BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50-247
	)	
(Indian Point Station, Unit No. 2)	)	

Testimony of
Gerald J. Lauer, Ph.D.
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on
Effects of Elevated Temperature and
Entrainment on Hudson River Biota

April 5, 1972

TABLE OF CONTENTS

Consolidated Edison's Indian Point power generating units are designed to utilize once-through passage of Hudson River water to cool the condensers. Unit 1, operating at rated capacity and design circulating water flow, uses approximately 280,000 gallons per minute of cooling water, the temperature of which is raised about $15^{\circ}F$. Unit 2 has design circulating water flow requirements of 840,000 gpm at rated capacity operation. The design ΔT across the condenser for this unit is $15.1^{\circ}F$.

The accumulating information in the literature indicates that the manner in which aquatic organisms are effected by elevated temperature is determined by both the amount of the temperature rise and the duration of exposure to the temperature rise.

Studies of phytoplankton and micro-invertebrate zooplankton populations of the Hudson River near Indian Point and in the Unit 1 discharge canal during 1968 and 1969 indicated that operation of Unit 1 had no discernible effect on those populations. During these studies temperatures in the discharge canal were from $5^{\circ}F$ (July) to $18^{\circ}F$ (December) above ambient temperatures in the river.

Aquatic organisms small enough to pass through the 3/8 inch mesh intake screens are exposed to these temperature elevations and to change in pressure and turbulence.

Lengthening of the discharge canal to accomodate the cooling water discharge from Unit 2 and 3, modifications in the design and operation of the cooling water circulating systems to reduce flow velocities into the intakes during the winter, and various possible combinations of operating modes among the two units, produce a possible range of ΔT 7-29.5°F; and a range of possible exposure times from 2.5 to 40 minutes. The higher temperature rises and greater exposure times are related to reduced flows.

The laboratory temperature tolerance studies initiated in 1971 were designed to cover the full range of ΔT's and exposure times that could be produced during various seasons of the year by all possible combinations of power level operation of Units 1 and 2.

The results from these studies to date indicate that the temperature tolerance of bacteria, phytoplankton, and representative species of micro and macro-invertebrate zooplankton will not be exceeded by the ΔT's expected in the discharge canal water during the fall, winter, and spring. The data indicate that a 15°F ΔT in the summer would not exceed the temperature tolerance of the bacteria, phytoplankton and macro-invertebrates species studied to date. The laboratory studies do indicate that as discharge canal temperature rises above 90°F in summer a portion of the micro-invertebrate zooplankton (dominated by copepods) may be killed. This could involve up to 25% of the organisms passing through the plant at a 15°F ΔT over the maximum summer ambient temperature of 79°F.

Comparisons of the ratios of live to dead micro-invertebrate zooplankton in Unit 1 intake and discharge water net and pumped samples during the summer of 1971 indicated no significant mortality at ΔT's up to 11°F, which agree with projections from the laboratory studies.

The projected mortalities during the period of peak temperature of organisms such as copepods which have relatively short generation times, as a result of passage through the Indian Point condensers, appear to have little potential for affecting populations in the Hudson River. The literature indicates that 100% mortality of copepods during passage through power plants sited on large bodies of water have had no discernible effect on population abundance in those waters.

The temperatures in the plume from Indian Point Units 1 and 2 at all operating power levels must conform to the New York State Criteria (6 NYCRR 704.1 (b) (4)). The laboratory thermal tolerance studies and the intake-discharge canal survival studies indicate the temperatures in the plume will be less than the upper temperature tolerance of bacteria, phytoplankton, and representative species of micro and macroinvertebrate zooplankton species studied to date.

The literature indicates that growth and diversity of microbial organism populations tend to be improved by elevation of temperature up to 95°F; and that phytoplankton and zooplankton growth and diversity increase as the temperature increases up to an optimum of about 86°F. On the other hand exposure to temperatures above these optima tend to inhibit metabolism and growth; and prolonged exposure to temperature above 86° may reduce diversity and cause shifts in the species composition of the population from more to less desirable forms.

Hydrological characteristics of the Hudson River in the vicinity of Indian Point dictate that water borne organisms would not be exposed to more than a couple of degrees temperature elevation for more than a couple of hours. This exposure time is so short relative to probable generation times of such species that there would be insufficient time for such tendencies to shift diversity upward or downward to be expressed.

Preliminary analysis of data on bottom organisms indicate no alteration of population abundances or species composition in areas under the plume from Indian Point Unit 1 . At the time Unit 1 employed a surface discharge. Water temperature on the bottom at these sampling stations was no higher than at control stations.

The effects of the Indian Point plant operation on fish eggs and larvae are unknown. The literature on the subject is fragmentary. The little information which now exists could be used to project anything from zero effect to 100% decimation. The effects of the Indian Point plant on the fish eggs and larvae of Hudson River species is now underway. It is expected that a reasonably sufficient amount of data on which to evaluate this question will be available by August 1972.

PRELIMINARY OBSERVATIONS

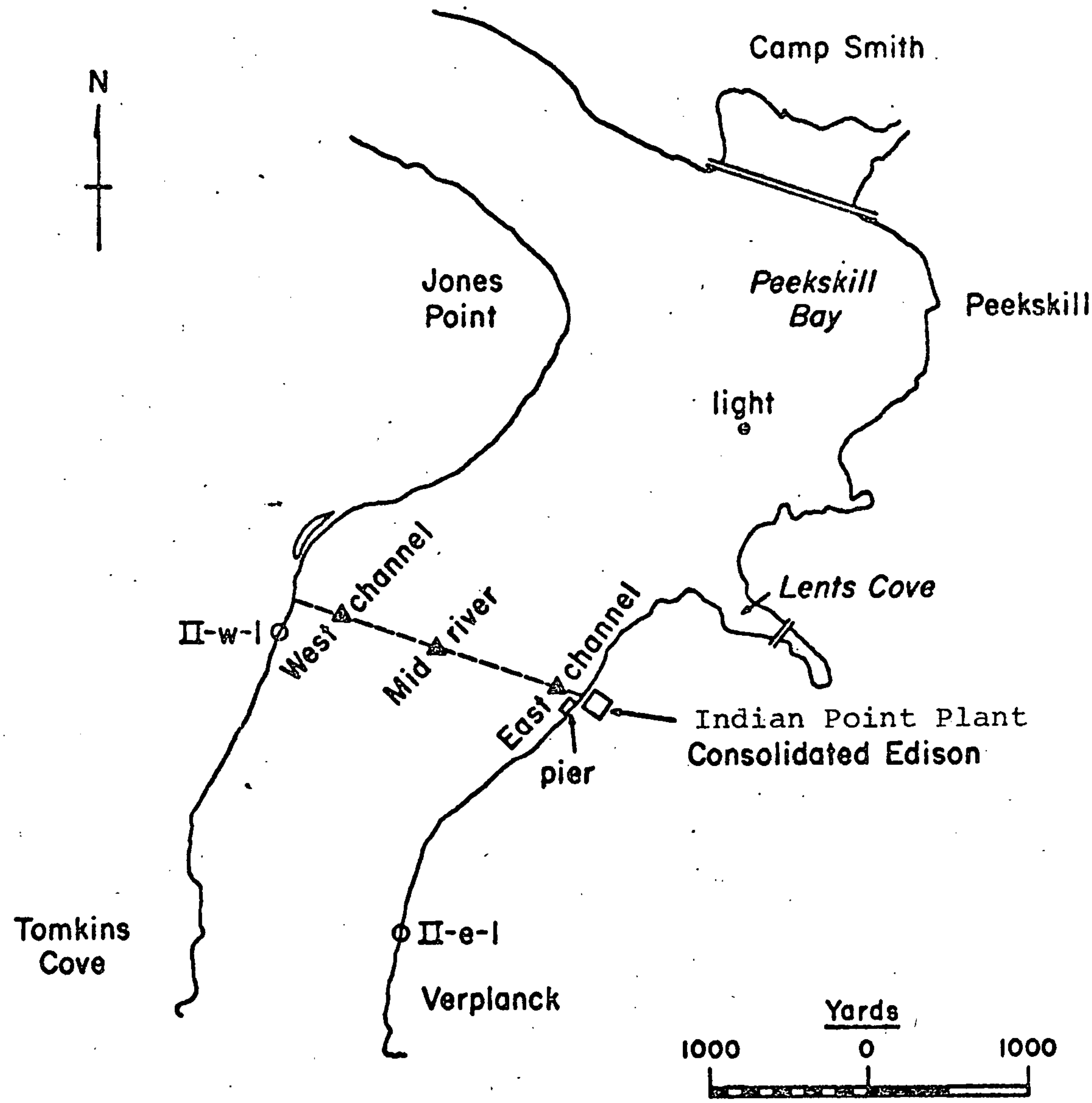
For field study at Indian Point three channel stations were established in a transect across the Estuary at mile 43. Two shore stations on either bank were also chosen, but because of physical restrictions did not correspond exactly with the channel transect (Fig. 1). Monthly collections of environmental data, and samples of water, mud, plankton, rooted plants and fish were made at these stations, with the exception of those months when the Estuary is ice-covered.

In the first half of the 3 year period of the study (1968-69) plankton was sampled by 10 meter depth hauls with a #20 net (aperture 76-80 μ). Counts of organisms were made according to a standard method (Ref. 3) with a Sedgwick-Rafter Cell at a 100 x magnification. Later samples were collected and analyzed by a different procedure (see below), which limits comparison of data between the years of the study. Although estimates for the second half of 1969 were based on samples collected in the same way, "observer difference" (using a higher magnification) led to an apparent discrepancy since more of the smaller organisms were recorded.

Channel Observations

Preliminary observations were that the phytoplankton is largely dominated by the diatom Melosira with Asterionella occasionally emerging as a secondary dominant form. The variety of species present in the samples changes with season and salinity. As the summer progresses and the water at

Fig. 1 INDIAN POINT TRANSECT, SITE LOCATIONS



Indian Point becomes more saline, more halophilic species replace limnetic species. At the same time, blue-green algae, almost never observed in winter months, become a more important constituent of the population. They were also found more consistently in shore collections than in channel samples.

The abundance of phytoplankton followed the usual seasonal pattern of increase in spring, with maximum abundance in early summer (Fig. 2).

Discharge Canal Observations

Observations of the variety and abundance of planktonic organisms in the discharge canal for Indian Point Unit 1 were made in 1968-69 (Ref. 4). This canal (now replaced by a longer canal to carry the combined discharge of 3 units) was about 50 yards in length. Temperature in the canal ranged from 5 to 18°F above ambient river temperatures. Plankton was collected at four sampling points along the canal.

