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Limnological study on a Samrat Ashok Sagar with special reference to zooplankton population

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Present investigation has been conducted on Samrat Ashok Sagar (popularly known as Halali reservoir) of Madhya Pradesh with special reference to its zooplankton diversity in relation physico-chemical characteristics. 105 (One hundred and five) zooplankton species were identified from Samrat Ashok Sagar which consisted of Rotifera 43 species (41%), Cladocera 25 species (24%), Protozoa 20 species (19%), Copepoda 12 species (11%) and Ostracoda 5 species (5%). The investigation on physico-chemical characteristics at different sites revealed its alkaline nature, suitable for aquaculture practices. Significant site variations have been recorded due to the interference of sewage and agricultural wastes. Among all the zooplankton groups, Rotifera recorded dominance. Maximum diversity of zooplankton population was recorded at macrophytic sites during summer season.

Key words: Water chemistry, zooplankton population, tropical reservoir.

INTRODUCTION

Zooplankton study is important as it could provide ways to predict the productivity of fresh water aquatic system (Borgmann et al., 1984; Morgan et al., 1978). In deciphering trophic status and biomonitoring of aquatic habitats, zooplankters play a vital role (Krishnamurthy et al., 1979). The biodiversity and distribution of zooplankton in aquatic ecosystem depend mainly on the physico-chemical properties of water. Pollution of water bodies by different sources results in drastic change in zooplankton populations, and thereby affects the production potential of the ecosystem (Singh and Mahajan, 1987; Harikrishnan and Azis, 1989). Zooplankton communities are highly sensitive to environmental variation. Hence, they are effective tools in environmental biomonitoring of an aquatic system. Changes in the zooplankton species composition have been used as indication of increased eutrophication of fresh waters (Wanganeo and Wanganeo, 2006). Some species flourish in highly eutrophic waters while others are very sensitive to organic or chemical wastes (El-Enany, 2009). In India, several important contributions on zooplankton and their diversity, density, ecological importance has been made in different parts of the country such as Ganapati (1949); Gulati (1964); Khan and Rao (1981); Subla et al., (1984); Patil and Goudar (1989); Wanganeo and Wanganeo (2006); Ramachandra et al., (2006); Raina et al., (2009) Chakrapani et al., (1996); Das et al., (1996) Dadhick and Sexena (1999); Dhanapathi (2000); Sharma (2009) and Kumar et al., (2011). But, information regarding the zooplankton diversity has not been thoroughly investigated in Madhya Pradesh and especially in Bhopal district.

Thus, the present work aimed to assess the biodiversity of Zooplankton and their Relation to the physico-chemical parameters of Samrat Ashok Sagar which is mainly used for irrigation purposes, commercial fishing practices and recreation.

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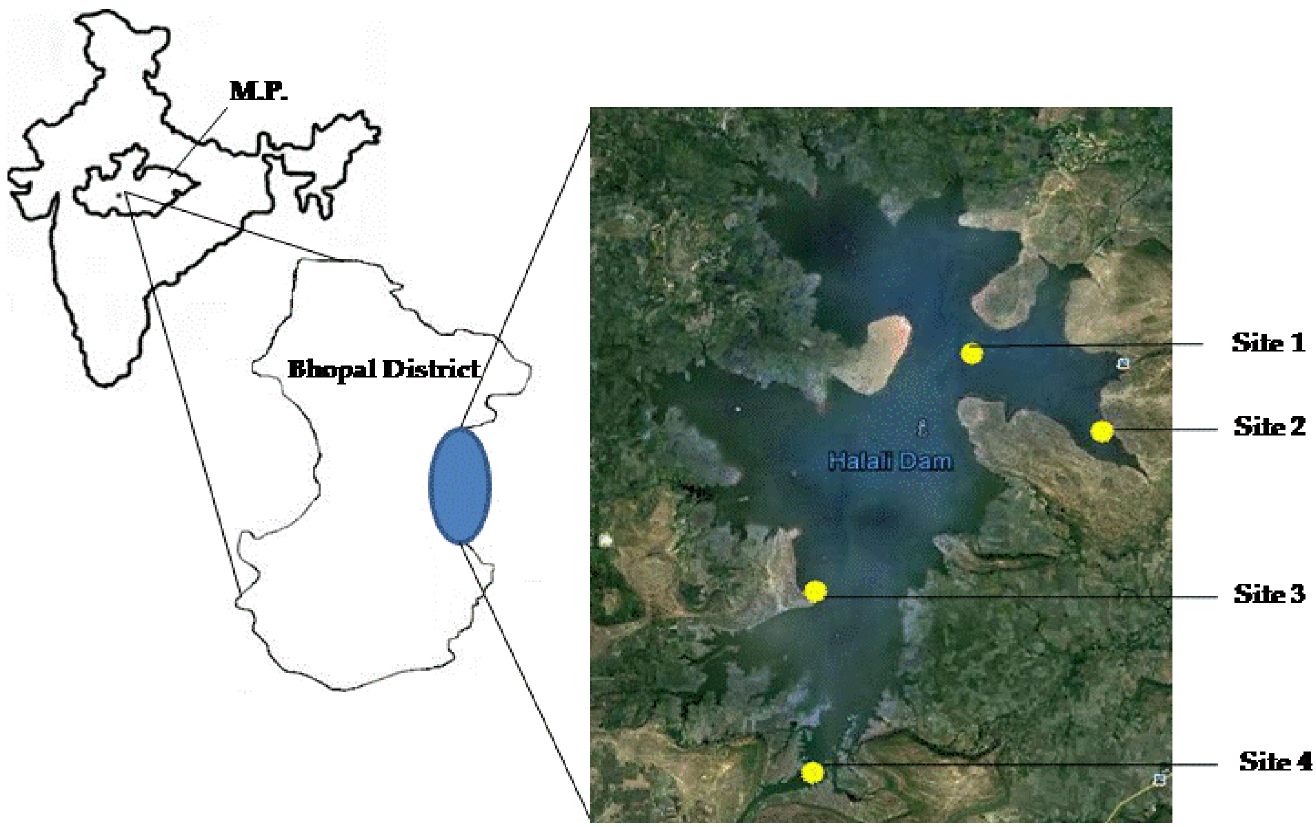

Figure 1. Location of sampling sites in Samrat Ashok Sagar.

MATERIALS AND METHODS

Physico-chemical analysis of water samples were carried out following the standard methods as described by Adoni (1985) and APHA (2000). For enumeration of zooplankton population surface water samples (100 liters) were filtered with the help of plankton net made of bolting silk of mesh size of 20 µm and concentrated samples were preserved with 5% formaldehyde solution in 100 ml plastic vials. The concentrated samples were examined under the inverted microscope (Metzer made) and identification of plankton was done following the taxonomic references of Needham and Needham (1962), Pennak (1978), Victor and Fernando (1979), Michel and Sharma (1988), Edmondson (1992), Battish (1992), Reddy (1994), Sharma (1999) and Dhanapathi (2003).

Study area

Samrat Ashok Sagar is a one of the major water body of Central India, situated 25 km away from Bhopal city towards the north east side (Figure 1). The water body (popularly known as Halali reservoir) is spread on three districts of Madhya Pradesh namely Bhopal, Raisen and Vidisha. Most part of Samrat Ashok Sagar lies in Bhopal and Raisen district while the dam is constructed in Vidisha district. Presently, Samrat Ashok Sagar is used for irrigation and aquaculture practices (Table 1). Present work has been conducted on four sampling sites of Samrat Ashok Sagar for the estimation of its zooplankton diversity as well as its physico-chemical properties. Site 1 was fixed at the deepest point of reservoir, site 2 was near Dam, site 3 was near Bhainsakheri village and site 4 was fixed at the confluence of Patra canal. Most of the sampling sites were infested with macrophytic vegetation except site 1.

