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Assessment of Zooplankton Diversity in Relation to Physico-Chemical Parameters of Water in Selected Waterbodies of Durgapur Industrial Region, West Bengal, India

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Abstract: Plankton diversity and physico-chemical parameters are important criteria for evaluating the suitability of water for irrigation and drinking purposes. In this study, we tried to assess the zooplankton species richness, diversity, and evenness and to predict the state of three selected studied sites of Durgapur industrial town according to physico-chemical parameters. Cyclopoid Copepods, Calonoid Copepods, Cladocera and Rotifers were found among the three studied sites. Copepods were found to be dominant for all the studied sites during the monsoon period. Higher species richness and abundance were recorded in Padmapukur followed by domestic sewage canal and agricultural run-off pond. The water samples were analyzed for temperature, pH, electrical conductivity, alkalinity, nitrate, phosphate, hardness, dissolved oxygen, TDS, chloride, GPP, CR and NPP. High values of parameters are recorded in summer period and low values are recorded in winter period. The zooplankton population shows positive significant correlation with physico-chemical parameters like humidity and total dissolved solid. From the overall study it can be concluded that Padmapukur wetland is highly productive in terms of zooplankton distribution and abundance and therefore needs prior conservation for its suitable use for drinking and irrigation purpose.

Key words: Zooplankton diversity, physicochemical parameters, Shannon's index, species richness.

Introduction

The consideration of different environmental factors in the study of limnology is basic to growth and abundance of zooplankton. The physico-chemical parameters and nutrient status of water body play an important role in governing the production of plankton which is the natural food of many species of fishes, especially zooplankton constitute important food source of many omnivorous and carnivorous fishes and also support the necessary amount of protein for the rapid growth of larval carps (Rahman and Hussain, 2008). Zooplankton are the primary consumer, critical to maintain aquatic food web foundations by being the second trophic level in most aquatic environments (Licandro and Ibaney, 2000). They respond quickly to aquatic environmental changes (e.g., water quality, such as pH, colour, odour, taste, etc.) for their short life cycle, and are therefore used as indicators of overall health or condition of their habitats (Thorpe and Covich, 1991; Carriack and Schelske, 1997). Hence, zooplankton can speak to condition of water body and can be used to assess overall lake health. The qualitative

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and quantitative abundance of zooplankton in a lake are of great importance for successful aquaculture management, as they vary from one geographical location to another and lake to lake within the same geographical location even within similar ecological conditions (Boyd, 1982). Literature on ecology of zooplankton population from different parts of India is available from the investigation of Sreenivasan (1967), Michael (1968), Mathivanan et al. (2007) and Kudari and Kanamadi (2008), etc. Chattopadhyay and Banerjee (2007, 2008) worked on seasonal variation of plankton and their relationship with physico-chemical parameters of water in Krishnasayer Lake, Burdwan, West Bengal.

Water quality assessment generally involves analysis of physico-chemical, biological and microbiological parameters and reflects on abiotic and biotic status of the ecosystem (IAAB, 1998; Kulshrestha and Sharma, 2006; Mulani et al., 2009). In ecology, zooplankton are one of the most important biotic components influencing all the functional aspects of an aquatic ecosystem, such as food chains, food webs, energy flow and cycling of matter (Murugan et al., 1998; Dadhick and Saxena, 1999; Sinha and Islam, 2002; Park and Shin, 2007). The distribution of zooplankton community depends on complex factors such as change of climatic conditions, physical and chemical parameters and vegetation cover (Rocha et al., 1999; Neves et al., 2003). Most of the species of planktonic organisms are cosmopolitan in distribution (Mukherjee, 1997).

According to Murugan et al. (1998) and Dadhich and Saxena (1999) the zooplankton plays an integral role and serves bio indicators and it is a well-suited tool for understanding water pollution status (Ahmad, 1996; Contreras et al., 2009). A number of studies have been carried out on ecological condition of freshwater bodies in various parts of India (Gulati and Schultz, 1980; Rana, 1991; Sinha and Islam, 2002; Singh et al., 2002; Smitha et al., 2007), but in southern part of Tamilnadu, the ecological studies of freshwater body is very scanty (Haniffa and Pandian, 1980; Smitha et al., 2007). However, information on relationship between physico-chemical parameters and planktonic fauna is very limited (Ahmad and Siddiqui, 1995; Choudhary and Singh, 1999). Therefore, the aim of the present investigation is to study the fluctuations of the zooplankton abundance with reference to changes in physico-chemical parameters of the three studied sites and to establish the correlations between zooplankton and different physico-chemical parameters. Also the present investigation attempts to study the zooplankton species richness, diversity and evenness in relationship between physico-chemical parameters.

Materials and Methods

Study Sites

For the present investigation three sites were selected. Site 1 is Padmapukur, which is a big pond located near Ashishnagar, Durgapur (Latitude (N) 23°29′56.9″ and Longitude (E) 87°17′16.6″ Elevation 117 m). The water is used for domestic consumption by the local people. Site 2 is a domestic sewage canal (Latitude (N) 23°32′23″ and Longitude (E) 87°19′45.1″ Elevation 83 m) near Amarabati, Durgapur receiving domestic sewage of Amarabati and adjoining areas. Site 3 is small pond (Latitude (N) 23°32′47.9″ and Longitude (E) 87°18′40.1″ Elevation 90 m) located near Kabiguru, Durgapur, which receives agricultural runoff from adjoining fields.

Water Quality Analyses

Water samples were collected from the three sites for each month throughout the year from December 2010 to November 2011, covering the three seasons viz. monsoon (June to September), winter (October to January) and summer (February to May). Some physico-chemical parameters such as air temperature (Thermometer), water temperature (Thermometer), conductivity (Auto ranging conductivity/TDS TCM 15+ meter), Total Dissolved Solids (Auto ranging conductivity/TDS TCM 15+ meter), Humidity (Hygrometer), Light intensity and pH (pH meter, Entech Instrument pH tutor pH/°cm.) were measured on the study sites by instruments and total hardness, alkalinity, dissolved oxygen (DO), chloride, nitrate nitrogen, phosphorous, acidity and primary productivity were estimated by using the standard methods of APHA (1998).

Zooplankton Sampling, Enumeration and Identification

The net zooplankton (NZP) were randomly collected in a 50 ml glass tube by filtering the surface water column (1 m long × 1 m wide × 1 m depth) by a nylon monofilament, 75 µm mesh conical net having 0.25 m mouth diameter, from the each predetermined sampling point on monthly basis. The NZP samples were transferred to another glass tube (100 ml) and preserved in 4% formaldehyde solution. Two drops of mild detergent (1:4 v/v, detergent concentrate and water; Eazee-Wollmark, Mumbai, India) were added to prevent any clumping of the net zooplankton. The sample was kept for about 24 h in dark to settle NZP. Analysis was done on a Sedgewick-Rafter counting cell by taking 1 ml sub sample from each of the sample under an Olympus light microscope and counting of cells were chosen randomly within 10 squares of cells. The results are expressed as number of organisms per litre of sample using the formula of Stirling (1985):

$$N = A \times 1000 \times C/V \times F \times L$$

where N is number of plankton cells or units per litre of original water; A = total number of plankton counted; C = volume of a field in cubic mm; F = number of fields counted and L is volume of original water in litres. NZP were identified using keys given by Ward and Whipple (1959), Needham and Needham (1972) and Battish (1992).