Comparison of samples from the discharge canal with those from the intake and channel stations showed few significant differences in zooplankton and phytoplankton variety or abundance. Relative abundance and seasonal distribution of phytoplankton organisms were similar at the intake and discharge canal sites (Fig. 3). No change in species composition toward dominance by other forms such as blue-green algae was observed. During the period of phytoplankton observations the temperature of water in the discharge canal was 7-10°F above ambient river temperatures.

Species of zooplankton observed in the second half of 1968 in the discharge canal were similar to those found at the intake and in the main river (Table 1). Indeed, the canal fauna was found to have a somewhat greater variety of species, perhaps because it provided a more sheltered and pool-type environment than the main channel. Two species of copepod, Eurytemora hirundoides and Microarthridion littorale were found consistently in the discharge canal during the period of observation, even though they were not always sampled at the intake. However, these two copepods are known to be present throughout the year in the main body of the river at Indian Point, while other copepod species fluctuate with the seasonally changing salinity pattern in the river (Ref. 5). Some organisms, such as nematodes and Amnicola, were seen in the discharge canal, but not in the intake samples, although they had previously been recorded for shore collections. A number of fragile organisms (e.g. the medusa Blackfordia and the opossum shrimp, Neomysis mercedis) as well as several fish species were found actively swimming in the discharge canal. These species may have entered the canal directly from the river and not through the plant; because of the unknown contribution of organisms directly from the river into the discharge canal, as well as impending changes in the canal structure, these studies were discontinued.

During these studies temperatures in the discharge canal were from $5^{o}F$ (in July) to $18^{o}F$ (in December) above ambient

Figure 2
Phytoplankton Abundance
Indian Point, 1968-69
(mean of 3 channel stations)

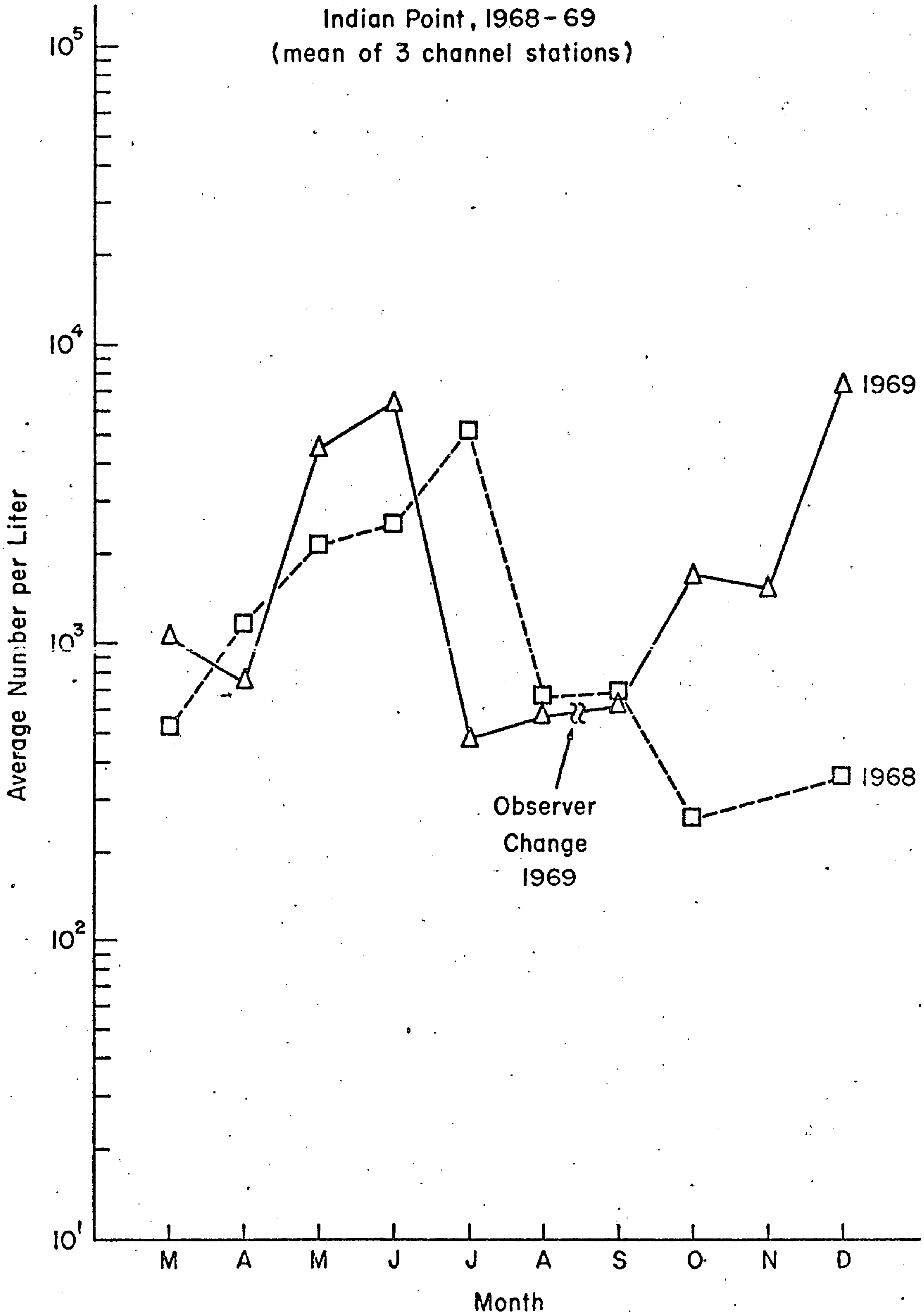


Fig. 3 Phytoplankton Abundance: Hudson River, 1968-1969 - Comparison with Heated Discharge Canal

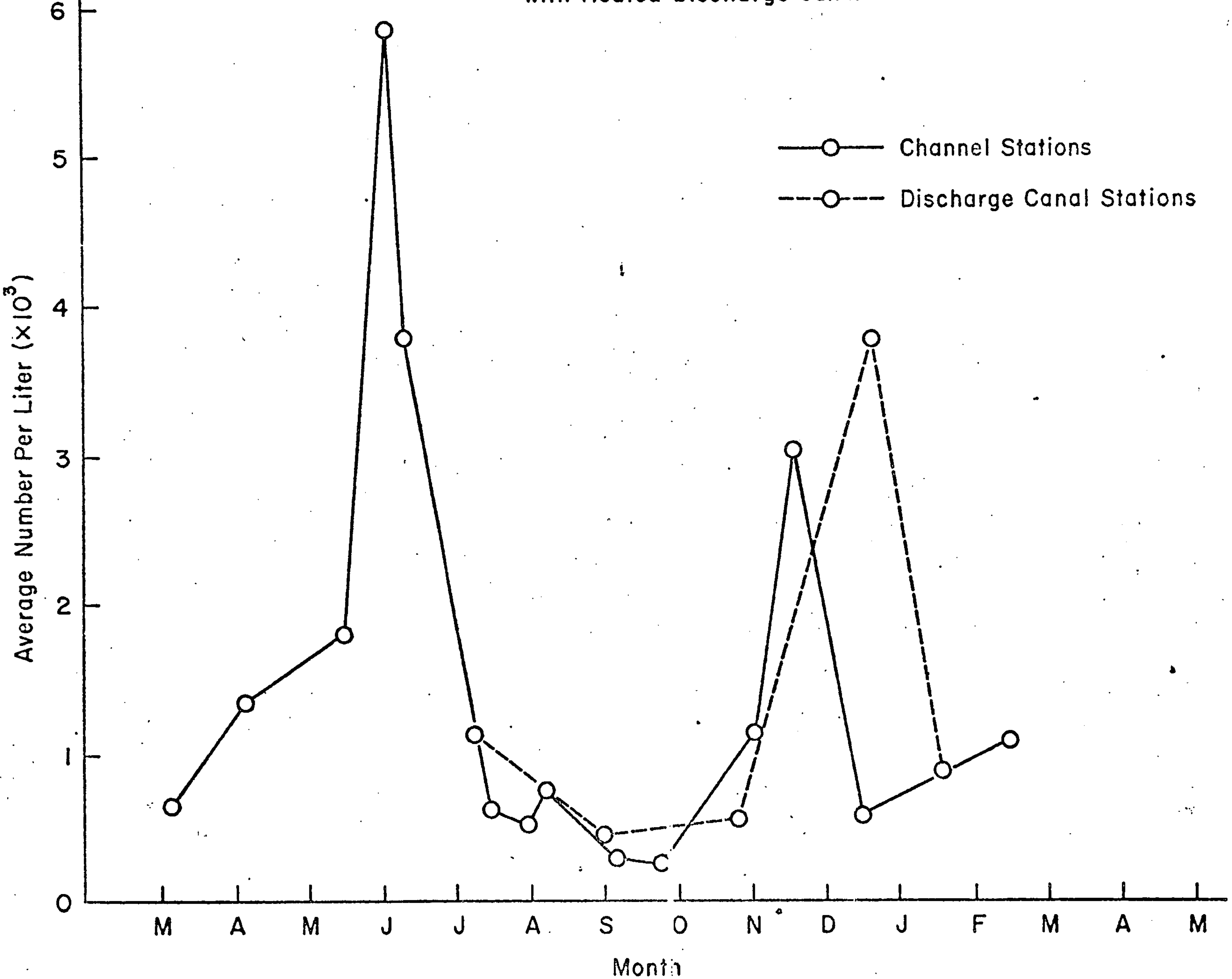


TABLE 1

OCCURRENCE OF SOME COMMON SPECIES OF ZOOPLANKTON IN THE INTAKE
AND DISCHARGE CANAL AT INDIAN POINT
(four collections, July - December, 1968)

	INTAKE			DISCHARGE		
Organism	Always	Sometime	Never	Always	Sometime	Never
Rotifers:						
Keratella quadrata		x				x
Keratella cochlearis		x			x	
Brachionus quadridentata			x		x	
Trichocerca sp.			x		x	
Kellicottia sp.		x				
Coelenterates						
Hydra oligactis		x				x
Blackfordia		x			x	
Nematoda			x		x	
Mollusca						
Amnicola			x		x	
Crustacea						
Daphnia pulex		x				x
Bosmina longirostris		x			x	
Leptodora kindtii		x			x	
Monoculoides edwardsii			x		x	
Neomysis mercedis		x			x	

TABLE 1 (contd)

Organism	INTAKE Always	INTAKE Sometime	INTAKE Never	DISCHARGE Always	DISCHARGE Sometime	DISCHARGE Never
Copepoda-nauplii		x			x	
Cyclops vernalis			x		x	
C. bicuspidatus		x			x	
Eurytemora hirundoides		x		x		
Microarthridion littorale				x		
Ectinosoma curticorne		x			x	
Acartia tonsa			x		x	
Canuella elongata		x			x	
Diaptomus sp.		x			x	

temperatures at the intake. Summer temperature at the intake generally ranges between 74°F and 77°F. Only on a few days does it go above 77°F.