RESULTS AND DISCUSSION

Physico-chemical analysis

Physico-chemical characteristics of Samrat Ashok Sagar are given in Table 2. Significant variations in the physico-chemical properties of Samrat Ashok Sagar at different sites have been recorded which is due to the various pollution loads from the incoming channels. The temperature of both air and water is an important factor influencing all aquatic flora and fauna and chemical solutes. Nearby Samrat Ashok Sagar air temperature ranged between 26 to 33°C (Table 2 and Figure 2). Minimum air temperature was recorded at site-1 during post monsoon season and maximum at site 3 during summer period. Water temperature ranged between 23 to 29°C (Table 2 and Figure 2). Air temperature recorded higher values as compared to the water temperature which is mainly governed by the local climatic conditions of the aquatic system. Higher air temperature as compared to surface water temperature has also been noticed by Bhatnagar (1982), Wanganeo (1998), Ayoade et al. (2006) and Wanganeo et al. (2011). Transparency values ranged between 34 cm to 80 cm and recorded minimum value at site 2 and maximum at site 1 during post monsoon, respectively (Table 2 and Figure 3).

High transparency at central site was due to the higher depth and absence of algal blooms. Comparatively, low

Table 1. Important features of Samrat Ashok Sagar, Madhya Pradesh.

Feature	Samrat Ashok Sagar
Location	Bhopal, Raisen and Vidisha District of M.P.
Year of construction	1973
River system	Halali River
Type of Dam	Earthen dam
Longitude	77° 26' 45.06" E
Latitude	23º 16' 17.10" N
Elevation (m)	465
Full Reservoir Level (m)	458.4
Dead Storage Level (m)	448.95
Catchment area (km^2)	699
Water spread area FRL (ha)	7,712
Maximum depth (m)	29.5
Sources of water	River channels, rain water, domestic sewage
Main use of water	Irrigation, potable water, aquaculture, recreation, washing and bathing

Table 2. Physico-chemical characteristics of Samrat Ashok Sagar.

Parameter	Site-1 (Central site)		Site-2 (Dam site)		Site-3 (Bhainsakheri)		Site-4 (Patra Confluence)	
	Summer	P. Monsoon	Summer	P. Monsoon	Summer	P. Monsoon	Summer	P. Monsoon
Air temperature (°C)	30	26	32	28.40	33	27	32	28
Water temperature (°C)	28	23	29.0	25.3	28.6	25	27.2	25.2
Secchi transparency (cm)	50	54	50	60	46	34	44	36.00
Depth (m)	14.8	18.80	1	1	1.2	1.3	1.1	1.20
pH (units)	8.1	8.5	7.2	7.8	8.2	8.5	7	7.3
TDS (ppm)	260	210	320	270	250	200	540	520
Conductivity (µs/cm)	340	300	580	540	380	340	780	740
Dissolved oxygen (mg/l)	7.2	6.4	3.8	4.50	5.4	8.40	4.16	5.70
Total alkalinity (mg/l)	140	120.0	136	144	144	156	136.00	146.00
Chloride (mg/l)	48	38.6	48.5	60	50.4	44.4	76.96	67.90
Total hardness (mg/l)	218	206	252	240	274	254	276	260
Calcium hardness (mg/l)	124	92.00	132	118	164	146	160.00	152.00
Mg contents (mg/l)	22.84	27.70	29	29.60	26.73	26.24	28.18	26.24
Nitrate (mg/l)	0.33	0.31	0.75	0.67	0.64	0.52	1.67	1.52
Nitrite (mg/l)	0.064	0.03	0.18	0.22	0.12	0.08	0.22	0.24
Orthophosphate (mg/l)	0.22	0.28	0.26	0.22	0.24	0.22	0.34	0.30
Ammonia (mg/l)	0.02	0.01	0.034	0.05	0.034	0.03	0.05	0.03
Sodium (mg/l)	4.4	4.8	6.4	5.2	6.6	4.8	12.2	9.4
Potassium (mg/l)	1.4	1.2	1.4	1.6	1.34	1.4	2.34	1.8

transparency at site 3 was due to the presence of algae, boating activity near shore which disturbed the mud water interface and increases turbidity of water. The type and concentration of suspended particles such as silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms control the transparency of the water (Chapman, 1992). Lee et al. (1981) reported transparency value of <170 cm as indicator of higher trophic status of water body which also confirmed by Wanganeo et al. (2011) and Kumar et al. (2010, 2011, 2012). Maximum depth of 18.8 m was recorded at central site during post monsoon while other sites are shallow because of their placement near shore of Samrat Ashok Sagar in shallow region (Table 2 and Figure 4). Higher depths control the growth of aquatic vegetation and help to maintain the trophic levels of water body. pH value in Samrat Ashok Sagar ranged between 7 to 8.5 units indicating its alkaline

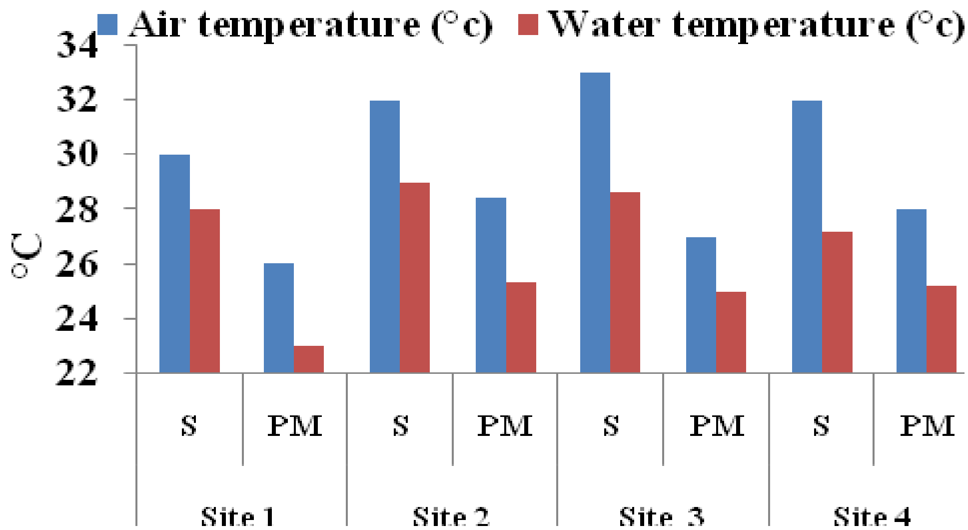

Figure 2. Seasonal variations in temperature.

