Comparative Plankton Ecology of Five Fish Tanks in Delhi, India[1]

by

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(with 10 figs.)

INTRODUCTION

The observations of PRASHAD (1916) on the seasonal conditions governing the pond life in the Punjab is the first limnological study in India. A more detailed account has been given by PRUTHI (1933) on the variability of water and plankton production in the Indian Museum tank at Calcutta. Similar ecological studies of a few ponds and reservoirs have appeared from time to time (GANAPATI, 1940, 1941, 1943, GONZALVES & JOSHI 1946; ALIKUNHI, CHOUDHURI & RAMACHANRAN, 1955; DAS & SRIVASTAVA, 1956a, 1956b, 1959). The symposium held in Delhi in 1959 (1960) has contributed much to our knowledge on algal ecology. However, quantitative data on plankton covering a period of at least one year from lentic waters in India are not available. With this in view, a detailed investigation was carried out from October 1958 till September 1959 on five fish tanks in Delhi to study the ecology of plankton with special reference to their quantitative variations.

MORPHOMETRY

The five fish tanks are located within a radius of 18 km from the Delhi University Campus.

Naini Lake

This pond was made in 1948. It is rectangular in shape and has a water area of about 48500 sq.m. The average depth of water in the

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Lake ranges from 2 m during the rainy season to about 1.1 m during summer. A small irrigation canal from the river Jamuna feeds the Lake in August for nearly two weeks. Water was clear for most part of the year and was exposed to sunshine throughout the day. The major carps were cultured in the Lake.

Indranagar Tank

It is believed to have been constructed in the 19th century. This Tank is also rectangular in shape and covers a water area of about 30000 sq.m. The water level reaches 2.2 m during the monsoon but in summer it falls to about 1 m .Water from the river enters the tank for nearly two weeks in August. There are a few trees on the western bank of the tank. Aquatic vegetation is wanting. The tank was stocked with fingerlings of the major carps.

Roshanara Tank

It is situated in the centre of a garden and has been named after Roshanara, the second daughter of the Mughal Emperor Shah Jahan. The tank is probably one of the oldest in Delhi dating back to 1700 A.D. It is almost circular in shape with a small island in the centre. The water area of the tank is about 25000 sq.m and the annual fluctuation in the water level is from 2—1 m. All round the tank there is a luxuriant growth of palm trees and many water birds abound the area. There is a small population of carps.

Shahdra Tanks

These two tanks are separated by a mud wall. The Stocking Tank is long and narrow and has an area of 20000 sq.m. Average depth in monsoon is about 3 m and in summer 1.7 m. The Nursery Tank, used for rearing fishes, is circular in shape and has an area of 4000 sq.m. During June, this tank completely dries up.

In all the tanks there is a general scarcity of aquatic vegetation. A very dense growth of *Potamageton pectinatus* LINNAEUS, however, appears in winter months in the tanks except in Roshanara Tank.

MATERIAL AND METHODS

Water and plankton samples from the tanks were collected once every fortnight between 8.30—10.30 a.m. on four consecutive days.

This gave fairly uniform meteorological conditions. The data presented in the tables and figures are the average of two fortnightly samples.

Water analysis

Water samples were collected by dipping a broad-mouthed bottle just below the surface of water. The water was immediately transported to the laboratory for chemical analysis which was generally completed within 24 hours. Temperature was recorded in the field by an ordinary thermometer. pH was also noted in the field by a Hellige Comparator. Turbidity was determined by the Jackson Candle Turbidimeter and the Hellige Turbidimeter. Water in a 250cc glass stoppered bottle was processed in the field for the determination of dissolved oxygen according to the Winkler Method (unmodified).

Carbonate and bicarbonate alkalinity were determined by titration with N/50 sulphuric acid using phenolphthalein and methyl orange as indicators; hardness by the EDTA titration method; chlorides by the Mohr Method; silicates by the Silicomolybdate Method; nitrates by the Phenoldisulphonic Acid Method and phosphates by the Stannous Chloride Method according tothe Standard Methods for the Examination of Water, Sewage and Industrial Wastes (1955). Free carbon dioxide was determined by titration with N/10 sodium hydroxide using phenolphthalein as indicator; sulphates by the Benzidine Method and oxygen consumed by the Potassium Permanganate Method (4 hours incubation) as given by DICKINSON (1950). All the results are expressed as mg/l.

Plankton analysis

The collection of plankton was made by a net made of Bolting Silk No. 21. This method was resorted to as the Roshanara Tank has a permanent bloom of *Microcystis aeruginosa* KUETZ (GEORGE, 1962). For each tank 10—12 stations were marked, eight to ten feet away from the margin of the tank. Water was collected from below the surface from these stations and in all 25 litres were passed through the net. The inside of the net was washed with water to obtain any adhering organisms within the meshes. The plankton concentrate was immediately preserved in 5% formalin and stored in vials.

For the enumeration of phytoplankton, the plankton concentrate was shaken well and 0.03 cc was taken with a 1 cc pipette graduated into 100 divisions. A count was made of all the algae in 0.03 cc under a cover slip (3/4") by moving the slide back and forth below the ob-

jective of a steroscopic binocular microscope (magnification 430). Four such sub-samples were counted and by taking the mean value for each organism, their numbers in one litre were calculated. The difficulty in determining the density of algal population has been emphasised by PROWSE (1955) and LUND & TALLING (1957). The „drop method" used in the present study gives tolerable accuracy (PEARSALL, GARDINER & GREENSHIELDS, 1946). The phytoplankton is expressed as cells/litre irrespective of whether they are cells, colonies or filaments. The limitations of the drop method is fully realised.

Zooplankton was enumerated by counting one fourth of the original concentrate under a binocular (dissection type) with a magnification of 100. Their number was calculated for one litre of water.

METEOROLOGICAL CONDITIONS

The data for the twelve months are given in Table I. The maximum temperature was recorded in June and the minimum during January. The air over Delhi was generally dry for most part of the year with relative humidity at its maximum in August and minimum in April and May. There was a wide variation in rainfall during the year, the peaks being soon after the onset of monsoon from June to September. In December and January, there were a few winter showers.

TABLE I

Meteorological data from October 1958 *and ending with September* 1959.

Month & year	Temperature Mean maximum C°	Mean minimum C°	Relative humidity 0830 hrs IST %	1730 hrs IST %	Total rainfall for the month mm	Mean hours sunshine
OCT '58	31.5	20.0	67	48	0.0	8.9
NOV '58	28.0	12.8	63	44	2.4	9.5
DEC '58	23.4	9.8	81	57	4.7	7.8
JAN '59	20.4	8.0	84	57	40.6	7.3
FEB '59	22.7	10.0	68	39	0.8	9.0
MAR '59	31.3	15.6	51	25	3.1	9.2
APR '59	36.2	21.7	36	18	0.0	9.0
MAY '59	39.4	25.5	35	21	22.0	6.9
JUN '59	40.6	29.1	47	27	25.9	4.9
JUL '59	35.4	26.9	72	58	128.2	5.9
AUG '59	34.0	26.5	77	66	218.1	6.3
SEP '59	33.8	25.5	74	61	113.4	6.7

TABLE II

Physico-chemical characteristics of water from Roshanara Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Temperature (C°)	28.5	20.3	15.2	13.7	17.0	22.7	27.8	29.5	30.4	31.1	31.0	30.6
Turbidity (T.units)	67	48	39	38	40	53	142	146	156	155	33	40
Total residue (mg/l)	552	470	682	408	594	708	1003	922	838	740	352	438
pH	8.6	8.7	8.6	8.5	8.8	8.9	9.0	9.2	9.1	9.1	8.7	9.1
Free carbon dioxide (mg/l)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	14	27	33	32	32	19	29	37	21	4	6	19
Total alkalinity as $CaCO_3$ (mg/l)	128	169	182	196	244	193	164	178	160	130	119	144
Total hardness as $CaCO_3$ (mg/l)	210	250	283	314	344	331	243	249	226	174	153	172
Chlorides as Cl (mg/l)	35	35	35	39	45	46	57	67	77	54	21	24
Dissolved oxygen (mg/l)	13.5	8.6	9.6	9.7	9.3	7.5	8.2	9.0	8.0	7.4	6.0	12.3
Oxygen percentage saturation	171.9	93.9	105.1	92.9	94.9	85.4	102.9	116.9	105.9	98.9	80.0	163.1
Oxygen consumed (mg/l)	4.3	5.9	5.7	5.6	5.4	6.2	10.3	13.2	10.2	18.1	4.8	6.3
Phosphates as PO_4 (mg/l)	0.25	0.23	0.25	0.22	0.13	0.10	0.07	0.04	0.05	0.15	0.19	0.20
Nitrates as N (mg/l)	0.09	0.11	0.02	0.02	0.01	0.01	0.03	0.05	0.02	0.07	0.06	0.03
Silicates as SiO_2 (mg/l)	25	13	8	8	8	3	3	8	10	12	17	13
Sulphates as SO_4 (mg/l)	128	160	172	180	215	201	205	240	280	201	138	83

TABLE III

Physico-chemical characteristics of water from Naini Lake, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Temperature (C°)	28.0	19.9	16.5	14.7	17.2	21.4	26.8	28.1	31.2	30.9	32.4	31.6
Turbidity (T.units)	45	32	22	19	14	17	51	59	82	172	31	21
Total residue (mg/l)	252	292	282	336	282	278	280	380	756	364	254	452
pH	8.5	8.5	8.5	8.5	9.0	9.3	9.1	8.5	8.4	8.6	8.5	8.6
Free carbon dioxide (mg/l)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	4	8	8	11	18	33	17	3	3	4	2	6
Total alkalinity as $CaCO_3$ (mg/l)	72	81	84	74	49	51	66	98	109	83	79	80
Total hardness as $CaCO_3$ (mg/l)	96	115	125	120	104	83	90	112	132	115	109	107
Chlorides as Cl (mg/l)	13	14	12	11	13	14	14	18	20	11	13	13
Dissolved oxygen (mg/l)	5.6	6.3	9.4	9.1	9.8	9.2	8.0	5.5	4.3	5.8	5.0	7.6
Oxygen percentage saturation	70.7	69.2	95.4	88.6	100.6	95.0	98.7	69.4	57.5	77.2	66.4	101.9
Oxygen consumed (mg/l)	2.0	1.9	1.1	0.8	0.53	1.6	2.8	3.3	3.2	3.9	1.2	1.1
Phosphates as PO_4 (mg/l)	0.04	0.04	0.09	0.01	0.01	0.03	0.02	0.02	0.04	0.04	0.03	0.07
Nitrates as N (mg/l)	0.02	0.02	0.02	nil	0.01	0.01	0.03	0.02	0.01	0.05	0.10	0.03
Silicates as SiO_2 (mg/l)	7	8	8	9	3	4	5	6	8	8	12	12
Sulphates as SO_4 (mg/l)	124	150	163	172	111	138	163	123	139	115	109	85

TABLE IV

Physico-chemical characteristics of water from Indranagar Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Temperature (C°)	29.5	18.5	15.9	14.5	17.1	22.4	26.2	28.6	28.5	30.4	31.6	31.9
Turbidity (T.units)	41	58	92	66	76	259	270	290	360	700	132	64
Total residue (mg/l)	48	80	500	380	400	600	700	740	1280	1760	360	360
pH	8.6	8.3	8.6	8.5	8.5	8.6	8.5	8.5	8.4	8.6	8.2	8.4
Free carbon dioxide (mg/l)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	10	9	16	11	11	12	7	5.5	2	3	1	2
Total alkalinity as $CaCO_3$ (mg/l)	104	133	145	143	143	147	155	204	233	179	100	116
Total hardness as $CaCO_3$ (mg/l)	124	155	171	188	193	179	169	187	231	194	110	127
Chlorides as Cl (mg/l)	23	24	24	29	25	33	40	82	105	141	24	40
Dissolved oxygen (mg/l)	5.3	5.8	7.8	8.5	7.3	7.5	5.9	3.9	2.1	3.0	2.7	4.0
Oxygen percentage saturation	68.8	61.3	78.2	83.7	75.1	85.7	72.8	49.9	26.9	79.6	36.9	53.9
Oxygen consumed (mg/l)	2.3	3.4	2.5	2.8	3.3	5.1	7.0	9.0	10.7	16.5	2.7	3.5
Phosphates as PO_4 (mg/l)	0.06	0.05	0.04	0.03	0.04	0.07	0.08	0.06	0.09	0.09	0.11	0.07
Nitrates as N (mg/l)	0.01	0.03	0.02	0.04	0.03	0.04	0.05	0.06	0.06	0.06	0.07	0.08
Silicates as SiO_2 (mg/l)	12	11	10	11	10	8	9	7	8	6	11	12
Sulphates as SO_4 (mg/l)	121	128	130	148	153	172	182	124	205	239	102	95

