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Full Length Research Paper

Study on Ecology of zooplankton profusion in Bhoj wetland, India

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The influence of physicochemical properties of wetland, on its zooplankton composition and abundance were investigated for two years between February 2008 and January 2010. In both the years, total of 62 species of zooplankton were identified. At all the stations of the water body Rotifera recorded the highest percentage of 45% followed by cladocera (29%), Protozoa (13%), Copepoda and Ostracoda (8 and 4%) respectively. In terms of density, total zooplanktonic density during 1st year was 7395 Ind.l-1 that increased to 8543 Ind.l-1 in the 2nd year. In the first year, Copepoda (2 Ind.1-1 to 2415 Ind.1-1) constituted the largest group making up 63.41% of the zooplankton population density, this was followed by Cladocera (21.27%) with having numerical density ranges between (3 Ind.1-1 to546 Ind.1-1) and Rotifera group (14.15%) having a density varied from 2 to 207 Ind.1-1. The genus Bosmina (34.7%) dominated the Cladoceran group and Polyarthra and Brachionus (19.8 and 18.7%) recorded highest in terms of percentage among the Rotifera group, while as the genus Cyclops (51.5%) recorded the highest number among the Copepoda group and was also dominant genus among the zooplankton genera. During second year of study period, the Copepoda (70.08%) which had a density variation between 2 Ind.1-1 to 4491 Ind.1-1 and this was followed by Cladocera (18.67%) with numerical density ranges between 3 to 337 Ind.1-1 and Rotifera (9.08%) having density between 2 Ind.1-1 to 171 Ind.1-1. The genus Chydorus (21.1%) dominated the Cladoceran group and genus Lecane (22.0%) recorded highest in terms of percentage among the Rotifera group, while as the genus Cyclops (75.0%) recorded the highest number among the Copepoda group and was also dominant genus among the zooplankton genera. The water body is receiving domestic discharge leading to large amount of nutrient inputs and high amount of phosphate and nitrate in the water body indicates that water is eutrophic in nature.

Key words: Zooplankton, abundance, diversity, Shannon –Weaver Index, Bhoj wetland.

INTRODUCTION

Zooplankton are the major trophic link in food chain and being heterotrophic organisms it plays a key role in cycling of organic materials in aquatic ecosystem. In addition, their diversity has assumed added importance during recent years due to the ability of certain species to indicate the deterioration in the quality of water caused by pollution or eutrophication. Monitoring the zooplankton as biological indicators could act as forewarning, when pollution affects food chain (Mahajan, 1981). The species composition, distribution and abundance of zooplankton in any water body depend upon the chemical and physical properties of water. The dependence of trophic status of lakes onzooplankton grazing capacity were studied by Baruah et al. (1993), Alfred and Thapa (1996) and Salaskar and Yeragi (2003). Planktons are considered as indicator of the trophic status of a water body because of their specific qualitative features and their capacity to reproduce in large number under environmental conditions that are favourable to them (Vollenweider and Frei, 1953). Similarly, changes in the water quality as well as zooplankton quality are indicators of rate and magnitude of cultural eutrophication (Kulshrestha et al., 1989; Chari and Abbasi, 2003). Zooplankton diversity and density refers to variety within the community. These are often an important link in the transformation of energy from producers to consumers due to their large density, drifting nature, high group or species diversity and different tolerance to the stress. Zooplankton plays an important role in lake ecosystem, as grazers that control algal and bacterial populations, as a food source for higher trophic levels and in the excretion of dissolved nutrients. The organization of biological communities in aquatic ecosystems is closely dependent on the variations of physical and chemical conditions linked to natural and anthropogenic factors (Pourriot and Meybeck, 1995).

The zooplankton communities, very sensitive to environmental modifications, are important indicators for evaluating the ecological status of these ecosystems (Magadza, 1994). They do not only form an integral part of the lentic community but also contribute significantly, the biological productivity of the fresh water ecosystem (Wetzel, 2001). The presence and the relative predominance of various copepod species have been used to characterize the eutrophication level of aquatic ecosystems (Park and Marshall, 2000; Bonecker et al., 2001). Herbivorous zooplankton is recognized as the main agent for the top-down control of phytoplankton, and the grazing pressure exerted by cladocerans and copepods on algae and cyanobacteria is sometimes an important controlling factor of harmful algal blooms (Boon et al., 1994).

STUDY AREA

Bhopal, the capital city of the state of Madhya Pradesh, India is famous for its numerous lakes. Of these the most important are the Upper and Lower Lakes, which have commonly been designated as Bhoj Wetland. The Bhoj Wetland is a wetland of international importance. The Upper Lake basin comprises of a submergence area of about 31.0 sq. km and a catchment area of 361 sq. km., whereas the Lower Lake basin comprises of a submergence area of 0.9 sq. km and catchment area of 9.6 sq. km. While Lower Lake is surrounded on all sides by dense urban settlements, only about 40% of the fringe area of Upper Lake has dense human settlement and the rest is sparsely populated having cropping as the major land use. The Upper Lake spread over longitude 77°18’00” to 77°24’00” E and latitude 23°13’00” to 23°16’00” N, whereas the considerably smaller Lower Lake is spread over 77°24’00” to 77°26’00” E and latitude 23°14’30” to 23°15’30” N. The Upper Lake was created in the 11th century by constructing an earthen dam across Kolans River, the main feeding channel of the lake with the objective of supplying potable water for the city dwellers. The wetland also supports a wide variety of flora and fauna. Several species of phyto and zooplankton, macrophytes, aquatic insects, amphibians, fishes and birds (resident as well as migratory) are found in these wetlands. Considering its ecological importance, Ramsar site declared by the Government of India in 2002. Increase in anthropogenic activities in the catchment during the second half of the last century resulted in environmental degradation of the lakes.