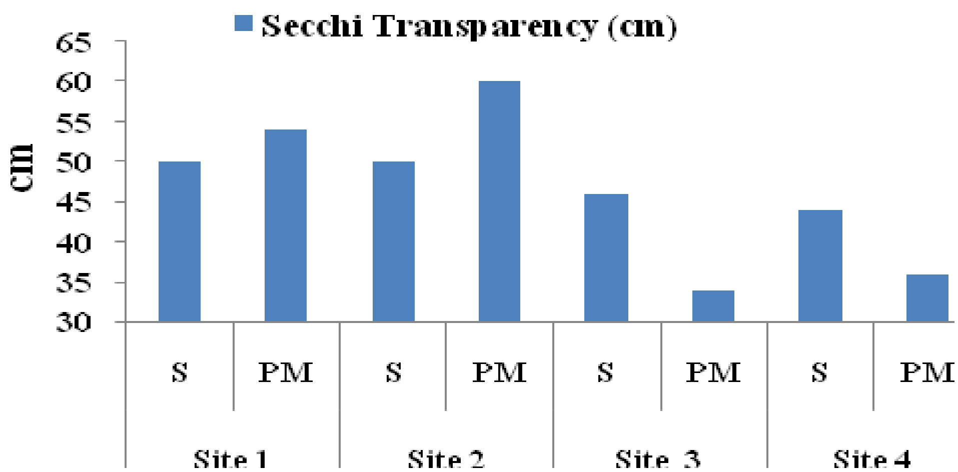

Figure 3. Seasonal variations in transparency.

nature (Table 2 and Figure 5). Low pH of 7 units recorded at site 4 during summer season was due to the higher decomposition rates of vegetation as well as mixing of sewage waters of Patra canal. Sewage waters with high pollution load decrease the pH levels of Samrat Ashok Sagar near the confluence site. Higher pH of 8.5 units recorded at sites 1 and 3 during post monsoon season of Samrat Ashok Sagar indicates its healthy mesotrophic status. The magnitude of daily and seasonal variation in pH at different locations of water body depends on the buffering capacity, alkalinity of water and rates of photo-synthesis (Boyd and Tucker, 1998). The alkaline pH range (7 to 8.5) of Samrat Ashok Sagar indicates productive nature which is favorable for good growth and survival of fishes (Adhikari, 2003) and also supports growth of zooplankton population (Wanganeo and Wanganeo, 2006).

Dissolved oxygen in Samrat Ashok Sagar ranged between 3.8 to 8.4 mg/l (Table 2 and Figure 5). Higher dissolved oxygen value was documented at site 3 during post monsoon which is attributed to higher photosynthetic activity by submerged aquatic vegetation especially *Vallisneria* sp. and filamentous algae. Besides this, turbulence caused by boating activity also leads to increase in dissolve oxygen. Whereas, low dissolved oxygen recorded during summer season at confluence site is attributed to the impact of sewage (at site 4) and higher decomposition rate of organic matter (at site 2).

Low dissolved oxygen nearby polluted sites of some water bodies of Bhopal has also been reported by Bhatnagar (1982), George (1992), Agarkar (1994), Wanganeo et al. (1997) and Kulshreshta (2005). TDS ranged between 200 to 540 ppm in Samrat Ashok Sagar (Table 2 and Figure 6). Higher TDS values recorded at

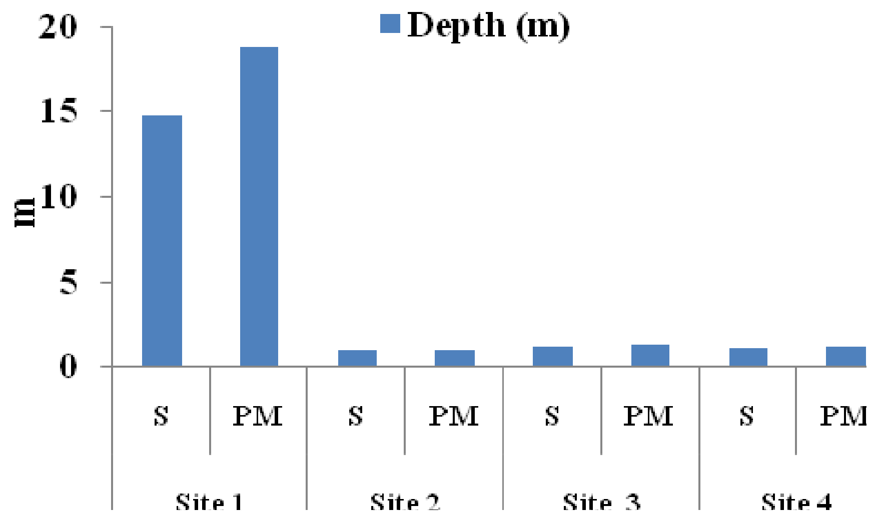

Figure 4. Seasonal variations in depth.

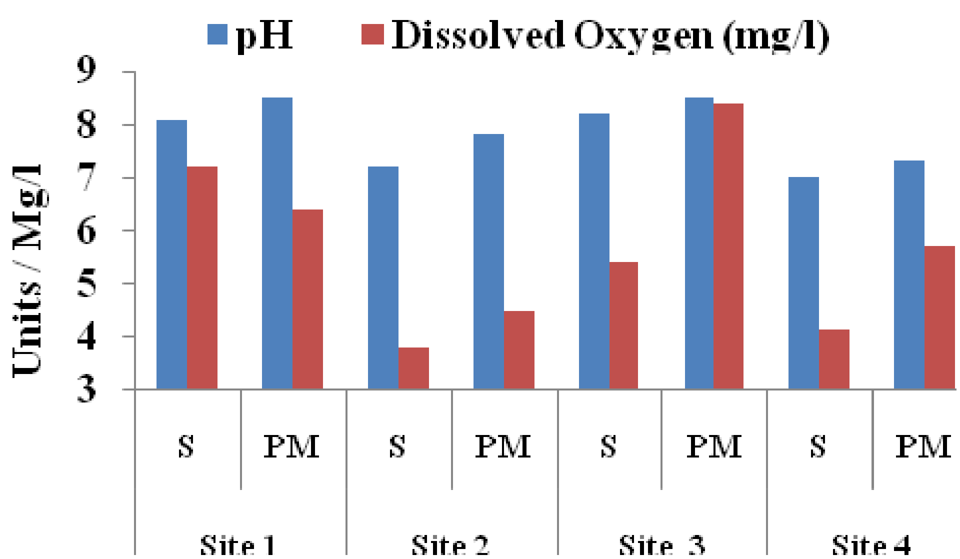

Figure 5. Seasonal variations in pH and D.O.

site 4 indicate regular interference (anthropogenic activities) from respective catchment area and continuous direct mixing of sewage waters in the water body. Whereas, comparatively low TDS values recorded at sites 1 and 3 indicate mesotrophic status of Samrat Ashok Sagar. Comparatively low TDS values recorded at sites 1, 2 and 3 also indicate good quality of water (Kumbar et al., 2008) in Samrat Ashok Sagar.