SUBSEQUENT FIELD STUDIES

In the second half of the period of study (1970-71) attempts have been made to achieve better quantitative estimates of the variety and abundance of phytoplankton in the river at Indian Point, and to provide a comparison of channel sites for evaluation of the ecological effects of the discharge on the aquatic life in the river.

Methods

During 1970 and 1971 the phytoplankton samples were collected by passing a measured volume of river water (surface and 10 m depth) through a nannoplankton net (aperture size 16-20 μ). Samples were preserved with Acid-Lugol's Solution and aliquots were analyzed with gridded filter techniques at a magnification of 1250X. The counts treated each cell as a unit in the case of diatoms and those forms which could occur either as individual cells or in colonies, i.e. *Actinastrum* sp. and *Ankistrodesmus* sp. Colonial and filamentous green and blue-green algae were counted as a single unit per colony or filament. Only those cells, colonies, or filaments which appeared to have normally shaped and located chloroplasts, or coloration in the case of blue-greens, were counted (Ref. 6 p. 729).

Results

The composition of the phytoplankton throughout the study period was predominantly a "diatom assemblage" with other algal forms (greens and blue-greens) being a significant portion of the phytoplankton only from September to December. In 1970 for instance, diatoms were 69%, with greens 24%, and blue-greens 6%, contributing significantly to the flora in the latter part of the year (Table 2 and Fig. 4). Green and blue-green algae were slightly greater proportion of the phytoplankton at the east channel site than at the other two sites.

Shannon-Weaver (Ref. 9) diversity indices for the 1970 phytoplankton data show a trend of decreasing diversity during later summer and early fall at all three channel sites, but within any month there was very little variation (Table 3). Mean diversity indices for 1970 at each channel, mid-river, and west channel sites were 2.1, 2.1, 2.0 respectively.

Comparison of data for the 3 channel stations in the river indicate only insignificant differences in phytoplankton abundance at these sites (Fig. 5). Those differences observed between stations can be attributed to sampling differences (due to variable currents or other factors), and to the discontinuous distribution of plankton within a water body. (Note that the order of magnitude difference between 1969 and 1970 data is due to a change in technique - see page 13 above).

Samples of plankton at the two shore stations are not strictly comparable on a quantitative basis, partly because sampling in the shallow water close to shore inevitably disturbs bottom sediments, and partly because the presence of emergent plants and the bottom muds provide an increased

TABLE 2

PHYTOPLANKTON COMPOSITION AT INDIAN POINT
PERCENTAGE COMPOSITION BY MONTH

	April	May	June	July	August	September	October	November	December	Average
East Channel										
Diatoms	88.9	97.5	98.8	96.9	92.5	46.2	7.2	44.7	41.9	68.28
Greens	10.6	2.6	1.2	3.1	6.1	41.0	55.8	44.2	54.8	24.35
Blue-greens					1.5	12.9	35.7	9.9	3.0	6.99
Desmids								0.7	0.2	0.09
Other	0.5						1.4	0.7	0.2	0.31
Mid-River										
Diatoms	85.4	97.2	97.6	95.5	95.6	59.3	19.1	35.1	38.3	69.23
Greens	13.2	2.7	2.4	3.9	3.9	29.5	55.2	48.6	51.7	23.45
Blue-greens	0.3	0.1		0.6	0.5	9.9	25.8	16.3	7.7	6.80
Desmids									1.9	0.21
Other	1.1					1.3			0.5	0.32
West Channel										
Diatoms	85.6	98.0	96.9	95.6	97.0	71.4	17.3	32.6	64.4	73.17
Greens	12.3	1.8	3.1	4.4	2.3	23.6	59.5	59.3	33.2	22.16
Blue-greens	0.8	0.2			1.8	5.0	23.3	8.1	2.2	4.57
Desmids	0.4									0.05
Other	0.8								0.3	0.12

Figure 4 Relative Proportions of Diatoms, Green and Blue green Algae in the Standing Crop at Indian Point, 1970 (East Channel Station)

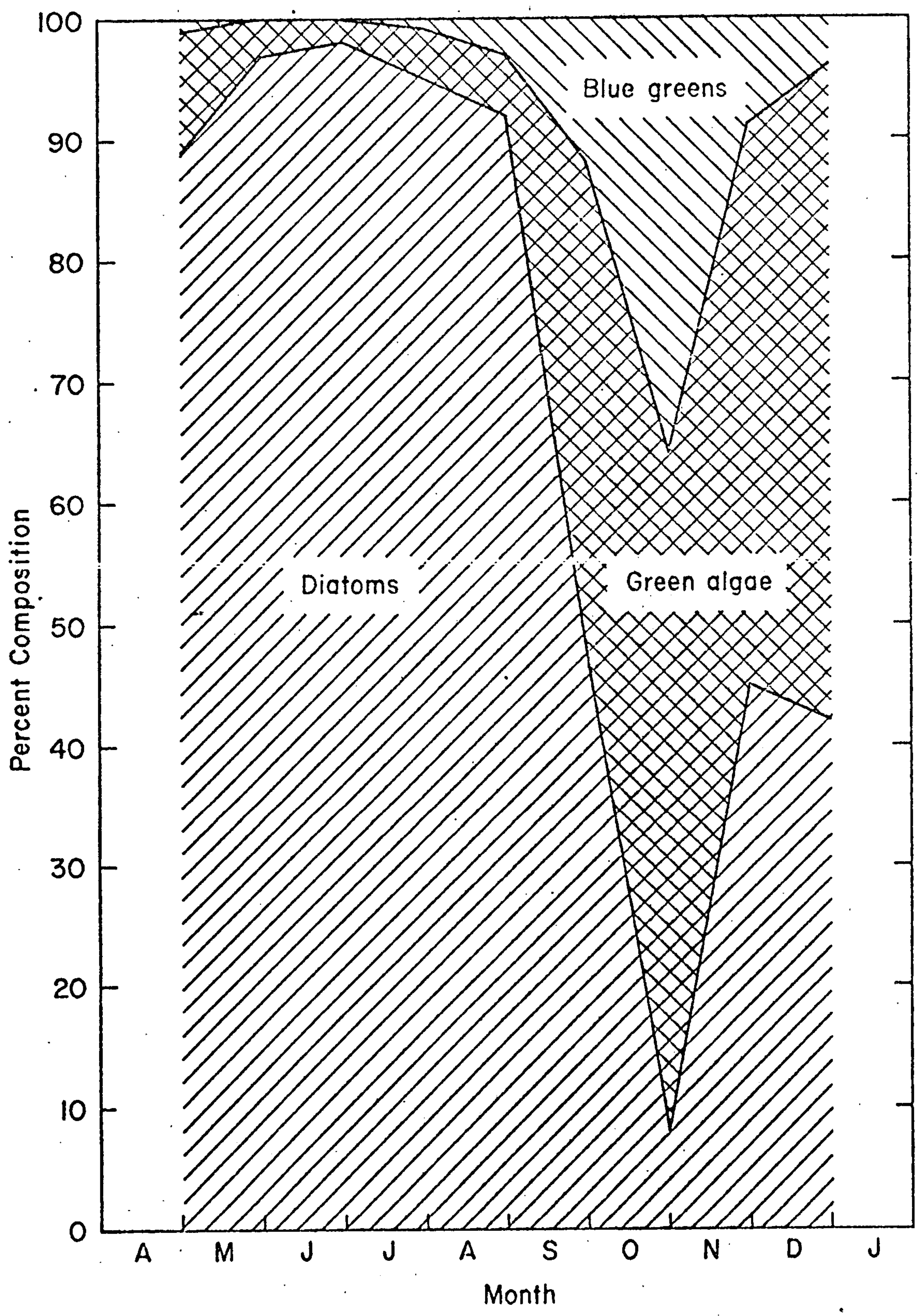
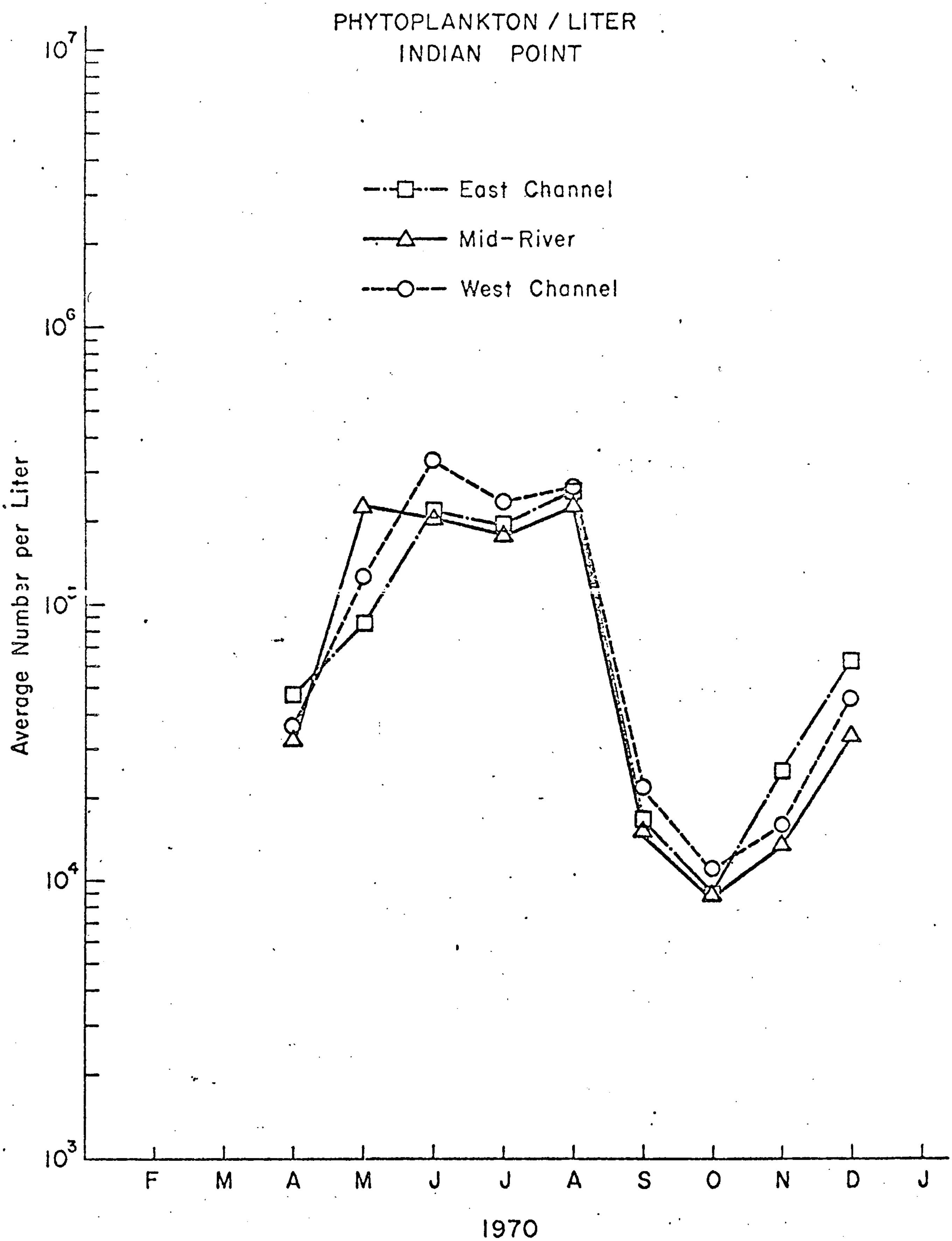


