Original Research Article

Zooplankton Diversity and Limnological Parameters in River Sal, Goa

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Abstract: Water is the key substance for the survival of all living organisms. The quality of water in terms of physicochemical parameters affect the conditions for the existence of zooplankton. India is blessed with thousands of water bodies, both large and small, ranging from pond to large lakes, rivers and streams of lentic or lotic nature. Despite several studies, still a large number of them are virgin and yet to be studied. Hence studies on the diversity and seasonal abundance of zooplankton in river Sal, one of the lesser known rivers of Goa was carried out. Analyses of physicochemical parameters showed the following range: Temperature (24.5-30°C), pH (6.60-8.0), EC (17782-52845), total alkalinity (36.03-1188.33mg/l), DO (3.96-7.10mg/l), turbidity (10.35-34.12NTU), nitrates, (0.07-1.94 mg/l), phosphates (0.01-0.19 mg/l), calcium (15.76-1438 mg/l) and magnesium (1.93-240 mg/l). A total of 30 species belonging to Cladocera (10 sps.), Copepoda (9 sps.), Rotifera (9 sps.) and Ostracoda (2 sps.) were identified. Rotifers showed dominance in number followed by Copepoda, Cladocera and Ostracoda. The percentage of zooplankton population was highest (45%) during the pre-monsoon and lowest (22%) during the monsoon period. The observations further reveal the presence of *Alona quadrangularis* only during the monsoon season whereas *Mesocyclops hyalinus* and *Testudinella patina* only during the post-monsoon season. Shannon-Wiener Index, Simpsons diversity index, Margalef's richness index and equitability were calculated for zooplankton diversity in this river. No vast variation was observed in the Shannon diversity index (H). Taxa richness was the least in the monsoon season while pre-monsoon season accounted for the highest diversity.

Key words: Physicochemical, river Sal, seasonal variation, zooplankton

Introduction

The river Sal is a valuable resource for irrigation and aquaculture practices. In the last few decades, several coastal areas have changed from a virtual wilderness to haphazardly developed stretches full of concrete buildings and related structures leading to altered ecosystems. Further zooplankton plays an important role in indicating the water quality, eutrophication status and productivity of freshwater body (Mikschi, 1989). Also, the secondary production of an aquatic ecosystem directly or indirectly relies on them (Sharma *et al.,* 2013).

Zooplankton species are cosmopolitan in nature. The freshwater zooplankton comprises mainly of Protozoans, Rotifers, Cladocerans, Copepods and Ostracods. Rotifers, the tiny wheel animalcules are the most prominent group among the zooplankton of a water body irrespective of its trophic status. This may be due to the less specialized feeding, parthenogenetic reproduction, and high fecundity. These generally respond quickly to the environmental changes (Gannon and Stemberger, 1978). Cladocerans, also known as water fleas, are tiny aquatic crustaceans. They are highly

responsive against pollutants and thus serve as good biological indicators of water pollution. Copepods are known for their resilience and adaptability to changing environmental conditions and ability to withstand varying environmental stresses (Barnes *et al.,* 1988). They are high in stable environmental conditions and disappear as pollution level increases (Das *et al.,* 1996). Ostracods are generally bottom dwellers and are also called as seed shrimp. In the aquatic environment, a variety of fauna prey upon ostracods.

Zooplankton density, diversity, seasonal abundance, composition etc. studies have been carried out by several workers like Kiran *et al.,* (2007), Islam (2007), Korai *et al.,* (2008), Mukherjee *et al.,* (2010), Dhembare (2011), Goswami and Mancodi (2012), Kadam and Tiwari (2012).

The river Sal is one of the six major rivers in Goa, which has not attracted the attention of the researchers for reasons lesser known. Hence, data on this river is almost lacking.

In order to understand the status of the Sal River, it is necessary to analyze physicochemical parameters, biological parameters, seasonal variation etc., Thus an attempt was carried out to comprehend the same.