Data Analysis

The statistical analysis like mean, standard deviation, principal component analysis (PCA) and correlation matrix were done using SPSS 11.0 programme. Diversity indices of zooplankton are calculated by past softwares.

Results

Physico-chemical Parameters

In the present investigation, all the mean data of selected physico-chemical parameters (i.e., temperature, pH, light intensity, humidity, conductivity, TDS, alkalinity, hardness, acidity, chloride, nitrates, phosphates, dissolved oxygen, net primary productivity, community respiration, and gross primary productivity) obtained from the monthly analysis of water samples from three studied sites during the study period of 12 months (December 2010 to November 2011) are summarized in Tables 1, 2 and 3 respectively. Higher atmospheric and water temperature for all the three study sites were recorded during the summer months and lower atmospheric temperature were recorded in winter months with moderate level of air temperature being recorded in monsoon period. Water temperature showed similar trend under the present investigations. The atmospheric and water temperature varied between 24.2 to 35.5°C and 18.5-33°C for Padmapukur wetland, 24.3-45°C and 21.6-30.3°C for domestic sewage canal, and 20.6-37.8°C and 18.2 to 33°C for agricultural run-off pond respectively.

The water samples of the three studied sites were found to be alkaline throughout the study period. Among the three studied sites maximum and minimum pH value were 8.89 and 7.04 in site 1; 8.74 and 7.18 in site 2; 7.4 and 7.1 in site 3. High pH value was recorded during May, June and July (summer) for all the three studied sites (Tables 1-3).

In the present investigation, light intensity gradually increased from the winter to summer and then decreased during the monsoon for all three study sites. The range of light intensity was found 205 to 560 lux in site 1, 575 to 963 lux in site 2 and 556 to 971 lux in site 3.

Humidity values ranged between 11% to 74% in site 1, 28% to 61% in site 2, 37% to 54% in site 3. Humidity was maximum in months of May, June and July and minimum in months of February among the three studied sites (Tables 1-3).

During the present investigation, higher level of conductivity value of water samples were recorded during the summer periods for all the three studied sites and lower values were recorded during the winter months. TDS values were higher in summer and lower in winter. TDS values increased from winter to summer and were decreased from summer to monsoon (Tables 1-3).

Total alkalinity in three sites ranged from 0.1 to 2.8 mmol/l. Maximum value was recorded at Padmapukur wetland (range: 1.3 to 2.5 mmol/l), followed by domestic sewage canal (range: 1.1 to 1.5 mmol/l) and agricultural run-off pond (range: 0.1 to 1.6 mmol/l). Total alkalinity showed an increasing trend from monsoon to winter and then summer for site 1. For site 2 and site 3 the level of total alkalinity showed considerable fluctuation among the different seasons throughout the investigation period (Tables 1-3).

The value of total hardness fluctuates from 0.9 to 1.4 mmol/l at Padmapukur wetland, 1.1 to 1.5 mmol/l for domestic sewage canal, 0.3 to 0.5 mmol/l for agricultural run-off canal. High value of hardness was recorded during monsoon and winter months for first two studied sites, whereas high value were recorded during summer months for site 3 (Tables 1-3).

During the present investigation, the values of chloride content of water samples of three studied sites were found to be higher in summer in comparison to other seasons (Tables 1-3). Phosphate content in water samples showed considerable variation among the three studied sites. Minimum level of phosphate content was found to be in case of site 3 throughout the study period. There is no significant variation in the level of phosphate content of water samples in site 3. The phosphate content of water samples were low during premonsoon and monsoon months(May to July) for site 1 and site 2 (May-June, Aug to Sept) (Tables 1-3).

Table 1: Physico-chemical analysis of water in site 1

Parameters	*Dec*	*Jan*	*Feb*	*March*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*
Atm. Temp. (°C)	24.2±0.2	26.1±0.5	31.5±0.3	31.9±0.6	34.1±0.3	35.5±0.2	35.1±0.3	34.8±0.3	32.9±0.2	28.8±0.3	27.1±0.3	23.9±0.3
Water temp. (°C)	18.5±02	24.3±0.1	23.8±0.1	25.5±0.2	31.3±0.1	33±0.4	32.9±0.2	32.4±0.3	29.5±0.3	25±0.3	23.5±0.4	21.1±0.4
Water pH	7.1±0.1	7.2±0.1	7.85±0.04	7.70±0.2	7.72±0.03	8.89±0.06	8.31±0.06	8.45±0.08	8.25±0.06	7.93±0.04	7.4±0.03	7.04±0.08
LI (×100 Lux)h	318±0.2	350±0.5	385±0.3	560±0.4	510±0.1	205±0.4	340±0.2	314±0.2	308±0.1	305±0.3	246±0.2	256±0.1
Humidity	50±0.1	33±0.4	11±0.2	50±0.2	20±0.3	65±0.2	74±0.5	65±0.1	59±0.6	55±0.2	52±0.3	48±0.4
Conductivity (μΩ)	0.376±0.004	0.395±0.002	0.405±0.001	0.406±0.005	0.410±0.001	0.428±0.003	0.409±0.002	0.369±0.004	0.358±0.001	0.331±0.002	0.339±0.002	0.311±0.001
TDS (mg/l)	0.161±0.003	0.161± 0.005	0.172±0.003	0.172±0.005	0.182±0.005	0.182±0.003	0.181±0.003	0.179±0.005	0.157±0.005	0.159±0.004	0.156±0.005	0.152h±0.007
Alkalinity (mmol/l)	2.5±0.02	2.4±0.03	2.3±0.03	2.2±0.01	2.5±0.1	2.8±0.09	2.6±0.04	2.3±0.03	1.7±0.03	1.8±0.08	1.4±0.02	1.3±0.08
Hardness (mmol/l)	1.4±0.07	1.2±0.01	1.1±0.05	0.9±0.2	1.2±0.03	1.1±0.07	1.1±0.1	1.4±0.02	1.3±0.01	1.5±0.06	1.3±0.03	1.4±0.03
Chloride (mg/l)	32±0.8	35±0.54	38±0.41	38±0.3	30±0.2	30±0.18	29±0.16	30±0.13	31±0.21	27±0.14	29±0.16	34±0.5
Phosphate (ppm)	5±0.1	5±0.05	5±0.04	5±0.1	5±0.07	1±0.12	1±0.11	1±0.14	5±0.01	5±0.07	5±0.09	5±0.07
Nitrate (mg/l)	0.12±0.01	0.12±0.03	0.13±0.02	0.14±0.02	0.15±0.01	0.15±0.03	0.13±0.01	0.14±0.03	0.12±0.01	0.11±0.01	0.11±0.03	0.12±0.04
DO (mg/l)	5.1±0.09	5.4±0.01	5.8±0.02	4.5±0.03	2.6±0.01	1.7±0.04	1.5±0.02	2.1±0.05	4.2±0.05	4.9±0.03	5.1±0.07	5.2±0.02
NPP (mg C/m^3/day)	999.99±0.03	999.99±0.01	1125±0.02	1125±0.03	1375.01±0.02	749.976±0.077	728.99±0.12	812.99±0.08	837.99±0.05	910.99±0.1	902.99±0.07	985.99±0.04
CR (mg C/m^3/day)	621±0.03	624.99±0.05	621±0.05	749.98±0.06	874.992±0.005	1125±0.05	945.9±0.04	776±0.09	582±0.06	769.99±0.07	723.8±0.03	669±0.09
GPP (mg C/m^3/day)	1620.99±0.06	1624.99±0.08	1746±0.05	1874.98±0.07	2250±0.11	1874.97±0.08	1856.58±0.03	1735.90±0.03	1662.67±0.04	1616.10±0.05	1621.86±0.05	1628±0.03

