

Diurnal and Seasonal Variations of Tropical Infralittoral Heleozooplankton*

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Thermocyclops hyalinus Rehberg and *Neodiaptomus diaphorus* Kiefer (copepods) were more abundant during day time, while *Moina dubia* Guerne and *Diaphanosoma paucispinosum* Brehm (cladocera) were so during the night. A diurnal succession of abundance of number of diurnal maxima was recorded during the day in the order of *Diaphanosoma paucispinosum*, *Neodiaptomus diaphorus*, *Thermocyclops hyalinus* and *Moina dubia* at 4.30, 9.00, 15.00 and 22.00 hr respectively. A shift in the time of occurrence of the diurnal maxima from day time to night during 1958-'59 and '59-'60 in the case of *Thermocyclops hyalinus* was associated with increase in diurnal amplitude of temperature. The diurnal maxima which were associated with diurnal minimum temperatures of above 30°C were all recorded only in the second-half of the day. The majority of diurnal maxima of these four zooplankters were recorded at the diurnal minimum and near minimum temperatures. An apparent case of littoral avoidance of *Neodiaptomus diaphorus* in the infralittoral area of a tropical freshwater pond thickly vegetated by only *Najas flexilis* was recorded.

Key Words: Diurnal, Seasonal, Tropical, Infralittoral, Heleozooplankton

Introduction

Hutchinson (1967) reviewed the research work carried out on diurnal and seasonal variations of zooplankton of freshwater ponds of many countries. There is no information on the diurnal and seasonal variations of infralittoral heleozooplankton of tropical freshwater ponds of India. Studies on physiological ecology of a tropical fresh-

water pond community during 1958-1960 which included physico-chemical conditions, macroscopic animals, plants, growth rates of animals, calorific values of organisms, community metabolism and efficiencies were already reported (Sitaramaiah 1961, 1966a,b, 1967a,b, 1979). In the present study diurnal and seasonal variations of four infralittoral heleozooplankters, namely, *Thermocyclops*

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hyalinus Rehberg, *Neodiantomus diaphorus* Kiefer, *Moina dubia* Guerne, and *Diaphanosoma paucispinosum* Brehm which were studied during 1958-1960 (Sitaramaiah 1961) are correlated with the diurnal and seasonal variations of temperature and presented here.

The Physical Environment

The detailed description of this physical environment was already reported (Sitaramaiah 1961, 1966a, 1967a).

Methods

The methods employed in the present study were reported earlier (Sitaramaiah 1961, 1966a). Diurnal studies were made at 4.30, 9.00, 15.00 and 22.00 hr of the day at inter-

vals of two months for a period of two years. Estimations of zooplankton, *Najas flexilis* and records of temperature were made for the months intervening the months of diurnal studies. The data of diurnal variations of the months which showed breaks are not considered for comparison with normal months.

Results & Discussion

Diurnal variations of zooplankton

The results of the diurnal variations of zooplankton are presented (table 1 and figure 1). Three diurnal maxima were recorded for *Neodiantomus diaphorus* during February 1959, June & August 1960 which included two recorded during day time. A total of eight diurnal maxima were recorded

Table 1 *Diurnal variations of zooplankton (Thousands/m²), Najas flexilis (kg wet wt./m²) and temperature of a tropical freshwater pond community during 1958-1960*

Date	Time	<i>Thermocyclops hyalinus</i> Rehberg	<i>Moina dubia</i> Guerne	<i>Diaphanosoma paucispinosum</i> Brehm	<i>Neodiantomus diaphorus</i> Kiefer	<i>Najas flexilis</i> Rostk & Schmidt	Temperature (°C)
1	2	3	4	5	6	7	8
19-12-1958	4.30	13.3	6.7	—	—	—	25.0
	9.00	15.3	8.3	2.1	5.1	—	25.0
	15.00	0.7	0.7	0.3	1.0	—	27.0
	22.00	2.3	—	—	—	—	26.0
20-2-1959	4.30	26.7	30.0	2.7	4.0	—	29.0
	9.00	73.3	156.6	—	13.3	0.21	28.0
	15.00	16.7	13.3	1.3	3.3	—	31.0
	22.00	60.0	26.7	—	3.3	—	30.0
17-4-1959	4.30	32.0	18.7	32.0	—	—	31.0
	9.00	36.6	24.9	20.0	—	1.59	32.0
	15.00	56.7	120.0	16.7	—	—	38.0
	22.00	40.0	140.0	33.3	—	—	32.0

Table 1 (Contd.)

