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ABUNDANCE OF CLADOCERAN ZOOPLANKTON IN VARUNA, MADAPPA AND GIRIBETTETHE LAKES OF MYSORE, KARNATAKA STATE, INDIA

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Abstract: Cladocerans are small crustaceans commonly known as "water fleas" are found in most freshwater habitats, including lakes, ponds streams and rivers. Abundance is an ecological concept and is usually measured as the total number of individuals of a species found per sample within the given area. Mean abundance of Cladocerans was significantly high in Madappa lake (16 Org/L) followed by Giribettethe (10 Org/L) and Varuna (7 Org/L) lakes. It was interesting to note that a high abundance of Cladocera was observed during January 2010 in all the three lakes studied. Minimum abundance of Cladocera was observed during July 2010 in Varuna and Madappa lakes and February 2010 in Giribettethe lake. The stepwise regression analysis between the abundance of Cladocera and physico-chemical parameters, shows that water temperature, COD and Conductivity are the major factors which affect the abundance of Cladocera. The seasonal variations in the abundance of Cladocera revealed that the abundance was relatively maximum during winter season and minimum during summer season in all the three lakes studied. Higher abundance of Cladocera in winter season may be due to favourable temperature and availability of abundant food in the form of bacteria and suspended detritus. Decline in the number of Cladocerans during summer months may be due to predation by fish and active competition between Cladocerans and other groups.

Keywords: Abundance, Cladocera, Varuna, Madappa, Giribettethe, zooplankton.

Introduction

Cladocerans are tiny aquatic crustaceans also known as "water fleas" because of their general appearance and jerkey swimming motion. Cladocera have a single compound eye and possess a carapace that is used as a brood chamber. With the exception of two species, nearly all Cladocerans range in size from 0.2 to 3.0 mm. They have life spans of approximately 50 days, with different reproductive periods. To reach their peak reproductive capacity, Cladocerans require 14-15 days. In addition to providing an important food source for planktivorous fish and aquatic invertebrates, they are important grazers on algae and detritus (Balayla & Moss, 2004), and can play an important role in the recycling of nutrients in aquatic ecosystems. Because of their intermediate trophic position, they often have a critical

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role in the transfer of energy through aquatic food webs, as well as in regulating the transfer of contaminants and pollutants to higher trophic levels (Hall *et al*., 1997). They control the algal growth by efficient grazing, therefore, are considered as indicators of water quality (Rajashekhar *et al*., 2009; Joshi, 2011) and are important diet for zooplanktivorous fish. Thus, Cladocerans are an important link in the transmission of the energy from the primary producers to the top consumers. The abundance of Cladoceran zooplankton of some lakes are investigated by various workers. For example, Mondal et al., (2013) studied on the diversity of Cladocerans in Mirik Lake in Darjeeling, Himalaya and reported that Bosmina sp. and Leydigia sp. were found to be the most common Cladoceran species. Mohideen et al., (2008) made some investigative studies on the diversity and abundance of Cladocerans in Guntur pond, Tamilnadu, India and they recorded about 10 species of cladocera wich belong to four families of Daphnidae, Moinidae, Macrothricidae and Chydoridae. Shah and Pandit (2013) in their study on the diversity and abundance of cladoceran zooplankton in Wular Lake, Kashmir state of India revealed 23 species of cladoera belonging to six families. Burns and Schallenberg (2001) made some observations on the consumer effects of protozoa by Cladoceran and Copepods in the lakes of Newzealand reported that copepods are more effective consumers of protozoa than Cladocerans, particularly in eutrophic conditions. The above studies reveal that only few works has been carried out on the abundance of Cladocera. Further, to the best of our knowledge, the abundance of Cladoceran zooplankton of Varuna, Madappa and Giribettethe lakes has not been studied so far. Hence, the present investigative study was undertaken; the main objective was to find monthly and seasonal (winter, rainy and summer) changes in the abundance of Cladoceran zooplankton of these lakes.

Materials and Methods

The location of three sampling site is shown in Fig 1. The first sampling site was on Varuna Lake at Chikkhalli village, Mysore. The lake is situated at latitude of $76^0$44’ E, longitude of $12^0$16’N at an elevation of 719 meters above the Mean Sea Level (MSL) and with a total area of about 0.8 sq.kms. The second sampling site was Madappa Lake at Chornahalli village**.** This Lake is situated at latitude of $76^0$43’ E and a longitude of $12^0$17’N at an elevation of about 706 meters above MSL and a total area of about 0.3 sq. kms. The third sampling site was on Giribettethe Lake at Duddagere village. The Lake is situated at a latitude of $76^0$46’ E and a longitude of $12^0$15’N and at an elevation of about 688 meters above MSL having a length of about 3 kms and the boundaries are 3 acres. Surface water samples were collected fortnightly for two years (June 2009 to May 2011) and 21 Physico- Chemical parameters

were analyzed as per the standard methods given in APHA (1992) and Trivedy and Goel (1986).

