Rec. zool. Surv. India, 79 : 411-436, 1982

DIURNAL VARIATIONS IN PHYSICO-CHEMICAL FACTORS AND PLANKTON IN SURFACE LAYERS OF THREE TROPICAL FRESHWATER FISH TANKS OF NAGPUR*

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(With 3 Text-figures and 9 Tables)

INTRODUCTION

Extensive work on the diurnal variation of fresh water bodies has been carried out in the temperate region. Such investigations from tropical waters are few and scattered. Cushing (1951) has reviewed the earlier investigation on the vertical migration of planktonic crustaceans. Vaas and Sachlan (1953) observed the diurnal fluctuations in shallow ponds of Indonesia. Chacko and Krishnamoorthi (1954) noted the diurnal variation of phytoplankton and zooplankton of fish ponds from Madras. Ganapati (1955) observed the diurnal variations of some physico-chemical factors from a stream bed at Mettur dam. Talling (1957), Hussainy and Abdulappa (1963), noted that superficial stratification in the lake takes place during the day. George (1961) opined that the diurnal migration pattern of the plankton in the tropics was not similar to that found in temperate waters. Krishnamoorthi and Visweswara (1965) stated that the principal factor involved in the diurnal movement was light. Khan and Siddiqi (1970) studied the diurnal variations in a pond at Aligarh and Saha *et al.* (1971) contributed to our knowledge about the diurnal variations in a perennial fish pond. However, a detail study on diurnal variation of the water bodies of the Nagpur area is not available. In order to enhance our knowledge in this field, the present investigation have been carried out. The present observation is an outcome of the study of diurnal changes in water chemistry and plankton populations during March 1974 in three water bodies of Nagpur.

*Part of the thesis approved for the Ph. D. Degree of the University of Nagpur.

Morphometry and Topography of the tanks

All three tanks are located within a radius of 5 km and are used for rearing fish (Text-fig. 1).

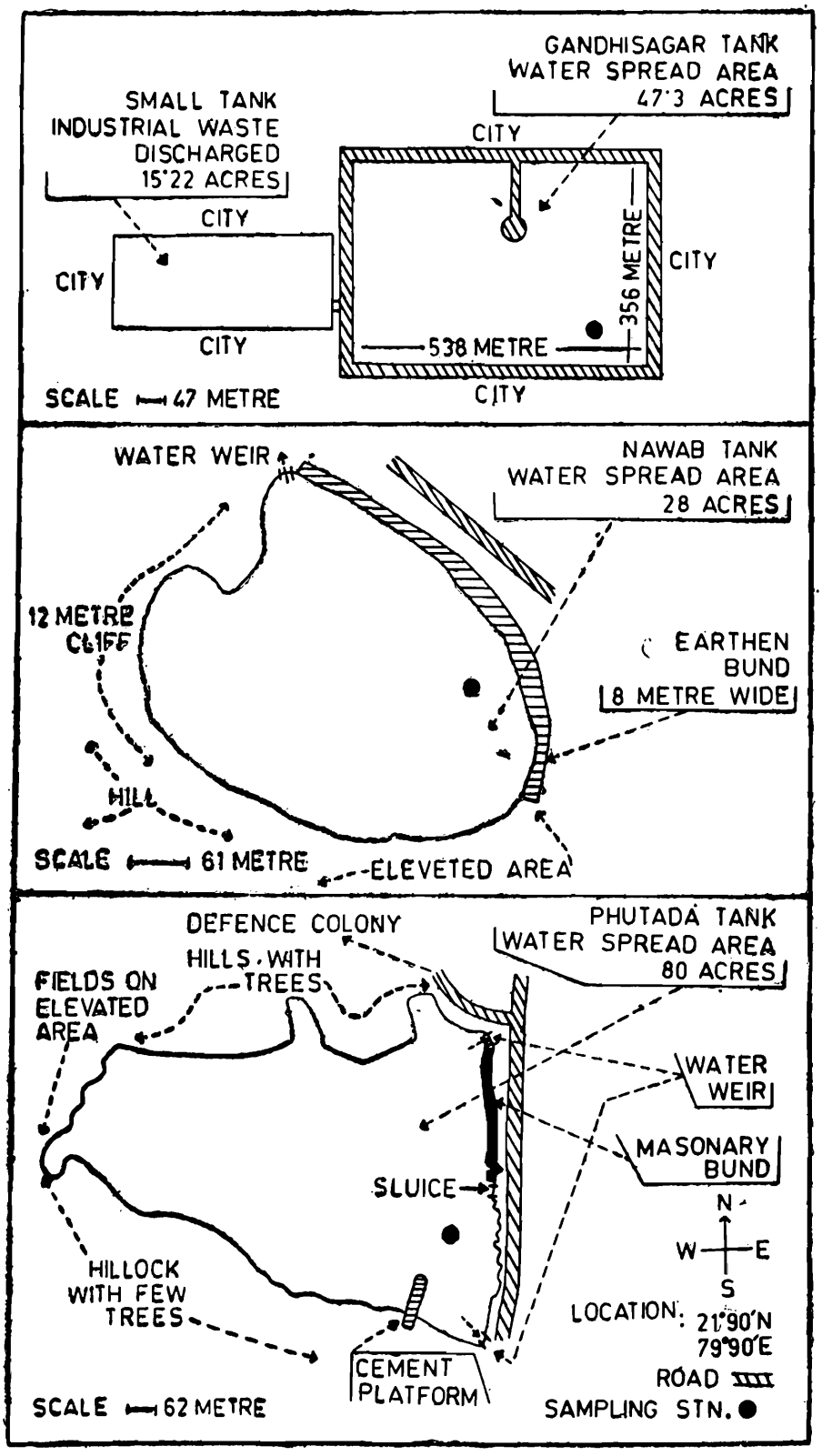


FIG. 1

Text-fig. 1. Map of Gandhisagar tank, Nawab tank and Phutada tank.

1. *Gandhisagar tank* : This is a rectangular tank situated in the heart of the city. The area is 47.3 acres, and on the three sides of the tank there are cement roads and on the fourth side the tank is

seperated from another small tank with an area of 15.22 acres. The depth of the tank is almost uniform and varies from 6 to 10 m. Three sides of the tank have stone embankment with stone steps running into the water level. The tank is partly polluted by domestic sewage and due to seepage from the adjoining small tank receiving textile mill effluent. Clothes are washed here on the stone steps.

2. *Nawab tank* : This is a small tank and the area being 28 acres. The depth of the tank varies from 2 to 10 m. This tank receives a continuous supply of water due to seepage from Ambazari, a large water reservoir, which is located close by. Hence, the water level is not reduced much in summer.

3. *Phutada tank* : This tank is used by State Fisheries department for rearing fish. The depth of the tank varies from 3 to 12 m. and the area being 80 acres. It receives land run-off and is subjected to recreational activities, like boating, angling etc. The tank is also used for bathing and washing purposes. The shore line is wavy and on one side there is a stony embankment. There are few trees on Western and Southern banks of the tank.

