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RESEARCH ARTICLE

Zooplankton Composition, Diversity and Physicochemical Features of Bandam Kommu Pond, Medak District, Telangana, India

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Abstract The present investigation aims to study the zooplankton composition, diversity along with physicochemical profile in a chosen pond at Medak district from December, 2010 to November, 2012. The study revealed the occurrence of 80 zooplankton species including 60 rotifers, 18 cladocerans and 02 copepods. Zooplankton density fluctuated between 119 and 26,463/L, diversity $H' = 0.89$–2.68, species richness 5–21 and dominance 18.6–74.1 % over the 2 years study period. Rotifers were more predominant than other zooplankton communities, especially family Brachionidae and Lecanidae. High density of the overall zooplankton community was due to more rotifer population and the numerical dominance of the species *Brachionus angularis, B. calyciflorus, B. caudatus, Keratella tropica, Filinia terminalis* and *Epiphanies mucronata*. It was observed that the zooplankton density significantly correlates with pH values of the pond. Physicochemical profile of the pond shows tropical climate, hard water and alkaline in nature. Chloride content was found to be high may be due to the anthropogenic pressure and influx of sewage. The high content of phosphate and nitrate reveals that the pond is enriched with nutrients. This has significant correlation with zooplankton dominance. The present findings clearly indicates the eutrophication of the pond.

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Introduction

Smaller water bodies like ponds which are an important component of the landscape, are seriously threatened by climate change, eutrophication and their combined effects (Moss et al. 2011). It is often neglected and not sufficiently studied (Cereghino et al. 2008). In terms of services, ponds offer sustainable solutions to key issues of water management and climate change such as nutrient retention, rainfall interception, or carbon sequestration (Cereghino et al. 2013). Ponds are biodiversity hotspots both in terms of species composition and biological traits, and have a significant role to play in the provision of ecosystem services (EPCN 2008). It constitutes an important component of urban and rural landscapes. They provide ecosystem services including habitats for wildlife, livestock, fish production and recreational amenities (Jeffries 2005). Ponds are subjected to anthropogenic pressure even though these ecosystems have obvious ecological functions (Hansson et al. 2005) and recognized as social and economic uses (Chapman et al. 2001). In light of recent economic development, a major challenge is to understand the turnover of pond communities in relation to changes in local–regional environments and pond habitat characteristics (EPCN 2008).

Zooplankton has a fundamental role in energy flow and nutrient cycling in aquatic ecosystem.Its fast growth rates can provide meaningful and quantifiable indicators of ecological change in short as well as long timescales (Schindler 1987; Paerl et al. 2003). Therefore zooplankton community can help to understand the shifts in the trophic status, environmental changes and water quality of an aquatic ecosystem

(Blancher 1984; Pinto-Coelho et al. 2005; Ferdous and Muktadir 2009). This has been recommended as regional bioindicators of eutrophication. Also, there is an increasing demand by environmental monitoring programs for bioindicators of water quality (Andronikova 1996; Sousa et al. 2008). Zooplankton communities in small ponds are subjected to extreme fluctuations, the causes of which are not adequately understood (Patil and Gouder 1985). The abundance, diversity of zooplankton community is usually considered to be good indicator of environmental changes and largely regulated by the resource base and tend to increase with the trophic status (Canfield and Jones 1996; Sharma et al. 2008). Very few reports are available on variation of zooplankton community in the aquatic ecosystems of Telangana (Seenayya 1971; Rao 1972; Ahsan 1982; Reddy 1984; Chandrasekhar and Kodarkar 1994, 1995, 2008; Chandrasekhar 2004, 2007; Ranjan and Reedy 2007). Zooplankton community structure is shaped primarily by the physical and chemical environment (Blancher 1984).

Bandam Kommu pond lies on the Deccan plateau of the Indian subcontinent, Medak district, Telangana, India. Recent rapid urbanisation and industrial development are degrading and depleting the water quality and aquatic habitats. This pond is situated very close to the urban city of Hyderabad and thus subjected to severe anthropogenic and industrial pressure. The purpose of the investigation was to evaluate the species composition and diversity of zooplankton communities inhabiting the littoral zones in relation to physicochemical profile of the pond.

Materials and Methods

Study Area

Bandam Kommu pond is located at Medak district, Telangana, India (17°28′47″N and 78°47′36″E). The area is about 2 $km^2$and shallow in nature. Littoral margin of the pond is covered with abundant macrophytic vegetations like water lily—*Nymphaea alba*, Amphibious *amphibium—Polygonum amphibium*, Bulrush—*Typha latifolia*, Red weed—*Polygonum persicaria*, water fern—*Azolla filiculoides*, Rigid horn wort—*Ceratophyllum demersum*, Duck weed—*Lemna minor* and Rootless duck weed—*Wolfo iaarrhiza*. The study was carried out on monthly basis from December 2010 to November 2012 in the pond.

Zooplankton Collection and Enumeration

Both qualitative and quantitative collections were made from littoral surface of the water column at different stations. Qualitative collections were done by towing surface water column, quantitative samples were collected by filtering 50 L of water through zooplankton net made of bolting silk (No. 25), 62 µm mesh size. The samples were transferred to clean plastic containers of 100 ml capacity and preserved in 4 % neutralized formaldehyde solution and containers were labelled. Identification of zooplankton species was done by using regional level literature (Michael and Sharma 1988; Sharma 1992; Ranga Reddy 1994; Segers 1995; Dhanapathi 2000; Sharma and Sharma 2008) under light microscope (Carl Zeiss 10 × 25x). Sedgwick-Rafter cell method was applied to estimate zooplankton quanititatively and the results were expressed in Ind. L^{-1}(Welch 1948).

Physicochemical Parameters

The ambient and subsurface water temperature, electrical conductivity, pH, total dissolved solids were recorded in the field with the help of digital electronic testers (Orlab). Water samples were collected in clean plastic containers (1 L) and brought to the laboratory for chemical analysis. Dissolved oxygen content was estimated through Winkler's method. Total hardness, total alkalinity, calcium, chloride, phosphate, nitrate and nitrite were analysed by using Orlab water quality kits prepared by following standard methods (APHA 1985).

Statistical Analysis

Standard statistical methods like Shannon diversity index H' for species diversity; hill numbers index for species richness and abundance; Pielou index for evenness; Berger–Parker dominance index for dominance were applied (Hayek and Buzas 1997) and their working equations by using *Biodiversity pro* software. Principal component analysis was made by using Jolliffe (2002) method by using XLSTAT software.

$$\text{Shannon diversity index } H' = -\sum p_i \ln(p_i)$$

where Pi = proportion of the number of individuals of species to the total number of individuals ($P_i = n_i/N$) n = total number of species, N = total number of individuals

$$\text{Evenness } J' = H_{max'}/\text{Log}^2 S$$

H_{max}' = is the Shannon maximum diversity index, S = the total number of species in the sample. Hill Numbers, $H_0 = S$ (species richness), $H_1 = \exp H'$ exponential of Shannon diversity Indices (abundance) Berger–Parker Dominance index $d = N_{max}/N$ N_{max} = the number of individuals in the most abundant species, N = the total number of individuals in the sample.