Materials and methods

Study site

The study area included three sampling sites of river Sal. It is the third largest river in Goa. It starts in Cavelossim and passes through Margao, Benaulim, Navelim, Varca, Orlim, Carmona, Dramapur, Chinchinim, Navelim, Assolna, before leading into the Arabian Sea at Betul. Geographically it is situated between 15°10′54′′ N- 15°8′33′′ N Latitude and 73°57′47′′ E - 73°56′59′′ E Longitude. The locations of the three sampling sites are located at (i) 15°10′22′′ N and 73°56′37′′ E (ii) 15°13′10′′ N and 73°57′31′′ E (iii) 15°8′27′′ N and 73°57′2′′ E (Fig.1). The southwest monsoons (June-September), is an annual phenomenon occurring along the west coast of India altering the hydrographic features. The seasons are therefore divided into monsoon (June-September), post-monsoon (October- January) and pre-monsoon (February to May).

(Source:https://www.google.co.in/maps)

Fig. 1. Satellite view of River Sal, Goa along with sampling sites

Sampling and analysis

Monthly zooplankton samples were obtained from each of these sites during October 2015 to September 2016. Concurrently, water samples were taken for measuring selected physicochemical variables. For zooplankton samples, we filtered 50l of water using plankton net (30 cm in mouth opening diameter, 1-m long, 55µ in mesh size). Samples were collected from the surface (0.5 m) during the morning hours. The zooplankton samples obtained were immediately preserved in 250 ml polyethylene bottles with 4% formalin. The samples were then transported to the laboratory for further processing and identification of the species.

At the time of sampling, we measured the surface water temperature and pH. A celsius thermometer (scale ranging from 0°C to 100°C) was used to measure surface water temperature. pH of the water was measured directly in a digital electronic pH meter. Turbidity was measured with the help of a turbidometer.

Water for dissolved oxygen (DO) was collected in amber colored bottles and was estimated as per the procedures of Trivedy and Goel (1987). Other parameters such as electrical conductivity, total Alkalinity, calcium (EDTA titrimetric), magnesium (EDTA titrimetric), phosphate (Stannous Chloride) and nitrate (Brucine Method) were analyzed after filtering the water samples through Whatman GF/C filters. The analysis was carried out by standard methods described by APHA (1992) and Trivedy and Goel (1987).

The quantitative analysis of planktonic organisms was carried out using Sedgwick Rafter plankton counting cell Adoni *et al.* (1985). Taxonomic identification was done with the help of Olympus stereoscopic dissection microscope and standard literature, by using standard keys of Edmondson (1959), Needham and Needham (1962), Pennak (1978), Bhouyain and Asmat (1992), Battish (1992), Sharma (1998) and Dhanapathi (2000).

Results

Seasonal Variation of Physicochemical Parameters

The average seasonal variations of physicochemical parameters from October 2015 to September 2016 are presented in Table 1. Temperature is a key factor, which controls most of the chemical and biological reactions in a water body. During the present studies, water temperature was the lowest (24.5°C) during the post-monsoon period and highest (30°C) during the pre-monsoon period. pH ranged from 6.60-8.0 and was the lowest in the monsoon season. EC was the highest in the pre-monsoon period (49312) and lowest in the monsoon period (34795). A significant variation between seasons was noted in dissolved oxygen ($F = 4.79$: $P < 0.05$). It ranged from 4.04 mg/l (pre-monsoon) to 6.28 mg/l (post-monsoon). Highest turbidity was noted during the monsoon season (23.77 NTU). Nitrates did not vary much. It ranged from 0.10 mg/l (Monsoon) to 1.07 mg/l (post-monsoon). Low values of phosphates were recorded during the study period. It was the lowest in the post-monsoon period (0.02mg/l) and highest in the pre-monsoon period (0.11 mg/l). Total alkalinity was seen to vary seasonally ranging from 102.83 mg/l to 645.83 mg/l and was highest during the pre-monsoon, than monsoon and post-monsoon season. However, ANOVA indicated a non- significant variation ($F = 2.2$; $P > 0.05$). The maximum (738.17 mg/l) and minimum (33.93 mg/l) values of calcium were recorded in the post-monsoon and pre-monsoon seasons respectively. Magnesium concentration varied from 9.66 mg/l (pre-monsoon) to 120.97 mg/l (monsoon).