Investigations on the ecology of Bhoj wetland of Madhya Pradesh indicate that this man- made wetland is under severe degradation pressure. Siltation, solid waste disposal and weed infestation, dumping of agricultural waste, hospital waste disposal and idol immersion in the wetland during the festival season pollutes the wetland ecosystem beyond the tolerable limits of any aquatic system (Figure 1).

MATERIALS AND METHODS

Water samples were collected on monthly basis for a period of two year. For the present study nine sampling points in the wetland were selected and each point, taking into account the human activities such as washing, bathing, fishing and boating etc. the outlets, inlets, morphometric features and growth of aquatic vegetation etc., and other important factors considered during the selection of the sampling sites. Some of the feature of the sampling sites.

Station I (Kamla Park) - This station is situated on eastern end of the wetland. It is subjected to maximum anthropogenic pressure. The idol immersion activity at this site has been reduced after developing Prempura Ghat particularly for immersion activity.

Station II (Gandhi Medical College) - It is situated close to the inlet of Shaheed Nagar Nallah adjacent to Gandhi Medical College.

Station III (Koh and Fiza) - There is an intake point for water supply in this area. This station is also the site of Tazia immersion.

Station IV (Van Vihar) - This station represents the area that comes under protected forest (Van Vihar). The station is comparatively free from human intervention and other anthropogenic activities.

Station V (Yatch Club) - This is the boating station, where maximum human interaction takes place. Tourists start their motor and paddle boats from this station, and a crowd of tourists can be observed from morning till evening at this station.

Station VI (Bairagarh) - This station of Bhoj wetland is situated near Bairagarh where substantial inflow of domestic sewage can be

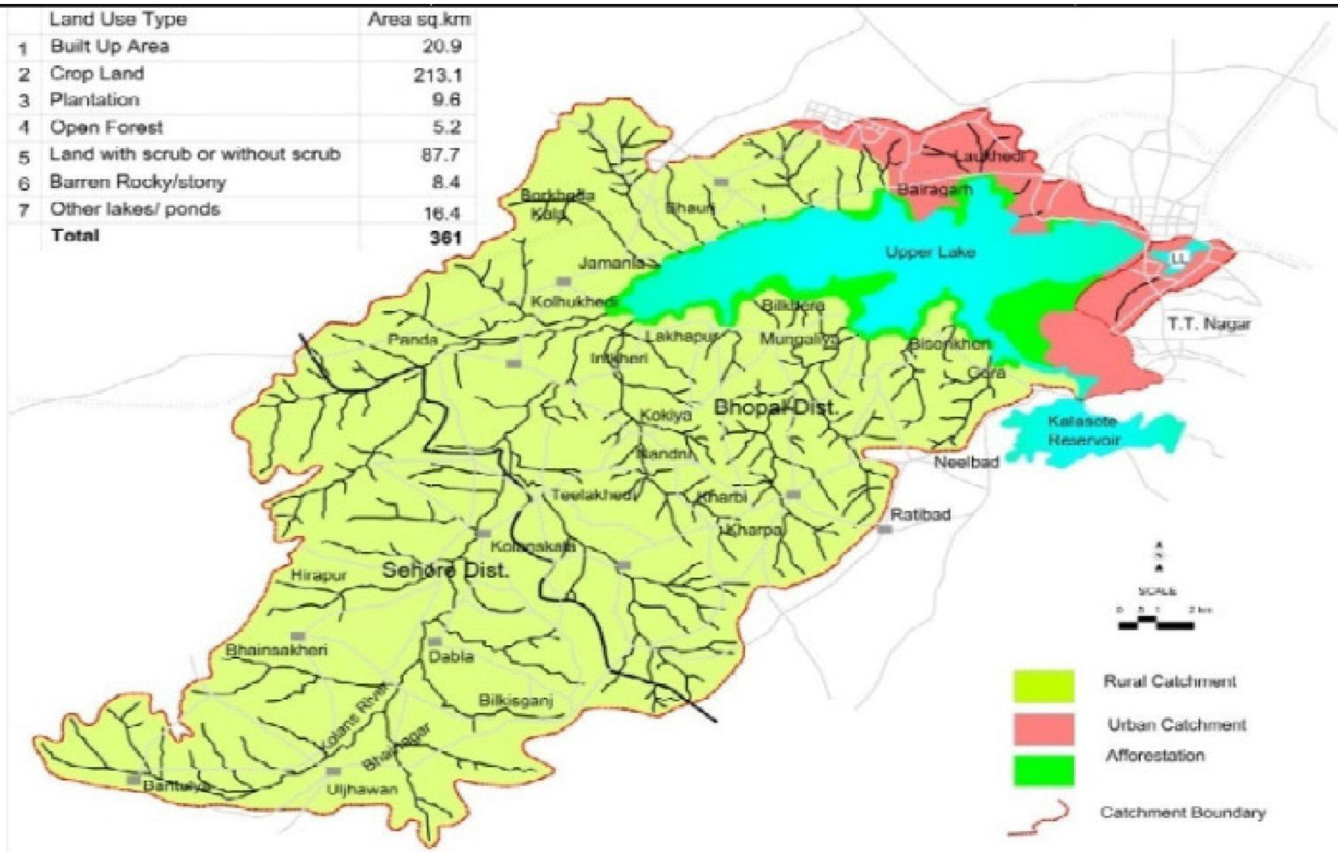

Figure 1. Catchment area of Bhoj wetland Bhopal.

seen. The area has become shallow due to high density of free floating, emergent, and submerged macrophytes.