The day air temperature, especially in March, was generally high and ranged between 19.42°C to 38.70°C recorded from Meteorological data. Investigations were carried out for twenty four hours from 8.30 a.m. onwards on 13th March 1974, in Gandhisagar and from 10 a.m. onwards on 16th March 1974 in Nawab tank. Phutada tank was also investigated for twenty four hours from 9 a.m. onwards on the same day, *i.e.*, on 16th March 1974, as the latter two tanks are located near each other. On 13th and 16th March 1974 the sky was clear with bright sunshine.

METHODS OF INVESTIGATION

Water samples from the surface layers were taken with the help of a bottle from the same collecting stations every two hours and the chemical analysis was carried out immediately in the field. Special samples were taken for estimating dissolved oxygen (D.O.) and free carbon dioxide (Co_2). The water samples were always collected by gently allowing the water to flow into the bottles without causing entry of air bubles. For the plankton samples, water from the surface layers was taken into a plastic bucket of 20 liters capacity and filtered through the plankton net. Facilities for collecting the samples from deeper layers were not available, hence only surface samples were taken. The temperature was recorded with the help of an ordinary thermometer and pH by a pH meter. Turbidity was determined by a

turbidometer. Chemical factors such as dissolved oxygen, free carbon dioxide, bicarbonate and carbonate alkalinity, chloride, free ammonia, phosphate and total hardness due to calcium and magnesium were estimated as per methods given in the "Standard methods for the examination of water and waste water" (American Public Health Association, 13th Edition 1971).

Plankton samples were collected every two hours along with the water samples collected for chemical analysis. The samples were immediately preserved in 5% formalin. The phytoplankton counts were made by the "drop method" and the zooplankton was estimated with the help of a "Sedgwick Rafter cell".

Observations

Diurnal variations in the water chemistry of the tanks are given in Tables 1 to 3.

Temperature : Temperature fluctuations were between 20° to 23.5°C in Gandhisagar, 20° to 23° C in Nawab tank and 20.5° to 23.5°C in Phutada tank. The range of variations in the temperature was 3 to 3.5° C. The maximum temperature was recorded in all the tank between 2 p. m. to 3 p. m. and the lowest at 6 a. m. in Nawab tank between 1 to 5 a. m. in Phutada and from 4.30 to 6.30 a. m. in Gandhisagar. Thus marked variations in the day and night temperatures were not noticed as the difference being only 3° to 3.5°C.

Turbidity : Fluctuations in turbidity were ranged between 132 to 177 mg/litre in Gandhisagar. The minimum value was recorded from 12.30 a. m. to 8.30 a. m. and the maximum was at 12.30 p. m. The same was continued upto 6.30 p. m. After this there was decrease in value till 12.30 a. m. In Nawab tank maximum value observed was 177 mg/litre at 6. p. m. and 8 p. m., while the minimum of 144 mg/litre was seen at 10 a. m. In Phutada the turbidity values were low and ranged between 36 to 51 mg/litre. The minimum turbidity value was noted at 9. a. m. to 11 a.m. and after that there was a slight increase upto 42 mg/litre, which continnued from 1 p. m. to 11 p.m. The maximum was reached at 1 a. m. and contiued upto 7 a. m. of the second day.

pH : In all the tanks the pH was above 8. In Gandhisagar the range was between 8.85 and 9.30. The maximum was noticed at 4.30 p. m. and the minimum from 12.30 a. m. to 2.30 a. m. In Nawab tank, the fluctuation was between 8.1 to 8. 9. The minimum was noticed at 6 a. m. and the maximum was from 2 p. m. to 4 p.m. In Phutada

TABLE 1. Diurnal variations in the Physico-chemical factors in Gandhisagar tank on 13th/14th March 1974.

Time	Temperature (C)°	Turbidity mg/litre	pH	Free carbon-dioxide/ mg/litre	Carbonate as per $CaCo_3$ mg/litre	Bicarbonate as $CaCo_3$ mg/litre	Total Hardness as $CaCo_3$ mg/litre	Chloride as Cl mg/litre	Dissolved Oxygen mg/litre	Phosphate mg/litre	Free Ammonia mg/litre
1	2	3	4	5	6	7	8	9	10	11	12
8.30 a. m.	20.5	165	9.0	Nil	72	519	230	160	3.6	4.8	Nil
10.30 a. m.	20.5	165	9.0	Nil	80	534	195	165	5.2	4.8	Nil
12.30 p. m.	21.0	177	9.2	Nil	80	541	200	177	10.1	4.8	Nil
2.30 p. m.	23.5	177	9.25	Nil	88	546	185	177	14.5	4.8	Nil
4.30 p. m.	23.0	177	9.3	Nil	126	558	195	177	15.1	4.8	Nil
6.30 p. m.	22.5	177	9.15	Nil	120	560	190	177	12.9	5.2	Nil
8.30 p. m.	22.0	144	9.1	Nil	95	536	175	144	9.2	5.2	0.04
10.30 p. m.	21.0	144	9.0	Nil	94	523	180	144	8.4	5.6	Nil
12.30 a. m.	21.0	132	8.85	Nil	90	520	185	132	7.0	5.6	Nil
2.30 a. m.	21.0	132	8.85	Nil	80	520	175	132	5.8	5.6	Nil
4.30 a. m.	20.0	132	8.9	Nil	78	518	185	132	3.0	5.6	Nil
6.30 a. m.	20.0	132	8.9	Nil	78	514	190	132	2.8	5.6	Nil
8.30 a. m.	20.0	132	8.9	Nil	81	596	185	132	3.1	5.6	Nil

TABLE 2. Diurnal variations in the Physico-chemical factors in Nawab tank on 16/17 March 1974.

Time	Temperature (C)°	Turbidity mg/litre	pH	Free carbon-dioxide mg/litre	Carbonate as per $CaCo_3$ mg/litre	Bicarbonate as $CaCo_3$ mg/litre	Total Hardness as $CaCo_3$ mg/litre	Chloride as Cl. mg/litre	Dissolved Oxygen mg/litre	Phosphate mg/litre	Free Ammonia mg/litre
1	2	3	4	5	6	7	8	9	10	11	12
10.00 a. m.	22.0	144	8.6	Nil	10	92	115	50.0	7.8	0.4	Nil
12 Noon.	22.5	165	8.5	Nil	12	95	105	50.5	8.9	0.4	0.08
2.00 p. m.	23.0	165	8.9	Nil	18	98	100	46.0	9.4	1.0	Nil
4.00 p. m.	22.5	165	8.9	Nil	20	96	100	52.0	9.8	0.2	Nil
6.00 p. m.	22.0	177	8.7	Nil	22	92	100	53.0	9.6	0.2	2.0
8.00 p. m.	22.0	177	8.55	Nil	14	88	125	46.0	9.0	1.6	1.0
10.00 p. m.	21.0	165	8.5	Nil	12	85	100	56.0	8.2	1.0	1.0
12.00 a. m.	20.5	165	8.6	Nil	12	82	115	48.0	6.0	0.4	Nil
2.00 a. m.	20.5	165	8.4	Nil	11	81	105	47.0	6.1	1.6	1.0
4.00 a. m.	20.5	165	8.4	Nil	8	80	100	47.0	5.8	1.0	0.2
6.00 a. m.	20.0	165	8.1	0.1	Nil	86	100	48.0	2.8	0.8	1.0
8.00 a. m.	20.5	165	8.3	0.1	Nil	87	100	48.5	3.0	0.8	Nil
10.00 a. m.	21.0	165	8.5	Nil	9	90	115	49.5	6.2	0.8	Nil

TABLE 3. Diurnal variations in the Physico-chemical factors in Phutada tank on 16/17 March, 1974.