TABLE 3

PHYTOPLANKTON DIVERSITY HUDSON RIVER
AT INDIAN POINT, 1970

Month	DIVERSITY INDEX East Channel	Mid River	West Channel
April	2.73	2.73	2.76
May	2.76	2.56	2.92
June	2.80	2.60	2.62
July	2.80	1.68	1.64
August	1.77	1.29	1.34
September	1.40	1.47	1.04
October	1.82	2.01	1.84
November	1.91	2.17	1.59
December	2.14	2.43	2.45
Average	2.12	2.11	2.02

Figure 5



PHYTOPLANKTON / LITER
INDIAN POINT
East Channel
Mid-River
West Channel
Average Number per Liter
10^7
10^6
10^4
10^3
F
M
A
M
J
J
A
S
O
N
D
J
1970

substrate area for epiphyton. The shore samples, however, exhibit a similar composition and June/July peak of abundance as the channel samples. The range of abundance is somewhat greater (due to the reasons given above) from about $10^4/m^3$ early in spring, to 10^6 or more/m^3 in early summer.

STUDIES IN 1971
LABORATORY ENTRAINMENT STUDIES

A number of experimental laboratory studies was undertaken to elucidate further the effect of passage through the power station condensers on a variety of organisms.

Bacterial Studies

Experimental heat exposures were designed to match the temperature regime and exposure times expected during plant operation. When no effects were observed, ΔT was raised and exposure times lengthened beyond those normally expected. Samples for culture were taken from the intake water at the power station. Two liter flasks were left in the flow for 10 to 15 minutes; full flasks were stirred for a further period and then 100-150 ml samples were transferred to BOD bottles for exposure to experimental temperatures.

Bacteriological procedures (Membrane Filter Method) were those recommended in "Standard Methods" (Ref. 6 p. 678). These methods call for incubation at 35° C (95°F) incubation temperature, representing a 20-hour exposure to a temperature more than 35°C (63°F) above the temperature of collection (0°C = 32°F). This increased temperature and exposure time required by the culture technique far exceeds the scale and duration of the thermal rise to which the bacteria are exposed during passage through the Indian Point plants.

To more closely simulate customary events within the plant, cultures were incubated at 4°C (39°F) for varying periods before incubation in the standard conditions, while others were treated only in accordance with the "Standard Methods" procedure. Samples incubated initially at the lower temperature were examined over periods of one to seven days for visible signs of growth. However, none was observed at this temperature. After subsequent incubation for 20 hours at 35°C (95°F), colonies were counted and compared with those of samples subjected only to the higher temperature. No differences due to the different incubation techniques could be seen.

A second experimental procedure exposed intake samples to different regimes of temperature increment and exposure time from 4 to 22°C (7 to 40°F) and 2½ to 30 minutes. Both total coliform and total bacterial colonies were counted (Tables 4 and 5) and were compared with control cultures not exposed to any additional heat procedures. Not surprisingly (since heat exposures in the experimental regime were less than those dictated by the technique) a wide range of values was observed and no consistent pattern relating exposures to counts could be detected for either total coliforms or total bacteria.

A further experiment exposed samples to a range of temperatures 22-44°C (40-80°F) above the ambient of 32°F for periods of 10, 20 and 30 minutes.

TABLE 4

TOTAL BACTERIAL COUNTS AFTER EXPERIMENTAL HEAT EXPOSURE

Ambient Temperature 32°F
Control counts 8,300/ml, range 3,850-17,700/ml(6).
Single samples except where range and numbers of samples (bracketed) are given.

Exposure Time (mins)	Means and range of percent change from controls at temperature (°F) above ambient 7	15	22	28	33	40
2½	+19 0to40 (3)	+19 4to40 (4)	+14	+30 -10to98 (3)	+28 -23to115 (3)	-11
5	+21	+2 -3to8 (2)	0	-8	-21	-10
10	+12	+3	-37	-15	-22	-13
15	+3	-6	-7	-37	11	+13
20		-5	-9	-37	-13	-20 -15to-24 (2)
25		-14	-18	-24	-22	+20
30			-15	-24	0	+12 -40to+65 (2)
Mean % Change	+16	+6	-10	-7	0	0

TABLE 5

TOTAL COLIFORM COUNTS AFTER EXPERIMENTAL HEAT EXPOSURE

Ambient Temperature 32°F
Control counts 52/ml, range 27-71 (6)
Single samples except where range and numbers of samples (bracketed) are given.

Exposure Time (mins)	Means and range of percent change from controls at temperature (°F) above ambient: 7	15	22	28	33	40
2½	+4 -30to41 (3)	-9 -29to19 (4)	-5	+18 9to28 (3)	-7 -29to11 (3)	-26
5	+10 9.8to10.3 (2)	+16 -7to38 (2)	-12	-12	-9	-22
10	-7	-5	+8	-15	-10	-4 -15to8 (2)
15	-2	-5	-10	-21	-8	-8
25	-	-44	+18	+5	-5	-15
30			0	-13	-5	-2
Mean % Change	+3	-9	+2	-2	-8	-10

A summary of the protocol of these experiments and the results for coliform cultures are shown in Table 6 and Fig. 6. Total bacterial counts showed a slight trend of decreasing numbers with increasing exposure temperatures while coliform counts demonstrated more clearly a decrease of approximately 10 colonies for each additional 5.5^{o}C (10^{o}F) rise in exposure temperature from 22-39^{o}C (40 to 70^{o}F). With exposure to an 44^{o}C (80^{o}F) rise, the number of coliform colonies dropped sharply. There appears to be no consistent effect of temperature with differing exposure periods.

Thermal entrainment studies on bacteria in a similar manner to the studies performed during Jan. Feb. 1971, were performed during July, Aug. and Sept. 1971 when the ambient river temperature ranged from 74^{o}F to 76^{o}F. The results of these warm weather studies have shown that total bacterial counts were reduced in number by 25% or greater, when the ΔT was 30^{o}F for an exposure time of 15 minutes or longer and at a ΔT of 40^{o}F at an exposure time of 5 minutes or longer. The total bacterial counts were apparently unaffected by a ΔT of 20^{o}F for an exposure time as long as 45 minutes and for a 5 minute exposure time to a ΔT of 30^{o}F.

The total coliform counts as determined by these warm-weather studies were apparently unaffected by temperature increases up to 30^{o}F for exposure times as long as 45 minutes and at a ΔT for 40^{o}F for an exposure time of 5 minutes. Only when the ΔT of 40^{o}F was applied for 15 minutes or longer were the total coliform counts affected, reduced by 25% or greater.

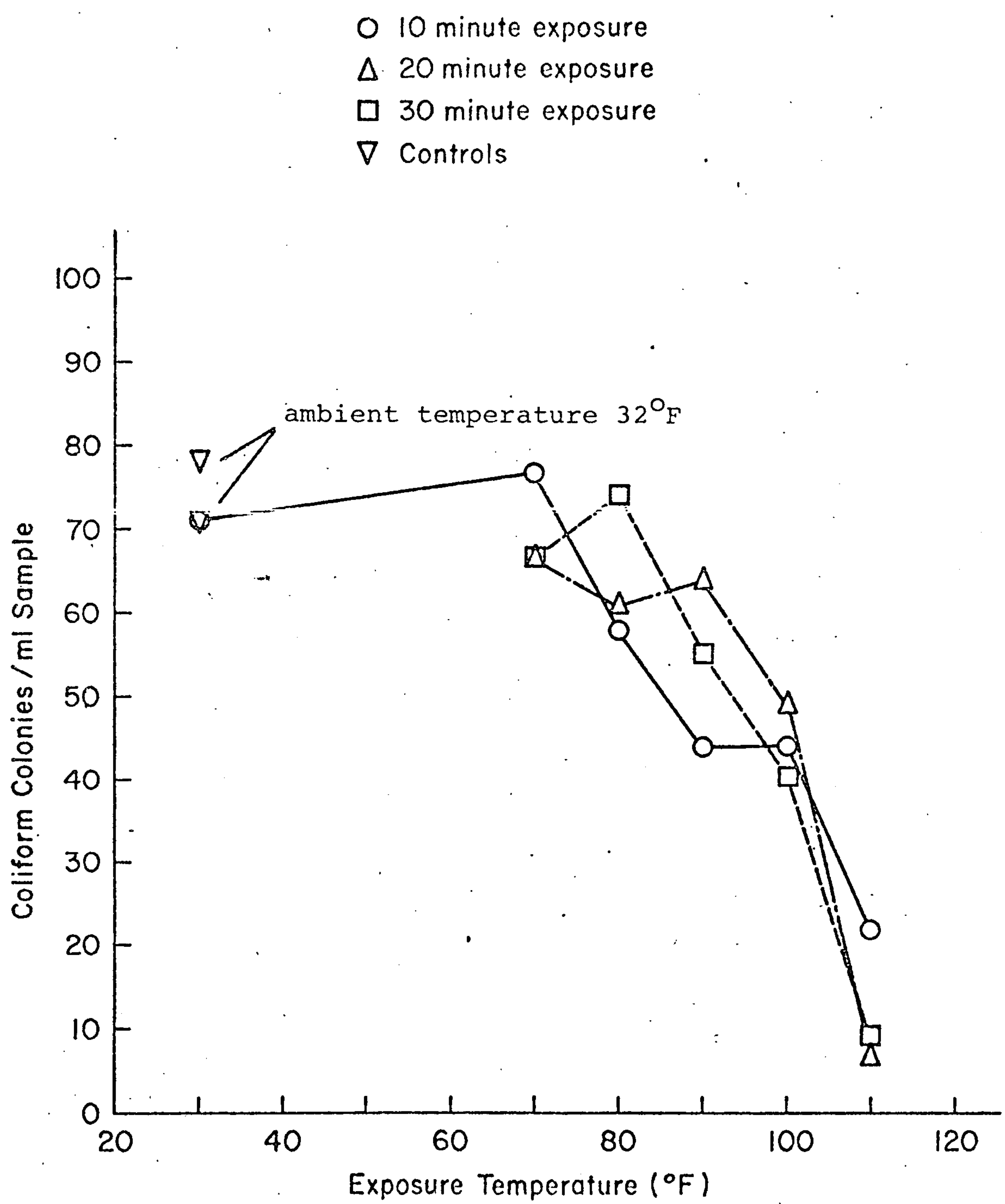
TABLE 6

TOTAL COLIFORM COUNTS AFTER EXTREME HEAT EXPOSURE (incubated 24 hr. at 39°F and 20 hr. at 95°F).