TABLE V

Physico-chemical characteristics of water from Stocking Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Temperature (C°)	26.8	19.2	16.2	14.5	18.2	23.0	27.0	28.3	30.7	30.3	31.7	31.4
Turbidity (T.units)	23	21	20	18	15	13	30	31	102	92	84	23
Total residue (mg/l)	648	604	719	740	740	740	752	860	1290	950	1432	1212
pH	8.5	8.5	8.6	8.4	8.8	8.8	8.8	8.8	8.6	8.6	8.5	8.5
Free carbon dioxide (mg/l)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	10	15	26	27	34	29	26	31	25	21	10	13
Total alkalinity as $CaCO_3$ (mg/l)	196	230	223	223	227	197	258	330	323	387	361	323
Total hardness as $CaCO_3$ (mg/l)	180	216	221	246	247	254	244	262	306	323	302	307
Chlorides as Cl (mg/l)	82	83	81	86	90	94	117	137	158	171	161	148
Dissolved oxygen (mg/l)	5.1	9.0	8.9	9.8	9.4	8.9	7.2	5.7	3.7	5.0	4.6	6.2
Oxygen percentage saturation	62.2	91.6	96.9	95.5	98.9	102.5	89.2	72.4	49.0	67.4	61.9	83.1
Oxygen consumed (mg/l)	0.94	1.9	1.8	1.8	1.8	1.9	3.3	3.4	2.1	4.6	3.9	2.3
Phosphates as PO_4 (mg/l)	0.06	0.06	0.05	0.02	0.01	0.01	0.04	0.03	0.04	0.04	0.07	0.03
Nitrates as N (mg/l)	nil	0.01	0.04	0.06	nil	0.02	0.01	0.02	0.02	0.04	0.03	0.01
Silicates as SiO_2 (mg/l)	13	6	11	9	6	3	5	8	9	11	12	14
Sulphates as SO_4 (mg/l)	230	214	200	210	216	200	211	182	289	301	357	292

TABLE VI

Physico-chemical characteristics of water from Nursery Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Temperature (C°)	26.8	19.2	16.2	14.5	18.2	22.0	27.2	28.0	—	—	32.8	31.7
Turbidity (T.units)	24	21	19	17	10	12	31	47	—	—	240	29
Total residue (mg/l)	548	688	670	680	780	852	1038	1060	—	—	1230	774
pH	8.5	8.5	8.7	8.6	9.1	9.4	9.4	9.4	—	—	8.5	8.6
Free carbon dioxide (mg/l)	nil	nil	nil	nil	nil	nil	nil	nil	—	—	nil	nil
Carbonate alkalinity as $CaCO_3$ (mg/l)	20	60	91	82	97	92	88	93	—	—	4.5	18
Total alkalinity as $CaCO_3$ (mg/l)	200	216	212	187	207	214	282	535	—	—	164	280
Total hardness as $CaCO_3$ (mg/l)	180	186	165	165	166	153	135	168	—	—	153	223
Chlorides as Cl (mg/l)	90	92	92	94	96	122	170	340	—	—	97	110
Dissolved oxygen (mg/l)	9.5	7.8	11.7	9.4	10.0	10.1	6.6	6.9	—	—	5.1	7.1
Oxygen percentage saturation	117.3	84.1	120.1	91.6	105.1	114.3	82.0	87.1	—	—	69.6	99.5
Oxygen consumed (mg/l)	2.5	2.6	3.3	3.9	4.4	6.1	8.3	10.0	—	—	4.7	2.9
Phosphates as PO_4 (mg/l)	0.06	0.01	0.04	0.01	0.01	0.01	0.03	0.03	—	—	0.06	0.04
Nitrates as N (mg/l)	nil	0.01	0.01	0.03	0.03	nil	0.05	0.04	—	—	0.09	0.03
Silicates as SiO_2 (mg/l)	13	7	6	4	5	4	5	8	—	—	6	12
Sulphates as SO_4 (mg/l)	149	202	195	206	224	143	206	226	—	—	175	174

Results

The variations in the physical and chemical conditions of water are given in Tables II—VI.

Temperature

Temperature of water in the tanks varied considerably in different months, the range being about 17.0°C. In the tanks, it indicated a fall from October till January when the lowest readings were recorded. From February onwards there was a rise in temperature till September. A maximum temperature of 32.8°C was recorded in the Nursery Tank in August.

Turbidity

Turbidity of water in the tanks decreased from October till about February and in March lowest values were recorded. After that, the turbidity increased progressively and reached the highest value in July with the onset of monsoon. There was a general fall in turbidity from August onwards. Of the five tanks, Indranagar Tank indicated relatively high turbidity, the maximum ever reached being 700.0 mg/l in July.

Total residue

Total residue in the tanks as expected followed the same seasonal variation as turbidity. A range of 48—1760 mg/l was noticed in the tanks during the year.

p H

The water in all the tanks was alkaline, the lowest pH recorded being 8.2.

Throughout the period of investigation, free carbon dioxide was never detected.

Carbonate alkalinity

Except in Naini Lake and Indranagar Tank, carbonates showed high values in summer and they decreased during and after the rains.

Carbonate alkalinity increased from 20.0 mg/l in October and attained a maximum of 93.0 mg/l in May, just before the water dried up in Nursery Tank. In August, after the rains, it was only 8.5 mg/l but afterwards it was on the increase. Carbonates showed the maximum value in May and minimum in July in Roshanara Tank. The seasonal variation was of a lesser magnitude in other tanks.

Bicarbonate alkalinity

In Nursery Tank, bicarbonates increased from October to January and after that the values registered a fall. From February onwards, they increased and reached 535.0 mg/l in May. The Stocking Tank always showed bicarbonates above 500.0 mg/l except in October. After the rains the bicarbonates showed a fall. In Indranagar Tank they increased till June, and showed a sharp fall after the rains. In Naini Lake, bicarbonates were low in winter months, but rose in May and June and decreased again after the rains. A pronounced summer maximum was absent in Roshanara Tank.

Total hardness

Total hardness was generally high in all the tanks. All the tanks exept Naini Lake showed hardness above 100.0 mg/l. It was highest in February and March in Roshanara Tank, in July in Stocking Tank, in September in Nursery Tank and June in Indranagar Tank and Naini Lake. Except in Stocking Tank, hardness was low in August in the tanks, a period immediately after the rains.

Chlorides

Water in the Stocking and Nursery Tanks had a very high chloride content and it always exceeded 80.0 mg/l. Naini Lake had the lowest value, the maximum being only 20.0 mg/l in June. In the five tanks, chlorides were almost constant from October till February. From March, they increased and showed maxima in May, June or July. During the rainy season, chlorides were low.

Dissolved oxygen

In the tanks, dissolved oxygen was generally noted to be high in winter and spring. It was very high in Roshanara Tank most of the time and the maximum was recorded in October, the percentage saturation being 171.9. Dissolved oxygen was relatively low in In-

dranagar Tank, with a maximum saturation percentage of 85.7 in March and the lowest 26.9 in June.

Oxygen consumed

The values for oxygen consumed remained almost constant till February in all the tanks. There was a steady increase in the values from March onwards till July and the values were low in August in all the tanks. Irregular fluctuations were observed in June in Roshanara and Stocking Tanks.

Phosphates

In the tanks, phosphates were generally high in December. In January, February and March, their values were low in Stocking and Nursery Tanks. In Naini Lake and Indranagar Tank, the lowest values were in January and February and from April they increased and reached high values in August, except for a few minor fluctuations. They were always present in the tanks in quantities above 0.01 mg/l.

Nitrates

Nitrates were generally low in all the tanks in November and December except in Roshanara Tank which showed the highest value of 0.11 mg/l in November. In the tanks, nitrates increased from March till about July and August, though in June there were sharp falls in their content in Roshanara Tank and Naini Lake. But for these two irregular values, they were high in summer. Among the tanks, Roshanara and Indranagar Tanks showed comparatively high nitrate content.

Silicates

Silicates were generally high in October and from December to March they registered a fall. Maximum values were noted in summer except in Indranagar Tank. Silicates were relatively high in Roshanara Tank, the range being 3.5—25.0 mg/l.

Sulphates

The variation in sulphate concentration in the tanks ranged from 83.0—257.0 mg/l. There was no regular pattern in the seasonal variation in sulphate content of these waters, but a tendency for a summer or late summer maximum could be observed. After the monsoon season there was a general decline.

PHYTOPLANKTON POPULATIONS

From a year round study of the five tanks, 81 genera of algae were recorded of which 38 belonged to Chlorophyceae, 21 to Bacillariophyceae, 17 to Myxophyceae, 3 to Euglenophyceae an 1 each to Dinophyceae and Xanthophyceae. The seasonal variations in the major groups and the different genera are given in detail in Tables VII—XI.

Chlorophyceae

The seasonal changes in the numbers of green algae are given in Fig. 1. There was an initial winter maximum in Naini Lake, Nursery and Indranagar Tanks while a late spring maximum was noted in Roshanara Tank. Indranagar Tank had a high Chlorophyceae population in April. There is no definite trend in their variations in different tanks. But there was a tendency for the population to increase from March to July. The algae that contributed to Chlorophyceae peaks were *Cylindrocapsa* in Nursery Tank, *Spirogyra* in Stocking Tank and *Chlamydomonas* and *Scenedesmus* in Indranagar Tank.

Euglenophyceae

The members of Euglenophyceae showed a different cycle in the quantitative variation as compared to the green algae. Although marked by high and low numbers in different seasons, there is no definite cycle common to all the tanks. In Indranagar Tank, their numbers were relatively high throughout the year with three distinct peaks in December, April and July (Fig. 2). In none of the tanks *Phacus* was found to share in the Euglenophyceae maximum. *Euglena* produced the maxima in Naini Lake, Stocking and Indranagar Tanks and *Trachelomonas* in Roshanara and Nursery Tanks.

Bacillariophyceae

The diatoms showed a winter maximum in all the tanks occurring either in November, December or January (Fig. 3). Naini Lake, Stocking and Nursery Tanks showed only a winter maximum, while Roshanara Tank had an autumn and winter maximum and Indranagar Tank had a winter, spring and late summer maximum. The diatoms causing the pulses were *Synedra* in Naini Lake, Stocking and Nursery Tanks, *Fragilaria* for the winter maximum and *Navicula* for the autumn maximum in Roshanara Tank and *Cyclotella* for all the pulses in Indranagar Tank.