Species abundance and composition of zooplankton species

Zooplankton community of river Sal from October 2015 to September 2016 comprised of 30 species including Cladocera (10 sps.), Copepoda (9 sps.) Rotifera (9 sps.) and Ostracoda (2 sps.). The species recorded during the study with their occurrence in monsoon, post-monsoon and pre-monsoon are presented in Table 2.

Rotifer was the dominant group among the zooplankton community with nine species. The species belonging to family Asplanchnidae, Brachionidae, Filinidae, Lecanidae, Testidinellidae and Trichocercidae showed 37.87% population of the total zooplankton community. This was

Table 1. Seasonal variation of physicochemical parameters of river Sal

	Post-monsoon (Oct-Jan)			Pre-monsoon (Feb-May)			Monsoon (June-Sept)			F- value
Parameters	Min	Max	Avg. ± SD	Min	Max	Avg. ± SD	Min	Max	Avg. ± SD	
Temp (°C)	24.5	28.00	26.25±2.47	25.50	30.00	27.75±3.18	27.40	28.06	27.73±0.47	1.19
pH	6.73	7.56	7.15±0.59	6.66	8.00	7.33±0.95	6.60	6.93	6.77±0.23	2.00
EC (µs/cm)	32607	47923	40265±10830	45780	52845	49312±4995	17782	51808	34795±2406	1.58
DO (mg/l)	7.10	5.47	6.28±1.16	3.96	4.13	4.04±0.12	4.90	7.06	5.98±1.53	4.79*
Turbidity (NTU)	10.84	20.66	15.75±6.94	10.35	29.40	19.88±13.47	13.41	34.12	23.77±14.64	2.96
Nitrates (mg/l)	0.2	1.94	1.07±1.23	0.07	0.34	0.21±0.19	0.038	0.17	0.10±0.09	1.95
Phosphates (mg/L)	0.01	0.04	0.02±0.01	0.02	0.19	0.11±0.12	0.02	0.17	0.09±0.11	1.76
Total Alk. (mg/L)	52.33	153.33	102.83±71.42	103.33	1188.33	645.83±767.2	36.03	506.26	271.15±332.5	2.18
Calcium (mg/L)	38.33	1438	738.17±989.7	25.70	42.16	33.93±11.64	15.76	320.33	168.05±215.3	0.73
Magnesium (mg/l)	2.77	190.73	96.75±66.45	3.51	15.80	9.66±8.69	1.93	240	120.97±168.3	0.87