Station VII (Sehore side) - A lot of agricultural land surrounds this station in Bhoj wetland. Most of the catchment area consists of agricultural land. Because of this all the fertilizers, pesticides and agricultural residues used in the fields find their way as run off into the wetland waters.

Station VIII (Prempura Ghat) - This is the idol immersion station. During the Hindu religious festivals, lots of idols are immersed in water.

Station IX (Nehru Nagar) - This station is highly influenced by anthropogenic and cattle activities. The run-off from the catchment area adds nutrients to the wetland. The region is covered with high density of emergent/submerged macrophytes. The run-off from the catchment area also adds considerable quantities of nutrients to the wetland.

The water samples have been collected in one liter polyethylene canes of the surface waters by the boat between 8 AM to 12 PM from the selected sites of the Bhoj wetland. For the quantitative analysis of zooplankton, water was collected from the surface with minimal disturbance and filtered through a No. 25 bolting silk cloth, net of mesh size 63 µm. Ten liters of water were filtered and concentrated to 100 ml and were preserved by adding 2 ml of 4% formalin simultaneously. The quantitative analysis of zooplankton was done by using Sedgwick-Rafter cell with dimensions of 50 mm x 20 mm x 1 mm, following the method given in APHA (2000). 1 ml of concentrated sample was taken in a Sedgwick-Rafter counting cell and the entire contents were counted. The identification of aquatic biota (zooplankton) have been done following the standard works and methods of Edmonson (1959), Needham and Needham (1962), Pennak (1978), Victor and Fernando (1979), Michael and Sharma (1988), Battish (1992) and Sharma (1999). The results have been expressed as individuals (Wanganeo and Wanganeo, 2006).

$$\text{Number of zooplankton “n”} = \frac{C \times 1000\ \text{mm}^2}{A \times D \times E}$$

C	=	Number of organisms recorded
A	=	Area of field of microscope
D	=	Depth of field (SRC depth) in mm
E	=	Number of fields counted.

$$\text{Number of zooplankton/l} = \frac{\text{N x Vol. of concentrate (ml)}}{\text{Vol. (litres) of water filtered}}$$

Shannon diversity index

This index is an index applied to biological systems derived from a mathematical formula used in communication area by Shannon in 1948.

$H' = -\Sigma [(n_i / N) \times (\ln n_i / N)]$

H': Shannon Diversity Index

n_i : Number of individuals belonging to I species

N : Total number of individuals

Table 1. Physico-chemical parameters on annual mean basis of Bhoj wetland, Bhopal.

Parameter	Units	First year			Second year		
		Summer	Monsoon	Winter	Summer	Monsoon	Winter
Air temperature	°C	37.31	30.63	24.94	30.13	28.77	22.48
Water temperature	°C	25.07	24.02	20.78	27.08	25.17	19.82
pH	Units	8.46	7.86	8.22	8.26	8.16	8.20
Total Dissolved Solids	mg L^{-1}	169.26	197.61	177.28	182.08	149.26	140.37
Elect. Conductivity	mg L^{-1}	254.07	268.98	324.44	285.83	239.35	220.74
Dissolved Oxygen	mg L^{-1}	7.04	6.93	5.34	5.72	5.39	5.73
Total Alkalinity	mg L^{-1}	80.48	79.86	95.94	78.67	66.61	53.70
Total Hardness	mg L^{-1}	96.59	85.93	113.00	98.67	93.76	87.19
Calcium Hardness	mg L^{-1}	74.26	64.25	77.88	63.88	72.78	65.18
Magnesium Hardness	mg L^{-1}	5.33	5.26	8.53	8.45	5.09	5.34
Chloride	mg L^{-1}	31.06	32.70	42.21	36.95	26.74	19.51
Nitrate nitrogen	mg L^{-1}	0.50	0.57	0.48	0.53	0.87	0.59
Total Phosphorus	mg L^{-1}	0.21	0.26	0.33	0.26	0.31	0.30