Results

Composition

Eighty species of zooplankton comprising 60 species of rotifers, 18 species of cladocerans and two species of copepods were recorded in Bandam Kommu pond (Table 1). It is found that the rotifers are the most dominant component in the zooplankton community components, especially genus *Lecane* and *Brachionus* were the most common elements. In Cladocera, families Chydoridae and Daphniidae have more number of species. Copepoda had only two species which belongs to Diaptomidae and Cyclopoidae. *Brachionus forficula, Trichotria tetractis, Macrochaetus sericus, Lecane hornemanni, L. simonneae, L. pyriformis, Scaridium* sp., *Conochilus* sp., *Hexarthra* sp., *Testudinella patina, Daphnia lumholtzi, Pseudochydorus globosus* occurred only in the samples collected during 2010–2011, and species like *Epiphanies clavulata, Brachionus bidentata,B. plicatilis, Lecane arcula, Karualona karua* and *Kurzia longirostris* are recorded during 2011–2012.

Density

The overall zooplankton density varied between 119 and 2646/L throughout the study period (Table 2). High density was mainly because of rotifer population in June 2011(26,463/L) and 2012 (4354/L) and October 2012 (1534/L). The cladocerans fluctuated between 34 and 1088/L, high in May 2012 (1003/L) and October 2012 (1088/L). Similarly, copepod ranges between 1 and 1072/L. The high density of copepods was recorded in May, 2012 (1072/L), due to abundance of *Mesocyclops leuckarti* (Figs. 1and 2). The correlation analysis between physicochemical and biological parameters (Table 4) reveals that the pH and phosphate moderately correlates with overall zooplankton (r = 0.5049 and 0.4428) and rotifer density (r = 0.4894 and 0.4576). Total zooplankton density significantly correlates with rotifer density (r = 0.995) and cladocerans had moderate correlation with copepod and overall species richness (r = 0.587 and 0.499 respectively).

Diversity

During the study period, it is found that zooplankton diversity varied between $H' = 0.893$–2.683 (Table 2), the diversity was more in 2011–2012 (1.9 ± 0.3) than 2010–2011 (1.6 ± 0.5). The high diversity was in November, December, 2011 and October, 2012; less in September, 2011 (Fig. 3). It had significant correlation with abundance (r = 0.914), species richness (r = 0.779) and evenness (r = 0.660) (Table 4). Evenness varied between $J' = 0.47$–0.961 (Table 2), less in December, 2010 and September, 2011 and high in February and March, 2011 (Fig. 4). This had moderate correlation with abundance of zooplankton (r = 0.503). The richness of the species varied between 5 and 21 (Table 2), high number of 21 species recorded in November, 2011 and 20 species in October, 2012 (Fig. 5). Similarly the abundance ranged between 11.4–69, high in November, 2011 and October, 2012, which was 69.2 and 55.2 % respectively (Fig. 6). Dominance of zooplankton of the pond varied between 16.3–80.1 % and the values are reciprocal to the abundance (Fig. 7). Nitrate, nitrite and ammonia contents correlated with dominance (r = 0.5385, 0.3792, 0.4415 respectively). The present investigation over 2 years showed that the high density, less diversity, low species richness, less abundance and more dominance during 2010–2011. The diversity, evenness and abundance decreased, whereas the dominance increased.

Physicochemical Parameters

The physicochemical profile of the pond was given in Table 3. The atmospheric temperature ranges from 25 to 33 °C and surface water temperature varied between 19 and 25 °C (Fig. 8). Significant correlation between atmospheric and surface water temperature (r = 0.7930) was observed. The pH of the pond ranges between 7.5 and 8.9 (Fig. 9). Electrical conductivity was 0.9–4.8 mS (Fig. 10), this had significant correlation with total dissolved solids (r = 0.9000) and chloride (r = 0.9082), moderate correlation with total hardness (r = 0.6532) and magnesium (r = 0.6756). The dissolved oxygen content fluctuated between 0.8 and 12.35 mg/L, low in October, 2011 and high 12.35 mg/L in August, 2012 (Fig. 9). Dissolved oxygen has moderate correlation with phosphate content (r = 0.5557). Total dissolved solids ranged between 690 and 2000 ppm, which was less in the initial months and gradually increased to 2000 ppm from February to May, 2012 (Fig. 12). It has significant correlation with total hardness (r = 0.7949) and chloride (r = 0.9263). Total hardness ranged between 189 and 355 mg/L (Fig. 11) and significantly correlated with chloride (r = 0.7046) and Magnesium (r = 0.9816). Alkalinity ranges between 204 to 331 mg/L (Fig. 11). Similarly, the ionic contents such as chloride, calcium and magnesium ranged between 182–445, 28.4–47.4 and 34.7–77.5 mg/L respectively (Figs. 12 and 13). Nutrient content of the pond such as total phosphate, nitrate, nitrite and ammonia ranged between 0.1–0.4, 0.3–1.2, 1–40, and 1–3.7 mg/L respectively (Figs. 14, 15 and 16). Nitrate has significant correlation with nitrite (r = 0.7473). Principal component analysis (PAC) of bio-physicochemical parameters shows the variability 24.66 % (p value < 0.0005) and among the physiochemical parameters the variability was 37.16 % (p value < 0.05 %) and among biological parameters variability was 42.4 % (p value < 0.05). The scattered

Table 1 List of zooplankton species recorded from Bamdam Kommu pond of Telangana

S. no	Name of the species	Study period	
		2010–2011	2011–2012
	Rotifera		
	Epiphanidae		
1	*Epiphanes clavulata* (Ehrenberg, 1832)	–	+
	Brachionidae		
2	*Anuraeopsis fissa* Gosse, 1851	+	+
3	*Brachionus angularis* Gosse, 1851	+	+
4	*Brachionus bidentatus* Anderson, 1889	–	+
5	*Brachionus budapestinensis* Daday, 1885	+	+
6	*Brachionus calyciflorus* Pallas, 1776	+	+
7	*Brachionus caudatus* Barrios & Daday, 1894	+	+
8	*Brachionus diversicornis* (Daday, 1883)	+	–
9	*Brachionus durgae* Dhanapathi, 1974	+	+
10	*Brachionus falcatus* Zacharias, 1898	+	+
11	*Brachionus forficula* Wierzejski, 1891	+	–
12	*Brachionus plicatilis* Muller, 1786	–	+
13	*Brachionus quadridentatus quadridentatus* Hermann, 1783	+	+
14	*Brachionus quadridentatus melhemi* Barrios & Daday 1894	+	+
15	*Brachionus rubens* Ehrenberg, 1838	+	+
16	*Keratella tropica* (Apstein, 1907)	+	+
17	*Platious patulus* (Muller, 1786)	+	+
18	*Platyias quadricornis* (Ehrenberg, 1832)	+	+
	Euchlanidae		
19	*Euchlanis dilatata* Ehrenberg, 1832	+	+
20	*Tripleuchlanis plicata* (Levander, 1894)	+	+
	Mytilinidae		
21	*Mytilina acanthophora* Hauer, 1938	+	+
22	*Mytilina ventralis* (Ehrenberg, 1832)	+	+
	Trichotriidae		
23	*Trichotria tetractis* (Ehrenberg, 1830)	+	–
24	*Macrochaetus sericus* (Thorpe, 1893)	+	–
	Lepadellidae		
25	*Colurella obtuse* Gosse, 1886	+	+
26	*Lepadella (Lepadella) ovalis* (Muller, 1786)	+	+
27	*Lepadella* sp.	+	+
28	*Lepadella (Heterolepadella) ehrenbergii* Perty, 1850	+	+
	Lecanidae		
29	*Lecane arcula* Harring, 1914	–	+
30	*Lecane bulla* (Gosse, 1851)	+	–
31	*Lecane closterocerca* (Harring and Myers, 1926)	+	+
32	*Lecane curvicornis* (Murray, 1913)	+	+
33	*Lecane hamata* (Stokes, 1896)	+	+
34	*Lecane hornemanni* (Ehrenberg, 1881)	+	–
35	*Lecane leontina* (Turner, 1892)	+	+
36	*Lecane ludwigii* (Eckstein, 1883)	+	+
37	*Lecane luna* (Muller, 1776)	+	+
38	*Lecane lunaris* (Ehrenberg, 1832)	+	+
39	*Lecane papuana* (Murray, 1913)	+	+