Ambient Temperature 32°F
Control samples incubated at 95°F (20 hr.) 78/ml
Control samples incubated at 39 and 95 (24 and 20 hr.) 71/ml

Exposure Time (mins)	Coliform colonies/ml Exposure Temperature, °F above ambient 40	50	60	70	80
10	77	58	44	44	22
20	66	61	64	49	7
30	67	74	55	40	9
Mean	70	64	54	44	13

Figure 6 Effect of High Temperature Exposure to Coliform Counts



PHYTOPLANKTON

(a) Effects of turbulence

During December 1970, the Indian Point 1 plant was not operating for power production but operation of the circulating pumps alone allowed us to determine visually the extent of any mechanical damage to the flora. Samples were collected from the intake and discharge canal every two hours. The samples were analyzed for physical breakage and chloroplast dislocation in the diatom frustules. The results do not indicate any substantical physical damage to diatom cells being pumped through the plant. The mean values for damaged specimens in the intake samples was 23.6% of the total, and 21.2% in the effluent samples (Table 7).

(b) Effects of heat determined by visual damage

Phytoplankton samples were collected from the intake composited, and subdivided into equal portions of which six served as controls. The other samples were exposed to increments of temperature of 8.3, 12.2, 15.5, 19.4 and 23.3^{o}C (15, 22, 28 35 and 42^{o}F) for periods of 2.5, 30 and 60 minutes. After exposure the samples were quickly cooled to ambient river temperature (4^{o}C = 39^{o}F) at which they remained for 1.5 hours before being preserved with Lugol's solution. The results (Table 8) do not indicate that increments of 15.5^{o}C (28^{o}F) above the ambient 4^{o}C (39^{o}F) for as long as 60 minutes, or of 19.4 to 23.3^{o}C (35 to 42^{o}F) above ambient for 30 minutes, have any effects that can be detected visually.

TABLE 7

DAMAGED DIATOMS OBSERVED IN INTAKE AND EFFLUENT WATER AT INDIAN POINT, WITHOUT TEMPERATURE INCREMENT

Sampling Date	Time	Percent of Damaged Specimens Intake	Effluent
12/8/70	09.00	22	32
	11.00	23	13
	13.00	32	24
	15.00	30	25
	17.00	20	18
	19.00	20	21
12/9/70	09.00	14	14
	11.00	39	24
	13.00	20	23
	15.00	22	20
	17.00	18	20
Means		23.6 ± 7.2	21.2 ± 5.3

(c) Effect as measured by C^{14} uptake

The effect of temperature on primary productivity depends on the seasonal ambient river temperature, and the duration of exposure.

During the Spring period with cooler temperatures (34 - 45)^{o}F there is an increase in the amount of photosynthesis in waters which have received a ΔT of (28 - 35)^{o}F for exposures of 5-25 minutes. However, when exposed to a ΔT of 40^{o}F for 40 minutes exposure, the amount of metabolic productivity was observed to decrease.

In the summer season with a temperature range of (79-80)^{o}F the system was much more sensitive. Exposure to a ΔT of (15-21.5^{o}) still increased photosynthesis, but only very slightly. At a 25^{o} ΔT there was no net effect; but ΔT's above this caused a deerease in photosynthesis.

Exposure to temperature elevations of 6^{o} and 10^{o} during passage through the plant in slightly cooler weather caused no net change in the normal phytosynthetic rate. (Table 9)

Microzooplankton (rotifers, copepods, cladocerans)

The paucity of zooplankton during early spring in 1971 required the filtration of large volumes of water to obtain a sufficient number of organisms for laboratory tests. Damage by the heavy accumulation of debris in the nets made the acquisition and identification of healthy specimens difficult. Samples were collected from the intake stream at Indian Point.

A common zooplankter from the Hudson River at Indian Point, the cyclopoid copepod, Halicyclops sp. was exposed

TABLE 8

DAMAGED DIATOMS AFTER HEAT EXPOSURE

Ambient Temperature 39°F
Percent damaged in control samples 39% ± 8.2(6)

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

Table 9

Laboratory Thermal Shock. Entrainment effects on Phytoplankton Photosynthesis.

Date	Ambient °F	ΔT °F	Temp. after heating	Exp. Time	Change in C^{14} uptake
3/23/71	34	35	69	15 min.	increase
3/24/71	34	28	62	25 min.	increase
	34	40	74	40 min.	decrease
4/15/71	45	28	73	5 min.	increase
	45	28	73	10 min.	increase
	45	28	73	15 min.	increase
	45	28	73	20 min.	increase
8/18/71	80	15	95	30 min.	small increase
8/12/71	79	21.5	100.5	30 min.	small increase
8/11/71	80	25	105	30 min.	no effect
8/9/71	79	26	105	30 min.	small decrease
8/11/71	80	28	108	30 min.	decrease
8/3/71	79	31	110	30 min.	decrease
			Con Ed Indian Point T (1)		
9/27/71	70	6	76		no change
9/27/71	70	10	80		no change

(1) Samples from water box of Unit 1

to temperature increments of 6.1, 15.5, 19.4 and 23.3°C (11, 22, 28, 35, and 42°F) above an ambient river temperature of 48°F for periods, of 2.5, 5, 10, 20, 30, 40, 50, and 60 minutes. The samples were then quickly cooled to ambient river temperature at which they remained for 1.5 hours. Numbers of dead organisms were recorded for each sample before the addition of any heat, immediately after the addition of heat, and after the 1.5 hours at ambient temperature. The samples were then preserved with a 10% formalin solution and the total number of organisms was observed and recorded. The percentage of motile specimens after return to ambient temperature is shown in Table 10.

Temperature increments as high as 15.5°C (28°F) above the ambient river temperature of 10°C (48°F) for as long as 60 minutes of exposure had no effect on short term survival. While temperature increments of 19.4°C (35°C) for 30 minutes appeared to have no effect, an increment of 23.3°C (42°F) reduced survival to 30% after an exposure of only 2.5 minutes; as the exposure time increased to 30 minutes at this temperature the survival rate decreased to zero.

Whereas the copepod (<u>Halicyclops</u>) survival was 100 percent at ΔT's up to 35°F in the spring when the ambient temperature was 48°F, there is less safety margin in the summer. Survival at a 12.6°F ΔT above the ambient 77°F, projected to from the laboratory studies, is ≈98 to 88% depending on the exposure time (Table 11). At a 15°F ΔT above the ambient of 77°F survival is projected to be ≈86 to 76% depending upon the exposure time (Figure 7).

TABLE 10

EFFECT OF TEMPERATURE INCREMENTS ON SHORT TERM SURVIVAL OF *Halicyclops sp*.

Ambient temperature 48^{o}F
Numbers of organisms/test are bracketed.

Exposure Time (mins)	Percent survival: Temperature (^{o}F) above ambient 11	22	28	35	42
2½	95(20)	100(25)	100(14)	100(21)	30(17)
5	100(15)	100(28)	100(21)	70(20)	19(11)
10	100(19)	92(25)	100(20)	100(26)	6(18)
20	96(41)	100(24)	100(19)	82(38)	5(20)
30	100(15)	100(20)	100(20)	98(40)	0(14)
40	85(19)	100(19)	100(25)		
50	100(18)	86(21)	100(50)		
60	100(13)	100(25)	89(26)		
Controls: No temperature increment					
60	100(14)	100(19)	100(70) 100(11)	100(18) 100(23)	100(15) 100(10)

Figure 7

Halicyclops Survival

Laboratory Thermal Shock Studies

Ambient Temperature = 77°F.

