVA indicate no effect of station location on abundance in all but four analyses (Table 5-15 and 5-16). Significant station effects are shown for day abundances of Halicyclops fosteri, total Cyclopoida, Bosmina longirostris and total cladocera (Table 5-15). In all four cases where ANOVA indicates a significant station effect, Scheffé tests ($\alpha = 0.10$) showed that abundances at station F were less than those at all other stations (Table 5-15). In addition, abundances of Halicyclops fosteri at stations D and E were greater than at all other stations and greater at station C than at station A. The Scheffé test showed that abundances of total cyclopoids at stations D and E were greater than at stations A and B (Table 5-15).

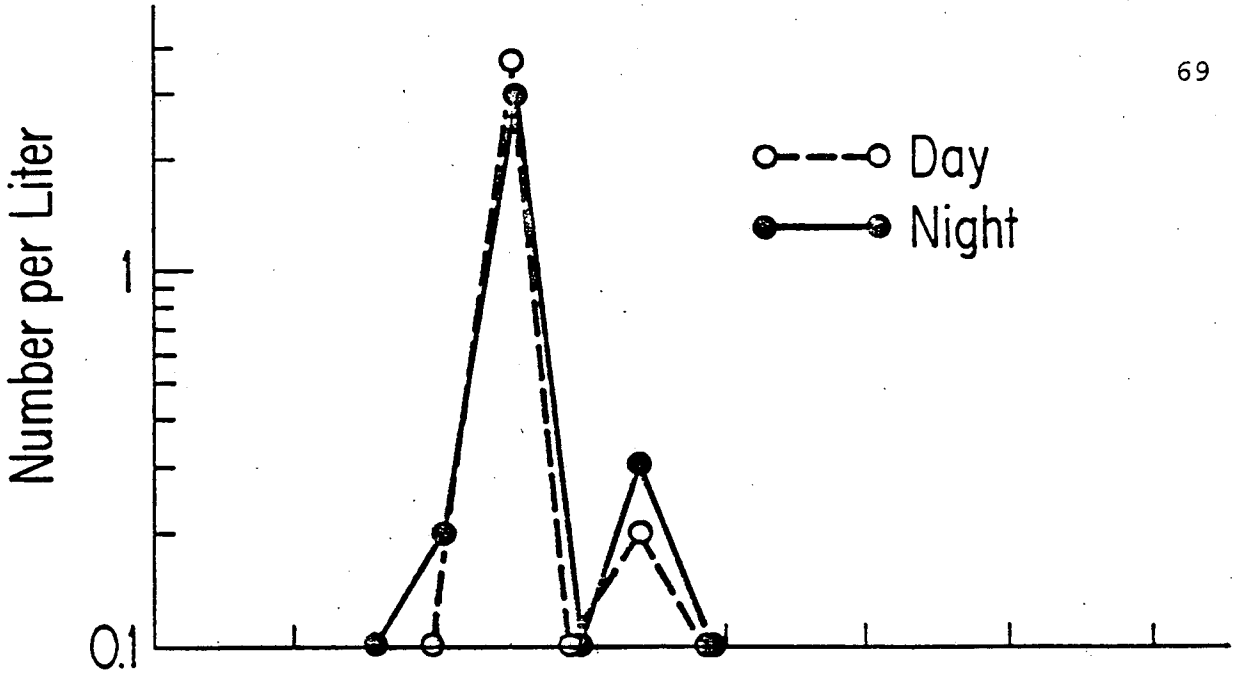

Figure 5-11. Mean day and night abundance of Diaphanosoma brachyurum, 1976.

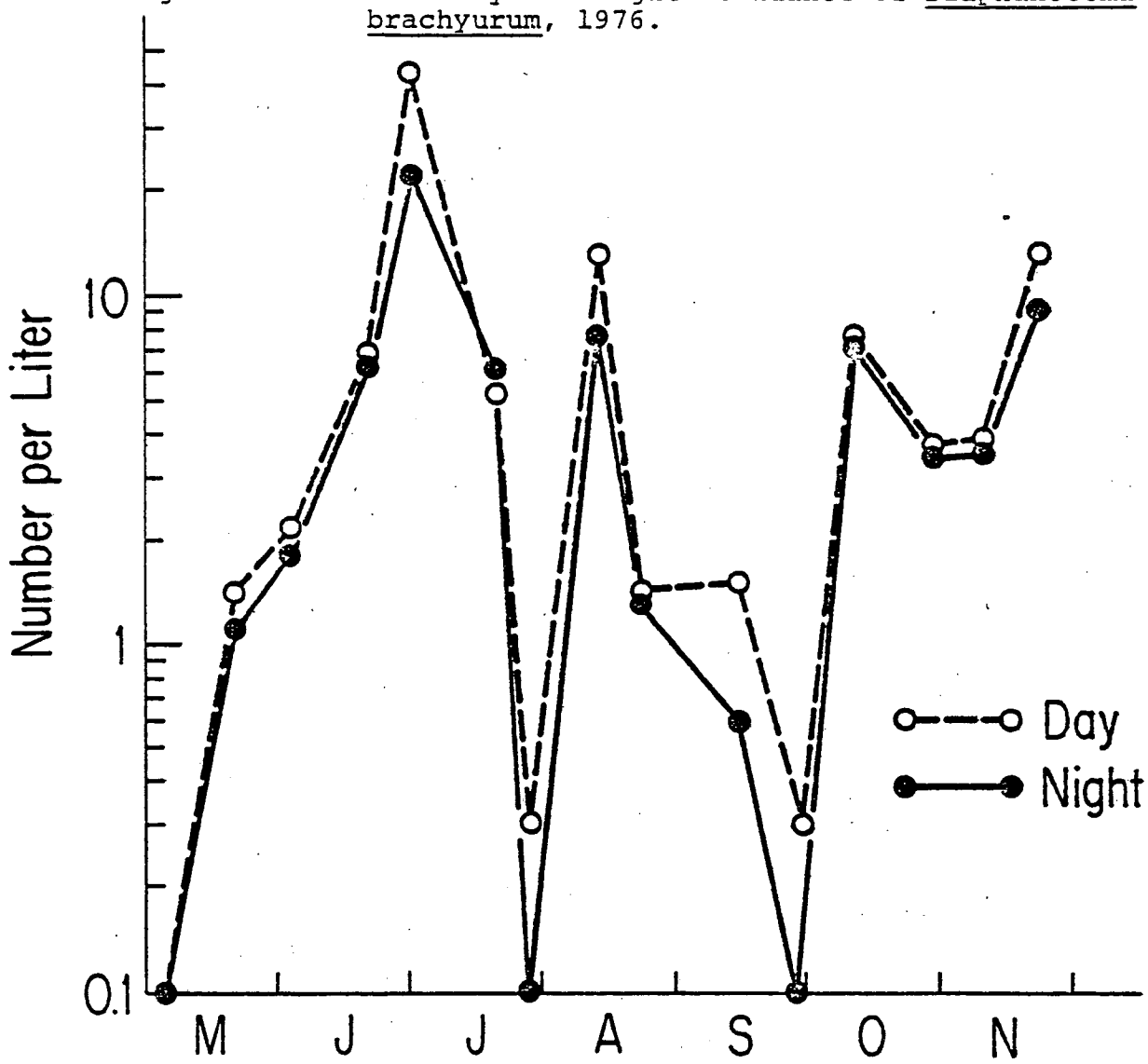

Figure 5-12. Mean day and night abundance of Bosmina longirostris, 1976.

Table 5-13. Day and night abundances of *Diaphanosoma brachyurum*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5/20	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/03	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/16	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/29	0.00	0.00	0.00	0.00	.49	.20	.31	.1
7/15	4.29	5.59	4.66	.43	1.46	5.87	3.43	3.7
7/27	0.00	0.00	0.00	0.00	.26	0.00	.40	.1
8/12	0.00	.27	.56	.14	.17	.16	.20	.2
8/23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9/29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
10/26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/09	0.00	0.00	0.00	0.00	.21	0.00	0.00	0.0
11/22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

Night

5/05	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
5/20	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/03	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
6/16	0.00	0.00	0.00	0.00	0.00	0.00	*	0.0
7/01	0.00	.21	0.00	0.00	0.00	.79	.23	.2
7/14	3.82	2.52	3.32	3.59	4.17	1.94	1.62	3.0
7/28	0.00	0.00	0.00	.31	0.00	0.00	0.00	.0
8/12	0.00	0.00	.18	.45	0.00	0.00	1.15	.3
8/25	0.00	.69	0.00	0.00	0.00	0.00	0.00	.1
9/15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
9/28	0.00	.15	0.00	0.00	0.00	0.00	0.00	.0
10/12	0.00	0.00	0.00	0.00	0.00	.10	0.00	.0
10/27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
11/22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0

* Sample missing due to loss or breakage

Table 5-14. Day and night abundances of *Bosmina longirostris*, 1976. Number per liter.

Day

Stations

Date	A	B	C	D	E	F	G	Mean
5/05	.18	.11	.07	0.00	0.00	0.00	.12	.1
5/20	1.36	1.20	2.76	.76	1.21	1.21	*	1.4
6/03	3.56	2.22	3.19	1.91	1.68	.83	*	2.2
6/16	7.28	8.77	6.09	5.59	8.69	4.60	*	6.8
6/29	90.37	24.36	39.56	40.62	65.82	5.97	40.25	43.9
7/15	4.29	1.48	3.06	6.68	9.50	5.87	5.57	5.2
7/27	.44	.38	.31	.45	0.00	0.00	.40	.3
8/12	5.03	41.14	16.20	15.50	5.36	.08	6.43	12.8
8/23	2.97	1.61	1.60	1.34	.89	0.00	1.46	1.4
9/14	1.76	5.08	1.76	.45	.24	.49	.93	1.5
9/29	.78	.73	.58	0.00	0.00	0.00	0.00	.3
10/13	3.74	12.58	16.27	2.44	4.98	5.05	8.83	7.7
10/26	1.19	7.98	4.48	1.34	1.01	2.84	7.03	3.7
11/09	1.51	2.39	7.12	6.26	5.96	2.43	.79	3.8
11/22	23.12	10.10	18.09	19.26	12.36	5.34	3.21	13.1

Night

5/05	0.00	0.00	0.00	.11	0.00	0.00	*	.0
5/20	.67	1.67	.83	1.41	.48	1.72	*	1.1
6/03	2.97	2.28	3.08	.68	1.32	.68	*	1.8
6/16	4.43	9.02	4.72	7.55	6.85	4.36	*	6.2
7/01	8.45	4.97	36.57	56.47	16.09	15.55	25.86	23.4
7/14	3.53	6.08	4.11	4.02	9.23	1.81	14.15	6.1
7/28	.26	0.00	0.00	0.00	.44	0.00	0.00	.1
8/12	6.98	4.81	3.07	4.53	5.82	19.03	9.45	7.7
8/25	1.46	2.40	1.19	1.43	2.14	0.00	.31	1.3
9/15	.40	.49	.77	1.29	.60	.96	0.00	.6
9/28	0.00	0.00	.19	0.00	.42	0.00	.18	.1
10/12	1.08	7.57	7.73	10.89	10.72	4.09	9.92	7.4
10/27	1.70	2.94	4.04	5.05	4.29	.64	5.77	3.5
11/10	3.37	1.56	3.52	1.99	5.94	5.37	2.61	3.5
11/22	10.93	6.21	19.42	7.24	2.54	7.39	9.18	9.0

* Samples missing due to loss or breakage

Table 5-15. Results of analysis of variance of day abundances of microzooplankton, 1976. N.S.=not significant, * denotes statistical significance.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha<0.10$)
All species	0.15	N.S.	
Crustacea	0.33	N.S.	
Rotifera	0.32	N.S.	
Protozoa	1.98	N.S.	
Copepoda-Adults	1.39	N.S.	
Copepoda-Copepodids	2.07	N.S.	
Copepoda-Nauplii	0.63	N.S.	
Acartia tonsa	0.01	N.S.	
Eurytemora affinis	1.25	N.S.	
Diacyclops bicuspidatus	1.60	N.S.	
Halicyclops fosteri	2.95	*	D,E>All; C>A; All>F
Total Copepoda	0.39	N.S.	
Total Calanoida	0.95	N.S.	
Total Cyclopoida	3.41	*	D,E>A,B; All>F
Total Harpacticoida	1.39	N.S.	
Bosmina longirostris	4.17	*	All>F
Diaphanosoma brachyurum	0.93	N.S.	
Total Cladocera	5.01	*	All>F

Table 5-16. Results of analysis of variance of night abundances of microzooplankton, 1976.

Analysis	"F"	Station Effect	Scheffe Test ($\alpha<0.10$)
All species	1.31	N.S.	
Crustacea	1.06	N.S.	
Rotifera	1.49	N.S.	
Protozoa	0.46	N.S.	
Copepoda-Adults	1.02	N.S.	
Copepoda-Copepodids	0.56	N.S.	
Copepoda-Nauplii	1.54	N.S.	
Acartia tonsa	2.32	N.S.	
Eurytemora affinis	1.18	N.S.	
Diacyclops bicuspidatus	0.76	N.S.	
Halicyclops fosteri	1.99	N.S.	
Total Copepoda	0.56	N.S.	
Total Calanoida	1.38	N.S.	
Total Cyclopoida	1.50	N.S.	
Total Harpacticoida	2.07	N.S.	
Bosmina longirostris	1.02	N.S.	
Diaphanosoma brachyurum	1.02	N.S.	
Total Cladocera	0.36	N.S.	

5.1.3 Discussion

Comparisons of microzooplankton abundance within sampling years seldom show differences attributable to factors other than season. The few differences in abundance between stations are probably the result of random factors associated with the characteristically patchy distribution of plankton (Wiebe and Holland, 1968; Fleminger and Clutter, 1965). For this reason and additional considerations, e.g. year-to-year variations in river flow, tidal exchange and mixing (Abood, 1974), quantitative comparisons between and among years are probably best executed in non-dimensional terms, such as diversity components and community structure (Pielou, 1975) rather than abundance.

A comparison of microzooplankton data collected in 1976 with those of previous years (New York University Medical Center, 1975, 1976a) shows the magnitude of peak abundances and seasonal patterns of abundance to be similar. Species composition between and among years of the dominant species also, has remained essentially unchanged (Table 5-17). The absence of some of the less abundant rotifers and protozoans from year-to-year samples (Table 5-17) are not considered significant. Their presence or absence in a given year's samples may reflect errors inherent in the methodology (the inability to collect and preserve everything), and the absence of the rare or uncommon forms in field samples, does not necessarily indicate their absence in the environment

Table 5-17. List of microzooplankton species collected in Hudson River samples for 1971-1976.

Crustacea	1971	1972	1973	1974	1975	1976
Copepoda						
Acartia tonsa	+			+	+	+
Canthocamptid	+			+	+	+
Canuella sp.	+			+	+	+
Copepodids	+			+	+	+
Diacyclops bicuspidatus	+			+	+	+
Ectinosoma curticorne	+			+	+	+
Epischura sp.	+			+	+	-
Ergasilus sp.	+			+	+	+
Eurytemora affinis	+			+	+	+
Halicyclops fosteri	+			+	+	+
Mesocyclops edax	+			-	-	+
Nauplii	+			+	+	+
Cladocera						
Bosmina longirostris	+			+	+	+
Chydorid	+			+	+	+
Daphnia pulex	+			+	+	+
Diaphanosoma brachyurum	+			+	+	+
Leptodora kindtii	+			+	+	+
Moina sp.	+			+	+	-
Ostracoda						
(no further identification)	+			+	+	+
Cirripedia						
Nauplii	+			+	+	+
Rotifera						
Asplancha sp.	+			+	+	+
Brachionus angularis	+			+	+	+
B. calciflorus	+			+	+	+
B. quadridentata	-			+	+	+
Collotheca sp	+			-	-	-
Felina longiseta	+			+	+	+
Kellicottia longispina	+			+	+	+
Keratella cochlearis	+			+	+	+
K. quadrata	+			+	+	+
K. serrulata	-			+	+	-
K. taurocephla	+			-	-	-
Lecane sp.	-			+	+	-
Monostyla sp.	+			-	-	-

Table 5-17 (cont.)

Rotifera (cont.)	1971	1972	1973	1974	1975	1976
Notholca accuminata	+			+	+	+
Philodina sp	+			+	+	+
Platyias patulus	-			+	+	+
P. quadricornis	-			+	+	-
Pleosoma truncatum	+			+	+	+
Polyarthra sp.	+			+	+	+
Synchaeta sp.	-			+	+	-
Trichocerca sp.	+			+	+	+
Unidentified rotifers	+			+	+	+
Protozoa						
Mastigophora						
Ceratium hirudinella	+			+	+	+
Dinobryon sp.	+			+	+	-
Eudorina sp.	+			+	+	+
Pandorina sp.	+			+	+	-
Pleodorina sp.	+			+	+	+
Volvox sp.	+			+	+	+
Sarcodina						
Arcella sp.	+			+	+	-
Centropyxis sp.	+			+	+	+
Difflugia sp.	+			+	+	+
Euglypha sp.	+			+	+	-
Ciliophora						
Carchesium sp.	+			+	+	+
Codonella cratera	+			+	+	-
Epistylis sp.	+			+	+	+
Eutintinnus sp.	+			-	-	-
Tintinnopsis sp.	+			+	+	-
Vorticella sp.	+			+	+	-
Suctoria						
Metacineta sp.	+			+	+	-
Staurophrya sp.	+			+	+	-
Miscellaneous						
Annelid larvae	+			+	+	+
Gastropod veliger	+			+	+	+
Pelecypod veliger	+			+	+	+
Nematodes	+			+	+	+
Tardigrades	+			+	+	+

(Cairns, Lanza and Parker, 1972). Where dominant species within taxa have been found to differ (e.g., the change from the dominance of Branchionus in 1971, to Nothalca in 1974 and 1975 to Keratella in 1976) it should be noted that year-to-year and station-to-station shifts in dominance are a natural occurrence and may stem from the fact that certain microzooplankton, such as rotifers, are characterized by peak abundances of extremely short duration, not all of which will have been sampled. These shifts have been noted in various taxa throughout the lower Hudson since intensive ecological studies began (see e.g., New York University Medical Center, 1973, 1975; Lawler, Matusky and Skelly Engineers, 1974, 1975).

As the near field data (this report and New York University Medical Center, 1975, 1976a; Lawler, Matusky and Skelly Engineers, 1975, 1976) and far field data (Lawler, Matusky and Skelly Engineers, 1974) indicate 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 1971-1976, we conclude that the river populations of microzooplankton have not been affected by the operation of the Indian Point power station.

6. MACROZOOPLANKTON

6.1 RIVER POPULATION STUDIES

6.1.1 Methods

Macrozooplankton and ichthyoplankton were collected as one sample. Organisms of these two major biological groups, which were obtained in collections at all seven standard stations (Figure 1-7) and at three different depths, were then separated for detailed analysis.

Metered 0.5 m-diameter, 571μ-mesh plankton nets, similar to those used in the intakes and discharge canal were used to sample in the river for macrozooplankton. These nets were towed simultaneously against the prevailing current for ten minutes at each of three depths (6-12 inches below the surface, at mid-depth and at approximately 1 foot off the bottom). Replicate samples were taken at all seven stations.

After mid April, day and night river samples were collected each week throughout the "striped bass season" (from the first week in May to the end of July). In August samples were collected every other week, and then once per month until the end of December, so as to encompass the season for other fish species.

All macroinvertebrates were sorted from the samples, identified to species (when possible) and enumerated. The data were examined by analysis of variance to determine whether significant differences existed in the temporal and

spatial distribution of river macrozooplankton. Catch per unit effort (CPUE) analysis was compared to the catch per 1000 m^3 as an estimate of the consistency of volumes sampled. CPUE was time-related, expressed simply as the number of organisms caught per 10-min sampling event. The comparison of results derived from abundance (#/1000 m^3) with CPUE was considered critical as a technique for identifying abnormally high or abnormally low flows which may have occurred and otherwise been discarded as outliers.

6.1.2 Results and Discussion

6.1.2.1 Species Composition

A total of 826 macrozooplankton samples were collected and analyzed in 1976. These include 413 samples taken during the daylight hours from April 12 to December 7, and 413 samples taken at night from April 13 to December 2.

Twenty-seven invertebrate forms were identified from these samples (Table 6-1). This number is one less than the inventory for 1975, and includes two taxa not previously identified in our samples from the vicinity of Indian Point: the isopod *Cassidinidea lunifrons* and a number of trichopteran nymphs. Nonetheless, the species inventory in 1976 resembles closely those for the preceding years, beginning in 1971.

Numerical abundances were determined for 13 of the 27 taxa collected in 1976 (Tables 6-9 through 6-12). The

Table 6-1. Macrozooplankton taxa in Indian Point collections, 1971, 1972, 1974, 1975 and 1976. X denotes the presence of that organism for the given year.

Taxa	1971	1972	1974	1975	1976
Annelida					
Oligochaeta	X	X	X	X	X
Polychaeta	X	X	X	X	X
Hirudinea		X	X	X	X
Arthrophoda					
Crustacea					
Copepoda					
Caligus sp.			X		
Branchyura					
Argulus sp.			X	X	X
Malacostraca					
Cumacea		X	X	X	X
Mysidacea					
Neomysis americana	X	X	X	X	X
Isopoda					
Chiridotea almyra	X	X	X	X	X
Cyathura polita	X	X	X	X	X
Edotea sp.	X	X	X	X	X
Cirolana sp.			X	X	X
Cassidinidea lunifrons					X
Amphipoda					
Gammarus spp.	X	X	X	X	X
Monoculodes edwardsi	X	X	X	X	X
Leptocheirus plumulosus	X	X	X	X	X
Corophium sp.	X	X	X	X	X
Decapoda					
Crangon septemspinosa	X	X	X	X	X
Decapod larva (zoea)		X	X	X	X
Palaemonetes sp.				X	X
Insecta					
Odonata (nymph)			X	X	X
Odonata (adult)	X	X		X	
Diptera (larvae)					
Chaoborus sp.	X	X	X	X	X
Chironomus sp.	X	X	X	X	X
Diptera (pupae)	X	X	X	X	X
Diptera (adult)	X	X	X	X	X
Plecoptera (nymph)				X	
Tricoptera (larva)					X

Table 6-1 (cont.).

Taxa	1971	1972	1974	1975	1976
Arachnida					
Hydracarina	X	X	X	X	X
Coelenterata					
Medusae	X	X	X	X	X
Ctenophora			X	X	X
Mollusca					
Gastropoda	X	X			
Pelecypoda	X	X		X	

remaining taxa were not enumerated either because they were difficult to sample accurately (e.g. jellyfish medusae and ctenophores), or because they were not considered part of the plankton community (e.g. Argulus, Cirolana, Cumacea and some insect life stages). Decapod larvae were not enumerated because they were too small to be retained consistently in the 571μ-mesh nets.

As in previous years, the macrozooplankton community was dominated by three taxa, Gammarus spp., Monoculodes edwardsi, and Neomysis americana (New York University Medical Center, 1975, 1976a; Ginn, 1977). Because of the relatively high constant concentrations of Chaoborus spp. larvae this taxonomic group was also considered a dominant taxa (Table 6-2). Together these four groups accounted for 57% of the total daytime macrozooplankton catch and 60% of the total nighttime catch (Table 6-2). On a station-by-station basis, Gammarus, Monoculodes, Neomysis, and Chaoborus accounted for between 54% and 81% of the total macrozooplankton daytime catch, and between 63% and 97% of the nighttime catch.

The proportional representation of the four dominant forms at Station A through G varied (Tables 6-3 and 6-4). Gammarus was dominant at 6 stations (A, B, C, D, E, G) during the daytime, while Neomysis was dominant at one station (F). Nighttime samples at station A, B, D, E, and G were predominantly Gammarus, while stations C and F were predominantly Neomysis. Of the four dominant forms, Monoculodes was the least abundant.

Table 6-2. Percent composition of macrozooplankton species collected in the vicinity of Indian Point, 1976.

Species	Percent of total	
	Day collections	Night collections
Gammarus spp.	38.31%	35.60%
Monoculodes edwardsi	2.23%	3.71%
Neomysis americana	8.88%	14.16%
Chaoborus sp. (larvae)	7.79%	6.86%
"others"	42.79%	39.67%

Table 6-3. Total macrozooplankton river abundance and abundance by major groups in day/night collections, 1976. Data shown are mean numbers caught per 1000 m^3 by station ±95% confidence intervals. n = number of samples in which the particular species was observed.

	Stations						
Day	A	B	C	D	E	F	G
Total	8577 ±5004 n=60	4421 ±6890 n=60	11511 ±6890 n=60	6815 ±1759 n=60	5446 ±3893 n=59	5201 ±2930 n=60	3912 ±2749 n=54
Gammarus	4016 ±2536 n=60	1446 ± 653 n=60	4352 ±2925 n=60	2592 ±1799 n=60	2206 ±1877 n=58	1533 ± 959 n=60	1353 ±1103 n=53
Monoculodes	189 ± 154 n=57	99 ± 110 n=57	216 ± 170 n=57	142 ± 113 n=57	69 ± 45 n=56	181 ± 202 n=57	194 ± 215 n=51
Neomysis	1286 ±2012 n=33	662 ±1038 n=33	1015 ±1161 n=33	700 ± 669 n=33	774 ± 950 n=32	1872 ±1698 n=33	1061 ±1817 n=33
Chaoborus	438 ± 376 n=60	412 ± 463 n=60	597 ± 470 n=60	661 ± 584 n=60	535 ± 725 n=59	603 ± 725 n=60	342 ± 287 n=54
Night							
Total	20883 ±5520 n=60	19201 ±5043 n=60	17850 ±4443 n=60	23852 ±7378 n=60	23839 ±5490 n=59	22836 ±8856 n=60	19095 ±5206 n=54
Gammarus	8206 ±2491 n=60	6884 ±1998 n=60	5102 ±1364 n=60	9180 ±3380 n=60	8502 ±2684 n=59	9809 ±5170 n=60	6885 ±2635 n=54
Monoculodes	855 ± 424 n=60	762 ± 501 n=60	902 ± 503 n=60	424 ± 185 n=60	965 ± 491 n=59	945 ± 519 n=60	598 ± 263 n=54
Neomysis	2866 ±1842 n=30	2845 ±2002 n=30	7734 ±5193 n=30	5957 ±4511 n=30	6354 ±3647 n=30	10436 ±10754 n=30	4965 ±3511 n=30
Chaoborus	1345 ± 619 n=60	1585 ± 841 n=60	1542 ± 760 n=60	1458 ± 778 n=60	1893 ± 956 n=60	910 ± 572 n=59	1378 ± 771 n=54

Table 6-4. Total macrozooplankton river abundance and abundance by major groups in day/night collections, 1976. Data shown are mean number/catch per unit effort by station ±95% confidence intervals. n=Number of samples in which the particular species was observed.

Day	A	B	C	D	E	F	G
Total	983 ±567 n=60	567 ±294 n=60	1246 ±682 n=60	760 ±398 n=60	658 ±503 n=59	669 ±374 n=60	461 ±322 n=54
Gammarus	452 ±284 n=60	171 ± 77 n=60	468 ±296 n=60	287 ±182 n=60	266 ±243 n=58	195 ±122 n=60	160 ±128 n=53
Monoculodes	20 ± 15 n=57	20 ± 17 n=57	26 ± 18 n=57	23 ± 11 n=57	18 ± 5 n=56	25 ± 23 n=57	26 ± 25 n=51
Neomysis	147 ±209 n=33	101 ±160 n=33	114 ±138 n=33	78 ± 71 n=33	96 ±114 n=32	230 ±209 n=33	130 ±217 n=33
Chaoborus	63 ± 53 n=60	64 ± 21 n=60	73 ± 56 n=60	76 ± 69 n=60	66 ± 68 n=59	83 ± 96 n=60	42 ± 33 n=54
Night							
Total	2325 ±642 n=60	2236 ±607 n=60	2076 ±542 n=60	2619 ±817 n=60	2635 ±581 n=59	2296 ±781 n=60	2193 ±594 n=54
Gammarus	908 ±283 n=60	782 ±230 n=60	581 ±154 n=60	1013 ±372 n=60	939 ±293 n=59	885 ±350 n=60	779 ±283 n=54
Monoculodes	94 ± 47 n=60	92 ± 62 n=60	109 ± 61 n=60	49 ± 20 n=60	102 ± 48 n=59	93 ± 47 n=60	71 ± 31 n=54
Neomysis	330 ±210 n=30	378 ±288 n=30	946 ±654 n=30	663 ±466 n=30	666 ±361 n=30	693 ±669 n=30	598 ±438 n=30
Chaoborus	153 ± 76 n=60	191 ±107 n=60	177 ± 88 n=60	165 ± 85 n=60	215 ±113 n=59	75 ± 44 n=60	162 ± 89 n=54

6.1.2.2 Day Versus Night Comparisons

Macrozooplankton abundance was significantly greater during the night than during the day (Tables 6-5 through 6-7); total macrozooplankton nighttime catches exceeded daytime catches by a factor of 3.7 (Tables 6-3 through 6-6). The abundance of *Gammarus* spp. was greatest in nighttime samples, exceeding daytime samples by a factor of approximately three. *Gammarus* spp. were present in 411 out of 413 daytime samples and in each of the 413 nighttime samples collected; they comprised 38% of all macrozooplankton in the daytime and were nearly 36% of all those collected at night.

Although *Neomysis* was found in only 51% of the daytime samples, its numbers, surpassed only by *Gammarus*, accounted for 9% of the total macrozooplankton collected during the day. At night *Neomysis* again occurred in 51% of the samples collected, and its numbers were 14% of the total collected. Day versus night differences in abundance (Tables 6-3 through 6-6) were more than that for *Gammarus* spp., *M. edwardsi* and *Chaoborus* spp. larvae differing by a factor of 6 during the sample period.

The amphipod *M. edwardsi* was present in 392 out of 413 samples collected in the daytime and in all of the nighttime samples collected in the vicinity of Indian Point power plant. Its abundance at night was significantly greater than during the day (Tables 6-3 through 6-6); the numbers at night were 5 times greater than during the day.

Table 6-5. Macrozooplankton abundance in pooled river samples, 1976. Data are mean numbers caught per $1000m^3$ with 95% confidence intervals. N= number of samples in which species was observed.

	Mean	95% C.I.	n
Day			
Total	6611	± 760	413
Gammarus	2545	± 173	411
Monoculodes	155	± 1	392
Neomysis	1160	± 146	209
Chaoborus	440	± 14	413
Night			
Total	21112	±1567	413
Gammarus	7517	± 259	413
Monoculodes	782	± 9	413
Neomysis	5879	±1217	210
Chaoborus	1448	± 14	413

Table 6-6. Macrozooplankton abundance in pooled river samples, 1976. Data are mean numbers caught per unit effort with 95% confidence intervals. N = number of samples in which species was observed.

	Mean	95% C.I.	n
Day			
Total	768	±9664	413
Gammarus	287	±1985	411
Monoculodes	18	± 19	392
Neomysis	137	±2048	209
Chaoborus	65	± 262	413
Night			
Total	2343	±15505	413
Gammarus	842	± 3042	413
Monoculodes	86	± 105	413
Neomysis	611	± 7266	210
Chaoborus	163	± 186	413

Table 6-7. Comparison of macrozooplankton abundance in day vs. night river sampling, 1976.

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

The insect Chaoborus spp. larvae was present in all daytime and nighttime samples. Although its abundance was less than Gammarus spp. and N. americana, Chaoborus larvae abundance was greater than than of M. edwardsi (Tables 6-5 and 6-6). Chaoborus larvae concentrations at night were significantly greater than during the day, differing by a factor of 3 (Tables 6-3 through 6-6).

6.1.2.3 Depth Distribution of Macrozooplankton

The abundance of macrozooplankton in river samples was the greatest at the bottom of the water column. Since the depths of sampling stations differed, the "bottom" samples from the different stations were, of necessity, from different depths. Nevertheless, samples from the bottom strata yielded 98% of the macrozooplankton in the daytime samples and 50% of the macrozooplankton in nighttime samples.