FIGURE - 1

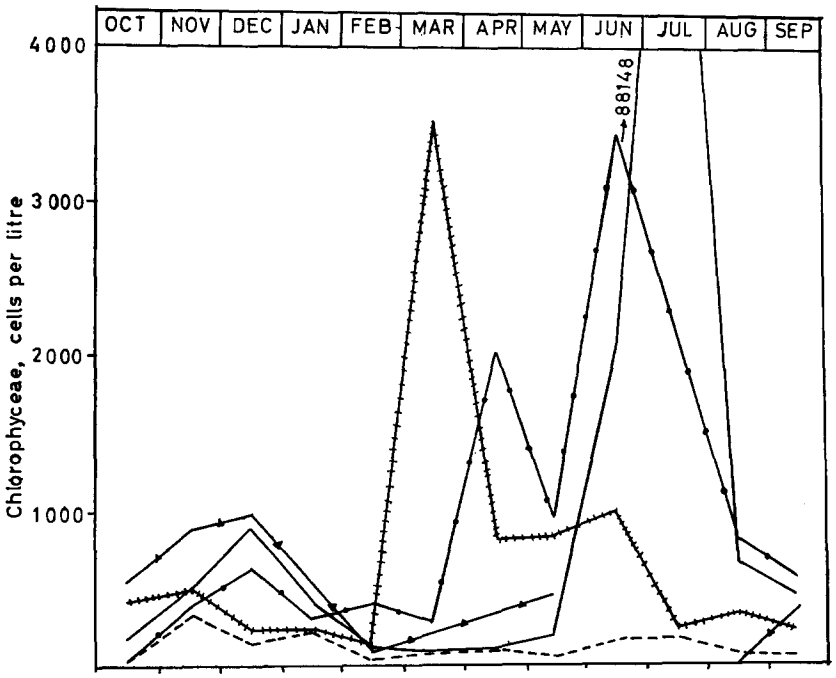

FIGURE - 2

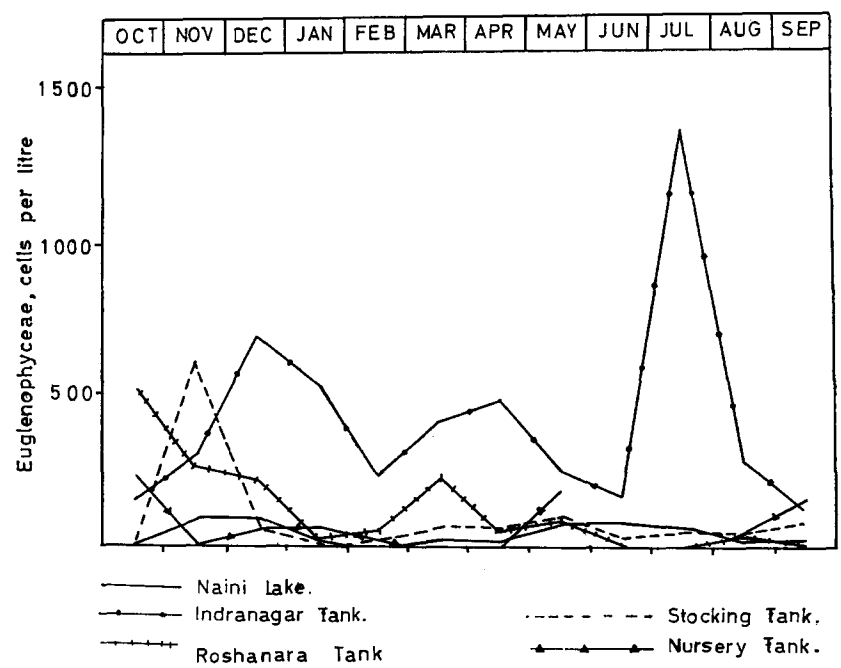

Figure 1 and 2: Seasonal variations in the Chlorophyceae and Euglenophyceae population.

FIGURE - 3

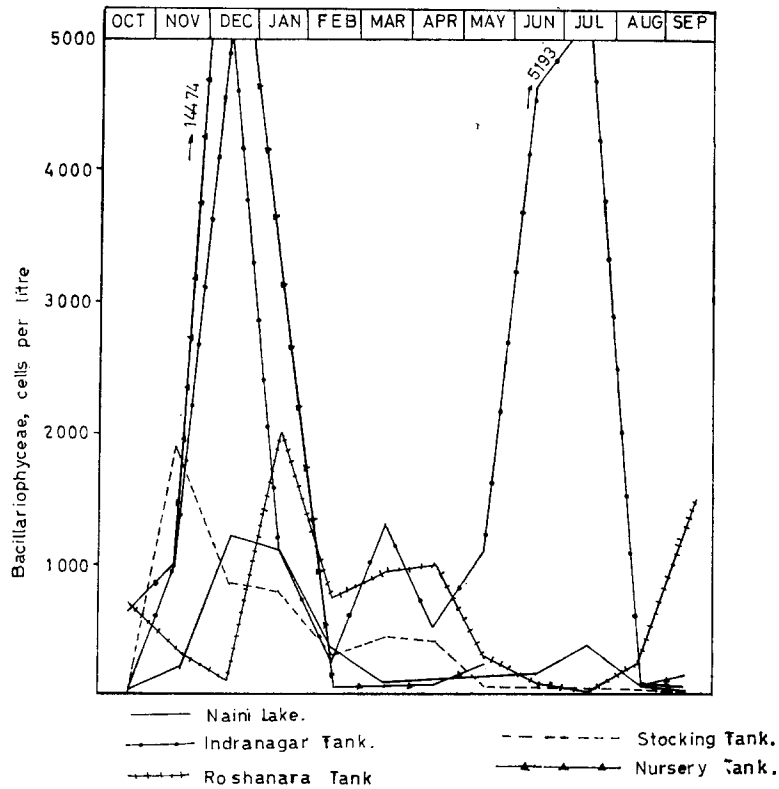

FIGURE - 4

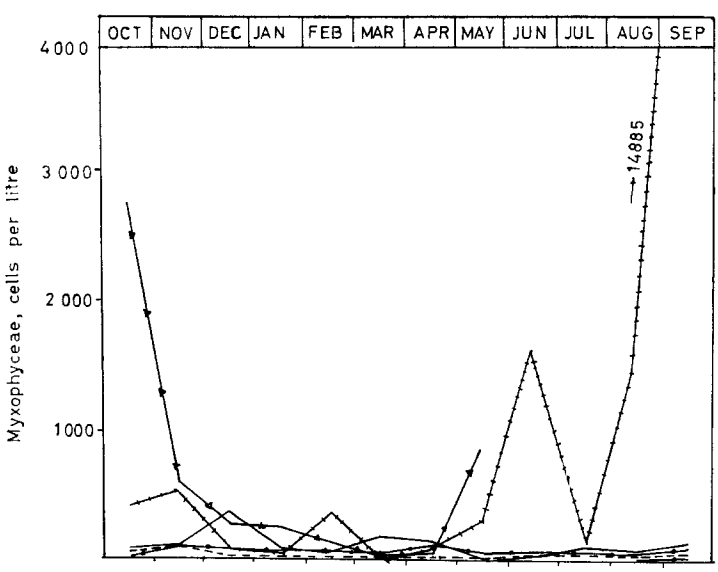

Figure 3 and 4: Seasonal variations in the Bacillariophyceae and Myxophyceae population.

Myxophyceae

Detailed account of the Myxophyceae bloom in Roshanara Tank has already appeared (GEORGE, 1962). In the present paper only the variation in the other members of blue-greens are given. The blue-green algae showed their peak development in October (Fig. 4). They were relatively less in Naini Lake, the maximum ever attained being 385 cells/litre in December. A still smaller Myxophyceae population was present in Indranagar Tank and Stocking Tank.

Total phytoplankton

The seasonal cycle of the total phytoplankton is shown in Fig. 5. The population consisting of diatoms showed a definite winter maximum in all the tanks. A second maximum was observed in Indranagar Tank which also was produced by diatoms. Blue-green algae dominated the pulses in May in Nursery Tank and in September in Roshanara Tank. Green algae were the more important group in

FIGURE - 5

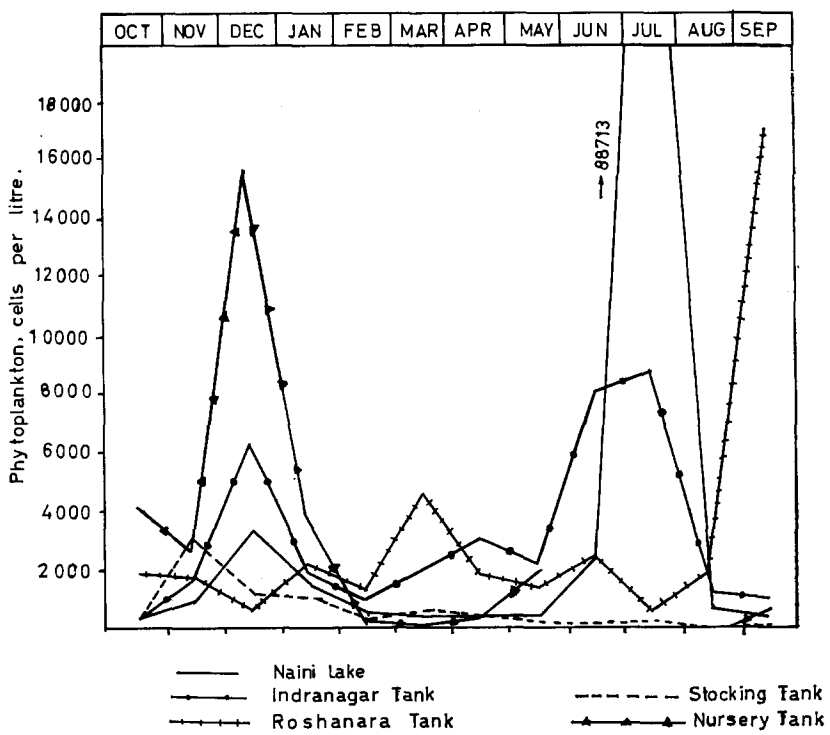

Figure 5: Seasonal variations in the total phytoplankton population.

TABLE VII

Phytoplankton population, cells/litre, in Roshanara Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CHLOROPHYCEAE												
Chlamydomonas	400	228	221	246	48	3500	480	568	204	210	148	170
Gloeocystis	—	—	10	—	—	—	—	—	—	—	—	—
Tetraspora	—	—	—	—	—	—	—	—	6	—	—	—
Pediastrum	—	—	—	—	4	—	—	—	6	—	28	40
Coelastrum	—	4	—	—	—	—	—	—	—	—	—	—
Ankistrodesmus	—	9	—	—	8	23	—	30	—	—	—	—
Dictyosphaerium	—	—	—	—	—	—	5	30	—	—	—	—
Kirchneriella	—	—	6	23	16	8	—	6	—	—	—	—
Actinastrum	—	—	—	—	—	—	—	—	—	—	42	—
Oocystis	—	20	5	—	45	—	315	—	12	16	15	—
Selenastrum	—	230	20	—	—	—	20	186	774	—	—	—
Crucigenia	—	—	5	—	—	—	—	—	—	—	—	—
Scenedesmus	—	—	—	—	—	—	—	12	—	—	94	—
Closterium	—	—	—	—	—	—	—	6	—	—	—	—
Cosmarium	—	2	—	—	4	33	—	—	—	—	14	—
Total	400	493	267	269	125	3564	820	838	1002	226	341	210
EUGLENOPHYCEAE												
Euglena	100	269	209	23	28	220	55	82	—	—	10	—
Trachelomonas	400	—	5	—	—	—	—	6	—	—	14	—
DINOPHYCEAE												
Glenodinium	—	—	—	—	4	—	—	—	—	—	—	—
BACILLARIOPHYCEAE												
Melosira	—	22	33	146	160	305	55	24	—	—	28	—
Cyclotella	100	275	27	108	40	43	10	—	—	—	28	—
Fragilaria	200	—	—	1701	496	20	510	—	6	—	29	360
Gomphonema	—	2	—	—	—	—	—	—	—	—	—	—
Navicula	300	9	—	25	28	565	400	144	—	—	134	1370
Synedra	100	17	—	24	—	—	—	—	—	—	—	—
Stauroneis	—	9	—	—	—	—	—	—	—	—	—	—
Surirella	—	4	—	—	—	—	—	—	—	—	—	—
Total	700	338	60	2004	724	933	975	168	6	—	219	1730
MYXOPHYCEAE												
Rhaphidiopsis	—	28	35	10	165	—	15	174	180	66	357	4000
Aphanocapsa	—	2	—	—	—	—	—	—	—	—	—	—
Chroococcus	—	8	11	—	—	—	—	6	—	—	—	—
Dactylococcopsis	—	8	6	—	8	—	25	36	—	—	10	—
Merismopedia	—	—	—	—	—	—	—	—	6	—	—	—
Synechocystis	—	20	5	—	8	—	10	18	36	—	—	—
Oscillatoria	400	44	12	30	40	—	25	86	1374	60	42	10300
Spirulina	—	2	—	—	—	—	—	—	—	—	—	60
Anabaenopsis	—	—	—	—	—	—	—	—	—	—	1031	240
Nostoc	—	567	—	—	—	—	—	—	—	—	—	—
Ababaena	—	50	—	—	145	—	20	18	42	16	49	285
Total	400	729	69	40	366	—	95	338	1638	142	1489	14885
TOTAL PHYTOPLANKTON	2000	1829	610	2336	1247	4717	1945	1432	2646	368	2073	16825