Time	Temperature (C)°	Turbidity mg/litre	pH	Free carbon-dioxide mg/litre	Carbonate as per $CaCo^3$ mg/litre	Bicarbonate as $CaCo^3$ mg/litre	Total Hardness as Cl. mg/litre	Dissolved Oxygen mg/litre	Chloride as Cl. mg/litre	Phosphate mg/litre	Free Ammonia mg/litre
1	2	3	4	5	6	7	8	9	10	11	12
9.00 a. m.	21.0	36	8.1	Nil	1.0	152	168	7.8	19.0	0.2	Nil
11.00 a. m.	21.5	36	8.25	Nil	6.0	156	184	9.0	18.0	0.2	Nil
1.00 p. m.	22.5	42	8.4	Nil	10.0	154	180	9.4	20.0	0.2	0.2
3.00 p. m.	23.5	42	8.4	Nil	12.0	174	175	9.6	21.0	Nil	0.2
5.00 p. m.	22.0	42	8.3	Nil	8.0	162	175	9.9	19.0	Nil	0.2
7.00 p. m.	22.0	42	8.2	Nil	2.0	152	175	9.2	18.5	Nil	0.04
9.00 p. m.	21.0	42	8.2	Nil	2.0	152	180	8.2	18.0	Nil	0.04
11.00 p. m.	21.0	42	8.15	Nil	1.0	154	160	6.0	19.0	Nil	0.02
1.00 a. m.	20.5	51	8.1	Nil	1.0	151	175	6.1	18.0	0.4	Nil
3.00 a. m.	20.5	51	8.0	Nil	1.0	150	160	5.8	17.5	Nil	0.04
5.00 a. m.	20.5	51	8.0	0.2	Nil	152	160	2.8	18.0	Nil	0.2
7.00 a. m.	21.0	51	8.1	0.3	Nil	142	165	3.0	18.0	Nil	0.2
9.00 a. m.	21.0	51	8.15	0.2	Nil	146	165	6.2	17.0	Nil	0.2

tank, the pH value was between 8 and 8.4 and the maximum noticed was from 1 p. m. to 3 p. m. and the minimum from 3 a. m. to 5 a. m.

Free carbon dioxide : Free carbon dioxide was not detected in Gandhisagar whereas it was present in Phutada tank from 5 a. m. to 7 a. m. and in Nawab tank from 6 a. m. to 8 a. m.

Carbonate : In Gandhisagar the carbonate content of water was slightly higher than in the other two tanks. The maximum value was 120 mg/litre at 6.30 p. m. and the minimum was 7.20 mg/litre at 8.30 a. m. of the first day. In Nawab tank, the maximum value of 22 mg/litre was noticed at 6 p. m. but no carbonate was detected at 6. a. m. and 8 a. m. In Phutada the maximum value of 12 mg/litre was noticed at 3 p.m. and the absence of carbonate was recorded at 5 a. m.

Bicarbonate : In Gandhisagar the bicarbonate fluctuations were between 514 to 560 mg/litre, the maximum at 6. 30 p. m. and the minimum at 6. 30 a. m. There was a gradual fluctuation in bicarbonate content in Nawab tank and the maximum value of 98 mg/litre was found at 3 p. m. and the minimum of 80 mg/litre at 4 p. m. In Phutada, the range was between 142 and 174 mg/litre, the maximum value was noticed at 3 p. m. and the minimum at 7 a. m. In all the tanks maximum bicarbonate content was noticed between 2 to 6 p. m. and the minimum from 4 a. m. to 7 a. m.

Total hardness ; Total hardness fluctuated from 175 to 230 mg/litre in Gandhisagar, 100 to 125 mg/litre in Nawab tanks and 160 to 184 mg/litre in Phutada. The maximum value was found at 8.30 a. m. in Gandhisagar at 8 p. m. in Nawab tank and at 11 a. m. in Phutada. The minimum values were recorded either in the evening or early morning hours.

Chloride : The chloride content of the Gandhisagar tank varied between 132 to 177 mg/litre. There was a gradual increase in the chloride content from 8.30 a. m. to 12.30 p. m. It stabilised there upto 6.30 p. m. and afterwards there was a gradual decrease. In Nawab tank, the chloride content did not show much variation. The fluctuations were between 46 to 56 mg/litre. In Phutada the range was still more limited and the fluctuations were between 17.5 to 21 mg/litre.

Dissolved oxygen : In Gandhisagar dissolved oxygen showed a fluctuation from 2.8 to 15.1 mg/litre. The amount of dissolved oxygen was maximum at 4.30 p.m. and minimum at 6.30 a.m. In Nawab tank, the highest value of 9.8 mg/litre was at 4 p. m. and the minimum of 2.8 mg/litre was at 6 a.m. Dissolved oxygen varied from 2.8 to 9.9 mg/litre in Phutada tank and the highest value was noticed at 5 p.m. and the

lowest at 5 a.m. Gandhisagar showed a rich phytoplankton population, and had a steep rise in dissolved oxygen value from 12.30 p.m. to 4.30 p.m. but the minimum value was the same as in the other tanks.

Phosphate : In Gandhisagar, the phosphate content ranged between 4.8 to 5.6 mg/litre. From 8.30 a.m. upto 4.30 p.m. the values were minimum and 6.30 p.m. onwards a slight increase was observed and the maximum value was reached at 10.30 p.m. This value remained constant till 6.30 a.m. next day. In Nawab tank, the minimum value observed was 0.2 mg/litre and the maximum was 1.6 mg/litre. The phosphate content, showed the least value in Phutada tank and during certain hours of the day, *i.e*, from 3 p.m. to 11 p.m. and from 3 a. m. to 7 a.m. It was totally absent. The range was between 0.2 to 0.4 mg/litre.

Free ammonia : In Gandhisagar, free ammonia of 0.04 mg/litre was noticed at 8.30 p.m. In Nawab tank, the maximum value of free ammonia content recorded was 2 mg/litre at 6 p.m. Free ammonia was not noticed between 2 p.m. to 4 p.m. and at 8 a.m. In Phutada tank free ammonia was noticed from 1 p.m. to 11 p.m. and again from 3 a. m. to 7 a.m. The maximum value recorded was 0.2 mg/litre.

ZOOPLANKTON

Diurnal variations in the zooplanktonic forms of the three tanks is given in Tables 4 to 6. The zooplankton of the three tanks (Text-fig. 2) showed three peaks during the 24 hours. In Gandhisagar the maximum number of planktons was 7186 units/litre at 12.30 a.m. and the minimum of 103 units/litre at 12.30 p.m. The highest number of the zooplankters was observed at 5 a.m. in Phutada and at 8 a.m. in Nawab tank. The maximum number of plankters were 679 units/litre in Nawab tank and 538 units/litre in Phutada.

The Zooplankton mainly consists of Rotifers, cladocerans, copepods and nauplius larvae. In all the three tanks Rotifera was the dominant group followed by nauplius larvae, copepods and cladocerans. The maximum Rotifer population was noticed in Gandhisagar. In Nawab tank the cladocerans were not found excepting a few forms at 10 p.m. (9 units per litre). The copepod population in Nawab tank and Phutada tank was roughly the same but in Gandhisagar it was muchmore. In Phutada the number of nauplius larvae was comparatively small.