The relative abundance of macrozooplankton at the various depths differed significantly between day and night samples (Table 6-8; and Figures 6-1 through 6-5). Surface and mid-depth abundances at night were greater than in the day by a factor of approximately 12. Nighttime bottom samples were about 55% greater than daytime bottom samples. Populations of macrozooplankton susceptible to net capture at night, but not during the day, may be assumed to occupy a daytime habitat not sampled by the gear currently in use. Data from other investigations in the Hudson River (Texas

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

Day	Surface	Middle	Bottom
Total	133 ±2285 n=138	2453 ±2285 n=138	17323 ±2301 n=137
Gammarus	28 ± 518 n=138	1091 ± 522 n=137	6563 ± 526 n=136
Monoculodes	0 ± 4 n=131	51 ± 4 n=131	416 ± 4 n=130
Neomysis	1 ± 439 n= 70	187 ± 439 n= 70	3322 ± 446 n= 69
Chaoborus	16 ± 45 n=138	226 ± 45 n=138	1309 ± 45 n=137
Night			
Total	6111 ±4713 n=138	25654 ±4713 n=138	31646 ±4747 n=137
Gammarus	1559 ± 778 n=138	10335 ± 778 n=138	10678 ± 783 n=137
Monoculodes	154 ± 26 n=138	839 ± 26 n=138	1358 ± 26 n=137
Neomysis	3054 ±3706 n= 70	3512 ±3706 n= 70	11072 ±3706 n= 70
Chaoborus	774 ± 43 n=138	1793 ± 43 n=138	1778 ± 43 n=137

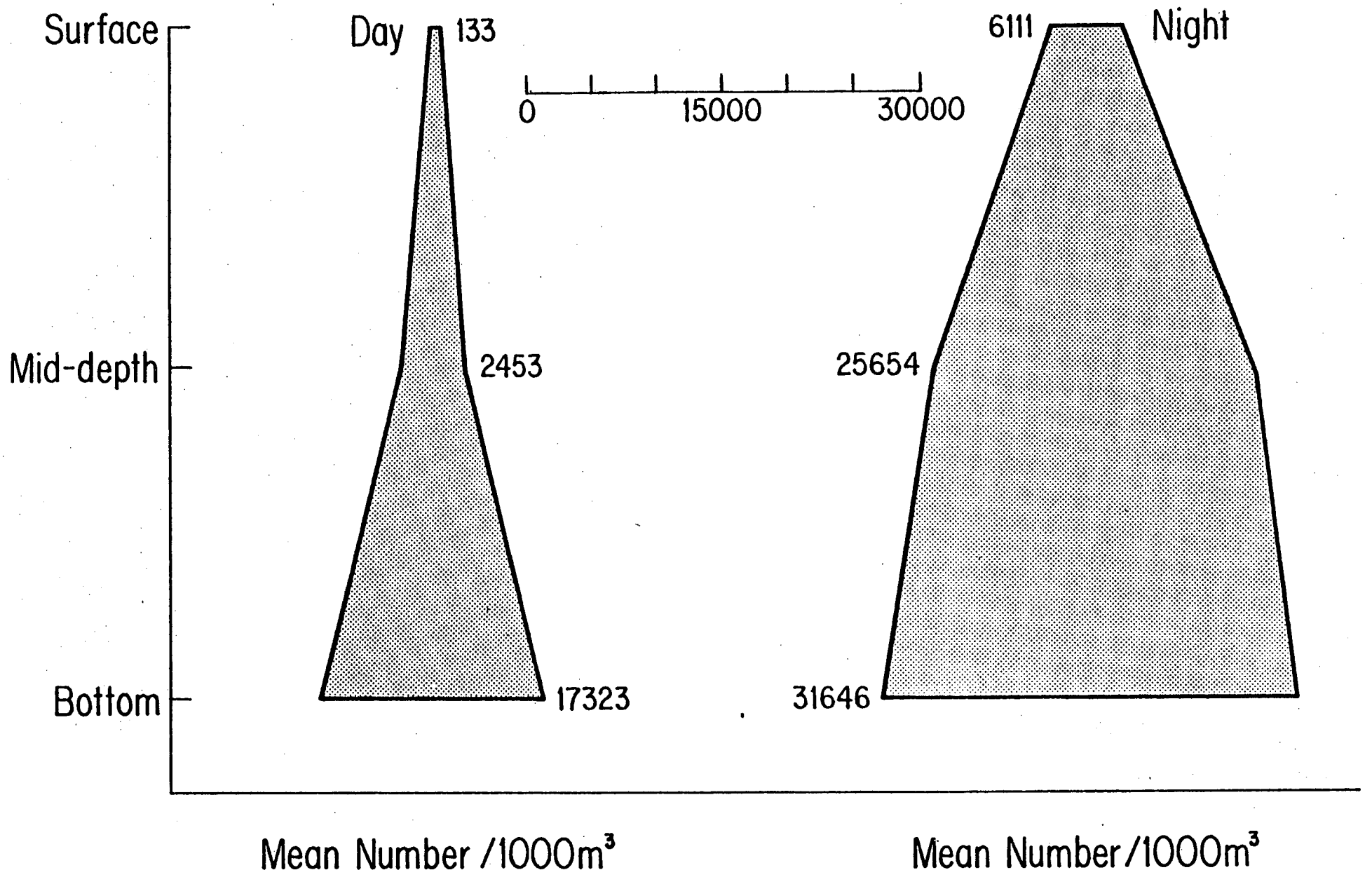

Figure 6-1. Depth distribution for total macrozooplankton in day and night samples from the Hudson River at Indian Point, 1976.

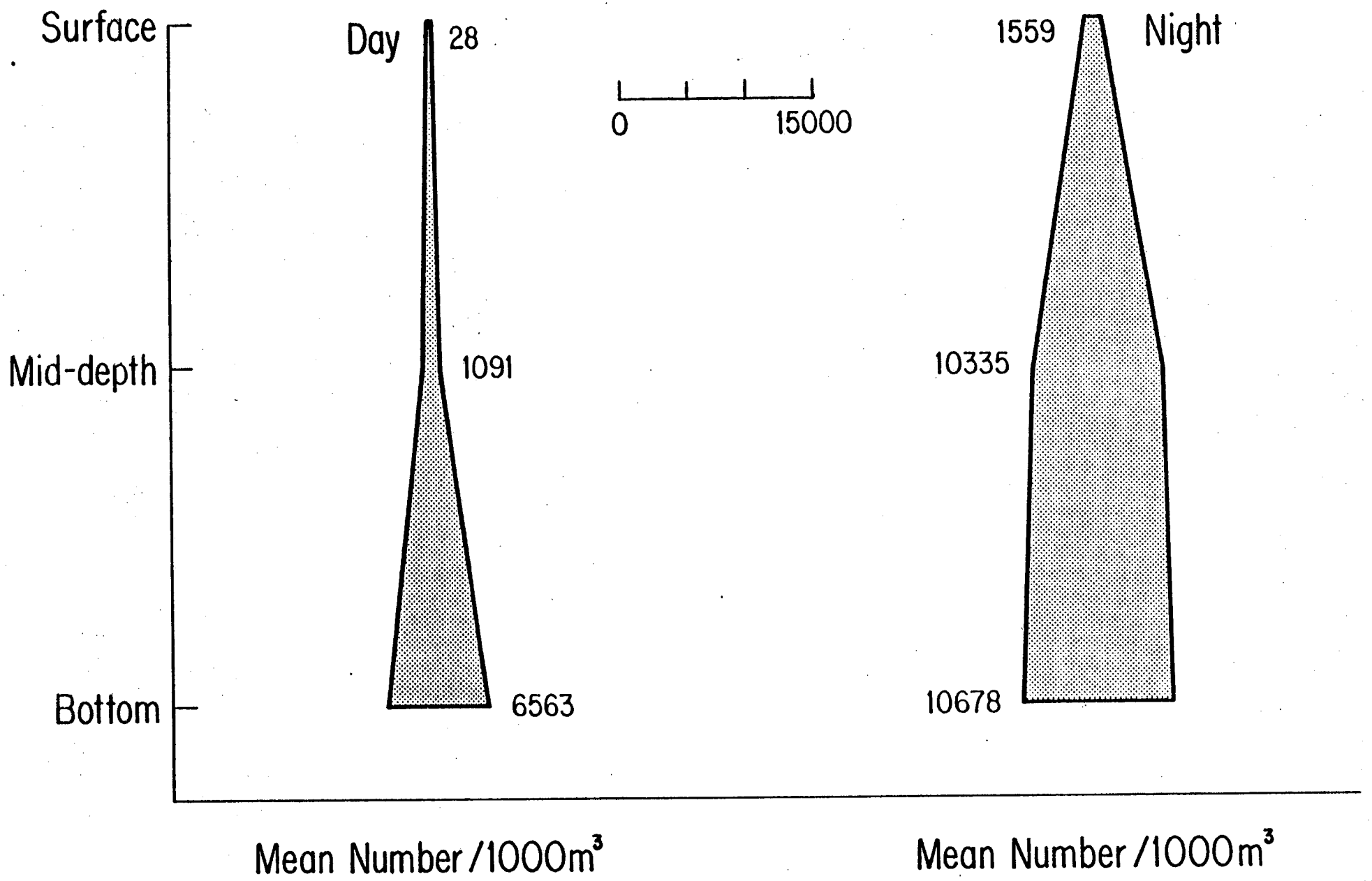

Figure 6-2. Depth distribution for Gammarus spp. in day and night samples from the Hudson River at Indian Point, 1976.

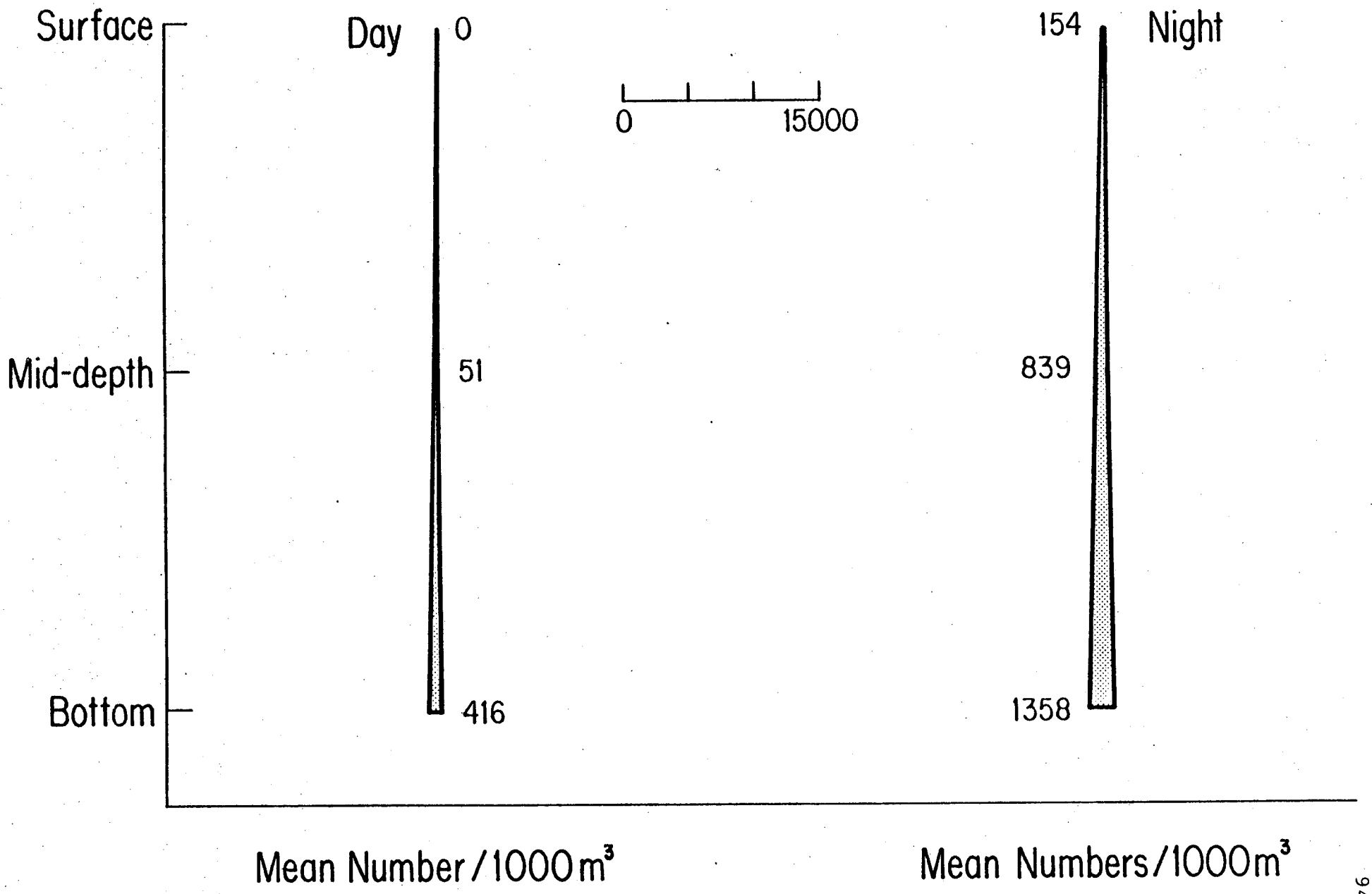

Figure 6-3. Depth distribution for Monoculodes in day and night samples from the Hudson River at Indian Point, 1976.

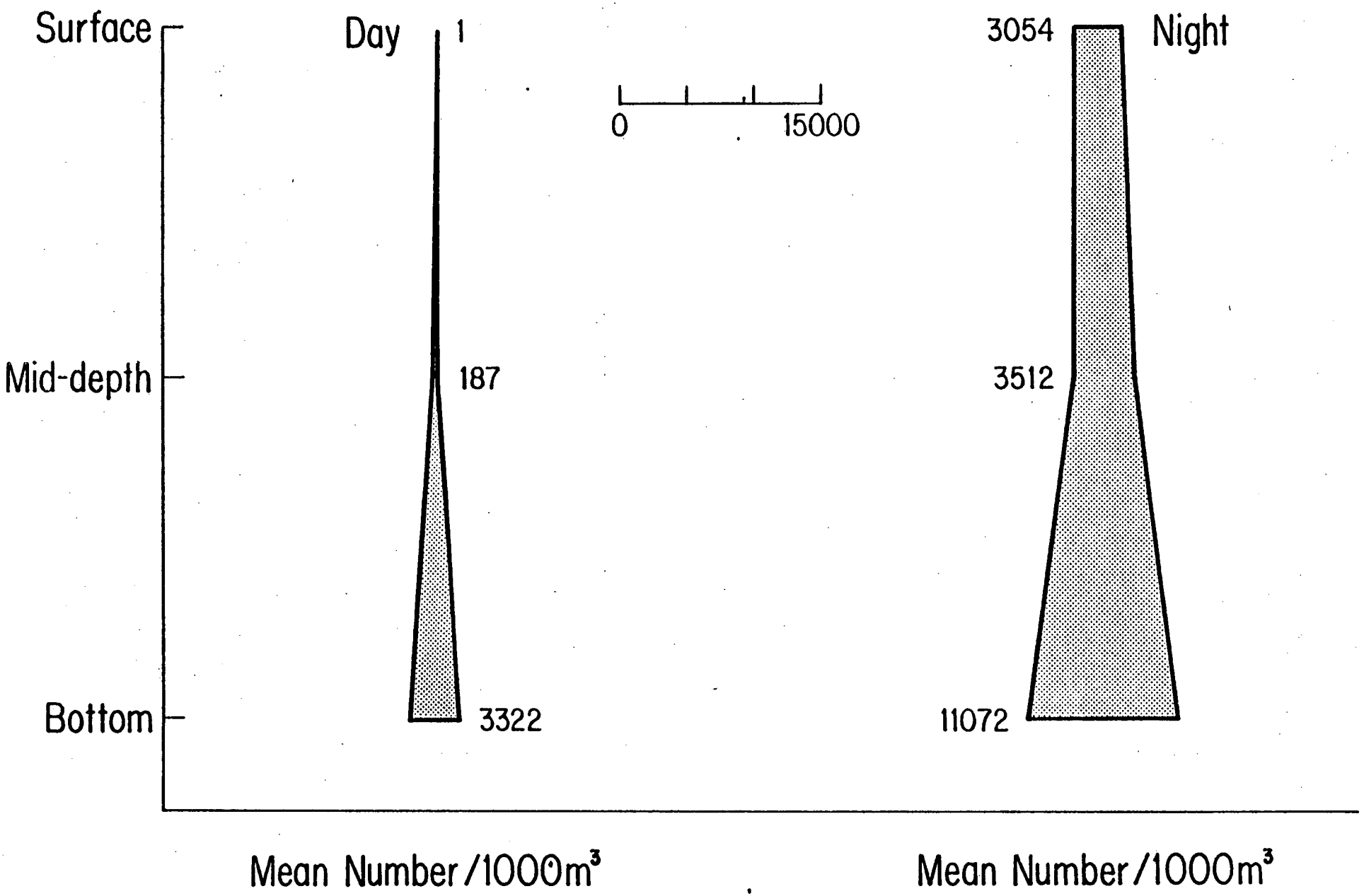

Figure 6-4. Depth distribution for Neomysis americana in day and night samples from the Hudson River at Indian Point, 1976.

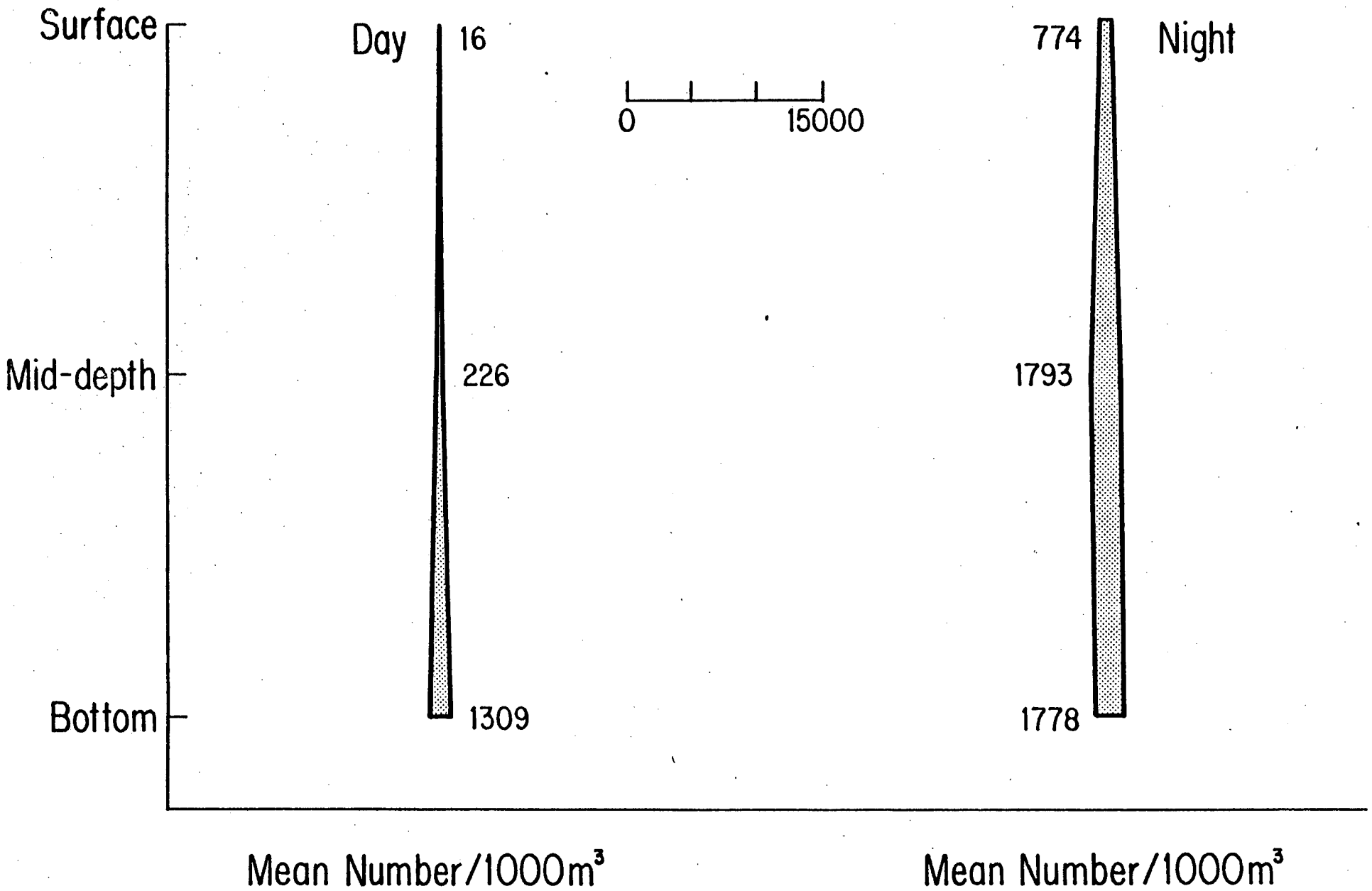

Figure 6-5. Depth distribution for Chaoborus in day and night samples from the Hudson River at Indian Point, 1976.

Instruments, 1975; Lawler, Matusky and Skelly Engineers, 1975) identify the surficial bottom deposits of the river as an important habitat for many of the species which are collected regularly in plankton nets. As none of our gear are designed to sample this habitat, it must be assumed that the increased abundance of macrozooplankton at night is due to the nocturnal emergence of epibenthic forms from the sediments to assume a planktonic existence (Bousfield, 1973; Muller, 1963).

The distribution of the major macrozooplankton components (Gammarus, Neomysis, Monoculodes and Chaoborus) during the day was similar; less than 1% of the totals for each group occurred in the surface samples, while 84-94% were found in the bottom samples (Figures 6-2 through 6-5). Of these four groups, Neomysis had the sharpest distribution profile with depth, in which, approximately 94% of the individuals recorded were from the bottom stratum.

Depth distribution was more even for nighttime samples of the dominant forms. For Gammarus spp. and Chaoborus the nighttime abundance at mid-depth and in bottom samples exceeded that of the surface, but did not differ much from each other (Table 6-8; Figures 6-2, 6-5). The profile for Neomysis showed the bottom strata to have the greatest abundance with essentially no difference between the mid and surface depths (Table 6-8; Figure 6-4). With a gradient of increasing abundance from bottom to the surface Monoculodes

showed differences among all strata (Table 6-8; Figure 6-3). Vast differences in depth distribution between day and night were observed for Neomysis, whose surface abundances at night were over 3000 times that for the day. Although increased numbers of Gammarus, Monoculodes, and Chaoborus were observed for surface samples collected at night over those collected during the day, the differences were not as great (approximately 56%, 154%, and 48%, respectively).

6.1.2.4 Seasonal Abundance

The abundance of macrozooplankton varied significantly with season (Tables 6-9 through 6-12; Figures 6-6, 6-7). The total for daytime samples ranged from a mean of 1,250 organisms per 1000m^3 (June 8) to 15,604 organisms per 1000 m^3 (November 9; Table 6-9). Nighttime abundance was greater overall, ranging between 3,550 organisms per 1000 m^3 (May 6) to 34,658 organisms per 1000 m^3 (August 2; Table 6-10). In general, the pattern of macrozooplankton abundance was similar for daytime and nighttime samples, showing major peaks in summer and fewer organisms in late fall (Figure 6-6 and 6-7). Given the pronounced tendency toward diel vertical migration in the zooplankton as a whole, the variability in daytime samples could be attributed to differences in cloud cover on the various dates, thus leading to greater or lesser congregations of the zooplankters at the mud-water interface.

Table 6-9. Daytime abundance in mean numbers per $1000m^3$ of individual macrozooplankton taxa by date for all stations, 1976. Percent of total represents the abundance of the major species (Gammarus, Monoculodes, Neomysis and Chaoborus) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chaoborus	Chiridotea	Corophium	Leptocheirus	Crangon	Cyathura	Oligochaete	Polychaete	Insect Pupae	Chironomus
4/12	20	80	1550	67	628	71	22	0	10	0	28	496	8	0	25
5/03	18	61	1419	0	150	90	7	1	6	0	1	975	3	54	33
5/10	18	56	727	0	78	62	2	0	2	0	2	587	1	32	51
5/17	21	90	7236	0	33	72	26	<1	0	0	<1	679	<1	57	19
5/24	21	78	5145	0	3	30	81	0	3	0	5	1239	0	102	9
6/01	21	60	2139	0	8	40	32	0	<1	0	1	1314	2	66	36
6/08	21	70	850	0	4	16	82	<1	6	0	4	258	3	17	9
6/15	21	86	4286	0	60	21	29	<1	1	0	2	630	0	22	11
6/22	21	49	722	<1	3	6	20	<1	<1	0	4	722	1	18	3
6/29	21	74	1383	17	103	385	119	1	1	0	3	309	0	152	88
7/06	21	69	701	0	8	267	38	1	0	0	2	125	3	250	25
7/13	21	84	1670	0	0	2842	16	0	0	0	3	760	0	61	16
7/20	21	89	116	169	<1	2043	2	0	0	0	1	229	0	44	14
7/27	21	84	1245	2076	129	1157	16	8	0	0	24	597	0	204	49
8/02	21	96	1469	4859	1117	2767	13	27	8	17	14	66	0	231	80
8/24	21	95	79	2760	136	115	<1	5	3	3	7	40	0	20	72
9/14	21	88	1653	957	159	34	10	12	<1	26	2	336	0	1	4
10/12	21	96	1579	1	131	43	1	1	0	0	3	55	1	0	8
11/09	21	100	15417	0	88	40	10	35	0	0	0	13	0	0	1
12/07	21	70	1387	641	123	57	24	21	<1	0	16	858	2	0	4

Table 6-10. Nighttime abundance in mean numbers per $1000m^3$ of individual macrozooplankton taxa by date for all stations, 1976. Percent of total represents the abundance of the major species (Gammarus, Monoculodes, Neomysis and Chaoborus) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chaoborus	Chiridotea	Corophium	Leptocheirus	Crangon	Cyathura	Oligochaete	Polychaete	Insect Pupae	Chironomus
4/13	21	93	8470	4	2313	113	194	0	221	0	1	249	80	0	34
5/06	18	94	2844	0	338	144	18	0	2	0	5	157	5	31	6
5/13	18	94	14932	0	183	400	29	0	4	0	6	760	1	146	23
5/20	21	97	14350	0	61	219	338	0	4	0	0	80	8	54	22
5/27	21	93	18581	17	5	337	190	<1	1	1	6	835	2	366	42
6/03	21	84	3230	26	74	134	319	0	6	0	1	225	1	101	25
6/10	21	73	6161	<1	333	240	1354	2	12	0	17	366	4	691	28
6/17	20	85	7444	0	277	76	447	1	4	0	2	806	1	50	44
6/24	21	87	7838	321	423	131	768	1	0	2	18	159	0	312	30
7/01	21	82	5615	0	1971	912	680	0	14	0	9	161	0	1084	13
7/08	21	82	10037	0	100	596	287	0	0	0	6	31	0	1958	20
7/15	21	92	7066	0	26	7394	75	0	0	0	16	395	0	686	12
7/22	21	87	7256	2010	497	5137	39	32	0	0	40	753	0	1193	76
7/29	21	95	7355	12598	1404	4998	173	25	98	8	43	79	6	914	58
8/02	21	95	2114	22791	2625	5308	6	4	12	71	36	55	30	1150	456
8/26	21	94	3713	15484	3208	1347	110	343	554	16	131	171	0	238	31
9/14	21	99	5545	5389	768	356	8	25	4	28	33	12	<1	8	12
10/12	21	96	3146	0	591	114	3	8	0	0	4	160	0	<1	1
11/11	21	97	11873	0	23	114	246	68	0	0	0	243	2	0	3
12/02	21	95	3151	177	231	66	4	1	0	9	0	1102	0	0	64

Table 6-11. Daytime abundance in mean number, catch per unit effort of individual macrozooplankton taxa by date for all stations, 1976. Percent of total represents abundance of major species (Gammarus, Monoculodes, Neomysis and Chaoborus) to the abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chaoborus	Chiridotea	Corophium	Leptocheirus	Crangon	Cyathura	Oligochaete	Polychaete	Insect Pupae	Chironomus
4/12	20	77	487	21	193	26	8	0	3	0	12	182	3	0	9
5/03	18	59	647	0	66	40	3	0	3	0	1	483	1	24	15
5/10	18	56	314	0	34	26	1	0	1	0	1	258	0	14	22
5/17	21	90	2838	0	14	29	10	0	0	0	0	279	0	25	9
5/24	21	80	2217	0	1	12	31	0	1	0	2	473	0	38	3
6/01	21	60	916	0	4	16	13	0	0	0	0	575	1	26	15
6/08	21	71	364	0	2	6	33	0	2	0	1	100	1	8	4
6/15	21	86	1138	0	20	6	9	0	0	0	1	168	0	7	4
6/22	21	48	299	0	1	2	8	0	0	0	2	309	0	7	1
6/29	21	75	519	5	37	135	40	0	1	0	1	115	0	53	28
7/06	21	68	276	0	3	104	15	0	0	0	0	51	1	100	10
7/13	21	84	638	0	0	1059	6	0	0	0	1	299	0	23	6
7/20	21	90	44	62	0	788	1	0	0	0	0	75	0	17	4
7/27	21	83	496	800	51	464	6	3	0	0	9	238	0	83	20
8/02	21	96	546	1807	409	1035	5	10	3	7	5	29	0	90	29
8/24	21	95	20	782	40	32	0	1	1	1	2	8	0	6	28
9/14	21	87	636	385	61	13	4	5	0	10	1	135	0	0	2
10/12	21	96	471	0	42	11	0	0	0	0	1	18	0	0	3
11/09	21	100	4217	0	22	10	3	8	0	0	0	4	0	0	0
12/07	21	70	319	235	28	15	5	4	0	0	4	242	1	0	1

Table 6-12. Nighttime abundance in mean number, catch per unit effort of individual macrozooplankton taxa by date for all stations, 1976. Percent of total represents abundance of major species (Gammarus, Neomysis, Monoculodes and Chaoborus) to abundance for all species of macrozooplankton observed.

Date	Number of Samples	Percent of Total	Gammarus	Neomysis	Monoculodes	Chaoborus	Chiridotea	Corophium	Leptocheirus	Crangon	Cyathura	Oligocheate	Polycheate	Insect Pupae	Chironomus
4/13	21	92	2632	1	757	37	65	0	82	0	0	98	27	0	12
5/06	18	94	1096	0	124	52	7	0	0	0	2	58	2	11	2
5/13	18	94	5623	0	67	147	11	0	1	0	1	296	0	56	9
5/20	21	97	4872	0	19	71	115	0	1	0	0	27	2	19	7
5/27	21	92	6421	6	1	118	67	0	1	0	2	315	0	143	14
6/03	21	85	1263	0	44	49	120	0	2	0	0	69	0	40	9
6/10	21	79	2322	0	125	93	520	1	4	0	7	149	1	265	11
6/17	20	84	2424	0	103	25	139	0	1	0	1	311	0	15	16
6/24	21	87	2540	113	142	43	248	0	0	1	5	55	0	104	11
6/01	21	81	1801	0	646	303	230	0	0	0	2	55	0	340	4
7/08	21	83	3349	0	33	194	95	0	0	0	2	8	0	645	7
7/15	21	92	2364	0	9	2652	25	0	6	0	6	139	0	235	4
7/22	21	87	2372	625	155	1602	11	8	3	6	13	276	0	354	24
7/29	21	95	2724	4627	521	1822	67	10	47	3	15	30	2	333	20
8/02	21	96	685	7480	861	1983	2	1	4	22	11	21	9	397	14
8/26	21	93	1037	3340	940	250	36	77	152	3	20	61	0	77	10
9/14	21	99	1932	2062	273	123	2	9	1	11	12	5	0	3	5
10/12	21	95	989	0	193	37	1	3	0	0	1	62	0	0	0
11/11	21	95	3351	0	7	35	74	20	0	0	0	82	1	0	1
12/02	21	74	1011	60	80	21	1	0	0	0	3	380	0	0	20

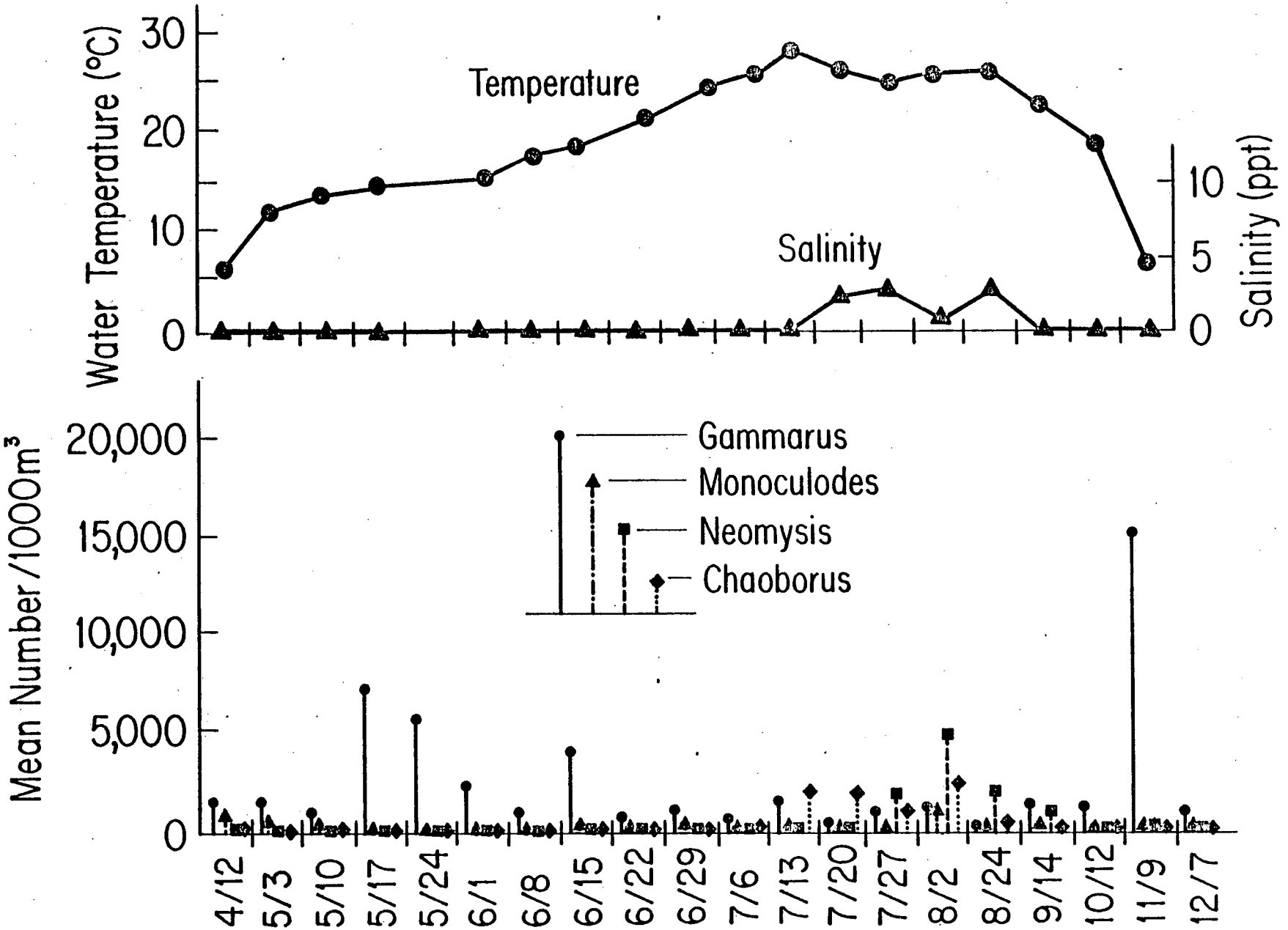

Figure 6-6. Seasonal distribution of Gammarus, Neomysis, Monoculodes and Chaoborus relative to temperature and salinity for daytime samples in the Hudson River at Indian Point, 1976.