Table 2: Physico-chemical analysis of water in site 2

Parameters	*Dec*	*Jan*	*Feb*	*March*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*
Atm. Temp. (°C)	24.3±0.03	26.3±0.01	34±0.12	37±0.43	36.1±0.11	45±0.17	43±0.34	39±0.12	31±0.11	27±0.31	26.8±0.04	25±0.12
Water temp. (°C)	21.6±0.03	24.2±0.07	25.8±0.03	26.3±0.05	29.4±0.07	30.3±0.03	29.8±0.07	28±0.12	27.6±0.04	24.3±0.05	25.5±0.08	23.6 ±0.02
Water pH	7.5±0.02	7.4±0.07	7.6±0.03	7.77±0.04	7.5±0.01	8.74±0.02	8.43±0.03	8.25±0.08	7.64±0.05	7.43±0.02	7.45±0.06	7.18±0.09
LI (×100 Lux)	575±0.05	634±0.03	789±0.11	810±0.91	660±0.08	963±0.01	814±0.1	793±0.07	703±0.13	646±0.21	644±0.02	612±0.03
Humidity	28±0.03	31±0.11	34±0.09	35±0.08	34±0.01	44±0.13	54±0.07	61±0.1	59±0.05	47±0.03	39±0.04	31±0.12
Conductivity (μΩ)	0.360±0.044	0.350±0.041	0.386±0.008	0.386±0.015	0.428±0.017	0.398±0.047	0.378±0.007	0.347±0.014	0.358±0.036	0.346±0.017	0.339±0.032	0.341±0.014
TDS (mg/l)	0.147±0.026	0.155±0.013	0.166±0.009	0.166±0.005	0.183±0.008	0.170±0.008	0.168±0.008	0.161±0.008	0.154±0.009	0.149±0.007	0.142±0.011	0.136±0.014
Alkalinity (mmol/l)	1.1±0.03	1.1±0.08	1.2±0.03	1.2±0.01	1.5±0.05	1.1±0.07	1.1±0.04	1.2±0.03	1.2±0.08	1.3±0.03	1.1±0.05	1.1±0.02
Hardness (mmol/l)	0.7±0.03	0.7±0.01	0.6±0.06	0.6±0.03	0.5±0.06	0.5±0.03	0.5±0.04	0.6±0.01	0.5±0.07	0.4±0.04	0.7±0.07	0.6±0.09
Acidity (mmol/l)	0.3±0.09	0.3±0.03	0.5±0.05	0.4±0.07	0.6±0.05	0.4±0.08	0.4±0.03	0.3±0.02	0.4±0.01	0.2±0.04	0.3±0.07	0.3±0.08
Chloride (mg/l)	20.3±0.03	29±0.17	38±0.06	38±0.02	30±0.05	28±0.12	27±0.01	25±0.09	28±0.03	26±0.07	28±0.05	23±0.04
Phosphate (ppm)	10±0.09	10±0.12	10±0.02	10±0.07	10±0.05	5±0.05	5±0.03	10±0.03	5±0.11	5±0.08	10±0.13	10±0.05
Nitrate (mg/l)	0.01±0.003	0.01±0.007	0.03±0.004	0.02±0.009	0.05±0.001	0.05±0.003	0.05±0.007	0.04±0.002	0.02±0.005	0.02±0.002	0.03±0.008	0.01±0.002
DO (mg/l)	5.2±0.07	5.3±0.02	5.6±0.05	6.7±0.04	2.2±0.02	4.5±0.05	3.1±0.06	4.6±0.03	5.1±0.11	5.4±0.1	5.6±0.06	5.2±0.1
NPP (mg C/m^3/day)	874.99±0.064	749.99±0.077	874.99±0.119	962.99±0.03	1249.99±0.23	749.99±0.09	744.99±0.109	856.99±0.02	1010.99±0.07	980.99±0.04	999.99±0.13	987.99±0.22
CR (mg C/m^3/day)	624.99±0.2	500±0.117	624.99±0.1	999.99±0.02	874.99±0.213	874.99±0.118	854.99±0.09	761.99±0.11	746.99±0.17	621.99±0.19	610.99±0.035	590.99±0.111
GPP (mg C/m^3/day)	1500.98±0.059	1249.99±0.017	1499.98±0.089	1624.99±0.079	2124.99±0.23	1624.99±0.013	1660.99±0.035	1589.99±0.1	1527.99±0.12	1441.99±0.11	1212.99±0.21	1225.99±0.17