ROTIFERA

In Gandhisagar the maximum Rotifer population was noticed at 12.30 a.m. and the minimum at 12.30. p.m. At 6.30 p.m. as many as

TABLE 4. Showing the diurnal variations of Zooplankton in Gandhisagar tank on 13/14th March, 1974 (Units/Litre).

Name of the Genera & species.	8.30 a. m.	10.30 a. m.	12.30 p. m.	2.30 p. m.	4.30 p. m.	6.30 p. m.	8.30 p. m.	10.30 p. m.	12.30 a. m.	2.30 a. m.	4.30 a. m.	6.30 a. m.	8.30 a. m.
ROTIFERA													
Rotaria sp.	10	—	—	—	—	6	—	—	—	—	—	20	—
Floscularia sp.	—	—	5	—	—	6	—	—	—	—	—	—	—
Sinantherina sp.	—	—	—	5	10	—	—	—	—	—	—	—	—
Filinia longiseta Ehrenberg	5	8	—	—	—	6	—	—	—	—	12	—	—
Keratella cochlearis (Gosse)	480	301	50	170	770	362	432	1001	2386	156	563	1268	887
Keratella tropica (Apstein)	265	250	—	280	1070	678	528	252	1298	451	358	998	755
Asplanchna intermedia Hudson	—	—	—	—	—	—	—	—	58	12	—	—	—
Brachionus angularis (Gosse)	685	121	—	25	740	356	128	121	512	178	179	374	524
Brachionus urceolaris O. F. Muller	—	—	—	—	10	—	—	—	—	—	—	—	—
Total :	1445	680	55	480	2600	1414	1088	1374	4249	797	1112	2660	2166
CLADOCERA													
Diaphanosoma sarsi Richard	—	—	—	—	—	—	32	—	140	42	38	41	64
Moina micrura	30	33	—	5	10	6	72	44	194	97	356	187	—
Ceriodaphnia rigaudi Richard	—	8	—	—	—	—	—	—	—	—	—	—	—
Total :	30	41	—	5	10	6	104	44	334	139	394	228	64
COPEPODA													
Cyclops sp.	110	223	16	80	120	30	1560	1012	620	132	397	395	230
Mesocyclops hyalinus (Rehberg)	—	43	—	—	—	—	40	76	53	4	12	41	12
Total :	110	266	16	80	120	30	1600	1088	673	136	409	436	242
Nauplius larvae	1120	86	32	695	1350	1410	168	594	1930	165	908	747	816
Total Zooplankton	2705	1073	103	1260	4080	2860	2960	3100	7186	1237	2723	4071	3258

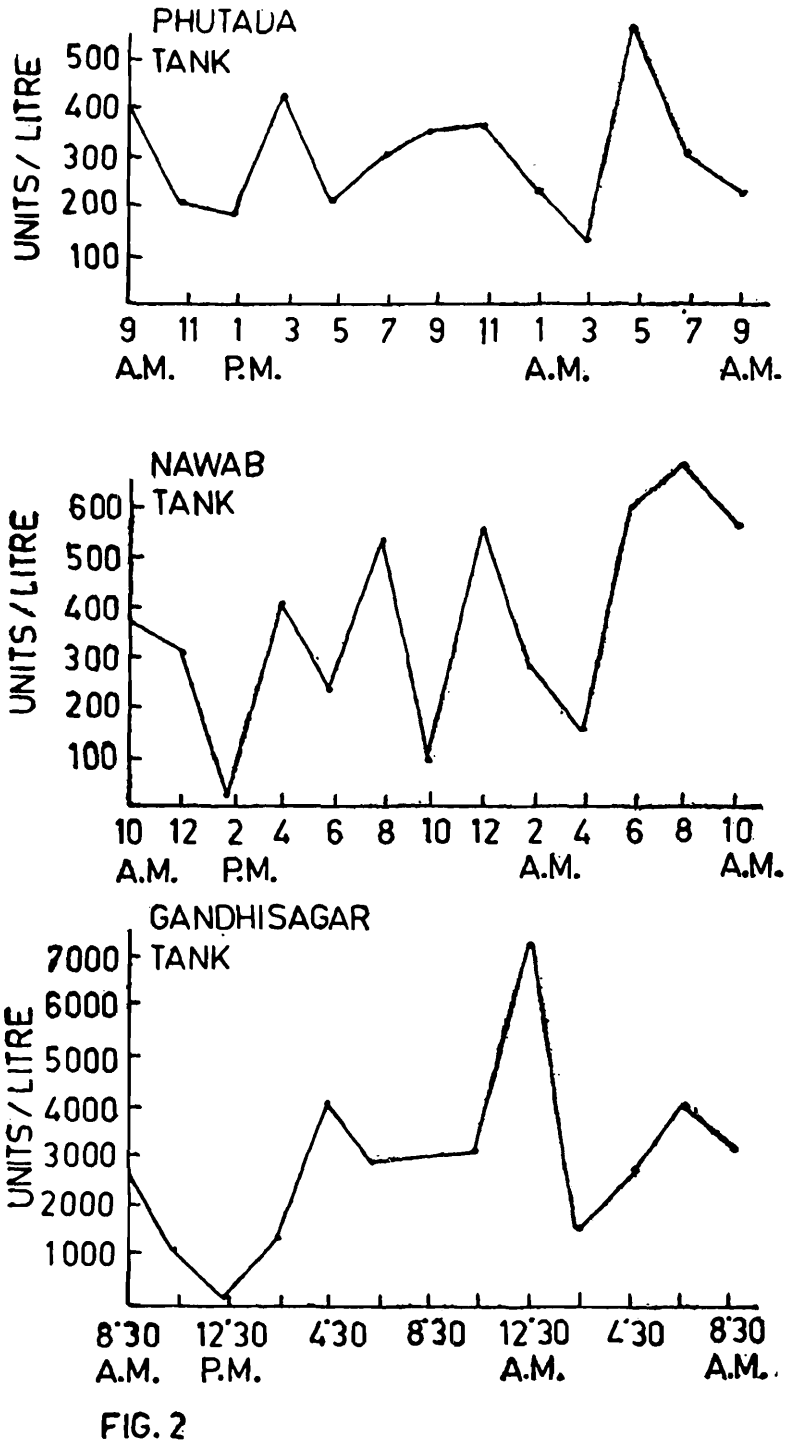
TABLE 5. Showing the diurnal variations of Zooplankton in Nawab tank on 16/17th March, 1974 (Units/Litre).