Key: * $p < 0.05$

Table 2. Species composition of zooplankton at river Sal

Sl. No.	Species	Post monsoon	Pre monsoon	Monsoon
	Cladocera			
	Family- Bosminidae			
1	*Bosmina longirostris* (Müller 1776)	+	+	+
2	*Bosmina fatalis* (Burckhardt 1924)	-	+	+
	Family-Chydoridae			
3	*Chydorus ventricosus* (Daday 1898)	+	+	-
4	*Alona quadrangularis* (Müller 1776)	-	-	+
5	*Alona rectangula* (Sars 1861)	-	+	-
6	*Alona verrucosa* (Sars 1861)	-	+	+
	Family- Daphinidae			
7	*Ceriodaphnia cornuta* (Sars 1885)	+	+	+
8	*Daphnia carnita,* (King, 1852)	+	-	+
	Famly- Moinidae			
9	*Moina micrura* (Kurz 1875)	-	+	+
	Family- Sididae			
10	*Diaphanosoma sarsi* (Richard 1894)	+	+	+
	Copepoda			
	Order- Cyclopoida			
	Family- Cyclopidae			
11	*Mesocyclops leuckarti* (Forbes 1890)	+	+	+
12	*Mesocyclops hyalinus* (Rehberg 1880)	+	-	-
13	*Trophocyclops prascinus* (Fischer 1860)	+	+	+
14	*Eucyclops serrulatus* (Fischer 1851)	+	+	+
15	*Microcyclops varicans (*Wolf 1905)	+	+	-
	Order- Calanoida			
	Family- Diaptomidae			
16	*Undinula valgaris* (Dana, 1849)	+	+	+
	Family- Pseudodiaptomidae			
17	*Pseudodiaptomus Nostradamus* (Brehm 1933)	+	+	-
18	Mysis sp.	+	+	+
19	Nauplius larvae	-	+	-
	Rotifera			
	Family- Asplanchnidae			
20	*Asplanchna priodonta* (Gosse 1850)	+	+	+
	Family- Brachionidae			
21	*Brachionus angularis* (Gosse 1851)	+	+	+
22	*Brachionus calyciflorus* (Pallas 1766)	+	+	+
23	*Brachionus forficula* (Wierzejski 1891)	+	+	+
24	*Keratella tropica* (Apstein 1907)	+	+	+
	Family- Filinidae			
25	*Filinia opoliensis (*Zacharias 1898)	-	+	-
	Family- Lecanidae			
26	*Lecane bulla* (Gosse 1851)	+	+	-
	Family- Testidinellidae			
27	*Testudinella patina* (Hermann 1783)	+	-	-
	Family- Trichocercidae			
28	*Trichocera rattus* (Müller 1776)	+	+	+
	Ostracoda			
	Family-Cyprididae			
29	*Cypris sp.*	+	+	+
30	*Heterocypris sp.*	+	+	+

followed by Copepoda species belonging to family Cyclopidae, Diaptomidae and Pseudodiaptomidae showing 30% population. In the class Cladocera, family Bosminidae, Chydoridae, Daphinidae, Moinidae and Sididae showed the

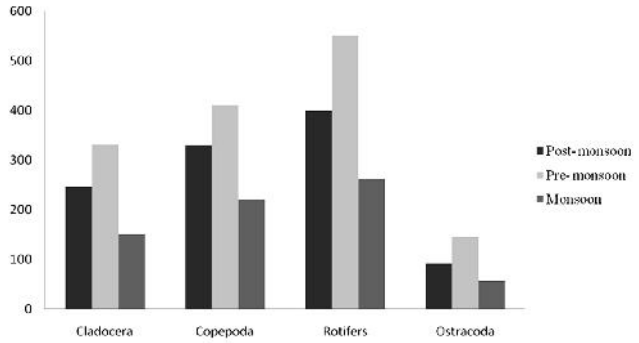

Fig. 2. Relative abundance of zooplankton of river Sal.

maximum number of species (10) which comprised of 22.80% of the total population. Ostracoda showed the least population of 9.2%.

The relative abundance of zooplankton shows that Rotifers, Copepods Cladocerans, and Ostracods were dominant

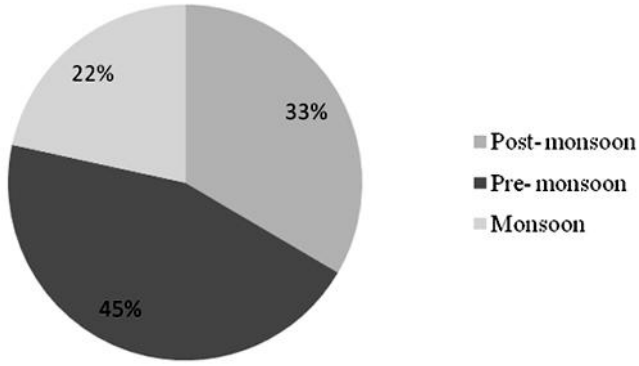

Fig. 3. Seasonwise total percentage of zooplankton of river Sal.

during the pre-monsoon period followed by post-monsoon and monsoon (Fig. 2).