Abundance of Cladocera

For the study of abundance of Cladocera, one hundred liters of water sample was collected from each sampling site and filtered through 60µm mesh size net. 50 ml of the concentrated zooplankton sample was collected from the bottle attached at the end of the net. Zooplankton samples were fixed and preserved using 4% formalin at the field itself. For enumeration of zooplankton abundance, the modified Sedgwick Rafter method was used as described by Kamaladasa (2007). On return to the laboratory, one ml from the concentrated sample from each sampling site was transferred out to one ml Sedgwick Rafter counting chamber and observed under Olympus binocular microscope (40X). Identification and abundance of Cladoceran zooplankton group was carried out using the key given in Edmondson (1959) and Battish (1992). The following formula was used to find out the abundance of Cladoceran zooplankton as given in APHA (1992),

$$\text{No: of Organisms/m}^3 = \frac{C \times V_1}{V_2 \times V_3}$$

Where,

C= Number of organisms counted

V_1= Volume of concentrated sample (50 ml)

V_2= Volume of sample counted (1 ml)

V_3= Volume of grab sample ($0.1 m^3$)

Finally, to obtain organisms/ L, the No: of organisms per m^3 was divided by 1000.

Results

The fortnightly variation in the mean abundance of Cladoceran zooplankton group and physico-chemical parameters is given in Table 1. Mean abundance of Cladocerans was significantly high in Madappa lake (16 Org/L) followed by Giribettethe (10 Org/L) and Varuna (7 Org/L) lakes. The highest fortnightly variation in the abundance of Cladocera was shown by Madappa lake (CV=75%) followed by Giribettethe (CV=69%) and Varuna (CV=62%) lakes. The highest fortnightly variation in the physicochemical parameters was shown by Nitrate in Varuna (132%) and Giribettethe lakes (119%) whereas in Madappa lake, the highest fortnightly variation was shown by Conductivity (91%). The least fortnightly variation in the physicochemical parameters was shown by hardness (4%) in Varuna lake, BOD (3%) in Madappa lake and Field pH (4%) in Giribettethe lake.

Only the respective abundance of Cladocera that showed correlations (positive or negative) with physico-chemical parameters in the Varuna, Madappa and Giribettethe lakes are illustrated in Fig: 2, 2.a, 3 and 4. From the graph, it is interesting to note that a high abundance of Cladocera was observed during January 2010 in all the three lakes studied [Varuna lake, 12 Org/L, Madappa lake, 18 Org/L and Giribettethe lake, 14 Org/L]. The least abundance of Cladocera was observed during the month of July 2010 in Varuna (1 Org/L) and Madappa (2 Org/L) lakes and February 2010 in Giribettethe (2 Org/L) lake. The graphs clearly indicated an inverse relationship between the Cladoceran abundance with water temperature and Total Suspended Solids (TSS) in Varuna lake. Similarly, an inverse relationship between Cladoceran abundance and COD was observed in 5 during summer season. However, during second year, Varuna and Giribettethe lakes showed a maximum abundance of Cladocera during winter season and minimum abundance during summer season. But, in Madappa lake, the abundance was almost similar during rainy and winter seasons, and least during summer season.

The relationship between Cladoceran abundance and physico-chemical parameters is shown in Table 2. In Varuna lake, the abundance of Cladocera was positively correlated with Lab pH, Turbidity, DO and TASA, and showed negative correlation with TSS and Water Temperature. In Madappa lake, Cladoceran abundance showed positive correlation with Alkalinity and DO and negative correlation with COD. In Giribettethe lake, the abundance of Cladocera showed only positive correlations with Conductivity, Hardness and Alkalinity.

The step wise regression analysis between the abundance of Cladocera and physico chemical parameters is shown in Table 3. 34% of Cladoceran abundance was negatively controlled by water temperature in Varuna lake which means Cladoceran abundance is higher when the water temperature is lower. 41% of Cladoceran abundance in Madappa lake was negatively controlled by COD i.e., Cladoceran abundance increases when COD decreases and 24 % of Cladocera abundance was positively controlled by Conductivity in Giribettethe lake. Here, an increase in conductivity value increases the abundance of Cladocera and vice versa. Moreover, other physicochemical parameters like Lab pH, Turbidity, DO and Alkalinity also entered in the regression equation thus participating in deciding the abundance of Cladocera.

The season wise grouped data given in Table 4 showed that during first year, the abundance of Cladocera was relatively high and significantly different during winter season in all the three lakes studied. During second year, Varuna and Giribettethe lakes showed a high and

significant difference during winter season in the Cladoceran abundance, whereas, Madappa lake did not show any significant difference between all the three seasons.

Discussion

The results clearly revealed that water temperature; COD and Conductivity are the major factors which are affecting the abundance of Cladocera. Temperature is the prime factor affecting the occurrence and abundance of Cladocerans (Patel et al., 2013). Dhembare (2011) in his study on the diversity and density of zooplankton with water factors in Mula Dam in Maharashtra reported that the density and diversity of zooplankton depends upon water temperature and Conductivity. Karuthapandi et al., (2012) in their study of zooplankton in a temporary freshwater pond in Attapur, Hyderabad, Andhra Pradesh State of India reported that Cladocera showed positive correlation with alkalinity. Similarly, our study also reported a positive correlation of Cladoceran abundance with Alkalinity. Mohideen et al., (2008) in their study on the diversity and abundance of Cladocerans in Guntur pond reported that the variation in pH is always associated with species composition of plankton inhibiting them. Shah and Pandit (2013) found an increase in Cladoceran density with the increase in the nutrient content of the water body in their study on the diversity and abundance of Cladoceran zooplankton in Wular Lake, Kashmir. Our study reports a positive correlation of TASA with Cladoceran abundance where TASA includes nutrients like Sulphate and Nitrate. A negative relationship between Caldoceran abundance and COD is reported by Paulose and Maheshwari (2008) in their study on the seasonal variation of zooplankton in Ramgarh lake, Rajasthan state of India which supports our result. A study on the influence of connectivity on Cladocera diversity in Oxbow lake in Brazil by Guntzel et al., (2010), reported that the richness of species was positively correlated to DO in lake and pH. The season wise grouped data revealed that the abundance of cladocera was significantly high during winter season and low during summer season. Similar findings were reported by Goswami and Mankodi (2012) on the study of zooplankton of a fresh water reservoir Nyari, Gujarat in which they reported that higher abundance of Cladocera in winter can be linked to favourable temperature and availability of abundant food in the form of bacteria and suspended detritus. Beenamma and Yamakanamardi (2011) observed a maximum abundance of Cladocera during the month of December in their study on the monthly changes in the abundance and biomass of zooplankton and water quality parameters in Kukkarahalli Lake of Mysore, Karnataka State of India. Savitha and Yamakanamardi (2012) also reported a high abundance of Cladocera during winter season in their studies on the abundance of zooplankton in Kalale, Alanahalli