Table 3: Physico-chemical analysis of water in site 3

Parameters	*Dec*	*Jan*	*Feb*	*March*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*
Atm. Temp.(˚C)	20.6±0.06	21.8±0.04	29±0.05	37.8±0.03	35±0.03	33.5±0.08	34±0.11	32.1±0.28	30.6±0.05	27±0.12	23.3±0.08	22.4±0.09
Water temp.(°C)	18.2±0.03	19±0.11	23.1±0.18	33±0.02	27.7±0.05	29±0.07	29.1±0.21	28.1±0.08	27±0.01	24.4±0.09	21.5±0.07	18.1±0.23
Water pH	7.1±0.12	7.2±0.1	7.1±0.18	7.3±0.13	7.4±0.06	7.4±0.15	7.3±0.19	7.2±0.09	7.2±0.05	7.2±0.04	7.3±0.08	7.1±0.07
LI(×100 Lux)	556±0.13	560±0.89	581±0.03	701±0.08	315±0.04	971±0.07	899±0.15	861±0.09	785±0.19	759±0.15	613±0.07	573±0.06
Humidity	42±0.08	40±0.14	39±0.05	37±0.01	54±0.07	57±0.19	53±0.12	51±0.23	40±0.13	36±0.05	38±0.21	39±0.02
Conductivity(μΩ)	0.186±0.009	0.189±0.017	0.190±0.079	0.192±0.007	0.453±0.022	0.432±0.01	0.419±0.02	0.409±0.018	0.399±0.022	0.385±0.012	0.379±0.028	0.371±0.006
TDS(mg/l)	0.078±0.009	0.079±0.008	0.079±0.013	0.083±0.006	0.193±0.005	0.184±0.002	0.194±0.016	0.187±0.008	0.151±0.006	0.147±0.01	0.097±0.011	0.0859±0.0027
Alkalinity(mmol/l)	0.9±0.04	0.9±0.08	0.7±0.05	0.6±0.06	1.6±0.03	0.7±0.03	0.1±0.05	0.8±0.09	0.7±0.07	0.6±0.08	0.7±0.08	0.8±0.03
Hardness(mmol/l)	0.3±0.08	0.3±0.03	0.4±0.06	0.4±0.02	0.4±0.07	0.5±0.06	0.5±0.04	0.5±0.08	0.4±0.03	0.3±0.09	0.4±0.162	0.3±0.11
Acidity(mmol/l)	0.5±0.06	0.5±0.02	0.4±0.08	0.5±0.04	0.6±0.03	0.7±0.04	0.7±0.08	0.5±0.11	0.6±0.08	0.5±0.09	0.5±0.1	0.5±0.15
Chloride(mg/l)	10.1±0.05	20.1±0.12	25±0.11	18±0.07	55±0.04	42±0.07	43±0.05	41±1.06	33.2±0.09	25±0.14	21±0.02	15±0.19
Phosphate(ppm)	0.5±0.06	1±0.93	0.5±0.04	0.5±0.09	1±0.93	1±0.92	1±0.96	0.5±0.02	1±0.1	0.5±0.06	0.5±0.02	0.5±0.08
Nitrate(mg/l)	0.025±0.003	0.020±0.01	0.021±0.002	0.020±0.01	0.025±0.004	0.025±0.002	0.022±0.003	0.021±0.005	0.022±0.001	0.021±0.005	0.024±0.01	0.024±0.005
DO(mg/l)	7±0.09	7.3±0.12	7.5±0.08	8.8±0.06	2.1±0.11	3.3±0.08	2.5±0.02	3.5±0.04	5.6±0.06	7.3±0.05	7.2±0.09	7.4±0.05
NPP(mg C/m^3/day)	750±0.09	1000±0.01	1125±0.07	1125±0.04	1250±0.11	874.99±0.12	949±0.02	1029±0.005	984.9±0.09	876.99±0.17	753.99±0.2	747.99±0.11
CR(mg C/m^3/day)	250±0.04	250±0.07	500±0.03	749.99±0.13	749.99±0.22	625±0.11	620±0.05	639.99±0.26	398±0.18	281.99±0.25	277.99±0.07	250.99±0.27
GPP(mg C/m^3/day)	1000±0.06	1250±0.02	1625±0.11	1874.99±0.22	2000±0.06	1500±0.17	1530±0.21	1525±0.15	1449±0.18	1427±0.09	1300±0.24	1288±0.17

The nitrate concentration of water of all the study sites showed significant fluctuation throughout the study period. Higher level of nitrates in water samples were recorded during summer months (April to June) for all the studied sites. Maximum level of nitrate concentration in water samples were recorded in site 3 (Tables 1-3).

Dissolved oxygen (DO) is an important aquatic parameter whose measurement is vital in the context of culture of any aquatic animal as oxygen plays a crucial role in its life processes. Dissolved oxygen ranged from 1.5 to 5.8 mg/l at Padmapukur wetland, 2.2 to 6.7 mg/l at domestic sewage canal and 2.1 to 8.8 mg/l at agricultural run-off pond. There is a gradual decline in dissolved oxygen concentration from winter to summer in all the three sites. Jain et al. (1996) similarly reported a sharp decline in dissolved oxygen values from winters to summers in Halali reservoir at Vidisha (Tables 1-3).

During the study period, the net primary productivity, community respiration and gross primary productivity ranged 728.99 to 1375.01, 250 to 1125 and 1000 to 2250 mgC/m^3/day respectively. In three sites highest productivity were recorded in April month and lowest in October and December (Tables 1-3).

Species diversity indices such as species richness and evenness were studied in order to measure the status of water quality in the three sites and relationship that exists between the physico-chemical characteristics. Data obtained from the study indicates that cyclapod copepods were more frequent in site 3, calonoid copepods were more frequent in site 2 in terms of % of occurrence. Cladocerans were more frequent in site 1 and rotifers in site 3 (Table 4). Higher number of zooplankton species were recorded during June to September 2000, during monsoon period, and lowest during February and May during summer months. Our findings are supported by the earlier findings of Rajagopal et al. (2010). High mean value of Shannon's index (H′) was recorded in Padmapukur wetland (1.07±0.27) and domestic sewage canal (1.07±0.19) as compared to agricultural run-off canal (1.01±0.30) (Table 3). Highest Simpson's index was similarly recorded at Padmapukur wetland followed by domestic sewage canal and agricultural runoff pond. Out of the three studied sites, the zooplankton species richness (Menhinick and Margalef) was found to be high in Padmapukur Wetland (Menhinick: 1.01±0.29; Margalef: 0.99±0.26) followed by domestic sewage canal (Menhinick: 0.89±0.18; Margalef: 0.87±0.09) and agricultural run-off pond (Menhinick: 0.80±0.16; Margalef: 0.81±0.14). The mean value of the evenness index ranges for Pielou's evenness index between 0.85 to 1 and Equitibility 0.82 to 1 at Padmapukur wetland, Pielou's evenness index = 0.85 to 1 and Equitibility = 0.82 to 1, Pielou's evenness index = 0.82 to 1 and Equitibility = 0.87 to 1 at domestic sewage canal and Pielou's evenness index = 0.82 to 1 and Equitibility = 0.72 to 1 at agricultural run-off.

The monthly fluctuation in relative abundance of zooplanktons at three sampling sites is presented

Table 4: Percentage frequency distribution of different groups of zooplanktons

	Site 1	*Site 2*	*Site 3*
Cyclopods Copepods	37.05	29.77	20.77
Calanoid Copepods	37.19	25.95	23.52
Cladocera	36.25	34.78	27.05
Rotifera	12.35	8.01	7.24

Table 5: Monthly variation in the distribution and abundance of zooplanktons in the three studied sites

Months	*Site 1*				*Site 2*				*Site 3*			
	Cyco	*CACo*	*CL*	*RO*	*Cyco*	*CACo*	*CL*	*RO*	*Cyco*	*CACo*	*CL*	*RO*
December	+	+	+	-	-	+	+	-	+	-	+	-
January	+	+	+	-	+	+	+	-	+	+	+	-
February	+	+	+	-	-	+	+	+	+	+	+	-
March	+	+	+	-	-	+	+	+	+	-	+	+
April	+	-	+	-	+	+	+	-	+	+	+	-
May	+	-	-	+	+	+	+	-	+	+	-	-
June	+	+	+	+	+	+	+	+	+	+	+	+
July	+	+	+	+	+	+	+	+	+	+	+	+
August	+	+	+	+	+	+	+	+	+	+	+	+
September	+	+	+	+	+	+	+	+	+	+	+	+
October	+	+	+	+	+	+	+	-	+	+	+	-
November	+	+	+	+	+	+	+	-	+	-	+	-

in Tables 4 and 5. In the present investigation, low abundance and distribution of zooplanktons were reported in site 3, highest values were recorded for sites 1 and 2 respectively. Number of zooplankton population were found to be higher during the winter and post-winter season for the three study sites. From the correlation study, it was observed that a positive correlation exists between humidity with distribution and abundance of population of zooplanktons (r = –0.61 and r = –0.93 respectively) for sites 1 and 2. In site 3, total dissolved solid is positively correlated with distribution and abundance of population of zooplanktons (r = 0.67) (Tables 6-8).