The seasonal variation of various zooplanktons numbers in River Sal is tabularized in Table 3. The population density during the study period was highest in pre-monsoon (45%) followed by post-monsoon (33%) and monsoon season (22%) (Fig. 3).

During the pre-monsoon season percent composition was as follows, Rotifera (38.24%), Copepoda (28.58%),

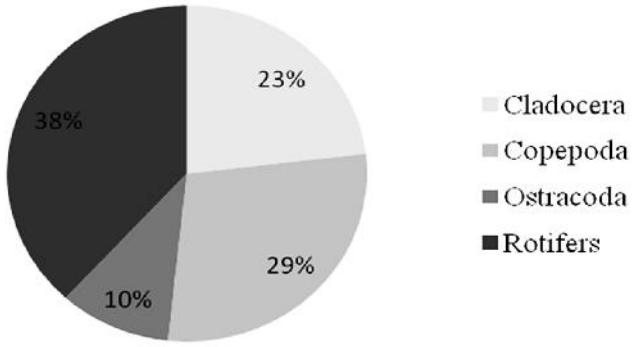

Fig. 4. Percet composition of zooplankton during pre-monsoon season from study area.

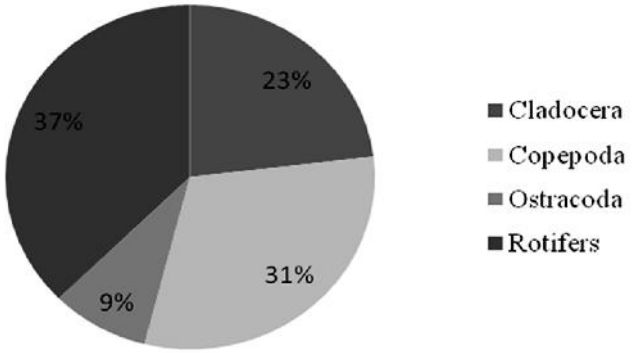

Fig. 5. Percent composition of zooplankton during post-monsoon season from study area.

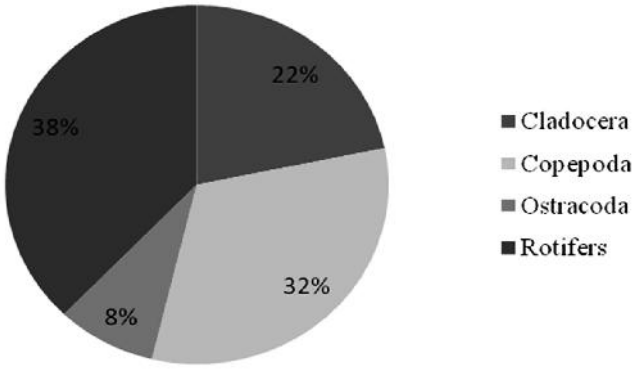

Fig. 6. Percent composition of zooplankton during monsoon season from study area.

Cladocera (23.08%) and Ostracoda (10.08%) (Fig. 4). During the post-monsoon period, the percent composition of Rotifera was (37.41%), Copepoda (30.86%), Cladocera (23.10%) and Ostracoda (8.60%) (Fig. 4). In monsoon season percent composition of Rotifera was (37.82%), Copepoda (32.02%), Cladocera (21.73%) and Ostracoda (8.40%) (Fig. 6).

Alona quadrangularis was observed only during the monsoon season whereas *Mesocyclops hyalinus* and

Testudinella patina were present during the post-monsoon season. The Filinia genus, *Nauplius* larvae and *Alona rectangula* were observed only in the pre-monsoon period.

