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Diversity of macrobenthic populations in Ramsagar reservoir: ecological determinant and taxonomic positions

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Abstract

The structure of benthic community in Ramsagar reservoir was studied in two distinct periods of two years comprised between April, 2003 to March, 2005 which contains the results of an investigation of the relationships between the environmental variables and the taxonomic diversity of common and important groups of benthic macrofauna i.e., Oligochaeta, Hirudinea, Decapoda, Diptera, Hemiptera, Coleoptera, Gastropoda and Pelecypoda. Nutrient and other limnological parameters i.e., water temperature, transparency, electrical conductivity, pH, free carbon dioxide, total alkalinity, total hardness, chloride, calcium, nitrate-nitrogen, phosphates analyses revealed that the reservoir is in advanced eutrophication process and categorized as mesotrphic water body and most important factors controlling the distribution and abundance of the benthic fauna in the reservoir. Bottom fauna of the reservoir was composed by 32 invertebrate species, belonging to the following faunistic groups: Oligochaeta, Hirudinea, Decapoda, Diptera, Hemiptera, Coleoptera, Gastropoda and Pelecypoda. The majority of species showed low densities, being that the gastropoda formed the most important components of benthos densities followed by oligochaetes, whereas, *Vivipara dissimilis* was the dominant taxa, representing 14.04% (2003-04) and 10.02% (2004-05) of total benthos. Comparing both periods, major densities were registered in dry season for most of the taxa. Cluster analysis revealed population densities as group wise distribution which shows relation of the group in which group gastropoda is not related with other group and gone away from other groups. The actual structure of benthic community in Ramsagar reservoir is probably a consequence of the advanced state of environmental degradation.

Keywords: Benthic macroinvertebrates, biodiversity indices, eutrophication, biodiversity, threats to biodiversity.

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1. Intruduction

Benthic macroinvertebrates have been attractive targets of biological monitoring efforts because they are a diverse group of long-lived, sedentary species that react strongly and often, predictably to human influence on aquatic ecosystems (Rosenberg and Resh, 1993). Macroinvertebrates and water quality are also interrelated to each other, as they are a potential indicator of water quality (Sharma and Rawat, 2009). They are most frequently used in bio-monitoring studies because the responses to organic and inorganic pollution have been extensively documented (Thorne and Williams, 1997; Kazanci and Dugal, 2000). They have sensitive life stages that respond to stress and integrate effects of both short-term and long-term environmental stressors (EPA, 1998) and those they are important areas for maintaining biodiversity (Meyer *et al*., 2007; Richardson and Danehy, 2007).

Pollution is an important hazard, which threatens the biology and productivity of this unique ecosystem. A thorough knowledge on the components of the biotic communities of an aquatic environment is of paramount importance for understanding the productivity of such water resources. The benthic macroinvertebrate population may vary in time and space and their diversity within a certain area are clearly related to fertility and productivity of overlying water. Macrobenthos offer several advantages as indicators of environmental quality in both lakes and rivers: as a group, they have worldwide distribution and the species composition and community structure are sensitive to changes in environmental conditions, nutrient enrichment (Sarkar and Choudhury, 1999; Taylor *et al.*, 2000; Jha and Barat, 2003) and different levels of pollution (Holz and Hoagland, 1996; Koteswari and Ramanibai, 2004; El-Bassat and Taylor, 2007). Macrobenthos are also play an important ecological role in lakes and rivers, feeding on non-living organic matter, planktons and bacteria, and in turn being eaten by secondary consumers such as fish (Ayodele and Adeniyi, 2005).

The physico-chemical parameters of an aquatic ecosystem are very important in assessing the composition of any aquatic biota and also their sensitivity to pollution (Ayodele and Adeniyi, 2005). Therefore, a major interest in macrobenthic investigation is to understand environmental factors that influence their diversity (Arimoro *et al.,* 2008). Certain knowledge of the responses of benthos to changes in water quality could therefore constitute an important tool to be used by water managers in India to continually and rapidly assess the health of the water bodies.

2. Material And Methods

2.1 Study Site

Ramsagar, a small man-made reservoir with 140.097 ha water spread area, was built over a Nichroli Nallah in the basin of Sindh river. The reservoir is located approximately 8 km northwest of Datia city in Madhya Pradesh and approximately 80 km south of Gwalior. Geographically, it lies between 25^0 40’ N latitude and 78^0 23’ E longitude and at an altitude of 229 m from mean sea level. Reservoir is used for different purposes like drinking water supply, irrigation, fisheries and thus is true a multipurpose tank. Four sampling stations viz., Station-A, B, C and D were established for macrobenthic and water samples collection covering whole area of reservoir (Fig. 1).