The specific conductivity in Samrat Ashok Sagar varied between 300 to 780 µs/cm (Table 2 and Figure 6). The high conductivity value of 780 µs/cm recorded at confluence site during summer season could be attributed to the high amount of dissolved solid and salt ions coming from domestic raw waters. The specific conductivity value of site 2 recorded 580 µs/cm during summer season and 540 µs/cm during post monsoon season signify high amount of anthropogenic pressure (Table 2 and Figure 6). Site-4 was noticed as eutrophic in nature and most polluted site of Samrat Ashok Sagar. These results coincide with work of Wanganeo (1980), Raina (1981) and Wanganeo et al. (2011) who reported variation in specific conductivity at different sites of a water body. Total alkalinity in surface waters of Samrat Ashok Sagar ranged between 120 to 156 mg/l (Table 2 and Figure 7). Maximum total alkalinity was documented at site 3 during post monsoon season. Due to the growth of algal population and aquatic vegetation, photosynthetic activity also increases which increases total alkalinity

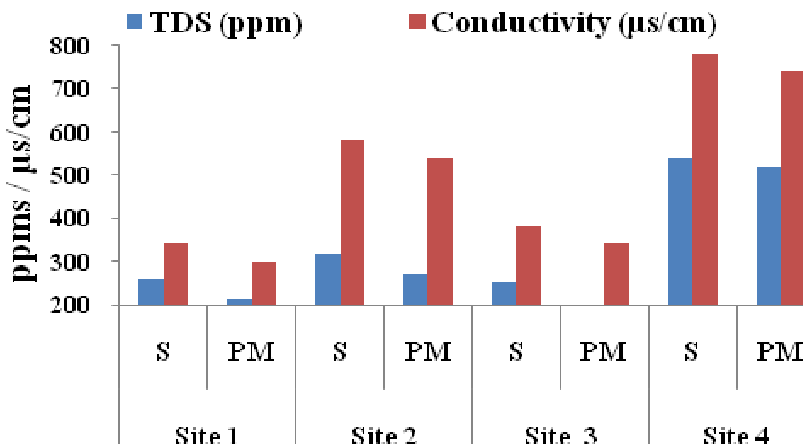

Figure 6. Seasonal variations in TDS and conductivity.

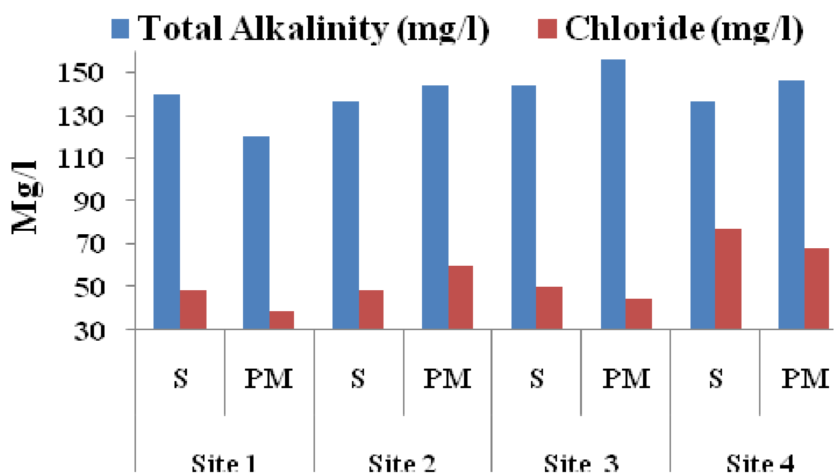

Figure 7. Seasonal variations in total alkalinity and chloride.

(Vijayarghavan, 1971). Water bodies having total alkalinity above 100 mg/l can be considered productive in nature as reported by Moyle (1946) and Alikunhi (1957). Chloride varied between 38.6 to 76.96 mg/l in Samrat Ashok Sagar (Table 2 and Figure 7). Maximum chloride value (76.96 mg/l) recorded at confluence site during summer season which depicted higher pollution level and eutrophic condition of the site due to the domestic polluted waters with high salinity. While minimum chloride (38.6 mg/l) was recorded at site 1 during post monsoon season. Higher accumulation of chloride due to the impact of sewage in a tropical water body has been also reported by Kumbhar et al. (2008). Further, similar ranges of chloride concentrations have also been reported by various authors in Indian water bodies (Goel et al., 1980; Dhamija and Jain, 1995; Wanganeo, 1998; Wanganeo et al., 2011).

A range between 206 to 276 mg/l of total hardness was documented in Samrat Ashok Sagar (Table 2 and Figure 8). Maximum total hardness (276 mg/l) was recorded at site 4 during summer season and minimum 206 mg/l at site 1 during post monsoon season. Higher values of total hardness were recorded at shallow sites due to the low water level and some anthropogenic activities. Besides this, the water current nearby shore of the water body also dilutes soil and mud from bottom layer which increases the hardness of water. Sometimes decomposed material such as vegetation and algae also accelerate the total hardness. Maximum hardness values at shallow sites have been recorded due to the low water level and high rates of evaporation (Garg, 2003; Krishnamoorthi, 2011). Calcium hardness recorded maximum value of 164 mg/l at site 3 during summer season (Table 2 and Figure 8) due to anthropogenic pressure and some amount of calcium also contributed by rocks. Composed by calcium concentration (160 mg/l during summer and 152 mg/l during post monsoon season) was also documented at site 4 probably due to direct mixing of sewage

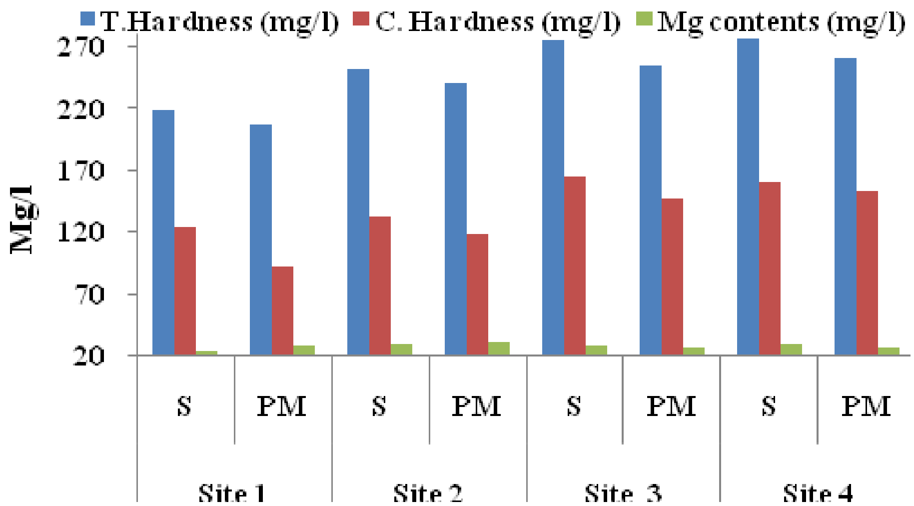

Figure 8. Seasonal variations in hardness.

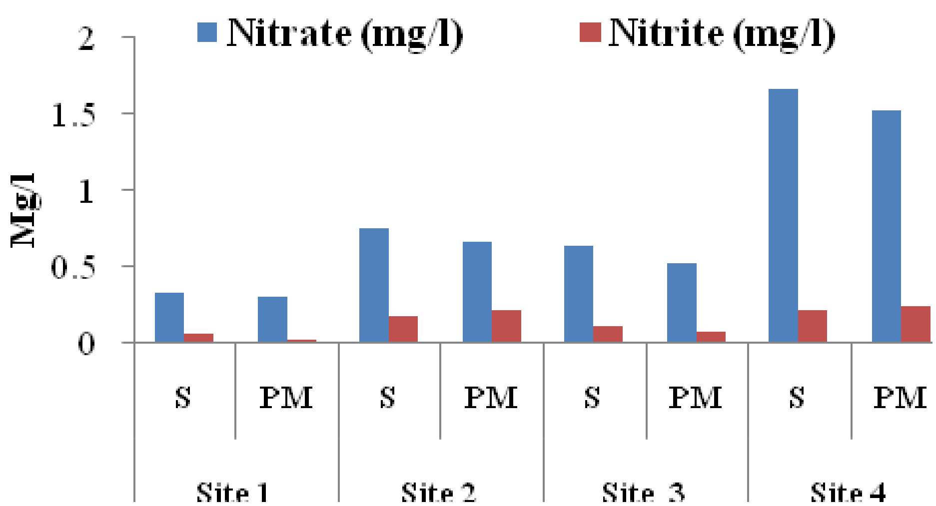

Figure 9. Seasonal variations in nitrate and nitrite.

waters into the reservoir coming from Bhopal city. Increase in calcium due to the decomposition of plants has been reported by Purohit (1989) in some Indian freshwater bodies.