RESULTS AND DISCUSSION

The physico-chemical parameters of water at upper basin of Bhoj wetland have been given in the Table 1. The atmospheric temperature ranged from 24.94°C (winter) to 37.31°C (summer) and 22.48°C (winter) to 30.13°C (summer) in the first and second year of study period. Water temperature recorded in the first and second year varied between 20.78°C (winter) to 25.07°C (summer) depending on the seasonal atmospheric temperature. Similarly in the pH value ranges between 7.86 units (monsoon) to 8.45 units (summer) units in the first year of study while in the second year of study period, pH ranges from 8.16 to 8.26 units in the monsoon and summer season, it indicates alkaline nature of water body in both years. Das (1978) considered pH values ranging from 7.3 to 8.9 units to favour the growth of planktonic organisms. In summer, increased photosynthesis regulated the pH towards alkaline side (Singhal et al., 1986). In the present investigation of first year, electrical conductivity (EC) values ranged from 254.07 µS/cm (summer) to 324.44 µS/cm (winter) at 25°C while during second year electrical conductivity fluctuated from 220.74 to 285.83 µS/cm in the winter and summer seasons respectively. Increase in conductivity value during summer season was due to increased water evaporation and churning action of wind and waves. Lashari et al. (2009) while working on Keenjhar Lake reported electrical conductivity range from 320 to 496 µS/cm, during post monsoon and summer-winter season. Total dissolved solids fluctuated from 169.26 to 197.61 mgL^{-1} in the summer and monsoon of first year while during second year it varied from 140.37 mgL^{-1} (winter) to 182.08 mgL^{-1} (summer).The maximum total dissolved solids concentration was found during monsoon on account of catchment interaction (surface inflow) from the surrounding human habitation. Gonzalves and Joshi (1946) also recorded rise in total dissolved solids values during monsoon. Minimum dissolved oxygen content of water samples to be 5.34 mgL^{-1} in the winter season and maximum 7.04 mgL^{-1} (summer) of first year study while during second year of study it fluctuated from 5.39 mgL^{-1} (monsoon) to 5.73 mgL^{-1} (winter). Low level of dissolved oxygen indicates the high level of organic load. Fluctuation in dissolved oxygen is also due to fluctuation in water temperature and addition of sewage waste demanding oxygen (Koshy and Nayar, 2000). Dissolved oxygen levels were higher in the monsoon season as compared to summer season due to the increased current flow that enhances the diffusion rate and mixing of oxygen into the water. Present findings are in agreement with those reported by Welcomme (1979) Offem and (Akpan) 1993 who observed that tropical African aquatic systems generally have low dissolved oxygen in the summer season than the wet season. The total alkalinity values ranged between 79.86 to 95.94 mgL^{-1} in the monsoon and winter during first year of study while minimum total alkalinity value to be 53.70 mgL^{-1} was noted during winter season and maximum of 78.67 mgL^{-1} in the summer season in the second year. Increase in alkalinity values may be due to decrease in the water level. Alkalinity increases, with decreases in water levels have also been reported by Singhal et al. (1986). The higher alkalinity values may be due to the discharge of municipal and domestic sewage. As per Sorgensen (1948) and Moyle (1949) classification, Bhoj wetland falls under nutrient rich category. The value of total hardness fluctuated from 85.93 mgL^{-1} (monsoon) to 113.0 mgL^{-1} (winter) in the first year and in the second year it varied from 87.19 mgL^{-1} during winter to 98.67 mgL^{-1} during summer season. High concentration of total hardness recorded in winter of first year may be attributed to the decomposition of submerged macrophytes. Iqbal and Katariya (1995) however, reported higher hardness values in summer and lower in monsoon in the same water body. Bhatt et al. (1999) reported a total hardness range of 280 mgL^{-1} (monsoon) to 352 mgL^{-1} (summer) in Taduaha Lake, Katmandu. In the first year, the average values of calcium hardness in waters varied from 64.25 mgL^{-1} (monsoon) to 77.88 mgL^{-1} (winter) and in the second year it varied from 63.88 to 72.78 mgL^{-1} in the summer and monsoon season. During winter months calcium concentration reached maximum, which may be due to the low water level and additional amount of detergents added by way of human activities and incoming domestic waste. However, during 2nd year, calcium hardness varied between 64 mgL^{-1} (summer) to 74 mgL^{-1}, monsoon which is in agreement with the reports of Wanganeo (1998) who found minimum value of calcium hardness during summer months and maximum during monsoon months in the same wetland. On the other hand, minimum magnesium hardness was noted to be 5.26 mgL^{-1} as against maximum value of 8.53 mgL^{-1} in the monsoon and winter season of first year similarly in the second year the minimum and maximum values were recorded to be 5.09 and 8.45 mgL^{-1} in the monsoon and summer season. High magnesium hardness during winter season may be due to the low water level and human activities in the catchment area which led to the entry of domestic waste into the wetland. As in the case of calcium, there was a general increase in the average concentration of magnesium ions in water. The chloride concentrations in the wetland waters ranged between 31.06 mgL^{-1} (summer) and 42.21 mgL^{-1} (winter) during first year of study. However, during second year of study the values ranged from 19.51 mgL^{-1} (winter) to 36.85 mgL^{-1} (summer). High values during winter may be due to low water level, which is in accordance with the findings of Gonzalves and Joshi (1946) and Osborne et al., (1987). During IInd year it varied from a lowest value of 19.5 mgl^{-1} (winter) to a highest of 36.9 mgL^{-1} in summer. Singh and Balasingh (2011) also observed maximum chloride in summer. Rajshekhar et al. (2007) related high chloride in summer to rise in temperature and evaporation. Shinde et al. (2010) recorded higher values of chlorides during summer and lower during winter season in Harsool Savangi water body. The nitrate nitrogen content water varied aberrantly throughout the lake. Maximum value of nitrate nitrogen was 0.57 mgL^{-1} in the monsoon and minimum amount was found to be 0.48 mgL^{-1} during winter of first year of study, while during second year it varied between 0.53 mgL^{-1} (summer) to 0.85 mgL^{-1} (monsoon). The most important source of NO_3-N in waters is biological oxidation of nitrogenous organic matter of both autochthonous and allochthonous origin, which include domestic sewage, agricultural run-off and effluents from industries (Wanganeo, 1998; Saxena, 1998). Mostly higher values of nitrate content were recorded in the ambient waters during rainy season. This may be attributed to the influx of nitrogen rich storm water that brings large amount of contaminated sewage water from the surrounding areas, which is densely populated by human population and rural agri-catchment area. Phosphorus the most vital nutrient effecting productivity of natural water, the total phosphorus concentration in surface waters of Bhoj wetland fluctuated between 0.21 mgL^{-1} (summer) to 0.33 mgL^{-1} (winter) in the first year of study and in the second year it fluctuated from 0.26 mgL^{-1} (summer) to 031 mgL^{-1} (monsoon) respectively. The increased total phosphorus concentration was mainly by flood washing and mixing of fertilizers from nearby agricultural land (Wanganeo, 1998; Sharma and Sarang, 2004; Kumar et al., 2006; Singh and Balasingh,2011). The minimum concentration of total phosphorus during the summer season may be due to the abundance of phytoplankton population which utilizes it. Such findings have also been reported by Kataria et al. (1996).