and Dalvoy lakes of Mysore, Karnataka State of India. The maximum population of Cladocera during winter season may be attributed to favourable temperature and availability of food in the form of bacteria, nanoplankton and suspended detritus and factors like DO, water temperature and turbidity also play an important role in controlling the density of Cladocerans (Edmondson, 1965; Pullie and Khan, 2003). Parveen and Mola (2012) in their study on the diversity of zooplankton groups in two perennial ponds in Aligarh, Uttarpradesh State of India also reported a highest abundance of Cladocera during winter season. Mondal et al., (2013) in their study on the diversity of Cladocerans Mirik Lake in Darjeeling, reported that temperature adversely affected Cladoceran abundance and they are more abundant during winter season. Sitre (2012) in his study on the seasonal variation of freshwater zooplankton in Ambazari lake of Nagpur City, Maharashtra, also recorded high abundance of Cladocera during winter season. The season wise grouped data also revealed a minimum abundance of Cladocera during summer season in all the three lakes studied. Similarly, Yousuf and Quadri (1985) studied the seasonal fluctuation of zooplankton in lake Manasbal, Kashmir, and reported that the abundance of Cladocerans were lowest during summer season. Kiran et al., (2007) in his investigative studies on the diversity and seasonal fluctuations of zooplankton in a fish pond of Bhadra, Shankaraghatta, Karnataka State of India also reported a minimum Cladoceran abundance during summer season. Decline in the number of Cladocerans during summer months may be due to fish predation and the active competition between Cladocerans and other groups as reported by Pandey *et al.*, 2009.

Summary

The highest fortnightly variation in the abundance of Cladocera was shown by Madappa lake followed by Giribettethe and Varuna lakes. The highest fortnightly variation in the physicochemical parameters was shown by Nitrate in Varuna and Giribettethe lakes whereas, in Madappa lake, the highest fortnightly variation was shown by Conductivity. The least fortnightly variation in the physicochemical parameters was shown by Hardness in Varuna lake, BOD in Madappa lake and Field pH in Giribettethe lake. In Varuna lake, the abundance of Cladocera was positively correlated with Lab pH, Turbidity, DO and TASA, and showed negative correlation with TSS and Water Temperature. In Madappa lake, Cladoceran abundance showed positive correlation with Alkalinity and DO and negative correlation with COD. A study on the influence of connectivity on Cladocera diversity in Oxbow lake in Brazil by Guntzel et al., (2010), reported that the richness of species was positively correlated to DO in lake and pH. A negative relationship between Caldoceran abundance and COD is

reported by Paulose and Maheshwari (2008) in their study on the seasonal variation of zooplankton in Ramgarh lake, Rajasthan state of India which supports our result. In Giribettethe lake, the abundance of Cladocera showed only positive correlations with Conductivity, Hardness and Alkalinity. From the step wise regression analysis, it is clear that water temperature, COD and Conductivity are the major factors which affect the abundance of Cladocera. Finally, the seasonal variations in the abundance of Cladocera revealed that the abundance was relatively maximum during winter season and minimum during summer season in all the three lakes studied. The maximum population of Cladocera during winter season may be attributed to favourable temperature and availability of food in the form of bacteria, nanoplankton and suspended detritus and factors like DO, water temperature and turbidity also play an important role in controlling the density of Cladocerans (Edmondson, 1965; Pullie and Khan, 2003). Pandey *et al.*, (2009) reported that the decline in the number of Cladocerans during summer months may be due to fish predation and the active competition between Cladocerans and other groups.