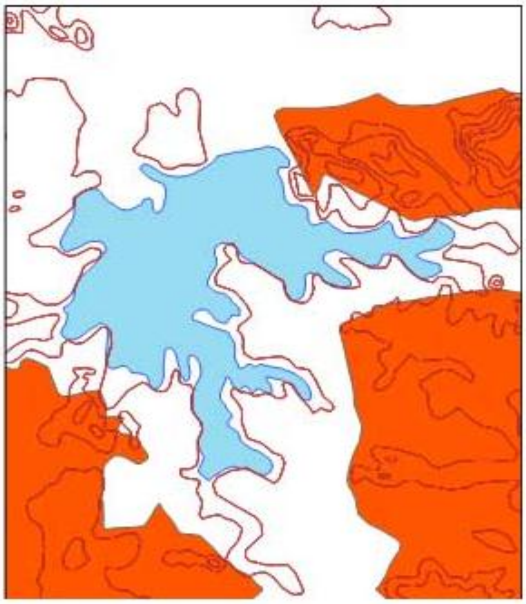

Fig. 1: Study site ‘Ramsagar reservoir, Datia, Madhya Pradesh

2.2 Collection of water and macrozoobenthic samples and their analyses

Monthly samples of sub-surface water in triplicate were collected during first week of each month in the early hours of the day (7 a.m. to 9 a.m.). Iodine treated double stoppard polyethylene bottles were used for collection of water samples. Bottles were kept in ice bucket and brought to the laboratory for analysis. Some of the physico-chemical characteristics of water including water temperature, transparency, pH, free carbon dioxide, total alkalinity, total hardness, chlorides, calcium and magnesium were analyzed at the sampling stations while other parameters including electrical conductivity, nitrate-nitrogen and phosphates were analyzed in the laboratory within the 6 to 8 h following the methods of APHA (1995) and Trivedy and Goel (1986).

The macrozoobenthos samples were collected with D-shaped net and Eckman's grab (from deep profundal zone) followed by the methods of Welch (1952) and Wetzel (2001). Samples were preserved by adding 10% formalin solution for further analysis. In the laboratory, the macrozoobenthos were isolated by several methods as sieving (through 30 no. standard sieves, 11 meshes/cm, 0.589 mm openings) and floatation. After isolating the macrozoobenthos organisms were counted and identified to genus and species level using keys provided by Ward and Whipple (1959), Tonapi (1980), Adoni *et al.* (1985) and Kurian and Sebastian (1982). Finally, various types of diversity indices were analyzed by Past software versions 1.91 (Hammer et al., 2001).

3. Results and Discussion

3.1 Water quality and trophic status of Ramsagar reservoir

The seasonal variations in the physico-chemical characteristics of water is shown in table 1, while, trophic status based on nutrients is depicted in table 2 with the various references. Most of the physico-chemical parameters such as ambient and water temperature, electrical conductivity, total dissolved solids, pH, free carbon dioxide, total alkalinity, total hardness, chlorides, sulphates, nitrate-nitrogen, nitrite-nitrigen, phosphates, silicates, ammonia, sodium and potassium were higher in summer season in both years of study periods. However, a number of parameters like depth and turbidity in monsoon, transparency, dissolved oxygen, total hardness, calcium and magnesium in winter season were high during study periods (Table 1). Based on range of various water quality parameters and values of different indices like transparency (Lee et al., 1981), electrical conductivity (Olsen, 1950), total alkalinity (Spence, 1964), Calcium (Ohle, 1934), nitrate-nitrogen (Vollenweider, 1964) and phosphates (Lee et al., 1981) with suggested trophic status (Table 2), it is concluded that, the Ramsagar reservoir is measured as mesotrophic water body with slightly rich amount of nutrients which may be due to agricultural practices being done by farmers in surrounding catchments area of this reservoir.

3.2 Macrobenthos species composition

Table 3 representing macrobenthic species recorded in Ramsagar reservoir and their seasonal fluctuations. 32 species of macrozoobenthos were recorded in the Ramsagar reservoir representing 09 species of annelids in which 06 species belong to order Oligochaeta (*Chaetogaster langi*, *Dero digitata*, *Dero dorsalis*, *Tubifex tubifex*, *Branchiura sowerbyi Limnodrilus socialis*) and 03 species to order Hirudinea (*Glossiphonia weberi*, *Glossiphonia complanata* and *Herpobdella hexaculata*) were recorded in the reservoir. Total number of arthropod were 10 in which 01 species from crustacea (*Macrobrachium rosenbergii*) and 09 species to class insecta representing 01 species of Diptera (*Chironomus* (*Tendipes*), 06 species of Hemiptera (*Corixa hieroglyphica*, *Notonecta undulate*, *Lithocerus indicum*, *Sphaerodema rusticum*, *Nepa cinerea* and *Ranatra elongate*). 13 species were from phylum mollusca in which, 12 species from gastropods (*Melania scabra*, *M. striatella*, *M. scabra var elegans*, *Faunus ater*, *Vivipara dissimilis*, *Zootecus chion*, *Opeas gracile*, *Planorbis exustus*, *Anisus convexiusculus*, *Lymnaea acuminate*, *L. luteola*, *L. pinguis* and 01 species (*Lamellidens corrianus*) belongs to class pelecypoda.

Table -1: Seasonal fluctuations in the physico-chemical characteristics of water of Ramsagar reservoir