Zooplankton species composition

In an aquatic ecosystem, interaction occurs between living and non-living components. Environmental factors comprising physical and chemical components have been reported in several studies to have a great influence on the well-being of aquatic species, plankton inclusive (Kawo, 2005; Okogwu and Ugwumba, 2006). Strong relationships exist between phytoplankton and zooplankton. For instance, the main systematic groups of zooplankton include many taxa, which feed on phytoplankton. Selective grazing by zooplankton is an important factor affecting the structure of phytoplankton communities. However, phytoplankton structure also influences the taxonomic composition and dominance of the zooplankton. These animal components are mainly filtrators, sedimentators or raptorial predators (Karabin, 1985). Among them, filtrators usually exert the strongest effect on phytoplankton abundance in lakes. Grazing by cladocerans creates a selective pressure on the phytoplankton community, causing elimination of organisms that do not exceed a precisely defined size (Gliwicz, 1980). As a result inedible large-sized algae dominate phytoplankton communities (Kawecka and Eloranta, 1994). The rotifera plays significant role in the food chain and biological productions of waters such as aqua pollution indicators or and water quality monitor (Pontin, 1978; Sladecek, 1983). In many cases, predatory copepods exert a strong influence on the phytoplankton composition. The copepods suppress large phytoplankton, whereas nano-planktonic algae increase in abundance (Sommer et al., 2003). The algal species that are resistant to grazing and predation are more likely to survive, but also can make filter feeding more difficult. Because of the constant feeding pressure of zooplankton on phytoplankton, the more resistant algae may become more and more abundant during the growing season. This, in combination with the pressure exerted by fish on large-sized zooplankton, results in the restructuring of the

Table 2. List of zooplankton species obtained in two years of investigation in Bhoj Wetland.

Cladocera	**1st year**	**2nd Year**		**1st year**	**2nd Year**
Alona sp.	√	√	*Monostyla* sp.	√	√
Alonella sp.	√	√	*Mytilina*sp.	√	√
Bosmina sp.	√	√	*Philodina*sp.	√	√
Bosminopsisdeitersi		√	*Platyias* sp.	√	√
Ceriodaphnia sp.	√	√	*Ploesoma* sp.	√	
*Chydorus*sp	√	√	*Polyarthra* sp.	√	√
*Conochiloides*sp.	√		*Rotaria*sp.	√	√
Daphnia sp.	√	√	*Scaridium*sp.	√	√
Diaphanosoma sp.	√	√	*Synchaeta* sp.	√	
Leydgia sp.	√	√	*Tetramastixapoliensis*		√
Macrothrix sp.	√	√	*Trichocerca* sp.	√	√
Moina sp.	√	√	*Trichotria*sp.	√	√
Moinadaphnia sp.	√	√	*Triploceros limnias*	√	
Pleuroxusaduncus		√	*Trochosphaera*sp.		√
Scapholebris sp.	√	√	**Copepoda**		
Sida sp.	√	√	*Cyclopoid copepod*	√	
*Simocephalus*sp	√	√	*Cyclops* sp.	√	√
Streblocerus sp.	√	√	*Diaptomus* sp.	√	√
Rotifera			*Mesocyclops* sp.	√	√
*Asplanchna*sp.	√	√	Nauplius larvae	√	√
Asplanchnopsis sp.	√	√	**Ostracoda**		
*Ascomorpha*sp.	√	√	*Cyprinotus* sp.	√	√
Brachionus Angularis	√	√	*Cypris* sp.	√	√
Cephalodella sp.	√	√	*Stenocypris* sp.	√	
Colurella sp.	√	√	**Protozoa**		
Conochilus sp.	√	√	A*ctinophyrus*sp.	√	
Filinia sp.	√	√	*Arcella* sp.		√
Gastropus sp.	√	√	*Centropyxix* sp.	√	√
*Harringia*sp.	√	√	*Climacostomum* sp.		√
*Hexarthra*sp.	√	√	*Coleps* sp.	√	
Keratella sp.	√		*Colpidium* sp.	√	√
Lecane sp.	√	√	*Oxytricha* sp.	√	√
Lepodella sp.	√	√	*Verticella* sp.		√

community of zooplankton towards the dominance of small-sized organisms resistant to disturbances and trophic interactions (Gulati, 1990; Meijer, 2000; Kozak and Gołdyn, 2004).

In the two years of study period, total of 62 species of zooplanktons were identified among them 55 species were recorded during the 1styear (2008-2009) of study, while as 54 species of zooplanktons were documented during the 2ndyear (2009-2010) of study period (Table 2). At all the nine stations during first year group Rotifera recorded the highest number of species (47%) followed by Cladocera (29%), which in turn was followed by Copepoda (9%), Protozoa (9%) and Ostracoda (5%). Similarly in the second year of investigation at all the nine stations, Rotifera group again recorded the highest number of species (44%) followed by Cladocera (31%), which in turn was followed by Protozoa (11%), Copepoda (9%) and Ostracoda (4%).

The dominance of rotifer species was due to its reference for warm waters as highlighted by Dumont (1983) and Segers (2003). High rotifer species in the water body indicates enrichment due to direct inflow of untreated domestic sewage from adjacent areas into the wetland, as was suggested by Arora (1966). Chandrashekhar (1998) recorded diversity of rotifers to be influenced by the different water quality and other chemical factors. The diversity patterns greatly depend on the water temperature and availability of food in the water body. The sufficient nutrient availability and other favourable conditions result in dominance of rotifers. Phytoplankton populations constituting the essential component of the rotifera dietary spectrum, increase with higher water temperature in summer that influences species diversity in the wetland. Further, high nutrients like (nitrate annual $\bar{X}$=0.59 mgL^{-1} and phosphate $\bar{X}$=0.27 X X mgL^{-1}) and favourable temperature and dissolved oxygen conditions particularly at station VIII resulting from decomposition of macrophytes enables higher diversity of zooplankton particularly rotifera. Similar trend has also been reported by Subla et al. (1992) and Padmanabha and Belagali (2006). The progressive decrease in the zooplankton diversity at station VII might be attributed to drought conditions. The highest rotifera species diversity was observed by Robinson (2004) in Geordian wetlands, characterized by dense well developed macrophyte stands, which provides shelter, varied niches and comparatively good quality water. High species diversity of rotifera has also been recorded with the peaks of phytoplankton, which suggests that the increase in zooplankton production may be attributed to greater availability of food in form of phytoplankton coupled with enabling temperature (Wadajo, 1982; Wadajo and Belay, 1984; Webber and Roff, 1995; Christou, 1998; Uyeet al., 2000). The dominance of genus Brachionus is an indication that the Bhoj wetland is eutrophic and their abundance was due to the presence of high levels of organic matter in the water body.