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Table 1. Summary of the Physico-Chemical parameters and the Abundance of Cladocera (Org/L) in Varuna, Madappa and Giribettethe Lakes, June 2009- May 2011

Sl.no	Physico-Chemical parameters	VARUNA LAKE	MADAPPA LAKE	GIRIBETTETHE LAKE
		Mean (Range) CV%	Mean (Range) CV%	Mean (Range) CV%
1	Cladocera(Org/L)	7 [a] (0 – 13) 62	16 [b] (1-25) 75	9[a] (0-21) 69
2	Air temperature(°C)	21.15[a] (14 - 22.5) 15	20.85[a] (14 - 21.5) 10	21.65[a] (15 - 24) 18
3	**Water temperature(°C)**	**22.53[a] (21 - 25.5) 16**	23.65[a] (21 - 25.5) 9	24.97[a] (21 - 26) 15
4	Field pH	8.85[a] (7.9 - 9.4) 8	8.12[a] (8 - 8.7) 4	8.56[a] (8 - 9) 4
5	**Lab pH**	**8.75[a] (8.1 - 9.5) 7**	8. 2[a] (8.1- 8.4) 4	8.44[a] (8 - 9) 4
6	**Conductivity(μS^{-cm})**	385.8[a] (316 - 563) 22	930.4[b] (745 -1270) 91	**1252.5[c] (1010 - 2060) 31**
7	**Turbidity(NTU)**	**6.48[a] (2.1 - 20.6) 72**	10.89[b] (3 - 22) 51	7.21[a] (2.4 - 11) 30
8	**Dissolved Oxygen(mg/L)**	**5.95[a] (0.56 - 10.69) 54**	**4.19[a] (1.24 - 6.42) 41**	4.81[a] (1.6 - 7.09) 32
9	BOD(mg/L)	2.23[a] (0.33 - 4.5) 59	3.09[b] (0.23-5.63) 4	2.98[a] (0.56 - 6.75) 53
10	**COD(mg/L)**	12.25[a] (7.2 - 21.6) 38	**17.8[b] (8.8 - 28) 26**	19.3[c] (6.4 - 37.6) 40
11	Carbon-di-oxide(mg/L)	3.56[b] (0 - 11) 70	5.16[c] (0 - 11) 53	2.56[a] (0 - 8.8) 105
12	**Hardness(mg/L)**	101.3[a] (84 - 143) 4	264.37[b] (182 - 392) 9	**287.88[b] (171 - 296) 10**
13	Calcium(mg/L)	18.55[a] (12.8 - 41.3) 6	35.34[b] (13.6-53.3) 11	39.21[b] (18.6 - 52.5) 11
14	**Alkalinity(mg/L)**	187.1[a] (127.5 - 265) 13	**431.25[b] (292.5- 525) 39**	**453.63[b] (312.5 - 642.5) 37**
15	Chloride(mg/L)	32.69[a] (22 - 40.5) 17	34.83[a] (17.8-48.9) 33	32.64[a] (17.8 - 41.2) 16
16	Phosphate(mg/L)	0.02[a] (.01 - .06) 9	0.04[b] (.01 - .06) 14	0.02[a] (0.02 - 0.06) 12
17	Nitrate(mg/L)	0.22[a] (0 - .6) 132	0.26[a] (.1 - .9) 88	0.26[a] (0.1 - 0.6) 119
18	Sulphate(mg/L)	11.56[a] (5 - 25) 49	51.25[c] (25 - 75) 40	23.81[b] (5 - 40) 45
19	**TSS(mg/L)**	**15[a] (0 - 30) 54**	28.75[b] (10 - 15) 38	14.32[a] (10 - 20) 36
20	POM(mg/L)	1[a] (0 - 30) 52	3.31[b] (1 - 8) 64	1[a] (0 - 1) 52
21	Chlorophyll-a(µg/L)	3.02[a] (0 - 3.6) 11	3.44[a] (1.2 - 5.9) 11	2.23[a] (0 - 7.2) 9
22	**TASA(mg/L)**	**43.46[a] (32 - 56.10) 14**	89.51[c] (52.9 - 124.3) 31	55.75[b] (34.9 - 75.7) 5

n=18. BOD=Biological Oxygen Demand, COD=Chemical Oxygen Demand, TSS=Total Suspended Solids, POM=Particular Organic Matter, TASA=Total Anions of strong acids, CV=Coefficient of variation. Parameters shown in bold showed correlations with the Abundance of Cladocera (Org/L).

Table 2. Interrelationship between Abundance of Cladoceran zooplankton with Physico-chemical parameters in the Varuna, Madappa and Giribettethe Lakes, June 2009 to May 2011.

Caldoceran Abundance (Org/L)				
Sl.No	**Physico-chemical parameters**	**Varuna Lake**	**Madappa Lake**	**Giribettethe Lake**
1	WT	**-0.368***	NS	NS
2	pH(L)	**0.325***	NS	NS
3	Cond	NS	NS	**0.442****
4	Turb	**0.341***	NS	NS
5	DO	**0.236***	**0.334***	NS
6	COD	NS	**-0.334***	NS
7	Hard	NS	NS	**0.258***
8	Alk	NS	**0.473***	**0.334***
9	TSS	**0.346***	NS	NS
10	TASA	**0.363***	NS	NS

Values are Pearson correlation coefficient, a 2-tailed test was applied and calculated after $\log_{10}$ transformation of all parameters after scaling so that all values were >1, *$P < 0.05$, **$P < 0.005$, and NS= Non significant . E.vari.= Physico-chemical parameters, WT= Water temperature, pH (L)= pH measured in the laboratory, Cond= Conductivity, Turb= Turbidity, DO= Dissolved Oxygen measured in the field, COD= Chemical Oxygen Demand, Hard= Hardness, Alk= Alkalinity, TSS= Total Suspended Solids, TASA = Total Anions in Strong Acid

Table 3. Results of Stepwise multiple regression analysis between Abundance of Cladoceran zooplankton and physico- chemical parameters in Varuna, Madappa and Giribettethe Lakes, June 2009 – May 2011. (Note: Only those parameters which entered the regression equation are shown in the following table.