S. No.	Parameters	Units	2003-2004 Winter season	Summer season	Monsoon season	2004-2005 Winter season	Summer season	Monsoon season	Average Water quality
1.	Ambient temperature	^0C	25.58	34.28	28.01	23.71	30.11	26.59	28.04
2.	Water temperature	^0C	21.57	29.86	25.51	19.21	24.70	22.83	23.946
3.	Depth	m	4.52	3.35	5.035	4.62	3.55	6.98	4.67
4.	Transparency	cm	103.74	100.45	88.97	88.88	85.16	80.03	91.20
5.	Electrical conductivity	µS/cm	182.35	209.46	145.39	159.94	228.88	166.08	182.01
6.	Turbidity	NTU	4.71	5.96	7.84	5.88	7.22	11.72	7.22
7.	Total dissolved solids	mgl^{-1}	173.84	201.12	183.28	203.31	221.43	192.03	195.83
8.	pH	-	8.28	8.55	8.34	7.88	8.71	7.77	8.25
9.	Dissolved oxygen	mgl^{-1}	9.49	7.74	8.64	9.87	7.02	8.22	8.49
10.	Free carbon dioxide	mgl^{-1}	2.20	0.00	3.71	1.80	2.20	3.02	2.15
11.	Total alkalinity	mgl^{-1}	102.21	114.24	94.03	104.34	128.65	80.65	104.02
12.	Total hardness	mgl^{-1}	68.06	41.37	49.81	56.12	51.81	50.87	53.00
13.	Chlorides	mgl^{-1}	15.52	16.4	16.42	17.52	19.62	14.88	16.72
14.	Calcium	mgl^{-1}	22.96	13.317	16.82	21.58	21.50	16.25	18.73
15.	Sulphates	mgl^{-1}	3.23	5.21	4.03	5.34	7.03	4.65	4.91
16.	Nitrate-nitrogen	mgl^{-1}	0.016	0.021	0.018	0.022	0.024	0.019	0.020
17.	Nitrite-nitrogen	mgl^{-1}	0.009	0.010	0.012	0.015	0.019	0.013	0.013
18.	Phosphates	mgl^{-1}	0.018	0.028	0.014	0.020	0.035	0.018	0.022
19.	Silicates	mgl^{-1}	3.087	3.48	5.492	4.307	7.40	6.267	5.005
20.	Ammonia	mgl^{-1}	0.19	0.44	0.372	0.297	0.597	0.165	0.343
21.	BOD	mgl^{-1}	2.082	2.202	1.515	1.687	3.27	1.115	1.978
22.	COD	mgl^{-1}	5.25	8.925	7.975	6.80	14.07	6.16	8.196
23.	Magnesium	mgl^{-1}	2.532	1.947	1.955	3.62	2.94	2.56	2.592
24.	Sodium	mgl^{-1}	26.952	30.222	26.12	25.38	28.61	19.06	26.057
25.	Potassium	mgl^{-1}	2.912	3.62	2.537	2.50	4.00	3.12	3.114

Table- 2: Trophic status of the Ramsagar reservoir on the basis of different indices

S. No.	Parameters	Unit	Water quality of Ramsagar reservoir	Trophic status of Ramsagar reservoir	References
1.	Water temperature	^0C	15.92-31.87	Meso-thermal	Lee *et al.* (1981)
2.	Transparency	cm	66.59-116.00	Eutrophic	Lee *et al.* (1981)
3.	Electrical Conductivity	µS/cm	108-246.30	Mesotrophic	Olsen (1950)
4.	pH	-	7.41-8.95	Alkaliphilous	Venkateswarlu (1983)
5.	Free carbon dioxide	mgl^{-1}	Nil-6.32	Soft	Reid & Wood (1976)
6.	Total alkalinity	mgl^{-1}	64.25-146.25	Productive with rich nutrient	Alikunhi (1957) Spence (1964)
7.	Total hardness	mgl^{-1}	34.00-75.25	Soft water	Sawyer (1960)
8.	Chlorides	mgl^{-1}	13.13-22.36	No Pollution	Unni (1983)
9.	Calcium	mgl^{-1}	11.21-33.81	Medium to rich	Ohle (1934)
10.	Nitrate-nitrogen	mgl^{-1}	0.011-0.033	Oligo-mesotrophic	Vollenweider (1968)
11.	Phosphates	mgl^{-1}	0.013-0.054	Mesotrophic	Lee *et al.* (1981)
Overall trophic status of Ramsagar reservoir			Mesotrophic		

3.3 Spatial distribution of abundance, biomass of species, macrozoobenthic diversity

Seasonal fluctuations of various species have been shown in table 3, table 4 showing seasonal variations of group biomass, while species composition percentage exposed in table 5. Similarly, year wise group biomass percentages covered in table 6. Gross total of macrozoobenthos represents a minimum density of 93 org/m^2 and 74 org/m^2 in monsoon season and maximum of 450 org/m^2 and 370 org/m^2 in summer season during 2003-04 and 2004-05 respectively. Out of macrozoobenthos group recorded, the greatest density was that of Mollusca, which ranges up to 455 org/m^2/year followed by Annelida 121 org/m^2/year, insecta 114 org/m^2/year and crustacea 62 org/m^2/year.
The largest contribution was that of Gastropoda ranging up to 56.91% of total macrozoobenthos,

this is followed by Oligochaeta 14.78%, Hemiptera 8.42%, Decapoda 8.24%, Diptera 5.40% and Coleoptera 4.13% (Table 6). The above data represents the ecological compositions of the respective animal groups in the shallower profundal zone. A brief consideration of the seasonal variation and periodicity of various macrozoobenthic groups throughout the study period given here with a view of emphasizing their relative importance in their contribution to the bottom fauna composition.

The density of Oligochaetes was ranged between 05 to 63 org/m^2 with minimum density in monsoon season and maximum density in summer season. The contribution of Oligochaetes species to the total macrozoobenthic fauna in the order of dominance were recorded as *Branchiura sowerbyi*, *Tubifex tubifex*, *Chaetogaster langi*, *Limnodrilus socialis*, *Dero digitata* and *Dero dorsalis*. The Hirudinea group was represented by 03 species in this reservoir i.e., *Glossiphonia complanata*, *Glossiphonia weberi* and *Herpobdella hexaculata*.

Decapoda was represented by only one species i.e., *Macrobrachium rosenbergii* and it had contributed 3.13 8.24% of total macrozoobenthos species. The density of Decapoda ranged between 08 org/m^2 to 24 org/m^2 with maximum density 24 org/m^2 was recorded in winter and summer season and contributed 8.24% biomass density. The group Diptera was represented by one species viz., *Chironomus sp.* It has contributed 3.13% of the total macrobenthic species composition and 5.31% of the total macrozoobenthic population in the reservoir. Hemiptera represented by 06 species i.e., *Sphaerodema rusticum*, *Notonecta undulata*, *Corixa hieroglyphica*, *Nepa cinerea*, *Ranatra elongata* and *Lithocerus indicum* and as a whole it contributed 8.42% of the total macrozoobenthic population in the reservoir while density was from 02 to 43 org/m^2 with minimum in monsoon and maximum summer season. Coleoptera contributed 2.92% of the total macrozoobenthos biomass and density varied from 01 to 18 org/m^2 with a maximum in summer season. Amongst the Coleopteran population, the dominancy as *Hydrophilus indicus* and *Dytiscus marginalis* while group diversity of species was 6.25% of the total species.