Table 1 continued

S. no	Name of the species	Study period	
		2010–2011	2011–2012
40	*Lecane pyriformis* (Daday, 1905)	+	–
41	*Lecane quadridentata* (Ehrenberg, 1832)	+	+
42	*Lecane simonneae* (Segers, 1993)	+	–
43	*Lecane stenroosi* (Meissner, 1908)	+	+
44	*Lecane tenuiseta Harring*, 1914	–	+
45	*Lecane unguitata* (Fadeev, 1925)	+	+
46	*Lecane ungulata*(Gosse, 1887)	+	+
	Notommatidae	+	+
47	*Cephalodella* sp.		
48	*Cephalodella forficula* (Ehrenberg, 1830)	–	+
	Scaridiidae		
49	*Scaridium* sp.	+	–
	Asplanchnidae		
50	*Asplanchna brightwellii* Gosse, 1850	+	+
	Synchaetidae		
51	*Polyarthra* sp.	+	+
	Conochilidae		
52	*Conochilus* sp.	+	–
	Trichocercidae		
53	*Trichocerca* sp.	+	+
	Hexarthridae		
54	*Hexarthra* sp.	+	–
	Filiniidae		
55	*Filinia* sp.	+	+
56	*Filinia opoliensis* (Zacharias, 1898)	+	+
57	*Squatinella lamellaris* (Muller, 1786)	–	+
	Testudinellidae		
58	*Testudinella patina* (Hermann, 1783)	+	+
	Philodinidae	+	+
59	*Rotaria neptunia* Ehrenberg, 1832		
60	*Rotaria* sp.	+	+
	Cladocera		
	Sididae	+	+
61	*Diaphanosoma sarsi* Richard, 1895		
	Daphniidae		
62	*Ceriodaphnia cornuta* Sars, 1885	+	+
63	*Daphnia (Ctenodaphnia) lumholtzi* Sars, 1885	+	–
64	*Scapholeberis kingi* Sars, 1903b	+	+
65	*Simocephalus* sp.	+	+
	Moinidae		
66	*Moina micrura* Kurz, 1874	+	+
	Macrothricidae		
67	*Macrothrix spinosa* King, 1853	+	+
68	*Ilyocryptus spinifer* Herrick, 1882	–	+
	Chydoridae	+	+
69	*Alona* sp.		
70	*Chydorus sphaericus* (O. F. Muller, 1776)	+	+

Table 1 continued

S. no	Name of the species	Study period	
		2010–2011	2011–2012
71	*Coronatella rectangular* Sars, 1862a	+	+
72	*Dunhevedia crassa crassa* King, 1853	+	+
73	*Euryalona orientalis* Daday, 1898	+	+
74	*Karualona karua* King, 1853	+	+
75	*Kurzia (Rostrokurzia) longirostris* (Daday, 1898)	–	+
76	*Leberisdavidi davidi* Richard, 1895	+	+
77	*Pleuroxus aduncus* Jurine, 1820	+	+
78	*Pseudochydorus globosus* (Baird, 1843)	+	–
	Copepoda		
	Diaptomidae	+	+
79	*Tropodiaptomus orientalis* (Brady,1886)		
80	Cyclopoidae		
	Mesocyclops leuckarti Claws, 1857	+	+

+ indicates presence, – indicates absence)

Table 2 Zooplankton density and diversity indices of Bandam Kommu pond

Parameters	Duration	Range	Mean ± SD
Total Zooplankton (Ind./L)	2010–2011	119–26463	2831 ± 7481
	2011–2012	207–4716	1306 ± 1306
Rotifer (Ind./L)	2010–2011	34.3–25,930	2438 ± 7402
	2011–2012	103.0–4354	788.3 ± 1191
Cladocera (Ind./L)	2010–2011	34.0–1003	184.0 ± 290
	2011–2012	34.0–1088	256.8 ± 332
Copepoda (Ind./L)	2010–2011	0–1072	208.8 ± 310
	2011–2012	0–657	261.8 ± 212
Diversity (H′)	2010–2011	0.8–2.7	1.6 ± 0.5
	2011–2012	1.4–2.5	1.9 ± 0.3
Evenness (J′)	2010–2011	0.5–1.0	0.8 ± 0.2
	2011–2012	0.6–0.9	0.8 ± 0.1
Species richness (H_0)	2010–2011	5.0–21.0	9.1 ± 4.7
	2011–2012	8.0–20.0	12.7 ± 3.4
Abundance (H_1)	2010–2011	4.3–69.2	19.3 ± 17.0
	2011–2012	11.4–55.3	26.6 ± 13.2
Dominance (d %)	2010–2011	20.0–80.1	41.8 ± 18.3
	2011–2012	16.3–58.0	36.2 ± 14.4

interrelationship and their correlation are given in Figs. 17, 18 and 19.

Discussion

The zooplankton composition of the Bandham Kommu pond was higher compared to the other ponds of this region (Ahsan 1982; Arshaduddin and Khan 1991; Karuthapandi et al. 2012). The study reveals that among the various zooplankton communities, rotifer component was more dominat, especially genus *Brachionus* and *Lecane*. The presence of *Brachionus* and *Lecane* is a general tropical character of the ponds (Sharma 1987, 1991, 1996; Segers 1996; Sharma and Naik 1996; Kiran et al. 2007). The family Chydoridae and Daphniidae of the Cladocera have more number of species than other families, whereas copepoda represented only two species

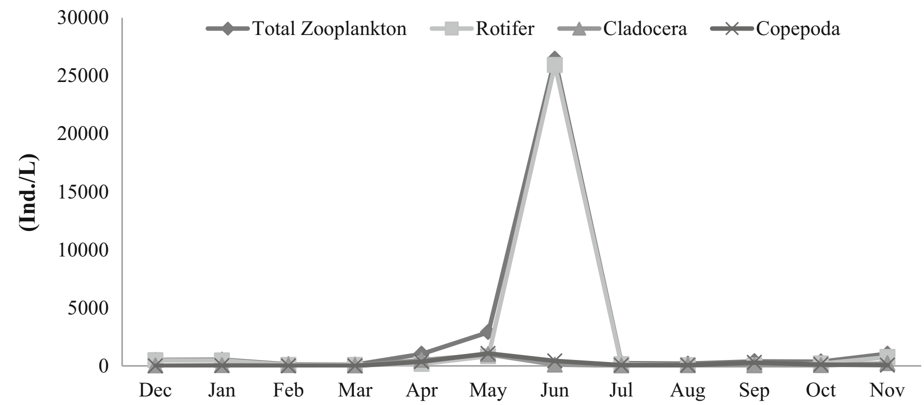

Fig. 1 Zooplankton, Rotifera, Caldocera and Copepoda density from December 2010 to November 2011