1	2	3	4	5	6	7	8
19-6-1959	4.30	86.7	86.7	40.0	—		30.5
	9.00	49.9	119.9	6.6	3.3	1.0	32.0
	15.00	520.0	566.7	133.3	—		37.0
	22.00	146.7	66.7	26.7	—		32.5
21-8-1959	4.30	20.0	146.7	6.7	—		26.5
	9.00	3.3	30.3	—	—	3.14	27.0
	15.00	26.7	93.3	6.7	—		29.0
	22.00	20.0	86.7	6.7	—		28.0
20-12-1959	4.30	20.0	23.3	—	—		24.0
	9.00	6.6	6.6	—	—	1.41	25.0
	15.00	26.7	26.7	—	—		28.0
	22.00	53.0	53.0	—	—		26.5
19-2-1960	4.30	73.3	40.0	—	—		22.0
	9.00	28.3	13.3	—	—	2.53	24.0
	15.00	26.7	26.7	—	—		29.0
	22.00	6.7	53.3	—	—		24.0
22-4-1960	4.30	40.0	40.0	—	—		28.5
	9.00	28.3	8.3	—	—	0.87	31.0
	15.00	23.3	16.7	—	—		40.0
	22.00	63.3	76.7	—	—		31.0
17-6-1960	4.30	—	—	1.8	0.6		26.0
	9.00	—	—	1.3	11.0	—	29.0
	15.00	—	—	1.3	1.5		35.0
	22.00	—	—	1.2	0.3		29.0
19-8-1960	4.30	—	—	63.0	36.0		27.0
	9.00	—	—	3.7	7.5	—	30.0
	15.00	—	—	43.0	30.0		32.0
	22.00	—	—	36.0	13.3		29.0
19-10-1960	4.30	1.0	—	—	0.6		27.0
	9.00	—	—	—	—	—	28.0
	15.00	0.87	—	0.45	1.2		32.0
	22.00	2.0	—	1.0	0.27		29.0

for *Thermocyclops hyalinus* during December 1958 to April 1960 which included five recorded during day time. The diurnal maxima for this Zooplankter were recorded at all

the four times of the day with three maxima at 15.00 hr. A total of four diurnal maxima were recorded for *Diaphanosoma paucispinosum* during April and June 1959 and June

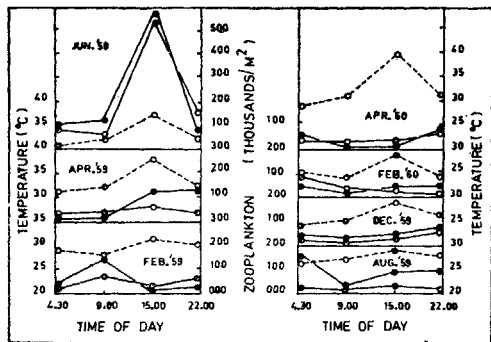


Figure 1 Diurnal variations of *Thermocyclops hyalinus* (O—O), *Moina dubia* (●—●) and temperature (O-----O) of a tropical freshwater pond during 1959-1960

& August 1960 which included a maximum of three recorded during night. Seven diurnal maxima were recorded for *Moina dubia* during February '59 to April '60 which included five recorded during night. Diurnal maxima of *Moina dubia* were recorded at all the four times of the day with a highest number of four at 22.00 hr. The diurnal maxima for *Thermocyclops hyalinus*, *Moina dubia*, *Neodiantomus diaphorus* and *Diaphanosoma paucispinosum* were recorded both during day time and night.

A diurnal succession of abundance of number of diurnal maxima was recorded during the day at 4.30, 9.00, 15.00 and 22.00 hr in the order of *Diaphanosoma paucispinosum*, *Neodiantomus diaphorus*, *Thermocyclops hyalinus* and *Moina dubia* during the respective times. The annual diurnal maxima of *Thermocyclops hyalinus*, *Moina dubia* and *Diaphanosoma paucispinosum* were recorded at 15.00 hr in June '59. The annual diurnal maxima of *Neodiantomus diaphorus* was recorded at 4.30 hr in August '60. The results of this study (table 1 and figure 1) indicated that *Neodiantomus diaphorus* and *Thermocyclops hyalinus* were

more abundant during the day time at 9.00 and 15.00 hr respectively. It is also observed that the *Diaphanosoma paucispinosum* and *Moina dubia* were more abundant during night at 4.30 and 22.00 hr respectively.