Varuna Lake	**WT(-), (R^2=0.34, F=7.18, P<0.05), pH(L)(+), Turb(+), TSS(+).**
Madappa Lake	**COD(-), (R^2=0.41, F=5.78, P<0.05), DO(+).**
Giribettethe Lake	**Cond(+), (R^2=0.24, F=7.39, P<0.05), Alk(+)**

Physico-chemical (independent) parameters in the final regression equation (P in=0.05, P out=0.1) are shown: multiple coefficients of determinations (r^2) and overall F and P values for each equation are given in the parenthesis. Physico-chemical parameters which were not in the final equation but which are correlated (P<0.05) with the relevant Zooplankton parameters are then listed in order of decreasing magnitude of correlation coefficient; the sign of the correlation is indicated in the parenthesis. The physico-chemical parameters were ; WT= Water temperature, pH(L) = pH measured in the Laboratory, Cond = Conductivity, Turb = Turbidity, COD =Chemical Oxygen Demand, DO= Dissolved Oxygen, TSS= Total Suspended Solids, Alk=Alkalinity.

Table 4: Season wise comparison of Cladoceran abundance in Varuna, Madappa and Giribettethe lakes, June 2009 – May 2011

Lakes	**Cladoceran Abundance (Org/L)**				
	Rainy	Winter	Summer	**F-value**	**P-value**
Varuna	$4^{b}_{5^{a}}$ ($_{4^{a}}$)	$_{8^{b}}$ ($_{9^{b}}$)	$2^{a}_{3^{a}}$ ($_{4^{a}}$)	**8.99 (9.24)**	**0.020* (0.001**)**
Madappa	$5^{b}_{10^{a}}$ ($_{9^{a}}$)	$4^{b}_{19^{b}}$ ($_{9^{a}}$)	$3^{a}_{11^{a}}$ ($_{6^{a}}$)	**14.12 (1.12)**	**0.001** (0.261)**
Giribettethe	$5\,b_{4^{a}}$ ($_{4^{a}}$)	$4\,a_{16^{b}}$ ($_{8^{b}}$)	$3\,a_{0^{a}}$ ($_{2^{a}}$)	**6.19 (8.05)**	**0.004** (0.022*)**

n=24. The superscripts are obtained from ANOVA post hoc non parametric test (Student- Newman Keuls Test). *= significant, p=<0.05. NS = non significant, p>0.05, ZP=Zooplankton.

Note: Data presented in paranthesis pertains to 2nd year of study, June 2010 – May 2011.

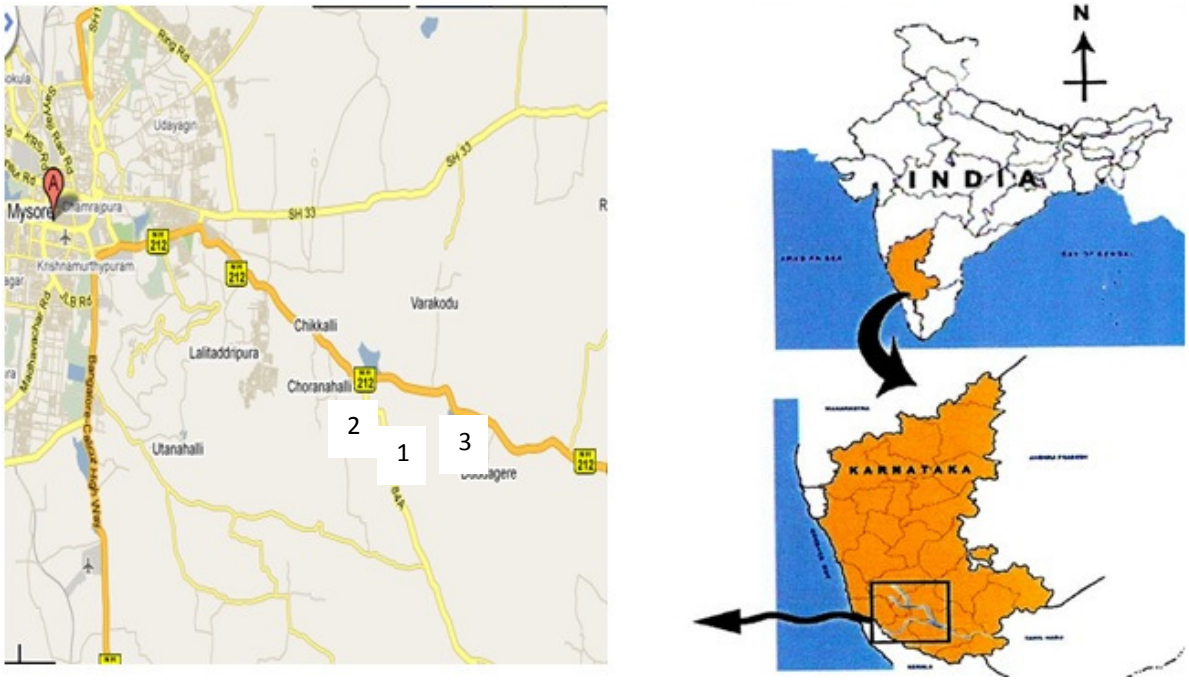

Fig.1. Map showing the sampling sites on Varuna (1), Madappa (2) and Giribettethe (3) Lakes of Mysore