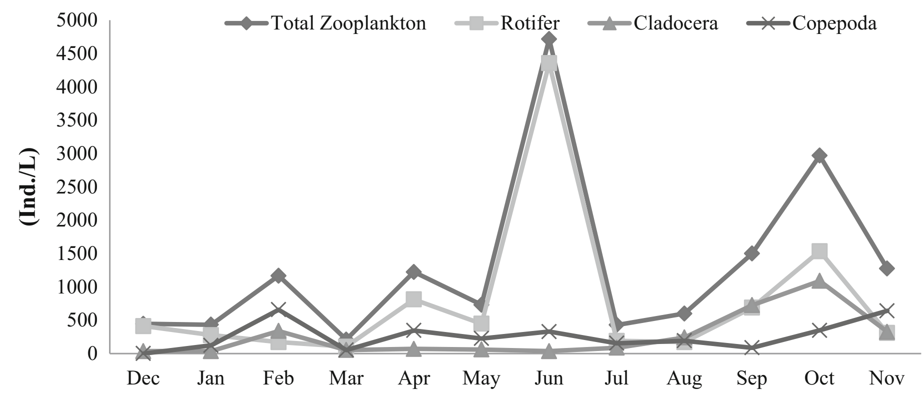

Fig. 2 Zooplankton, Rotifera, Caldocera and Copepoda density from December 2011 to November 2012

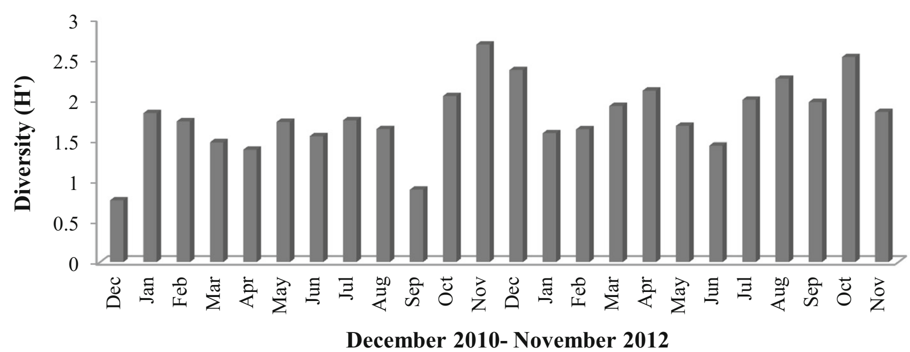

Fig. 3 The overall zooplankton diversity from December 2010 to November 2012

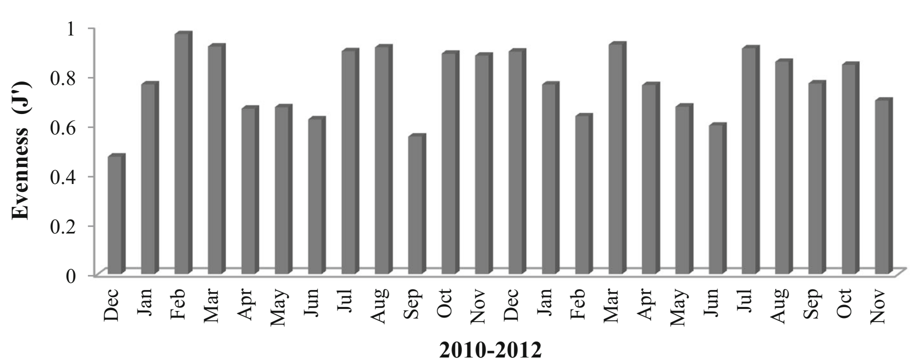

Fig. 4 Zooplankton evenness from December 2010 to November 2012

Tropodiaptomus orientalis and *Mesocyclops leuckarti*. The species *Tropodiaptomus orientalis* is being reported for the first time from Telangana Table 4.

The high density of zooplankton was due to numerical abundance of rotifer population. This was due to the occurrence of *Brachionus angularis, B. calyciflorus, B.*