The available amount of food for Cladocerans is also considered to influence the morphology of individuals (Richman, 1958). And it grows continuously at high food concentrations, but stops growth after maturation at low food concentrations (Urabe, 1991). Usha (1997) observed that among total zooplanktonic population, cladocera come second in order of abundance in Gandhisagar reservoir. In the present study 11 species of Cladocerans have been recorded. Iqbal and Kazmi (1990) have recorded 15 species of cladocerans from Hub Dam Lake. The population was comparatively higher during the high temperature, but was low during rainy seasons of the year.

In the present study, the total zooplanktonic density during 1styear was 7395 Ind.l^{-1} that increased to 8543 Ind.l^{-1} in the 2ndyear (Table 3). There was variation in zooplankton density during two years which may be attributed to low water volume caused by drought conditions in the second year (Table 3). The maximum population density recorded in the 2ndyear also reflected a positive relationship with temperature, nitrate and phosphate concentrations. Similar observations were recorded by Paliwal (2005). The maximum population density of zooplankton in the 2ndyear may also be attributed to greater availability of food viz., phytoplankton. The factors like temperature, dissolved oxygen play an important role in controlling the diversity and density of zooplankton (Edmondson, 1965; Baker, 1979). According to Kurbatova (2005) and Tanner et al. (2005) pH more than (8 units) means highly productive nature of a water body, in the present study, the average pH recorded was 8.3 units , indicating water highly productive for zooplankton population.

In terms of density Copepoda (2 to 2415 Ind.1^{-1}) constituted the largest group making up 63.41% of the zooplankton population density, this was followed by Cladocera (21.27%) with having numerical density ranges between (3 to 546 Ind.1^{-1}) and Rotifera group (14.15%) having a density varied from 2 to 207 Ind.1^{-1} and least contribution from the groups Protozoa and Ostracoda (0.66% and 0.52 %)(Table 3). The genus *Bosmina* (34.7%) dominated the Cladoceran group and *Polyarthra* and *Brachionus*(19.8 and 18.7%) recorded highest in terms of percentage among the Rotifera group, while as the genus *Cyclops* (51.5%) recorded the highest number among the Copepoda group and was also dominant genus among the zooplankton genera. On an overall total zooplankton density were recorded to be 7395 Ind.1^{-1} during first year of investigation period in the Bhoj wetland.

During second year of study period, the Copepoda (70.08%) which had a density variation between 2 to 4491 Ind.1^{-1} and this was followed by Cladocera (18.67%) with numerical density ranges between 3 to 337Ind.1^{-1} and Rotifera (9.08%) having density between 2 to 171 Ind.1^{-1}, while least contribution density from the groups Protozoa and Ostracoda (1.86 and 0.3%)(Table 3). The genus *Chydorus* (21.1%) dominated the Cladoceran group and genus *Lecane* (22.0%) recorded highest in terms of percentage among the Rotifera group, while as the genus *Cyclops* (75.0%) recorded the highest number among the Copepoda group and was also dominant genus among the zooplankton genera. On an overall total zooplankton density were recorded to be 8543 Ind.1^{-1} during second year of investigation period in the Bhoj wetland.

The optimal temperature requirement varied for different groups of zooplankton suggesting their abundance in different seasons. Copepoda during the entire period was mainly represented by *Cyclops* sp. and nauplii larvae. This was attributed to enriched nature of waters. Verma et al. (1984) and Ahmad et al. (2011) observed that *Cyclops* sp. and nauplii were sensitive to pollution and increase with an increase in nutrients. Copepods were directly related to nitrogen and phosphorus and showed tolerance to different physico-chemical characteristics (Kulshreshta et al., 1992). Joshi (1987) reported dominant population of Copepoda (*Cyclops* sp.) throughout the year from Sagar lake while Gupta (1989) reported similar condition in Gulabsagar and Ganglooan water bodies of Jodhpur. Syuhei (1994) stated that individual growth rate of Copepoda may also depend on temperature conditions. Khan (2002) also reported dominance of copepoda in floodplain wetlands of west Bengal. Hansson et al. (2007) opined Copepoda to be more tolerant to harsh environmental conditions. Thus, copepods were found to be dominant at sites which were densely infested by macrophytes in the present study.

Table 3. Zooplankton Composition and abundance in Bhoj Wetland Bhopal.