Gastropoda was ranged between 25 to 48 org/m^2 with maximum density in summer and minimum in monsoon season and amongst them *Vivipara dissimilis* was most dominant and contributed 14.04% of the total macrozoobenthic species followed by *Faunus ater*, *Lymnaea acuminata*, *Zootecus chion*, *Melania striatella*, *Opeas gracile*, *Planorbis exustus*, *Lymnaea pinguis*, *Melania scabra var elegans*, *Lymnaea luteola*, *Melania scabra* and *Anisus convexiusculus*. Pelecypoda group represented by 01 species viz., *Lamellidens corrianus* and it contributed 5.32% of the total macrobenthic fauna, whereas, biomass wise it contributed 5.40% of total macrozoobenths in 2004-05 with a maximum density as 34 org/m^2 during summer season.

3.4 Relationship of macrobenthos distribution with environmental factors

The relationship found between physico-chemical characteristics and the density of macrozoobenthic fauna were studied and has been summarized in Table 8. The relationships found between physic-chemical characteristics and the density of macrobenthic invertebrate fauna were studied and has been summarized in Table 3. Annelida showed a significant positive correlation with air temperature and a negative correlation with bicarbonates and Ca^{2+}. However, Arthropods showed a positive correlation with FCo2 and bicarbonates and negative correlation with air and water temperature. Mollusca were found negatively correlated with bicarbonates.

The correlations between total diversity of the analyzed benthic fauna and the values of environmental parameters were highly divergent. It did not correlate with pH, conductivity, hardness, concentrations of oxygen, ortho-phosphates, nitrates, ammonia, chloride, anionic surfactants and sulphide, or with Ext/Int and DeBS indices. It seems to be generally positively correlated with the diversity of riparian vegetation and negatively correlated with the degradation of riparian vegetation and the distance to the nearest standing water-body (Tab. 4).

Table- 3: Seasonal fluctuations in macrozoobenthic fauna (organisms/m^2) in Ramsagar reservoir, during April, 2003 to March, 2005

PHYLUM Class Order	FAMILY Genus & species	2003-2004 Winter season	 Summer season	 Monsoon season	2004-2005 Winter season	 Summer season	 Monsoon season
ANNELIDA							
Oligochaeta	**NAIDIDAE**						
Plesiopora							
	Chaetogaster langi (Bretscher)	04	10	02	02	12	01
	Dero digitata (Muller)	01	02	-	02	04	01
	Dero dorsalis (Oken)	-	01	-	01	02	-
	TUBIFICIDAE						
	Tubifex tubifex (Muller)	10	18	06	06	10	01
	Branchiura sowerbyi (Beddard)	14	26	06	16	24	02
	Limnodrilus socialis (Steph)	01	06	-	01	04	-
Hirudinea	**GLOSSIPHONIIDAE**						
Rhynchobdellida							
	Glossiphonia weberi (Blanchard)	01	03	-	01	02	01
	Glossiphonia complanata (Linnaeus)	02	14	-	01	03	-
Arhynchobdellida	**ERPOBDELLIDAE**						
	Herpobdella hexaculata (Kaburaki)	-	02	-	01	02	-
ARTHROPODA							
Crustacea							
Decapoda							
	Macrobrachium rosenbergii (De)	24	24	14	15	22	08
Insecta	**TENDIPEDIDAE (CHIRONOMIDAE)**						
Diptera							
	Chironomus (Tendipes) (Meigen)	12	18	10	12	18	04
Hemiptera	**CORIXIDAE (WATER BOATMANS)**						
	Corixa hieroglyphica (Duff.)	02	10	-	01	06	-
	NOTONECTIDAE (BACK-SWIMMERS)						
	Notonecta undulata (Linnaeus)	06	12	-	02	08	-
	BELOSTOMATIDAE (GIANT WATER BUGS)						
	Lithocerus indicum (Lepel. and Serv.)	-	01	-	01	04	01
	Sphaerodema rusticum (Fabricius)	02	12	02	04	18	01
	NEPIDAE (WATER SCORPIONS)						
	Nepa cinerea (Linnaeus)	02	06	-	02	04	01
	Ranatra elongata (Fabricius)	-	02	-	1	02	-
Coleoptera	**DYTISCIDAE (DIVING BEETLES)**						
	Dytiscus marginalis (Linnaeus)	02	06	01	04	08	01
	HYDROPHILIDAE						
	Hydrophilus indicus (Bedel)	04	08	01	03	10	01
MOLLUSCA							
Gastropoda	**MELANIIDAE (TIARIDAE)**						
Mesogastropoda							
	Melania (Plotia) scabra (Muller)	08	16	03	02	12	02
	Melania (Plotia) striatella (Muller)	10	22	04	04	12	06
	Melania (Plotia) scabra var elegans (Hutton)	06	16	04	08	14	02
	Faunus ater (Linnaeus)	12	18	06	16	20	02
	VIVIPARIDAE						
	Vivipara dissimilis (Muller)	36	58	12	24	32	08
Basommatophora	**SUBULINIDAE**						
	Zootecus chion (Pfeiffer)	16	24	04	06	10	02
	Opeas gracile (Hutton)	12	21	02	10	14	-
	PLANORBIDAE						
	Planorbis(Indoplanorbis) exustus (Deshayes)	08	24	02	02	12	07
	Anisus(Gyraulus) convexiusculus (Hutton)	06	18	02	02	12	04
	LYMNEIDAE						
	Lymnaea (Pseudosuccinea) acuminata (Walker)	10	18	06	12	19	07
	Lymnaea (Pseudosuccinea) luteola (Walker)	03	08	01	06	14	03
	Lymnaea (Pseudosuccinea) pinguis (Walker)	02	08	02	06	14	08
Pelecypoda	**UNIONIDAE**						
Eulamellibranchia							
	Lamellidens corrianus (Lea)	06	18	03	12	22	-