TABLE VIII

Phytoplankton population, cells/litre, in Naini Lake, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CHLOROPHYCEAE												
Chlamydomonas	110	75	58	14	5	3	13	44	51	16	41	19
Eudorina	—	—	8	2	—	—	—	—	—	—	—	—
Pandorina	—	—	—	2	—	—	5	2	2	2	4	2
Tetraspora	—	—	—	4	2	10	2	1	1396	87400	117	124
Ulothrix	—	—	—	—	—	—	—	1	—	—	—	—
Rhizoclonium	—	—	2	—	—	—	—	—	—	—	—	—
Oedogonium	—	1	16	5	2	—	—	1	—	—	—	3
Pediastrum	29	227	626	254	108	49	80	77	331	467	348	137
Coelastrum	16	22	16	18	—	5	8	—	—	54	14	13
Ankistrodesmus	1	—	2	—	—	1	2	—	4	4	—	4
Chlorella	—	—	—	3	—	—	—	—	—	—	—	—
Dictyosphaerium	5	1	2	—	—	15	4	—	89	4	108	113
Dimorphococcus	—	—	—	—	—	—	—	1	4	4	—	3
Kirchneriella	—	27	12	—	2	—	—	1	8	3	3	3
Tetraëdron	5	46	78	127	23	12	12	24	112	31	3	9
Actinastrum	—	—	—	—	—	—	—	—	—	—	2	—
Oocystis	—	—	3	3	2	—	2	8	—	1	5	1
Quadrigula	—	16	2	—	—	—	—	—	—	89	5	7
Selenastrum	—	20	26	2	—	2	5	2	35	6	—	—
Crucigenia	2	18	6	4	—	—	—	—	—	1	—	—
Scenedesmus	1	80	26	7	—	17	6	8	44	58	10	8
Tetrastrum	—	—	2	—	—	—	—	1	32	—	—	—
Spirogyra	5	—	—	—	—	—	—	—	—	—	—	—
Closterium	—	—	—	4	—	—	—	2	2	1	—	—
Cosmarium	—	2	40	9	—	6	3	32	—	7	2	2
Staurastrum	—	—	—	—	—	—	—	—	8	—	—	—
Total	174	535	925	458	144	120	142	205	2118	88148	662	448
EUGLENOPHYCEAE												
Euglena	2	96	76	11	—	8	23	49	42	19	9	8
Phacus	1	—	14	—	—	—	3	30	18	4	6	3
Trachelomonas	2	—	5	—	—	22	8	6	17	35	11	10
Total	5	96	95	11	—	30	34	85	77	58	26	21
DINOPHYCEAE												
Glenodinium	—	—	14	45	—	16	15	22	54	6	23	2
BACILLARIOPHYCEAE												
Cyclotella	5	2	18	4	2	—	3	4	—	6	1	—
Melosira	2	—	35	12	2	—	6	4	9	7	—	—
Diatoma	—	—	—	—	—	1	—	—	—	—	—	—
Fragilaria	—	—	—	5	78	14	26	34	71	357	3	1
Tabellaria	—	—	—	135	40	—	—	—	—	—	—	—
Cocconeis	1	—	—	—	—	—	—	—	—	—	—	—
Gomphonema	—	—	60	57	12	—	—	—	—	3	—	2
Navicula	1	—	288	35	36	14	30	22	26	—	12	3
Amphora	1	18	37	15	2	—	—	1	6	—	—	1
Synedra	17	182	677	159	74	13	4	8	22	—	—	6
Cymbella	—	—	20	158	75	2	18	6	10	—	5	4
Stauroneis	1	—	62	65	14	2	—	5	—	3	2	—
Epithemia	1	—	4	2	—	6	—	4	—	—	3	—
Rhopalodia	—	42	2	—	4	5	5	4	4	5	—	—
Brebissonia	—	—	8	284	—	—	—	—	—	—	—	—
Gyrosigma	—	—	2	5	—	—	—	—	—	1	—	2
Achnanthes	—	—	—	—	—	1	2	1	—	—	—	—
Surirella	—	—	—	—	4	—	8	1	—	—	—	
Total	29	244	1213	936	343	58	102	94	148	382	26	20
MYXOPHYCEAE												
Rhaphidiopsis	—	—	—	—	—	2	—	—	—	—	—	—
Aphanocapsa	—	2	5	7	—	—	2	3	—	5	—	16
Chroococcus	—	—	—	—	—	2	2	1	—	—	—	—
Dactylococcopsis	—	7	150	4	—	2	2	1	2	50	—	8
Merismopedia	37	38	140	23	13	142	74	1	6	18	40	11
Microcystis	—	—	10	16	11	4	15	2	8	2	—	23
Synechocystis	—	56	22	6	3	2	—	3	45	10	—	—
Oscillatoria	52	2	58	15	11	2	2	8	3	29	2	3
Spirulina	2	—	—	—	—	—	2	—	—	1	2	—
Anabaenopsis	—	—	—	—	—	—	22	16	—	2	—	1
Nostoc	—	6	—	—	—	—	—	—	—	—	—	—
Anabaena	—	—	—	—	2	2	10	8	2	2	—	3
Total	91	111	385	71	40	156	131	43	66	119	44	65
TOTAL PHYTOPLANKTON	299	986	2632	1521	527	380	424	449	2463	88713	781	556

TABLE IX

Phytoplankton population, cells/litre in Indranagar Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CHLOROPHYCEAE												
Chlamydomonas	12	79	82	122	74	34	1179	160	1520	1032	888	180
Eudorina	—	—	—	—	—	—	—	28	28	—	—	9
Pandorina	3	—	—	4	5	—	—	16	—	61	—	294
Gloeocystis	—	—	—	6	—	—	—	—	24	—	—	—
Tetraspora	—	—	24	4	3	—	—	—	—	14	5	—
Elaktothrix	—	—	24	5	—	—	—	—	—	—	—	—
Ulothrix	—	—	—	—	3	3	—	—	—	—	—	—
Oedogonium	—	—	5	9	—	—	—	—	9	—	—	—
Pediastrum	—	14	12	10	4	—	—	12	84	32	—	9
Coelastrum	3	26	8	4	15	6	35	36	52	42	20	3
Ankistrodesmus	—	—	57	35	120	41	228	4	52	12	—	3
Dactylococcus	—	—	44	—	—	—	—	—	16	—	—	—
Dictyosphaerium	—	—	3	—	—	—	6	—	—	—	3	38
Kirchneriella	—	13	21	2	65	79	—	32	60	17	32	—
Oocystis	—	8	5	8	6	7	100	48	52	12	—	—
Quadrigula	—	38	77	26	18	17	—	—	—	171	6	—
Selenastrum	—	50	9	5	—	5	4	48	52	83	4	—
Tetraëdron	6	6	—	2	3	6	—	4	36	53	—	3
Actinastrum	—	20	11	8	4	25	33	16	—	—	—	—
Crucigenia	3	19	65	14	13	3	91	276	276	14	—	—
Scenedesmus	6	88	197	45	69	55	308	192	1040	366	34	6
Tetrastrum	—	—	—	—	—	—	—	—	—	1	—	—
Spirogyra	—	—	5	3	8	—	—	—	—	—	—	—
Closterium	—	—	3	—	—	5	92	32	124	—	4	—
Cosmarium	—	—	3	—	—	—	—	—	—	11	—	9
Spondylosium	—	—	—	2	—	13	—	—	—	—	—	—
Staurastrum	1	—	12	3	—	—	—	—	—	—	—	—
Total	34	361	667	317	410	302	2076	904	3425	1921	996	554
EUGLENOPHYCEAE												
Euglena	42	234	547	242	97	133	236	112	84	811	62	21
Phacus	—	—	26	40	—	15	25	32	—	24	10	6
Trachelomonas	108	62	108	240	115	253	214	100	72	504	200	78
Total	150	296	681	522	212	401	475	244	156	1339	272	105
DINOPHYCEAE												
Glenodinium	—	—	—	6	2	5	4	—	8	—	4	491
XANTHOPHYCEAE												
Ophiocytium	—	3	5	—	—	—	—	—	—	—	—	—
BACILLARIOPHYCEAE												
Melosira	9	203	85	23	32	39	169	712	75	—	—	—
Stephanodiscus	—	—	—	—	18	36	11	4	—	—	—	—
Cyclotella	48	503	4618	196	92	79	—	73	3864	4124	16	6
Fragilaria	—	—	—	23	—	3	45	32	630	568	4	—
Navicula	3	211	157	624	52	326	188	292	48	501	20	3
Gomphonema	—	—	22	2	—	—	—	4	—	—	—	—
Amphora	—	—	6	3	2	2	—	—	—	—	—	—
Synedra	6	85	61	42	39	788	—	—	—	—	—	—
Cymbella	—	—	—	4	4	—	3	—	—	—	—	—
Stauroneis	—	4	24	73	8	14	—	8	—	—	4	—
Rhopalodia	—	—	—	2	3	—	—	—	—	—	—	—
Surirella	—	—	—	26	2	—	—	—	—	—	—	—
Total	66	1006	4973	1018	252	1287	416	1125	4617	5193	44	9
MYXOPHYCEAE												
Aphanocapsa	6	13	—	5	3	5	9	—	—	12	5	—
Rhaphidiopsis	—	—	6	—	—	—	—	—	8	—	—	—
Chroococcus	—	—	12	2	—	—	4	—	8	—	—	3
Dactylococcopsis	—	—	5	—	22	12	54	—	—	—	—	—
Merismopedia	9	13	—	—	—	—	21	—	—	18	—	6
Microcystis	—	—	—	11	9	—	—	—	—	—	—	—
Spirulina	—	—	—	2	2	—	—	12	4	—	16	—
Synechocystis	9	53	28	3	13	—	9	—	—	—	—	—
Lyngbya	—	—	4	—	—	—	—	—	—	—	—	—
Oscillatoria	—	2	15	18	10	5	11	4	16	—	—	5
Anabaena	—	—	6	26	11	20	40	32	7	12	—	—
Anabaenopsis	—	—	—	—	—	—	—	24	—	—	—	—
Nostoc	—	5	10	3	—	—	—	—	—	—	—	—
Total	24	86	86	70	70	42	148	72	43	42	21	14
TOTAL PHYTOPLANKTON	274	1752	6412	1933	946	2037	3119	2345	8349	8495	1337	1173

TABLE X

Phytoplankton population, cells/litre, in Stocking Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CHLOROPHYCEAE												
Chlamydomonas	21	73	30	98	10	11	11	10	27	21	22	14
Pandorina	—	—	—	—	—	3	11	3	4	15	—	—
Tetraspora	—	—	—	—	—	—	—	8	37	30	25	12
Stigeoclonium	3	—	—	—	—	—	—	—	—	—	—	—
Rhizoclonium	—	—	54	14	—	—	26	10	5	—	—	—
Bulbochaete	—	8	—	—	—	2	—	—	—	—	—	—
Oedogonium	—	84	12	42	14	34	2	—	—	3	—	—
Pediastrum	—	—	—	—	2	—	—	17	77	66	8	2
Coelastrum	—	3	—	2	—	—	—	—	—	—	—	2
Ankistrodesmus	—	—	—	—	—	4	—	2	—	6	—	—
Dictyosphaerium	3	—	—	—	—	—	4	—	—	—	2	10
Dimorphococcus	—	—	—	—	—	—	—	—	5	—	—	4
Dactylococcus	—	—	—	—	—	—	2	—	—	—	—	—
Kirchneriella	—	—	—	—	—	2	—	—	—	—	—	9
Oocystis	6	3	—	—	4	3	4	—	—	3	2	2
Selenastrum	—	—	3	—	—	—	—	—	—	—	—	2
Crucigenia	—	3	—	—	—	—	4	4	6	3	6	6
Tetraëdron	3	—	—	—	—	—	—	—	—	—	—	—
Treubaria	—	—	—	—	—	—	—	—	3	—	—	—
Scenedesmus	—	2	16	12	2	20	55	13	—	25	7	4
Mougeotia	—	76	—	—	—	—	—	—	—	—	—	—
Spirogyra	3	102	36	86	27	12	2	—	—	—	—	—
Cosmarium	—	12	6	4	—	2	3	—	—	—	—	2
Spondylosium	—	—	—	—	—	—	—	—	—	3	2	—
Staurastrum	—	—	—	—	—	—	2	—	—	—	—	—
Total	39	366	157	258	59	93	126	67	164	175	74	69
EUGLENOPHYCEAE												
Euglena	24	608	69	—	3	54	30	62	20	36	4	42
Phacus	—	—	—	—	—	—	16	16	—	9	—	2
Trachelomonas	9	9	3	6	10	17	17	10	8	12	17	32
Total	33	617	72	6	13	71	63	88	28	57	21	76
DINOPHYCEAE												
Glenodinium	—	—	—	4	5	11	22	5	—	—	—	—
XANTHOPHYCEAE												
Ophiocytium	—	—	3	—	—	—	—	—	—	—	—	—
BACILLARIOPHYCEAE												
Melosira	3	—	6	2	—	6	—	—	3	—	—	—
Stephanodiscus	—	—	—	—	—	4	—	—	—	—	—	—
Cyclotella	12	21	3	10	2	—	3	—	3	3	—	2
Diatoma	9	—	3	—	—	8	—	—	—	—	—	—
Achnanthes	—	12	4	—	18	80	47	2	—	—	—	—
Fragilaria	—	—	3	42	—	112	—	—	—	15	8	2
Navicula	—	645	285	92	102	71	32	22	41	24	12	8
Gomphonema	—	225	57	24	2	60	10	—	—	—	—	—
Amphora	—	130	84	30	4	3	—	—	—	—	—	—
Synedra	18	653	180	264	99	39	68	13	2	3	—	—
Cymbella	—	182	159	280	56	33	11	4	—	—	—	—
Stauroneis	21	92	26	16	—	—	—	2	9	3	3	—
Epithemia	—	—	9	—	—	—	—	—	—	—	—	—
Rhopalodia	9	15	—	—	3	2	2	—	—	—	—	—
Brebissonia	—	—	6	—	—	—	18	—	—	—	—	—
Pleurosigma	—	6	6	—	—	—	—	—	—	—	—	—
Gyrosigma	—	—	6	2	—	—	—	—	—	—	—	—
Surirella	—	—	—	4	—	—	—	—	—	—	—	—
Total	72	1981	837	766	286	418	191	43	58	48	23	12
MYXOPHYCEAE												
Aphanocapsa	—	—	3	10	12	2	6	2	—	—	—	—
Raphidiopsis	—	—	—	—	—	—	—	—	—	—	6	6
Chroococcus	—	—	3	2	—	—	—	—	—	—	—	2
Dactylococcopsis	—	—	—	—	—	—	2	4	—	—	—	—
Merismopedia	2	6	3	6	5	—	4	21	6	—	16	38
Microcystis	—	—	18	6	12	3	—	3	3	20	—	—
Spirulina	—	—	3	—	—	5	—	—	—	—	—	—
Synechocystis	9	—	3	—	2	14	6	—	3	3	2	2
Anabaena	—	—	—	—	4	2	2	—	—	3	—	—
Oscillatoria	18	88	12	—	—	9	21	2	13	6	2	2
Nostoc	—	6	—	—	—	—	—	—	—	—	—	—
Gloeotrichia	3	—	—	—	—	—	—	—	—	—	—	—
Total	32	100	45	24	35	35	41	32	25	32	26	50
TOTAL PHYTOPLANKTON	176	3064	1111	1058	398	628	443	235	275	312	144	207