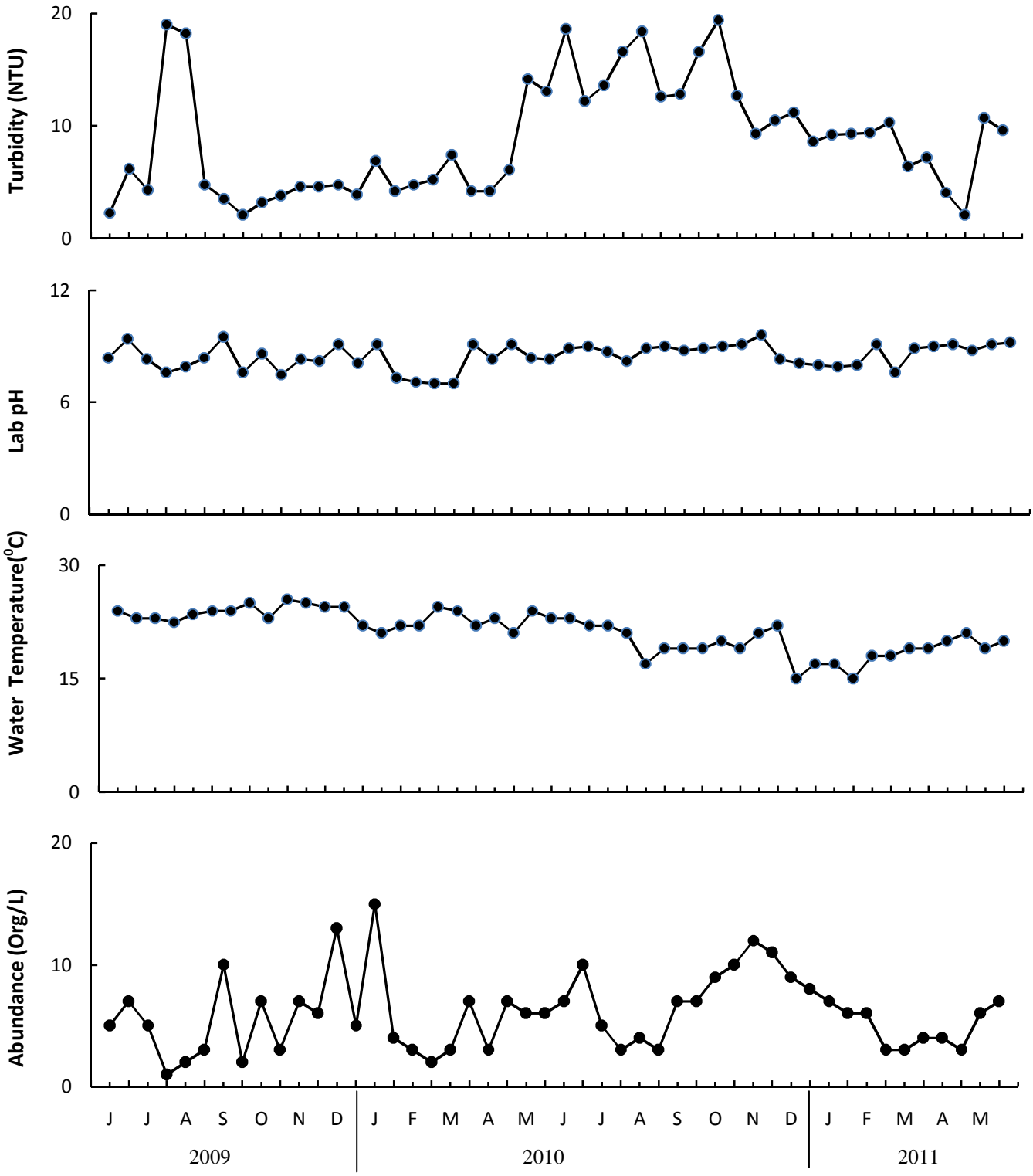

Fig.2. Fortnightly variations in the Abundance of Cladocera (Org/L) with Physico-chemical parameters in Varuna Lake, June 2009 – May 2011