The correlation matrix of the water quality parameters are presented in Tables 6, 7 and 8 for sites 1, 2, and 3 respectively. The correlation coefficient values were, in most cases, above 0.3 and significant at $P < 0.05$, thus justifying the use of multivariate statistics (PCA). Table 9 shows that factor analysis extracts three factors according to eigenvalues (>1) for the three studied sites. For site 1 the first, second and third factors account for 45.599%, 23.820% and 15.683% of variability in the water quality. Parameters such as air temperature, water temperature, pH, TDS, alkalinity, nitrate, community respiration and gross primary productivity were found to be significantly loaded in factor 4; light intensity, total dissolved solid, conductivity, net primary productivity and gross primary productivity were significantly loaded in factor 2; and conductivity, alkalinity and chloride in factor 3. For site 2 the first, second and third factors account for 39.636%, 21.367% and 20.505% of variability in the water quality. Parameters such as air temperature, water temperature, light intensity, pH, conductivity, TDS, alkalinity, nitrate, community respiration and GPP were found to be significantly loaded in factor 4; water temperature, water pH and humidity were significantly loaded in factor 2; and hardness, net primary productivity and gross primary productivity in factor 3. For site 3 the first, second and third factors account for 41.526%, 17.194% and 16.606% of variability in the water quality. Parameters such as water temperature, conductivity, TDS, alkalinity, nitrate nitrogen, community respiration and GPP were found to be significantly loaded in factor 1; air and water temperature, hardness, phosphate, NPP, community respiration and GPP were significantly loaded in factor 2; and water pH, humidity and alkalinity were significantly loaded in factor 3.

With the help of hierarchical cluster analyses based on physicochemical conditions of site 1 (Figure 1), site 2 (Figure 2), and site 3 (Figure 3) the sampling months could be clustered and categorized into several small groups. The dendrogram shows that for site 1, December-October formed a cluster which is closely related. Month of November and August, September and July, October and February. This cluster is distantly related with the month of May which forms another distant cluster with April.

For site 2, May-April formed closely related clusters adjoined by the months of December and February through separate cluster. Months of June and September and September and July formed separate clusters. These two clusters are joined by a distantly related cluster.

In site 3, January-September and months of July-February formed two separate clusters that are closely related. These two clusters are joined by a distantly related cluster formed between August and May. This in turn are distantly joined by another cluster formed between December and April. January form a cluster with months December-February. These clusters again joined with the clusters of March-May. Again this newly formed cluster is distantly related with the month April following another cluster.

With the help of hierarchical cluster analyses based on zooplanktons found in site 1 (Figure 4), site 2 (Figure 5), and site 3 (Figure 6) the sampling months could be clustered and categorized into several small groups. The dendrogram shows that for site 1, two distant clusters were formed between the months of May and February and between Nov and July. These two clusters are distantly joined by another cluster formed between the months of March and August.

For site 2, May-April formed closely related clusters adjoined by the month of December and February through separate clusters. Months of June and September and August and July formed separate clusters. These two clusters are joined by a distantly related cluster between April and September.

In site 3, months of March to April formed closely related clusters. These clusters are joined by a distantly related cluster formed between December and August.

Discussion

Temperature is one of the essential and changeable environmental factors, since it influences the growth and distribution of flora and fauna. The atmospheric temperature and water temperature were found to be congenial for growth of zooplankton communities in the three studied sites. Water temperature ranging between 13.5 and 32°C is reported to be suitable for

Table 6: Relationship among physico-chemical parameters and between zooplankton abundance with physico-chemical parameters of site 1

	AT	WT	pH	LI	HUMI	COND	TDS	ALKA	HARD	ACID	CHLO	PHOS	NITRA	DO	NPP	CR	GPP
WT	0.93																
pH	0.88	0.88															
LI	0.23	0.05	-0.08														
HUMI	0.22	0.36	0.34	-0.47													
COND	0.35	0.22	0.32	-0.01	0.21												
TDS	0.83	0.76	0.59	0.35	0.04	0.42											
ALKA	0.51	0.45	0.25	0.27	-0.03	0.62	0.81										
HARD	-0.47	-0.3	-0.31	-0.55	0.17	-0.63	-0.54	-0.47									
ACID	0.71	0.79	0.78	-0.37	0.59	0.48	0.62	0.51	-0.14								
CHLO	-0.13	-0.33	-0.23	0.49	-0.46	0.45	0.02	0.13	-0.64	-0.44							
PHOS	-0.65	-0.74	-0.65	0.32	-0.63	-0.48	-0.68	-0.52	0.15	-0.88	0.26						
NITRA	0.72	0.65	0.48	0.41	-0.08	0.29	0.88	0.68	-0.57	0.37	0.16	-0.5					
DO	-0.8	-0.9	-0.67	0.03	-0.52	-0.21	-0.8	-0.55	0.21	-0.8	0.39	0.86	-0.69				
NPP	-0.17	-0.3	-0.41	0.74	-0.85	-0.4	0.05	0.03	-0.21	-0.68	0.37	0.65	0.23	0.36			
CR	0.63	0.7	0.61	-0.11	0.4	0.26	0.72	0.52	-0.32	0.78	-0.37	-0.73	0.63	-0.82	-0.28		
GPP	0.64	0.59	0.35	0.6	-0.26	-0.07	0.77	0.52	-0.51	0.2	0	-0.2	0.82	-0.59	0.5	0.57	
ZOOP	0.18	0.29	0.28	-0.35	0.61	-0.17	-0.12	-0.31	0.52	0.3	-0.44	-0.37	-0.33	-0.26	-0.62	-0.14	-0.37

*AT - Atmospheric temperature, WT - Water temperature, pH - Water pH, LI - Light intensity, COND -Conductivity, TDS - Total dissolved solids, HUMI - Humidity, ALKA - Alkalinity, HARD - Total Hardness, ACID - Acidity, CHLO - Chloride, PHOS - Phosphate, NITRA - Nitrate, DO - Dissoled oxygen, NPP - Net primary productivity, CR - Community respiration, GPP - Gross primary productivity.

Table 7: Relationship among physico-chemical parameters and between zooplankton abundance with physico-chemical parameters of site 2