Name of Genera and species	10.00 a. m.	12.00 noon	2.00 p. m.	4.00 p. m.	6.00 p. m.	8.00 p. m.	10.00 p. m.	12.00 mid-night.	2.00 a. m.	4.00 a. m.	6.00 a. m.	8.00 a. m.	10.00 a. m.
ROTIFERA													
Filinia longiseta Ehrenberg	—	—	—	—	—	—	—	—	—	—	18	—	33
Polyarthra vulgaris Carlin	58	120	—	120	27	—	8	140	20	—	18	63	50
Keratella cochlearis (Gosse)	185	30	4	100	18	162	17	80	80	108	90	252	151
Keratella tropica (Apstein)	12	10	8	40	—	—	—	—	—	—	54	—	—
Asplanchna intermedia Hudson	6	22	8	26	12	129	9	—	—	—	18	38	101
Trichocerca cylindrica Imhof	6	25	—	60	3	—	17	40	20	—	18	63	50
Brachionus quadridentata Hermann	—	—	—	—	—	—	—	40	—	—	—	—	16
Epiphanes sp.	—	17	—	—	9	16	9	—	—	—	—	25	16
Lecane sp.	—	6	—	—	—	—	—	—	—	—	—	—	—
Monostyla sp.	—	—	—	—	—	—	—	—	20	—	162	88	16
Total :	267	230	20	346	69	307	60	300	140	108	378	529	423
CLADOCERA													
Moina dubia de Guerne et Richard.	—	—	—	—	—	—	9	—	—	—	—	—	—
COPEPODA													
Cyclops sp.	—	—	4	20	—	48	17	—	20	—	—	—	—
Mesocyclops leuckarti Claus	42	58	4	20	151	97	9	140	40	48	54	37	51
Total :	42	58	8	40	151	145	26	140	60	48	54	37	51
Nauplius larvae.	58	22	—	26	18	92	17	140	80	12	162	113	84
Total Zooplankton	367	310	28	412	238	549	112	580	280	168	594	679	568

TABLE 6. Showing the diurnal variations of Zooplankton in Phutada tank on 16/17th March 1974 (Units/Litre).

Name of Genera and species.	9.00 a. m.	11.00 a. m.	1.00 p. m.	3.00 p. m.	5.00 p. m.	7.00 p. m.	9.00 p. m.	11.00 p. m.	1.00 a. m.	3.00 a. m.	5.00 a. m.	7.00 a. m.	9.00 a. m.
ROTIFERA													
Conochilus sp.	—	—	—	—	—	5	5	25	8	—	15	5	15
Keratella cochlearis (Gosse)	27	10	—	—	—	5	10	5	77	—	25	10	30
Keratella tropica (Apstein)	165	64	27	85	18	61	82	76	77	25	173	65	70
Asplanchna intermedia Hudson	11	—	5	5	—	—	—	—	—	—	5	5	10
Trichocerca cylindrica Imhof	—	—	—	10	—	—	5	—	—	—	—	—	—
Brachionus angularis (Gosse)	5	5	10	—	—	—	2	—	—	—	—	—	—
Brachionus quadridentata Hermann	93	43	59	205	80	120	172	34	34	20	100	85	45
Brachionus urceolaris O. F. Muller	—	5	5	5	5	5	—	4	4	—	15	—	—
Brachionus caudatus Barrois & Daday	—	—	—	5	—	10	—	—	—	—	—	5	—
Epiphanes sp.	—	—	5	—	5	15	—	4	4	—	—	—	—
Total :	301	127	111	315	108	221	174	162	144	45	333	175	170
CLADOCERA													
Simocephalus vetulus Schodler	—	—	—	—	—	—	—	—	—	5	—	—	20
Moina brachiata (Jurine)	—	10	5	—	—	10	48	52	25	15	35	20	5
Macrothrix sp.	—	—	—	—	—	—	—	10	—	10	—	—	—
Total :	—	10	5	—	—	10	48	62	25	30	35	20	25
COPEPODA													
Cyclops sp.	60	16	16	40	23	50	81	76	25	25	120	35	—
Diaptomus sp.	—	—	—	—	—	—	5	25	8	5	15	—	5
Total :	60	16	16	40	23	50	86	101	33	30	135	35	5
Nauplius larvae.	49	59	48	65	75	15	40	35	25	10	35	70	30
Total Zooplankton	410	212	180	420	206	296	348	360	227	115	538	300	230

six different species of rotifers were noticed. The populations were dominated by *Keratella cochlearis*, *Keratella tropica* and *Brachionus angularis*. In Nawab tank fluctuations were observed in the rotifer population and the maximum number were noticed from 6 a.m. to



Text-fig. 2. Diurnal variations in the total Zooplankton population in the three tanks.

10 a.m. and the minimum at 2 p.m. The rotifers mainly consisted of *Keratella cochlearis* and *Polyarthra vulgaris*, *Asplanchna intermedia* and *Trichocerca cylindrica* was also present in good numbers. *Asplanchna* showed a peak at 8 p.m. and was not recorded from 12 a.m. to 4 a.m. In

Phutada tank three major peaks of rotifer population were observed at 9 a.m., 3 p.m. and 5 a.m. The population being dominated by *Keratella tropica* and *Brachionus quadridentata*.

Keratella cochlearis

In Gandhisagar a major peak of 2386 units per/litre of *Keratella cochlearis* was recorded at 12.30 a.m. and a minor peak of 1269 units/ litre at 6.30 a.m. The minimum number of only 50 units per litre was noticed at 12.30 p.m. In Nawab tank this rotifer was not found in large numbers, the maximum number was 252 units/litre at 8 a.m, and the minimum was 4 units/litre at 2 p.m. In Phutada the maximum number was 27 units/litre at 9 a.m. and in the samples collected from 1 to 5 p.m. it was not present.

Keratella tropica

In Gandhisagar *Keratella tropica* was found in abundant numbers and showed two major peaks at 12.30 a.m. and 4.30 p.m. One minor peak was recorded at 6.30 a. m. This rotifer was totally absent from the sample taken at 12.30 p. m. In Nawab tank the rotifer was recorded from 10 a. m. to 4 p. m. and again at 6 a. m. It was not observed from 6 p. m. to 4 a.m. The maximum number recorded was 54 units/litre In Phutada, the rotifer was present in the samples throughout the period of collection but its number varied from 18 to 173 units/litre. The maximum number was noticed at 5 a. m. and the minimum at 5 p. m.

Brachionus angularis

This form was present in good numbers in Gandhisagar. It was totally absent in the samples collected from Nawab tank and only a few forms were noticed in the samples from Phutada from 9 a. m. to 1 p. m. In Gandhisagar tank, *Brachionus angularis* showed three peaks, at 8. 30 a. m., 4.30 p. m. and 12.30 a. m. At 12.30 p. m. (noon) they were totally absent.

Brachionus quadridentata

Brachionus quadridentata was absent in all the samples from Gandhisagar. In Nawab tank it was recorded in small numbers only in two samples. *Brachionus quadridentata* along with *Keratella tropica* formed the major bulk of the rotifers in the samples of Phutada. It was present in moderate numbers throughout the period of collection. The maximum number of 105 units/litre was observed at 3 p. m.

Asplanchna intermedia

In Gandhisagar tank it was found only in two samples collected at 12.30 and 2.30 a. m. In Nawab tank the maximum number was recorded in the samples collected from 12 a. m. to 4 a. m. In Phutada this rotifer was recorded in the samples collected at 5 a. m., 9 a. m., 1 p. m. and 3 p. m. Their number never exceeded 10 units/ litre.

Polyarthra vulgaris

This rotifer was present in the samples of Nawab tank and the highest number of 140 units/litre was found at midnight. It was not recorded at 2 p. m., 8 p. m. and 4 a. m.