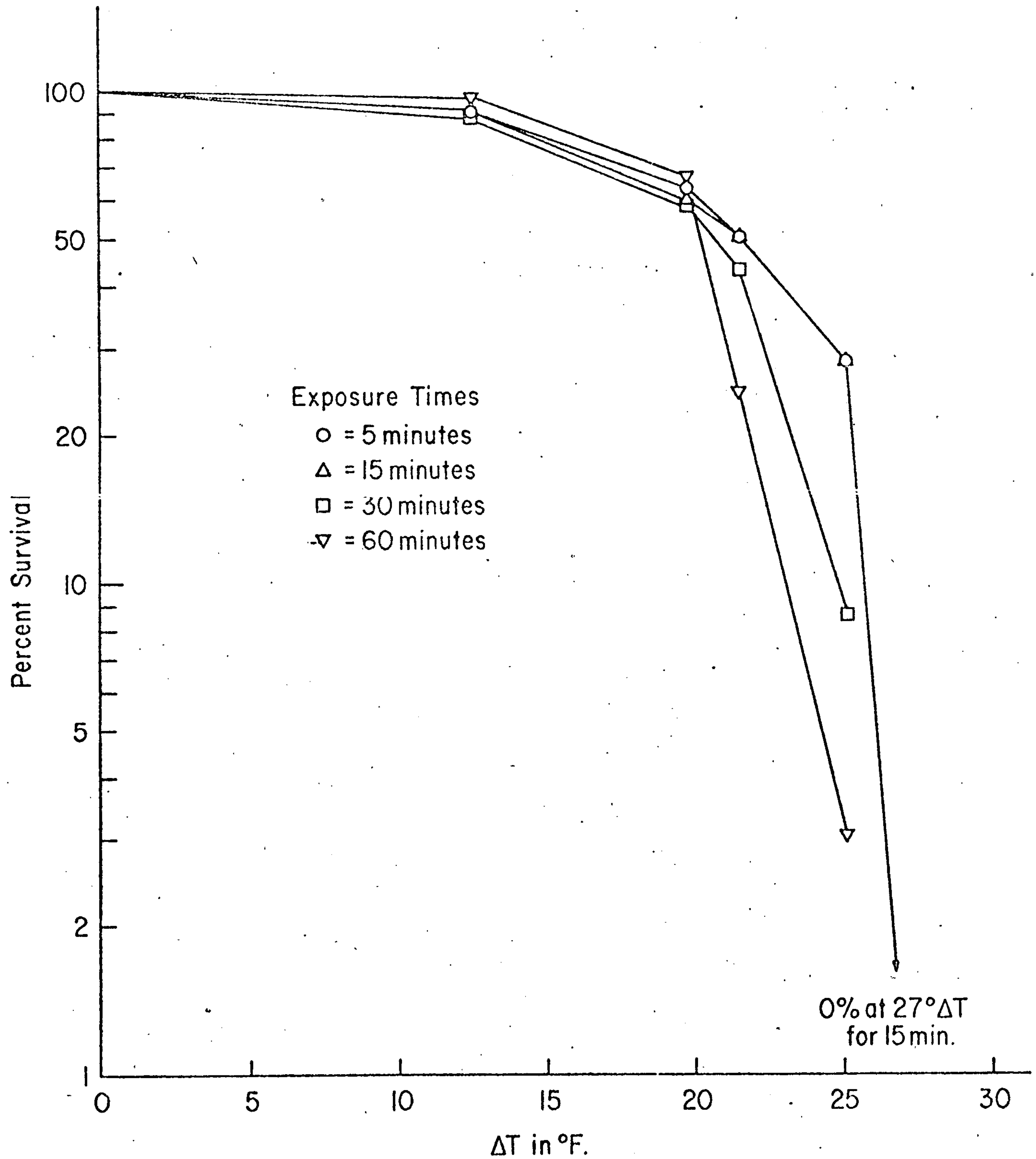


Table 11-Laboratory Shock Studies

Halicyclops at ambient temperature of 77°F.

Temp. °C	°F	% Survival* at Exposure times of: 5 min.	15 min.	25 min.	30 min.	60 min.	Controls (ambient temp. of 60 min.)
7	12.6	90.8 ± 7.7	91.5 ± 3.4	100 ± 0	88.0 ± 7.5	96.7 ± 4.1	97.6 ± 2.7
11	19.8	63.8 ± 12.2	59.3 ± 15.5		58.3 ± 10.1	66.3 ± 13.4	95.0 ± 2.4
12	21.6	49.8 ± 15.0	50 ± 15.5		42.8 ± 15.2	24.0 ± 9.9	96.3 ± 2.6
14	25.2	27.7 ± 22.8	27 ± 7	37.5 ± 53.0	8.5 ± 12.0	3 ± 4.2	87.7 ± 8.9
15	27.0		0 ± 0				100 ± 0
17	30.6		0 ± 0				100 ± 0

* Numbers in parenthesis = No. of Experiments done.

It is highly unlikely that populations of the organisms in the Hudson River would be altered significantly if these projected mortality levels of microzooplankton species such as the copepod Halicyclops were to occur during passage through the plant. The literature indicates that up to 100% mortality of copepods during passage through power plants sited on large bodies of water have had no significant effect on populations in those waters, even in the vicinity of the plants. Fast turn-over rates, surplus reproductive capacity, and other as yet undertermined compensatory mechanisms have been given as possible explanations for these observations.

Studies of these populations in the Hudson are being continued. Included are studies to determine generation times and turn-over rates.

Daphnia pulex, another organism endemic to the area and collected from the intake stream, was subjected to temperature increments and observed for effects on survival and reproduction. The results are summarized in Table 12.

The tests indicate that temperature increments as high as 21.7°C (39°F) above the ambient (68-79°F) have little observable effect on the survival and reproduction of Daphnia pulex if the increased temperature is reached and maintained for less than one minute. However, a lower temperature increment (14.4°C = 26°F) applied for a longer period (4.5 to 6 minutes) resulted in total mortality of the Daphnia. A ΔT of 17°F for 30 minutes (compared to the 15°F ΔT of the plant at the time of critical summer ambient temperature) caused no no mortality. In a number of experiments, specimens increased

TABLE 12

EFFECT OF TEMPERATURE INCREMENTS ON LONG AND SHORT TERM SURVIVAL OF *Daphnia pulex*

Ambient temperature 68-79°F
Animals in each test 10±1

Temperature increment °F	Minutes to reach higher T	Exposure Time (min)	PERCENT SURVIVAL Initial	1 day	1 week	Re-productio
7	-	30	100	100	75	7 days
7	-	30	100	100	90	7 days
11	0.42	0.25	100	100		3 days
11	0.42	0.25	100	100	50	4 days
17	4.0	30	90			
17	4.0	30	100	100	78	
22	0.33	0.25	100	100	56	2 days
22	0.33	0.25	100	100		3 days
26	4.0	2.0	0			
26	3.5	1	0		40	
36	0.42	0.33	100	100		1 day
39	0.42	0.33	100	90		1 day

in motility as temperature increased. Another effect of temperature increments was to reduce reproduction time with higher temperature increments.

Similar experiments with unidentified ostracods collected from the intake stream have indicated that they are able to survive a temperature increment of 17°C (29°F) for 30 minute exposure (from an ambient temperature of 23.9°C = 75°F). However, survival following a temperature increment of 17.8°C (32°F) for 30 minutes was only 54% and 20% in two tests.

Macrozooplankton

The results of laboratory thermal shock studies on the *Gammarus* are summarized in Table 13 and Figures 8 through 10. *Gammarus* survival was 100% at ΔT's up to 43°F above an ambient of 45°F, whereas at a summer-time ambient of 78°F *Gammarus* survival was 100% at ΔT's up to 18°F.

INTAKE-DISCHARGE CANAL SURVIVAL STUDIES

Microzooplankton

Micro-zooplankton entrainment studies results during the high ambient temperature summer season are summarized in a preliminary fashion in Table 14. There is no indication of significant decreased survival in the discharge canal samples compared to samples from the intake.

Macrozooplankton

The percent live *Gammarus* and *Neomysis* in samples from the discharge canal near its emergence from Unit 1 (Discharge I) and from the far end of the discharge canal near the dis-

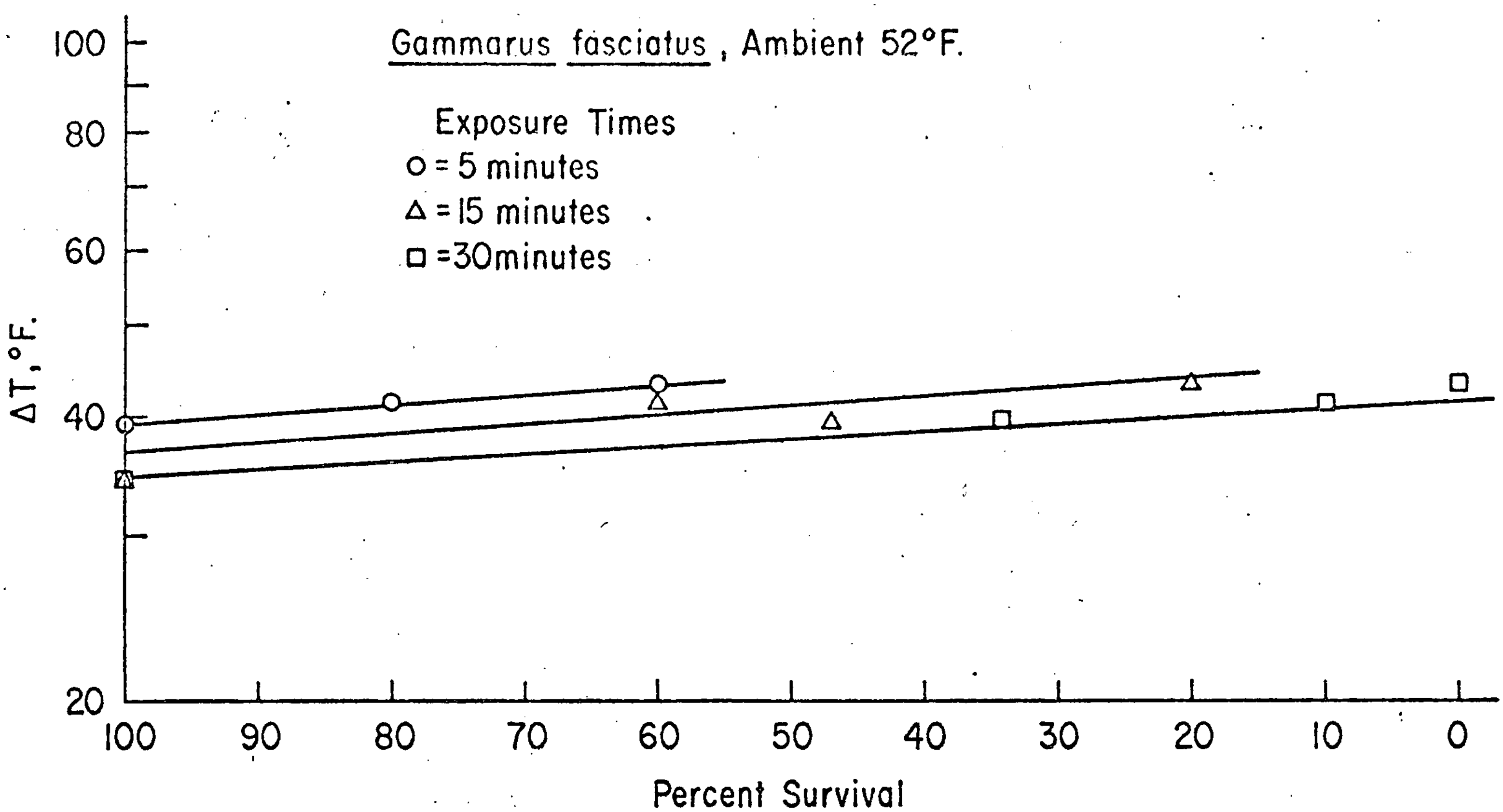
Table 13 - Laboratory Thermal Shock Studies

Gammarus at ambient temperature of 73.4 - 78.8.

Temp. ^{0}C	^{0}F	% Survival* at Exposure times of: 5 min.	15 min.	25 min.	30 min.	60 min.	Controls (ambient temp. of 60 min.)
6	10.8	100	100		100	95 ± 1.6	100 ± 0
7	12.6	100	100	100	100	100	100 ± 0
10	18.0	99 ± 1	96.3 ± 2.4	100 ± 0	95.1 ± 1.8	100	100 ± 0
11	19.8	85 ± 10	79 ± 12		62.2 ± 13.3	57.7 ± 11.2	98.0 ± .8
12	21.6	72.3 ± 12.8	63.2 ± 13.3		48.8 ± 12.8	45.0 ± 13.7	98.0 ± .8
13	23.4	43.1 ± 13.0	15.7 ± 4.9		.5 ± .5	0 ± 0	100 ± 0
14	25.2	47.0 ± 14.1	15.0 ± 8.4		0 ± 0	0 ± 0	100 ± 0
15	27.0	.4 ± 3.2	0 ± 0		0 ± 0	0 ± 0	100 ± 0
17	30.6	0 ± 0	0 ± 0				100 ± 0

*Numbers in parenthesis = No. of Experiments done.