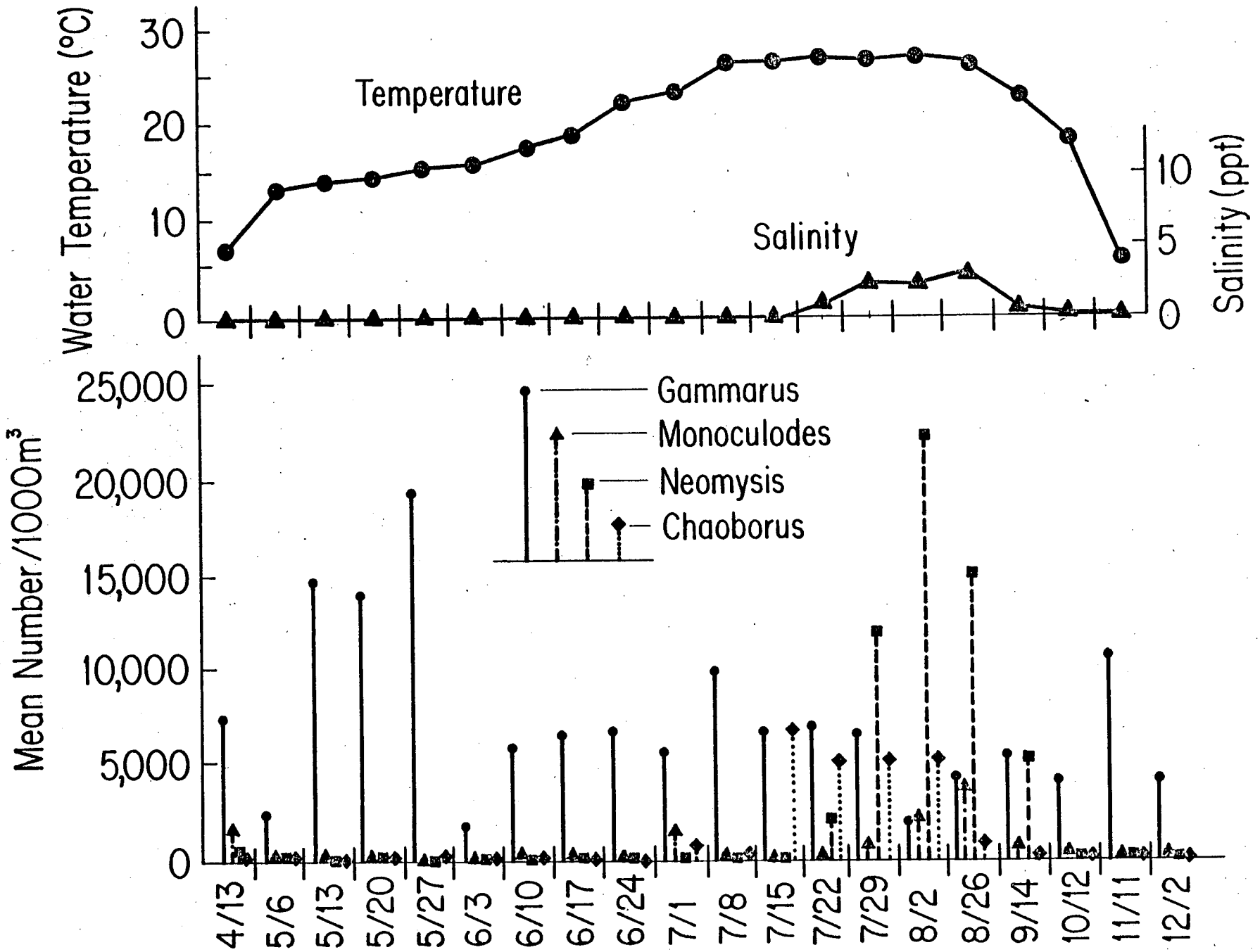

Figure 6-7. Seasonal distribution of Gammarus, Neomysis, Monoculodes and Chaoborus relative to temperature and salinity for nighttime samples in the Hudson River at Indian Point, 1976.

Variation in abundance on a date-to-date basis may be accounted for primarily by variation in the abundance of the four dominant macrozooplankters, Gammarus spp., Monoculodes, Neomysis and Chaoborus larvae. On one sampling date (June 22) Gammarus, Monoculodes, Neomysis and Chaoborus failed to account for at least half the macrozooplankton collected (Table 6-9). On this date, oligochaeta, Chiridotea, and insect pupae were abundant and accounted for a large percentage of the total. There were no nighttime samples in which the four dominant macrozooplankters failed to account for at least half the total collected (Table 6-10 and 6-12).

The abundance and proportional representation of the various macrozooplankton taxa on a seasonal basis are attributable directly to two factors; 1) salt intrusion in the vicinity of Indian Point, and 2) the life history of the species present. During periods of high salinity at Indian Point an abundance of Neomysis and Monoculodes was observed, while during low salinity and freshwater periods, the amphipod Gammarus and annelid worms (Oligochaeta and Polychaeta) became dominant (Tables 6-9 through 6-12; Figures 6-6 and 6-7).

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

An analysis of variance (ANOVA) of the data revealed significant differences in numbers by station, by depth and

by date (Tables 6-13 through 6-20). There was a significant interaction of station and date in both daytime and nighttime samples for total species and for Gammarus, Monoculodes, Neomysis and Chaoborus which substantiates the seasonal relationship of Gammarus with freshwater periods and of Monoculodes and Neomysis with salt water intrusion (Tables 6-15 through 6-22).

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 if this entrainment will have any qualitative or quantitative impact upon the river populations.

As reported in our earlier reports (New York University Medical Center, 1975, 1976a) comparisons of macrozooplankton abundance within sampling years seldom show differences due to factors other than season; any differences found between stations are probably due to random factors since plankton distribution is characteristically patchy (Wiebe and Holland, 1968; Fleminger and Clutter, 1965). For the same reasons, and additional ones such as year-to-year variation in river flow, tidal exchange and mixing (Abood, 1974), quantitative comparisons of zooplankton populations between years is probably best executed in non-dimensional terms, such as components and community structure (Pielou, 1975) rather than abundance.

Table 6-13. Differences in macrozooplankton river abundance among stations in 1976. Letters refer to the respective river station locations.

Day	
Total	C>G
Gammarus	A>G
Monoculodes	none[1]
Neomysis	none
Chaoborus	none
Night	
Total	none[1]
Gammarus	none[1]
Monoculodes	none
Neomysis	none[1]
Chaoborus	E>F

[1] The analysis of variance ($\alpha<.05$) indicated a difference among stations. However, the Scheffé test ($\alpha<0.10$) was unable to locate the difference.

Table 6-14. Differences in macrozooplankton river abundance among depths in 1976. Depths refer to sample depths from surface to 50 feet for bottom samples.

Day	
Total	mid>sur; bot>sur; bot>mid
Gammarus	mid>sur; bot>sur; bot>mid
Monoculodes	bot>sur; bot>mid
Neomysis	bot>sur; bot>mid
Chaoborus	mid>sur; bot>sur; bot>mid
Night	
Total	none[1]
Gammarus	none[1]
Monoculodes	mid>sur; bot>sur; bot>mid
Neomysis	mid>sur; bot>sur; bot>mid
Chaoborus	mid>sur; bot>sur

[1] The analysis of variance ($\alpha<.05$) indicated a difference among depths. However, the Scheffé test ($\alpha<0.10$) was unable to locate the difference.

Table 6-15. Analysis of variance for all species of macrozooplankton collected during the day in 1976, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)= significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	1.3318	.2220	2.8066*
B/A	14	78.8906	5.6350	71.2539*
C	19	11.7157	.6166	7.7970*
AXC	112	9.5688	.0854	1.0803
Error	261	20.6409	.0791	
Total	412	122.1478		

Contrast among Stations	Scheffé test[1] $\log_{10}$ (catch/m^3+1)	
	Critical value	Contrast value
C vs G	0.1719	0.2066

[1]Only significant contrasts are shown here.

Table 6-16. Analysis of variance for all species of macrozooplankton collected during the night in 1976, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	2.1104	.3517	4.1331*
B/A	14	53.4463	3.8176	44.8597*
C	19	21.2269	1.1172	13.1280*
AXC	112	19.3190	.1725	2.0269*
Error	261	22.2113	.0851	
Total	412	118.3139		

Table 6-17. Analysis of variance for Gammarus collected during the day in 1976, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	1.1047	.1841	2.7661*
B/A	14	30.8494	2.2035	33.1047*
C	19	10.4315	.5490	8.2483*
AXC	112	5.9231	.0529	.7945
Error	259	17.2396	.0666	
Total	410	65.5483		

Contrast among Stations	Scheffé test[1] $\log_{10}$ (catch/m^3+1) Critical value	Contrast value
A vs G	0.1585	0.1704

[1]Only significant contrasts are shown here.

Table 6-18. Analysis of variance for *Gammarus* collected during the night in 1976, listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	1.2011	.2002	2.9711*
B/A	14	41.3903	2.9564	43.8793*
C	19	15.3858	.8098	12.0187*
AXC	112	14.5557	.1300	1.9289*
Error	261	17.5854	.0674	
Total	412	90.1182		

Table 6-19. Analysis of variance for Monoculodes collected at day and night during 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Day				
A	6	.0488	.0081	.8830
B/A	14	.9582	.0684	7.4324*
C	18	1.1294	.0627	6.8132*
AXC	106	.4376	.0041	.4483
Error	247	2.2746	.0092	
Total	391	4.8486		
Night				
A	6	.2235	.0373	1.3642
B/A	14	3.3741	.2410	8.8249*
C	19	10.0381	.5283	19.3456*
AXC	112	2.5695	.0229	.8401
Error	261	7.1278	.0273	
Total	412	23.3330		

Table 6-20. Analysis of variance for *Neomysis* collected at day and night during 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)= significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
Day				
A	6	.3911	.0652	.9570
B/A	14	5.2167	.3726	5.4716*
C	9	3.9226	.4358	6.3998*
AXC	54	1.8332	.0339	.4985
Error	125	8.5128	.0681	
Total	208	19.8763		
Night				
A	6	1.1839	.1973	2.8966*
B/A	14	4.7520	.3394	4.9829*
C	9	40.4535	4.4948	65.9860*
AXC	54	5.9894	.1109	1.6283*
Error	126	8.5829	.0681	
Total	209	60.9615		

Table 6-21. Analysis of variance for Chaoborus collected during the day in 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A=stations; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	.0572	.0095	.3046
B/A	14	3.1868	.2276	7.2754*
C	19	5.3351	.2808	8.9747*
AXC	112	2.1178	.0189	.6044
Error	261	8.1660	.0313	
Total	412	18.8628		

Table 6-22. Analysis of variance for Chaoborus collected at night during 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A=station; B=depth; C=date; Asterisk (*)=significant at .05 level).

Source	Degrees of freedom	Sum of squares	Mean square	F-value
A	6	.3878	.0646	2.9050*
B/A	14	2.4223	.1730	7.7766*
C	19	29.3747	1.5460	69.4876*
AXC	112	3.2460	.0290	1.3026*
Error	261	5.8070	.0222	
Total	412	41.2379		

Contrast among Stations	Scheffé test[1] $\log_{10}$ (catch/m^3+1)	
	Critical value	Contrast value
E vs F	.0890	.1088

[1]Only significant contrasts are shown here.

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 (1971-1976). Although there are differences in the number of individual species observed from 1971-1976, many of these are of little consequence; they are marine forms and their abundance depends upon the extent of saltwater intrusion into the area.

Although a relatively large number of Neomysis may be killed at the Indian Point plant (New York University Medical Center, 1976a; Ginn, 1977), it is our opinion that the Neomysis population in the river is not impacted. Since Neomysis is at the northern fringe of distribution, and is transitory at the plant site (Tattersall, 1951; Wigley and Burns, 1971; New York University Medical Center, 1975, 1976a and this report), the impact from plant-related mortalities on the river population have not been observed.

Thus, it is our opinion that the river populations of macrozooplankton have not been affected by the operation of the Indian Point station.

7. ICHTHYOPLANKTON

7.1 RIVER POPULATION STUDIES

7.1.1 Methods

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

The river day and night sampling, as well as the river/plant simultaneous sampling was done each week throughout the striped bass "larvae season" (from the last week in April to the end of July). After July, all sampling was done every other week through August, and then once per month until the end of December, so as to encompass the season for other fish species. The sampling schedule was staggered so that day samples and night samples were collected on different days. Consequently, there may be differences, both in the numbers of samples and in the time period chosen for the calculations of abundances between day and night distributions.

Metered 0.5 m-diameter, 571 μ-mesh plankton nets, similar to those used in the intakes and discharge canal, were used to sample in the river for fish eggs and larvae.

These nets were towed simultaneously at each of three depths (6 to 12 inches below the surface, at mid-depth and approximately 1 foot off the bottom). Replicate samples were taken at all seven river stations, plus the one station used for river/plant comparisons.

Fish eggs and larvae were sorted from the samples, identified to species (when possible; see identification methods employed in New York University Medical Center 1971-72 report) and enumerated to determine abundance. Abundance is reported both as numbers per 1000 m^3 of water sampled as well as numbers per sampling effort (10-min tow). All abundance data were examined by analysis of variance (ANOVA) and by a posteriori tests (Sokal and Rohlf, 1969) to determine if significant differences exist in the temporal and spatial distribution of river ichthyoplankton relative to ichthyoplankton sampled at the plant intakes. To stabilize the variances, the data analyzed were transformed by the formula: $\log(\frac{N}{V} + 1)$, where N is the actual number caught and V the volume of water filtered. Adjustments were made in the degrees of freedom where appropriate. The data (for each life history stage) used in the comparisons were derived from all the samples collected within the period of initial appearance to final observation for a particular life stage. For example, for striped bass eggs, if only one egg was found in one sample from one station for a given date, all the samples for that date were included in the analysis; even though all

but one would be zeros. Data for that life history stage would continue to accumulate until such time that they were no longer observed in any of the samples. As we are unable to predict when a certain life history stage will appear or be absent in the river, this method of data selection may approximate the actual presence of each ichthyoplankton life history stage in the river.

7.1.2 Results and Discussion

A total of 2226 ichthyoplankton samples were collected from the Hudson River in 1976. One-half (1113 samples) was sorted and analyzed, the other half (replicate samples) was not examined, and was kept for reference purposes, or was used if difficulties in analyzing the primary samples became evident. The species and life stages identified in these collections are listed in Table 7-1. Twenty-four possible species were observed, (Table 7-2), 16 of which have been caught in each sampling year since 1971. The life stages and relative abundance for the season, of fish species taken in these samples are shown in Table 7-3; bay anchovy (*Anchoa mitchilli*) eggs, larvae and juveniles were again the most abundant. Yolk-sac larvae of anchovies, however, were not as abundant as for the other life stages of the species. This has been true for anchovy yolk-sac larvae since we were first able to identify them in 1974. Anchovy yolk-sac larvae are thread-thin and are between 2-3 mm long, and may be easily overlooked even with very careful examination in sorting or some may be lost through the mesh of our sampling nets.

Table 7-1. Ichthyoplankton species and life stages in the river population samples, 1976. YSL=yolk-sac larvae, Juv= juveniles, Older=older fish.

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

Table 7-1 (cont.)

Species	Eggs	YSL	Larvae	Juv	Older
Atherinidae (silversides)					
Menidia spp.			+	+	
Soleidae (soles)					
Trinectes maculatus (hogchoker)			+	+	+
Anguillidae (freshwater eels)					
Anguilla rostrata (American eel)				+	+
Syngnathidae (pipefishes and sea horses)					
Syngnathus fuscus (northern pipefish)			+	+	
Centrarchidae (sunfishes)					
Lepomis sp.			+		
Gadidae (codfishes)					
Microgadus tomcod (Atlantic tomcod)		+	+	+	+
Ictaluridae (freshwater catfishes)					
Ictalurus catus (white catfish)				+	+
Acipenseridae (sturgeons)					
Acipenser oxyrhynchus (Atlantic sturgeon)			+		
Cyprinodontidae (killifishes)					
Fundulus spp.			+	+	
Gobiidae (gobies)					
Gobiosoma bosci (naked goby)			+		

Table 7-2. Species comparisons from 1971 to 1976.

Species	1971	1972	1973	1974	1975	1976
Anchovy	+	+	+	+	+	+
Clupeids[1]	+	+	+	+	+	+
Striped bass	+	+	+	+	+	+
White perch	+	+	+	+	+	+
Tomcod	+	+	+	+	+	+
Darters	+	+	+	+	+	+
Cyprinids[2]	+	+	+	+	+	+
Hogchoker	+	+	+	+	+	+
Yellow perch	+	+	+	+	+	+
Smelt	+	+	+	+	+	+
Silversides[3]	+	+	+	+	+	+
American eel	+	+	+	+	+	+
Pipefish	+	-	+	+	+	+
Killifish[4]	+	-	+	-	+	+
Crevalle jack	+	-	-	-	-	-
Menhaden	+	-	-	-	-	-
Weakfish	-	+	+	+	+	+
Atlantic Sturgeon[5]	+	+	-	-	+	+
Sunfish	-	-	+	+	+	+
Silver perch	-	-	+	-	-	-
White catfish	-	-	+	-	+	+
Stickleback	-	-	+	-	-	-
Goby	-	-	-	+	-	+
Windowpane flounder	-	-	-	-	+	-
TOTALS	21	19	23	20	23	24

1 The clupeids included alewife, blueback herring and American shad.

2 The cyprinids included Spottail shiner and an unknown cyprinid species.

3 The silversides included Atlantic silverside and Tidewater silverside.

4 The killifish included banded killifish and mummichog during 1976.

5 The sturgeon shown for 1972, 1975 and 1976 may include Atlantic sturgeon or shortnose sturgeon or both.

Table 7-3. Percent relative abundance of fish eggs, larvae and juveniles occurring in the Hudson River between mile 39.0 and mile 47.0 for 1971 to 1976. Data for 1973 were not available for all species.

	Eggs					Yolk-sac Larvae				
Species	1971	1972	1974	1975	1976	1971	1972	1974	1975	1976
Anchovy	----	----	95.9	98.7	94.0	----	----	16.3	35.5	25.8
Clupeids[1]	7.2	1.1	+	+	+	16.6	6.8	3.9	2.6	5.0
Striped bass	92.7	87.2	3.1	1.2	5.6	55.6	65.6	54.8	43.3	51.6
White perch	+	0.8	0.5	0.1	0.3	22.2	6.6	22.7	15.3	7.7
Tomcod	----	----	----	----	----	----	13.1	----	+	0.1
Darter	----	----	----	----	----	4.0	4.9	1.7	1.6	7.0
Cyprinids[2]	----	+	0.5	+	+	1.6	1.9	0.6	0.9	2.6
Hogchoker	----	10.9	----	----	----	----	0.1	0.1	+	----
Yellow perch	----	----	----	----	----	----	+	----	+	0.1
Weakfish	----	----	----	----	----	----	----	----	----	----
Smelt	----	----	----	----	----	----	----	----	0.7	0.1
Silversides[3]	----	----	----	----	----	----	----	----	----	----
American eel	----	----	----	----	----	----	----	----	----	----
Pipefish	----	----	----	----	----	----	----	----	----	----
Sunfish	----	----	----	----	----	----	----	----	----	----
Goby sp.	----	----	----	----	----	----	----	----	----	----
Atlantic sturgeon[5]	----	----	----	----	----	----	----	----	----	----
Windowpane flounder	----	----	----	----	----	----	----	----	----	----
Killifish[4]	----	----	----	----	----	----	----	----	----	----
White catfish	----	----	----	----	----	----	----	----	----	----
Shad[1]	----	----	----	----	----	+	+	+	+	+
Menhaden	----	----	----	----	----	----	----	----	----	----
Species present	3	5	5	5	5	8	11	10	12	11

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

Table 7-3 (cont'd)

Species	Larvae 1971	1972	1974	1975	1976	Juveniles 1971	1972	1974	1975	1976
Anchovy	51.2	30.8	69.8	42.1	39.4	99.8	57.4	68.7	49.0	44.9
Clupeids[1]	10.7	47.8	7.9	10.9	40.8	+	3.4	1.4	2.2	6.1
Striped bass	14.3	7.1	12.2	21.8	8.1	+	7.3	0.4	0.2	4.6
White perch	21.8	8.0	9.4	23.6	8.1	+	30.1	0.1	1.2	3.5
Tomcod	----	5.2	----	+	2.4	+	----	9.6	16.0	9.8
Darter	0.1	0.4	0.1	0.3	0.2	----	+	----	0.5	----
Cyprinids[2]	+	0.4	0.2	0.3	0.3	----	+	+	----	----
Hogchoker	+	0.3	0.1	0.2	+	+	1.7	2.0	2.5	0.8
Yellow perch	+	0.8	+	+	+	----	----	----	----	----
Weakfish	----	+	0.1	+	0.1	----	+	2.7	0.5	1.4
Smelt	1.2	----	0.1	0.4	0.4	+	+	2.7	4.8	2.6
Silversides[3]	0.2	+	0.1	+	+	----	----	0.2	----	----
American eel	----	----	----	----	----	+	+	12.9	20.5	25.4
Pipefish	----	----	----	----	----	+	----	0.4	1.2	+
Sunfish	----	----	+	+	+	----	----	----	----	----
Goby sp.	----	----	+	----	+	----	----	----	----	----
Atlantic sturgeon[5]	----	+	----	+	+	+	----	----	----	----
Windowpane flounder	----	----	----	+	----	----	----	----	----	----
Killifish[4]	----	----	----	----	+	+	----	----	1.0	+
Crevalle jack	----	----	----	----	----	+	----	----	----	----
White catfish	----	----	----	----	----	----	----	----	0.2	0.5
Shad[1]	----	----	+	+	0.1	----	----	----	----	0.4
Menhaden	+	----	----	----	----	----	----	----	----	----
Species present	14	16	17	20	22	13	11	13	14	14

\+ indicates less than 0.1 percent.

2 The cyprinids included spottail shiner and an unknown cyprinid species.

3 The silversides included Atlantic silverside and Tidewater silverside.

4 The killifish included banded killifish and mummichog during 1976.

5 The sturgeon shown for 1972, 1975 and 1976 may include Atlantic sturgeon or shortnose sturgeon or both.

The seasonal distribution of fish species in 1976 and their occurrence relative to ambient water temperature and salinity at Indian Point are shown in Figure 7-1. As observed in previous years the seasonal presence of the various species identified appears to be dependent upon temperature and salinity.

The relative frequency of occurrence for the various life stages of the more abundant species are shown in Figure 7-2 through 7-5. Striped bass (Morone saxatilis) eggs first appeared in the Indian Point region during the month of May. They were followed sequentially by the eggs of white perch, (Morone americana) clupeids (Alosa sp.) and cyprinid fishes, during a time of low salinity (< 1.0 ppt) that lasted until the end of June. The appearance of anchovy eggs coincided with the first major influx of salt water into the Indian Point region on July 22. Large numbers of anchovy eggs remained in the Indian Point region until the end of August, at which time the salinity dropped below 3.0 ppt, and the spawning season was ending for this species.

Striped bass eggs were first collected on May 3 and were last seen on June 17 (Figure 7-6 and 7-7). This was one week earlier, and extended two weeks later than in 1975. Peak mean abundance (260/1000 m^3) occurred on May 13 (Figure 7-7).

White perch eggs were encountered in the samples from May 17 until June 29; peak mean abundance (20/1000 m^3) was on June 24 (Figures 7-8 and 7-9).

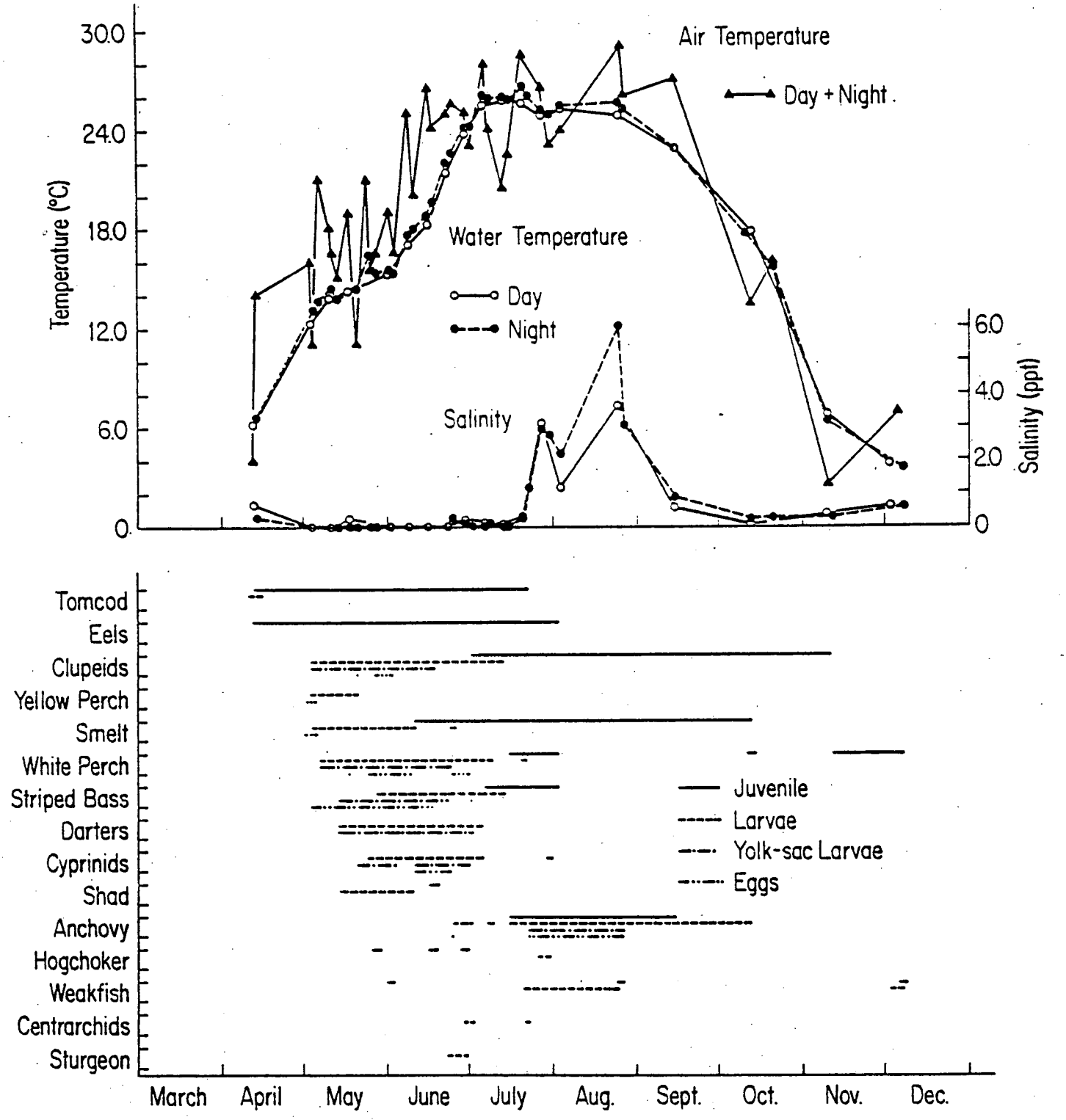

Figure 7-1. Seasonal distribution of fish eggs, larvae and juveniles relative to temperature and salinity, 1976.

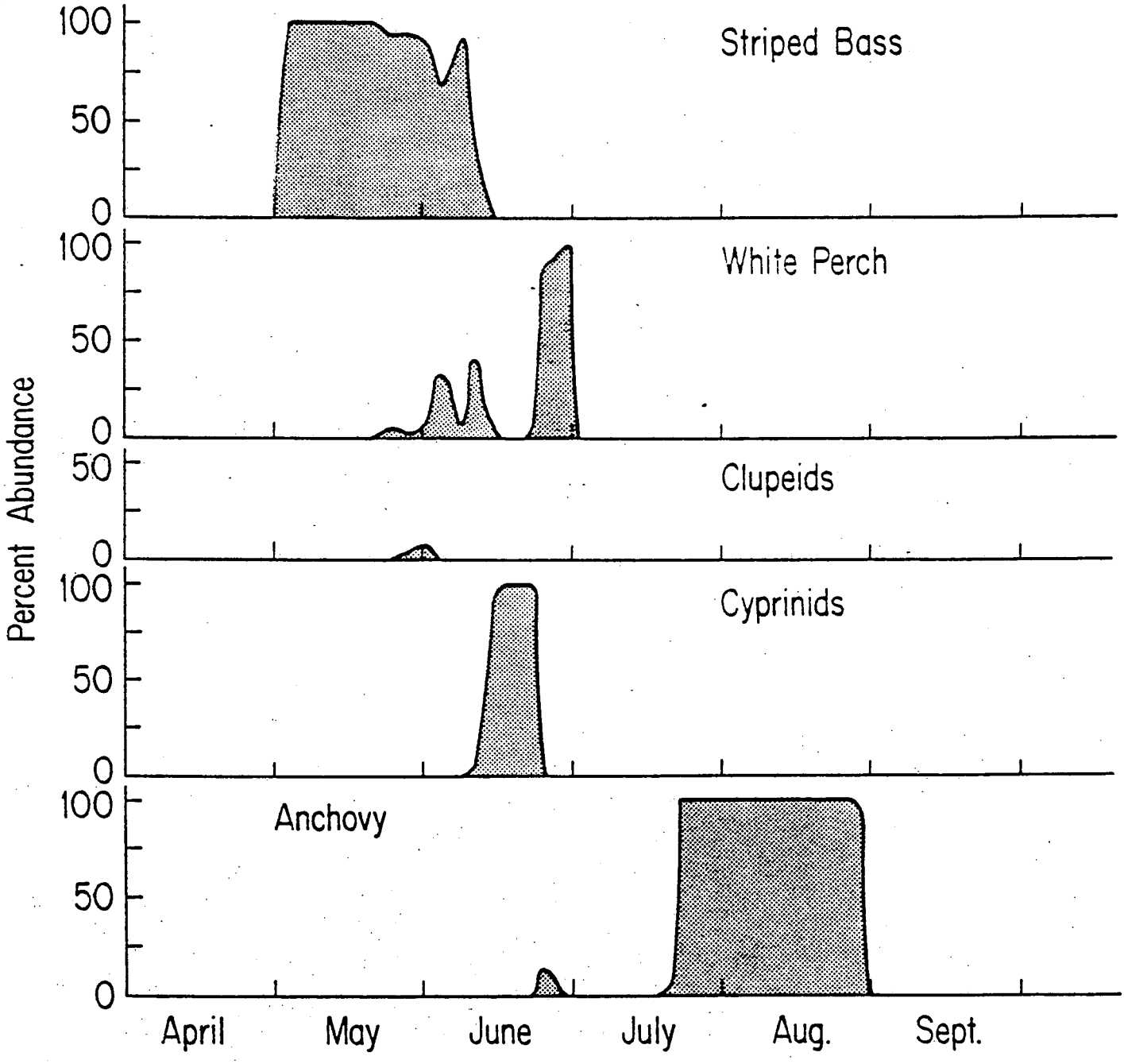

Figure 7-2. Seasonal occurrence and percent abundance for fish eggs by species, 1976. The values shown are pecent of total fish eggs in the samples analyzed.