TABLE XI

Phytoplankton population, cellsilitre, in Nursery Tank, October 1958 to September 1959..

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
CHLOROPHYCEAE												
Chlamydomonas	348	67	50	132	6	2	10	290	—	—	25	265
Eudorina	—	—	—	—	—	—	—	—	—	—	—	27
Pandorina	—	—	—	—	—	—	2	3	—	—	—	40
Volvox	80	—	—	—	—	—	—	—	—	—	—	—
Gloeocystis	—	4	6	—	2	—	—	—	—	—	—	—
Cylindrocapsa	—	40	549	60	42	—	—	—	—	—	—	—
Sphaerocystis	—	—	—	48	—	—	—	—	—	—	—	—
Tetraspora	—	—	—	—	—	—	56	12	—	—	—	—
Schizochlamys	—	—	—	39	—	—	—	—	—	—	—	—
Ulothrix	—	16	—	—	22	188	70	10	—	—	—	—
Stigeoclonium	—	66	—	—	—	—	—	—	—	—	—	—
Rhizoclonium	80	—	128	28	18	—	10	17	—	—	—	—
Bulbochaete	—	82	—	—	—	—	—	—	—	—	—	—
Oedogonium	25	164	16	4	2	—	—	—	—	—	3	—
Pediastrum	—	—	—	—	—	—	6	—	—	—	2	—
Coelastrum	—	7	—	3	—	—	—	7	—	—	—	3
Dictyosphaerium	—	—	—	3	—	—	6	2	—	—	—	—
Dimorphococcus	—	—	—	—	—	2	2	—	—	—	—	13
Kirchneriella	—	—	—	—	—	2	—	—	—	—	—	—
Oocystis	—	7	16	36	5	—	—	7	—	—	—	—
Selenostrum	—	58	8	—	—	—	84	—	—	—	—	8
Tetraëdron	—	—	—	—	—	—	—	6	—	—	—	5
Actinastrum	—	—	—	—	—	—	—	2	—	—	—	9
Crucigenia	—	—	28	—	—	—	2	—	—	—	—	—
Scenedesmus	—	200	16	12	—	—	15	19	—	—	3	15
Mougeotia	—	105	—	—	—	—	—	—	—	—	—	—
Spirogyra	—	63	48	87	9	4	—	4	—	—	—	—
Closterium	—	—	—	—	6	10	36	8	—	—	—	—
Cosmarium	—	—	108	87	—	2	36	68	—	—	—	—
Staurastrum	—	—	—	—	—	—	—	—	—	—	—	1
Total	533	879	973	539	112	210	335	455	—	—	33	386
EUGLENOPHYCEAE												
Euglena	58	10	38	37	14	—	8	37	—	—	17	33
Phacus	—	—	3	—	—	—	4	85	—	—	—	10
Trachelomonas	160	—	3	24	—	—	—	70	—	—	23	128
Total	218	10	44	61	14	—	12	192	—	—	40	171
DINOPHYCEAE												
Glenodinium	—	—	—	—	—	—	—	257	—	—	—	3
BACILLARIOPHYCEAE												
Melosira	295	26	—	—	—	—	6	—	—	—	—	10
Cyclotella	54	12	16	28	—	—	8	2	—	—	—	55
Fragilaria	26	—	4616	344	3	—	—	15	—	—	8	3
Navicula	125	310	3882	105	6	—	4	60	—	—	13	23
Nitzschia	—	—	—	—	—	—	—	10	—	—	—	—
Gomphonema	—	86	54	—	—	—	—	—	—	—	—	—
Amphora	—	4	87	—	—	—	—	—	—	—	—	—
Synedra	54	661	5697	2455	13	2	6	—	—	—	—	—
Cymbella	—	12	12	4	2	—	2	—	—	—	—	—
Stauroneis	25	—	24	2	—	—	2	115	—	—	3	3
Rhopalodia	26	—	12	16	3	2	6	—	—	—	—	—
Brebissonia	—	—	66	—	—	—	—	—	—	—	—	—
Gyrosigma	—	—	—	—	—	—	2	—	—	—	—	—
Pinnularia	—	—	8	—	—	—	—	—	—	—	—	—
Surirella	—	—	—	3	—	—	—	2	—	—	—	—
Total	605	1051	14474	2957	27	4	36	204	—	—	24	94
MYXOPHYCEAE												
Rhaphidiopsis	—	—	—	—	—	—	—	306	—	—	—	—
Aphanocapsa	—	18	22	54	—	2	—	6	—	—	—	5
Chroococcus	—	—	—	9	—	—	4	—	—	—	—	—
Dactylococopsis	—	—	—	—	—	—	2	175	—	—	—	5
Merismopedia	—	14	42	—	—	—	8	15	—	—	—	—
Microcystis	—	—	6	24	41	—	—	6	—	—	—	3
Synechocystis	54	63	44	8	2	2	8	2	—	—	—	—
Oscillatoria	—	60	—	—	—	—	10	25	—	—	—	5
Spirulina	—	—	—	—	—	—	8	9	—	—	—	—
Anabaena	54	423	—	52	26	12	54	—	—	—	21	8
Anabaenopsis	—	—	—	—	—	—	—	373	—	—	—	35
Nodularia	—	45	12	66	70	—	—	2	—	—	—	—
Nostoc	—	—	164	27	—	—	—	—	—	—	—	—
Tolypothrix	—	—	—	—	3	—	—	—	—	—	—	—
Lyngbya	—	4	—	—	—	—	—	—	—	—	—	—
Gloeotrichia	2628	—	—	—	—	—	—	—	—	—	—	—
Rivularia	—	—	—	8	—	—	—	—	—	—	—	—
Total	2736	627	290	248	142	16	94	919	—	—	21	61
TOTAL PHYTOPLANKTON	4092	2567	15781	3805	295	230	477	2027	—	—	118	715

TABLE XII

Zooplankton population, organisms/litre, in Roshanara Tank, October 1958 to September 1959 .

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Protozoa	—	—	—	—	10	—	—	—	—	—	—	—
Rotifera												
Polyarthra vulgaris CARLIN	—	12	1	—	—	—	—	—	—	—	—	—
Filinia terminalis PLATE	6	4	2	2	9	15	22	1	27	—	4	—
F. longiseta EHRENBERG	—	—	—	—	11	—	—	—	—	3	—	—
Keratella tropica APSTEIN	20	80	60	224	46	56	147	468	70	—	7	50
Horaella brehmi DONNER	—	—	—	—	2	1	—	13	16	—	3	—
Asplanchna priodonta GOSSE	—	—	—	—	—	—	1	3	—	—	—	—
Trichocerca sp.	—	—	—	—	—	—	6	—	—	—	—	—
Brachionus bidentata ANDERSON	—	129	5	2	—	152	461	195	30	15	1	1
B. angularis GOSSE	—	—	—	3	—	—	—	8	—	—	9	—
B. calyciflorus PALLAS	—	22	2	—	2	8	20	23	325	56	90	—
B. caudatus v. *personatus* AHLSTROM	—	—	—	—	1	—	—	25	4	—	34	—
Mytilina sp.	1	—	—	—	—	—	—	—	—	—	—	—
Testudinella sp.	—	30	—	—	—	—	1	—	—	—	—	—
Monostyla bulla GOSSE	—	—	—	—	—	—	—	—	—	—	—	5
Total	27	277	70	231	71	232	658	736	472	74	148	56
Cladocera												
Diaphanosoma sp.	—	—	—	—	—	—	—	9	62	28	—	—
Moina brachiata JURINE	—	—	—	—	—	—	15	16	524	175	37	76
Pleuroxus striatus SCHØDLER	1	—	1	—	—	—	—	—	—	—	—	—
Chydorus sphaericus O. F. MÜLLER	3	—	—	—	—	—	—	—	—	—	—	—
Total	4	—	1	—	—	—	15	25	586	203	37	76
Copepoda												
Heliodiaptomus contortus GURNEY	2	14	—	—	3	13	15	6	24	—	—	—
Cyclops sp.	2	12	2	1	1	14	55	18	135	33	95	48
Ectocyclops sp.	—	6	—	—	—	—	8	27	42	3	56	102
Total	4	32	2	1	4	27	78	51	201	36	151	150
Ostracoda												
Cypris sp.	—	—	—	—	—	—	—	—	—	5	—	—
Crustacean larvae	30	100	4	5	8	77	277	113	140	10	49	72
Insect larvae	—	—	2	—	—	—	3	—	—	3	—	—
TOTAL ZOOPLANKTON	65	409	79	237	83	336	1031	925	1399	331	385	354