Correlation studies of physicochemical parameters and zooplankton

To assess the overall impact of different parameters on zooplankton abundance, correlation analysis was made between total zooplankton population and water parameters (Table 4). Zooplankton population showed notable positive correlation with pH (r = 0.253), electrical conductivity (r = 0.31), D.O. (r = 0.292) and total alkalinity (r = 0.233). On the contrary, negative correlation were seen with water temperature (r = - 0.195), turbidity (r = - 0.636), calcium (r = - 0.185), magnesium (r = - 0.497), phosphate (r = - 0.044) and nitrate (r = - 0.048).

Diversity indices of zooplankton

A summary of the diversity indices of zooplankton found in river Sal is shown in Table 5. Margalef's index (R) was least in the monsoon season (3.06) while the pre-monsoon season accounted for the highest diversity (3.43). Though vast variation was not noticed in the Shannon diversity index (H), pre-monsoon season recorded the highest diversity (1.295) and least in monsoon season (1.272). Equitability was least in monsoon season (0.91) and highest in pre-monsoon season (0.93). Simpson's Diversity index ranged from 0.701 in monsoon to 0.709 during the pre-monsoon period. All the seasons had more or less equal diversity indices values.

Table 3. Seasonal variation of various zooplanktons density in river Sal.

Sl. No.	Zooplankton groups (no./l)	Post-monsoon	Pre-monsoon	Monsoon	Total
1	Cladocera	247	332	150	729
2	Copepoda	330	411	221	962
3	Rotifers	400	550	261	1211
4	Ostracoda	92	145	58	295
	Total	1069	1438	690	3,197

Table 4. Correlation values of physicochemical parameters and zooplankton.

Sl No.	Parameters	Correlation coefficient
1	Temp	-0.195
2	pH	0.253
3	EC	0.314
4	DO	0.292
5	Turbidity	-0.636
6	Total Alkalinity	0.233
7	Calcium	-0.185
8	Magnesium	-0.497
9	Phosphate	-0.044
10	Nitrate	-0.048

Table 5. Diversity indices of zooplanktons in river Sal.

	Post-monsoon	Pre-monsoon	Monsoon
Marglef's Index	3.14	3.43	3.06
Shannon Weiner diversity index	1.28	1.29	1.27
Equitability	0.92	0.93	0.91
Simpson's Diversity Index	0.70	0.71	0.70

Discussion

The determination of the physicochemical quality of water gives an impression of the status, productivity and sustainability of an aquatic ecosystem. A change in these parameters not only provides valuable information regarding the quality of water but also give significant knowledge about the aquatic organisms surviving there. During the present investigations, a seasonal variation was observed at the three selected study stations. A similar type of variations during various seasons was also noted by Sehgal *et al.* (2013), who worked on Dimbhe reservoir.

Temperature is considered an important factor controlling the functioning of the aquatic ecosystem. It affects aquatic life and also alters the concentration of dissolved gases. In the present study, a seasonal fluctuation of water temperature was observed. It was the highest during the pre-monsoon period, which was on par with reports of Goel and Trivedi (1986). Maximum water temperature during summer may be due to the increased day length and angle of incidence of sun rays.

The pH value of water is a measure of the hydrogen ion concentration in water and it indicates, whether the water is acidic or alkaline. World Health Organization has recommended water of pH range of 6.5-8.5 as suitable for

drinking purpose. In river Sal, the pH during the study period was found to be within limits making it suitable for drinking.

The electrical conductivity of water is basically due to dissolved substances in it. Pre-monsoon and monsoon recorded the highest and lowest conductivity respectively. The possible reason for fall in EC during monsoon season was due to the rainfall, which was observed from the month of June–September.

Dissolved oxygen is considered as the most important water quality parameter among all the chemical parameters in determining the status of a water body. Dissolved oxygen showed higher value in the winter season and low value in the summer season which may be due to the variation in temperature. Such variations were also noted by Jemi and Bala Singh (2011) and Sahni and Yadav (2012).

Higher turbidity observed during monsoon period in the present studies is due to the annual upwelling and mixing up of stormy water Arabian Sea with the river water. In addition, land runoff also increases the turbidity of the water. (Kishore *et al.,* 2005).