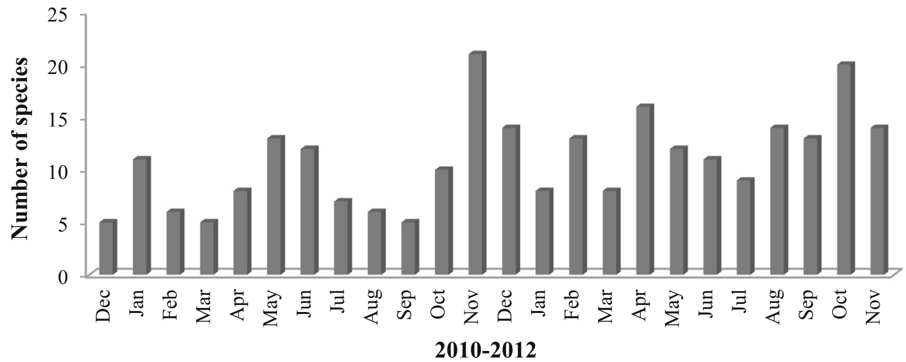

Fig. 5 Zooplankton species richness from December 2010 to November 2012

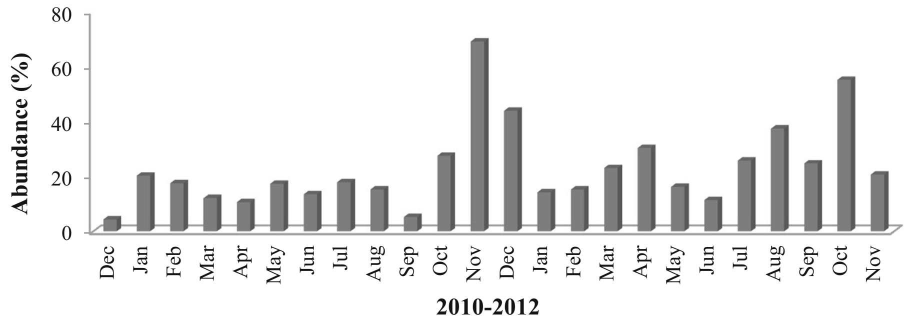

Fig. 6 Zooplankton abundance from December 2010 to November 2012

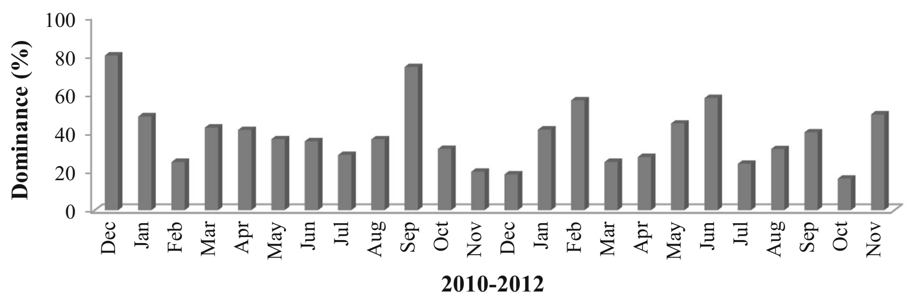

Fig. 7 Zooplankton dominance from December 2010 to November 2012

caudatus, Keratella tropica, Filinia sp. and *Epiphanies mucronata*. Laal and Karthikeyan (1993) found that these species in clean and polluted waters; *B. angularis, B. calyciflorus* were abundant in high chloride waters. The pH values of the pond water are moderately correlated with zooplankton and rotifer density. Singh et al. (2002) reported that high rotifer population dominance was due to hypertrophical conditions of the pond and may be due to high temperature and low level of water. Several earlier studies noted that the genus *Brachionus* was characteristic of hard water. *Brachionus calyciflorus, B. caudatus, Filinia* sp. have been considered as indicators of eutrophicated ponds (Saksena 1987; Mudgal et al. 1989; Sharma and Dudani 1992). Numerical variations in rotifers may apparently be influenced by water quality (Kiran et al. 2007). The study found that the abundance of cladoceran was mainly because of *Macrothrix spinosa, Karualona karua, Moino micrura*. Whereas the copepod abundance due to *Mesocyclops leuckarti*. Goswami et al. (2007) also made similar observations from a pond at East Kolkata. Yadav et al. (2003) recorded high rotifer peak in summer which corroborates with the present study. Rotifers are one of the prominent groups among the zooplankton of any water body irrespective of its trophic status. This may be due to the less specialized feeding, parthenogenetic reproduction and high fecundity (Sampaio et al. 2002). Predominant species may have more functional importance than total species numbers in the zooplankton community (Ferrara et al. 2002).

The high diversity, species richness and abundance coincided with the months November, 2011 and October, 2012. The overall diversity of the present pond is less than two. It indicates the poor water quality (Bhat et al. 2014). An increase in dominance, decrease in diversity, species richness and abundance might be due to high variation in physicochemical features. The low abundance and

Table 3 Physicochemical profile of Bandam Kommu pond in the study years

Parameters	Duration	Ranges	Mean ± SD
Atmospheric temperature (°C)	2010–2011	25–33	27.92 ± 2.27
	2011–2012	19–32	23.42 ± 4.01
Surface water temperature (°C)	2010–2011	19–29	24.5 ± 3.34
	2011–2012	17–24	19.7 ± 2.35
pH	2010–2011	7.4–8.9	7.91 ± 0.45
	2011–2012	7.6–8.7	7.93 ± 0.34
Electrical conductivity (mS)	2010–2011	1–1.9	1.45 ± 0.36
	2011–2012	0.9–4.8	2.53 ± 1.24
Dissolved oxygen (mg/L)	2010–2011	0.8–9.7	5.93 ± 3.15
	2011–2012	1.21–12.35	5.21 ± 2.92
Total dissolved solids (ppm)	2010–2011	690–1400	1096 ± 272
	2011–2012	740–2000	1499 ± 470
Total hardness (mg/L)	2010–2011	189.6–355.5	242.9 ± 54
	2011–2012	189.6–332	286.3 ± 52
Total alkalinity (mg/L)	2010–2011	204–331.5	259.2 ± 51
	2011–2012	153–331.5	233.7 ± 64
Chloride (mg/L)	2010–2011	182–506	313.7 ± 113
	2011–2012	101.2–1032	500.9 ± 310
Calcium (mg/L)	2010–2011	28.4–47.4	37.8 ± 8.06
	2011–2012	28.44–66.36	46.6 ± 14.2
Magnesium (mg/L)	2010–2011	34–77.5	49.9 ± 13.7
	2011–2012	30.07–74.02	58.5 ± 15.5
Phosphate (mg/L)	2010–2011	0–1.2	0.58 ± 0.35
	2011–2012	0.15–1.22	0.45 ± 0.30
Nitrates (mg/L)	2010–2011	0–40	3.67 ± 11.4
	2011–2012	0–8	1.08 ± 2.6
Nitrites (mg/L)	2010–2011	0–0.2	0.04 ± 0.07
	2011–2012	0–0.03	0.015 ± 0.01
Ammonia (mg/L)	2010–2011	0–29	3.25 ± 8.17
	2011–2012	0–4.88	0.49 ± 1.39

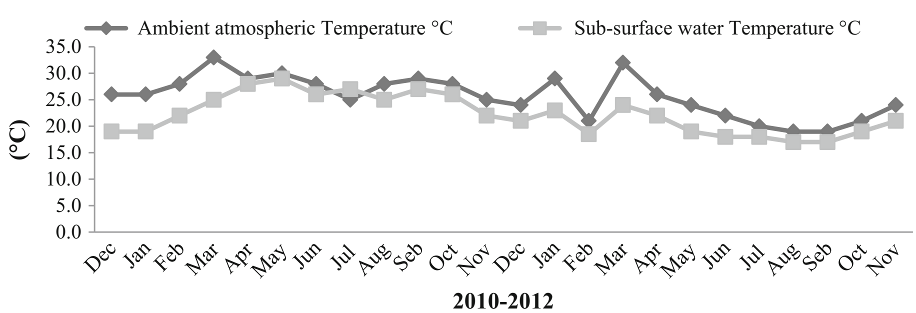

Fig. 8 Monthly variation of temperature from December 2010 to November 2012

diversity found in this study might be due to unfavourable conditions. Plafkin et al. (1989) reported that a community dominated by relatively fewer species indicates environmental stress. A scale of pollution in terms of species diversity shows Bandam Kommu pond is moderately polluted and rarely falls under heavy pollution (Staub et al. 1970; Mishra et al. 2010). The dominance of the zooplankton moderately correlating with nutrient contents of the Bandam Kommu pond was noticed. Sorf et al. (2015) reported that the zooplankton community respond to the combined effects of nutrients. Wani and Subla (1995) noted that the decrease in diversity and increase in density of rotifer may be attributed to high nutrient contents. This statement is true with the present findings.