TABLE XIII

Zooplankton population, organisms/litre, in Naini Lake, October 1958 to 1959 September.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Protozoa	5	3	7	1	3	1	—	1	1	1	2	—
Oligochaeta												
Chaetogaster sp.	—	—	—	1	—	—	—	—	—	—	—	—
Nais sp.	—	—	—	1	1	—	—	—	—	—	—	—
Total	—	—	—	2	1	—	—	—	—	—	—	—
Rotifera												
Polyarthra vulgaris CARLIN	—	—	—	—	1	—	—	—	1	1	1	—
Filinia terminalis PLATE	—	—	—	—	2	—	—	—	1	—	1	—
Keratella tropica APSTEIN	27	10	6	4	1	2	—	—	—	—	2	—
Horaella brehmi DONNER	—	—	—	—	—	—	—	2	2	1	—	—
Asplanchna priodonta GOSSE	—	—	—	—	—	—	—	—	1	—	—	—
Trichocerca sp.	—	—	—	1	—	—	1	—	—	—	—	—
Colurella sp.	—	—	2	—	—	—	—	—	—	—	—	—
Brachionus leydigii COHN	10	6	4	1	—	—	—	—	—	—	—	—
B. bidentata ANDERSON	6	7	6	—	1	—	26	18	32	—	11	7
B. quadridentatus HERMANN	—	—	6	—	3	—	—	—	—	—	—	—
B. calyciflorus PALLAS	—	—	14	3	1	—	—	—	—	—	—	—
B. angularis GOSSE	—	—	—	—	4	—	1	—	6	—	1	3
B. falcatus ZACHARIAS	—	—	—	—	3	—	—	—	—	—	—	2
B. pterodinoides ROUSSELET	—	—	—	—	—	—	—	—	4	—	1	—
B. caudatus v. *personatus* AHLSTROM	—	—	—	—	—	—	—	—	—	—	8	—
B. caudatus v. *apstenei* APSTEIN	—	—	—	—	—	—	—	—	—	—	2	—
B. caudatus BARROIS & DADAY	—	—	—	—	—	—	—	—	1	—	—	—
B. forficula WIERZEJSKI	—	—	—	—	—	—	—	—	—	—	4	5
B. diversicornis DADAY	—	—	—	—	—		—	122	62	—	4	3
Monostyla bulla GOSSE	—	—	—	—	1	1	—	—	—	—	—	1
Euchlanis sp.	—	—	3	2	6	—	—	—	—	—	—	—
Testudinella sp.	—	5	6	1	2	2	—	—	—	—	—	—
Testudinella patina HERMANN	18	—	—	—	—	—	—	1	2	—	—	—
Total	61	28	47	12	25	5	28	143	112	2	35	21
Cladocera												
Diaphanosoma sp.	—	—	—	—	—	—	—	—	1	—	—	—
Simocephalus serrulatus KOCH	—	1	—	1	—	—	—	—	—	—	—	—
Moina brachiata JURINE	—	—	1	—	—	—	—	—	—	—	—	—
Pleuroxus denticulatus BIRGE	—	1	—	—	—	—	—	—	2	—	—	—
Chydorus sphaericus O. F. MÜLLER	12	13	4	1	1	—	—	—	—	—	—	2
Total	12	15	5	2	1	—	—	—	3	—	—	2
Copepoda												
Heliodiaptomus cinctus GURNEY	—	—	—	—	—	—	—	1	1	1	1	—
Cyclops sp.	6	8	1	3	1	1	—	—	—	3	1	—
Ectocyclops sp.	10	6	—	—	—	1	—	1	2	1	—	1
Total	16	14	1	3	1	2	—	2	3	5	2	1
Ostracoda												
Cypris sp.	—	1	—	—	—	—	—	—	—	—	—	—
Crustacean larvae	—	2	5	2	5	8	8	18	24	18	66	13
Insect larvae	—	1	1	—	—	—	—	—	—	—	—	—
TOTAL ZOOPLANKTON	94	64	66	22	36	16	36	164	143	26	105	37

TABLE XIV

Zooplankton population, organisms/litre, Indranagar Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Protozoa	—	20	2	—	—	—	—	—	—	1	—	—
Oligochaeta												
Nais sp.	—	—	1	—	—	1	—	—	—	—	—	—
Rotifera												
Polyarthra vulgaris CARLIN	—	—	—	—	13	1	6	8	10	—	37	14
Filinia terminalis PLATE	2	—	—	40	69	—	2	10	3	—	8	1
F. longiseta EHRENBERG	—	—	1	19	20	7	4	4	—	—	—	—
F. opoliensis ZACHARIAS	—	—	—	—	—	—	—	—	—	—	5	32
Keratella tropica APSTEIN	3	50	185	15	54	6	188	82	5	—	6	20
Horaella brehmi DONNER	—	—	1	6	—	3	1	4	4	72	18	3
Asplanchna priodonta GOSSE	1	14	16	5	3	1	33	11	1	1	2	—
Brachionus quadridentatus HERMANN	—	—	1	—	—	—	—	—	10	27	—	—
B. bidentata ANDERSON	—	—	—	40	95	—	32	17	—	34	—	—
B. angularis GOSSE	—	—	9	40	95	—	32	46	105	85	25	4
B. calyciflorus PALLAS	1	—	26	3	13	1	1	57	65	82	4	—
B. falcatus ZACHARIAS	—	—	2	—	—	—	—	7	—	—	4	2
B. caudatus BARROIS & DADAY	—	—	—	—	—	—	—	—	—	2	—	—
B. caudatus v. *personatus* AHLSTROM	—	—	—	1	—	—	—	—	—	—	28	2
B. caudatus v. *apstenei* APSTEIN	—	—	—	—	—	—	35	16	2	—	—	—
B. caudatus v. *aculeatus* HAUER	—	—	—	1	26	1	—	—	—	—	2	—
B. diversicornis DADAY	—	—	—	—	—	—	—	—	81	—	—	10
Monostyla bulla GOSSE	—	—	—	1	—	—	—	—	—	—	—	—
Euchlanis sp.	—	—	1	—	—	—	—	—	—	—	—	—
Mytilina sp.	—	—	1	1	—	—	—	1	—	—	1	—
Cephalodella sp.	—	—	—	—	—	—	—	—	—	—	5	—
Testudinella sp.	—	1	2	5	—	2	1	—	—	—	2	—
Total	7	65	245	137	293	22	303	263	286	303	142	95
Cladocera												
Diaphanosoma sp.	1	9	1	—	—	5	11	6	2	2	1	1
Moina brachiata JURINE	2	9	4	2	8	2	23	20	41	16	6	—
Ceriodaphnia rigaudi RICHARD	—	1	—	—	—	—	2	—	—	—	—	—
Chydorus sphaericus O. F. MÜLLER	—	—	—	1	—	—	—	—	—	—	—	—
Comptocercus sp.	—	—	—	—	—	—	—	—	—	4	—	—
Macrothrix sp.	—	—	—	—	—	—	—	—	—	5	—	—
Total	3	19	5	3	8	7	36	26	43	27	7	1
Copepoda												
Diaptomus peregrinator BREHM	1	1	—	—	2	1	—	2	—	—	—	—
Neodiaptomus diaphorus KIEFER	—	—	—	2	2	5	2	—	—	—	—	—
Cyclops sp.	1	10	10	1	2	2	40	24	6	3	20	8
Ectocyclops sp.	5	9	2	1	2	42	8	15	2	—	5	12
Total	7	20	12	4	8	50	50	41	8	3	25	20
Ostracoda												
Cypris sp.	—	—	—	—	—	—	—	—	—	12	4	—
Herpetocypris sp.	—	—	—	—	—	—	—	—	—	16	—	—
Total	—	—	—	—	—	—	—	—	—	28	4	—
Crustacean larvae	1	51	23	9	17	60	68	72	82	—	93	47
Insect larvae	—	—	1	—	1	1	—	—	1	6	2	—
TOTAL ZOOPLANKTON	18	175	289	153	327	141	457	402	420	373	273	163

TABLE XV

Zooplankton population, organisms/litre in Stocking Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Protozoa	2	—	1	—	2	—	3	—	1	—	—	—
Oligochaeta												
Nais sp.	—	1	—	1	—	—	—	—	—	—	—	—
Pristina sp.	—	1	—	—	—	—	—	—	—	—	—	—
Total	—	2	—	1	—	—	—	—	—	—	—	—
Rotifera												
Polyarthra vulgaris CARLIN	1	—	—	—	—	—	—	—	—	1	—	3
Filinia terminalis PLATE	1	—	—	—	—	1	10	2	1	—	2	16
F. longiseta EHRENBERG	—	—	—	—	—	—	—	—	—	—	2	4
F. opeliensis ZACHARIAS	—	—	—	—	—	—	2	1	2	7	4	3
Keratella tropica APSTEIN	—	—	2	—	—	1	4	1	—	—	—	—
Horaella brehmi DONNER	—	—	—	—	—	1	—	—	1	1	—	—
Asplanchna priodonta GOSSE	—	—	—	—	—	—	2	—	—	—	1	—
Trichocerca sp.	—	—	1	—	—	—	—	—	—	—	—	—
Brachionus quadridentatus HERMANN	1	—	1	—	—	—	—	—	—	—	—	—
B. bidentata ANDERSON	—	—	—	—	—	—	2	—	—	—	—	2
B. angularis GOSSE	—	—	—	—	—	13	18	18	19	13	4	3
B. falcatus ZACHARIAS	—	—	—	—	—	—	—	4	6	8	16	6
B. calyciflorus PALLAS	—	—	—	—	—	—	—	—	1	—	—	—
B. diversicornis DADAY	—	—	—	—	—	1	3	2	—	—	1	4
B. caudatus v. *personatus* AHLSTROM	—	—	—	—	—	—	—	1	1	—	—	1
Monostyla bulla GOSSE	—	—	—	—	—	—	3	—	—	1	—	—
Mytilina sp.	3	1	7	—	3	—	—	1	—	—	—	—
Euchlanis sp.	—	—	8	1	1	—	—	—	—	—	—	—
Lecane luna MULLER	—	—	1	1	—	1	—	1	1	—	—	—
Hexarthra mira HUDSON	—	—	1	1	—	—	—	—	—	—	1	—
Testudinella sp.	—	—	—	—	2	4	—	—	—	—	—	—
T. patina HERMANN	1	—	—	—	—	—	—	—	—	—	—	—
Total	7	1	21	3	6	22	44	31	32	31	31	42
Cladocera												
Simocephalus vetulus SCHØDLER	—	1	—	1	—	—	—	—	—	—	—	—
Pleuroxus denticulatus BIRGE	2	5	3	2	1	2	—	—	—	—	—	—
Scapholeberis kingi SARS	2	—	1	2	1	1	—	—	—	—	—	—
Chydorus sphaericus O. F. MÜLLER	—	—	3	2	1	2	—	—	—	—	—	—
Macrothrix sp.	—	—	—	—	—	—	—	—	—	1	—	—
Total	4	6	7	7	3	5	—	—	—	1	—	—
Copepoda												
Heliodiaptomus cinctus GURNEY	1	—	—	—	—	—	—	1	1	2	1	8
Cyclops sp.	—	2	4	2	2	4	3	1	—	5	2	3
Ectocyclops sp.	5	2	3	6	1	3	4	1	2	—	—	—
Total	6	4	7	8	3	7	7	3	3	7	3	11
Ostracoda												
Cypris sp.	—	1	—	—	—	—	—	—	—	—	—	—
Spirocypris sp.	—	1	—	—	—	—	—	—	—	—	—	—
Total	—	2	—	—	—	—	—	—	—	—	—	—
Crustacean larvae	4	—	8	2	2	10	22	22	9	32	56	38
Insect larvae	1	—	2	—	—	2	1	—	—	—	—	—
TOTAL ZOOPLANKTON	24	15	46	21	16	46	77	56	45	71	90	91