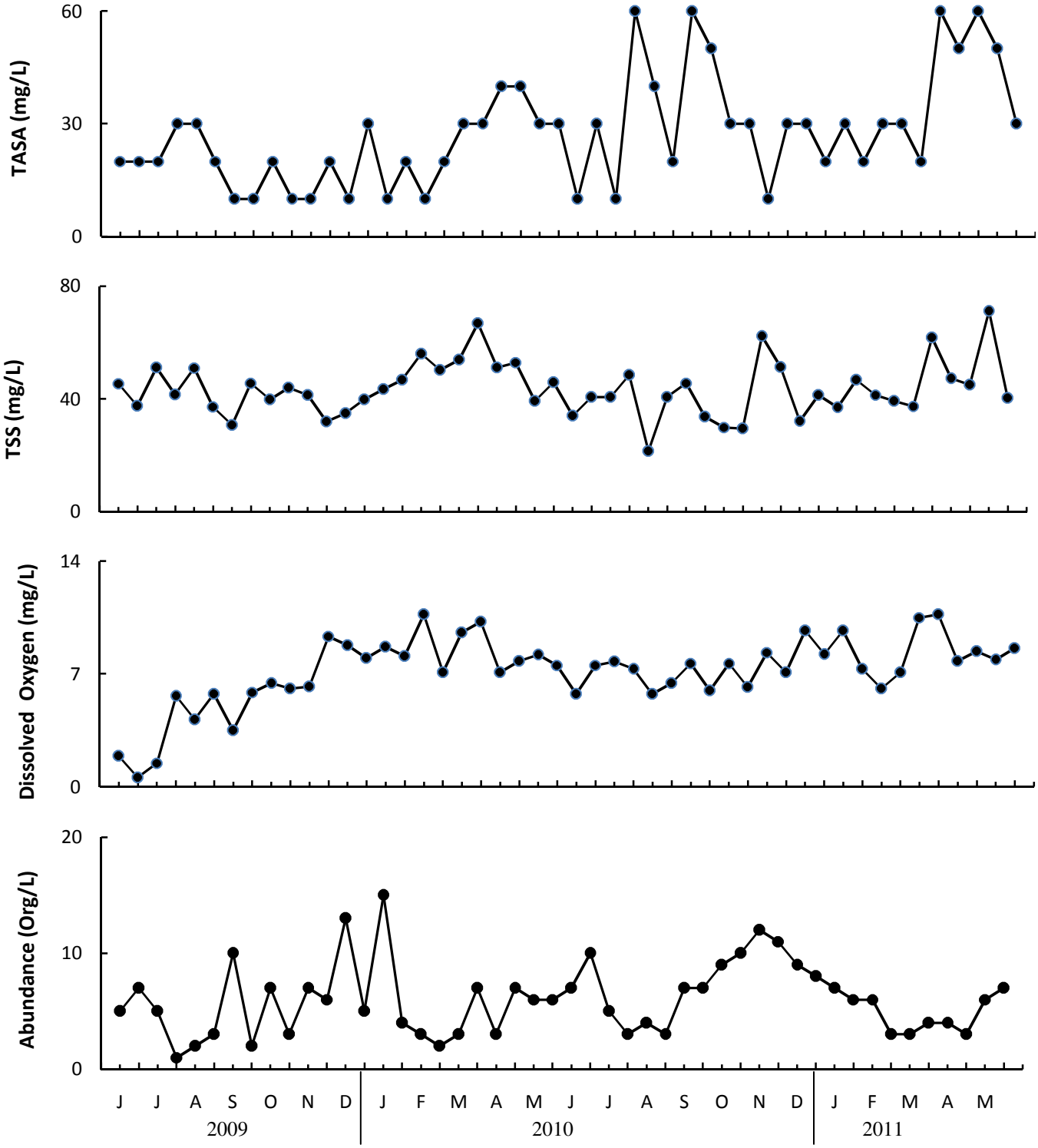

Fig.2.a. Fortnightly variations in the Abundance of Cladocera (Org/L) with Physico-chemical parameters in Varuna Lake, June 2009 – May 2011.