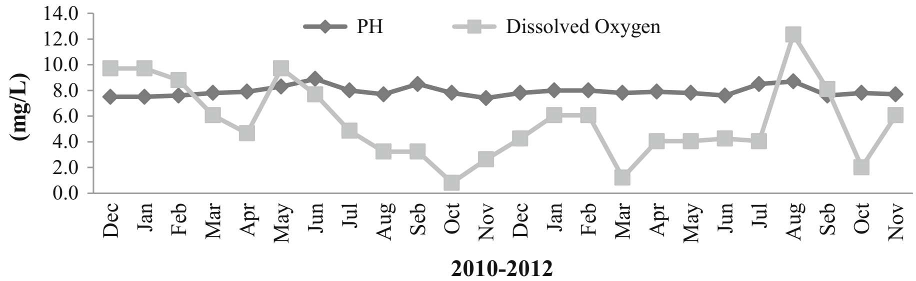

Fig. 9 Monthly variation of pH and dissolved oxygen from December 2010 to November 2012

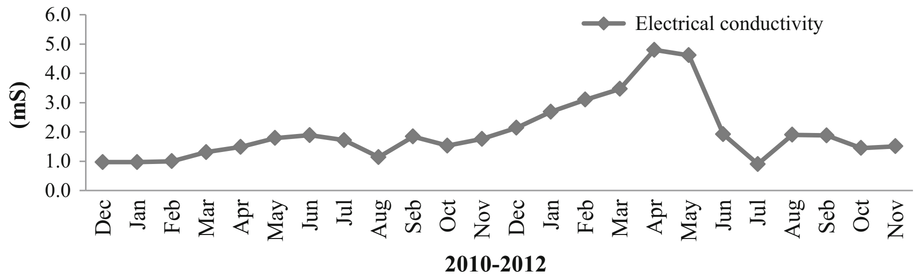

Fig. 10 Monthly variation of electrical conductivity from December 2010 to November 2012

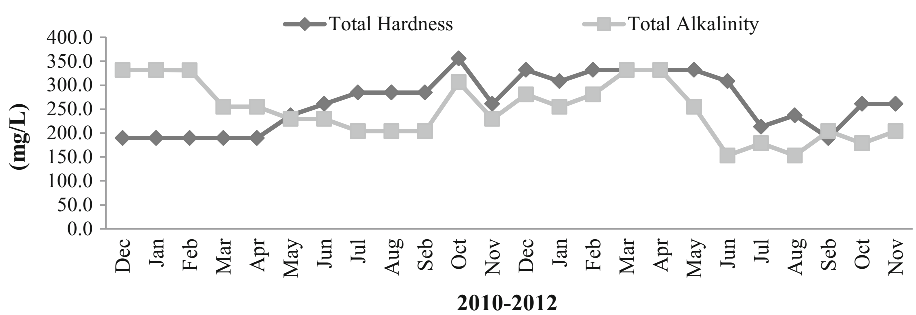

Fig. 11 Monthly variation of total hardness and alkalinity from December 2010 to November 2012

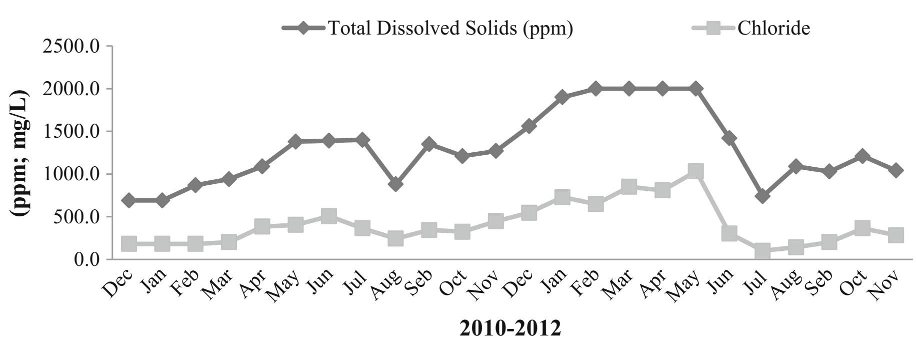

Fig. 12 Monthly variation of total dissolved solids and chloride from December 2010 to November 2012

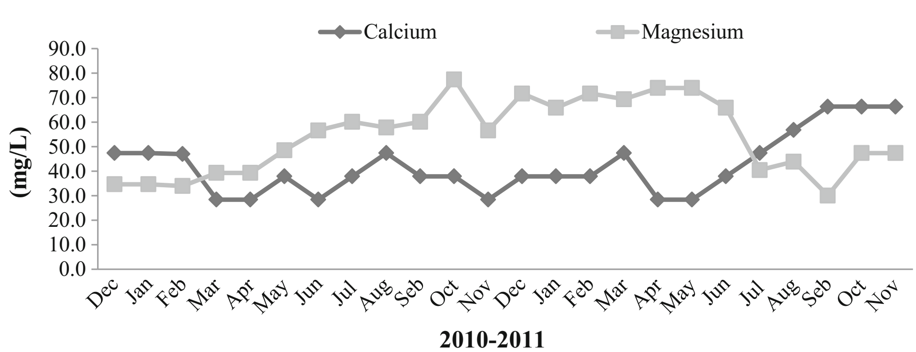

Fig. 13 Monthly variation of calcium and magnesium from December 2010 to November 2012