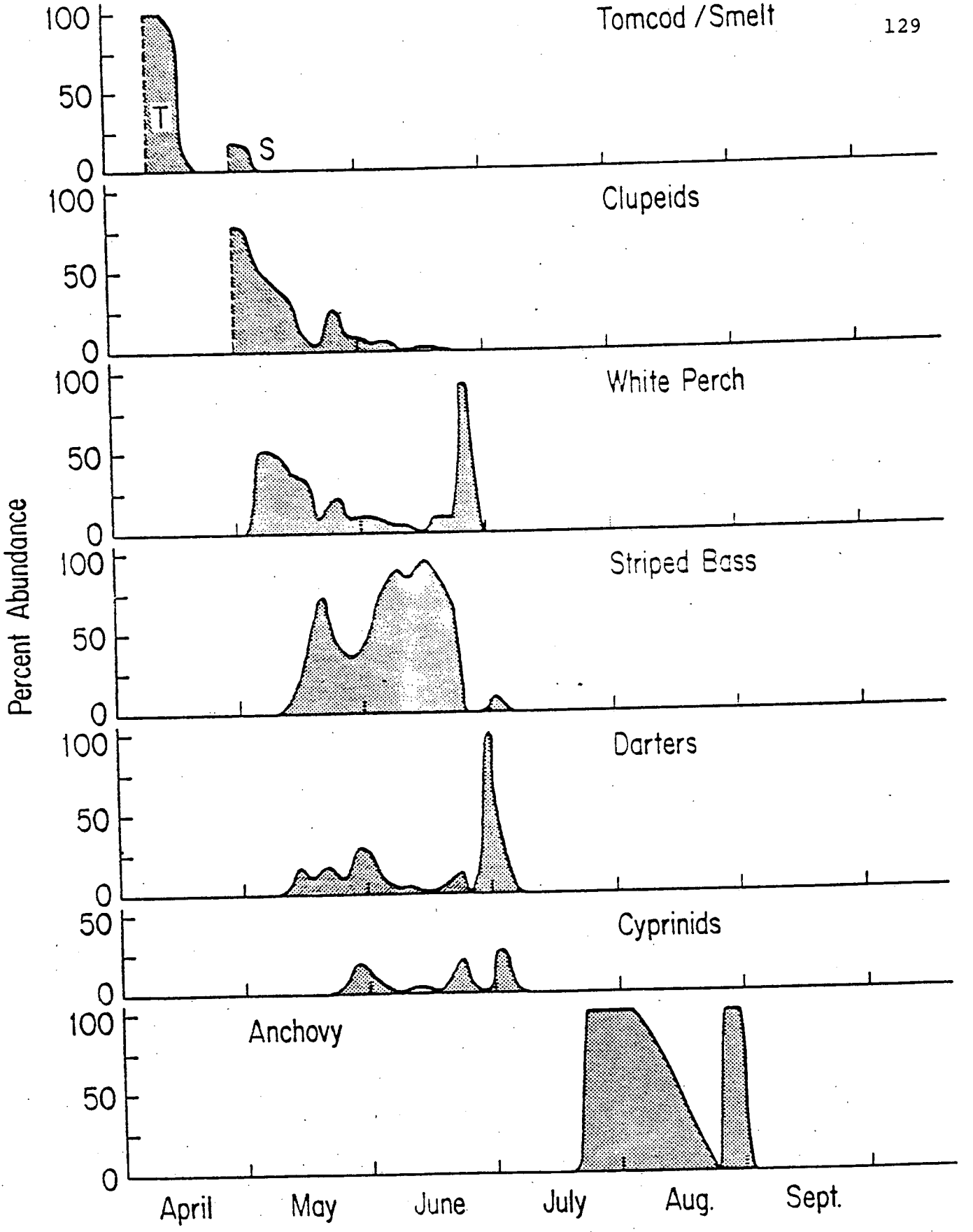

Figure 7-3. Seasonal occurrence and percent abundance for yolk-sac larvae by species, 1976; the values shown are percent of total yolk-sac larvae in the samples analyzed.

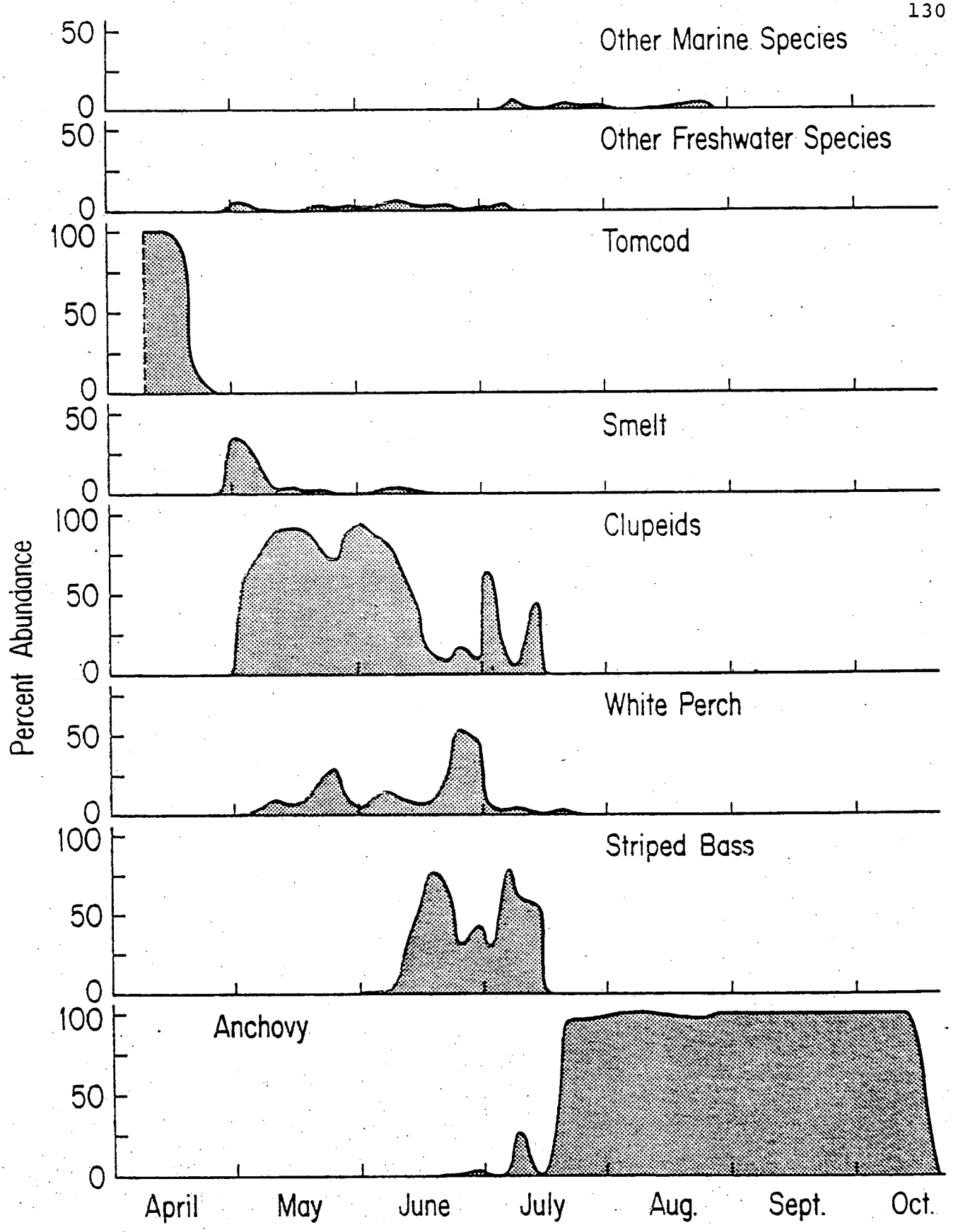

Figure 7-4. Seasonal occurrence and percent abundance for larvae by species, 1976; the values shown are percent of total larvae in the samples analyzed.

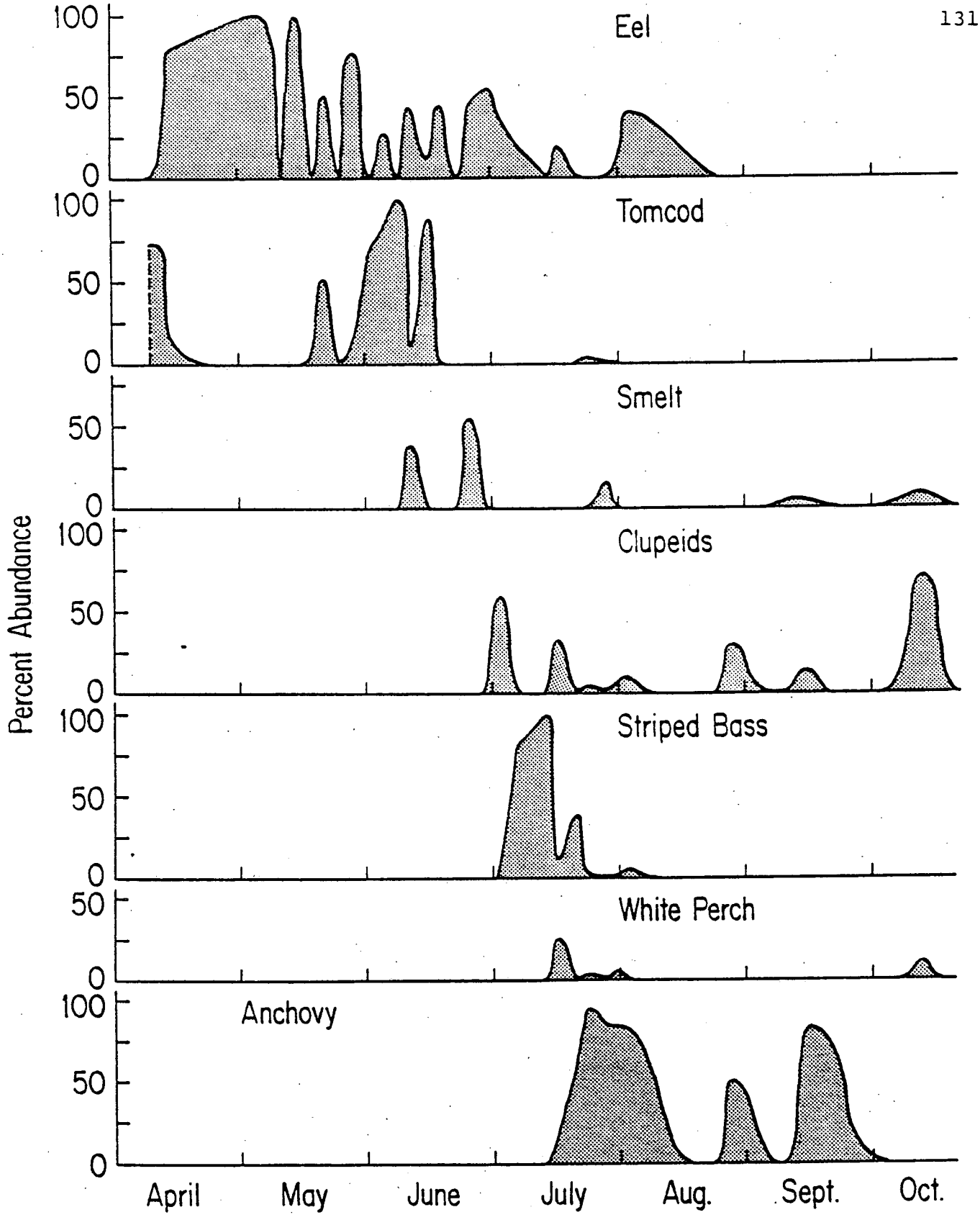

Figure 7-5. Seasonal occurrence and percent abundance for juveniles by species, 1976; the values shown are percent of total juveniles in the samples analyzed.

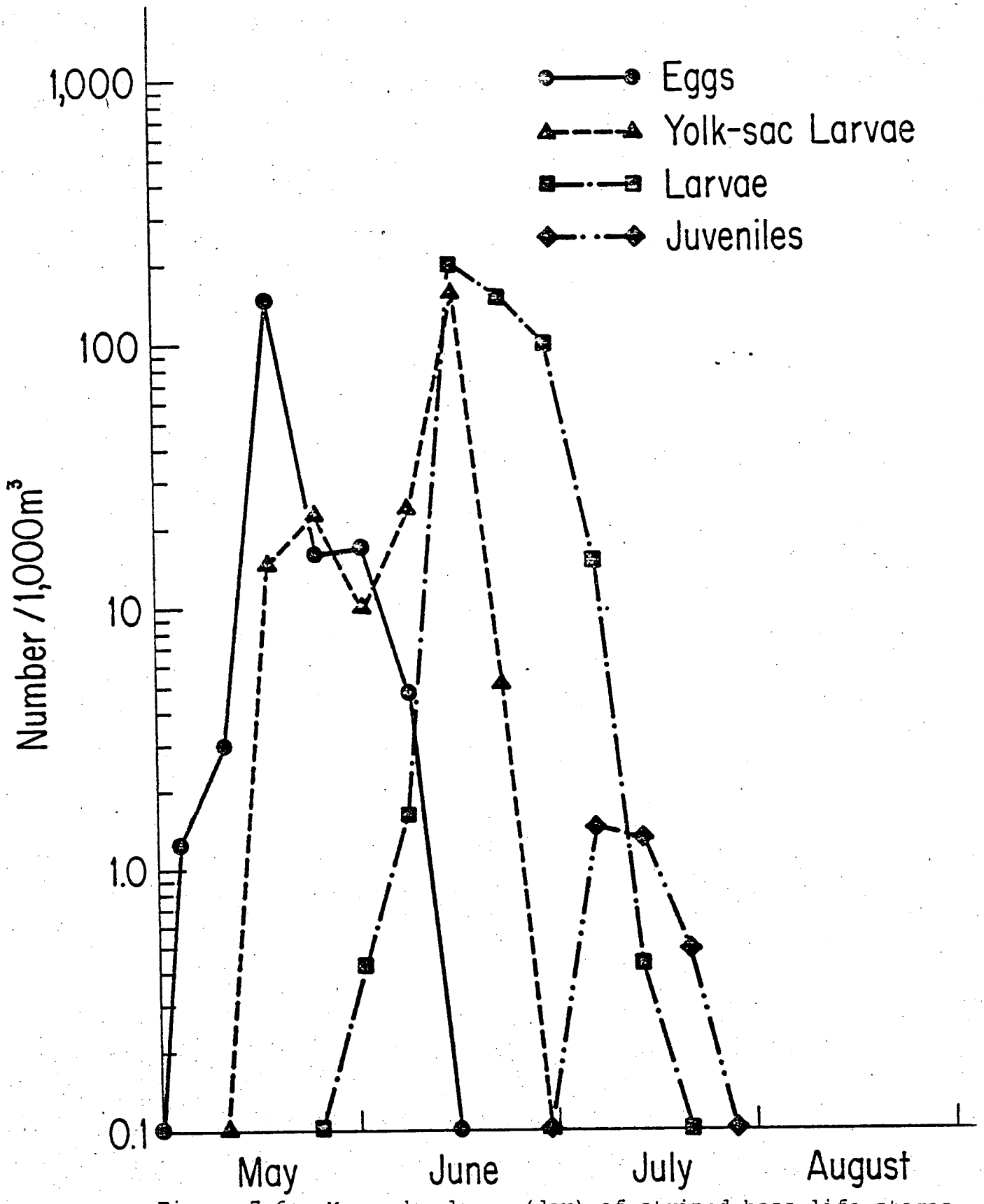

Figure 7-6. Mean abundance (day) of striped bass life stages collected in river tows, 1976.

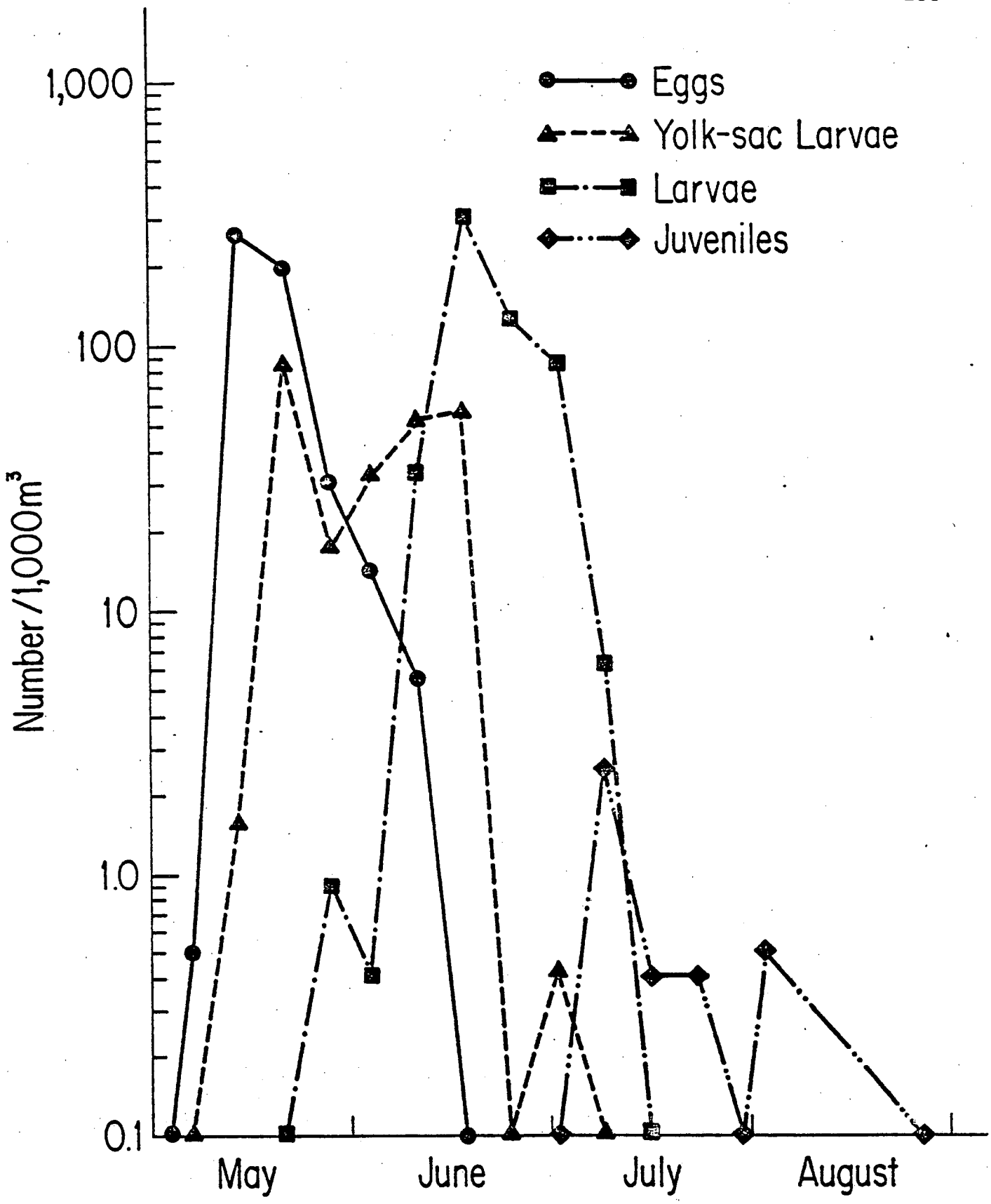

Figure 7-7. Mean abundance (night) of striped bass life stages collected in river tows, 1976.

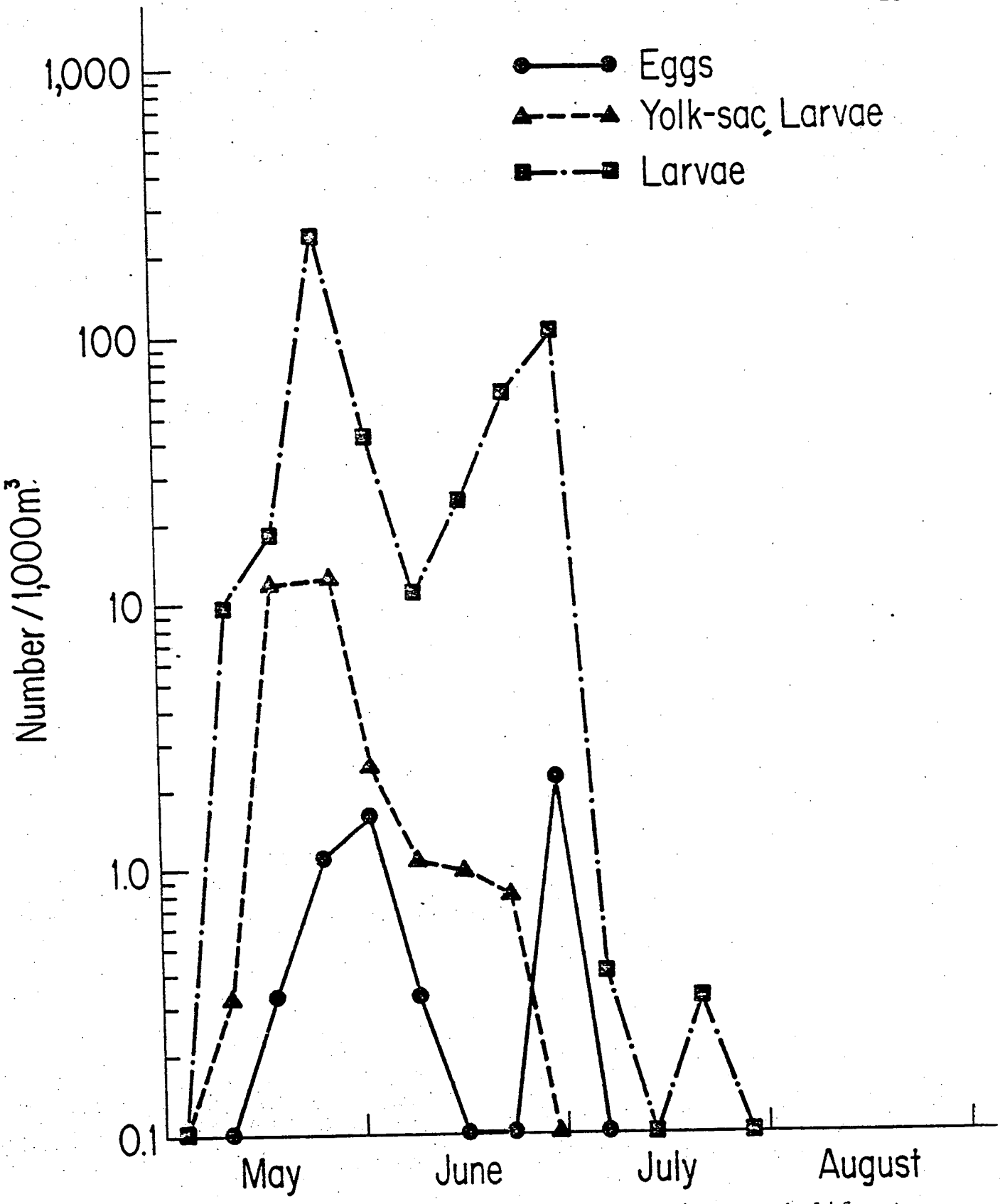

Figure 7-8. Mean abundance (day) of white perch life stages collected in river tows, 1976.

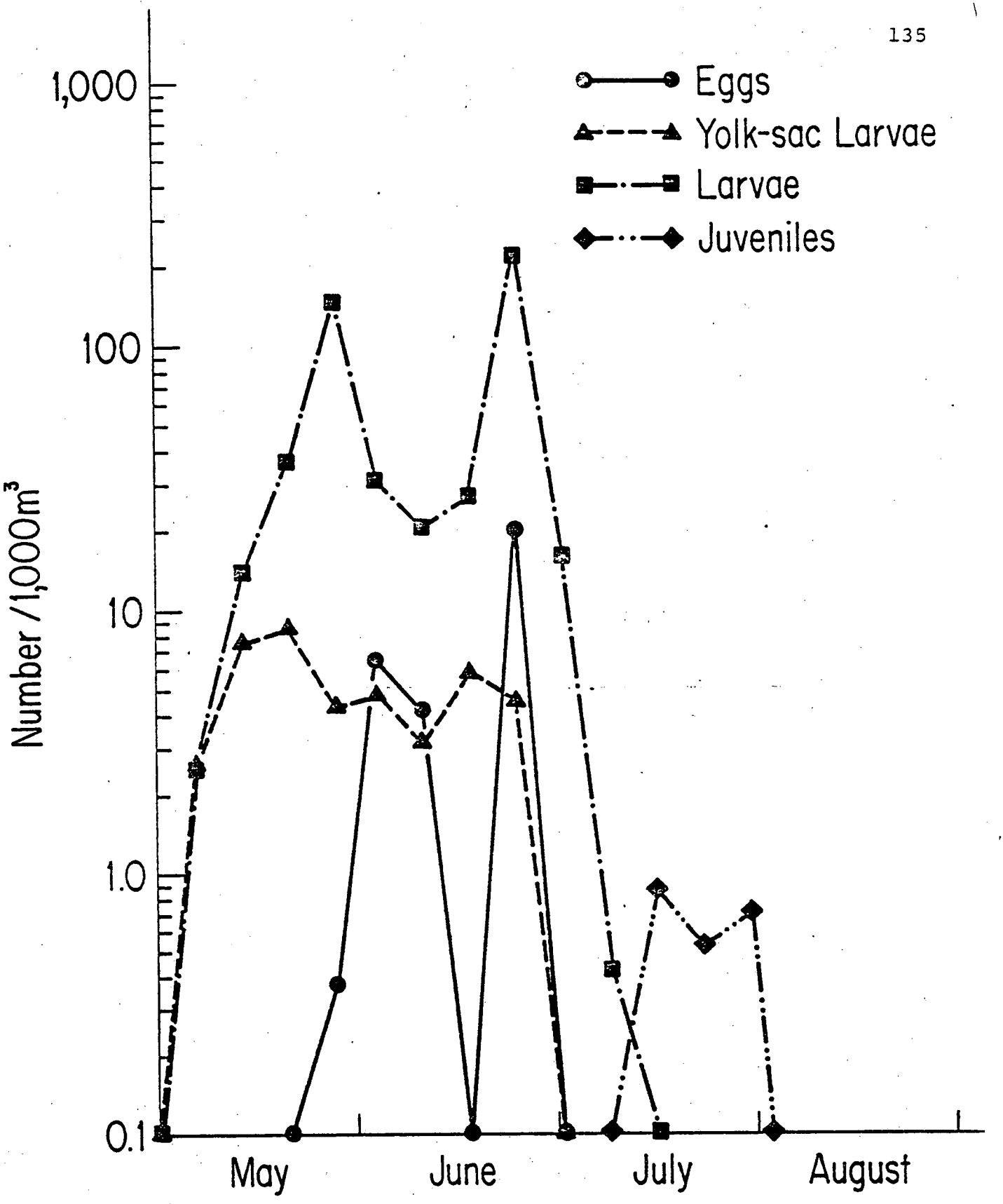

Figure 7-9. Mean abundance (night) of white perch life stages collected in river tows, 1976.

Clupeid eggs were present in samples taken from May 20 to June 1 (Figures 7-10 and 7-11); peak mean abundance (1.0/1000 m^3) was recorded on May 27.

Anchovy eggs were first observed on June 24, with 3.0/1000 m^3 and were not encountered again until July 22. Peak mean abundance (4800/1000 m^3) occurred at this time (Figures 7-12 and 7-13).

The abundance of yolk-sac larvae of each species collected occurred either simultaneously with egg occurrence, or was displaced to the right, showing indications of having been derived from the previous egg populations.

As in previous years, the first yolk-sac larvae to occur in the Indian Point region were those of the tomcod (Microgadus tomcod); and then those of the rainbow smelt (Osmerous mordax) Figure 7-3. Tomcod yolk-sac larvae were collected on April 12 (1.0/1000 m^3), and smelt were first collected on May 3 (1.0/1000 m^3)

Clupeid yolk-sac larvae occurred in the samples from May 3 to June 17. Peak mean abundance (15/1000 m^3) occurred on May 24 (Figure 7-10). No shad (Alosa sapidissima) yolk-sac larvae were observed in 1976.

White perch yolk-sac larvae occurred from May 6 until June 24. Peak mean abundance (12/1000 m^3) was observed on May 24 (Figure 7-8).

Striped bass yolk-sac larvae were first observed on May 13, (same time as observed for 1975) and their occurrence in

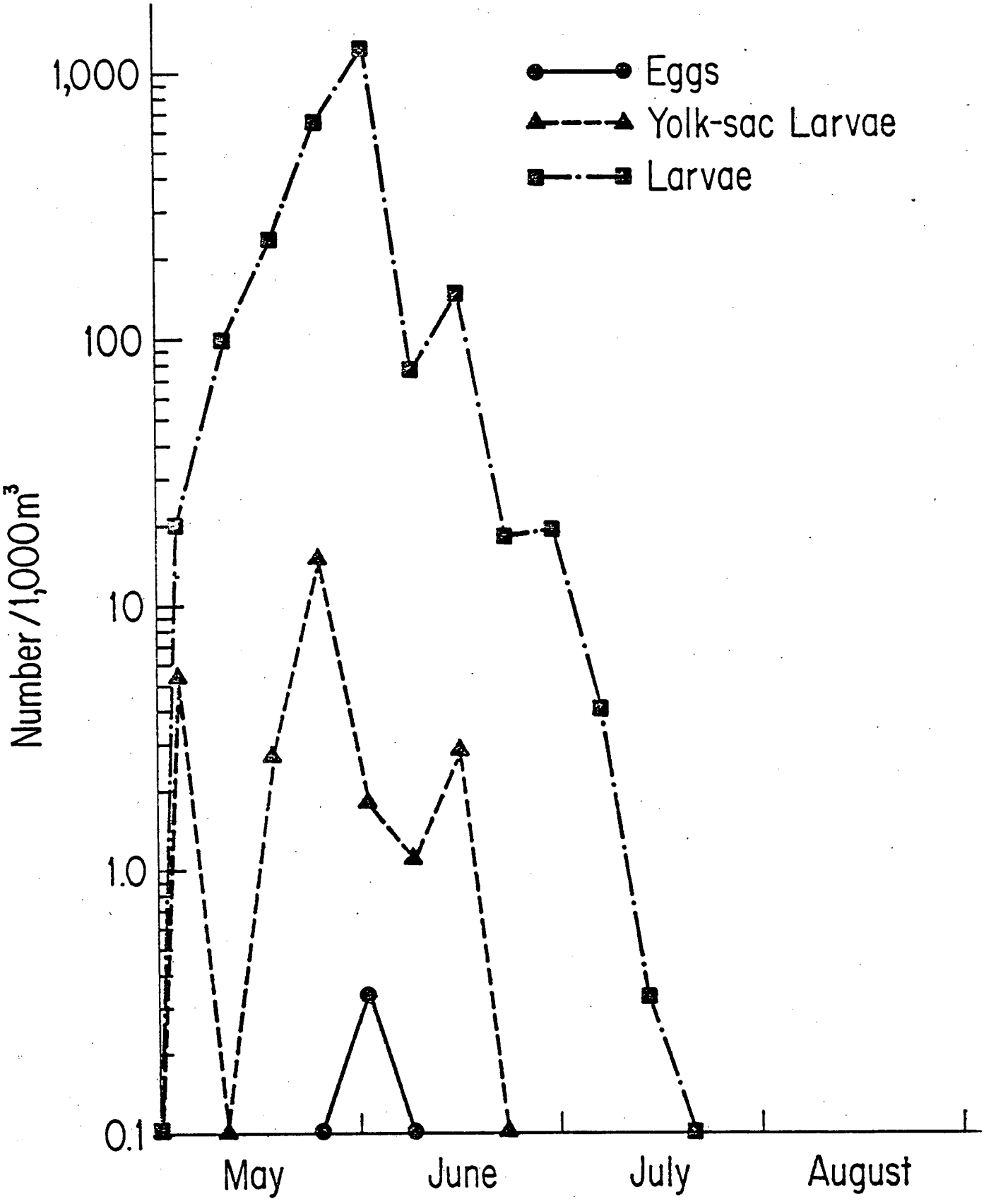

Figure 7-10. Mean abundance (day) of clupeid life stages collected in river tows, 1976.