	AT	WT	pH	LI	HUMI	COND	TDS	ALKA	ARD	ACID	CHLO	PHOS	NITRA	DO	NPP	CR	GPP
WT	0.9																
pH	0.9	0.75															
LI	0.91	0.75	0.88														
HUMI	0.48	0.57	0.56	0.42													
COND	0.62	0.61	0.34	0.46	-0.16												
TDS	0.79	0.76	0.53	0.6	0.15	0.9											
ALKA	0.11	0.29	-0.21	-0.12	0.03	0.56	0.55										
HARD	-0.43	-0.53	-0.32	-0.35	-0.52	-0.35	-0.39	-0.51									
ACID	0.5	0.58	0.16	0.33	-0.12	0.88	0.79	0.52	-0.18								
CHLO	0.34	0.28	0.04	0.44	-0.14	0.48	0.52	0.25	-0.05	0.55							
PHOS	-0.37	-0.44	-0.5	-0.4	-0.62	-0.05	-0.12	0.05	0.77	0.11	0.16						
NITRA	0.85	0.9	0.73	0.66	0.43	0.63	0.75	0.32	-0.45	0.55	0.17	-0.31					
DO	-0.43	-0.6	-0.31	-0.08	-0.22	-0.53	-0.56	-0.46	0.4	-0.51	0.26	0.22	-0.7				
NPP	-0.27	-0.01	-0.55	-0.44	-0.16	0.26	0.07	0.77	-0.22	0.37	0.09	0.25	0	-0.21			
CR	0.8	0.72	0.61	0.66	0.3	0.68	0.71	0.32	-0.43	0.53	0.37	-0.25	0.61	-0.29	0.15		
GPP	0.62	0.65	0.36	0.33	0.16	0.87	0.87	0.74	-0.49	0.75	0.22	-0.12	0.67	-0.69	0.4	0.74	
ZOOP	0.33	0.4	0.4	0.26	0.93	-0.32	0.02	-0.01	-0.4	-0.21	-0.14	-0.46	0.33	-0.18	-0.19	0.1	0.02

*AT - Atmospheric temperature, WT - Water temperature, pH - Water pH, LI - Light intensity, COND -Conductivity, TDS - Total dissolved solids, HUMI - Humidity, ALKA - Alkalinity, HARD - Total Hardness, ACID - Acidity, CHLO - Chloride, PHOS - Phosphate, NITRA - Nitrate, DO - Dissoled oxygen, NPP - Net primary productivity, CR - Community respiration, GPP - Gross primary productivity.

Table 8: Relationship among physico-chemical parameters and between zooplankton abundance with physico-chemical parameters of site 3

	AT	WT	pH	LI	HUMI	COND	TDS	ALKA	HARD	ACID	CHLO	PHOS	NITRA	DO	NPP	CR	GPP
WT	0.97																
pH	-0.19	-0.26															
LI	0.34	0.47	-0.64														
HUMI	0.39	0.33	0.01	-0.3													
COND	0.34	0.34	-0.17	0.31	0.14												
TDS	0.61	0.61	-0.32	0.43	0.47	0.84											
ALKA	-0.19	-0.3	0.59	-0.88	0.44	-0.11	-0.16										
HARD	0.72	0.73	-0.4	0.6	0.3	0.49	0.69	-0.46									
ACID	0.47	0.49	-0.52	0.47	0.28	0.64	0.74	-0.43	0.56								
CHLO	0.69	0.62	-0.23	0.19	0.63	0.73	0.92	0.03	0.71	0.65							
PHOS	0.31	0.27	-0.47	0.12	0.47	0.36	0.53	-0.09	0.32	0.77	0.62						
NITRA	-0.24	-0.26	0.08	-0.18	0.03	0.4	0.2	0.08	-0.17	0.22	0.08	-0.11					
DO	-0.5	-0.44	0.27	-0.24	-0.59	-0.73	-0.91	0.04	-0.69	-0.75	-0.92	-0.62	-0.22				
NPP	0.69	0.58	0.12	-0.24	0.61	-0.06	0.27	0.38	0.31	-0.01	0.54	0.31	-0.45	-0.28			
CR	0.95	0.88	-0.07	0.19	0.49	0.26	0.57	-0.05	0.74	0.4	0.7	0.27	-0.18	-0.56	0.73		
GPP	0.87	0.77	0.16	-0.11	0.44	0.24	0.42	0.19	0.45	0.18	0.62	0.21	-0.18	-0.34	0.85	0.86	
ZOOP	0.38	0.43	-0.16	0.52	0.22	0.53	0.67	-0.2	0.51	0.32	0.52	0.19	-0.31	-0.52	0.18	0.26	0.16

*AT - Atmospheric temperature, WT - Water temperature, pH - Water pH, LI - Light intensity, COND -Conductivity, TDS - Total dissolved solids, HUMI - Humidity, ALKA - Alkalinity, HARD - Total Hardness, ACID - Acidity, CHLO - Chloride, PHOS - Phosphate, NITRA - Nitrate, DO - Dissoled oxygen, NPP - Net primary productivity, CR - Community respiration, GPP - Gross primary productivity.

Table 9: Principal component analysis (PCA) of physico-chemical parameters of study sites 1, 2 and 3

Site 1

	Component		
	1	2	3
ATM_TEMP	.904	-1.564E-02	.170
W_TEMP	.932	-.152	-1.774E-02
W_PH	.765	-.290	7.186E-02
LI	.149	.817	.291
HUM	.273	-.797	-.111
CONDT	.208	-.359	.892
TDS	.896	.167	.323
ALK	.605	9.155E-02	.522
HRD	-.349	-.308	-.775
CL	-.315	.382	.795
PHOS	-.739	.561	-.171
NI	.803	.350	.295
DO	-.937	.224	4.855E-02
NPP	-.136	.983	-3.454E-02
CR	.844	-.197	1.323E-02
GPP	.758	.622	7.704E-03
Eigenvalue	7.752	4.049	2.666
% of Variance	45.599	23.820	15.683
Cumulative %	45.599	69.419	85.101

Site 2

	Component		
	1	2	3
ATM_TEMP	.883	.433	-.111
W_TEMP	.773	.533	.135
W_PH	.673	.578	-.396
LI	.816	.339	-.392
HUM	.113	.828	-.114
CONDT	.822	-7.022E-02	.472
TDS	.892	.103	.341
ALK	.220	3.485E-02	.905
HRD	-.207	-.717	-.400
CL	.635	-.435	-1.280E-04
PHOS	-6.692E-02	-.840	8.876E-02
NI	.733	.479	.191
DO	-.319	-.445	-.561
NPP	-.119	-.173	.872
CR	.774	.250	.170
GPP	.669	.204	.645
Eigenvalue	6.738	3.632	3.486
% of Variance	39.636	21.367	20.505
Cumulative %	39.636	61.004	81.509

Site 3

	Component		
	1	2	3
ATM_TEMP	.302	.914	-.164
W_TEMP	.277	.863	-.320
W_PH	-.432	5.328E-02	.602
LI	.270	.124	-.936
HUM	.486	.253	.773
CONDT	.814	8.379E-02	-5.898E-02
TDS	.840	.401	-.119
ALK	.133	1.759E-02	.880
HRD	.539	.573	-.407
CL	.864	.134	-.274
PHOS	.782	.561	.111
NI	.598	-.435	.330
DO	-.905	-.304	-7.702E-02
NPP	-2.442E-02	.873	.358
CR	.307	.902	1.329E-02
GPP	.118	.919	.224
Eigenvalue	5.456	5.217	3.314
% of Variance	32.092	30.689	19.496
Cumulative %	32.092	62.782	82.277

*AT - Atmospheric temperature, WT - Water temperature, pH - Water, LI - Light intensity, HMD - Humidity, CONDT - Conductivity, TDS - Total dissolved solids, ALK - Alkalinity, HRD - Total Hardness, CL - Chloride, PHOS - Phosphate, NI - Nitrate, DO - Dissolved oxygen, NPP - Net primary productivity, CR - Community respiration, GPP -Gross primary productivity.