Cladocera 2008-2009	First year				Second year			
	Ind./l	sp. % in class	sp. % in total zoo	class % in zoo	Ind./l	sp. % in class	sp. % in total zoo	Class % in Zoo
Alona sp.	53	3	0.7		49	3.1	0.6	
Alonella sp.	47	3	0.6		17	1.1	0.2	
Bosmina sp.	546	35	7.4		284	17.8	3.3	
Bosminopsisdeitersi					6	0.4	0.1	
Ceriodaphnia sp.	106	7	1.4		58	3.6	0.7	
Chydorus sp	163	10	2.2		337	21.1	3.9	
Conochiloides	10	1	0.1					
Daphnia sp.	29	2	0.4		11	0.7	0.1	
Diaphanosoma sp.	205	13	2.8		51	3.2	0.6	
Leydgia sp.	30	2	0.4	**21.27**	52	3.3	0.6	**18.67**
Macrothrix sp.	20	1	0.3		3	0.2	0.0	
Moina sp.	98	6	1.3		129	8.1	1.5	
Moinadaphnia sp.	72	5	1.0		263	16.5	3.1	
Pleuroxusaduncus					60	3.8	0.7	
Scapholebris sp.	3	0	0.0		9	0.6	0.1	
Sida sp.	3	0	0.0		13	0.8	0.2	
Simocephalussp	169	11	2.3		237	14.9	2.8	
Streblocerus sp.	19	1	0.3		16	1.0	0.2	
Total	**1573**	**100**			**1595**	**100**		
Rotifera								
Asplanchna sp.	43	4.1	0.6		9	1.2	0.1	
Asplanchnopsis	8	0.8	0.1		7	0.9	0.1	
Ascomorpha sp.	5	0.5	0.1		7	0.9	0.1	
Brachionus Angularis	196	18.7	2.7		86	11.1	1.0	
Cephalodella sp.	15	1.4	0.2		2	0.3	0.0	
Colurella sp.	5	0.5	0.1		5	0.6	0.1	
Conochilus sp.	6	0.6	0.1	**14.15**	6	0.8	0.1	**9.08**
Filinia sp.	120	11.5	1.6		85	11.0	1.0	
Gastropus sp.	10	1.0	0.1		15	1.9	0.2	
Harringia sp.	15	1.4	0.2		2	0.3	0.0	
Hexarthra sp.	25	2.4	0.3		8	1.0	0.1	
Keratella sp.	39	3.7	0.5					
Lecane sp.	106	10.1	1.4		171	22.0	2.0	
Lepodella sp.	30	2.9	0.4		16	2.1	0.2	

Table 3. Contd.

Monostyla sp.	77	7.4	1.0		154	19.8	1.8	
Mytilina sp.	14	1.3	0.2		5	0.6	0.1	
Philodina sp.	2	0.2	0.0		2	0.3	0.0	
Platyias sp.	5	0.5	0.1		12	1.5	0.1	
Ploesoma sp.	2	0.2	0.0					
Polyarthra sp.	207	19.8	2.8		53	6.8	0.6	
Rotaria sp.	7	0.7	0.1		7	0.9	0.1	
Scaridium sp.	15	1.4	0.2		7	0.9	0.1	
Synchaeta sp.	10	1.0	0.1					
Tetramastixapoliensis					12	1.5	0.1	
Trichocerca sp.	80	7.6	1.1		99	12.8	1.2	
Trichotria sp.	2	0.2	0.0		2	0.3	0.0	
Triploceros limnias	2	0.2	0.0					
Trochosphaera sp.					4	0.5	0.0	
Total	**1046**	**100**			**776**	**100**		
Copepoda								
Cyclopoid copepod	10	0.2	0.1					
Cyclops sp.	2415	51.5	32.7		4491	75.0	52.6	
Diaptomus sp.	82	1.7	1.1	**63.41**	167	2.8	2.0	**70.08**
Mesocyclops sp.	2	0.0	0.0		2	0.0	0.0	
Nauplius larvae	2180	46.5	29.5		1327	22.2	15.5	
Total	**4689**	**100**			**5987**	**100**		
Ostracoda								
Cyprinotus sp.	8	21.1	0.1		9	35	0.1	
Cypris sp.	20	52.6	0.3	**0.52**	17	65	0.2	**0.3**
Stenocypris sp.	10	26.3	0.1					
Total	**38**	**100**			**26**	**100**		
Protozoa								
Actinophyrus sp.	5	10.2	0.1					
Arcella sp.					5	3	0.1	
Centropyxix sp.	24	49.0	0.3		143	90	1.7	
Climacostomum sp.					3	2	0.0	
Coleps sp.	15	30.6	0.2	**0.66**				**1.86**
Colpidium sp.	2	4.1	0.0		4	3	0.0	
Oxytricha sp.	3	6.1	0.0		2	1	0.0	
Verticella sp.					2	1	0.0	
Total	**49.0**	**100**			**159**	**100**		

High population density of Cladocera was recorded in the wetland during the present study period. Among Cladocera genus *Bosmina* recorded dominant which has been considered a good indicator of trophic conditions for a long time (Swar and Fernando, 1980). This is usually a littoral species which becomes abundant in the limnetic habitat only when larger competing species are reduced or eliminated by some factors other than shortage of food (Selgeby, 1974). This species is very common in eutrophic lakes having abundant macrophytic vegetation and also found abundant in Ikeda lake (Baloch, 1995). Maximum population of *Chydorus* was also recorded in the lake ecosystem in the present study.

Among the species identified as indicators of eutrophication in this wetland as well as in other regions, the rotifer *Brachionus* sp. stands in its great tolerance to extremely eutrophic environments (Sladecek, 1983) and to high conductivity (Berzins and Pejler, 1989). Nogueira (2001) reported that the index of eutrophic waters is above 15 species and that its abundance is considered as a biological indicator for eutrophication. *Brachionus* sp. was frequently observed at all sampling sites and seasons in the Bhoj wetland. This species is considered to be an indicator of eutrophication (Sampaio et al., 2002). The results indicate that the Bhoj wetland water has already reached the stage of eutrophication. Nogueira (2001) reported *Brachionus* sp.to be an indicator of sewage and industrial pollution. *Polyarthra* sp.occurred throughout the year. Sladeček (1983) considered it as a permanent inhabitant of all types of fresh water, while Sharma and Pant (1985) regarded it as a good indicator of eutrophication. According to our results, the factors that explained the greatest percentage of the variations were nitrogen and phosphorus (also noted for the river Po (Ferrari et al., 1989), as well as water pH and oxygen which are also known to influence zooplankton abundance (Allan, 1976; Wetzel, 1983). Alkaline pH was also found to favor zooplankton growth and abundance in the river, as seen from the direct relationship with pH. Byars (1960) reported that zooplankton prefer alkaline waters. Both conductivity and total dissolved solids promoted high zooplankton growth and abundance. This agrees with the findings of Hujare (2005).