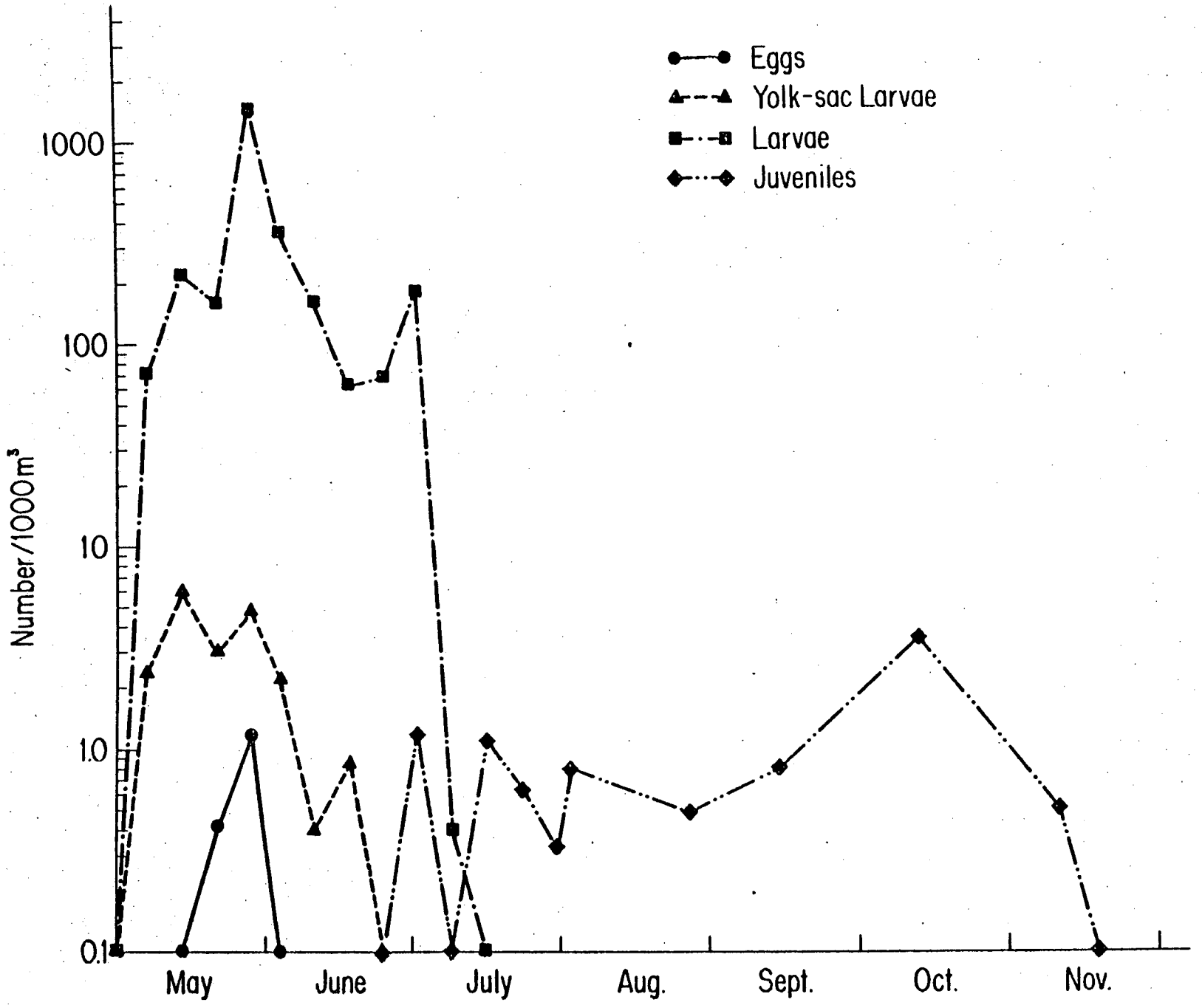

Figure 7-11. Mean abundance (night) of clupeid life stages collected in river tows, 1976.

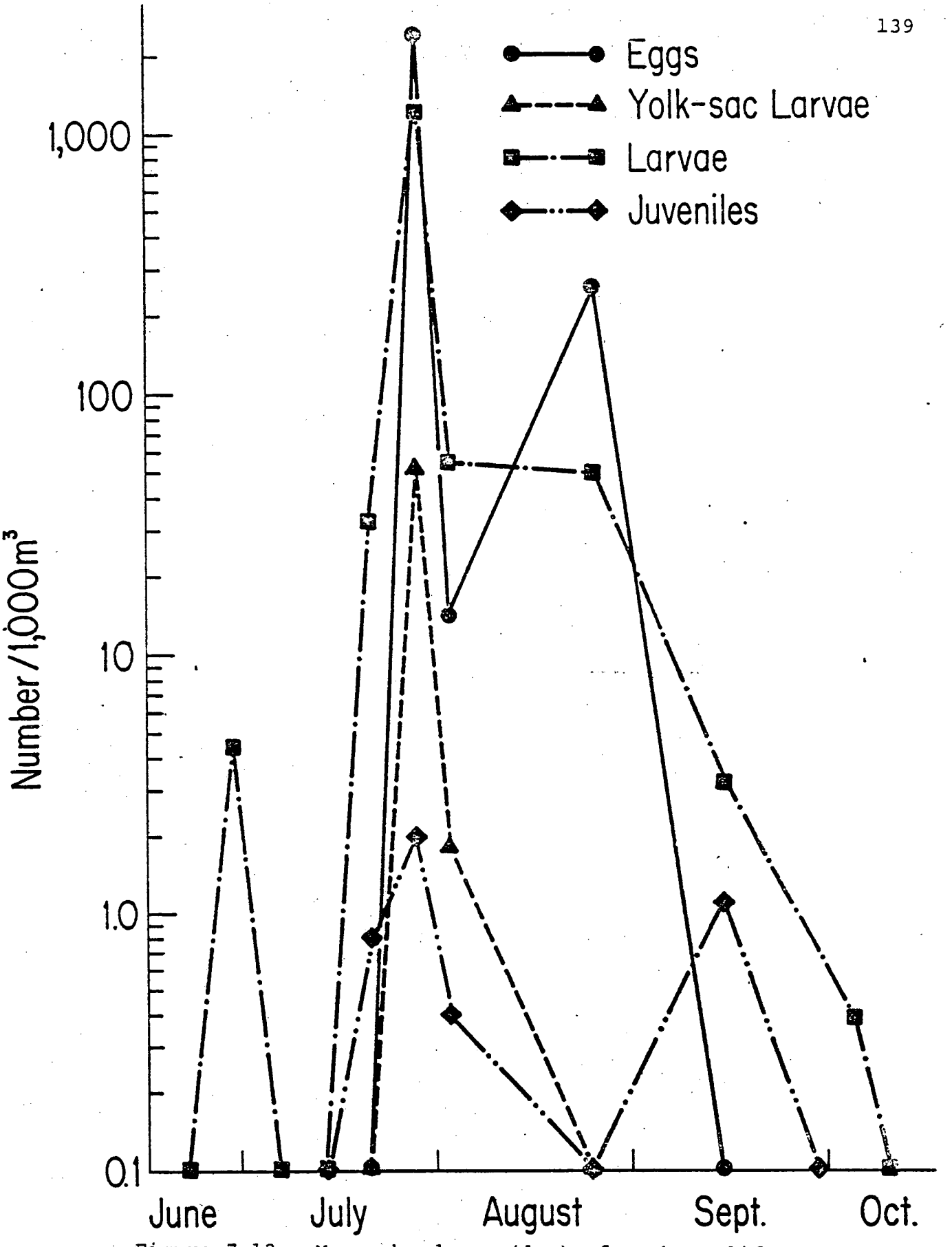

Figure 7-12. Mean abundance (day) of anchovy life stages collected in river tows, 1976.

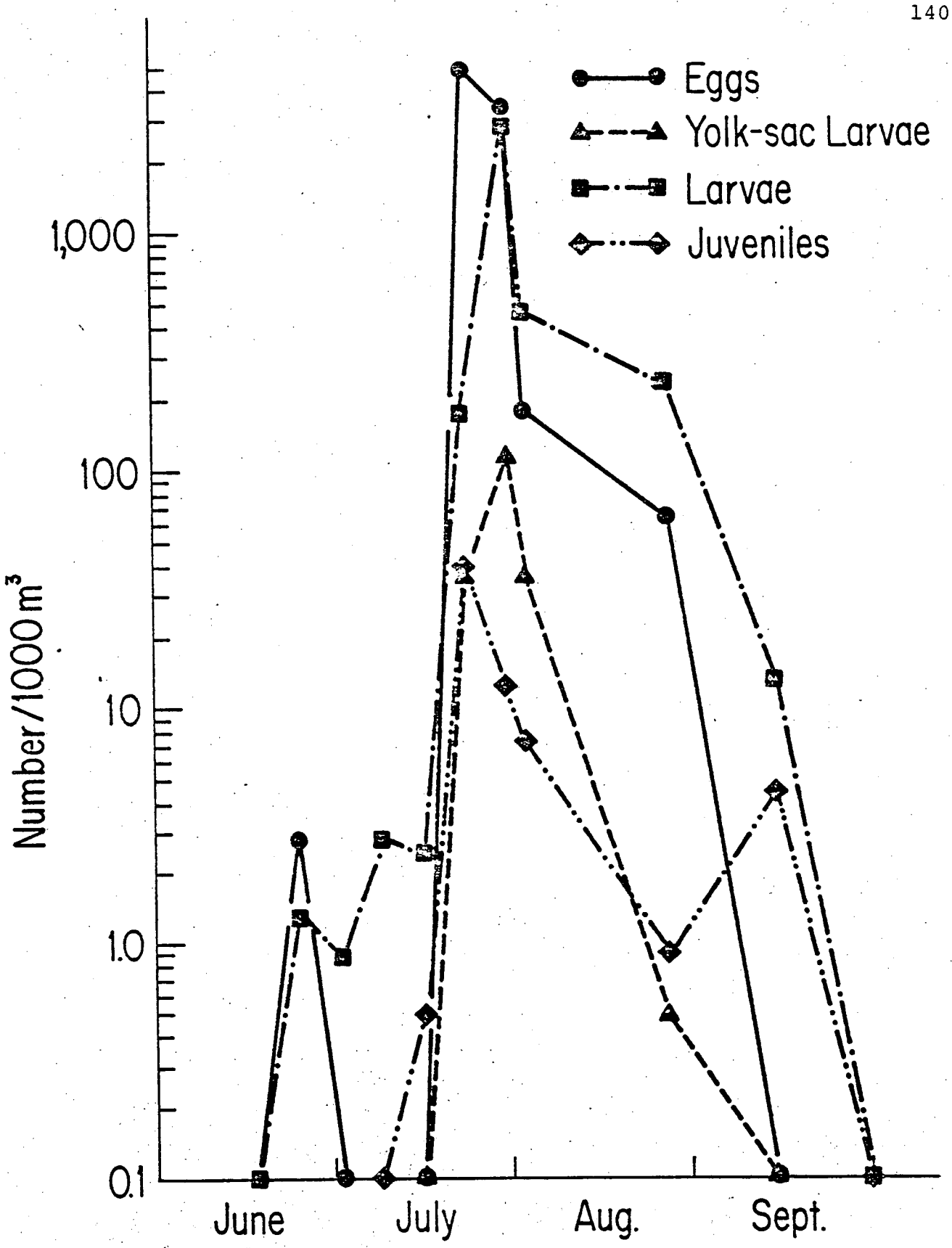

Figure 7-13. Mean abundance (night) of anchovy life stages collected in river tows, 1976.

the samples lasted until July 1. Peak mean abundance (154/1000 m^3) occurred on June 15 (Figure 7-6).

The occurrence of the anchovy yolk-sac larvae followed closely the peak egg abundance during July and August (July 22 to August 26; Figure 7-12 and 7-13). Peak mean abundance (144/1000 m^3) for yolk-sac larvae occurred on July 29 (Figure 7-13).

Other yolk-sac larvae seen in our collections were those of the darter (Etheostoma olmstedi) and two cyprinid fishes (Figure 7-3). Darters were present from May 13 through July 1; peak mean abundance (20/1000 m^3) occurred on May 20. The cyprinids occurred from May 20 to July 1 (Figure 7-3), with a peak mean abundance of 9/1000 m^3 on May 27. Similar abundances were observed when compared to 1975 for both the darter (19/1000 m^3) and cyprinids (7/1000 m^3); as well as time of occurrence for the cyprinids (May 20).

As observed from 1974 to 1976, larvae collected prior to the salt water influx into the Indian Point region were predominately clupeids, striped bass and white perch. These were preceded in time by those of tomcod and smelt. The tomcod occurred at a time when salinity was recorded in the Indian Point region. They move with this salt front as it is pushed downriver by the freshwater runoff. Other species occurring during this freshwater period are the smelt, yellow perch (Perca flavescens), sturgeon (Acipenser spp.) and the centrachids (Lepomis sp.). After salt water intrusion,

the dominant larval species collected was the bay anchovy. Incidental species occurring along with the anchovies, as seen in previous years, were the Atlantic silversides (Menidia spp.), weakfish (Cynoscion regalis), American sole or hogchoker (Trinectes maculatus) and the naked goby (Gobiosoma bosci). Since the larval numbers occurring in the samples for these incidental species are diluted by the dominant four species, they are grouped together under the heading of "other marine species" and "other freshwater" species (Figure 7-4).

Tomcod larvae were encountered in samples collected on April 12 and 13, with mean abundances of 194/1000 m^3 and 105/1000 m^3, respectively. This was the only species collected during this sampling period (Figure 7-4).

Rainbow smelt larvae occurred in our samples from May 3 until June 24. Peak mean abundance for this species (22/1000 m^3) was on May 6.

Clupeid larvae appeared in the samples from May 3 until July 8 (Figures 7-10 and 7-11). Peak mean abundance (1465/1000 m^3) was recorded on May 27. A similar peak occurrence was observed for this date during 1975. Shad larvae were observed in the samples from May 13 to June 10, with a seasonal relative abundance of 0.1 percent (Table 7-3).

White perch larvae occurred approximately a full month in advance of the striped bass larvae (May 6) and were present until July 20 (Figure 7-4). This was two weeks

earlier than they occurred for 1975. Peak mean abundances occurred on May 24 (242/1000 m^3) and on June 24 (215/1000 m^3; Figure 7-8 and 7-9).

Striped bass larvae occurred in the samples from May 27 to July 13, and showed a peak mean abundance of 305/1000 m^3 on June 17 (Figure 7-7). Similar larval occurrence was observed during 1975. However, peak abundance was one week later, with a 20 percent decrease from the previous year.

Anchovy larvae first appeared in the collections on June 24 and were collected in the samples until October 12. Anchovy larvae dominated in our samples from the second week in July until the middle of October (Figure 7-4). Peak mean abundance for this species occurred on July 29 with 2780/1000 m^3 (Figure 7-13). As in previous years this species occurs simultaneously with the intrusion of salinity into the Indian Point region.

Juvenile life stage occurrence for the various species found in our collections are represented in Figure 7-5. The dominant species was the anchovy, followed by the american eel (Anguilla rostrata), and the Atlantic tomcod. Juvenile stages of the tomcod and eel were the first to be seen in the samples; and continued to be represented sporadically until the end of summer. Peak mean abundance (6/1000 m^3) for tomcod, and 24/1000 m^3 for eels was observed on April 13. The smelt juvenile stage occurred during the first week of June and were last seen during October. A peak mean

abundance (1/1000 m^3) was observed on June 10. The same can be said for the clupeids, except their occurrence in the collections was approximately three weeks later, with a peak mean abundance (3/1000 m^3) on October 12 (Figure 7-11). Juvenile striped bass were observed in the samples from July 6 until August 2, with a peak mean abundance (2/1000 m^3) occurring on July 8 (Figure 7-7). White perch juveniles were seen in the samples from July 15 to December 7. Peak mean abundance (1/1000 m^3) was observed for July 15 and November 11 (Figure 7-9).

Anchovy juveniles were first collected on July 15 and were last seen by September 14. A peak mean abundance of 39/1000 m^3 was observed on July 22 (Figure 7-13).

Overall the species composition of the ichthyoplankton collected in 1976 is similar to that found for previous years (Table 7-2). The depth distribution patterns observed for the striped bass and white perch life stages are distributed towards the bottom during the day (Figures 7-14 to 7-17). During the night there is still a downward distribution, but there are increased numbers at the surface relative to daytime concentrations, indicating some did change in depth (Figures 7-15 and 7-17). Depth profiles for these two species were comparable to previous years data (New York University Medical Center, 1975, 1976a).

The distribution of clupeid eggs and yolk-sac larvae with depth is towards the bottom for both day and night. Larval distribution is towards the surface during day, and

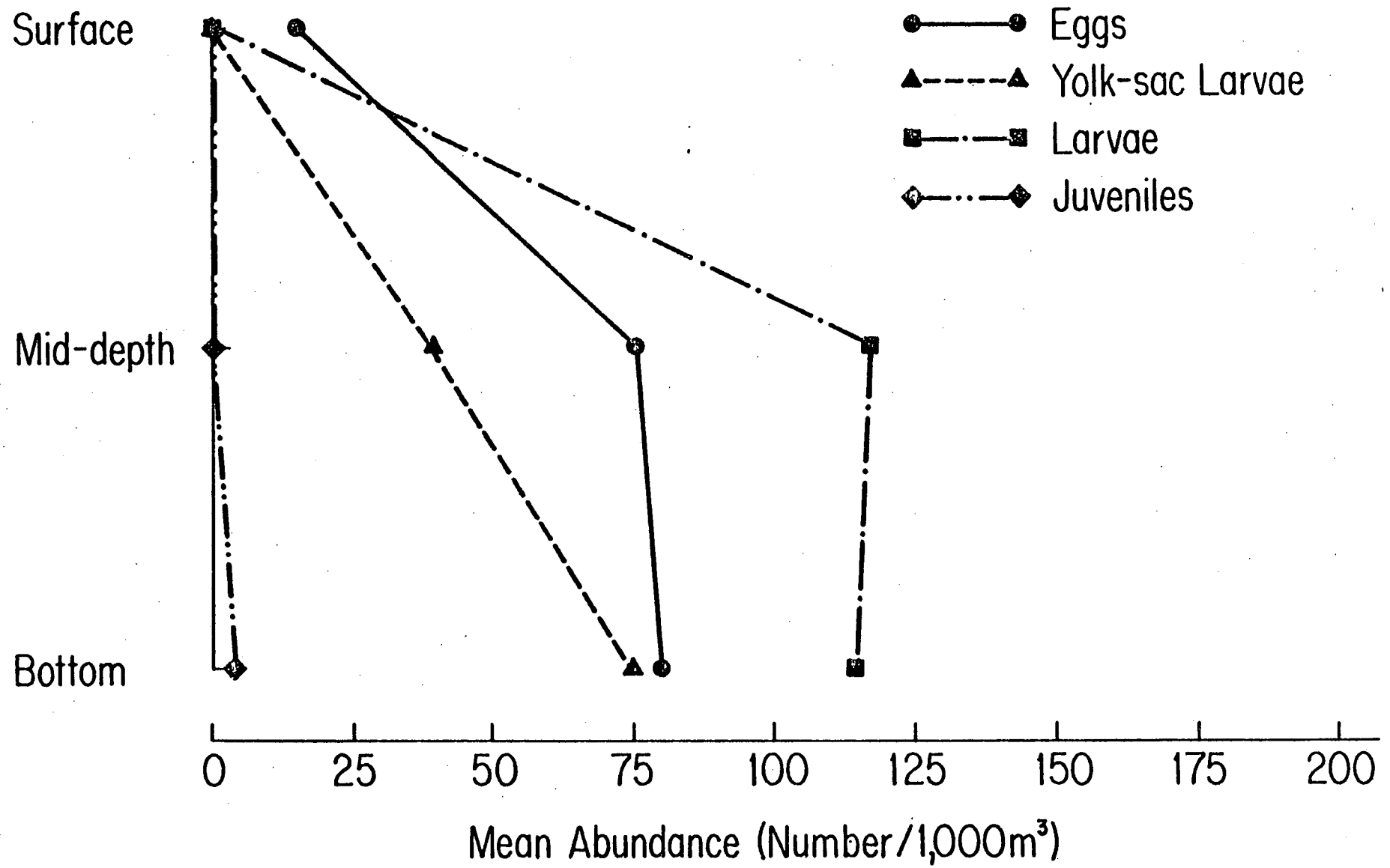

Figure 7-14. Daytime pattern of vertical distribution for striped bass, 1976.

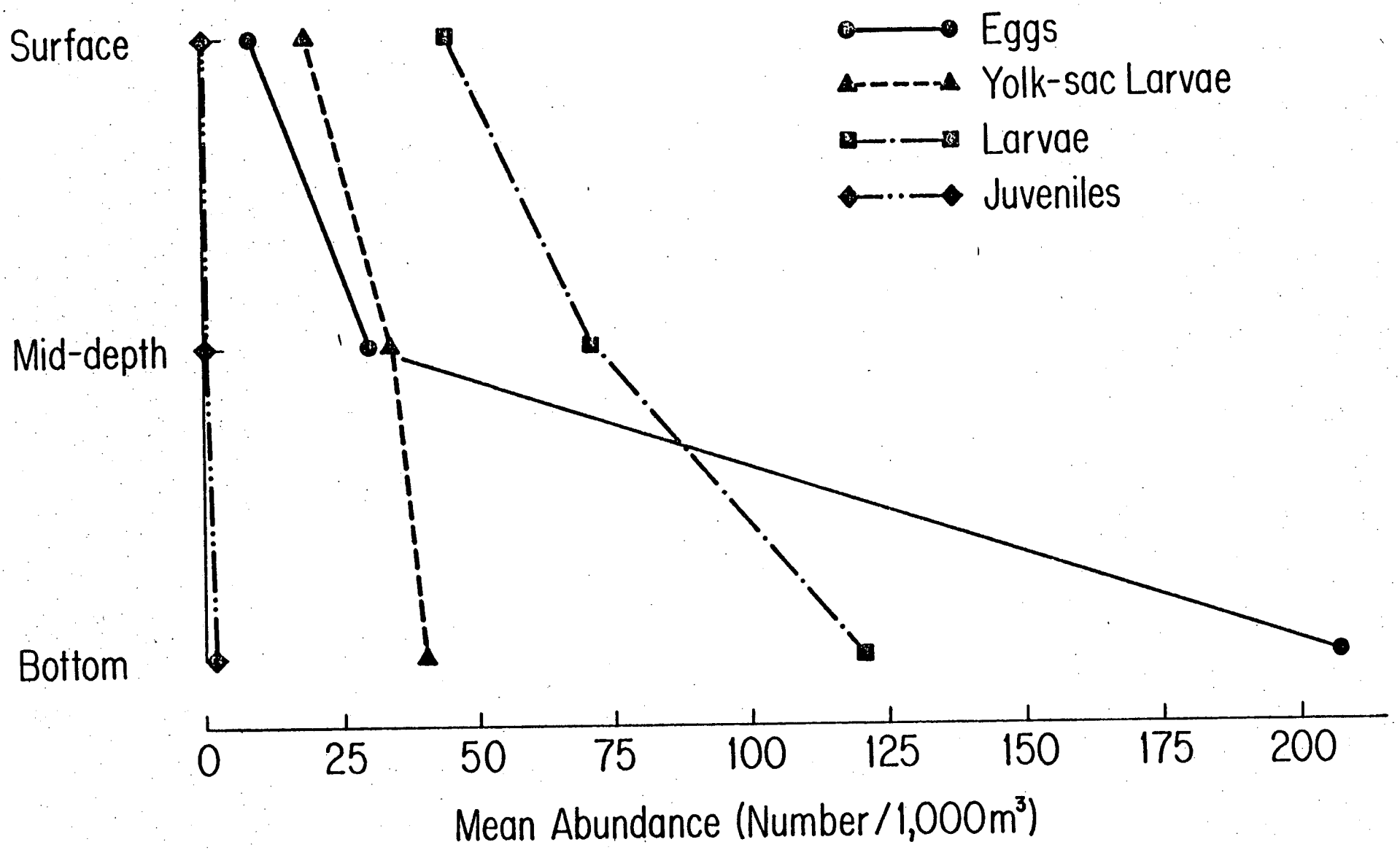

Figure 7-15. Nighttime pattern of vertical distribution for striped bass, 1976.

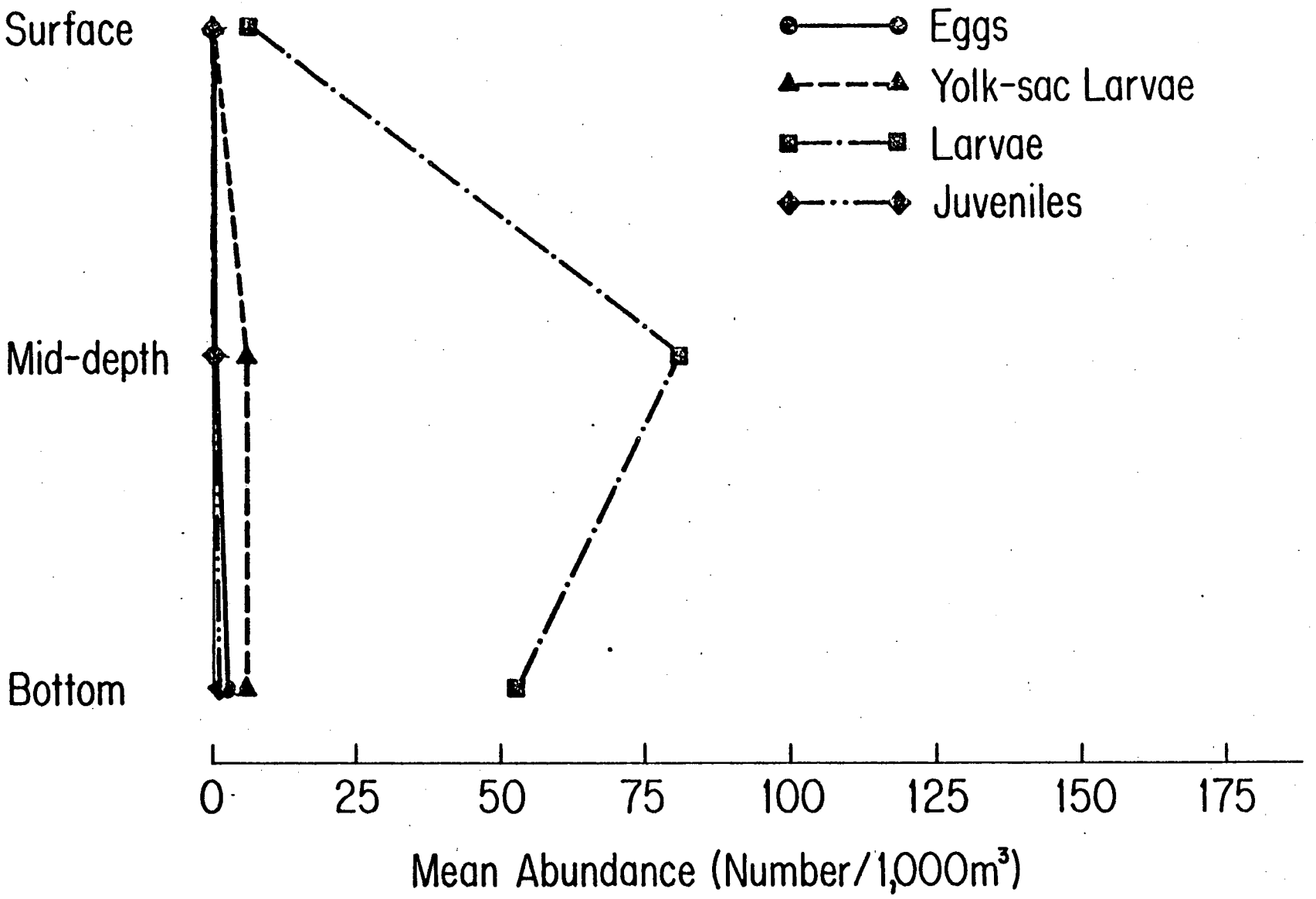

Figure 7-16. Daytime pattern of vertical distribution for white perch, 1976.

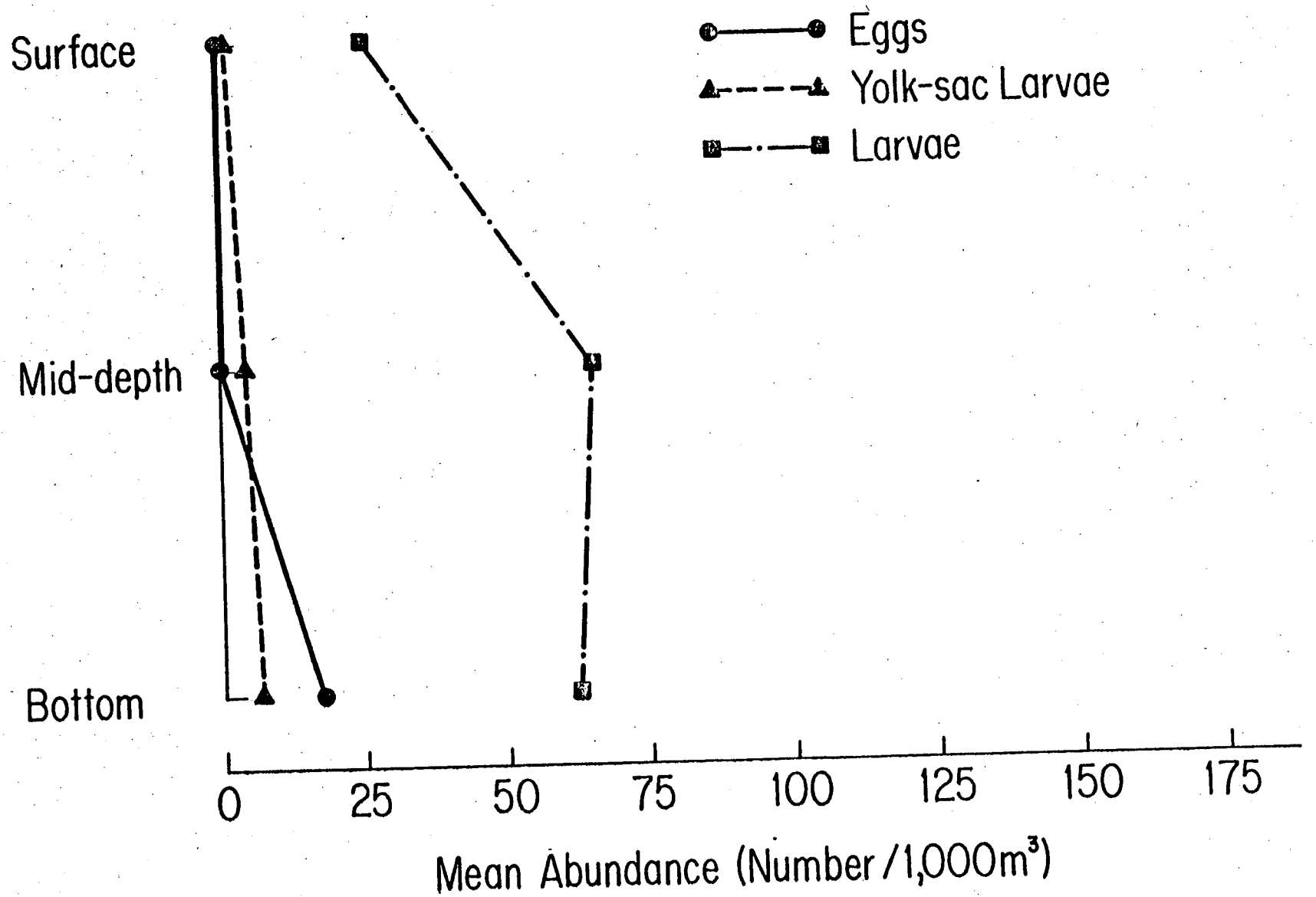

Figure 7-17. Nighttime pattern of vertical distribution for white perch, 1976.

distributed towards the bottom, with increased numbers, at night (Figures 7-13 and 7-19). This was similar to data taken from 1971 to 1975.

Anchovy eggs and yolk-sac larvae were more abundant near the bottom during the day and night for 1974 and 1975. The larvae of this species during 1976 were distributed towards the bottom in depth (Figures 7-20 and 7-21) and compared favorably with previous years data (New York University Medical Center, 1975 and 1976a).

Striped bass yolk-sac larvae, larvae and juvenile life stages were measured for total length (mm). Specimens were selected from samples taken between May 13 to July 15. The length frequency curves are shown in Figures 7-22 through 7-24. Yolk-sac larvae ranged in size from 1.0 mm to 7.0 mm. Average peak frequencies in size occurred at 4.0 mm during May, and at 5.0 mm for June. The small size of 1.0 mm observed on May 20 could be attributed to pre-yolk sac larvae that should have been counted as eggs, but were not since the chorion had separated from the yolk-sac larvae during sampling. The time of occurrence for this size coincides with the peak egg abundances observed in the river (Figure 7-6 and 7-7). High frequencies for smaller sized fish usually occurred immediately after an abundance in eggs (May 20; Figure 7-22).