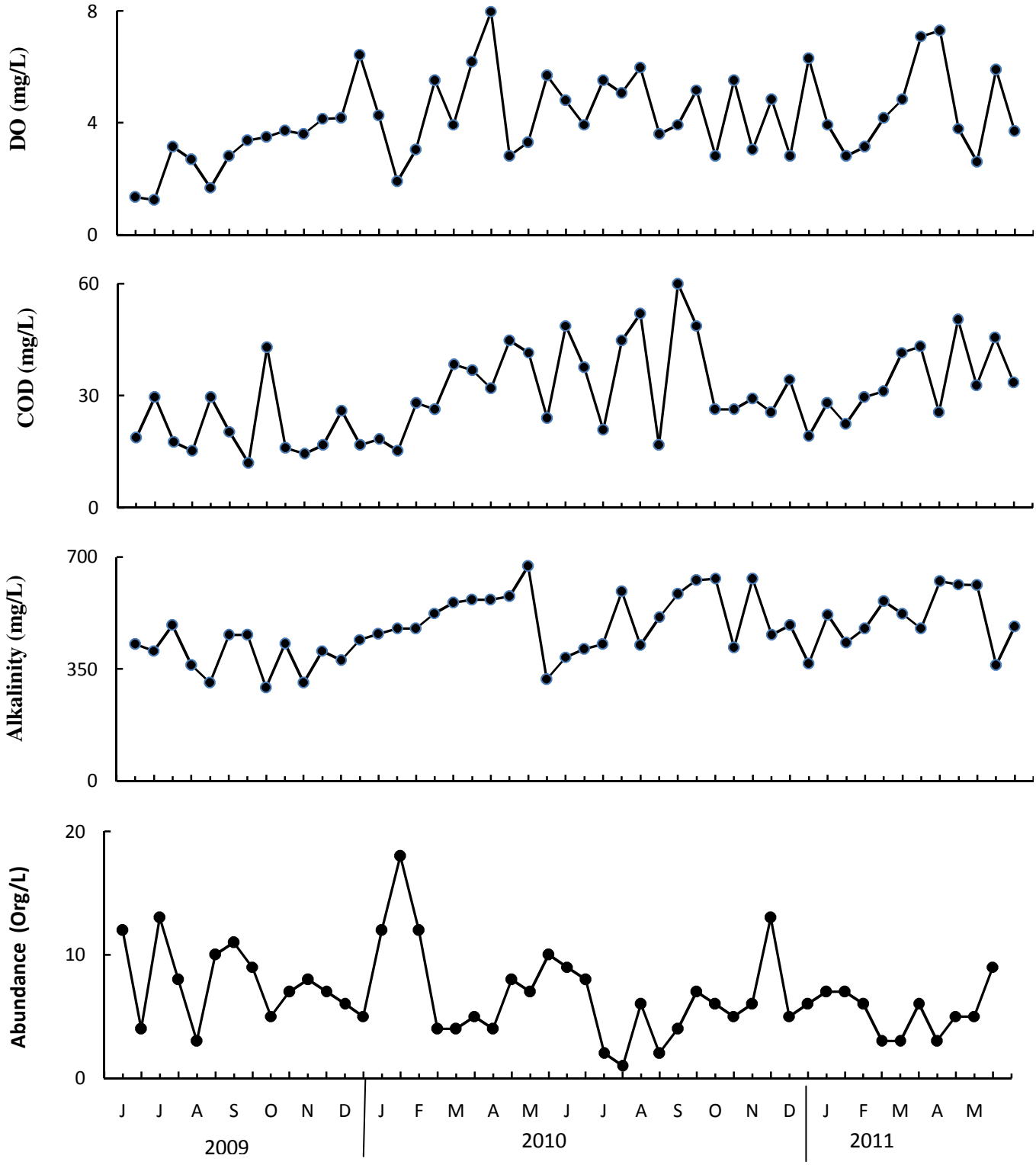

Fig. 3. Fortnightly variations in the Abundance of Cladocera (Org/L) with Physico-chemical parameters in Madappa Lake, June 2009 – May 2011.

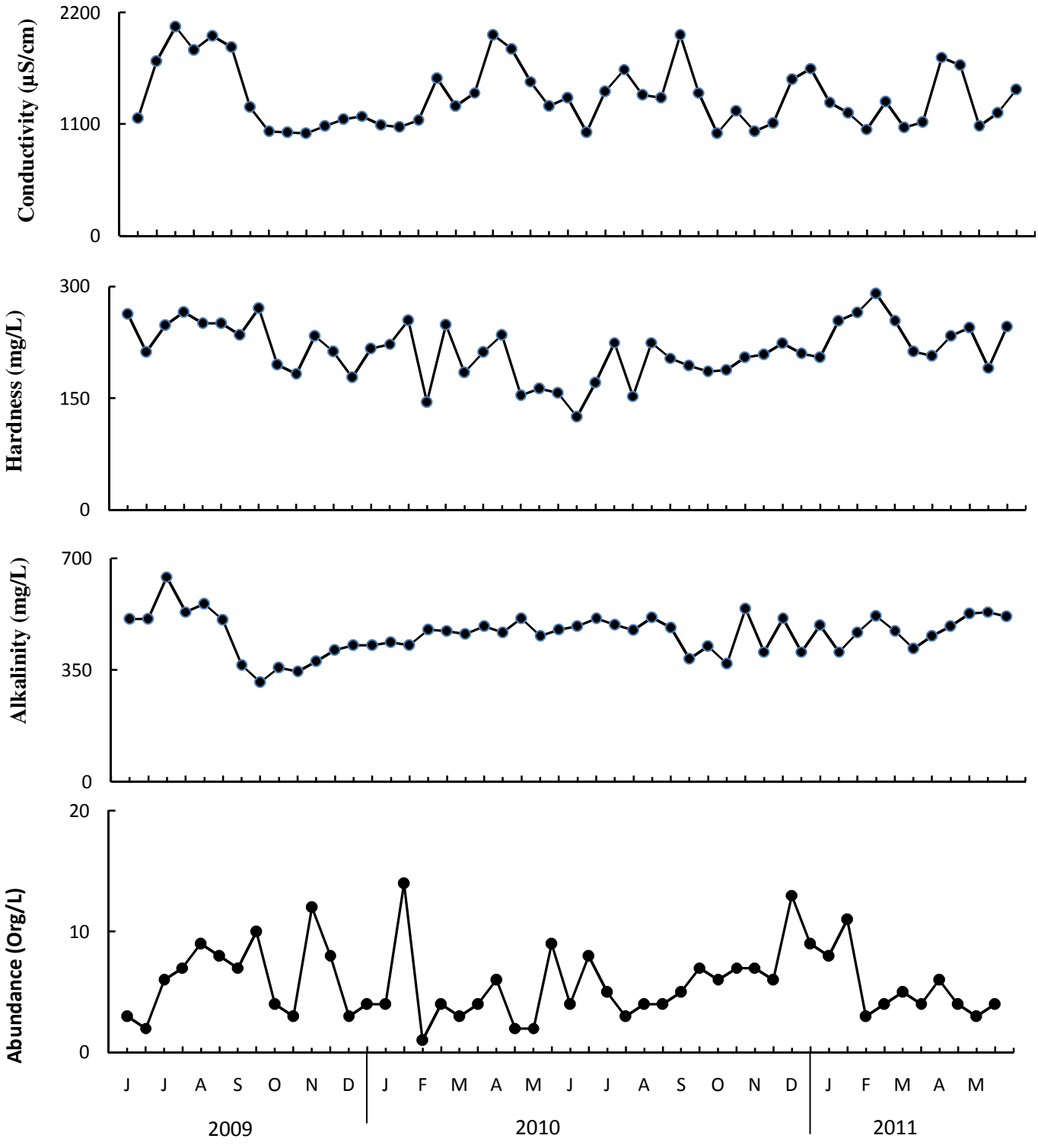

Fig.4. Fortnightly variations in the abundance of Cladocera with Physico chemical parameters in Giribettethe Lake, June 2009 – May 2011.