The zooplankton composition of the Bhoj wetland showed the water body to be productive and capable of supporting diverse species and populations of fish. The assemblage was strongly influenced by the physico-chemical factors which showed the water quality to be good, according to APHA (1998). The alkaline pH, food abundance and nutrients were some of the factors that could limit zooplankton growth, composition and abundance in the aquatic ecosystem. Maintenance of good water quality in the water body will enhance the structure of the zooplankton community and population dynamics. This is of great significance for fish production in the wetland since the energetic trophic foundation that supports fish are is well-established.

Despite the presence of a high nutrient load, other different chemical factors might have been responsible for checking the excess growth of autotrophs, leading to eutrophication. This study concluded that the water of Bhoj wetland is highly polluted by the direct contamination of sewage from nearby residential (domestic) and agricultural activities. Therefore, the water body has to be preserved for its intended use, and a sustainable and holistic management planning is necessary for the conservation of this water body. The present results provide useful information on zooplankton diversity particularly in view of the paucity of a detailed community analysis in the Indian floodplain lakes. In order to acquire better understanding of holistic environmental heterogeneity of this Ramsar site, investigations, however, need to be extended to more sampling stations with particular reference to variations in the macrophyte associations.

Diversity of zooplankton species

The diversity indices are all based on two assumptions:

(a) stable communities have a high diversity value and unstable ones a low diversity, and (b) stability in diversity is an index of environmental integrity and wellbeing. As a consequence, the diversity value decreases with environmental degradation (Magurran, 1988). Shannon-Weaver Index is a combination of the number of species and the evenness of distribution of individuals among taxa. It may function as a sensitive indicator for pollution (Klemm et al., 1990). In the present investigation, Shannon-Wiener diversity index ranged between 0.96 in the month of January 2010 to 2.75 in the month of October 2009 during the two years of study (2008-2010) (Figure 2). The above trend can be attributed to the surrounding disturbances in the riparian zone and also increasing anthropogenic interaction in the lake. Bhoj wetland can be classified as less diverse as Shannon-Wiener index (H') is > 2; it also indicates poor quality or pollution in the water body. McDonald (2003) stated that the value of the index ranging from 1.5 to 3.4 has low diversity and species richness while value above 3.5 has high diversity and species richness. The present study implicating that limnological processes affecting net zooplankton species diversity operated almost equally throughout the surface water column of the water body and across all seasons.

Zooplankton assessment is an important indicator of aquatic community structuring and water conditions. Zooplankton is directly or indirectly influenced by seasonal variation of complex limnological factors. The annual quantitative study of zooplankton population depends on the succession, appearance and disappearance of component species. Periods of quantitative increase and decrease of individuals do not

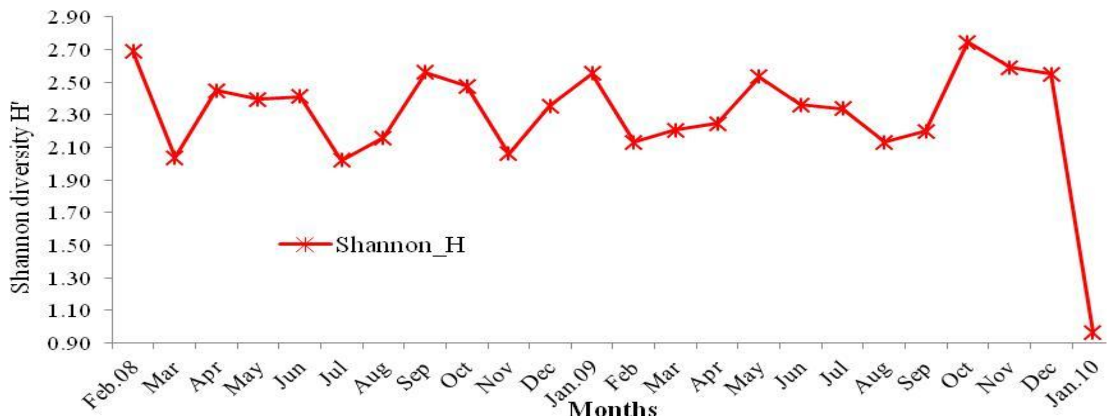

Figure 2. Shannon-Weiner diversity index of Zooplankton species during 2008-2010.

coincide with seasonal minima and maxima of the total zooplankton. Three main zooplankton groups were identified in the study (Rotifers, Cladocera and Copepoda) constitute the zooplankton population and contributed significantly to secondary production of the wetland. Some species increases slowly and more or less uniformly to the maximum while others show an almost starting burst of development visiting from an apparent absence to a numerical dominance of the whole net zooplankton within a very short period of time. The nature of wetland is closely related with the fluctuations of the zooplankton density. The analysis of species richness and diversity indices revealed clearly the status of the water body. The rapid modification of the planktonic communities in response to environmental stress confirms the strong instability of tropical shallow ecosystems and reinforces the interest of their ecological monitoring, particularly when, as for Bhoj wetland, they have multipurpose and potentially conflicting uses (drinking water, irrigated agriculture and fishing).

Conflict of Interest

The authors have not declared any conflict of interest.

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