TABLE XVI

Zooplankton population, organisms/litre, in Nursery Tank, October 1958 to September 1959.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Protozoa	54	3	—	4	—	—	—	—	—	—	602	300
Oligochaeta												
Nais sp.	—	1	1	—	—	—	—	—	—	—	—	—
Pristina sp.	—	1	—	—	—	—	—	—	—	—	—	—
Total	—	2	1	—	—	—	—	—	—	—	—	—
Rotifera												
Polyarthra vulgaris CARLIN	3	—	1	—	—	—	—	—	—	—	—	32
Filinia terminalis PLATE	—	—	—	—	—	—	71	—	—	—	2	24
F. longiseta EHRENBERG	—	—	—	—	—	—	—	—	—	—	—	—
Keratella tropica APSTEIN	—	—	—	1	—	—	1	—	—	—	—	3
Asplanchna priodonta GOSSE	—	—	2	—	—	—	—	—	—	—	—	1
Brachionus quadridenatus HERMANN	6	—	—	—	—	—	—	—	—	—	—	—
B. bidentata ANDERSON	—	—	—	—	—	—	—	—	—	—	—	1
B. angularis GOSSE	—	—	—	—	—	—	142	5	—	—	2	27
B. falcatus ZACHARIAS	—	—	—	—	—	—	—	—	—	—	2	1
B. caudatus BARROIS & DADAY	—	—	—	—	—	—	—	—	—	—	—	6
B. diversicornis DADAY	—	—	—	—	—	—	—	—	—	—	5	1
Diplois sp.	6	4	—	—	1	—	—	—	—	—	—	—
Mytilina sp.	—	—	1	2	—	2	—	3	—	—	—	—
Lecane luna MULLER	—	—	2	—	—	—	1	—	—	—	—	—
Monostyla bulla GOSSE	—	5	2	6	1	—	—	2	—	—	—	—
M. quadridentata HERMANN	—	—	1	3	—	—	—	—	—	—	—	—
M. closterocerca SCHMARDA	—	—	—	2	—	—	—	—	—	—	—	—
Euchlanis sp.	—	—	—	5	2	—	1	—	—	—	—	—
Hexarthra mira HUDSON	—	—	—	—	—	—	—	—	—	—	1	50
Testudinella sp.	—	—	—	3	5	—	—	—	—	—	—	—
T. patina HERMANN	—	—	—	—	—	6	4	1	—	—	—	—
Total	15	9	9	22	9	8	220	11	—	—	12	149
Cladocera												
Diaphanosoma sp.	—	—	—	—	—	—	—	2	—	—	6	8
Simocephalus vetulus SCHØDLER	—	—	18	5	6	—	—	—	—	—	—	—
Scapholeberis kingi SARS	—	13	12	14	2	—	—	—	—	—	—	—
Moina brachiata JURINE	—	—	—	—	—	—	—	—	—	—	3	2
Chydorus sphaericus O. F. MÜLLER	6	4	12	10	9	—	—	1	—	—	—	—
Pleuroxus denticulatus BIRGE	3	2	8	21	4	—	—	—	—	—	—	—
P. striatus SCHØDLER	—	—	—	3	1	—	—	—	—	—	—	—
Total	9	19	50	53	22	—	—	3	—	—	9	10
Copepoda												
Heliodiaptomus cinctus GURNEY	—	2	1	—	—	—	—	—	—	—	—	2
Cyclops sp.	21	—	2	4	—	—	3	—	—	—	—	—
Halicyclops sp.	—	14	14	13	7	2	5	4	—	—	10	20
Total	21	16	17	17	7	2	8	4	—	—	10	22
Ostracoda												
Cypris sp.	6	—	—	—	—	—	—	—	—	—	—	—
Spirocypris sp.	—	1	—	—	—	—	—	—	—	—	—	—
Total	6	1	—	—	—	—	—	—	—	—	—	—
Anostraca												
Eubranchipus vernalis VERRILL	—	—	—	—	—	—	—	—	—	—	4	—
Crustacean larvae	90	19	5	20	84	119	131	53	—	—	52	63
Insect larvae	—	1	2	2	1	—	—	4	—	—	1	1
TOTAL ZOOPLANKTON	195	70	84	118	123	129	359	75	—	—	690	545

March in Roshanara Tank and Indranagar Tank and in July in Naini Lake.

ZOOPLANKTON POPULATIONS

Zooplankton populations were mostly composed of rotifers, cladocerans, copepods and crustacean larvae. In Tables XII—XVI all the species recorded with their quantitative variations are given. From a year round study 32 species of rotifers, 11 of cladocerans and 7 of copepods were recorded.

Rotifers

Rotifers, Fig. 6, showed a minor pulse in Naini Lake in October with 61 individuals /litre, *Keratella tropica* being the dominant species. *Brachionus diversicornis* was very numerous in May and caused a number of maxima. Roshanara Tank had the largest rotifer population and there were two pulses, one in November and the other in January, *Keratella tropica* producing both the pulses. The rotifers showed a prolonged summer maximum from March to June. In Indranagar Tank, there was a winter maximum in December, early spring maximum in February and a prolonged maximum during the entire summer months. Each pulse was dominated by a different species. In the summer months *Brachionus angularis* were dominant in Stocking and Nursery Tanks and produced maxima. Taking the cycle of rotifers in all the tanks, a summer periodicity is evident and there was a reduction in their number after the rains.

Cladocera

Cladocerans, Fig. 7, were very few from October till March in Roshanara Tank and Indranagar Tank. Both the tanks showed cladoceran maxima in June, dominated by *Moina brachiata*. They were relatively less in Naini Lake. But the smallest cladoceran population was noted in Stocking Tank.

Copepoda

Roshanara Tank had the largest number of copepods (Fig. 8) throughout the year, the maximum population extending from April to September with a peak in June. In Naini Lake, the maximum number of copepods was observed in October and November. Indranagar Tank showed the maximum number in February, March and April, while in the Stocking and Nursery Tanks, there was no significant copepod pulse.

FIGURE - 6

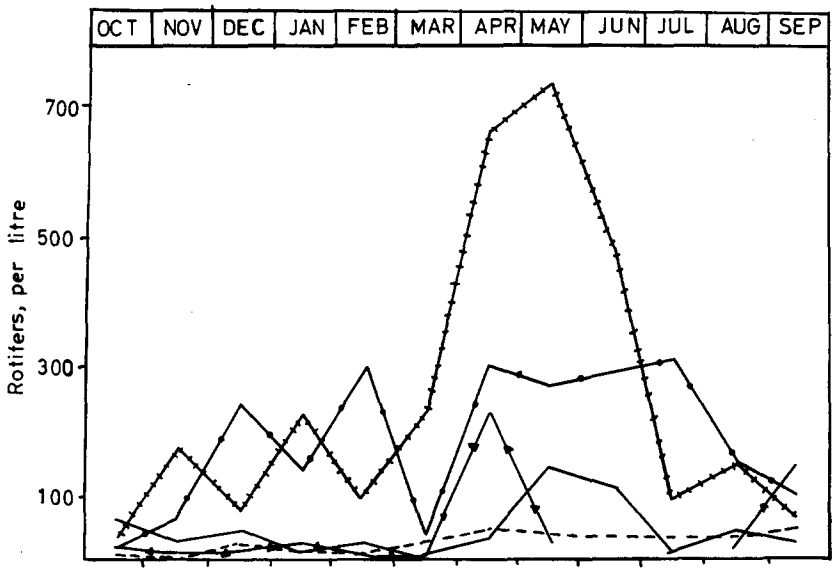

FIGURE - 7

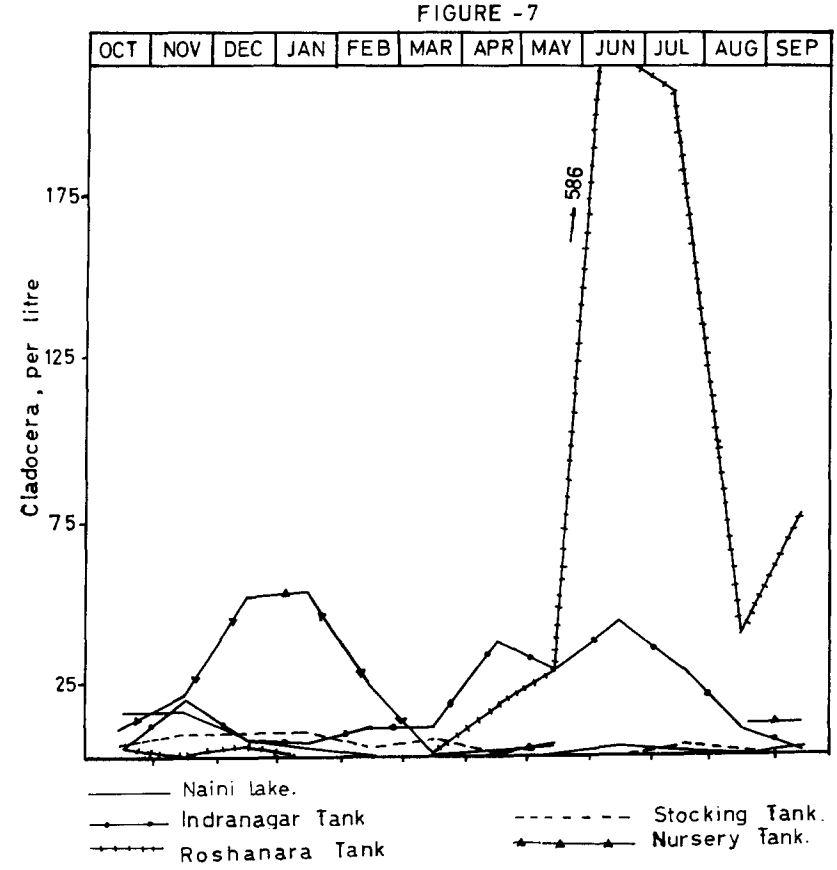

Figure 6 and 7: Seasonal variations in the rotifer and cladocera population.

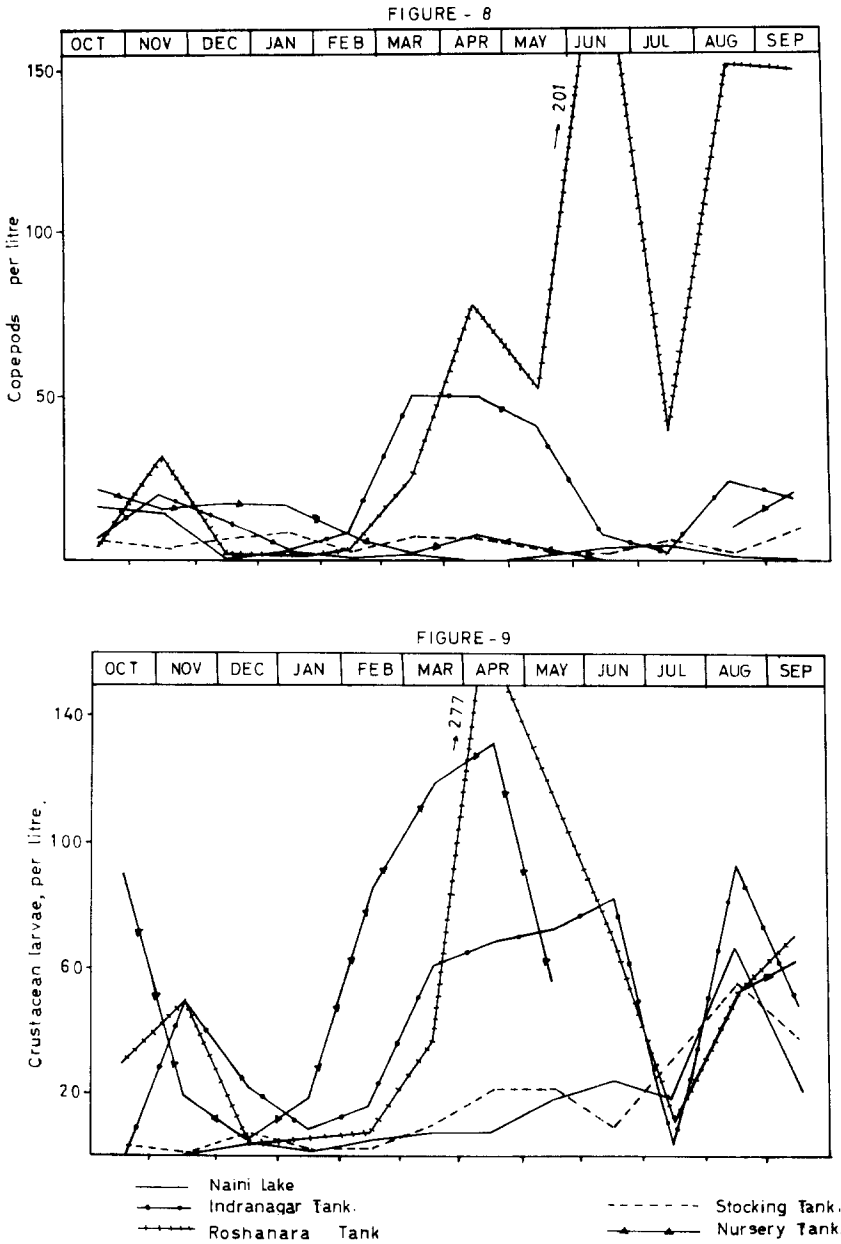

Figure 8 and 9: Seasonal variations in the copepod and crustacean larvae population.

Crustacean larvae

Crustacean larvae, Fig. 9, showed three well defined peaks in the group of tanks, the first in October and November, the second in March, April and May and the third in August. These periods coincide with the early winter, summer and post-monsoon seasons respectively.