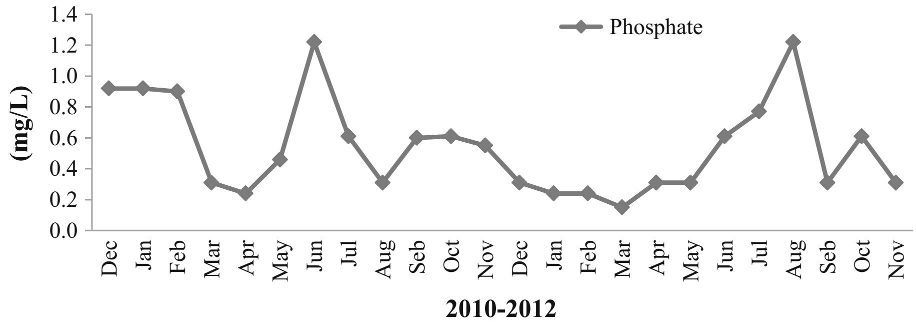

Fig. 14 Monthly variation of phosphate from December 2010 to November 2012

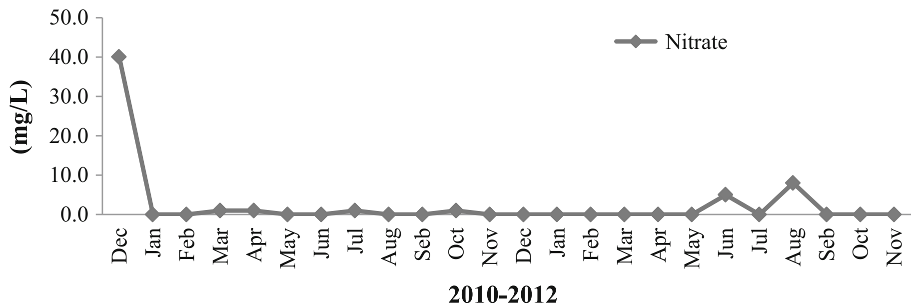

Fig. 15 Monthly variation of nitrate from December 2010 to November 2012

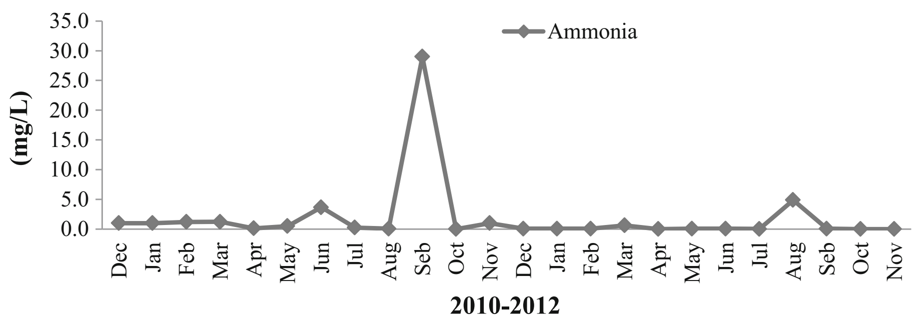

Fig. 16 Monthly variation of ammonia from December 2010 to November 2012

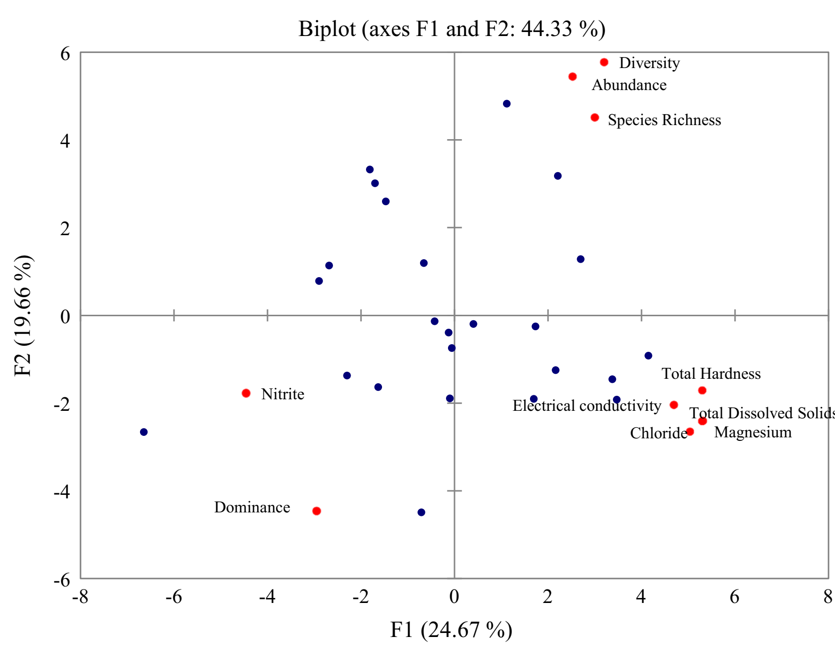

Fig. 17 PAC analysis of bio-physiochemical parameters of Bandam Kommu Pond

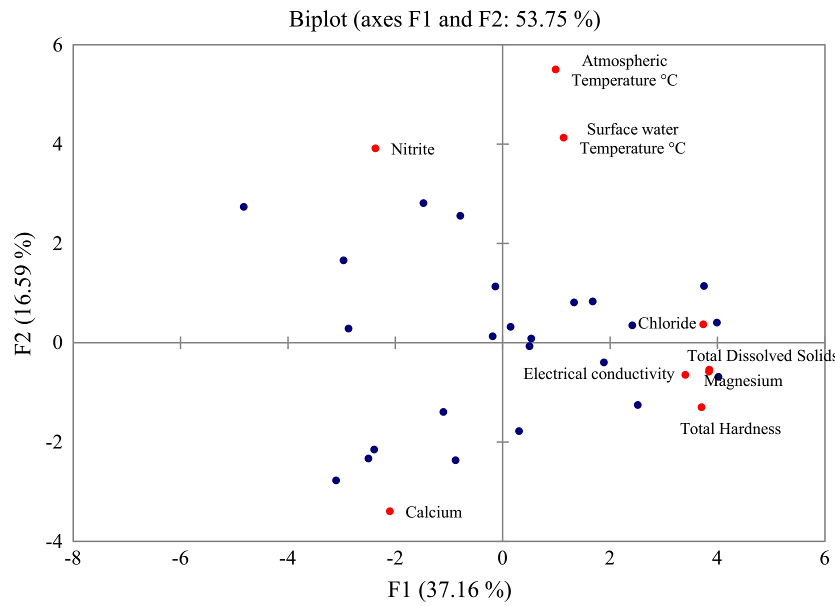

Fig. 18 PAC analysis of physicochemical parameter of Bandam Kommu Pond

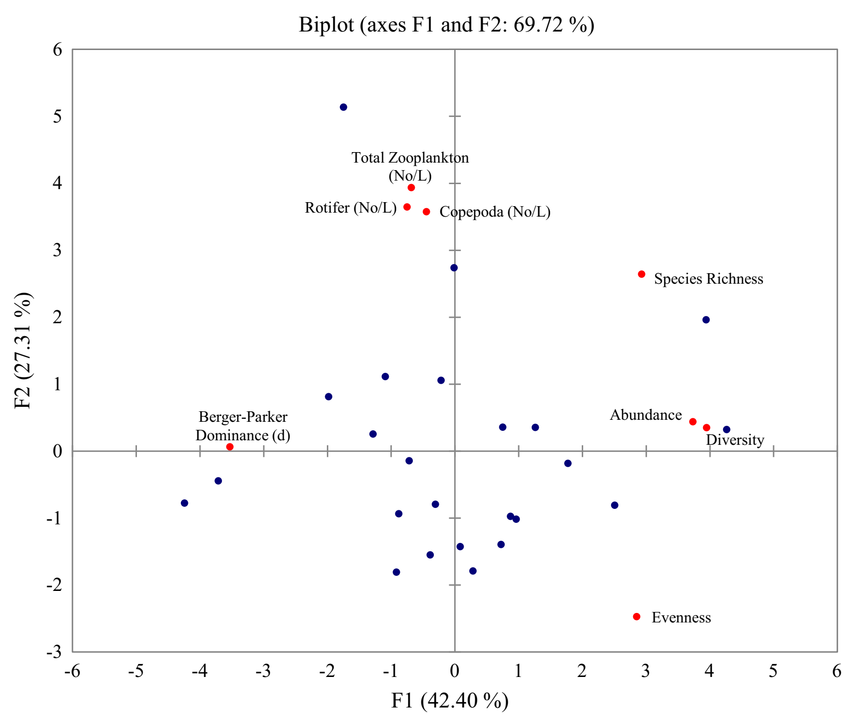

Fig. 19 PAC analysis of zooplankton density and diversity indices of Bandam Kommu Pond

Chattopadhyay and Barik (2009) reported that rotifer population was more abundant than other net zooplankton groups, because of their ability to withstand and survive in varying limnological conditions prevailing in different seasons.