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Table -4: Year wise seasonal macrobenthic group diversity

S. No.	Groups	Units	2003-2004 Winter season	Summer season	Monsoon season	2004-2005 Winter season	Summer season	Monsoon season	Average
1.	Oligochaeta	Org/m^2	2.00	10.50	4.66	4.66	9.33	1.25	6.069
2.	Hirudinea	Org/m^2	1.50	6.33	0.00	1.00	2.33	1.00	2.027
3.	Decapoda	Org/m^2	24.00	24.00	14.00	15.00	22.00	8.00	17.83
4.	Diptera	Org/m^2	12.00	18.00	10.00	12.00	18.00	4.00	12.33
5.	Hemiptera	Org/m^2	3.00	7.16	2.00	1.83	7.00	1.00	3.66
6.	Coleoptera	Org/m^2	3.00	7.00	1.00	3.50	9.00	1.00	4.083
7.	Gastropoda	Org/m^2	10.75	20.916	4.00	8.16	15.41	4.63	10.64
8.	Pelecypoda	Org/m^2	6.00	18.00	3.00	12.00	22.00	0.00	12.20

Table - 5: Macrozoobenthic group diversity & percentage composition

S. No.	Group Name	Number of species recorded	Percentage
1.	Oligochaeta	6	18.75
2.	Hirudinea	3	9.35
3.	Decapoda	1	3.13
4.	Diptera	1	3.13
5.	Hemiptera	6	18.75
6.	Coleoptera	2	6.25
7.	Gastropoda	12	37.5
8.	Pelecypoda	1	3.13
Total		**32**	**100%**

Table - 6: Years wise macrozoobenthic group biomass & their percentage composition

S. No.	Groups	No. of individuals 2003-2004	%	No. of individuals 2004-2005	%
1.	Oligochaeta	109	14.49	93	14.78
2.	Hirudinea	12	1.59	11	1.59
3.	Decapoda	62	8.24	45	7.15
4.	Diptera	40	5.31	34	5.40
5.	Hemiptera	52	6.91	53	8.42
6.	Coleoptera	22	2.92	26	4.13
7.	Gastropoda	428	56.91	334	53.10
8.	Pelecypoda	27	3.59	34	5.40

The correlation between diversity and pollution has different direction and strength in various taxa. The Spearman's correlation between stream morphology, diversity of riparian vegetation, pollution and the distance to the nearest standing water-body and various metrics expressing the taxonomic diversity of groups of fauna were found highly significant (Tab. 4). Three groups of taxa were featured on the basis of strength and direction of the relation between their diversity and the values of environmental parameters. In the first group, the diversity of Gastropoda and Hirudinea increased with the increasing of pollution index and decreased at deeper sites and at sites removed from water-bodies. The diversity of only those two taxa significantly differed as a result of seasonality. In the second group, the diversity of larval Chironomidae and Ephemeroptera are correlated with the diversity and degradation of riparian environments. The diversity of larval Odonata, being a third group, was higher in wider streams and lower when the distance to the nearest standing water-body increased.

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Table -7: Macrozoobenthic species diversity percentage compositions in Ramsagar reservoir

S. No.	Species	No. of Individuals 2003-04	%	No. of individuals 2004-05	%
1.	*Chaetogaster langi*	16	2.11	15	2.34
2.	*Dero digitata*	03	0.39	07	1.09
3.	*D. dorsalis*	01	0.13	03	0.46
4.	*Tubifex tubifex*	34	4.50	17	2.66
5.	*Branchiura sowerbyi*	46	6.09	42	6.57
6.	*Limnodrilus socialis*	07	0.92	05	0.78
7.	*Glossiphonia weberi*	04	0.53	03	0.46
8.	*G. complanata*	06	0.79	04	0.62
9.	*Herpobdella hexaculata*	02	0.26	03	0.46
10.	*Macrobrachium rosenbergii*	62	8.21	45	7.04
11.	*Chironomus (Tendipes)*	40	5.29	44	6.88
12.	*Corixa hieroglyphica*	12	1.58	07	1.09
13.	*Notonecta undulata*	18	2.38	10	1.56
14.	*Lithocerus indicum*	01	0.13	06	0.93
15.	*Sphaerodema rusticum*	16	2.11	23	3.59
16.	*Nepa cinerea*	08	1.06	07	1.09
17.	*Ranatra elongata*	02	0.26	03	0.46
18.	*Dytiscus marginalis*	09	1.19	13	2.03
19.	*Hydrophilus indicus*	13	1.72	14	2.19
20.	*Melania (Plotia) scabra*	27	3.57	16	2.50
21.	*M. striatella*	36	4.76	22	3.44
22.	*M. scabra var elegans*	26	3.44	24	3.75
23.	*Faunus ater*	36	4.76	38	5.94
24.	*Vivipara dissimilis*	106	14.04	64	10.0
25.	*Zootecus chion*	44	5.82	18	2.81
26.	*Opeas gracile*	35	4.63	24	3.75
27.	*Planorbis exustus*	34	4.50	21	3.28
28.	*Anisus convexiusculus*	26	3.44	18	2.81
29.	*L. acuminata*	34	4.50	38	5.94
30.	*L. luteola*	12	1.58	23	3.59
31.	*L. pinguis*	12	1.58	28	4.38
32.	*Lamellidens corrianus*	27	3.57	34	5.32

