

ROTIFERS, THEIR DISTRIBUTION, ABUNDANCE AND SEASONAL VARIATION IN CHILIKA LAGOON

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The distribution, diversity, abundance of rotifers and influence of environmental variables on them in Chilika lagoon have been studied. Twenty three species of rotifers, unreported earlier from Chilika, have been identified. Members of the family Brachionidae were most abundant in the lagoon. Northern sector of the lagoon was most diverse and southern sector was the least. Bray-Curtis similarity and PCA showed distinct seasonal difference in distribution and abundance. Salinity, transparency, silicate and total hardness were the most critical environmental parameters influencing rotifers in the lagoon.

Key words: Rotifers, Chilika lagoon, distribution, Canonical analysis

Introduction

Rotifers are microscopic ciliary invertebrates that play vital role in aquatic ecosystems. Most rotifers dwell in freshwaters and limno-terrestrial habitats, but there are a few recorded from the saline environments too (Fontaneto *et al.*, 2006). Rotifers, due to their large population size and high turn-over rates, are important component of food webs (Herzig, 1987; Starkweather, 1987; Walz, 1997). Rotifers, according to Segers (2008) complete their life cycle in aquatic habitats and are highly sensitive to physical and chemical changes in the environment (Gannon, 1978). Thus, these group of organisms are used as bioindicators of aquatic health (Mañemets, 1983; Saksena, 1987) and their abundance are used as measure of water quality (Kumar, 2004). They are also used as a part of saprobic assessment to determine relative level of eutrophication, using abiotic and biotic components as single variable (Slađeck, 1983; Marneffe *et al.*, 1998). According to Duggan (2001), rotifer bio-indicator could be used as potential scheme for lake trophic state. The Chilika, Asia's largest salt water lagoon, with

assorted ecological zones, has enormous flora and fauna and thus is both commercially and ecologically important. Several studies have been carried out on its plankton diversity (Patnaik, 1973; Jhingran, 1963; Srichandan, 2012), but only some genera of rotifers like *Brachionus* sp., *Filinia* sp. and *Keratella* sp. were reported. Study on zooplankton abundance of Chilika lagoon by Mohanty *et al.* (2009), reported that the rotifers amounted second highest (5.11%) among the total zooplankton. Although the studies indicated the group to be such significant when considering the zooplankton community, not many studies have been carried out on this group in the lagoon. In spite of their importance in the ecosystem, no attempt has been made to explore their diversity and analyze their relation to the environmental factors in the lagoon. The present work is an effort to study the diversity, distribution and dynamics of rotifers in the Chilika lagoon and analyze the factors (physico-chemical) influencing their distribution, which in turn would aid in understanding and assessing the health of the lagoon.

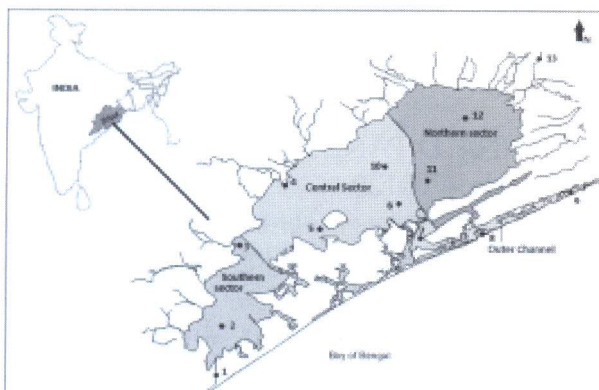


Fig. 1. Map of Chilika lagoon indicating sampling stations and different ecological sectors.

Materials and methods

Situated in Odisha, spread over Puri, Khurda and Ganjam districts, along the east coast of India, between 19° 28' and 19° 54' North Latitude and 85° 06' and 85° 35' East Longitude, Chilika lagoon has a water spread of 1165 km² (Annandale, 1916). The lake is shallow with water depth between 0.38 and 4.2 m. Chilika Lagoon has unique characteristics of an estuarine ecosystem, due to the freshwater flow from the distributaries of Mahanadi river system and seawater influx from Bay of Bengal through a channel.

The lake has been classified into four broad ecological zones, the southern zone (saline), central zone (brackish), northern zone (freshwater) and the outer channel (saline) based on salinity gradient and depth (Balachandran *et al.*, 2005). The lagoon whose connections were closed from the Bay of Bengal, has been restored by opening a new mouth to the sea in the year 2000, resulting in increase of biodiversity and fish yield of the lagoon.