The physicochemical profile of the pond viz. alkalinity, pH, and high electrical conductivity during perishing of macrophytic vegetation, and receding of the water level. Mustapha and Omotosho (2002) reported the pH ranges of 6–9 supports large communities of organisms. Mozumder et al. (2014) observed the similar variation of pH in fish pond of Manikganj. Total dissolved solid was high may be due to more ionic contents, decreasing water level and presence of various pollutants in the pond. This was in decreasing trend when the water level increased during the monsoon. The dissolved oxygen widely fluctuating and was less in the second year of the study period. The presence of high dissolved oxygen content is an indication of healthy system in a water body (Basu et al. 2010). The low value of dissolved oxygen may be because of biological oxygen demands. Patil and Gouder (1985) reported that considerable reduction in dissolved oxygen

Table 4 Correlation matrix among different physiochemical and biological parameters of Bandam Kommu pond

Variables	ST	pH	EC	DO	TDS	TH	TA	Cl	Ca	Mg	PO_4
AT	**0.793**	−0.038	−0.003	−0.166	0.086	0.011	**0.483**	0.199	**−0.495**	0.107	−0.291
ST		0.240	−0.092	−0.239	0.088	0.086	0.126	0.104	**−0.490**	0.177	−0.280
pH			0.043	0.209	0.127	0.052	−0.388	0.003	−0.131	0.076	0.262
EC				−0.251	**0.894**	**0.653**	0.256	**0.908**	−0.354	**0.676**	−0.399
DO					−0.363	**−0.607**	0.008	−0.390	0.219	**−0.606**	**0.556**
TDS						**0.795**	0.168	**0.926**	−0.399	**0.815**	**−0.465**
TH							0.075	**0.705**	−0.279	**0.982**	−0.383
TA								0.331	−0.287	0.123	−0.084
Cl									**−0.448**	**0.742**	**−0.455**
Ca										**−0.457**	0.148
Mg											−0.385
PO_4											
NO_3											
NO_2											
NH_4											
ZP (Ind./L)											
Rotifer (Ind./L)											
Cladocera (Ind./L)											
Copepoda (Ind./L)											
Diversity (H′)											
Evenness (J′)											
Richness (H_0)											
Abundance (H_1)											

Variables	NO_3	NO_2	NH_4	ZP (Ind./L)	Rotifer (Ind./L)	Cladocera (Ind./L)	Copepoda (Ind./L)	Diversity (H′)	Evenness (J′)	Richness (H_0)	Abundance (H_1)	Dominance (d)
AT	−0.062	0.254	0.168	0.057	0.074	−0.251	−0.042	−0.392	0.051	**−0.516**	−0.377	0.081
ST	−0.244	0.012	0.257	0.172	0.162	0.001	0.225	−0.274	0.034	−0.360	−0.274	−0.056
pH	−0.167	−0.235	**0.422**	**0.505**	**0.489**	0.044	0.368	−0.108	−0.141	−0.066	−0.169	−0.039
EC	−0.215	−0.341	−0.068	−0.011	−0.012	−0.116	0.172	0.129	−0.136	0.276	0.039	−0.075
DO	0.366	0.378	−0.047	0.146	0.133	0.120	0.147	−0.223	−0.257	−0.098	−0.264	0.277
TDS	−0.320	**−0.454**	−0.014	0.068	0.059	−0.065	0.267	0.121	−0.117	0.249	0.047	−0.112
TH	−0.284	**−0.580**	0.016	−0.001	0.008	−0.256	0.121	0.206	0.029	0.215	0.142	−0.137
TA	0.200	0.356	−0.184	−0.151	−0.121	−0.329	−0.248	−0.129	0.033	−0.217	−0.151	0.045
Cl	−0.256	−0.340	−0.101	0.079	0.078	−0.112	0.163	0.098	−0.118	0.222	0.042	−0.126
Ca	0.115	−0.058	−0.073	−0.210	−0.236	**0.419**	−0.016	0.223	0.139	0.157	0.176	−0.042
Mg	−0.284	**−0.528**	0.030	0.042	0.056	−0.318	0.117	0.147	−0.004	0.171	0.097	−0.117
PO_4	0.340	0.217	−0.186	**0.443**	**0.458**	−0.067	−0.123	0.143	0.049	0.126	0.149	−0.143
NO_3		**0.748**	−0.023	−0.067	−0.049	−0.146	−0.196	**−0.465**	**−0.459**	−0.265	−0.244	**0.539**

Table 4 continued

Variables	NO_3	NO_2	NH_4	ZP (Ind./L)	Rotifer (Ind./L)	Cladocera (Ind./L)	Copepoda (Ind./L)	Diversity (H')	Evenness (J')	Richness (H_0)	Abundance (H_1)	Dominance (d)
NO_2			−0.057	−0.137	−0.117	−0.123	−0.271	**−0.511**	−0.215	**−0.472**	−0.342	0.379
NH_4				0.034	0.040	−0.126	0.037	**−0.411**	−0.334	−0.268	−0.229	**0.441**
ZP (Ind./L)					**0.995**	0.032	0.268	−0.092	−0.305	0.147	−0.105	−0.026
Rotifer (Ind./L)						−0.055	0.187	−0.106	−0.279	0.104	−0.117	−0.023
Cladocera (Ind./L)							**0.587**	0.282	−0.107	**0.499**	0.295	−0.182
Copepoda (Ind./L)								−0.071	**−0.470**	0.321	−0.134	0.151
Diversity (H')									**0.660**	**0.779**	**0.914**	**−0.849**
Evenness (J')										0.064	**0.503**	**−0.818**
Richness (H_0)											**0.813**	**−0.456**
Abundance (H_1)												**−0.703**

Bold values indicates the more positive or negative correlatin between the parameters

AT Atmospheric temperature, *ST* surface water temperature, *EC* electrical conductivity, *DO* dissolved oxygen, *TDS* total dissolved solids, *TH* total hardness, *TA* total alkalinity, *Cl* chloride, *Ca* calcium, *Mg* magnesium, PO_4 phosphate, NO_3 nitrates, NO_2 nitrites, NH_4 ammonia, *ZP* zooplankton density

Physicochemical: p value < 0.0001 significance; variability 37.16 %. Biological parameters: p value < 0.05 %; variability 42.4 %

concomitant with rise in conductivity and the drop in pH strongly suggesting the higher levels of dissolved salts and less photosynthetic activity. Total hardness, alkalinity is high due to variation in the ionic content and changes in the climatic condition. Zooplankton community increase with rise in alkalinity of water was noticed by Rajashekar et al. (2010). According to Yeole et al. (2008) the water bodies with alkalinity value above 100 mg/L were nutrient rich and rotifers utilize nutrients more rapidly to build their population. Similar observation was also made by Jeelani et al. (2005) in Dal lake, Kashmir. Similar wide variation of temperature, pH, total dissolved solids, dissolved oxygen and total alkalinity were observed in a freshwater pond in Calcutta by Dattta et al. (1987). Chloride content was high because of anthropogenic pressure and sewage from the nearby pharma and soft drinking industries. Similarly, Sharma and Dudani (1992) noted the high chloride content in a eutrophicated pond in Bihar due to pollution and sewage influx. Most of the rotifer species occuring in the pond indicates the alkaline pH, conductivity, alkalinity and chloride tolerant (Kuezynski 1987). The nutrient enrichment might be due to the high content of the phosphates and nitrates. Robin et al. (2014) reported that nutrient rich freshwater ecosystems were generally considered as having low ecological quality and less biodiversity. Mirza et al. (2014) noted that the high electrical conductivity, total dissolved solid, chloride and presence of nitrate, nitrite may be due to sewage and anthropogenic pressure. They also reported the low dissolved oxygen because of less solubility due to pollution.

The present study in the Bandam Kommu pond shows decreasing diversity index, high density with dominant species indicates the moderate pollution of the pond. This was evidenced with nutrient enrichments, low dissolved oxygen, more electrical conductivity and chloride contents. The high density and dominance of species like *Brachionus angularis, B. calyciflorus, B. caudatus, Keratella tropica, Filinia terminalis* and *Epiphanies mucronata* were indicators of polluted aquatic environment. The investigation recommends that the zooplankton composition, density and diversity along with the physicochemical features would be helpful tool for assessing the status of the water body.

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