Striped bass larvae ranged in size from 4.0 mm to 14.0 mm. Peak frequency occurred on June 15, with a size of 6.0

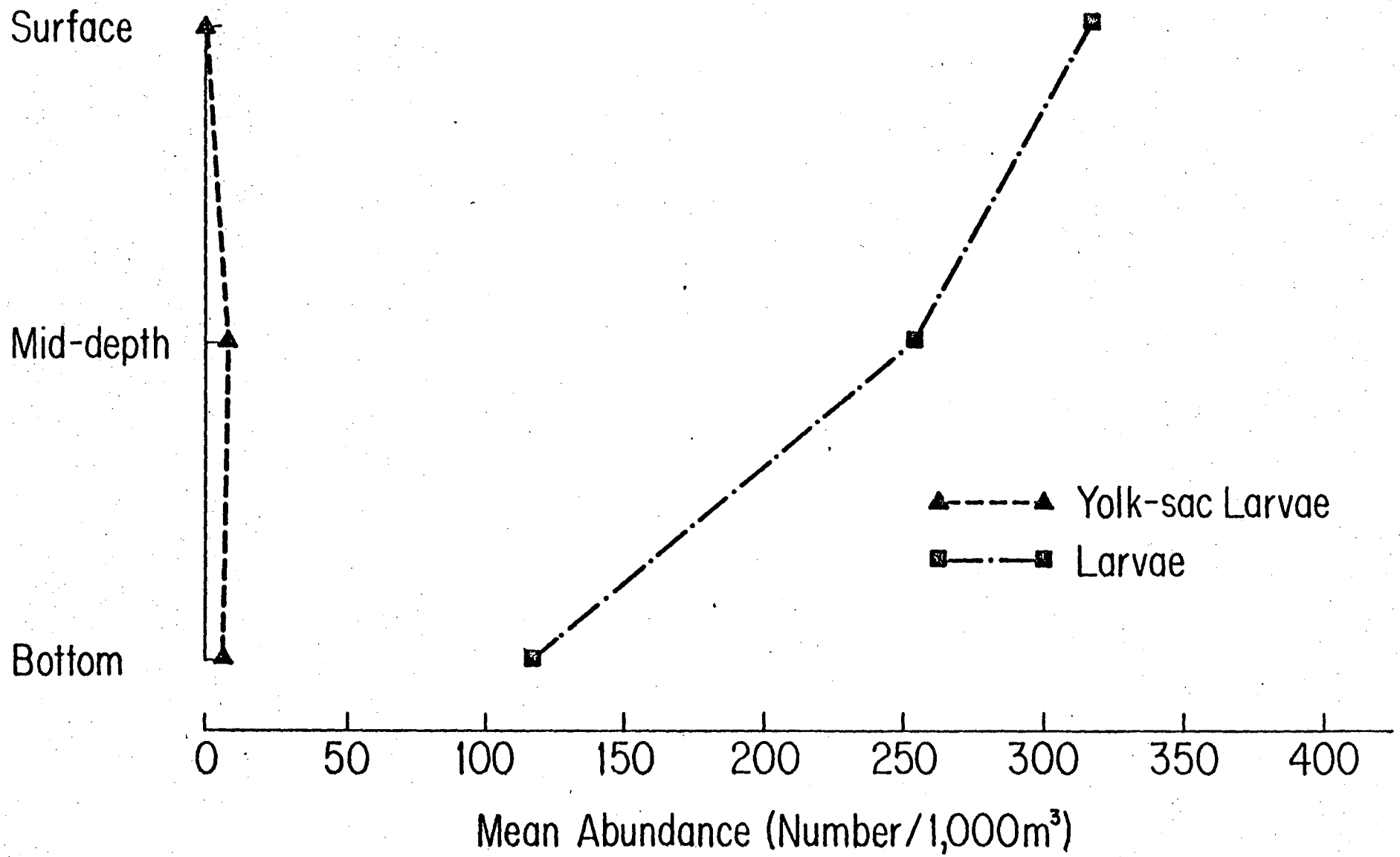

Figure 7-18. Daytime pattern of vertical distribution for clupeids, 1976.

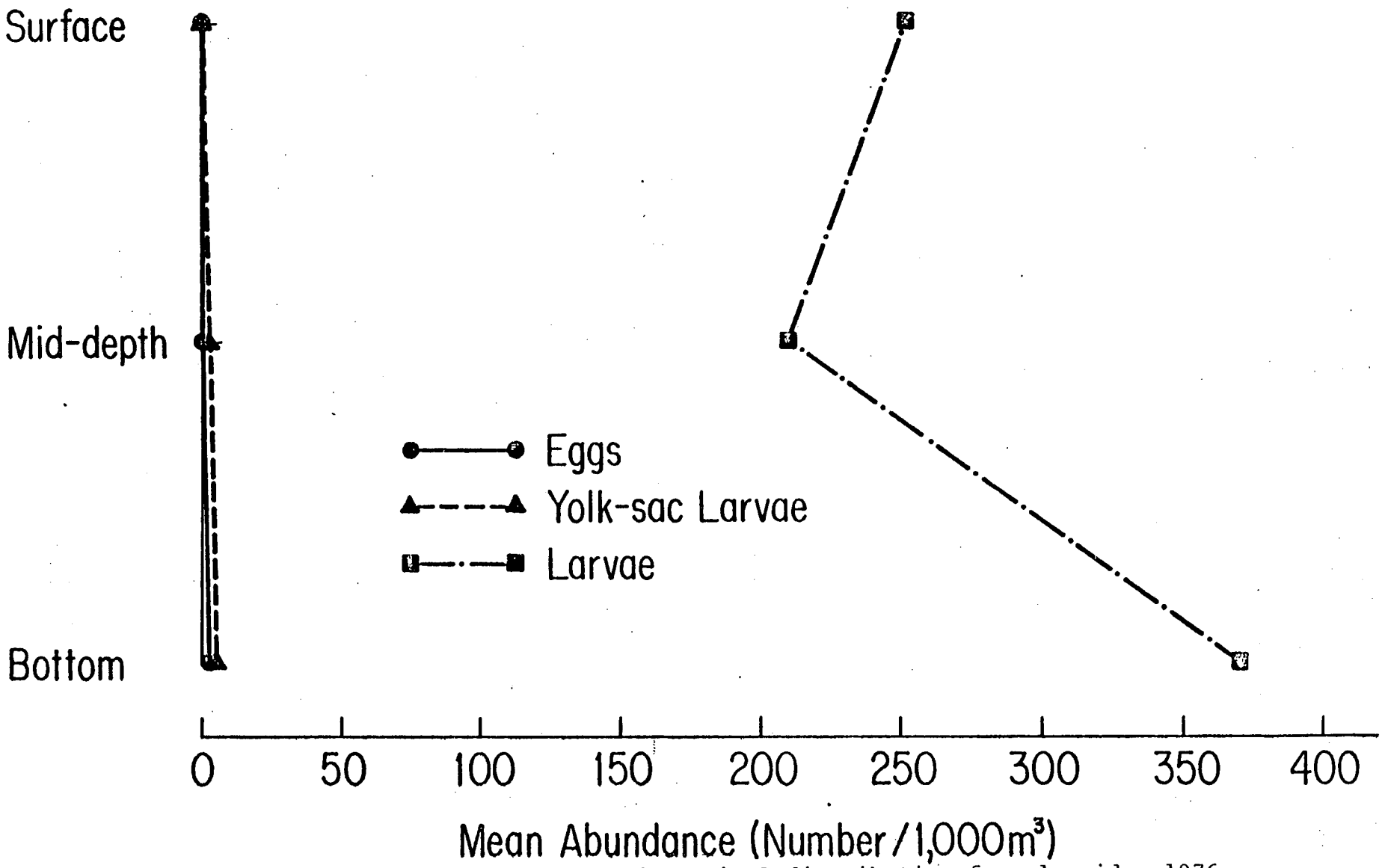

Figure 7-19. Nighttime pattern of vertical distribution for clupeids, 1976.

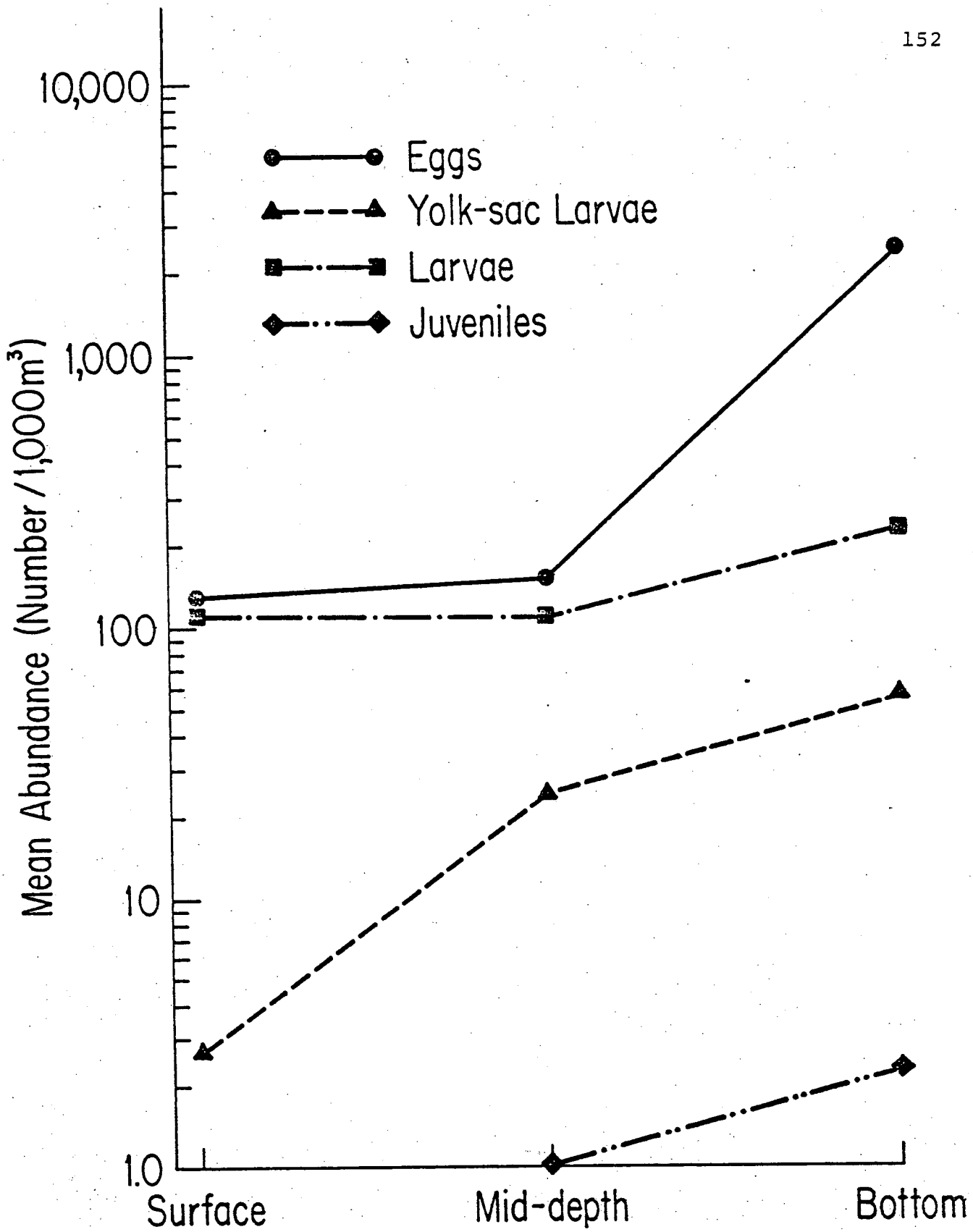

Figure 7-20. Daytime pattern of vertical distribution for anchovy, 1976.

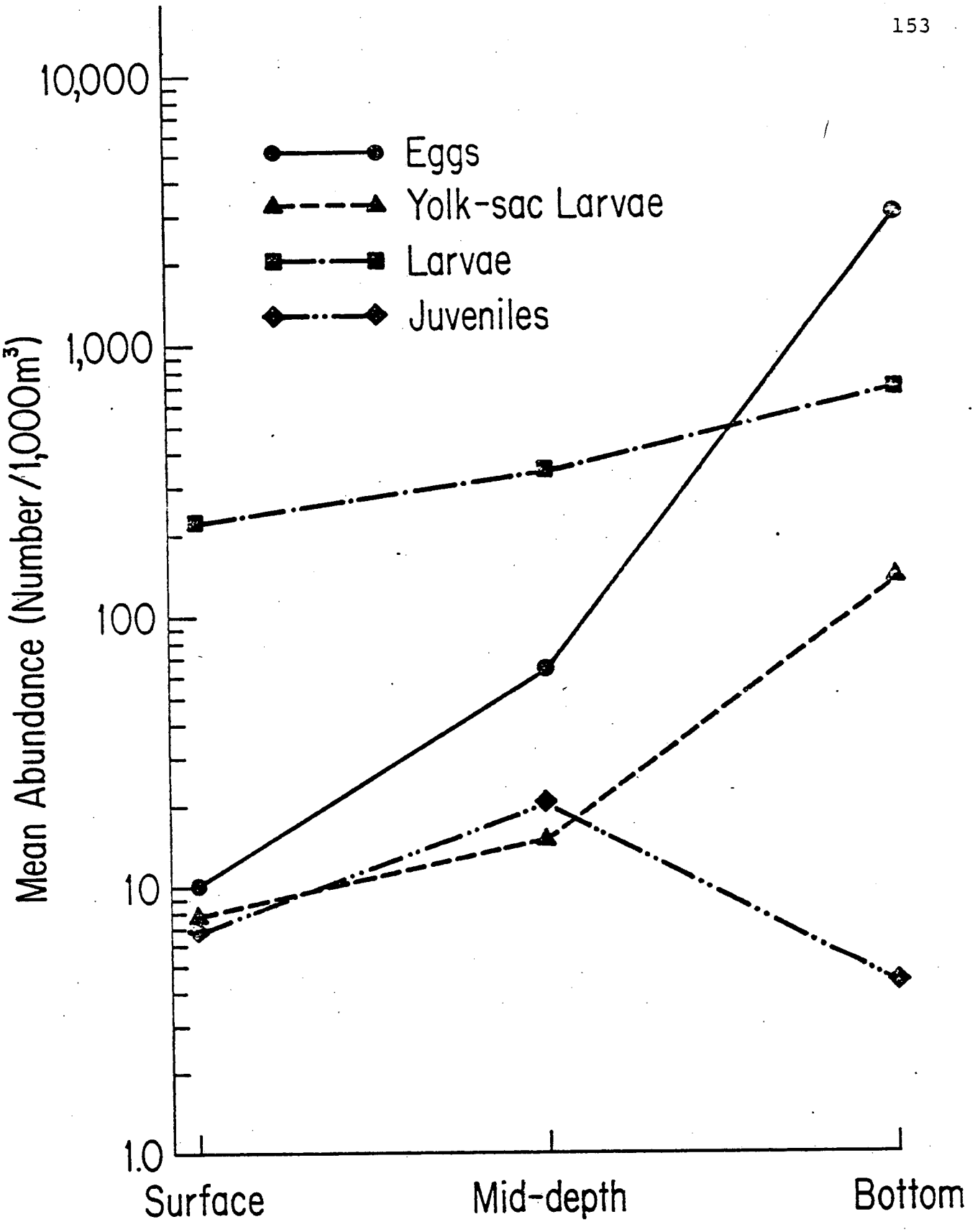

Figure 7-21. Nighttime pattern of vertical distribution for anchovy, 1976.

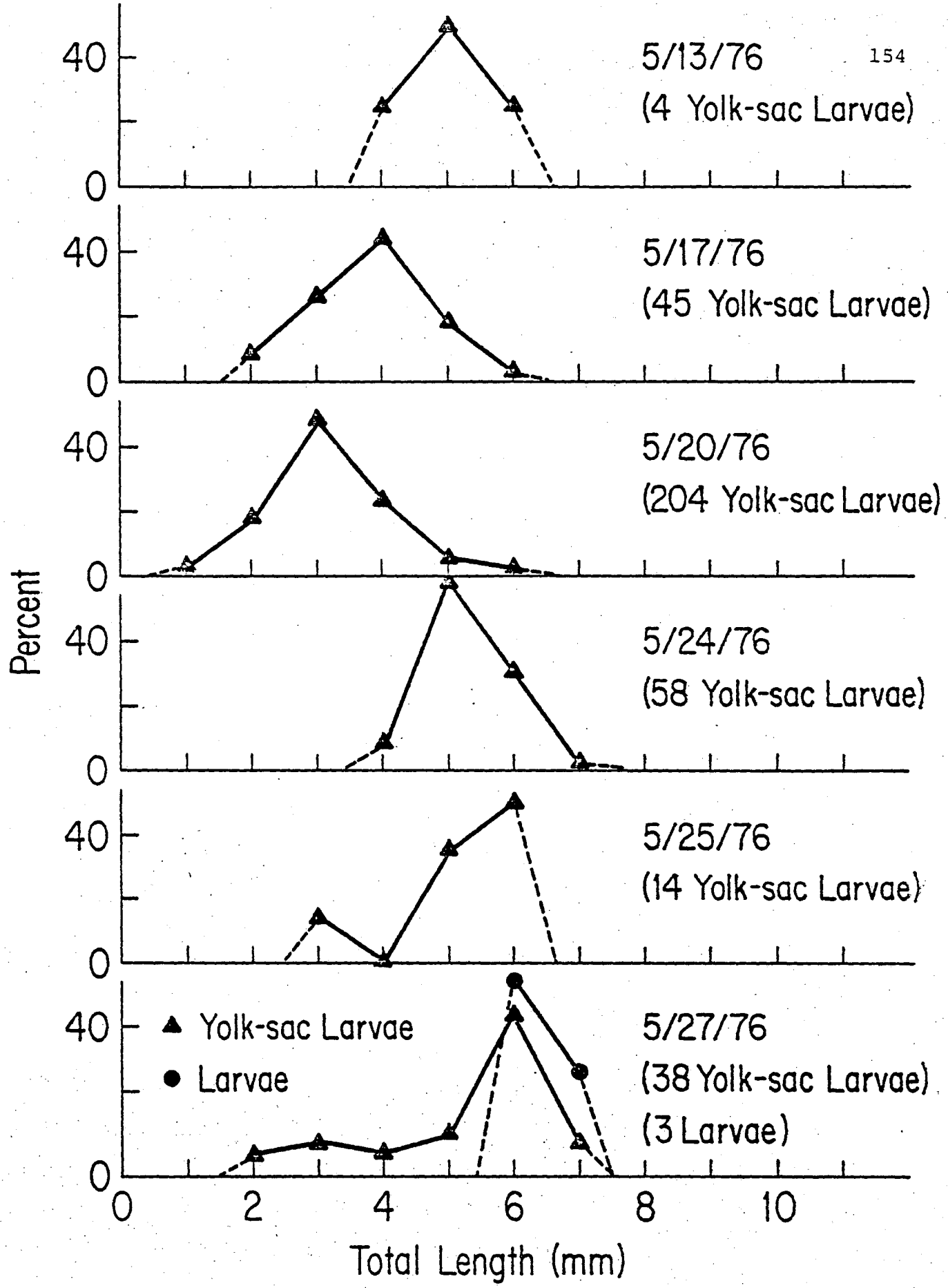

Figure 7-22. Length frequencies for striped bass life stages collected in the river, 1976.

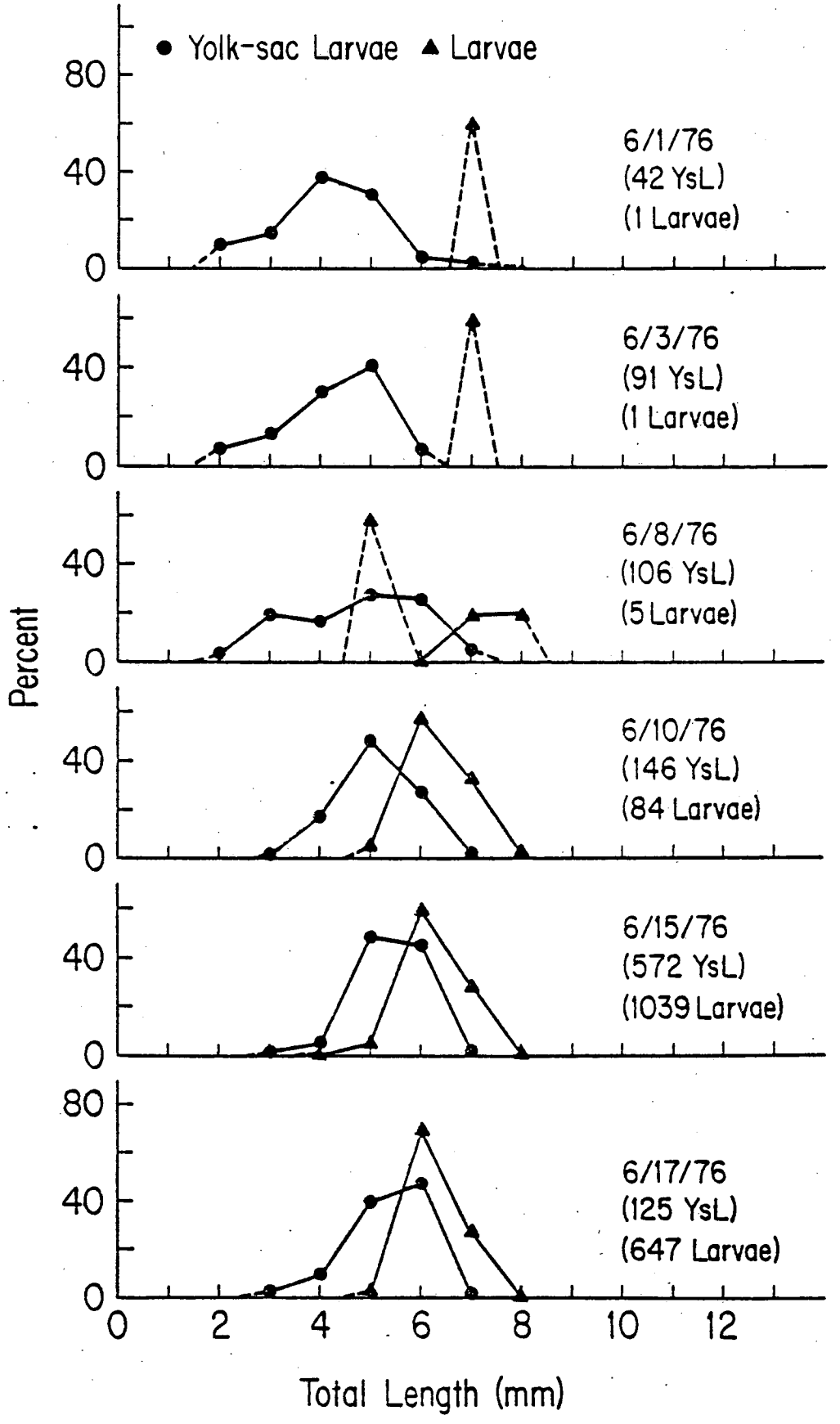

Figure 7-23. Length frequencies for striped bass life stages collected in the river, 1976.

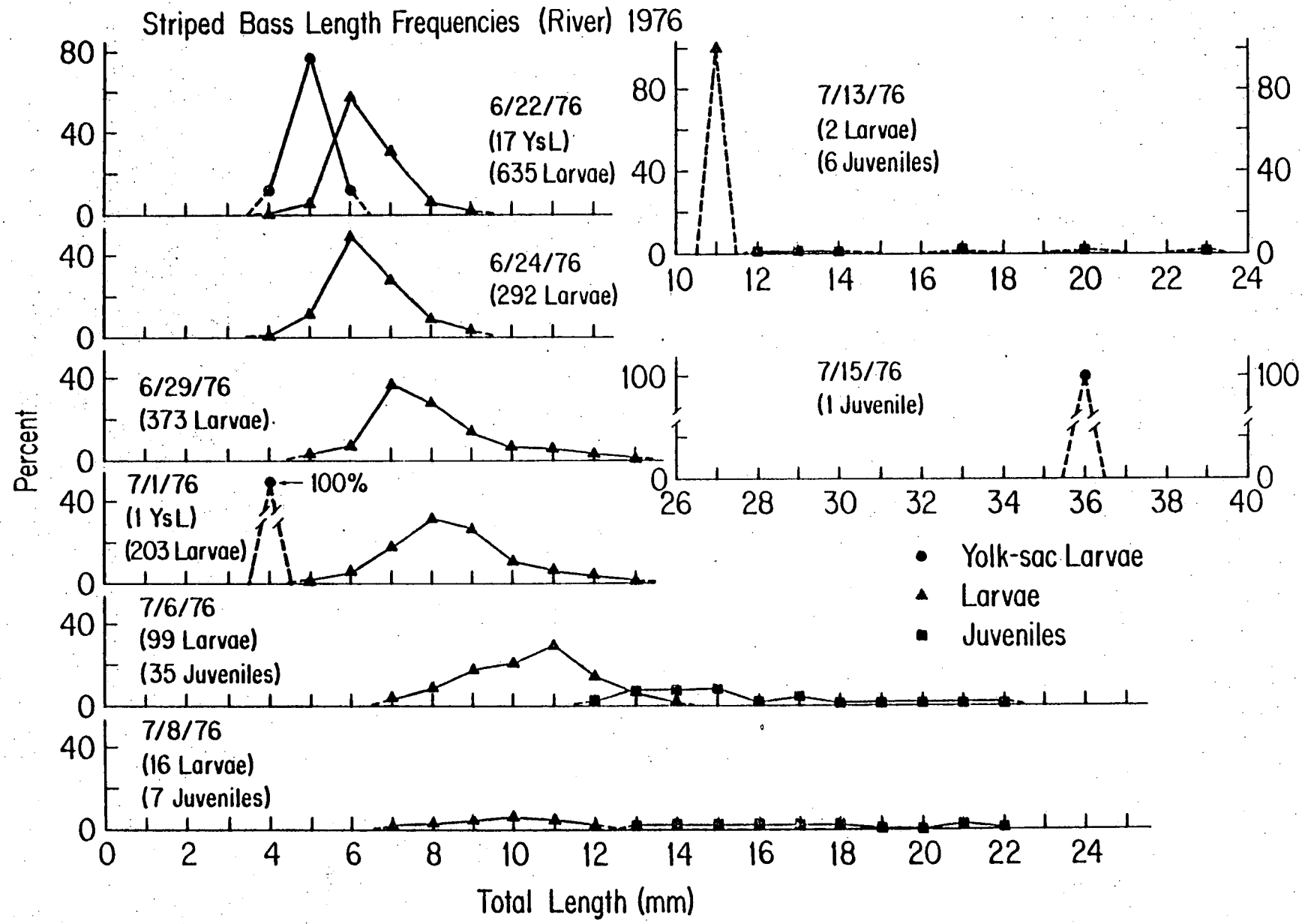

Figure 7-24. Length frequencies for striped bass life stages collected in the river, 1976.

mm, (Figure 7-23). The juvenile striped bass were found to range between 12.0 mm and 36.0 mm. Peak frequency occurred at 15.0 mm in size on July 6 (Figure 7-24).

Total length measurements were also taken for white perch yolk-sac larvae, larvae and juveniles. Specimens measured were collected from May 13 to July 20 (Figures 7-25 through 7-29). White perch yolk-sac larvae ranged between 3.0 mm and 4.0 mm in size, and showed a peak frequency at 3.0 mm in length. It appears from the length frequency curves that the white perch spawned continuously from May 13 to June 1, due to the fluctuation in the frequency peaks (Figures 7-25 and 7-26). The larvae ranged in size from 3.0 mm to 13.0 mm, with the peak frequency occurring at 4.0 mm prior to June 29 when 6 mm in size was observed. Juveniles ranged in size from 16.0 mm to 28.0 mm, with peak frequencies occurring at 17.0 and 18.0 mm in size during July 6 to 13 (Figure 7-29).

Differences in striped bass abundance at the seven river stations were tested for by analysis of variance (ANOVA); separate analyses were done for day and night samples and for each life stage. Analyses were run based on catch/unit effort and No./m^3 (seven stations; A-G), depth (three levels; surface, middle, and bottom) and date (changed with appearance in the river of a particular life stage). Depth was considered nested within stations and date was crossed with stations (Tables 7-4 through 7-9). Whenever

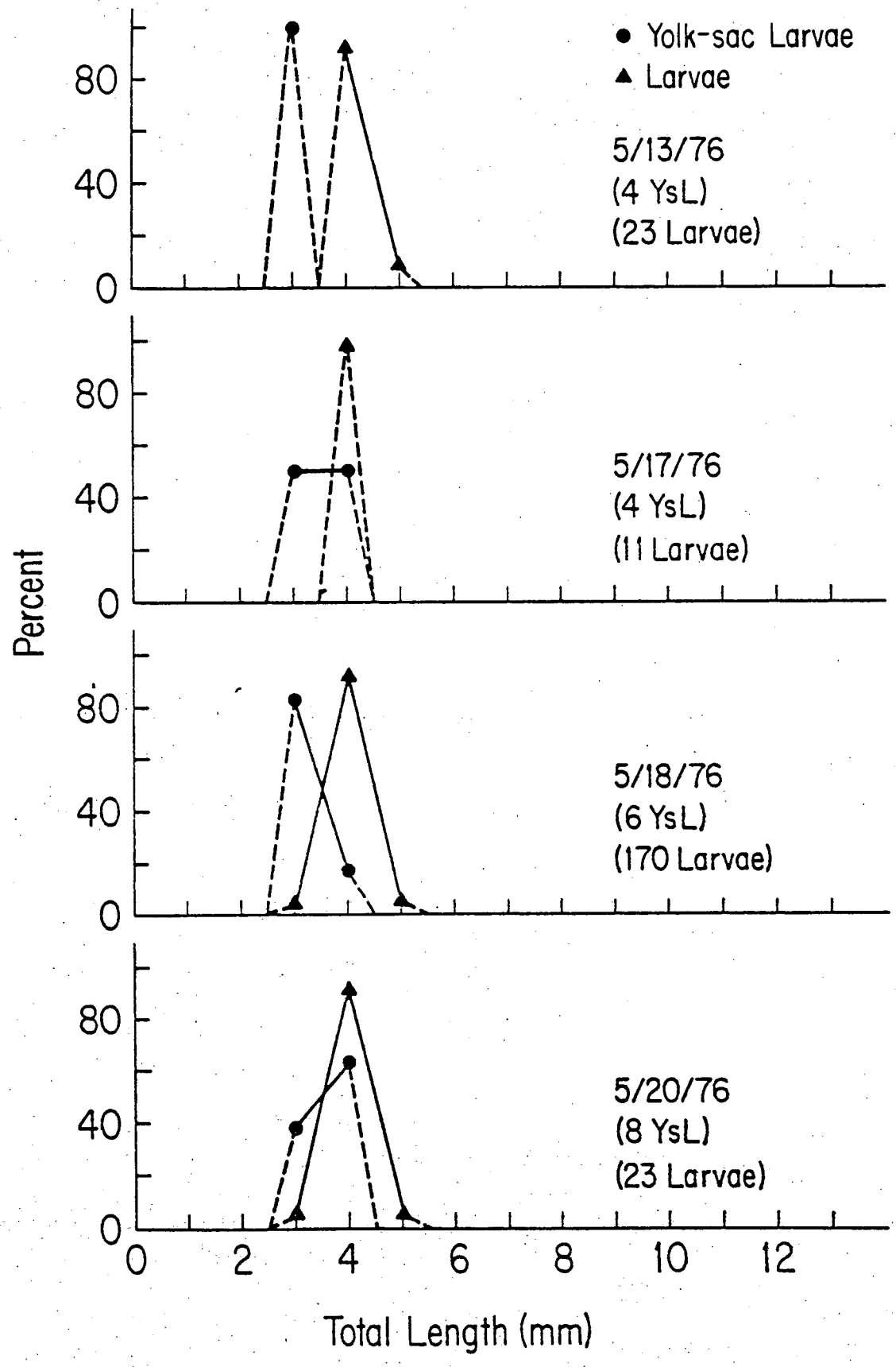

Figure 7-25. Length frequencies for white perch life stages collected in the river, 1976.

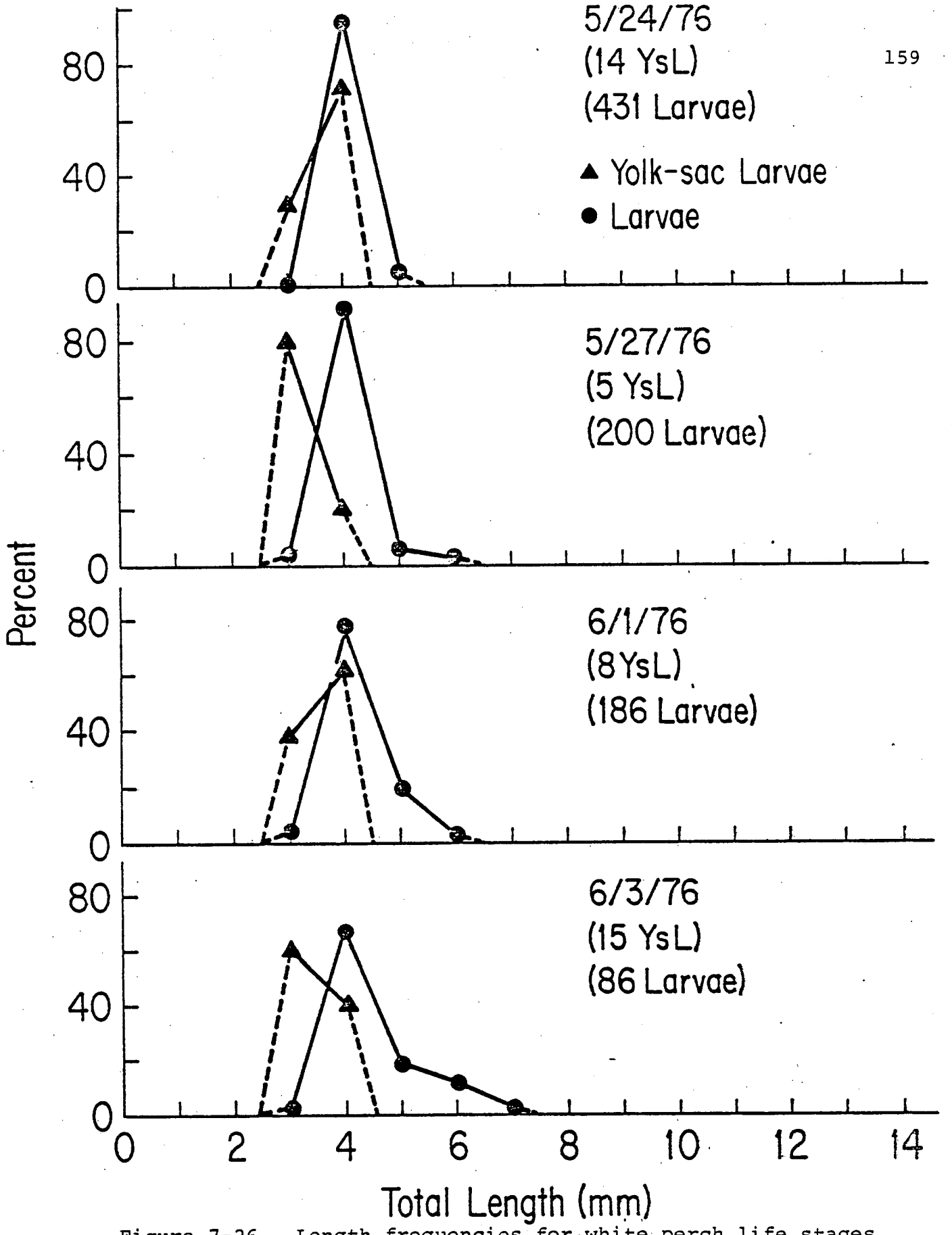

Figure 7-26. Length frequencies for white perch life stages collected in the river, 1976.