Table -8: Various diversity indices of based on season fluctuations at species level

Diversity Indices	Winter 2003-04	Summer 2003-04	Monsoon 2003-04	Winter 2004-05	Summer 2004-05	Monsoon 2004-05
Taxa_S	28	32	21	32	32	23
Individuals	222	450	93	186	370	74
Dominance_D	0.06891	0.05015	0.07827	0.06203	0.04408	0.07232
Simpson_1-D	0.9311	0.9498	0.9217	0.938	0.9559	0.9277
Shannon_H	2.952	3.189	2.766	3.036	3.254	2.828
Evenness_e^H/S	0.6836	0.7583	0.7565	0.6504	0.809	0.7354
Brillouin	2.746	3.05	2.45	2.781	3.089	2.439
Menhinick	1.879	1.508	2.178	2.346	1.664	2.674
Margalef	4.998	5.074	4.412	5.932	5.242	5.111
Equitability_J	0.8858	0.9202	0.9084	0.8759	0.9388	0.902
Fisher_alpha	8.478	7.876	8.449	11.14	8.405	11.44
Berger-Parker	0.1622	0.1289	0.1505	0.129	0.08649	0.1081

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Table -9: Correlation coefficient (r) between macrobenthos with physic-chemical parameters

	Oligochaeta	Hirudinea	Decapoda	Diptera	Hemiptera	Coleoptera	Gastropoda	Pelecypoda
AT	0.81	0.83	0.48	0.62	0.83	0.62	0.76	0.56
WT	0.70	0.72	0.36	0.47	0.68	0.42	0.60	0.36
Depth	-0.83	-0.62	-0.89	-0.98	-0.84	-0.82	-0.82	-0.87
Trasp.	0.18	0.49	0.79	0.47	0.34	0.18	0.52	0.19
EC	0.72	0.69	0.70	0.77	0.92	0.94	0.87	0.84
Turb.	-0.34	-0.31	-0.82	-0.69	-0.40	-0.40	-0.51	-0.49
TDS	0.70	0.34	0.12	0.55	0.60	0.78	0.48	0.80
pH	0.78	0.51	0.78	0.84	0.87	0.75	0.70	0.70
DO	-0.60	-0.47	-0.18	-0.41	-070	-0.63	-050	-050
FCO_2	-0.65	-0.92	-064	-0.68	-0.68	-065	-0.89	0.68
TA	0.83	0.52	0.78	0.96	0.88	0.95	0.79	0.96
TH	-0.64	-0.54	0.14	-0.23	-0.41	-0.29	-0.34	-0.31
Cl^-	0.67	0.10	0.36	0.70	0.58	0.76	0.39	0.81
Ca^{++}	-0.30	-050	0.22	0.08	-015	0.80	-017	0.10
SO_4^{2-}	0.69	0.30	0.12	0.54	0.60	0.77	0.45	0.78
NO_3^--N	0.70	0.33	0.11	0.55	0.55	0.74	0.46	079
NO_2^--N	0.31	-0.22	-0.17	0.21	0.21	0.46	-0.01	0.48
PO_4^{3-}	0.81	0.62	0.56	0.78	0.89	0.97	0.80	0.92
SiO2	0.10	-0.34	-0.43	-0.13	0.05	0.16	-0.25	0.09
NH_3	0.90	0.41	0.47	0.81	0.81	0.82	0.60	0.84
BOD	0.71	0.41	0.76	0.86	0.85	0.92	0.72	0.87
COD	0.78	0.30	0.35	0.68	0.76	0.81	0.51	0.78
Mg	-0.16	-0.33	-0.15	-0.02	-0.21	0.13	-0.15	0.22
Na	0.79	0.60	0.89	0.95	0.81	0.72	0.78	0.77
K	0.67	0.65	0.48	0.60	0.85	0.84	0.75	0.70

Note: *Significantly deferent at $p<0.05$ & **Significantly different at $p<0.01$. **Abbreviations:** AT= Ambient Temperature, WT= Water Temperature, Trans=Transparency, TDS=Total Dissolved Oxygen, FCO_2= Free Carbon Dioxide, TA=Total Alkalinity, TH=Total Hardness, Cl^-= Clorides, Ca^{++}= Calcium, SO_4^{2-}= Sulphates, NO_3^-N= Nitrate-Nitrogen, NO_2^-N= Nitrite-nitrogen, PO_4^{3-} =phosphates, SiO_2=Silicates, NH_3=Ammonia, Mg= Magnesium, Na= Sodium and K= Potassium.

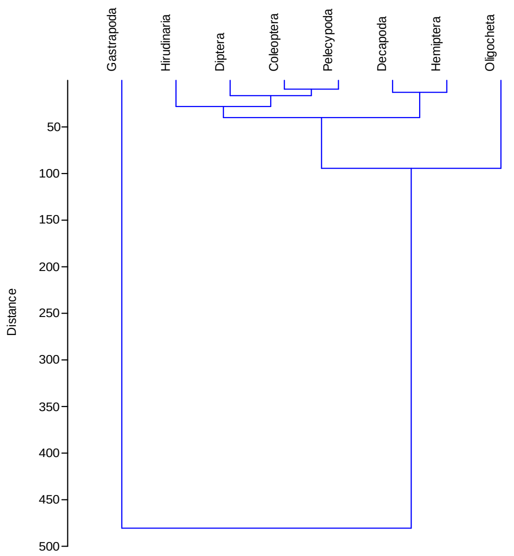

Fig. 2: Dendrogram based on paired algorithm of Euclidean to showing distance matrix between various groups

3.4 Cluster analysis

Comparing both periods, major densities were registered in dry season for most of the taxa. Cluster analysis revealed population densities as group wise distribution which shows relation of the group in which group gastropoda is not related with other group and gone away from other groups. The actual structure of benthic community in Ramsagar reservoir is probably a consequence of the advanced state of environmental degradation.