The magnesium content in the present study area varied from 22.84 to 29.6 mg/l (Table 2 and Figure 8). The maximum amount of magnesium was spread at site 2. The higher values of magnesium may be due to its release from the bottom sediment and decomposition of biota (Krishnamoorthi, 2011). Similar results have also been reported in some water bodies of Bhopal (Kulshreshta, 2005; Wanganeo et al., 2011). Nitrate controls the whole aquatic system and also indicates the trophic level of the water body. In Samrat Ashok Sagar, nitrate varied between 0.31 to1.67 mg/l and nitrite between 0.03 to 0.24 mg/l (Table 2 and Figure 9). High amount of nitrate (1.67 mg/l) and nitrite (0.24 mg/l) observed at site 4 is due to the mixing of domestic waste water which contains high nitrate content and also partly due to decomposition of biota. Nawange (1993) and Fadiran and Manba (2005) have also reported the excessive mixing of sewage waters and higher decomposition rates of aquatic biota in aquatic system to accelerate the amount of nitrate and nitrite. Orthophosphate, one of the major biologically importance nutrients recorded its maximum concentration (0.34 mg/l) at site 4 during summer season and minimum of 0.22 mg/l was documented at site 1 (during summer), site 2 and 3 during post monsoon respectively (Table 2 and Figure 10). Higher values of orthophosphate were recorded due to the domestic waste water containing high phosphate content. Golterman (1975) and Krishnamoorthi et al. (2011) reported higher

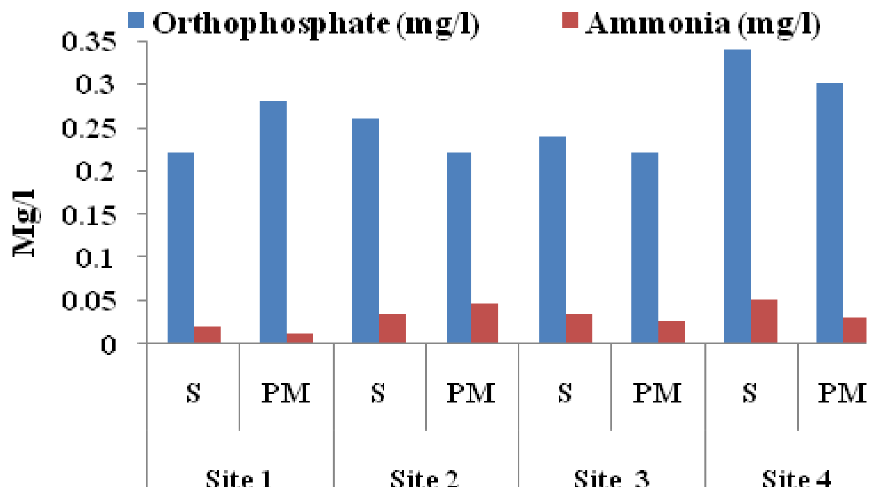

Figure 10. Seasonal variations in orthophosphate and ammonia.

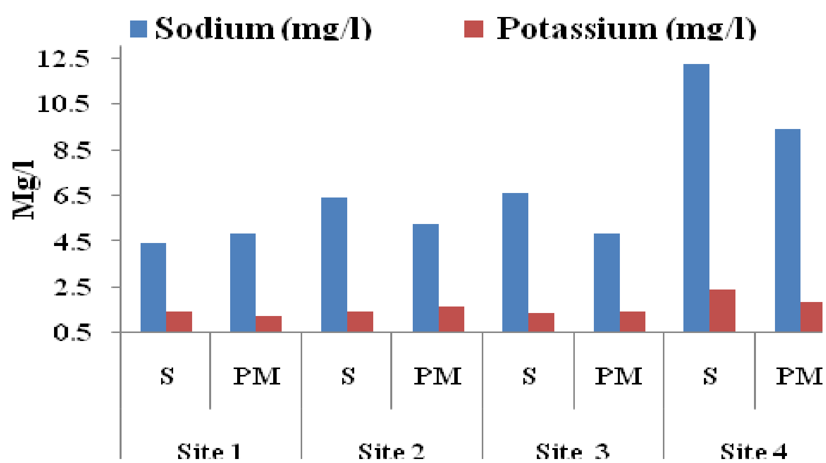

Figure 11. Seasonal variations in sodium and potassium.

concentration of orthophosphate due to the domestic sewage waters in some Indian water bodies during their respective works. Ammonia concentration ranged between 0.01 to 0.05 mg/l in Samrat Ashok Sagar (Table 2 and Figure 10).

Maximum concentration (0.05 mg/l) of ammonia was recorded at site 3 during post monsoon and at site 4 during summer season while minimum concentration of ammonia was recorded 0.01 mg/l at site 1. Ammonia occurs naturally in water bodies arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, reduction of the nitrogen gas in water by micro-organisms and from gas exchange with the atmosphere (Chapman, 1992). Further, comparatively higher values of ammonia in the water body under the present study are due to municipal waste water which enters the system. Sodium concentrations were found to be in the range between 4.4 to 12.2 mg/l (Table 2 and Figure 11). Maximum concentration of sodium was recorded at site 4 during summer and post monsoon season. Whereas, minimum concentration was documented at central site. Besides this, potassium in Samrat Ashok Sagar ranged from 1.2 to 2.34 mg/l (Table 2 and Figure 11). Maximum value of potassium was documented at site 4 during summer period while low value was recorded at site 1 during post monsoon season. The high amount of sodium and potassium at site 4 attributed to the input from sewage channels. The major source of sodium and potassium in natural fresh water is weathering of rocks but the quantities increase may be attributed to excessive use of fertilizers and disposal of waste water (Sivakumar and Karuppasamy, 2008; Trivedi and Goel, 1984).

Biological analysis

A total of 105 zooplankton species were identified in Samrat Ashok Sagar Reservoir (Table 3). Out of these 43

Table 3. Zooplankton composition of Samrat Ashok Sagar, Madhya Pradesh.