The concentration of nitrates is generally scarce in non-polluted waters, due to its low solubility (Chavan *et al.,* 2012); but the presence of nitrates in the present study, may possibly indicate the final stage of mineralization. Fertilizers, decayed vegetables and animal matter are the principal sources of nitrates in a water body.

Low values of phosphates recorded during post-monsoon are on par with the reports of Gonzalves and Joshi (1946), which was attributed to the utilization by the algal planktons for photosynthesis.

Alkalinity also known as Acid Neutralizing Capacity is the buffering capacity of carbonate system. The total alkalinity of freshwater lakes is often low, thus making them poorly buffered and susceptible to acidification (Wetzel, 2001). In the current studies, pre-monsoon and monsoon recorded values were higher than 120mg/l, indicating nutrient richness.

Calcium is one of the major ions, affecting the growth and population of freshwater flora and fauna. Higher amount of calcium was recorded during the post-monsoon period, which may be due to the increased solubility at low temperature, which corroborates with the findings of Chowdhary (2011).

Magnesium is required by animals in micro quantity. A vast difference in the seasonal concentration of magnesium ranging from 9.66 mg/l in summer to 120.97 mg/l in monsoon was noted, which possibly could be due to the low water level during summer and surface runoffs during monsoon.

The physicochemical parameters and zooplankton communities together form a comprehensive ecosystem. Highest zooplankton population was recorded in the pre-monsoon period which could be because of the high temperature and alkaline pH, which later reduced due to fall in temperature. Monsoon recorded the lowest numbers possibly due to dilution of water resulting in fewer nutrients and reduced DO. Damotharan *et al.,* (2010) and Khare (2005) also recorded a similar seasonal variation in zooplankton density. Among the zooplankton community, Rotifera was the dominant group followed by Copepoda and Cladocera. Similar studies carried out by Jose and Sanalkumar (2012) on seasonal variation in the zooplankton diversity of river Achencovil also reported that in summer, Rotifers were dominated followed by Copepods and Cladocera. High Rotifer population in pre-monsoon season may be attributed to high temperature, alkaline pH (Kedar and Patil, 2002) higher values of nitrates and phosphates in summer season (Shashikant, 2010) and abundant food (Edmondson, 1965).

The percent composition of Rotifers was the highest during all seasons, followed by Copepoda, and Cladocera. Parallel observations were reported by Dede and Deshmukh (2015) from Bhima river, Maharashtra, Manickam *et al*., (2014) from Thoppaiyar reservoir Dharampuri district, South India and Gayathri *et al.,* (2014) from Doddavoderhalli lake, Banglore, Karnataka.

The occurrence of *Alona quadrangularis* only in monsoon season was also reported by Jose and Sanalkumar (2012) and that of *Filinia*, only in the pre-monsoon period was noted by Dede and Deshmukh (2015).

The amount of predation greatly affects the diversity of prey population (Odum, 1983). This could be the reason for low diversity values of Nauplii, which is preferred by fish predators.

The absence of *Bosmina fatalis* during the post-monsoon period coincided with the large number of *Bosmina longirostris,* which may be due to seasonal succession of Cladoceran zooplankton by variation in optimum temperature between zooplankton species.

Rajagopal *et al.* (2010) and Veerendra *et al.* (2012) also reported positive correlation with pH, D.O., alkalinity and negative correlation with water temperature, calcium and magnesium. Such findings corroborate our results.

In the present study, the Shannon-Wiener diversity index (H) ranged from 1.27-1.29. The taxa richness was highest during the pre-monsoon season. Species diversity and species richness were almost the same during the study period.

Thus it can be concluded that, the population density and abundance of zooplankton varies according to seasons. The zooplankton population of the concerned river was found to be dominated by Rotifers in number and Cladocerans in diversity. Therefore, the present study on changes occurring in the Riverine ecosystems is necessary to understand and preserve the biodiversity of the river Sal.

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