FIGURE 8


Gammarus fasciatus, Ambient 52°F.
Exposure Times
○ = 5 minutes
△ = 15 minutes
□ = 30minutes
ΔT, °F.
100
80
60
40
20
100
90
80
70
60
50
40
30
20
10
0
Percent Survival

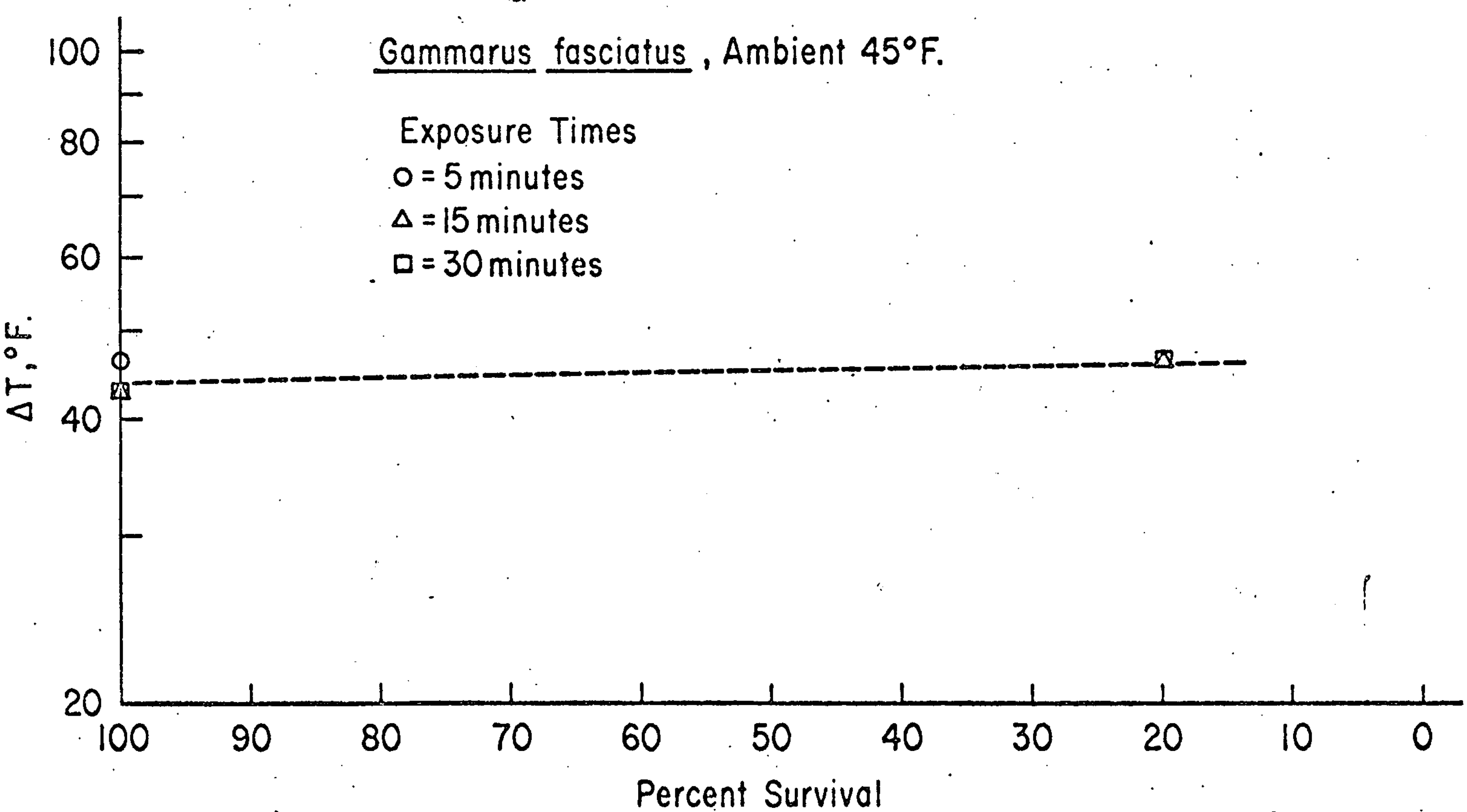
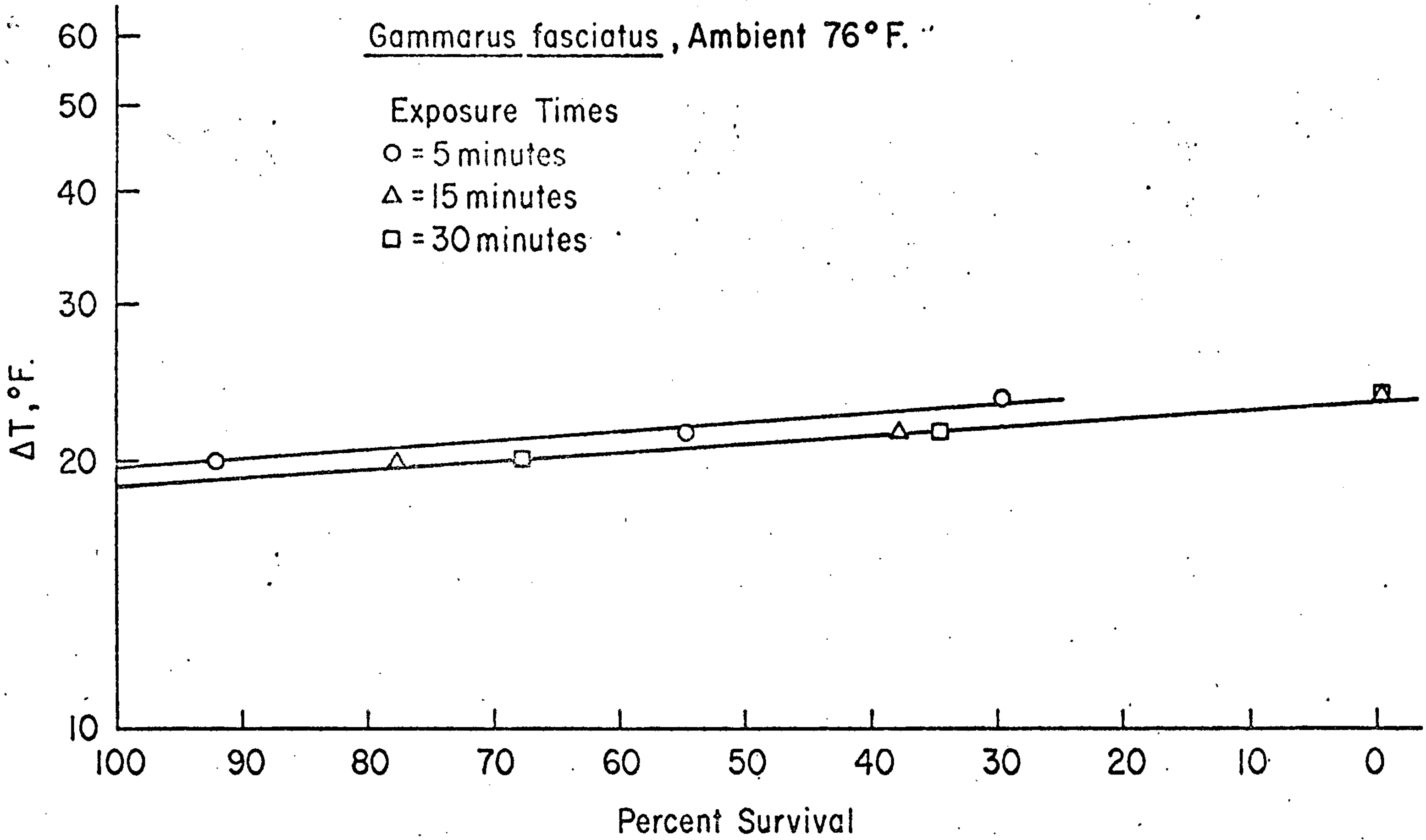

Gammarus fasciatus, Ambient 45°F.
Exposure Times
○ = 5 minutes
△ = 15 minutes
□ = 30 minutes
ΔT, °F.
100
80
60
40
20
100
90
80
70
60
50
40
30
20
10
0
Percent Survival

FIGURE 9


Gammarus fasciatus, Ambient 76° F.
Exposure Times
○ = 5 minutes
△ = 15 minutes
□ = 30 minutes
ΔT, °F.
60
50
40
30
20
10
100
90
80
70
60
50
40
30
20
10
0
Percent Survival