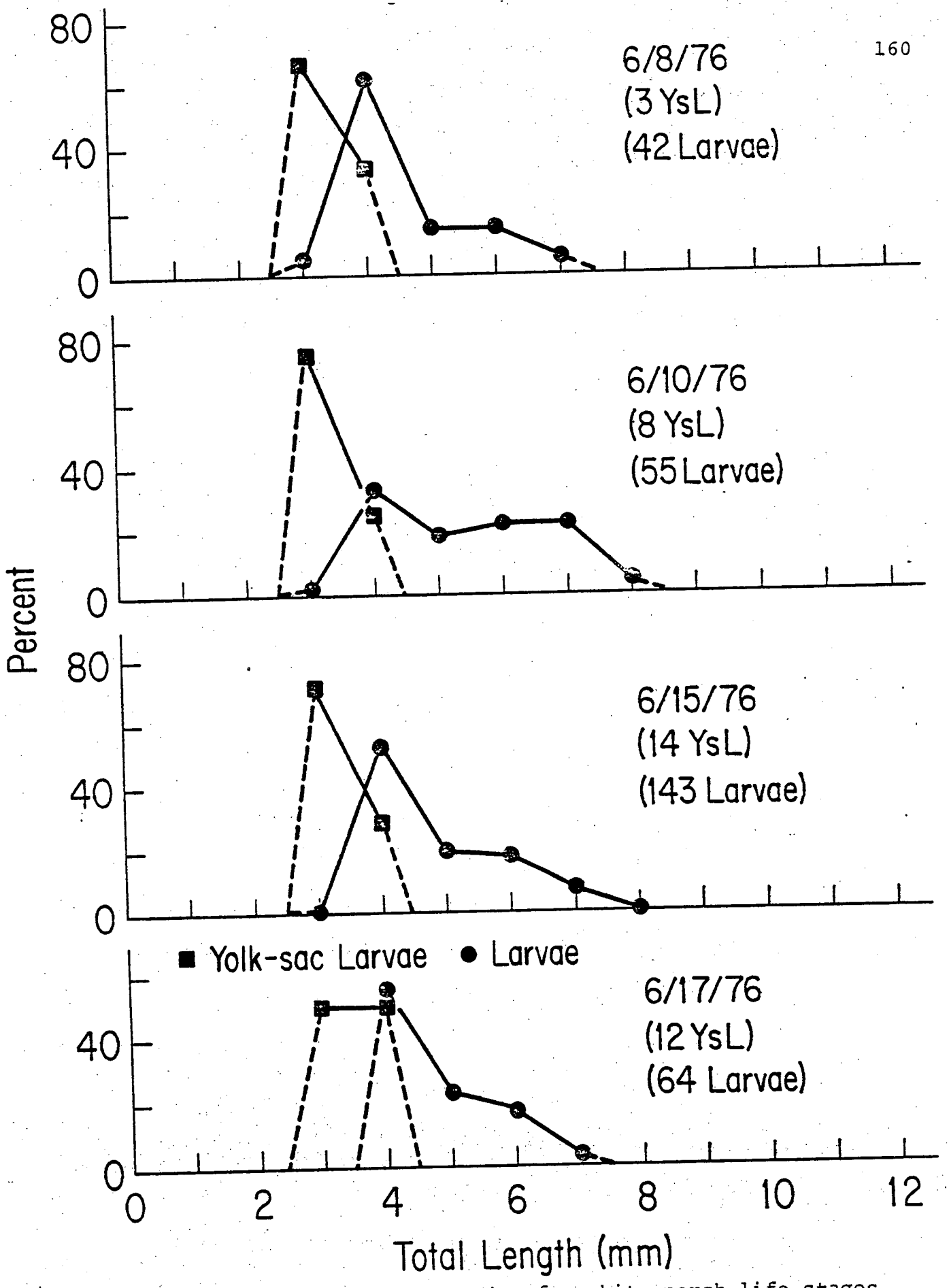

Figure 7-27. Length frequencies for white perch life stages collected in the river, 1976.

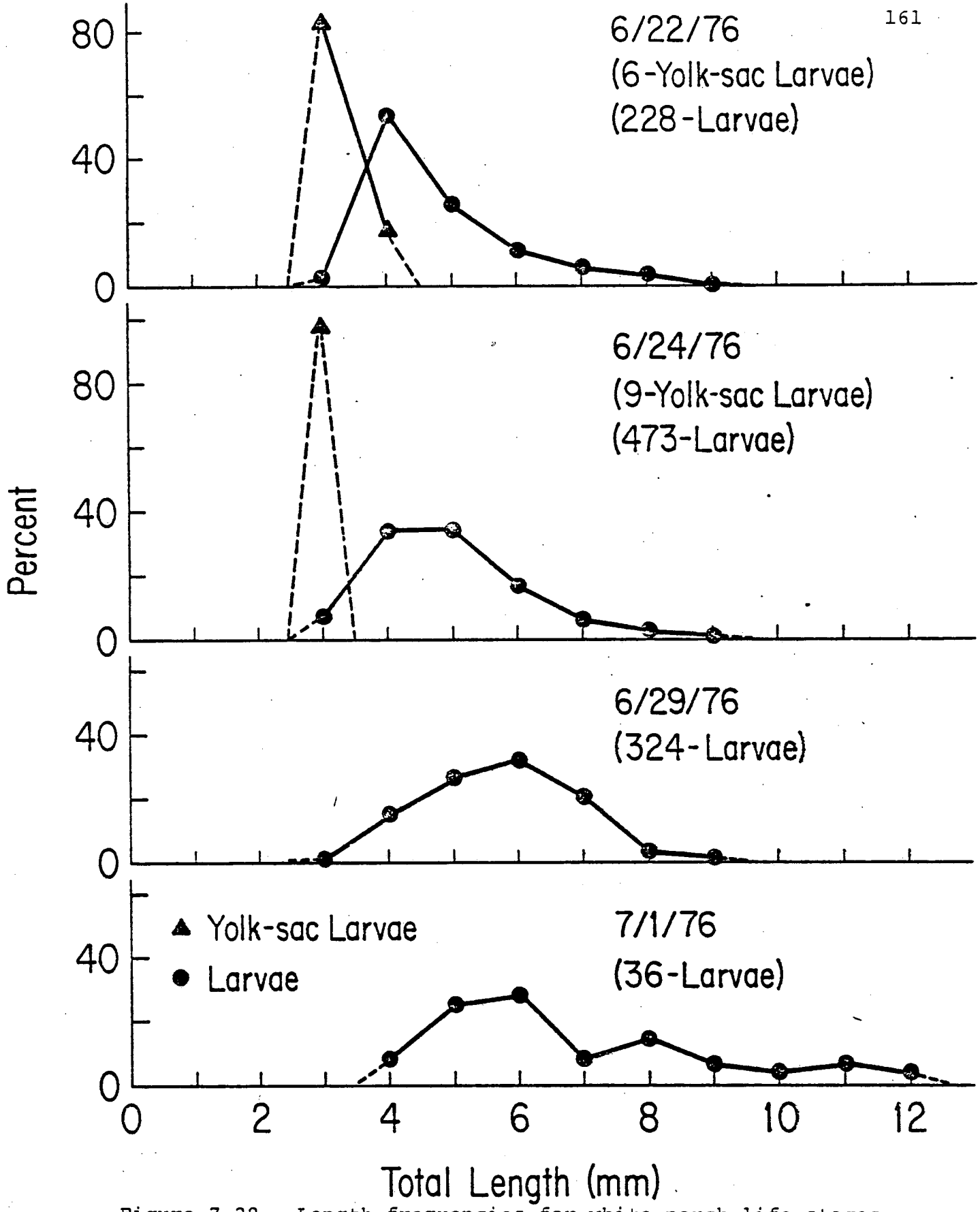

Figure 7-28. Length frequencies for white perch life stages collected in the river, 1976.

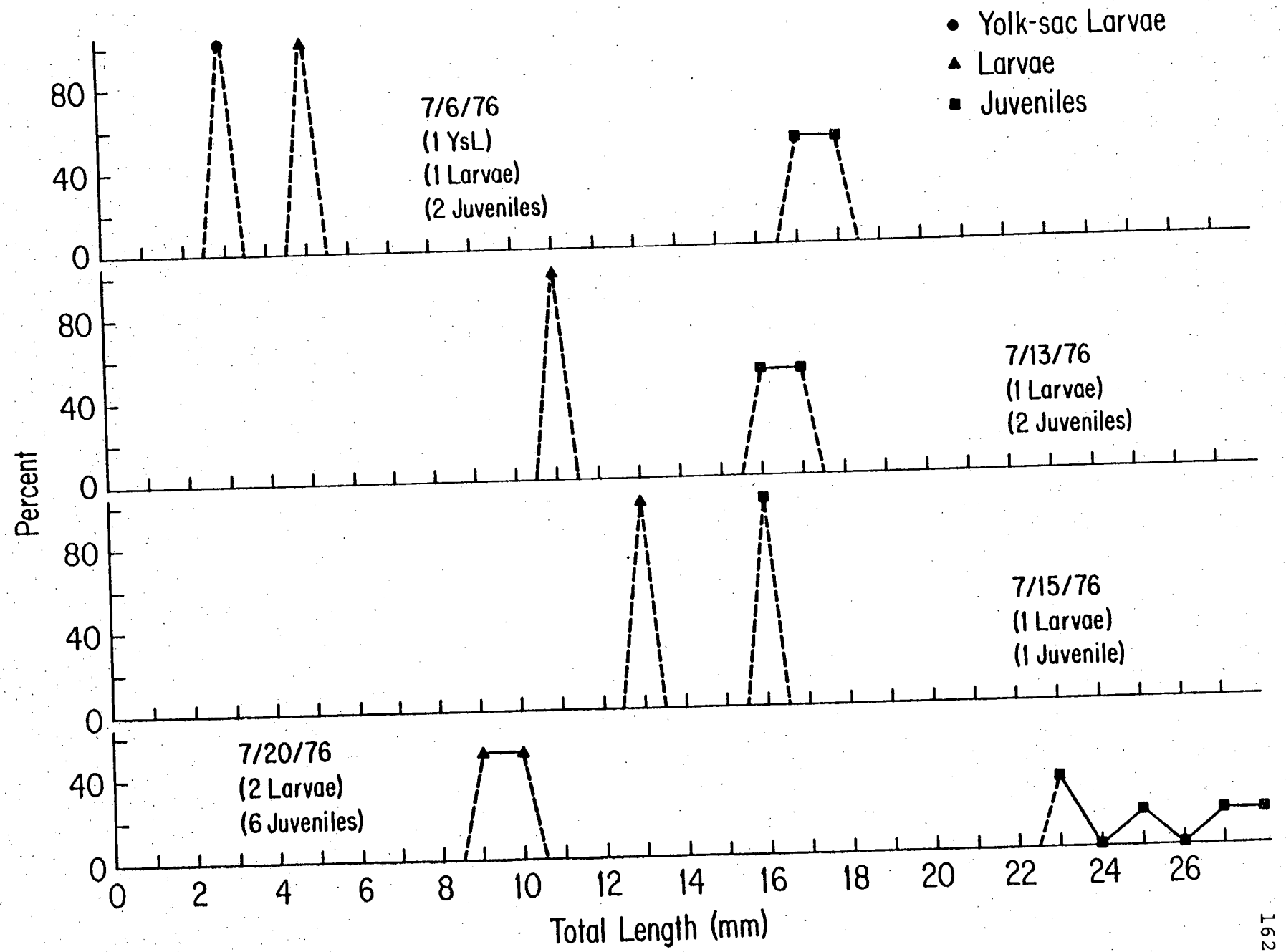

Figure 7-29. Length frequencies for white perch life stages collected in the river, 1976.

Table 7- 4. Analysis of variance for striped bass eggs collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/effort + 1). (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
Day (5/03 - 6/08)				
A	6	2.4751	.4125	3.3373*
B/A	14	2.9328	.2095	1.6948
C	5	14.1028	2.8206	22.8190*
AXC	28	7.7712	.2775	2.2454*
Error	65	8.0344	.1236	
Total	118	35.3163		
Night (5/06 - 6/10)				
A	6	4.0154	.6692	4.3413*
B/A	14	6.8551	.4896	3.1763*
C	5	9.0884	1.8177	11.7913*
AXC	28	6.6868	.2388	1.5492
Error	66	10.1742	.1542	
Total	119	36.8199		

Table 7- 5. Analysis of variance for striped bass yolk-sac larvae collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/effort +1). (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sum of squares; MS = Mean square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
Day (5/17 - 6/22)				
A	6	1.5273	.2545	1.9123*
B/A	14	8.3816	.5987	4.4977*
C	5	2.6688	.5338	4.0100*
AXC	30	3.9492	.1316	.9890
Error	70	9.3176	.1331	
Total	125	25.8445		
Night (5/13 - 7/01)				
A	6	.6068	.1011	.9020
B/A	14	3.3670	.2405	2.1450*
C	5	7.1590	1.4318	12.7700*
AXC	29	7.2439	.2498	2.2278*
Error	68	7.6243	.1121	
Total	122	26.0010		

Table 7- 6. Analysis of variance for striped bass larvae collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/effort + 1). (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sum of squares; MS = Mean square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-vlaue, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
Day (6/01 - 7/13)				
A	6	1.7792	.2965	1.6110
B/A	14	10.6326	.7595	4.1260*
C	6	15.8328	2.6388	14.3360*
AXC	36	5.8276	.1619	.8794
Error	84	15.4617	.1841	
Total	146	49.5339		
Night (5/27 - 6/08)				
A	6	.6943	.1157	.6552
B/A	14	4.0032	.2859	1.6192
C	6	22.9434	3.8239	21.6536*
AXC	36	6.5797	.1828	1.0350
Error	84	14.8339	.1766	
Total	146	49.0544		

Table 7-7. Analysis of variance for striped bass eggs collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
Day (5/03 - 6/08)				
A	6	.0246	.0041	1.8065
B/A	14	.0423	.0030	1.3284
C	5	.1307	.0261	11.5027*
AXC	28	.0951	.0034	1.4939
Error	65	.1477	.0023	
Total	118	.4404		
Night (5/06 - 6/10)				
A	6	.0504	.0084	1.4847
B/A	14	.1580	.0113	1.9941*
C	5	.0758	.0152	2.6795*
AXC	28	.1483	.0053	.9361
Error	66	.3734	.0057	
Total	119	.8059		

Table 7- 8. Analysis of variance for striped bass yolk-sac larvae collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/m^3 +1). (A = stations; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = Mean Square; F = F-value for analysis of variance; asterisk (*) denotes a significant F-value, $\alpha < 0.05$, for the test).

Source	DF	SS	MS	F
Day (5/17 - 6/22)				
A	6	.0142	.0024	1.5239
B/A	14	.0318	.0023	1.4624
C	5	.0331	.0066	4.2684*
AXC	30	.0469	.0016	1.0075
Error	70	.1087	.0016	
Total	125	.2348		
Night (5/13 - 7/01)				
A	6	.0028	.0005	1.4844
B/A	14	.0075	.0005	1.7387
C	5	.0152	.0030	9.8010*
AXC	30	.0206	.0007	2.2163*
Error	70	.0217	.0003	
Total	125	.0678		

Table 7- 9. Analysis of variance for striped bass larvae collected during the day and night in the river in 1976 and listed as $\log_{10}$ (catch/m^3 +1). 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, α <0.05, for the test).

Source	DF	SS	MS	F
Day (6/01 - 7/13)				
A	6	.0245	.0041	1.5422
B/A	14	.0737	.0053	1.9875*
C	6	.0970	.0162	6.1048*
AXC	36	.0856	.0024	.8979
Error	84	.2224	.0026	
Total	146	.5032		
Night (5/27 - 6/08)				
A	6	.0142	.0024	.7632
B/A	14	.0632	.0045	1.4528
C	6	.1422	.0237	7.6219*
AXC	36	.0991	.0028	.8852
Error	84	.2612	.0031	
Total	146	.5799		

the ANOVA resulted in a significant difference among stations or depth, a Scheffé test ($\alpha \leq 0.10$) was done to find where the difference lay.

For the analysis based on No./m^3 and for the analysis based on catch/unit effort there were differences in abundance among dates for the daytime and nighttime analysis of eggs, yolk-sac larvae, and larvae (Tables 7-4 through 7-9). Abundance differences by station (Table 7-10) were not detected by ANOVA based on No./m^3 (Table 7-11). When the data were analyzed in terms of catch/unit effort, differences between some of the stations were found for egg abundances during both the day and night (Table 7-12). Differences with depth were found in two instances in the analysis based on No./m^3 (Tables 7-13 and 7-14). Daytime abundances of larvae and nighttime abundances of eggs were greater in the bottom samples than either the surface or mid samples. The analysis based on catch/unit effort showed similar significant differences in depth distribution except in the case of yolk-sac larvae; both daytime and nighttime abundances of yolk-sac larvae were greater in the mid and bottom samples than in the surface samples (Table 7-15).

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

Observed differences in abundance among dates for the different life stages of striped bass are not unexpected for the same reasons mentioned in 1974 and 1975 (New York University Medical Center, 1975, 1976a).

Table 7-10. River abundance of striped bass life history stages in day and night collections, 1976. Data shown are mean numbers caught per $1000m^3$ with 95% confidence intervals at each station. n = Number of samples in which the particular life stage was observed.

	Stations						
Collections	A	B	C	D	E	F	G
Day							
Eggs 5/03-6/08	146±172 n=18	70±107 n=18	16± 28 n=18	27± 24 n=18	43± 53 n=18	4± 6 n=18	113±242 n=12
Yolk-sac larvae 5/17-6/22	125±192 n=18	35± 39 n=18	16± 18 n=18	14± 13 n=18	22± 21 n=18	45± 56 n=18	10± 8 n=18
Larvae 6/01-7/13	83± 90 n=21	34± 38 n=21	65± 67 n=21	24± 19 n=21	133±122 n=21	110±148 n=21	17± 23 n=21
Night							
Eggs 5/06-6/10	297±482 n=18	59± 84 n=18	21± 19 n=18	74± 72 n=18	2± 3 n=18	9± 17 n=18	131±250 n=12
Yolk-sac larvae 5/13-7/01	47± 31 n=24	33± 28 n=24	35± 23 n=24	33± 20 n=24	24± 18 n=24	17± 10 n=24	31± 27 n=24
Larvae 5/27-7/08	74± 54 n=21	58± 53 n=21	32± 20 n=21	75± 84 n=21	182±266 n=21	76± 77 n=21	57± 59 n=21

Table 7-11. Differences in striped bass river abundance among stations in $\log_{10}$ (catch/m^3 +1).

Life Stage	Day	Night
Eggs	none	none
Yolk-sac larvae	none	none
Larvae	none	none

Table 7-12. Differences in striped bass river abundance among stations in $\log_{10}$ (catch/effort +1).

Life Stage	Day	Night
Eggs	A>F	A,D>E D>F
Yolk-sac larvae	none	none
Larvae	none	none

Table 7-13. Day and night striped bass abundance in the Hudson River by depth, 1976. Data are mean numbers collected per 1000 m^3, with 95% confidence intervals. (n=number of samples).

Collections	Surface	Middle	Bottom
Day			
Eggs 5/03-6/08	15±19 n=40	77±76 n=40	79±81 n=40
Yolk-sac larvae 5/17-6/22	1±0.5 n=42	39±26 n=42	75±80 n=42
Larvae 6/01-7/13	1± .7 n=49	101±71 n=49	30±64 n=49
Night			
Eggs 5/06-6/10	9± 8 n=40	30±30 n=40	208±219 n=40
Yolk-sac larvae 5/13-7/01	17±11 n=55	34±13 n=55	40±18 n=55
Larvae 5/27-6/08	44±38 n=49	72±39 n=49	121±112 n=49

Table 7-14. Differences in striped bass river abundance among depths in $\log_{10}$ (catch/m^3 + 1).

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

Table 7-I5. Differences in striped bass river abundance among depths in $\log_{10}$ (catch/effort + 1).

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

The dates included in the daytime analysis of eggs are from May 3 to June 8, for yolk-sac larvae from May 17 to June 22, for larvae from June 1 to July 13. The dates included in the nighttime analysis of eggs are from May 6 to June 10, for yolk-sac larvae, from May 13 to June 17, for larvae from May 27 to July 8.

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. Unlike 1974 and 1975 (New York University Medical Center, 1975, and 1976a) there was no difference between daytime and nighttime striped bass abundance (Tables 7-16 and 7-17).

A total of 285 ichthyoplankton samples were collected simultaneous with plant collections during a 6-7 hour period from river site D (designated as D-S for this purpose) during 1976. The species and life stages identified in these collections are listed in Table 7-3. A total of 18 species were identified, 7 species less than was observed for the seven standard river stations. These included the sturgeon, Acipenser spp.; silversides, Menidia spp.; killifish, Fundulus spp. and northern pipefish, Syngnathus fuscus.

Striped bass eggs were first collected on May 11 at D-S and were observed in the collections until June 22. The initial occurrence was one week later than was observed for the seven river day samples, and continued at least one week

Table 7-16. Day abundance of striped bass in the vicinity of Indian Point, 1976. Data are mean numbers collected per $1000m^3$ with 95% confidence intervals. (C.I. = confidence intervals; n = number of samples).

	Mean	C.I.	n
Eggs	57	±37	120
Yolk-sac larvae	38	±28	126
Larvae	67	±31	126
Juveniles	1	± 1	63

Table 7-17. Night abundance of striped bass in the vicinity of Indian Point, 1976. Data are mean numbers collected per $1000m^3$ with 95% confidence intervals. (C.I. = confidence intervals; n = number of samples).

	Mean	C.I.	n
Eggs	82	±79	120
Yolk-sac larvae	31	± 8	165
Larvae	79	±41	147
Juveniles	1	± 1	105

later than was observed for both the seven river day and night collections. The peak mean abundance of 90/1000 m^3 occurred on May 11 (Figure 7-30). However when compared with the river abundance figures, this number was on the increase and the "true" peak was not observed until May 13 (Figure 7-7). Striped bass eggs were not observed in samples from the standard river stations after June 15, but were observed in samples from the D-S station. At this late date in the striped bass spawning season, the abundance of striped bass eggs in the river is on the decline. The probability of collecting striped bass eggs is likely to be a function of the sampling effort. As D-S was sampled more intensely (once every hour over a 6-7 hour period) than the seven river stations (once at each station at night and once at each station during the day), chances are better for egg collection at the D-S station than for any of the seven river stations.

Yolk-sac larvae of striped bass were first observed on May 25 and occurred in the samples until June 22. Peak mean abundance of 110/1000 m^3 occurred on June 15 (Figure 7-30). Similar findings were observed for the seven river collections (Figures 7-6 and 7-7).

Striped bass larvae occurred in the D-S samples from June 8 to July 6, and showed a peak mean abundance of 298/1000 m^3 on June 15. This peak mean abundance was similar to the 305/1000 m^3 observed for the seven river stations (Figures

7-6 and 7-7). However, the seasonal occurrence was observed to be much shorter in duration for D-S than was observed for the seven river stations.

Juvenile striped bass were observed in the D-S samples from July 6 to July 27, with a peak mean abundance of 15/1000 m^3 occurring on July 6 (Figure 7-30). Mean abundances observed for life stages of the white perch, clupeids and anchovy are shown in Figures 7-31 to 7-33.

The depth distribution pattern observed for the striped bass life stages are shown in Figure 7-34. According to this figure, the mean abundances are greatest at the mid-depth for eggs, yolk-sac larvae and larvae. This does not compare with the vertical distribution of these life stages at the seven river stations (Figures 7-14 and 7-15); they should be near the bottom. Thus some factor or factors may be raising the striped bass life stages from the bottom at D-S. We noticed, too, that all the samples collected at this station during flood tide were heavily laden with detritus, while those collected at ebb tide were free of detritus. We know that flood tide currents in the river are able to move particles from off the river bottom (Hairr, 1973) and that station D-S (located along the 50 ft depth contour) lies directly in the mixing zone of the river and the Indian Point discharge plume at flood tide, but not during ebb tide (LaSalle, 1976). This leads us to conclude that the distribution of striped bass eggs, yolk-sac larvae

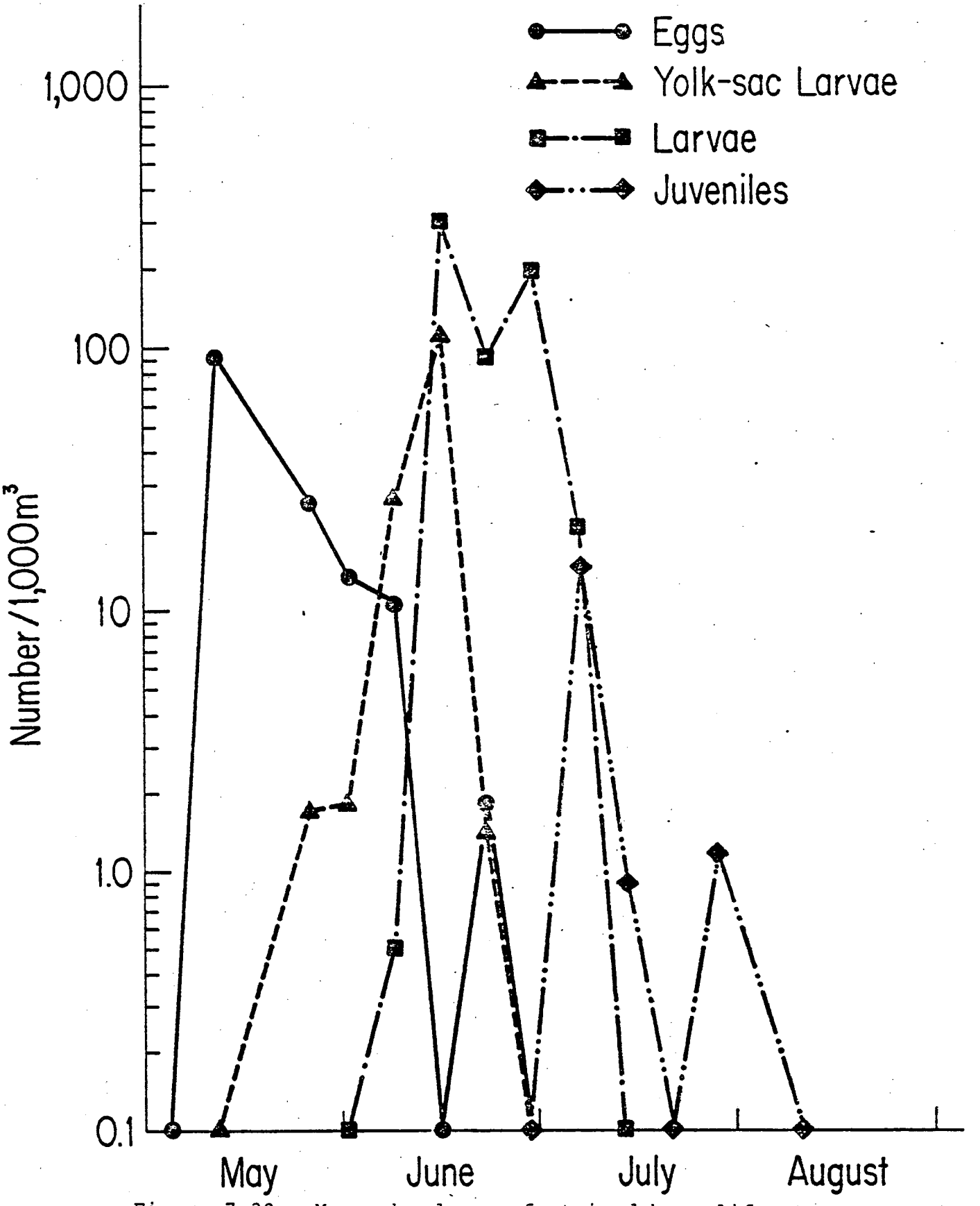

Figure 7-30. Mean abundance of striped bass life stages collected at site "D-S", 1976.

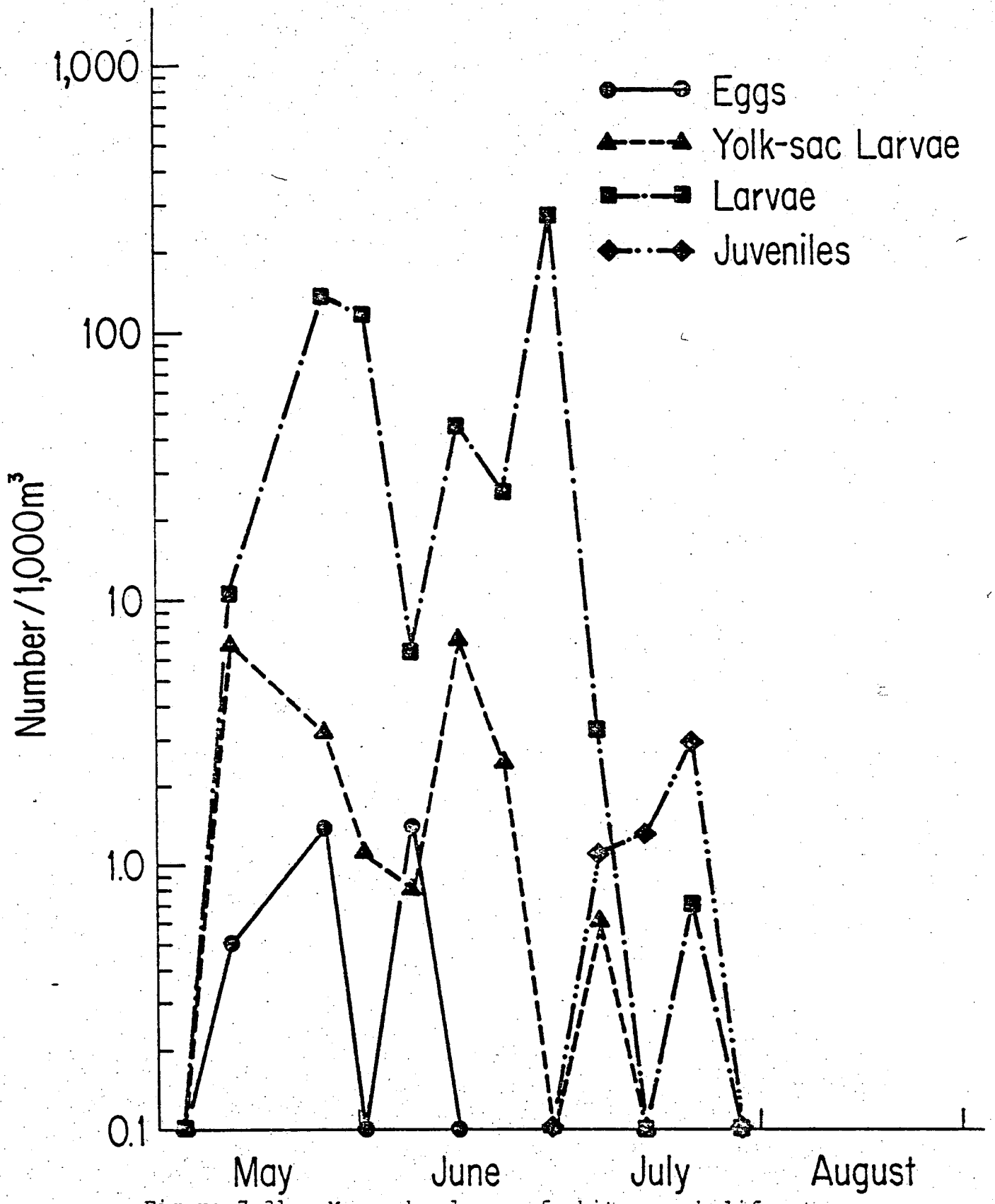

Figure 7-31. Mean abundance of white perch life stages collected at site "D-S", 1976.