Name of the Taxa	**Site-1 (Central site)**		**Site-2 (Dam site)**		**Site-3 (Bhainsakheri)**		**Site-4 (Patra Confluence)**	
	S	**PM**	**S**	**PM**	**S**	**PM**	**S**	**PM**
Rotifera	**March**	**Septembe r**	**March**	**Septembe r**	**Marc h**	**Septembe r**	**March**	**Septembe r**
Anuraeopsis fissa			+	+	D	+	+	+
Anuraeopsis sp.	+	+	+		+			
Asplanchna brightwelli			D		D		+	
Asplanchna sp.	+				+	D		+
Brachionus angularis	D	D	+	+	D	D	+	+
Brachionus bidentata		+	+		+	+		
Brachionus calyciflorus	D		D	D	D	D	+	+
Brachionus caudatus	+				+			
Brachionus diversicornis			+	+	+	+	D	D
Brachionus falcatus					+			
Brachionus forficula	D	+			+	+	+	+
Brachionus patulus					+			
Brachionus plicatilis			+					+
Brachionus quadridentata			+	+	D			
Brachionus rubens			+	+		+		
Cephallodella gibba	+		+		+	+	+	
Filinia longiseta	+	+	D		D	D	+	+
Filinia opoliensis	+	+	+	+				
Filinia terminalis					+			
Hexarthra mira					+			
Keratella cochlearis	D	D	D	D	D	+	D	D
Keratella procurva					+	+		+
Keratella tecta					+			
Keratella tropica	+	+	D		D	+	D	D
Lecane bulla					D			
Lecane luna	+						+	+
Lecane lunaris							+	
Lecane sp.			D	D	+	+		+
Lepadella ovalis			+	+	D	+		+
Monostyla bulla		+	+	+				
Monostyla punctata	+							
Monostyla quadridentatus					+	+		+
Mytilina ventralis			+		+			
Notholca accminata			+	+	+	+		
Platyias patulus					+			
Polyarthra appendiculata			D		+	+	+	+
Polyarthra dolichoptera					D		+	
Polyarthra vulgaris	+							
Synchaeta sp.			+					
Testudinella patina				D	D	D	+	+
Trichocerca similis	+	+	D		D	+		
Trichocerca sp.			+	+	D			+
Total	15	10	25	14	33	20	15	18
Cladocera	M		P M					
Alona intermediate					+	+		
Alona sp.	+	+		+	D			+

Table 3. Contd.

Alonella sp.			+			+		
Bosmina longirostris	+	+	D	D	D	D	+	+
Bosmina sp.				+		+		+
Ceriodaphnia reticulata					+	+	+	+
Ceriodaphnia sp.			+	+	+			
Chydorus sphaericus	+	+	D	D	D	D	+	+
Chydorus ventricosus					+	+		+
Daphnia lumholtzi	+		+	+	+			
Daphnia pulex			D	D		D		+
Daphnia similis	+		+		+			
Diaphanosoma excisum	+	+	+	+	D		+	+
Diaphanosoma sp.			+			D		
Indialona ganapati			+	+	+			
Leydigia acanthocercoids			+			+	+	
Leydigia sp.					+			
Macrothrix sp.				+	+			
Moina brachiata	+	+	+	+	D		+	+
Moina micrura			+	+		+		
Pleuroxus sp.	+		+	+	+			
Pseudochydorus globosus						+		
Sida sp.			+		+			
Simocephalus expinosus	+	+	+		+	+		+
Simocephalus vetulus				+	D			
Total	9	6	16	14	18	13	6	10
Protozoa	M		P M					
Actinosphaerium eichhorni					+			
Arcella discoides	D	D	D	D	D		+	+
Arcella rhomboides						+		
Arcella vulgaris	D	+	D	D	D	D	+	+
Ascomorpha sp.			+			+		
Astramoeba radiosa			D		+			
Centropyxis ecornis	D	D			D	+		+
Centropyxis aculeata		D		+	+			
Centropyxis constricta	+	+	+			+		+
Coleps sp.			D	D	D		D	+
Cryptodifflugia				+	+			
Difflugia rubsence	+	+	D		+	D	+	+
Difflugia urceolata			+	+				+
Euglypha tuberculata	+		+		+	D		
Leucophridium sp.				+	+			
Nuclearia simplex				+	D	D	+	
Paramecium caudatum					+	D		
Peredinium sp.						+		
Pleuronema sp.			+	+		+		
Vorticella sp.								+
Total	6	5	10	9	13	11	5	8
Copepoda	M		P M					
Cyclops sp.			+		D	+	+	+
Cyclops vicinus	+	+	D	+	D	D	+	
Diaptomus nudus			+	+	+	+		

Table 3. Contd.

Diaptomus sp.					+	+	+	+
Eucyclops sp.	+	+	+	+	D			
Heliodiaptomus contortus					+	+		
Mesocyclops leuckarti	+		D	D	D	D	+	+
Mesocyclops sp.			+	+	+		+	
Nauplius larvae	+	+	D	D	D	D	+	+
Thermocyclops crassus	+	+	+	+	D	+		
Thermocyclops hylinus			+		+			
Thermocyclops sp.			+	+		+		
Total	5	4	10	8	11	9	6	4
Ostracoda								
Cypricercus sp.						+		
Cypris sp.					D	+		+
Eucypris sp.			+	+	+			
Stenocypris sp.			+		+	+	+	+
Stenocypris malcolmsoni	+	+	+	+	D	D	+	+
Total	1	1	3	2	4	4	2	3

Note: S=Summer, PM=Post monsoon, D= Dominant, +=Present.

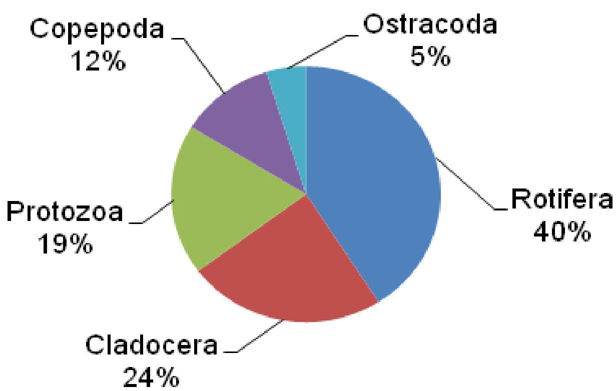

Figure 12. Class wise percentage composition of zooplankton in Samrat Ashok Sagar.

species (40%) were recorded from Rotifera, 25 species (24%) from Cladocera, 20 species (19%) from Protozoa, 12 species (12%) from Copepoda while Ostracoda contributed only 5 species (5%) (Table 3 and Figure 12). The class wise sequence of dominance of zooplankton in Samrat Ashok Sagar was as: Rotifera > Cladocera > Protozoa > Copepoda > Ostracoda. During present study period, Rotifera recorded its dominance at all the sites in Samrat Ashok Sagar. Maximum Rotifers (33 species) were recorded at site 3 while minimum (20 species) at central site (Table 3). The presence of maximum zooplanktonic fauna at site 3 is due to the impact of agricultural wastes and presence of macrophytic vegetation which provides food and habitat for zooplankton population. Wanganeo and Wanganeo (2006) reported that the macrophytic vegetation support the growth of planktonic fauna at shallow depths. Besides this, various authors have also reported the dominance of Rotifers in tropical water bodies (Unni, 1996; Alma and Manuel, 2004; Tripathi and Chishty, 2012). During the present investigation period, maximum Rotifers species were encountered during summer season and comparatively less in post monsoon season at sites 1, 2 and 3 (Table 3 and Figure 13); while, at 4, maximum Rotifer species recorded during post monsoon and minimum in summer season. Similar seasonal species composition and distribution trend was also recorded for all the taxonomic classes at different selected sites.