Diurnal maxima of zooplankton and temperature

The annual range of diurnal ranges of temperatures of this tropical freshwater pond varied from 22 to 40°C. A majority of five diurnal maxima were recorded at diurnal minimum and near minimum temperatures during December '58 (25°C), February '59 (28°C), December '59 (26.5°C), February '60 (22°C) and April '60 (31°C) in the case of *Thermocyclops hyalinus* which included three recorded at diurnal minimum temperatures. Annual diurnal maximum for this Zooplankter was recorded at 37°C. A majority of 6 diurnal maxima were recorded at minimum (two) and near minimum (four) temperatures during February '59 (28°C), April '59 (32°C), August '59 (26.5°C), December '59 (26.5°C), February '60 (24°C) and April '60 (31°C) for *Moina dubia*. The annual diurnal maximum for this zooplankter was recorded at 37°C. All the diurnal maxima of *Neodiantomus diaphorus* were recorded at the diurnal minimum and near minimum temperatures during February '59 (28°C), June '60 (29°C) and August '60 (27°C). The annual diurnal maximum for this zooplankter was recorded at 27°C. A majority of diurnal maxima for *Diaphanosoma paucispinosum* were recorded at diurnal minimum and near minimum temperatures during April '59 (32°C), June '60 (26°C) and August '60 (27°C). The annual diurnal maxima of *Diaphanosoma paucispinosum* was recorded at 37°C.

The times of occurrence of diurnal maxima were found to be associated with the diurnal minimum temperature. It is observed that in the months with the minimum

temperature above 30°C the diurnal maxima were recorded only in the second half of the day at 15.00 or 22.00 hr. These cases were observed during April and June '59 for *Thermocyclops hyalinus*, *Moina dubia* and *Diaphanosoma paucispinosum*.

The relation between diurnal amplitude of temperature and the time of occurrence of diurnal maxima are presented (table 2). In the case of *Thermocyclops hyalinus* the diurnal maxima for the months of December, February and April were recorded during day time and night for the years 1958-'59 and 1959-'60 respectively. Similar observations were made in the cases of *Moina dubia* and *Diaphanosoma paucispinosum* (table 2). This shift in the occurrence of these diurnal maxima were associated with increase in diurnal amplitude of temperature.

Seasonal variations of zooplankton

The results of seasonal variations of zooplankton and temperature are presented (table 1,3 and figure 2). The annual maximum

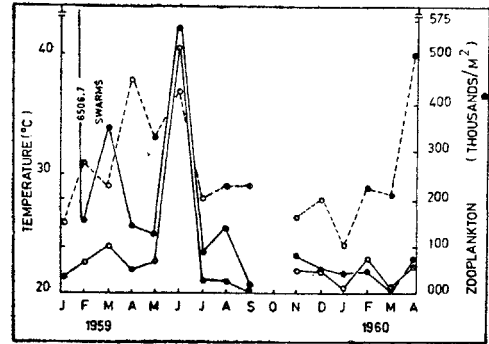


Figure 2 Variations of *Thermocyclops hyalinus* (O—O), *Moina dubia* (●—●) and temperature (O-----O) of a tropical freshwater pond during 1959-1960

Table 2 Temperature of water and the time of the diurnal maxima during 1958-1960

Name of the zooplankter	Year & month	Part of day and time of diurnal maxima hours	Temperature		
			of diurnal maxima (°C)	Diurnal range (°C)	Diurnal amplitude (°C)
<i>Thermocyclops hyalinus</i>	1958 Dec.	Day time 9.00	25.0	25-27	2.0
	1959 Dec.	Night 22.00	26.5	24-28	4.0
	1959 Feb.	Day time 9.00	28.0	28-31	3.0
	1960 Feb.	Night 4.30	22.0	22-29	7.0
	1959 Apr.	Day time 15.00	38.0	31-38	7.0
	1960 Apr.	Night 22.00	31.0	28.5-40	11.5
<i>Moina dubia</i>	1959 Feb.	Day time 9.00	28.0	28-31	3.0
	1960 Feb.	Night 22.00	24.0	22-29	7.0
<i>Diaphanosoma paucispinosum</i>	1959 June	Day time 15.00	37.0	30.5-37	6.5
	1960 June	Night 4.30	26.0	26-35	9.0