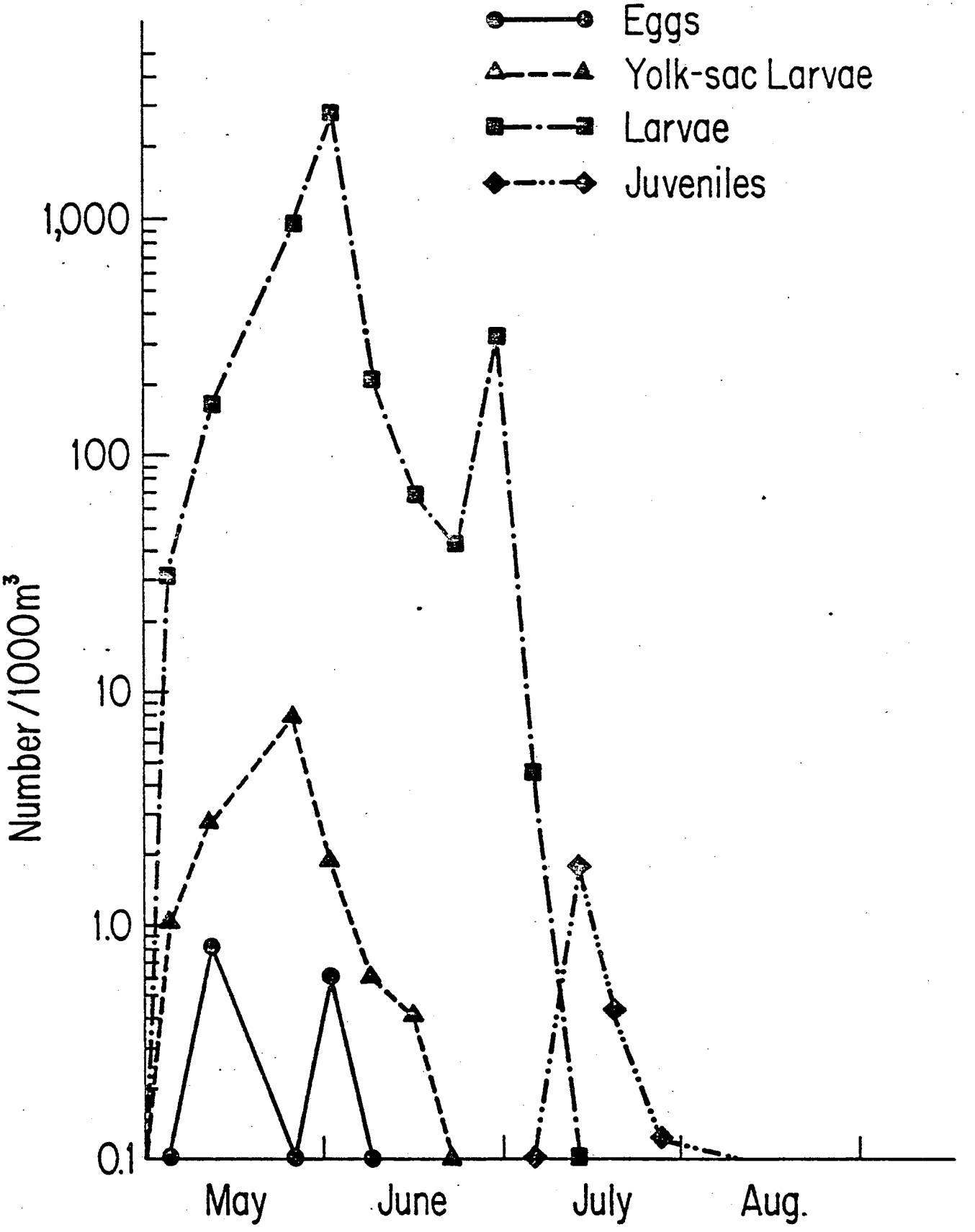

Figure 7-32. Mean abundance of clupeid life stages collected site "D-S", 1976.

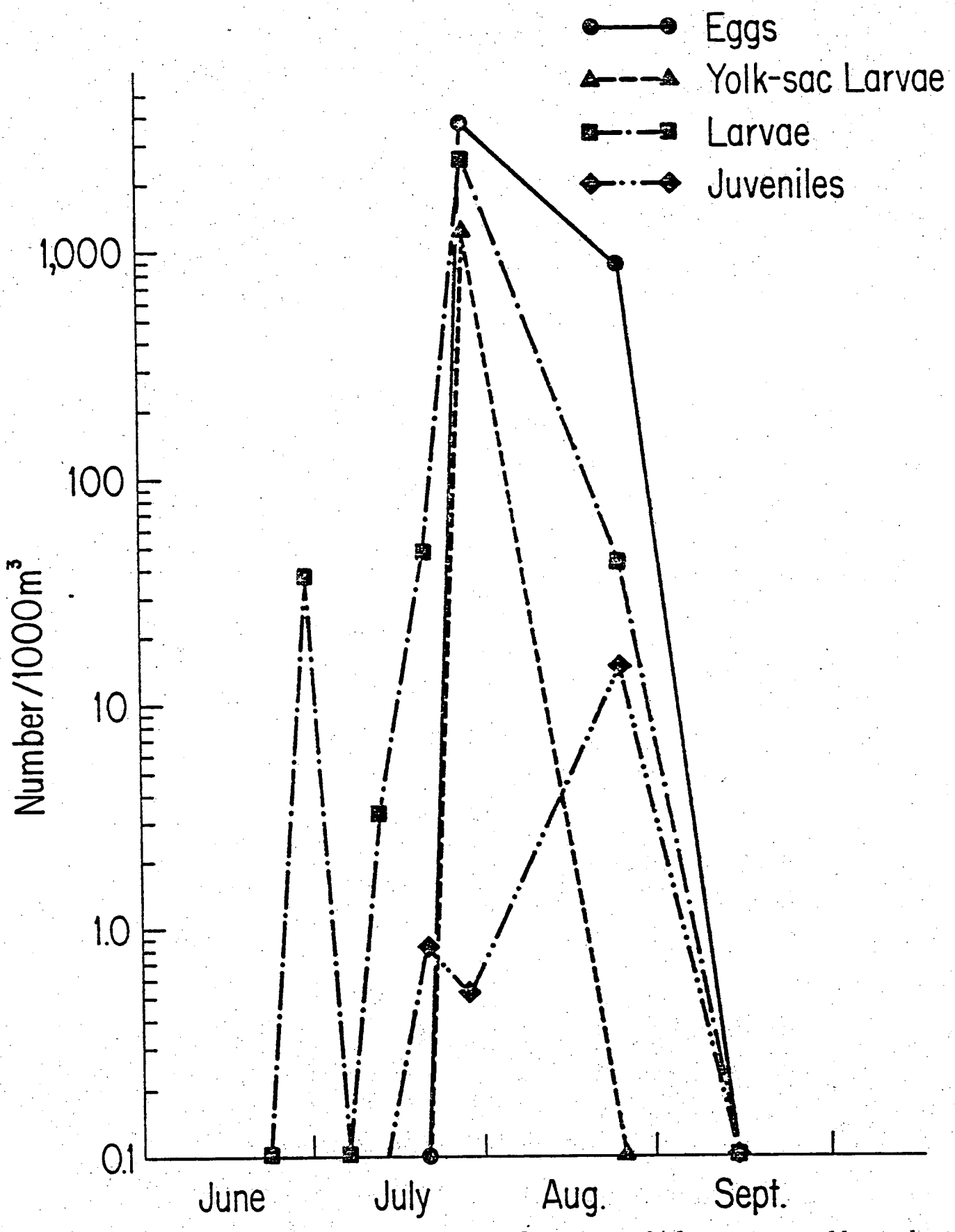

Figure 7-33. Mean abundance of anchovy life stages collected at site "D-S", 1976.

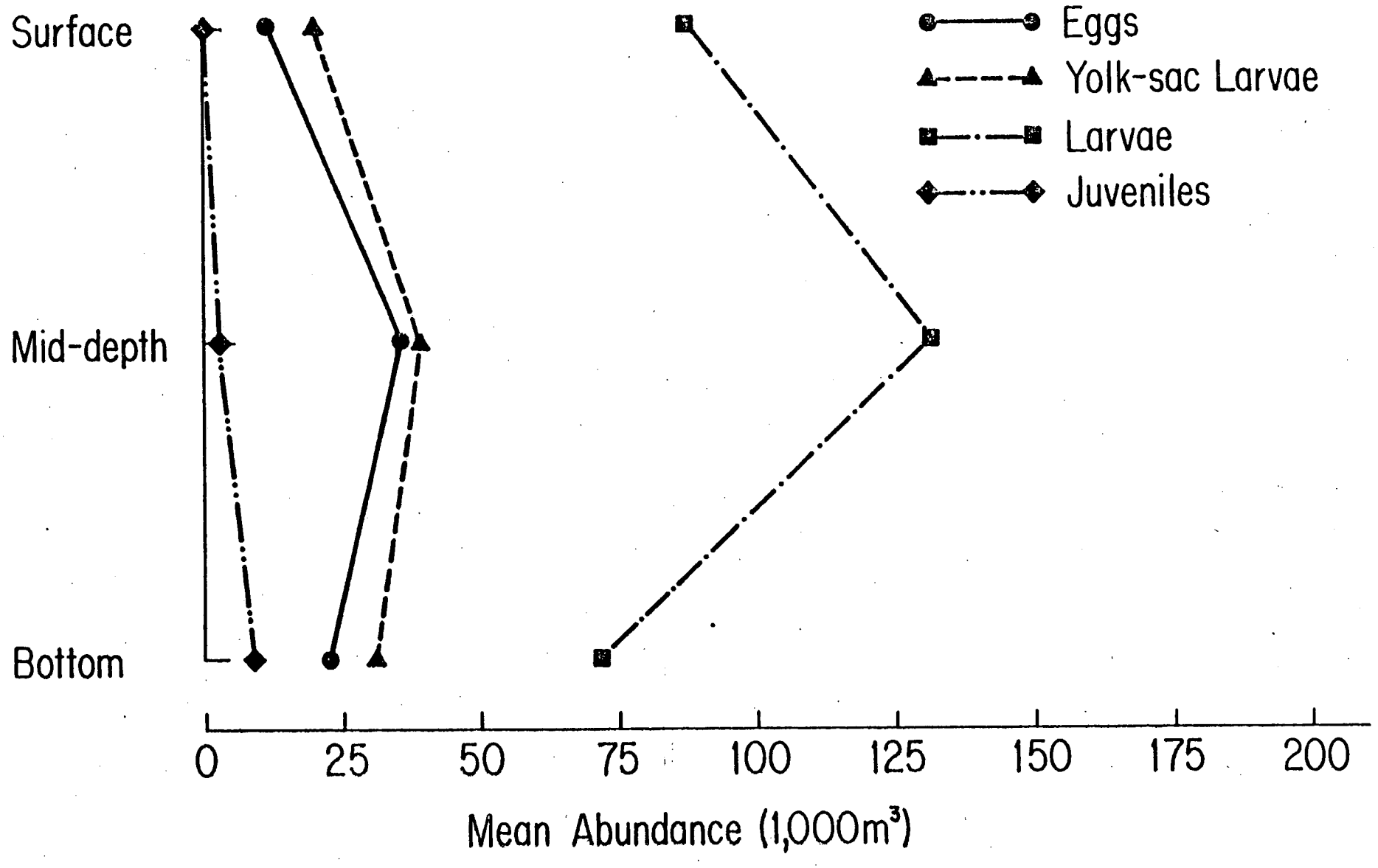

Figure 7-34. Nighttime pattern of vertical distribution for striped bass at site "D-S", 1976.

and larvae near mid-depth at D-S may be the effect of turbulence resulting from either tidal action, plant discharge or a combination of both. However, this may be true just for the larvae, as the ANOVA of the abundance data at D-S (Tables 7-18 to 7-21) indicate a depth difference for larvae only.

Possible tidal effects were examined by comparing the numbers of each life stage of striped bass caught on the flood tide with those caught on the ebb tide (Figures 7-35 and 7-36). On the flood tide egg and yolk-sac larvae were distributed up in the water column as would be expected because of the natural buoyancy of the eggs and the limited mobility of the yolk-sac larvae and because of the ability of flood tide currents to move particles from off the river bottom (Hairr, 1973). This was not true for larvae as they were distributed more near the bottom. Larvae are highly mobile and they may seek to avoid the current and the turbulence by moving to the bottom where turbulence is less, and also as a natural response to disturbance by sounding (Harvey et al., 1968; Haines and Butler, 1969)(Figure 7-35 and Table 7-22).

Although striped bass eggs will float in turbulence, they tend to sink and float at a level more near their density when currents and turbulence are slack and low; this is usually near the bottom. At ebbing tides the eggs at D-S are distributed towards the bottom. Although the yolk-sac larvae show a similar tendency for the bottom, their limited mobility affords them slight diel movement in the water

column. At ebb tide striped bass larvae move from off the bottom, possibly due to decreased turbulence in the water column (Figure 7-36). The data in Table 7-22 indicate that larvae appear more susceptible to net capture on an ebb tide than on a flooding tide.

Table 7-18. Analysis of variance for striped bass eggs collected at station D-S in the river in 1976. (A = time; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = mean square; F = F-value for analysis of variance at $\alpha = 0.05$).

Source	DF	SS	MS	F
A	5	1.0260	.2052	1.1081
B/A	12	.9893	.0824	.4452
C	3	2.4338	.8113	4.3810*
A X C	15	3.0075	.2005	1.0827
Error	36	6.6665	.1852	
Total	71	14.1230		

Table 7-19. Analysis of variance for striped bass yolk-sac larvae collected at station D-S in the river in 1976. (A = time; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = mean square; F = F-value for analysis of variance at $\alpha = 0.05$).

Source	DF	SS	MS	F
A	5	.1693	.0339	.3347
B/A	12	2.3848	.1987	1.9646*
C	4	7.1790	1.7948	17.7423*
A X C	20	3.8712	.1936	1.9134*
Error	48	4.8556	.1012	
Total	89	18.4598		

(*) denotes a significant F-value for the test.

Table 7-20. Analysis of variance for striped bass larvae collected at station D-S in the river in 1976. (A = time; B = depths; C = dates; DF = degrees of freedom; SS = sums of squares; MS = mean square; F = F-value for analysis of variance at $\alpha = 0.05$).

Source	DF	SS	MS	F
A	5	.4930	.0986	.6871
B/A	12	5.3641	.4470	3.1153 *
C	4	18.4003	4.6001	32.0585 *
A X C	20	4.1283	.2064	1.4385
Error	48	6.8875	.1435	
Total	89	35.2733		

(*) denotes a significant F-value for the test.

Table 7-21. Analysis of variance for striped bass juveniles collected at station D-s in the river in 1976. (A = time; B = depths; C = dates; DF= degrees of freedom; SS = sums of squares; MS = mean square; F = F-value for analysis of variance at $\alpha = 0.05$).

Source	DF	SS	MS	F
A	5	.1865	.0373	.6704
B/A	12	.6980	.0582	1.0452
C	2	.6173	.3087	5.5468*
A X C	10	.4105	.0410	.7376
Error	24	1.3355	.0556	
Total	53	3.2478		

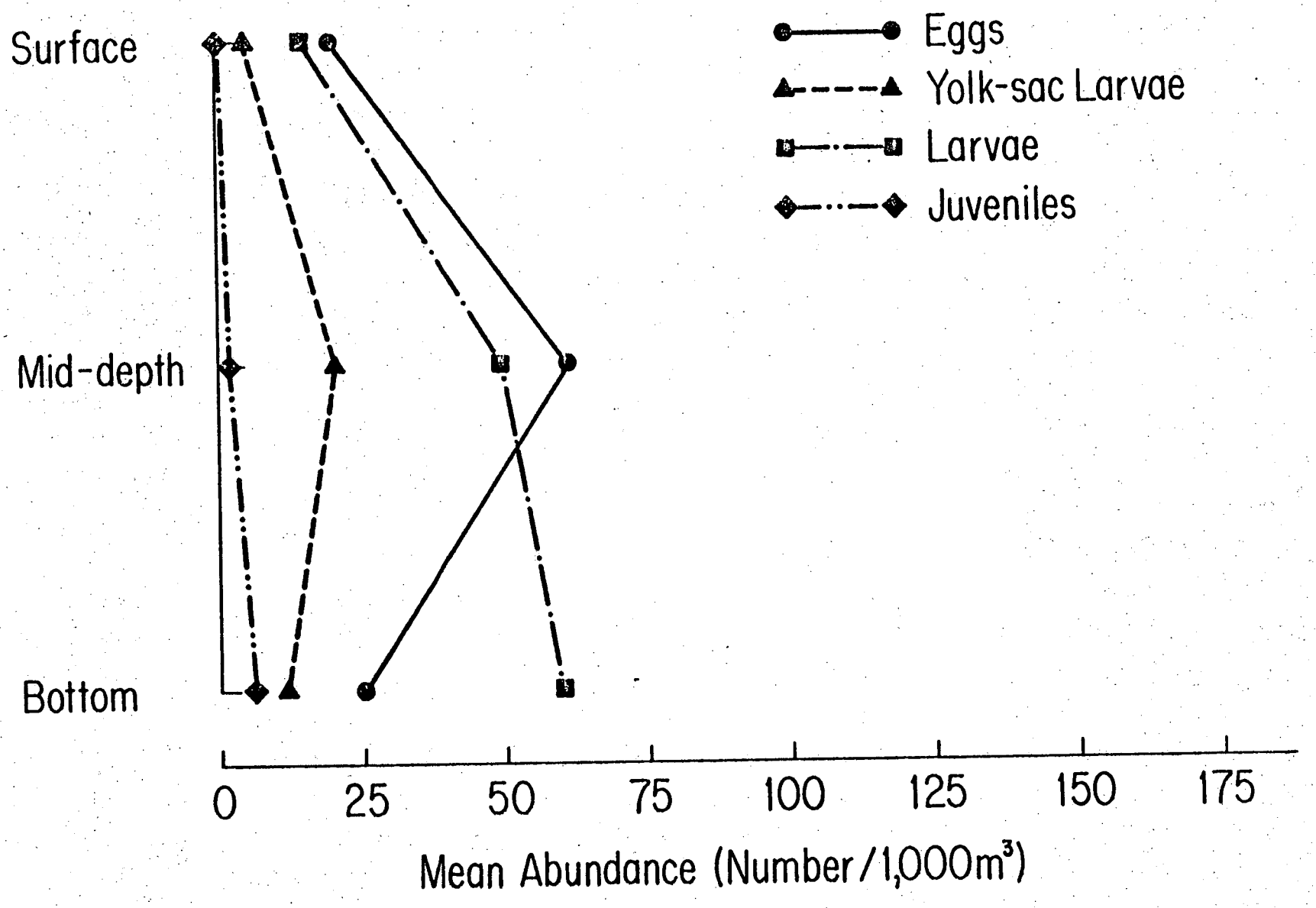

Figure 7-35. Nighttime pattern of vertical distribution (flood tide) for striped bass at site "D-S", 1976.

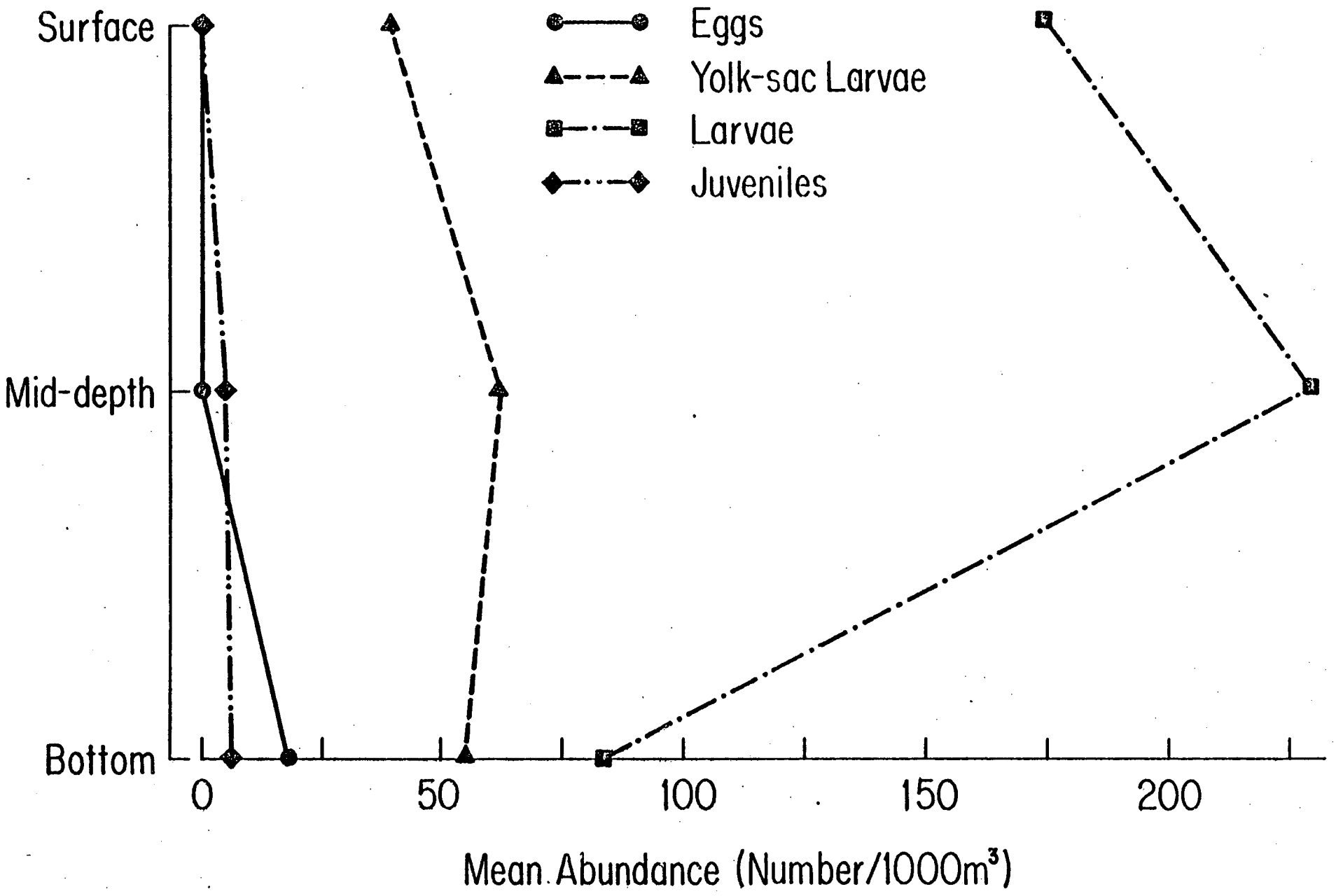

Figure 7-36. Nighttime pattern of vertical distribution (ebb tide) for striped bass at site "D-S", 1976.

Table 7-22. Mean abundance in numbers/1000m^3 with 95% confidence intervals for striped bass life history stages at station D-S with tide and depth, 1976.

Tide	Depth	Eggs	YSL	Larvae	Juveniles
	Surface	20.95±21.31 n=21	5.75± 5.40 n=16	15.21±13.08 n=14	0.0 ± 0.0 n=13
Flood	Middle	62.05±51.86 n=21	21.56±23.52 n=16	48.79±38.06 n=14	1.77± 2.64 n=13
	Bottom	25.48±30.36 n=21	13.88±11.07 n=16	62.07±37.89 n=14	6.08± 8.35 n=13
	Surface	0.0 ± 0.0 n=14	40.46±48.56 n=13	175.14±180.58 n=14	0.0 ± 0.0 n=9
Ebb	Middle	0.0 ± 0.0 n=14	63.62±58.91 n=13	231.36±124.85 n=14	4.56± 8.24 n=9
	Bottom	17.50±27.83 n=14	55.54±60.10 n=13	88.21±49.42 n=14	5.67±10.95 n=9

7.2 ENTRAINMENT EFFECTS STUDIES

7.2.1 Plant Abundance

7.2.1.1 Methods

The abundance of ichthyoplankton in the intakes and discharge canal of the Indian Point facility was determined by weekly sampling from May through July 27. Sampling prior to May and after July 27 was done once-per-month, weather permitting. Samples were taken using 0.5 m plankton nets with a 571 μ mesh in the net and cod-end bucket. All nets were equipped with flowmeters for the determination of the volumes of water filtered. Intake nets contained General Oceanic's digital flowmeters fitted with the R-2 rotor, sensitive to low velocity flows (0.2 ft/sec). Those at the discharge canal were fitted with General Oceanic's digital flowmeter with the standard rotor. As a check, the net used to collect the duplicate sample was fitted with a TSK flowmeter. The volume filtered for each sample was calculated from the net diameter, flowmeter readings and a meter constant supplied by the manufacturer.

Another set of samples (D-S) were collected from the river at a site approximately 200 ft in front of the plant intakes simultaneously with the plant samples for plant/river comparisons. Although this sample is a river sample, it will be discussed, in this instance, with the plant samples.

The inventory of ichthyoplankton species and life-history stages captured at the plant was similar to that documented previously (see Section 7.1 of this report). However, the

analysis contained in this section is limited to striped bass.

The data were tested by analysis of variance (ANOVA) using $\log_{10}$ (catch/m^3 +1) per sample as the numeric input. The log-transform was used to satisfy the major assumption of ANOVA, that the variance of the data was homogeneous. Catch per unit effort (CPUE) analysis was compared to the catch per 1000 m^3 as an estimate of the consistency of volumes sampled. CPUE was time-related, expressed simply as the number of organisms caught per 10-minute sampling event. The data (for each life history stage) used in the comparisons were derived from all the samples collected within the period of initial appearance to final observation for a giyen life stage. For example, for striped bass eggs, if only one egg was found in one sample from one station for a given date, all the samples for that date were included in the analysis, even though all but one would be zeros. Data for that life history stage would continue to accumulate until such time that it was no longer observed in any of the samples being compared. Where significant differences among main effects and/or interactions were detected (α = 0.05), an a posteriori test (Scheffé test) was employed (α = 0.10) to determine precisely where the difference occurred.

7.2.1.2 Results and Discussion

The abundances (in catch per 1000 m^3 and in catch per unit effort) for the various life history stages of striped

bass sampled during the 1976 entrainment studies are shown in Tables 7-23 and 7-24. These were tested to determine differences between the intake and discharge station, the intake and the river station (D-S) and the discharge station and D-S; the results are shown in Tables 7-25 and 7-26. As was the case in 1974 and 1975, the abundance of eggs at the intake was nearly twice that in the discharge canal. There was no difference in the concentration of yolk-sac larvae between the intake and the discharge canal in 1976; this too was as observed in previous years' studies. Few yolk-sac larvae are ever caught in the plant (refer to progress reports from New York University Medical Center). In 1976 larvae (post-yolk-sac) were more abundant in the discharge canal samples than in intake samples; this was true for 1974 but was the opposite of that seen in 1975. Juveniles will not be discussed as there were too few collected.

Some of these differences among the years between the intake and the discharge canal samples may be the result of difference in the sampling done at the Unit 2 and Unit 3 intakes. In years 1974 and 1975, samples were collected from Unit 2, while in 1976 the samples were collected from Unit 3. At Unit 2 the intake samples were collected within an enclosed forebay; those at Unit 3 , because of the location of the travelling screen, were collected in the river in front of the intake. The intake samples at Unit 3 were col-

Table 7-23. Differences in striped bass abundance in $\log_{10}$ (catch/1000 m^3 + 1) for intake (III), discharge (D-2) and river simultaneous (D-S) stations.

	Intake-III_5	D-2	D-S
Eggs 5/11-6/22	159.8±.03 n = 83	60.8±.4 n = 65	19.6±.02 n = 105
Yolk-sac larvae 5/25-6/22	26.3±.002 n = 68	18.1±.004 n = 55	30.5±.002 n = 90
Larvae 6/8-7/13	19.3±.006 n = 95	70.7±.009 n = 64	91.6±.006 n = 96

Table 7-24. Mean abundance of life history stages of striped bass in numbers/unit effort at the 95% confidence level for night collection at the Unit 3 intake, discharge canal station D-2 and the river simultaneous station D-S. n = number of samples included in the analysis.

	Intake-III_5	D-2	D-S
Eggs 5/11-6/22	0.881±.002 n = 101	4.031±.004 n = 65	2.048±.002 n = 105
Yolk-sac larvae 5/25-6/22	0.116±.002 n = 86	1.418±.003 n = 55	3.444±.002 n = 90
Larvae 6/8-7/13	0.295±.002 n = 95	6.563±.003 n = 64	10.833±.002 n = 96

Table 7-25. Differences in striped bass abundance in $\log_{10}$ (catch/m^3 + 1) for intake (III), discharge (D-2) and river simultaneous (D-S) stations.

	III vs D-2	III vs D-S	D-2 vs D-S
Eggs 5/11-6/22	III > D-2	III > D-S	D-2 > D-S
Yolk-sac larvae 5/25-6/22	N.S.	N.S.	D-2 < D-S
Larvae 6/8-7/13	III < D-2	III < D-S	N.S.

N.S. = not significant

Table 7-26. Differences in striped bass abundance in $\log_{10}$ (catch/effort + 1) for intake (III), discharge (D-2) and river simultaneous (D-S) stations.

	III vs D-2	III vs D-S	D-2 vs D-S
Eggs 5/11-6/22	III < D-2	III < D-S	D-2 > D-S
Yolk-sac larvae 5/25-6/22	III < D-2	III < D-S	D-2 < D-S
Larvae 6/8-7/13	III < D-2	III < D-S	N.S.

N.S. = not significant

lected with nets suspended on lines from a boat (see Section 1 of this report) moored in front of the intake structure in the river, while the samples collected at Unit 2 were collected with nets mounted in rigid frames.

In 1976 all volume comparisons are based upon volumes derived from the use of flowmeters. In 1947 and 1975, volumes were derived from calculations based upon plant operating capacities for that particular sampling period. The calculated volumes for those years, which were based upon the use of velocity-reduction cones, and which were later judged to be non-functional, may have been underestimated and thus elevated the abundance (see New York University Medical Center, 1975 and 1976a). Flowmeters having a rated sensitivity of 0.2 ft/sec were used in all the nets at the Unit 3 intake station, but because of its location (see Fig. 1-12) the measured flows, the resulting volumes and, hence, the abundances for the Unit 3 intake samples were extremely variable. Accordingly, statistical confidence limits about the data would be quite broad.

Ideally the abundance of organisms collected from the plant intakes should equal the abundance of organisms returned to the river via the discharge canal, assuming organism concentrations remain constant during plant transit. In this instance for 1976, the discharge canal samples may reflect, better, the abundance of organisms entrained into the plant's cooling water system.

The abundance, on a catch per effort basis, is shown and compared in Tables 7-24 and 7-26. Because of the more rapid

water flow at the discharge canal station, a sampling effort at the discharge canal will sample a much larger volume of water. As expected, the abundance per unit effort at the discharge station is greater than that at the intake for all striped bass life stages caught.

7.2.2 Plant and River Comparisons

The abundance of the pre-juvenile life history stages of striped bass in plant and in river samples (from D-S) is shown and compared in Tables (7-23 to 7-26). Egg abundance was higher in plant samples than in river samples, differing by a factor of approximately 3-5. This difference was observed in 1974 and 1975, and by essentially the same factors. Yolk-sac larvae were more numerous in river samples in 1976; this was true for 1974 and 1975, also. There was no difference in the abundance of larvae (post yolk-sac) between plant and river samples examined in 1976. This is different than was observed for either 1974 or 1975; in 1974 river samples were more abundant, while in 1975 plant samples were more abundant.

One-way analyses of variance were made comparing the abundance of these life history stages for the dates of their appearance in plant samples, simultaneous river samples and in each of the seven standard river stations sampled at night. The analyses showed no significant difference for all life stages and samples examined. This differs from that observed above for the comparison between plant and river samples as represented by D-S. Some of the discrepancy

may result from the difference in the stations themselves, which are selected for comparison. River values for plant-river comparisons in previous years' studies were based upon a river-wide mean from the seven standard stations. In light of the concept of patchy distribution for zooplankton (Wiebe and Holland, 1968), a river-wide mean may not be the value to use. Further, the use of any values derived from the seven standard stations for plant-river comparisons may be confused by the fact that the river samples are collected once during the day and once at night on separate days, while plant samples are sampled several times during a tidal cycle. The use of calculated volumes in abundance estimates in 1974 and 1975 instead of volumes based upon measured values in 1976 may tend to over-estimate the plant abundance in 1974 and 1975.

While it is expected that the plant which draws water from all depths and directions in a cone-like fashion will collect more organisms than river tows, which sample only from discrete depths, the difference for eggs is more conspicuous. The differences for yolk-sac larvae and larvae are not so evident, since they are mobile and their mobility may allow then to move away from areas within the influence of the plant intake pumps.

Given this observed fact that the Indian Point facility consistently draws a large number of eggs into the plant, the abundance of the pre-juvenile life stages of striped bass

in the river in the vicinity of Indian Point has remained relatively constant for the duration of our studies. To date, there is little evidence to show that the operation of the Indian Point nuclear facility has affected the abundance of striped bass eggs, yolk-sac larvae and larvae in the river.

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