Table 10: Zooplankton species richness, diversity and evenness of three studied sites

Diversity indices	*Padmapukur wetland*		*Domestic sewage canal*		*Agricultural run off*	
Mean ± SD	*Range*	*Mean±SD*	*Range*	*Mean±SD*	*Range*	*Mean±SD*
Richness						
Taxa_S	2-4	3.33±0.78	2-4	3.25±0.62	2-4	3.08±0.79
Individuals	5-52	22.25±15.69	3-40	17.25±12.04	2-37	14.17±2.64
Menhinick	0.66-1.5	1.01±0.29	0.63±1.16	0.89±0.18	0.55-1.13	0.80±0.16
Margalef	0.62-1.44	0.99±0.26	0.72-1.03	0.87±0.09	0.56-1.03	0.81±0.14
Diversity						
Dominance_D	0.27-0.68	0.38±0.12	0.27-0.56	0.37±0.08	0.25-0.68	0.41±0.14
Shannon_H	0.50-1.35	1.07±0.27	0.64-1.33	1.07±0.19	0.50-1.38	1.01±0.30
Simpson_1-D	0.32-0.73	0.63±0.12	0.44-0.73	0.63±0.08	0.32-0.75	0.59±0.14
Evenesse						
Evenness_e^$^{H/S}$	0.85-1	0.93±0.05	0.82-1	0.91±0.04	0.82-1	0.90±0.05
Equitability_J	0.92-1	0.93±0.07	0.87-1	0.92±0.04	0.72-1	0.91±0.08

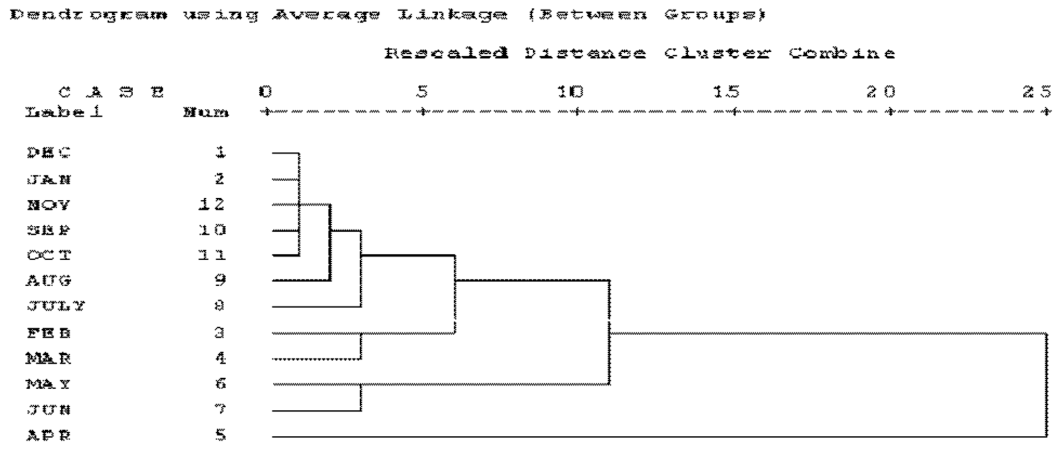

Figure 1: Hierarchical cluster analyses of site 1 for physico-chemical parameters of water.

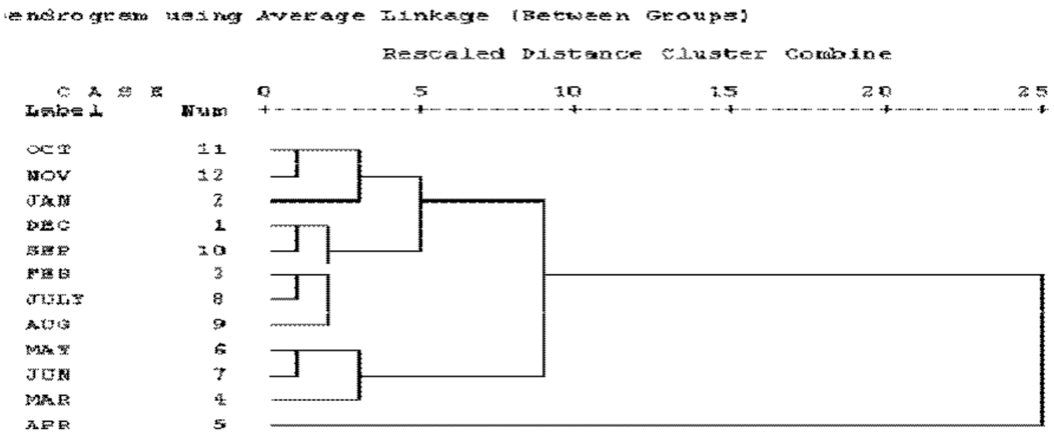

Figure 2: Hierarchical cluster analyses of site 2 for physico-chemical parameters of water.

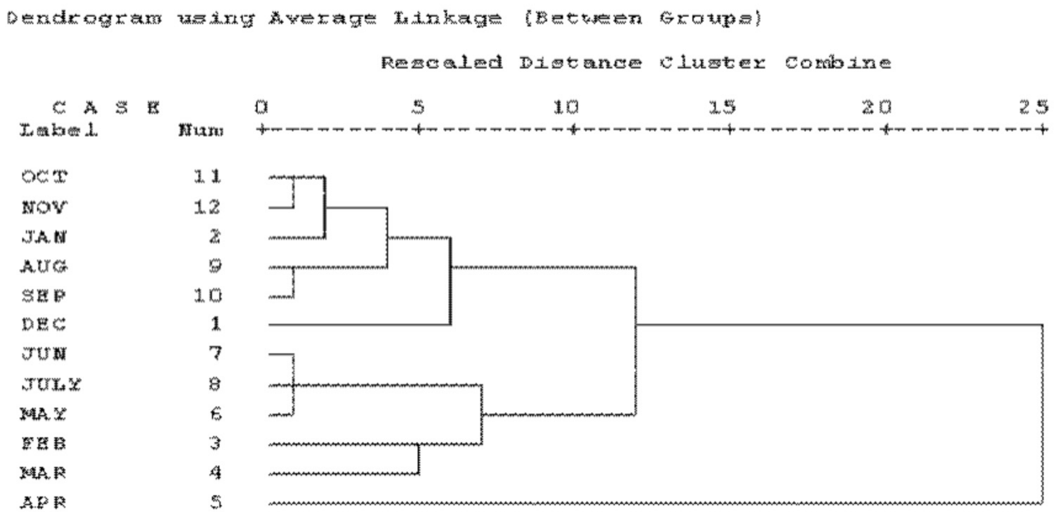

Figure 3: Hierarchical cluster analyses of site 3 for physico-chemical parameters of water.

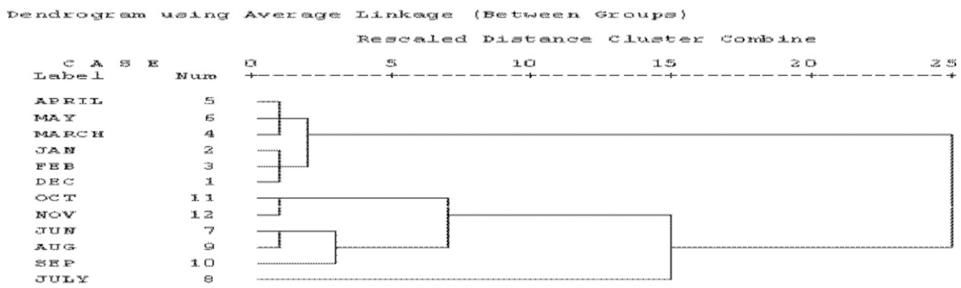

Figure 4: Hierarchical cluster analyses of zooplanktons of site 1.