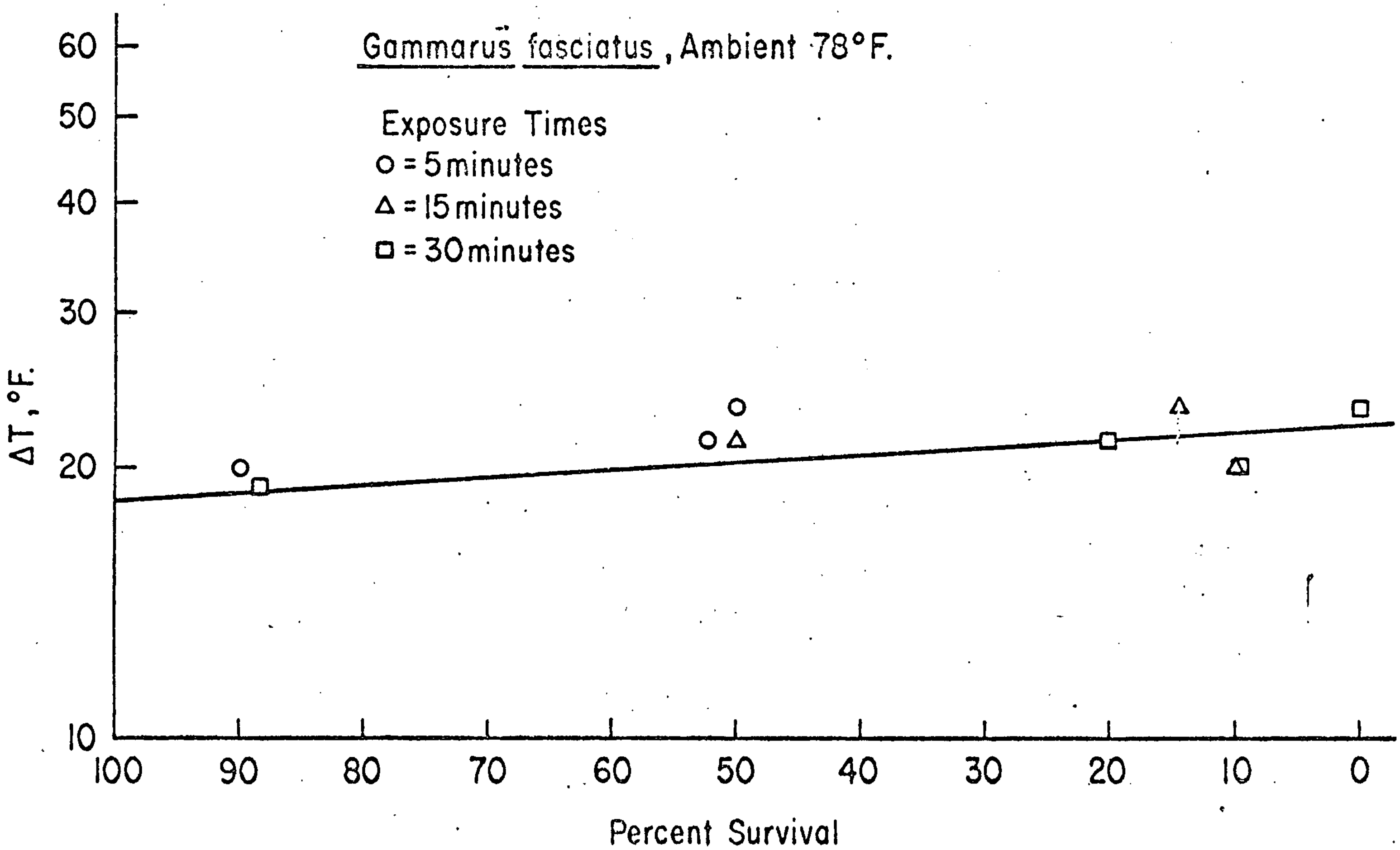

Gammarus fasciatus, Ambient 78° F.
Exposure Times
○ = 5 minutes
△ = 15 minutes
□ = 30 minutes
ΔT, °F.
60
50
40
30
20
10
100
90
80
70
60
50
40
30
20
10
0
Percent Survival

Figure 10

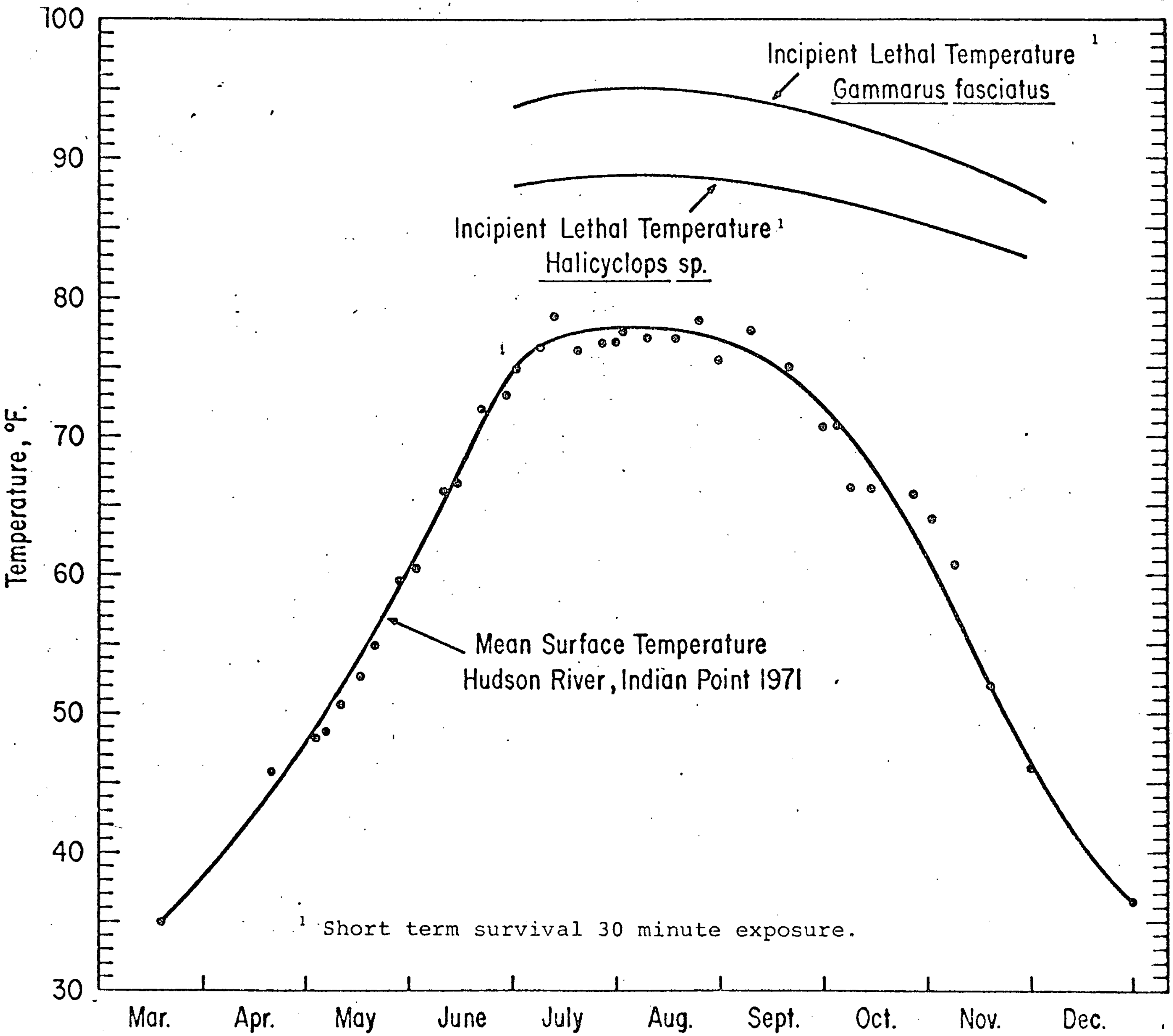

Incipient Lethal Temperature[1]
Gammarus fasciatus
Incipient Lethal Temperature[1]
Halicyclops sp.
Mean Surface Temperature
Hudson River, Indian Point 1971
[1] Short term survival 30 minute exposure.
Temperature, °F.
100
90
80
70
60
50
40
30
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

TABLE 14

MICRO-ZOOPLANKTON (rotifers, copepods, cladocerans)

INTAKE AND DISCHARGE CANAL PUMPED SAMPLES

	Temperature		# of	% Survival	
	Ambient	ΔT	Obs.	Intake	Discharge
June	66-73°F	4.7-10.3	10	70.4	73.0
July	73-78	1.2-10.3	10	71.1	56.2
Aug.	78-74	2.4-9.5	10	49.1	45.1
Sept.	77-75	1.4-11.1	12	28.1	49.3
Total	66-78°F	3.4.2-52.0	42	53.6	55.6

charge ports to the river (Discharge II) were virtually identical to the percent found alive in the intake samples (Table 15).

Gammarus is present in the reach of river at Indian Point throughout the year. Stomach analyses indicate that Gammarus is the major food item for juvenile and adult white perch. It is probably a major source of food for striped bass and other fish species.

Neomysis' presence in the vicinity of Indian Point appears to be dependent upon intrusion of salt water upstream to that area. Increases in fresh water flow which push the salt "front" downstream have made Neomysis virtually unavailable at Indian Point. The Raytheon Corporation Report also indicates that Indian Point is near the upstream limit of the range for Neomysis in the river.

Both Gammarus and Neomysis exhibit a very dramatic diurnal cycle of vertical movements in the river. During the day most are found near the bottom, while at night they are abundant throughout the water column.

The intake-discharge canal samples reflect this pattern. During the day very few Gammarus and Neomysis are present, but they are abundant in the discharge canal water at night. This indicates that the plant withdraws water primarily from the upper strata.

Fish Eggs and Larvae

Thermal shock studies on tomcod eggs and larvae are in progress. Very intensive thermal tolerance and survival studies on eggs and larvae of striped bass, white perch and

TABLE 15

MACRO-ZOOPLANKTON (gammarus and neomysis)

INTAKE AND DISCHARGE CANAL NET SAMPLES

	Temperature		# of	% Survival		
					Discharge	
	Ambient	ΔT	Obs.	Intake	I	II
Gammarus	75.2-77.0^{O}F	5.4-9.0	10	80	78	80
Neomysis	75.2-77.0^{O}F	5.4-9.0	10	77	80	81

other species will be done during the spring and summer of 1972.

Information now available on survival of fish eggs and larvae is limited to the sketchy data in Table 16.

RIVER BIOTA STUDIES, 1971

Preliminary analysis of the phytoplankton, micro-zooplankton and macro-zooplankton data from sampling within and outside the area traversed by the thermal plume from Indian Point Unit 1 indicate no significant differences in abundance or species composition attributable to the operation of the plant.

The combined facts: that the laboratory thermal shock study results described above show the operating ΔT of Unit 1 during 1971 to be less than the temperature tolerance of major component species of these populations; that the intake-discharge canal studies indicated no reduction in their survival during passage through Unit 1 condensers and the discharge canal; and, that the thermal plume ΔT is rapidly decreased by dilution below that which occurs in the discharge canal, help to explain why significant effects of the thermal discharge on these populations have not been found to date.

These findings that Unit 1 operation has had no discernible significant effects on phytoplankton and zooplankton, either in the discharge canal or river, are generally applicalbe for projection to Unit 2 as well. The full capacity design ΔT across the condensers of Unit 2 is nearly identical

TABLE 16

FISH LARVAE

INTAKE AND DISCHARGE CANAL STUDIES

	Temperature		# of	% Survival		
					Discharge	
	Ambient	ΔT	Obs.	Intake	I	II
Shad	75.2-77.0°F	7.2-7.9	4	19	3.0	-
Anchovy	75.2-77.0°F	5.9-9.9	4	53	52	35

to that of Unit 1. Time of passage through the discharge canal back to the river, and therefore the exposure time of entrained organisms to the maximum ΔT, will be less when both units are discharging cooling water to the common discharge canal. This will reduce the potential for damage to the organisms during the critical summer period of maximum ambient temperatures. On the other hand larger numbers of organisms will be passed through the plant when Unit 2 begins to withdraw cooling water from the river.

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