4. Discussion

Macrozoobenthic fauna encompasses a large component of the secondary productivity of lake and reservoir ecosystems. They plays significant role in the aquatic community. Macrozoobenthos are involved in the mineralization and recycling of organic matter. Macrozoobenthos are especially useful in the assessment of pollution and water quality. They play an important role in the decomposer food chain which in turn affects the cycling of minerals (Pandit, 1980). It is well known that the distribution density and biomass of benthic organisms depend upon (i) the physico-chemical characteristics of water (ii) the nature of sediments and (iii) the biological complexes such as food predation and other factors (Shukla, 1995). The composition, abundance and distribution of benthic organisms over a period of time provide an index of the ecosystems. The importance of bottom living organisms and their significant role in the trophic cycle of a water body was recognized quite early (Hora, 1936). The abundance of benthic fauna greatly depends on physical and chemical properties of the substratum (Jindal and Singh, 2005). Benthic macro-invertebrates can be used as a barometer of overall biodiversity in aquatic ecosystems (Anitha *et al.*, 2004). Both lentic and lotic environments, the study of benthos is important as these constitute the main bulk of food of bottom feeding fishes, and they are relatively less exposed to environmental fluctuations than the organisms on the surface water. Thus serving as better bio-indicators of ecological conditions of an aquatic habitat.

Aquatic organisms constitute a vital link in the food chain in the aquatic ecosystem and its productivity directly depends on physico-chemical features of water (Kaushik and Saksena, 1991a). Hence, knowledge on abundance, composition and seasonal variation of aquatic communities helps in planning and successful management of a water body.

In the present study, 32 species of macrozoobenthos were identified. The total macrozoobenthic organisms varied from 93 org/m^2 to 450 org/m^2 in shallow profundal zone during 2003-2004 while during 2004-2005 macrozoobenthic organisms varied from 74 organisms/m^2 to 370 organisms/m^2. Maximum macrozoobenthic density as 450 org/m^2 was observed during summer season, 2003 while minimum as 74 organisms/m^2 recorded in monsoon season during, 2005 in shallow profundal zone. Pahwa (1979) reported the average benthic production as 3, 476 organisms/m^2 with maximum population in June and minimum in August and September in Ganga river. Gupta (1976) reported macrozoobenthic density ranged from 1, 829.49 org/m^2 to 2, 386.51 org/m^2 in Loni reservoir, Rewa, Madhya Pradesh. Malhotra *et al.* (1996) reported macro-invertebrates fauna varied from 75 org/m^2 to 165 org/m^2 with maximum density in summer season in a fish pond at Jammu. Prasad and Singh (2003) observed maximum macrozoobenthos in summer (May) and minimum in spring (February) in a tropical water body. Jindal and Singh (2005) reported macrobenthic density from 15 org/m^2 to 85 organisms/m^2 with maximum density during summer season.

The freshwater annelids recorded from India are from the classes Oligochaeta and Hirudinea. Oligochaeta (aquatic earthworms) are truly aquatic earthworms are common in mud and debris of stagnant pools, ponds, reservoirs and lakes (Tonapi, 1980). Oligochaetes are typically segmented, bilaterally symmetrical, hermaphrodite annelids with an anterior ventral mouth and a posterior anus (Wetzel, 2001). In the present study, Oligochaeta population contributed 14.78% of total macrozoobenthos at Ramsagar reservoir with maximum density of 63 org/m^2 in summer season during 2003 while minimum density of 05 organisms/m^2 in monsoon season during 2005. Maximum Oligochaetes have been observed during summer months which may be the result of higher concentration of organic matter present in the deeper zones of the reservoirs (Shukla, 1995). Dutta and Malhotra (1986) observed the maximum development of Oligochaetes in summer. Decline in Oligochaeta organisms recorded in monsoon period, it may be due to the effect of increased turbidity and water level. During the period of present investigation, *Branchiura sowerbyi* (6.09%) exists as the most dominant species. *Tubifex tubifex* was second dominant with 4.50% in order of dominance followed by *Chaetogaster langi* (2.11%), *Limnodrilus socialis* (0.92%), *Dero digitata* (0.92%) and *Dero dorsalis* (0.47%). Class Hirudinea was represented by 3 species (*Glossiphonia complanata*, *Glossiphonia weberi* and *Herpobdella hexaculata*) and contributed 1.59% of total macrozoobenthos at Ramsagar reservoir. The season and periodicity of the leeches showed their dominant population as 19 organisms/m^2 in the summer season during, 2003.

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Maximum density of Hirudinea in summer season may be due to the breeding season of this group (Shukla, 1995). Similar observations were made by Gupta (1976), Rao *et al.* (1992), Malhotra *et al.* (1996), Kumar (1997), Shah and Pandit (2001) and Anitha *et al.* (2004).