Total zooplankton

The maximum zooplankton population, Fig. 10, was seen in Roshanara Tank. It showed maxima in November, January and April to September and the major pulse was in June with 1399 individuals/ litre. Similar summer and late summer maxima were observed in Indranagar Tank, the peak period being in April. The Nursery Tank

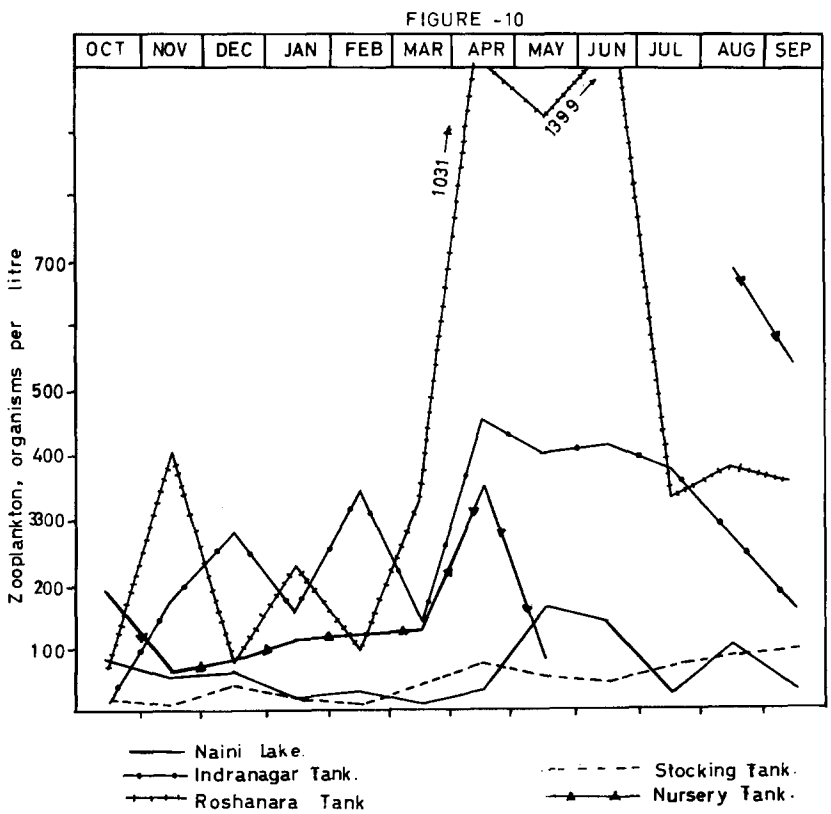

Figure 10: Seasonal variations in the total zooplankton population.

showed an October maximum and then a major pulse of short duration in April. There was another pronounced maximum during the rains. The Stocking Tank had a summer pulse in April and then a prolonged maximum in July, August and September. Zooplankton was maximum in Naini Lake in May and June.

Some plankton correlations

The inverse correlation between phytoplankton and zooplankton has been emphasised by Wright (1954, 1958) and Das & Srivastava (1956a). The results are often divergent in different areas (Pennak, 1949, 1955). The data from the five tanks were statistically analysed to ascertain the possible relationship between phytoplankton and zooplankton and also between the groups. The correlation coefficient „*r*" was calculated and the „t" test was applied to find the relative significance of *r*. Details are given in Table XVII.

Table XVII

Some correlation coefficients (r)

	Phytoplankton	Rotifera
Zooplankton	— 0.0160	+ 0.0127
Chlorophyceae	— 0.0480	—
Bacillariophyceae	— 0.3326	—
Myxophyceae	— 0.0750	—

Note: Significance of *r* has been derived from the „t" test in each case. None of the correlation coefficients is significant on the 5 % level of significance.

Discussion

In the Stocking Tank, pH of water varied from 8.4—8.8 and in Indranagar Tank from 8.2—8.6, the range being only 0.4. A maximum range of 0.9 pH units was observed during the year in the Nursery Tank. There is thus vey little seasonal variation in pH of these waters. Tucker (1958) has observed only slight variation in pH of hard waters and the same holds true in the water of Delhi tanks also.

The present observations and the study on diurnal variations (George, 1961) have shown a direct correlation between pH and carbonates under tropical conditions. Wiebe (1930) has pointed out that hydrogen ion concentration is controlled by photosynthesis, in which

case pH and carbonates would vary directly. LAUFF (1953) observed an apparent correlation between these two factors in Rogers Lake.

Total alkalinity was always more than 100.0 mg/l in the tanks except Naini Lake. Since the total alkalinity of natural waters is principally due to calcium and magnesium, the tanks are considered rich in these salts. MOYLE (1946) has given 40.0 mg/l as a natural separation point between soft and hard waters in which case the water of these tanks is very hard particularly the Stocking and Nursery Tanks.

Dissolved oxygen was very high in Roshanara Tank due to the algal bloom. Oxygen supersaturation of 405.8% by evening and undersaturation of 1.3% in the early hours of the morning were noticed in the same tank. The respiration of the biota caused the undersaturation, the algae creating the major depletion of oxygen (GEORGE, 1961).

Hydrogen ion concentration of water is important, since mineral matter in suspension is more likely to have silicates dissolved out when alkalinity is great. Such a relationship as noted by ATKINS (1926-27) and BEADLE (1930) is apparent from the present study.

The greatest fluctuations in sulphates were recorded in Roshanara, Stocking and Indranagar Tanks where there was comparatively more of phosphates and other nutrients. This phenomenon is in agreement with the view of MANN (1958) who has pointed out that in those waters where fluctuations in sulphate content were most marked, there was a good supply of phosphates and other nutrients released from the bottom deposits.

The sulphate content of the tanks in Delhi Territory shows a range of 83.0—357.0 mg/l. Thus sulphates which are considered as a limiting factor (BEAUCHAMP, 1953; FISH, 1956) are present in considerable amount in these waters. Practically nothing is known about the sulphate content in inland waters of India and hence it will be of interest to assess the amount of this nutrient present in different regions of India

From the present investigation 81 genera of algae and 50 species of zooplankton were recorded. Compared to temperate waters, as for example the Colorado lakes (PENNAK, 1955), the tanks studied showed a richer variety of organisms. But quantitatively, in Delhi Tanks, phytoplankton population is considerably lower and zooplankton almost equal to those of Colorado lakes.

In Delhi tanks, green algae were well represented by many genera. Quantitatively also they were important and it is interesting to find that in Naini Lake, green algae were the most dominant group. PENNAK (1949) has pointed out that probably the greens are almost always numerically subordinate and are generally considered to be only minor constituents of pulses and blooms.

Desmids were poorly represented in these waters both in quality and quantity, and they made irregular appearance irrespective of the amount of phosphates and nitrates in water. Naini Lake which had a low bicarbonate content showed relatively a higher population of desmids. It may be possible that desmids may be more in waters with low bicarbonates. COLE (1957) also has noticed an apparent inverse correlation between the bicarbonates and the desmid flora.

There was no precise relationship between the amount of organic matter and Euglenophyceae population and its occurrence and periods of abundance appear to be unrelated to any of the physicochemical factors of the water studied. It was noted by GONZALVES & JOSHI (1946) and RAO (1955) that Euglenophyceae population was abundant when organic matter was very high.

Diatoms showed a definite pulse in winter. PEARSALL (1932) has pointed out that diatoms show a late winter and early spring maximum. CHANDLER (1940, 1942) found in western Lake Erie spring and autumn pulses. PENNAK (1949, 1955) has observed that in Colorado lakes there were no regular diatom pulses. Further observations in tropical waters may corroborate the author's view of a definite periodicity of diatoms in winter in lentic waters.

It is of special interest to note that whenever there was only a single winter diatom maximum, as in Naini Lake, Nursery and Stocking Tanks, the dominant diatom causing the pulse was always *Synedra* of Pennales. When there was a second maximum as in Roshanara Tank, the dominant diatom of the winter maximum was *Fragilaria* and of the autumn, *Navicula* both of Pennales. Indranagar Tank showed three diatom pulses and in this case, *Cyclotella* of Centrales produced all the maxima. From the above analysis it is seen that unlike the conditions in temperate regions (CHANDLER 1940,1942) there is no alternation of the members of the orders Centrales and Pennales in different seasons in these waters.

There was noticed a reduction in the silicate content of the water before or after a diatom pulse, irrespective of the seasons. This result

is well in agreement with the observations of KING & DAVIDSON (1933) from experimental studies and also with the conclusions of many other workers from different waters.

In the tanks in Delhi, silicates, nitrates and phosphates were generally present far in excess of the minimum requirement for diatom growth and they were not limiting factors. But the maximum number of diatoms recorded from these tanks was only 14,474 cells/litre which is very low when compared with diatom population of temperate waters, as for example, Beaver Reservoir in Colorado, which showed a pulse of 31,440,000, cells/litre (PENNAK, 1955). Generally, diatoms do not appear to form a major part of the plankton in the tanks in Delhi. ALIKUNHI, CHOUDHURI & RAMACHANDRAN (1955) also recorded a relatively small diatom population in the tanks at Cuttack, India. This apparent numerical inferiority of the diatoms seems to be intimately related with the food chain (GEORGE, 1963). The different plankton algae are not of equal importance to carps and only certain forms are digested and others pass through the alimentary canal apparently unaffected. The diatoms are completely digested and there is no possibility of the same forms appearing again in the standing crop of plankton whereas most of the blue-greens and a few greens can appear again in water practically unharmed.

Blue-green are said to show a periodicity in summer months (PEARSALL, 1932; PEARSALL, GARDINER & GREENSHIELDS, 1946). They have pointed out that Myxophyceae population develops in late summer when there is an abundance of organic matter and depletion of nutrients. From the present study it was observed that organic matter increases progressively during summer. But with an increase in organic matter, only Roshanara and Nursery Tanks showed maxima of Myxophyceae population. It seems that high organic matter and long hours of sunshine which are characteristic of summer conditions, are not the only factors for the Myxophyceae pulses, but some other factors must be at play (GEORGE, 1962).

Rotifers showed a numerical superiority over other groups of zooplankton. This data on rotifers corroborates the view of NORDQVIST, 1921, (op. cit. FRITSCH, 1931) that the abundance of rotifers compared to other groups does point to the eutrophic nature of water bodies, which feature characterises the tanks studied. However, GANAPATI 1943; CHACKO & KRISHNAMURTHY 1954; and DAS & SRIVASTAVA 1959, have reported that copepods and cladocerans were the dominant groups.

Certain observations on the ecology of rotifers from Delhi have already been reported (GEORGE, 1961). Rotifers showed a major pulse in all the tanks in the summer months of April through July. PENNAK (1949, 1955) has concluded that there is no seasonal periodicity among rotifers in north America. In Danish waters their seasonal variations are not very marked (WESENBURG-LUND, 1930). The present observations point to the occurrence of a summer periodicity in rotifers. It is likely that in tropical waters they may be showing a summer maximum, but more extensive work is needed to confirm this.

The species compositions of *Brachionus* and *Filinia* are interesting. They showed the simultaneous occurrence of two or more species of the same genus in a single collection. PENNAK (1957) has pointed out that whenever two species of the same genus are present, one is almost always more abundant than the other. But an analysis of the present data does not reveal any significant dominance of one species over another. In the genus *Brachionus* for example, there were instances when more than two species of this genus had appeared at one time in almost equal numbers.

Another feature of the rotifer population is the predominance of one or two genera in the tanks. Either *Keratella tropica* or the different species of *Brachionus* always showed numerical superiority over the other rotifers. This feature appears to be characteristic of the tanks in Delhi, which have a pH always above 8.0.

Copepods and cladocerans do not show any regular periodicity. There were only irregular pulses in different months. DAS & SRIVASTAVA (1956a) have shown that the peak periods of copepods were in September, October and those of cladocerans in December and January. They have come to such a conclusion as their observations were confined only to a single tank.

From the present study it is seen that there is no significant correlation ($r \pm 0.016$) between phytoplankton and zooplankton. To arrive at more definite conclusions, it is essential to study the food habits of the various zooplankton organisms.

SUMMARY

A comparative account of the plankton ecology of five fish tanks inDelhi is given.

Variations in the physical and chemical characteristics of water such as temperature, turbidity, total residue, pH, free carbon dioxide,

carbonate alkalinity, total alkalinity, total hardness, chlorides, dissolved oxygen, oxygen consumed, phosphates, nitrates, silicates and sulphates observed for a period of one year are described. Chemical characteristics of water vary to a great extent in the five tanks. The dry summer and the monsoon rains considerably influence the physical and chemical conditions of water.

The quantitative variations in the phytoplankton populations are presented. Compared to temperate waters, the tanks in Delhi show a richer variety of organisms. The largest number of genera is noted among the green algae. Desmids are poorly represented in all the tanks. The phytoplankton populations show a regular winter maximum which is caused by diatoms.

Observations on the quantitative variations in the major groups of zooplankton are presented. Zooplankton population is represented by many genera. The dominant group among the zooplankton is the Rotifera which shows a summer maximum.

There is no significant correlation between the phytoplankton and the zooplankton.

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