Among Rotifera, total of 15 species in summer season and 10 in post monsoon season have been recorded at site 1 (Table 3 and Figure 13) in which *Brachionus angularis* and *Keratella cochlearis* recorded its dominance during summer and post monsoon period and *Brachionus calyciflorus* and *Brachionus forficula* were recorded in summer season only. At site 2, total of 25 species in summer season and 14 in post monsoon season have been recorded (Figure 13). Out of these, *B. calyciflorus*, *K. cochlearis* and *Lecane* sp. recorded dominance during summer and post monsoon season. *Asplanchna brightwelli*, *Filinia longiseta*, *Keratella tropica*, *Polyarthra appendiculata* and *Trichocerca similis* were dominant during summer season while *Testudinella patina* recorded its dominance only in post monsoon season at site 2 (Table 3). At site 3, *B. angularis*, *B. calyciflorus*, *Filinia longiseta* and *T. patina* recorded their dominance during summer and post monsoon season. Whereas, *Anuraeopsis fissa*, *A. brightwelli*, *Brachionus quadridentata*, *K. cochlearis*, *K. tropica, Lecane bulla*, *Lepadella ovalis*, *Polyarthra dolichoptera*, *T. similis* and

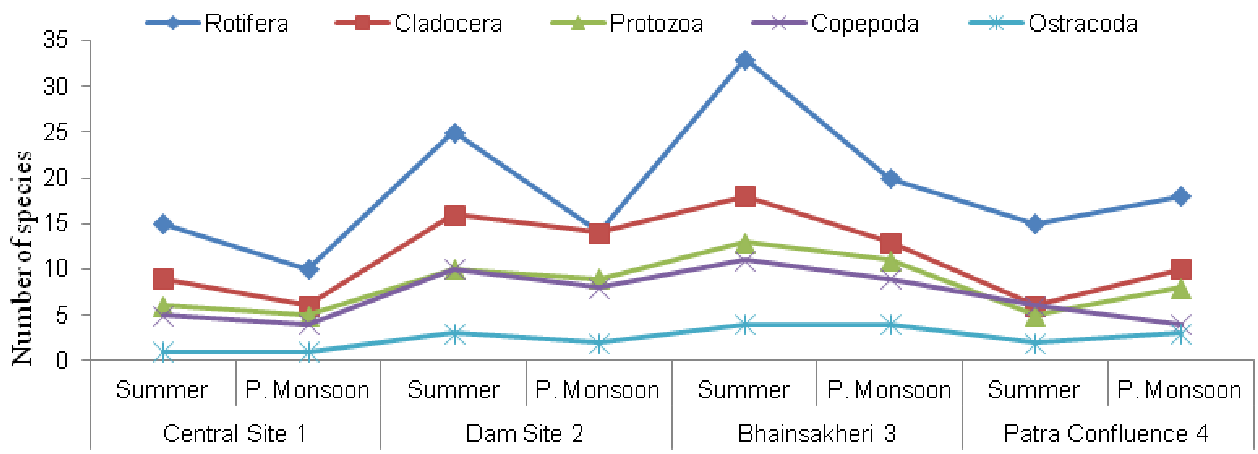

Figure 13. Class wise variation in zooplankton population during summer and post monsoon.

Trichocerca sp. were dominant in summer season only. Beside this, *Asplanchna* sp. recorded its dominance in post monsoon season only. *Brachionus diversicornis*, *K. cochlearis* and *K. tropica* recorded their dominance at site 4 during summer and post monsoon season only.

Maximum Rotifer species with their dominance have been documented at first three sites during summer season. Williams (1966) reported dominance of Rotifers in summer season in terms of diversity and density. Rumana et al. (2010) also observed the higher multiplication of Rotifers population during summer months. The presence of these species may be due to the high temperature as also confirmed by Pejler (1983), Sharma (1992) and Mahar (2003). Most of the species encountered in the present investigation are considered as sensitive indicators of change in water quality and also used as indicators of higher trophic status (Gannon and Stemberger, 1978; Sharma, 1992). Some of the Rotifer species recorded during the present study such as *B. angularis*, *B. calyciflorus*, *B. diversicornis*, *K. cochlearis*, *F. longiseta*, *T. patina* and *Lecane bulla* are considered as indicators of higher trophic status by many researchers (Pejler, 1965; Hakkari, 1972; Gannon and Stemberger, 1978; Maemetes, 1983a, Sharma, 1983b; Miura and Cai, 1990; Baloch et al., 2000). In Samrat Ashok Sagar, the Rotifers were more diverse when compared with the other zooplankton community. Rotifer population diversity in Samrat Ashok Sagar rises and falls according to its tolerance of environmental conditions, availability of habitat and food at different sites.

The presence of *Bosmina longirostris* and *Diaphanosoma brachyurum* in high abundance is usually also associated with a eutrophic environment as *Diaphanosoma* sp. is well adapted to eutrophic environments (Zago, 1976; Sendacz, 1984). Among Cladocera, total of 9 species were recorded in summer season and 6 species in post monsoon season at site 1 (Table 3 and Figure 13). At site 2, total of 16 species in summer season and 14 species in post monsoon season have been documented in which *B. longirostris*, *Chydorus sphaericus* and *Daphnia pulex* recorded their dominance during summer and post monsoon season respectively. At site 4, *B. longirostris*, *C. sphaericus* recorded dominance during summer and post monsoon season respectively while, *Alona* sp., *Diaphanosoma excisum*, *Moina brachiata* and *Simocephalus vetulus* were dominant only during summer season. Besides this, *D. pulex* and *Diaphanosoma* sp. were found to be dominant in post monsoon season only. At site 4, maximum (10 species) Cladoceran species were documented during post monsoon season and minimum (6 species) during summer season. Maximum Cladoceran species have been documented at sites 1, 2 and 3 during summer season due to availability of food and luxuriant vegetation. Cladocera were recorded maximum in post monsoon and minimum in summer season at site 4 due to the maximum pollution load during summer from respective catchment area, shallow depth, obnoxious smell and comparatively low oxygen which obstruct the growth of Cladoceran population.

Cladoceran species documented at different sites in the present investigation are: *B. longirostris*, *C. sphaericus*, *Chydorus ventricosus*, *Ceriodaphnia* sp., *D. excisum*, *Diaphanosoma* sp., *Simocephalus expinosus*, *D. pulex* and *M. brachiata.* These species have been reported as indicators of sewage pollution and eutrophication by various authors (Verma and Dalela, 1975; Kiefer, 1978; Swar and Fernando, 1980; Ryding and Rast, 1989; Prakash et al., 2002; Wanganeo and Wanganeo, 2006). A total of 20 Protozoan species were identified from Samrat Ashok Sagar, out of which maximum (18) species were recorded from site 3 and minimum 7 species from site 1 (Table 3 and Figure 14). *Arcella discoids* and *Centropyxis ecornis* recorded dominance during summer and post monsoon season respectively at site 1; whereas, the dominance of *Arcella vulgaris* and *Centropyxis*

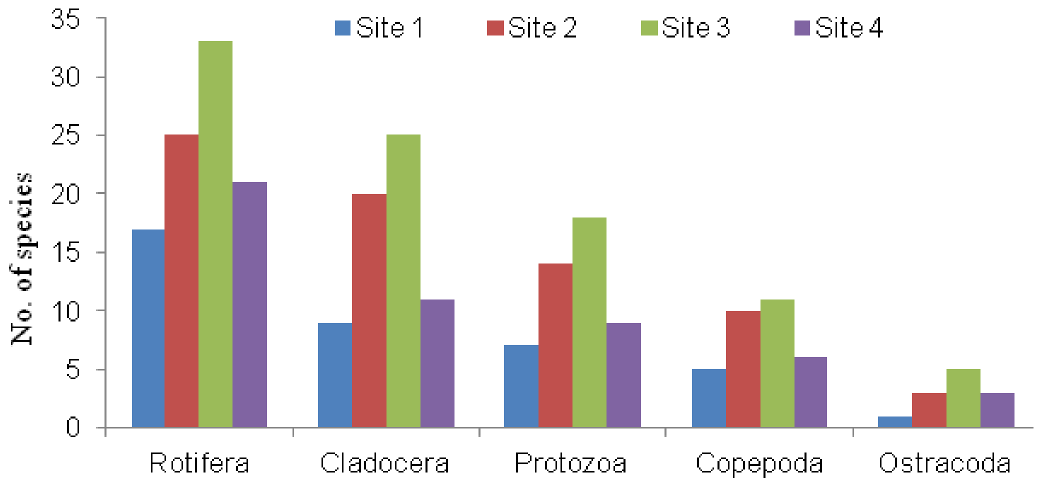

Figure 14. Class wise qualitative variations in zooplankton diversity at different sites.

aculeata was recorded in summer and post monsoon season respectively. At site 2, *A. discoides*, *A. vulgaris* and *Coleps* sp. documented their dominance in summer and post monsoon season while *Astramoeba radiosa* and *Difflugia rubsence* were documented in summer season only. The dominance of *A. vulgaris* and *Nuclearia simplex* in summer and post monsoon; *A. discoides*, *C. ecornis* and *Coleps* sp. in only summer season and *D. rubsence*, *Euglypha tuberculata* and *Paramecium caudatum* in post monsoon season was recorded at site 3. Only *Coleps* sp. recorded its dominance at site 4 in summer season.