Decapoda population contributed 8.24% of the total macrozoobenthos in the Ramsagar reservoir. This group was represented by one species viz., *Macrobrachium rosenbergii.* The density of same was ranged between 08 organisms/m^2 to 24 organisms/m^2 with maximum as 24 organisms/m^2 in winter and summer season. Similar seasonal variations were observed by Rao (1993). The group Diptera was represented by one species viz., *Chironomus sp.* (5.29%). The group Diptera constitutes 5.31% of total macrozoobenthic density ranged from 04 to 18 organisms/m^2 at shallow profundal zone. The maximum density was reported during summer months due to their tolerance to high concentration of physico-chemical characteristics and enrichment nutrients, while minimum in monsoon months due to increased level of water and dilution of nutrients. Similar findings were also made by Kaushik *et al.* (1990) in pond water at Gwalior. According to Hynes (1970), chironomid larvae are considered as the common inhabitants of mud, rich in organic matter and can tolerate high concentration of salts, sulphuriated hydrogen and ammonia. The population of Hemiptera contributed 8.42% of total macrozoobenthic population in Ramsagar reservoir and represented by six species *viz.*, *Sphaerodema rusticum* (3.60%), *Notonecta undulata* (2.38%), *Corixa hieroglyphica* (1.58%), *Nepa cinerea* (1.06%), *Ranatra elongata* (0.26%) and *Lithocerus indicum* (0.13%). Among the Hemiptera population *Sphaerodema rusticum*, *Nepa cinerea* and *Lithocerus indicum* were recorded throughout the year, while *Corixa hieroglyphica*, *Ranatra elongata* and *Notonecta undulata* were recorded in winter and summer months. The density of this group ranging from 02 to 43 organisms/m^2 with maximum density in summer season during, 2003. According to Tonapi (1980) temperature and rainfall affects the population fluctuation in Hemiptera. In the present study, Hemiptera showed favored environment status in summer and winter months. Group Coleoptera represented by its two species viz., *Hydrophilus indicus* (2.19%) and *Dytiscus marginalis* (1.72%) and contributed 2.92% of the total macrozoobenthos at Ramsagar reservoir. The density varied between 01 and 18 organisms/m^2 with a maximum in summer season during 2004-2005.

Phylum Mollusca is represented in freshwater by only two classes, Gastropoda and Pelecypoda (Tonapi, 1980; Mackie, 1998) and a group of most diverse and dominant benthic fauna in water bodies. They perform a key role in the functioning of aquatic ecosystems. In the Ramsagar reservoir, Gastropoda was represented by 12 species and recorded throughout the year. The density of this group was ranged between 48 and 251 organisms/m^2 with maximum density in summer and minimum in monsoon season. Amongst the Gastropoda group *Vivipara dissimilis* was the most dominant and contributed 14.04% of the total macrozoobenthic population in Ramsagar reservoir followed by *Faunus ater* (5.95%), *Lymnaea (Pseudosuccinea) acuminata* (5.95%), *Zootecus chion* (5.82%), *Melania (Plotia) striatella* (4.76%), *Opeas gracile* (4.63%), *Planorbis (Indoplanorbis) exustus* (4.50%), *Lymnaea (Pseudosuccinea) pinguis* (4.38%), *Melania (Plotia) scabra var elegans* (3.76%), *Lymnaea (Pseudosuccinea) luteola* (3.60%), *Melania (Plotia) scabra* (3.57%) and *Anisus (Gyraulus) convexiusculus* (3.44%). Similar observations were made by Rao *et al.* (1987) in Gandhisagar reservoir, Choubisa (1992) in some lentic and lotic environments at southern Rajasthan, Bath *et al.* (1999) in Harike reservoir, Singh and Saxena (2001) in a village pond near Bikaner, Prasad and Singh (2003) in a tropical water body, Anitha *et al.* (2004) in Mir-Alam lake, Andhra Pradesh and Jindal and Singh (2005) in some freshwater ecosystem of Punjab. The density and growth of Gastropoda was higher in the shallow regions during summer while minimum in deeper zones. This may be availability of macrophytic vegetation, food, high concentration of dissolved oxygen and optimum range of pH and alkalinity (Dutta and Malhotra, 1986). The population of Pelecypoda was represented by one species (*Lamellidens corrianus*) and it contributed 5.32% of the total macrobenthic fauna in Ramsagar reservoir. The group Pelecypoda abundant in relatively shallow

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zones, which may be attributed to the presence to weeds as they offer both food and shelter. Gupta (1976) and Rao (1987) stated that occurrence and abundance of this group is greatly influenced by pH and dissolved oxygen in addition to the food which is important.

Goel and Shrivastava (1981) observed 09 species of molluscs in Gwalior region. Ahmed and Singh (1989) observed 20 species of macro-invertebrates in lentic and 32 species in lotic environment and it was observed that the chief components of the bottom organisms were Polychaetes, Oligochaetes, insects and molluscs. Malhotra *et al.* (1996) observed 12 species of macro-invertebrates in a fish pond of Jammu. Kumar (1997) observed 22 species of macro-zoobenthos from river Mayurakshi and 21 species of zoobenthos in a pond at Dumka respectively. Biswas *et al.* (1998) observed 14 species of macrozoobenthos in river Damodar. Bath *et al.* (1999) observed 39 species of molluscs in Harike reservoir. Shah and Pandit (2001) observed 07 species of macro-invertebrates in various freshwater bodies of Kashmir. Singh and Saxena (2001) observed 04 species of Gastropoda in a village pond at Bikaner, Rajasthan. Anitha *et al.* (2004) observed 17 species of macrozoobenthos in Mir Alam lake, Hyderabad, Andhra Pradesh. Jindal and Singh (2005) observed 22 species of macrozoobenthos in some freshwater ecosystems of Punjab. If present study is comparing with above workers, the Ramsagar reservoir is also very rich macrozoobenthic faunal diversity with 32 species of macrozoobenthos.

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