Trichocerca cylindrica

Trichocerca cylindrica was present in Nawab tank and showed maximum number of 63 units/litre at 8 a.m. This rotifer was absent in the samples collected from Gandhisagar and Phutada.

CLADOCERA

The cladocera population was comparatively poor. In Gandhisagar only three forms were noticed and *Moina micrura* was the dominant form. The maximum number of 256 units/litre was recorded at 4.30 a.m. *Diaphanosoma sarsi* was observed during the night time and early morning hours, and the maximum number was 140 units/litre at 12.30 a.m. In Nawab tank the cladocerans were absent from all the samples excepting on one occasion, when only 9 units/litre of *Moina micrura* were recorded at 10 p.m. In Phutada, *Moina brachiata*, *Simocephalus vetulus* and *Macrothrix* sp. were present in small numbers. The maximum number of *Moina brachiata* was 52 units/litre at 11 p.m.

COPEPODA

The copepoda population was abundant in Gandhisagar and was found throughout the 24 hours period. The dominant form was *Cyclops* sp. The maximum number of *Cyclops* sp. (1560 units/litre) was found at 8.30 p.m. and they were found in good numbers during night hours, *i.e.*, from 8.30, p.m. to 6.30 a.m. *Mesocyclops hyalinus* was mainly present during the night hours and the maximum numbers recorded was 76 units/litre at 10.30 p.m. This form was absent from the samples collected from Nawab tank and Phutada tank. Nawab tank showed

maximum number of *Mesocyclops leuckarti* at 6 p.m. and the maximum was 151 units/litre. In Phutada tank the copepod population mainly consisted of *Cyclops* sp. and *Diaptomus* sp. The copepods showed two peaks of 101 units/litre and 135 units/litre at 11 p.m. and 5 a.m. respectively. The maximum number of *Cyclops* sp. (120 units/litre) was recorded at 5 a.m. *Diaptomus* sp. was observed during night hours and the maximum number was 25 units/litre at 11 p.m.

NAUPLIUS LARVAE

Nauplius larvae were present in almost all the samples of the three tanks. In Gandhisagar they were found in large numbers and showed one major peak at 12.30 a.m. and two smaller peaks at 6.30 p.m. and 8.30 a.m. of the first day.

In Nawab tank the maximum number recorded was 162 units/litre at 6 a. m. and 140 units/litre at 12 a. m. At 2 p. m. they were not noticed in the sample. In Phutada they were present in small numbers throughout the 24 hours period.

PHYTOPLANKTON

In all the samples phytoplankton was composed of (Table 7 to 9, Text-fig.3) Myxophyceae which was the dominant group. In Gandhisagar the phytoplankton was very rich and it showed two pulses, one at 12.30 p. m. and the other at 8.30 p. m. (148604 units/litre). In Nawab tank two pulses were noticed, one at 12 p. m. and the other at 8 to 10 p. m. (55213 units per litre). In Phutada also two pulses were noticed one at 1 p.m. and the other at 7 p. m. (35636 units/litre).

MYXOPHYCEAE

This group was represented by four genera namely *Microcystis*, *Oscillatoria*, *Spirulina* and *Nostoc* in Gandhisagar. *Nostoc* was present during the period, 12.30 p. m. to 4.30 p. m. and was represented in small numbers (200 to 615 units/litre). The other three genera were very well represented and showed two distinct peaks, one at 12.30 p. m. and other at 8.30 p.m. The minimum number was observed between 2.30 to 6.30 a. m. In Nawab tank *Nostoc* was not observed and the other three genera were well represented and showed two peaks, one at 12 p. m. and the other at 8 p. m. The minimum numbers were recorded late in the night or in early hours of the morning In Phutada only two genera namely, *Microcystis Oscillatoria* were observed. These algae showed a gradual rise in numbers from 9 a. m. to 7 p. m. and the minimum number was noticed from 1 a. m. to 7 a. m.

TABLE 7. Showing the diurnal variations of Phytoplankton in Gandhisagar on 13th March, 1974 (Units/Litre).

Name of Genera	8.30 a. m.	10.30 a. m.	12.30 p. m.	2.30 p. m.	4.30 p. m.	6.30 p. m.	8.30 p. m.	10.30 p. m.	12.30 a. m.	2.30 a. m.	4.30 a. m.	6.30 a. m.	8.30 a. m.
MYXOPHYCEAE													
Microcystis	13100	12000	88400	69780	60009	38955	96000	81312	24000	17877	13000	9650	11570
Spirulina	6560	11870	16800	14590	19672	24860	25000	16000	4400	8912	2500	4990	4886
Oscillatoria	16840	22384	24800	19900	12300	14663	24623	19912	3496	3190	10096	11213	14007
Nostoc.	—	—	625	200	300	—	—	—	—	—	—	—	—
Total :	36500	46254	130625	104470	92311	78478	145623	117224	31896	29979	25596	25853	30463
CHLOROPHYCEAE													
Scenedesmus	500	621	1850	892	509	603	2250	2104	400	476	396	342	421
Clostorium	150	151	240	168	190	121	291	300	258	130	102	100	136
Total :	650	772	2090	1090	699	724	2541	2404	658	606	498	442	557
EUGLENOPHYCEAE													
Euglena	102	216	480	491	522	448	340	302	366	470	309	218	89
Phacus	—	—	240	137	80	86	100	—	—	—	—	—	—
Total :	102	216	720	628	602	534	440	302	366	470	309	218	89
BACILLARIOPHYCEAE													
Pinnularia	48	79	240	196	—	48	—	—	52	68	—	—	—
Navicula	—	75	160	32	—	—	—	—	—	—	—	—	—
Total :	48	155	400	228	—	48	—	—	52	68	—	—	—
Total Phytoplankton.	37300	47397	133825	706386	93612	79784	148604	119930	32972	31123	26403	26513	31109

TABLE 8. Showing the diurnal variations of Phytoplankton in Nawab tank on 16/17th March, 1974 (Units/Litre).