Few Protozoan species such as *Actinosphaerium eichhorni*, *Arcella rhomboides* and *Paramecium* sp. were only present at site 3. Some Protozoan species such as *Arcella* sp., *A. discoids*, *A. vulgaris*, *Centropyxis* sp., *C. ecornis*, *Difflugia cuminata*, *Difflugia* sp. and *Paramoecium* sp. have been considered as indicators of nutrient rich waters by various authors in some Indian freshwater habitat (David and Roy, 1966; Agarkar et al., 1994; Wanganeo and Wanganeo, 2006; Kumar et al., 2010). Maximum Protozoan population in Samrat Ashok Sagar was recorded in summer season which is also confirmed by some authors (Ahangar et al., 2010; Samuelsson et al., 2006). During the present study period, maximum Copepods (11 species) and minimum (5 species) recorded at sites 3 and 1, respectively during summer season (Table 3 and Figure 14). Among Copepods, *Mesocyclops leuckarti* and *Nauplii* larvae recorded their dominance at site 3 in summer and post monsoon season while *Cyclops vicinus* was dominant only in summer season. The dominance of *C. vicinus*, *M. leuckarti* and *Nauplius* larvae was observed at site 2 in summer and post monsoon season. Whereas, the dominance of *Cyclops* sp., *Eucyclops* sp. and *Thermocyclops crassus* was documented only in summer season at site 3. Among all the Copepod species, *Heliodiaptomus contours* were present only at site 3 (Table 3). The maximum presence and dominance of Copepods at site 3 indicates the availability of nutrients as well as suitable habitat in the form of aquatic vegetation at the site. Burgis (1974) and Illyova and Nemethova (2002) also reported that the community composition of Copepods is influenced by various types of macro-vegetation and water with high contents of nutrients mainly nitrate and phosphate.

Ostracoda contributed maximum 4 species at site 3 and minimum 1 specie at site 1 during summer and post monsoon period respectively (Table 3 and Figure 14). *Stenocypris malcolmsoni* recorded its dominance in summer and post monsoon season at site 3 while *Cypris* sp. was dominant only in summer season. *Cypricercus* sp. belonging to Ostracoda was only documented at site 3 in post monsoon season (Table 3). All the species of Ostracoda recorded from Samrat Ashok Sagar seems to be very sensitive to the sewage pollution. The dominance of *Cypris* sp. and *S. malcolmsoni* also indicates higher pollution level at the site 3. These species have also been documented from eutrophic waters by some Indian workers (Verma and Dalela, 1975; Kulshreshta, 2005; Wanganeo and Wanganeo, 2006). The sequences of dominance of different zooplankton classes were similar at all the selected sites (Figure 14). The less diversity of zooplankton population at site 1 recorded due to the absence of macrophytic vegetation, higher depth and unpolluted waters. while maximum diversity at site 3 was recorded due to the higher nutrient loading by the sewage water of Patra canal. Overall, seasonal qualitative study of Samrat Ashok Sagar revealed that the maximum 79 species of zooplankton were encountered at site 3 followed by 78 species at site 2, 49 species at site 4 and 39 species at site 1 (Figure 15).

A significant variation in zooplankton population depending upon the selected sites was recorded during the present investigation. The maximum diversity (92 species)

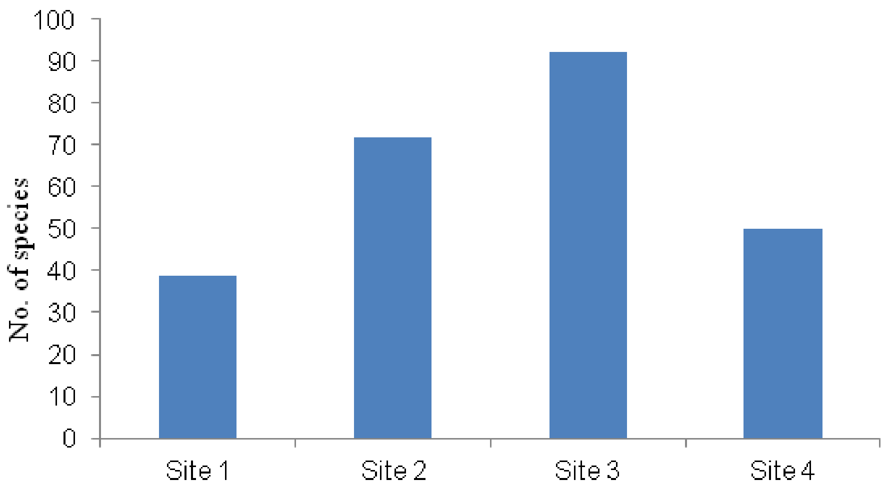

Figure 15. Qualitative distribution of zooplankton at different sites of Samrat Ashok Sagar.

as well as density of zooplankton population was observed at site 3 which was located near Bhainsakheri village of Bhopal district (Figure 15). Also, the site was situated in agricultural land where dense aquatic vegetation was observed during monsoon to winter season when water level is high in the reservoir. After site 3, site 2 was the most populated followed by sites 4 and 1. Various authors reported that the aquatic vegetation supports a greater diversity of planktonic fauna because they offer a larger variety of microhabitats (Edmondson, 1944; Wallace, 1977, 1980; Wanganeo, 1980; Duggan et al., 1998).

In the present study, a positive impact of temperature on the growth of zooplankton population has been noticed. Temperature has been considered as one of the primary factors to cause the abundance of zooplankton in freshwaters particularly in shallow waters where bottom exhibit considerable variations in temperature, especially with the progression of the warm season (Mecombie, 1953; Das, 1956; Bamforth, 1958; Moitra and Bhattacharya, 1965, Ahangar et al., 2012). Tripathi and Tiwari (2006) also reported highest zooplankton population in summer season. It was also observed that seasonal occurrence and distribution of zooplankton diversity at different locations of Samrat Ashok Sagar is influenced by various physico-chemical characteristics which indicates various activities and different land use patterns at different sites. Site 4 has been recognized as highly polluted site due to the sewage interference from Patra sewage canal which covers almost 75% area of Bhopal city. Samrat Ashok Sagar is mainly used for aquaculture practices. Hence, study of zooplankton population in this water body has great importance as they also used to estimate the fishery potential of any aquatic body. Also, the occurrence and abundance of zooplankton may be regarded as a major indicator of the entire environmental status of any water body.

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