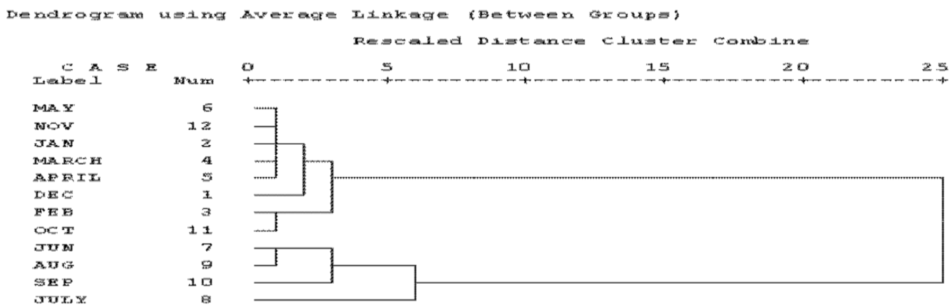

Figure 5: Hierarchical cluster analyses of zooplanktons of site 2.

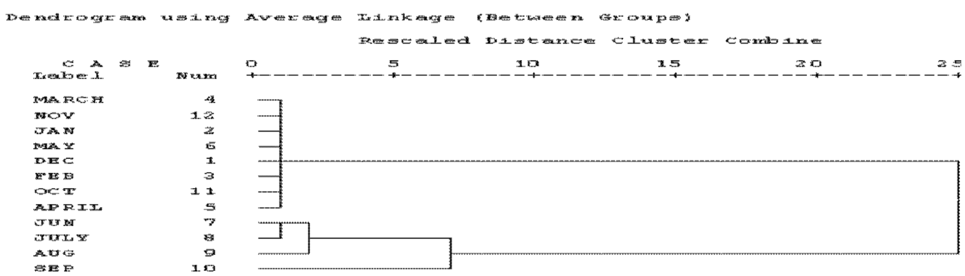

Figure 6: Hierarchical cluster analyses of zooplanktons of site 3.

the development of the planktonic organisms (Kamat, 2000; Gaikwad et al., 2008). The variation in water temperature may be due to different timing of collection and the influence of season (Jayaraman et al., 2003).

High pH value was recorded during May, June and July (summer). This may be due to low level of water and high photosynthesis of micro-macro organism resulting in high production of free carbon dioxide during the equilibrium towards alkaline side (Trivedy, 1989; Shiddamallayya and Pratima, 2008). According to Kurbatova (2005) and Tanner et al. (2005) the pH range between 6.0 and 8.5 indicates medium productive nature of a reservoir; more than 8.5 highly productive; and less than 6.0 low productive nature of a reservoir. In the case of first two sites average pH value observed during the study period was 7.96 and 7.95 respectively and for site 3 it is 7.25 which indicates medium productive nature of the studied water sites.

Light intensity value of the present investigation reflected the effect of different seasons on the four sites under the present investigation.

Higher level of humidity were recorded during pre-monsoon period for all the four studied sites due to higher evaporation rate from the surface water bodies during the pre-monsoon period and subsequent increase in the moisture content in the atmosphere during the monsoon period. Lower level of humidity were observed during post-monsoon period reflecting lower evaporation rate from the water bodies and therefore lower level of moisture content in the atmosphere.

EC is found to be good indicator of the water quality (Abbassi et al., 1996; Gaikwad et al., 2008). According to Gaikwad et al. (2008), the dilution of solid substance in turn reduces the EC value, alkalinity and zooplankton production. The high electrical conductivity value was observed during summer months, and this might be due to high temperature at less solubility and high degradation of organic substances (Rajagopal et al., 2010).

The TDS value were found to be higher during summer months which may be attributed towards the higher evaporation rate under higher solar insolation and therefore increase in the soluble salt concentration as well as addition of sediments in the three studied sites in terms of agricultural run-off, discharge of domestic sewage (Datta et al., 2009).

Higher alkalinity during summer months were recorded which may be attributed towards the increased photosynthesis in the algal blooms resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates causing higher alkalinity. Similar observations were made by Kulshrestha et al. (1992).

Higher level of hardness in water in site 1 and site 2 during monsoon and winter months may be due to the natural accumulation of salts from contact with the soil and geological formations or it may enter from the direct pollution by human activities (Joseph et al., 2010). High range of total hardness obviously was due to high loading of organic substance, detergents, chlorides and other pollutants during summer months for site 3 (Rajagopal et al., 2010).

The higher level of chloride content during summer months may be attributed towards continuous evaporation of water especially during summer season (Borase and Bhave, 2001). The pre-monsoon low value could be attributed towards high anthropogenic activities coupled with settling of particulate at the bottom due to restricted flow of water (Radhika et al., 2004). The low phosphate content during the monsoon period may be attributed towards lesser allochthonous input through rain water, leaching of soil and weathering of rocks (Jhingran, 1988).

The higher level of nitrate in water samples of studied sites during summer months may be attributed towards the allochthonous input due to leaching of soil and weathering of rocks (Jhingran, 1988).

Dissolved oxygen content has inverse relationship with temperature. As the temperature was slightly lower during monsoon and winter months the dissolved oxygen content was found to be higher in water samples of the studied sites (Datta et al., 2009). The higher water temperature may result in decline of dissolved oxygen concentration of water.

The high rate of productivity during summer may be due to low water level, high solar radiation, longer photoperiod, high water temperature. In the three sites, the productivity was minimum during winter months. It may be for the low temperature, low intensity of light, short photoperiod, low concentrations of nutrients and less number of phytoplankton (Kumar and Bohra, 2002).

High Shannon's index and Simpson's index were similarly recorded at Padmapukur wetland followed by domestic sewage canal and agricultural runoff pond. Dash (1996) reported that the higher the value of Shannon's index (H') the greater is the planktonic diversity. Although Balloch et al. (1976) and Ismael and Dorgham (2003) found the diversity index (Shannon's) to be a suitable indicator for water quality assessment. The species richness index value were found to be highest in Padmapukur wetland and lowest in agricultural run-off pond. Mukherjee (1997) reported that the higher species richness (Menhinick and Margalef) is characterized by larger food chain (Dumont, 1999). Peet (1974) has reported that species diversity implies both richness and evenness in the number of species and equitability for the distribution of individual among the species.

The findings of the present study indicate that the Padmapukur wetland exhibited higher levels of zooplankton species density as well as physico-chemical parameters (GPP, CR and NPP) than that of domestic sewage canal and agricultural run-off canal. Species diversity, species richness as well species evenness index value were higher for Padmapukur wetland. Therefore, the water body has to be preserved for their intended use, and a sustainable and holistic management planning is necessary for conservation of this pond.

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