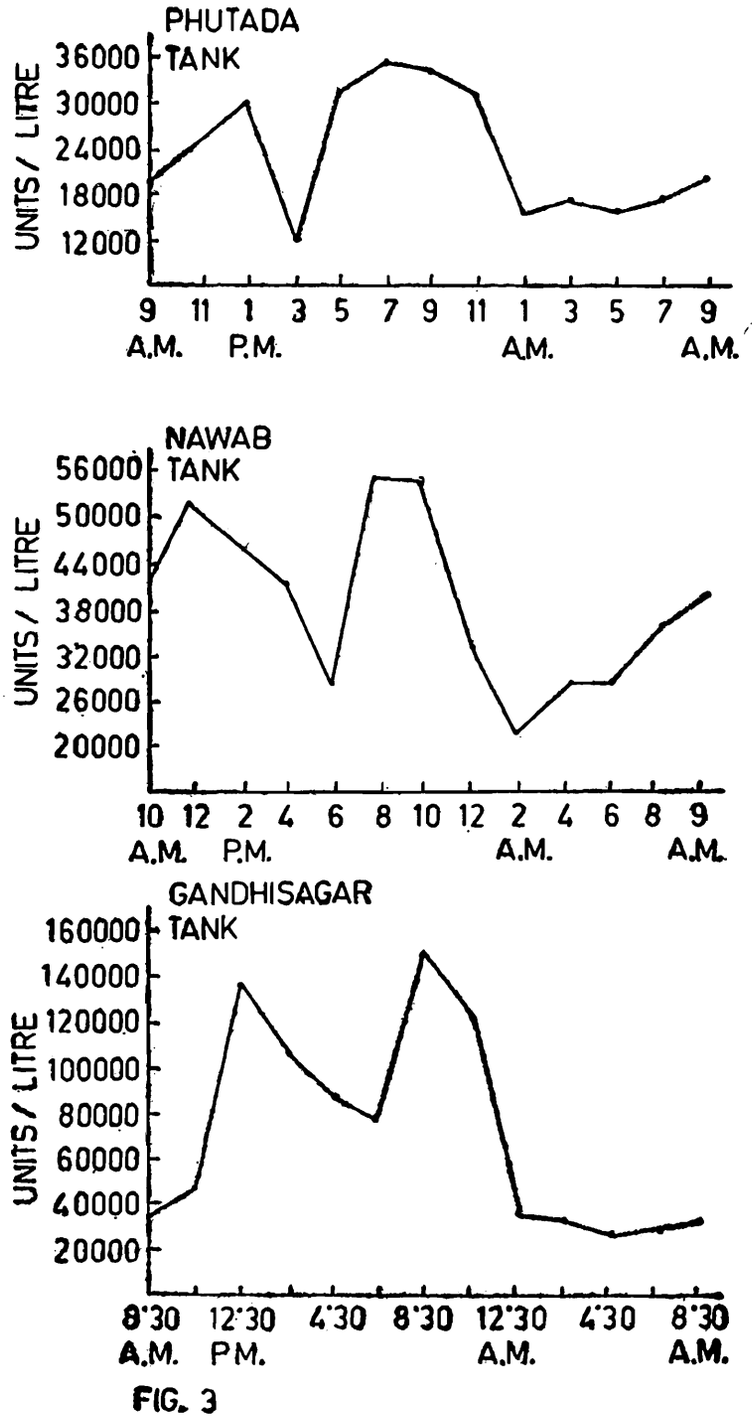
Name of Genera	10.00 a. m.	12.00 noon.	2.00 p. m.	4.00 p. m.	6.00 p. m.	8.00 p. m.	10.00 p. m.	12.00 midnight	2.00 a. m.	4.00 a. m	6.00 a. m.	8.00 a. m.	10.00 a. m.
MYXOPHYCEAE													
Microcystis	2600	25317	22950	18196	12980	28481	28612	14880	7289	15915	15110	24862	26106
Oscillatoria	5920	12180	10812	8902	5098	12930	11600	10707	8690	6961	7215	5000	5970
Spirulina	6420	10701	9868	10160	6412	11437	12016	7415	3915	3765	4081	3970	5186
Total :	38340	48198	43630	37258	24490	52848	52228	33002	19894	26636	26411	33832	37262
CHLOROPHYCEAE													
Eudorina	131	174	206	366	50	—	—	—	—	—	—	46	120
Pediastrum	200	288	174	280	160	203	385	155	190	175	88	170	176
Total :	331	462	380	646	210	203	385	155	190	175	88	216	296
EUGLENOPHYCEAE													
Euglena	677	1392	1012	1248	1300	896	808	509	200	415	341	251	576
Phacus	—	50	41	—	—	—	—	—	—	—	—	—	—
Total :	677	1442	1053	1284	1300	896	808	509	200	415	341	251	576
BACILLARIOPHYCEAE													
Navicula	1820	2160	1200	1981	2006	1266	890	312	765	571	571	965	1260
Total Phytoplankton	41168	52262	46263	41169	28006	55213	54311	33978	21049	27744	27411	35264	39394

TABLE 9. Showing diurnal variations of Phytoplankton in Phutada tank on 16/17th March, 1974 (Units/Litre).

Name of Genera	9.00 a. m.	11.00 a. m.	1.00 p. m.	3.00 p. m.	5.00 p. m.	7.00 p. m.	9.00 p. m.	11.00 p. m.	1.00 a. m.	3.00 a. m.	5.00 a. m.	7.00 a. m.	9.00 a. m.
MYXOPHYCEAE													
Microcystis	5416	9630	10038	10038	11161	12318	15980	16160	8463	8106	5960	6896	6000
Oscillatoria	15230	15133	19635	1835	20264	22898	18200	15033	7019	9813	10312	10930	13884
Total :	20646	24763	29673	11873	31425	35216	34180	31193	15482	17687	16272	17826	19884
CHLOROPHYCEAE													
Scenedesmus	206	330	284	150	230	300	364	218	250	180	126	159	189
BACILLARIOPHYCEAE													
Navicula	51	160	88	78	102	110	200	85	50	52	71	60	46
Total Phytoplankton	20719	25253	30045	12101	31757	35626	34744	31496	15782	17919	16469	18045	20119

CHLOROPHYCEAE

In Gandhisagar only two genera, namely, *Scenedesmus* and *Closterium* were found in the samples and the peaks were observed at 12.30 p. m. and 8.30 p. m. Their population was very much less than Myxophyceae. In Nawab tank, *Eudorina* and *Pediastrum* were present in small numbers.



Text-fig. 3. Diurnal variations in the total phytoplankton population in the three tanks.

Eudorina was not recorded from 8 p. m. to 6 a. m. and their maximum number (366 units/litre) was at 4 p. m. and the minimum at 6 a. m. In Phutada only one genus, namely *Scenedesmus* was observed in the

samples, and two minor peaks were noticed one at 11 a. m. and the other at 9 p. m.

EUGLENOPHYCEAE

This group was represented by two genera only *Euglena* and *Phacus* in Gandhisagar and Nawab tank. This group was not present in the samples from Phutada. In Gandhisagar *Phaeus* was noticed from 12.30 p. m. to 8.30 p. m. and the maximum number of 240 units/litre was recorded at 12.30 p. m. *Euglena* was present in all the samples and was recorded in good numbers (480 to 522 units/litre) from 12.30 p. m. to 4.30 p. m. In Nawab tank, *Phacus* was present in small numbers and was recorded between 12 p. m. to 2 p. m. *Euglena* was present throughout the 24 hours period and the maximum number of 1392 units/litre was recorded at 12 p. m. Their number was less during night.

BACILLARIOPHYCEAE

This group represented by *Pinnularia* and *Navicula*. *Pinnularia* was found only in Gandhisagar during certain hours of the day and the maximum number of 240 units/litre was recorded at 12.30 p. m. *Navicula* was recorded from 10.30 a. m. to 2. 30 p. m. in Gandhisagar and in the other two tanks it was noticed throughout the 24-hour period. In Nawab tank the maximum number was noticed at noon and in Phutada at 9 p. m.