Table 3 Zooplankton (Thousands/m²), *Najas flexilis* (kg/wet wt./m²) and temperature of a tropical freshwater pond community during 1958-1960

Year & Month	<i>Thermocyclops hyalinus</i> Rehberg	<i>Moina dubia</i> Guerne	<i>Diaphanosoma paucispinosum</i> Brehm	<i>Neodiantomus diaphorus</i> Kiefer	<i>Najas flexilis</i> Rostk & Schmidt	Temperature (°C)
1958						
Oct.	5.5	2.5	—	—	—	28.0
Nov.	8.3	1.7	6.67	9.17	—	26.75
1959						
Jan.	30.0	6506.7 "swarms"	—	10.0	—	26.0
Mar.	103.3	356.6	13.2	—	0.62	29.3
May	73.2	120.0	9.9	—	0.20	33.0
July	26.2	88.3	5.0	—	1.56	27.8
Sept.	—	8.3	—	—	1.83	29.4
Nov.	50.0	83.3	3.3	3.3	1.00	26.5
1960						
Jan.	14.99	38.3	1.7	—	1.00	24.4
Mar.	13.3	8.3	11.7	—	1.00	28.5
May	0.73	—	—	—	—	30.16
July	—	—	14.99	8.3	—	31.4
Sept.	—	—	8.8	17.4	—	30.0

and submaximum of *Thermocyclops hyalinus* were recorded in June '59 at 37°C (table 1) and in March '59 (table 3) at 29.3°C respectively. The annual maximum (Swarms) and submaximum of *Moina dubia* were recorded in January '59 at 26°C and in June '59 at 37°C respectively. The annual maximum and submaximum of *Diaphanosoma paucispinosum* were recorded in June '59 at 37°C and in August '60 at 27°C respectively. The annual maximum and submaximum of *Neodiantomus diaphorus* were recorded in August '60 at 27°C and September '60 at 30°C respectively.

This littoral area was thickly vegetated only with *Najas flexilis* during April '59 to April '60 when *Moina dubia* and *Thermocyclops hyalinus* were the most dominant

forms and *Diaphanosoma paucispinosum* was subdominant (tables 1 & 3). During this period (April '59–May '60) *Neodiantomus diaphorus* was absent except a few stray ones in November '59. During June to October, 1960 when this littoral area was devoid of vegetation of *Najas flexilis*, *Moina dubia* and *Thermocyclops hyalinus* were absent except a few individuals in October '60. During this period (June to October '60) *Diaphanosoma paucispinosum* and *Neodiantomus diaphorus* were the dominants. Ganapati (1943) recorded in a pond devoid of vegetation, that *Neodiantomus diaphorus* and *Diaphanosoma paucispinosum* were dominants and *Moina dubia* was subdominant and *Thermocyclops hyalinus* was rare. The complete absence of *Neodiantomus diaphorus* from March '59 to

May '60 in this littoral area when *Najas flexilis* was present appears to be a case of "littoral avoidance." Further research is needed in this line.

Seasonal abundance of zooplankton and temperature

The variations of temperature are shown in figure 2. The seasonal abundance of *Moina dubia*, *Thermocyclops hyalinus* and *Diaphanosoma paucispinosum* (table 3) during June '59 (table 1) were associated with an increase in the range of temperatures from 30 to 37°C. It appears that the higher temperatures influence the abundance of these zooplankters. Banta and Brown (1929a)

recorded that the upper limit of life as indicated by one minute thermal death point determination was 48°C for *Moina mucro-copa* which could be bred up to 35°C and develops faster at 30°C. Hall (1964) reported faster growth rate in the case of *Daphnia galeata mendotae* between 20 and 25°C. Banta and Brown (1929b, 1929c) observed in *Moina* that its growth rate depends on temperature.

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