DISCUSSION

In the study on the diurnal variations of the three water bodies it was observed that the temperature fluctuations ranged between 20°C to 23.5°C. The highest temperature reached at 2 p. m. in Nawab tank, at 2.30 p. m. in Gandhisagar and at 3 p. m. in Phutada. This is in conformity with the size of the tanks, Nawab tank being the smallest and Phutada the largest. Besides, Nawab tank is surrounded by a small practically barren hills and consequently is heated up early and takes longer time to cool and the lowest temperature was observed at 6 a. m. Phutada tank is located on the outskirts of the city and is exposed to wind, hence it cools earlier, the lowest temperature was observed between 1 to 5 a. m. In Gandhisagar the lowest temperature was reached at 4.30 a. m. The highest D. O. value was observed between 4 p. m. to 5 p. m. and the lowest from 5 a. m. to 6.30 a. m. Free carbon dioxide (0.1 to 0.3 mg/litre) was noticed in Phutada and Nawab tank between 5 a.m. to 7 a.m or 8 a.m. In Gandhisagar, free

carbon dioxide was not detected at all. This might have been due to the high carbonate values. In all the tanks the PH value was above 8. The highest pH was reached between 1 p. m. to 4 p. m. and the lowest from 12.30 a. m. to 6 a. m. These results are in agreement with the findings of Michael (1966). The Phosphate values were quite high in Gandhisagar (4.8 to 5.6 mg/litre) comparatively lower in Nawab tank (0.2 to 1.6 mg/litre) and very low in Phutada (0.2 to 0.4 mg/litre). The chloride value was quite high in Gandhisagar. The high chloride content indicates pollution of water (Sarkar and Rai, 1964 ; Mills, 1972).

Jolly (1965) found that some copepods and cladocera rise to the surface water in their greatest concentration exactly after two hours of sunset. Krishnamurthi and Visweswara (1965) stated that cladocera and copepods were most abundant at surface at night than during day indicating vertical diurnal movement. The present study confirms this view. It has been found that the phytoplankton showed bimodal peak one at noon and other between 7 p.m. to 10.30 p.m. Shetty *et al.* (1962) pointed out that phytoplankton peaks, should be followed by zooplankton peaks. Since the former serves food for latter. Gilyarow (1965) also observed a definite correlation between the distribution of zooplankton and phytoplankton while discussing vertical distribution of plankton. Considering Phytoplankton as food for cladocera and copepods the latter peak of phytoplankton between 7 p.m. to 10.30 p.m. might have brought the cladocerans and copepods to the surface layer for grazing purposes. This view is also confirmed by the grazing theory of Harvey *et al.* (1935). Welch (1952) also stated that the diurnal movement on the basis of food relations, are largely based upon the fact that phytoplankton is abundant near the surface, thus making such a region rich for the migrating forms. The absence of these organism (Crustacea) in the surface water during day time could be explained on the basis of the hypothesis of Davis (1955) who pointed out that though zooplankters are driven by hunger, yet stay away from surface layer due to day light. The diurnal variations in the zooplanktonic forms in all the three tanks showed three peaks during the 24-hours period. In Gandhisagar the highest number was found at 12.30 a.m. and the maximum number of zooplankton was noticed at 5 a.m. to 8 a.m. in Phutada and Nawab tank respectively. Zooplankton mainly consists of Rotifer, cladocera, copepoda and nauplii. Among the rotifers *Keratella*, *Brachionus*, *Asplanchna* and *Polyarthra* were the main genera to show their diurnal movement. *Keratella cochlearis* does not reveal any diurnal migration as its peaks were found at different times during the twenty four hours in all the three tanks.

Keratella tropica showed their maximum number during mid night at 12.30 a.m. and 4.30 p.m. in Gandhisagar. In Nawab tank it is recorded from 10.00 a.m. to 4 p.m. whereas in Phutada the maximum number was found at 5 a.m.

Brachionus angularis was present in Gandhisagar in good numbers and showed three peaks at 8.30 a.m., 4.30 p.m. and 12.30 a.m. In Phutada tank *Brachionus quadridentata* was present in moderate numbers throughout the period of collection, the maximum was observed at 3 p.m. *Polyarthra vulgaris* showed its highest number at midnight. *Trichocerca cylindrica* was present only in Nawab tank and the maximum number was found at 8 a.m. The above rotifers did not exhibit any prominent pattern of their migration and they show various peaks at different times in all the tanks. Probably their migration is different from tank to tank as stated by Welch (1952) that even the member of any one species may not exhibit a same pattern of diurnal movement in the different water bodies. As such rotifers do not manifest any diurnal migration which is in conformity with the view of Welch (1952) who stated that apparently the rotifer group as a whole is very little concerned to show diurnal migration. Nauplii showed their peak at midnight or early in the morning in all these water bodies.

In all the samples Phytoplankton was composed of Myxophyceae, Chlorophyceae, Euglenophyceae and Bacillario-phyceae. The main genera involved were *Mcrocystis*, *oscillatoria* and *Spirulina*, which showed two peaks one at noon and the other at 8 to 8.30 p.m. in Gandhisagar and Nawab tank. In Phutada only two genera *Microcystis* and *oscillatoria* were present and showed gradual rise from 9 a.m. to 7 p.m. The total phytoplankton showed bimodal peak one at noon and the other between 7 to 10 p.m. Out of these four groups, Myxophyceae was dominant which exhibited diurnal movement.

Thus the diurnal variation studies showed the abundance of the phytoplankton, in the early part of night. The cladoceran and copepods peaks were also observed at this time. The pH values were high in afternoon and comparatively low in the latter part of the night. The maximum D. O. values were recorded in the afternoon and the lowest between 5 a.m. to 6.30 a.m. The rotifer population was generally low at noon. The nauplius larvae showed a peak at midnight or early in the morning.

Maloney and Tressler (1942) noticed that the nauplii of copepods showed no diurnal movement in Carogo lake at New York. Pennak (1944) did not notice any vertical movement of nauplii in late summer in five northern Colorado mountain lake. Pew and Pennak (1949)

observed a diurnal movement of nauplii throughout the year in a lake in Indiana U.S.A. The present investigations carried out in March 1974 in three tropical water bodies reveal that the nauplii exhibit a diurnal movement showing peak at midnight or early in the morning. Probable reasons for the migration of planktonic forms have been discussed but in order to study the diurnal movement in detail, a much more extensive study is needed. Efforts should be made to find out some features about which our present knowledge is scanty. As such diurnal movement of plankton is rather a complicated phenomenon which requires further investigation.

Summary

Diurnal variations in the physico-chemical factors and plankton in surface layers of three tanks have been studied. The diurnal variation studies showed the abundance of phytoplankton in the early part of night. The Cladoceran and Copepod peaks were also observed in the early part of night. The pH values were high in afternoon and comparatively low in the latter part of night. The minimum dissolved oxygen values were reached in the afternoon and lowest between 5 a. m. to 6.30 a. m. The rotifer population was generally low at noon. The nauplius larvae showed a peak at midnight or early in the morning.

Acknowledgements

The present work was completed in the department of Zoology, Institute of Science, Nagpur. We are thankful to Dr. A. Gopalkrishna, Director, Institute of Science, Nagpur for providing facilities. Thanks are also due to Dr. R. G. Michael, Head, Zoology Department North Eastern Hill University, Shillong, Dr. M. G. George, Department of Biology, University of Waterloo, Ontario, Canada, and many others persons for providing literature.

One of us (S. G. P.) is thankful to the Director, Zoological Survey of India, Calcutta, and Dr. Asket Singh, Deputy Director, Eastern Regional Station, Zoological Survey of India ; Shillong for encouragement and suggestions.

This work was carried out during the tenure of a Scholarship received by one of us (SGP) from Maharastra Government.

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