Plankton and physico-chemical parameters of water from all four sectors of the lagoon were collected periodically during October 2012 to November 2013. Three stations each in

Northern, Southern and Outer channel and four stations in Central sector were selected for sample collection, ensuring representation of the lagoon (Fig. 1). Plankton samples were collected using plankton net made of No. 19 grade cloth (74 micron mesh) with 0.5 m diameter mouth, hauled horizontally for distance of 10 m. Volume of water filtered through the net was calculated as $\pi r^2 l$ (as the net forms a cylinder when hauled). Here 'r' is the radius of the plankton net mouth and 'l' is the distance hauled. The samples were then fixed and preserved in 4% formalin. Samples of replicate stations were mixed together to form composite sample representing each sector. These samples were then analyzed for both diversity and abundance. Images of plankton were captured under 10 to 60x magnification, using a Nikon Eclipse 50i microscope having image processing features. The rotifers were identified using Battish (1992), Shiel (1995) and Ward and Whipple (1959). Abundance was estimated using Sedgwick Rafter counting cell (APHA, 2005). Diversity indices like Shannon index, Dominance, Evenness and Margalef index were calculated following Ludwig and Reynolds (1988) and Magurran (1988). Physico-chemical parameters like pH, salinity, water temperature, transparency, DO, BOD, total alkalinity, free CO₂, hardness, chloride, phosphate, nitrate and silicate were measured following APHA (2005). The data on physico-chemical parameters of the lagoon were averaged for seasonal and sector wise analysis. Statistical analysis was based on 78 samples of six groups of rotifers and 13 physico-chemical parameters as mentioned above. Data were analyzed using Principal Component Analysis (PCA) and Canonical Correspondence Analysis (CCA) with the CANOCO 5 software (ter Braak, 1986; ter Braak and Prentice, 1988; ter Braak, 1994; ter Braak and Verdonschot, 1995). The present study has used canonical correspondence

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analysis (CCA), to environmental gradients emphasizing the fact that unimodal response models are to be preferred over linear models (Castro *et al.*, 2005 and Ji *et al.*, 2013).

Results and discussion

The seasonal changes in the physico chemical parameters along the sectors are shown in Table 1. The lagoon remained alkaline (pH- 7.60 to 9.28) with variations in DO (5.60- 8 ppm) and BOD (0.47- 1.33 ppm), nitrate (0.04-2.27 ppm) and phosphate (0.01-0.19 ppm). The average salinity varied between stations from pre monsoon (5.43- 27.93 ppt) to post monsoon period (0.07-10.83) being lowest during monsoon (0-10.67 ppt). There was considerable decrease in salinity (3.57) in outer channel during monsoon, which otherwise remained highest (10.83-27.93 ppt) in all other seasons. Transparency varied between seasons, remaining least (28.67 to 45 cm) during monsoon and increasing up to 99.5 cm during pre monsoon. Total hardness also varied from 200.67 ppm in monsoon to 8733.33 ppm in pre monsoon. Silicate was highest (12.83 ppm) during monsoon in northern sector and lowest in southern sector during post monsoon. These spatial or seasonal variation in physico- chemical parameters were reflected in the diversity and distribution of rotifer species of the lagoon.

Twenty three species of rotifers belonging to six families have been identified, all being new records from the Chilika lagoon. The present study indicated Chilika to have good diversity of rotifers, when compared to records by Hoai *et al.* (1997) from Mediterranean coastal lagoon and Branco *et al.* (2005) from a closed lagoon of Rio de Janeiro. Brachionidae with seven species of *Brachionus* and one species of *Platyias* and *Keratella* each was the major rotifer family in the lagoon, followed by Lecanidae, which had six

Table 1. Average Physico-Chemical variables of Chilika lagoon from October 2012 to November 2013

Seasons	Sectors	pH	Salinity (ppt)	Water temp (°C)	Transparency (cm)	DO (ppm)	BOD (ppm)	Total Alk.	Free CO ₂	Total hardness	Chloride (ppt)	Phosphate-P (ppm)	Nitrate-N (ppm)	Silicate (ppm)
Pre monsoon	Southern	8.77	13.90	29.97	69.00	6.93	1.27	128.67	4.00	4200.00	9.72	0.03	0.23	3.80
	Central	9.28	9.90	29.75	99.50	8.00	1.05	110.50	0.00	3013.75	5.74	0.01	0.06	2.80
	Outer Channel	7.93	27.93	28.63	71.00	6.56	1.16	124.00	3.33	8733.33	16.51	0.04	0.19	1.57
	Northern	8.40	5.43	29.60	55.67	7.53	0.47	100.67	0.00	1865.33	3.48	0.04	0.16	5.50
Monsoon	Southern	7.73	10.67	30.90	45.00	6.56	0.83	121.33	0.00	2150.00	7.23	0.07	0.05	5.73
	Central	8.58	4.45	32.08	42.75	6.35	0.75	94.00	2.00	1175.00	3.46	0.05	0.04	8.15
	Outer Channel	8.10	3.57	30.60	42.00	6.80	0.57	86.67	1.33	800.00	2.37	0.04	0.05	7.53
	Northern	8.50	0.00	31.70	28.67	6.80	1.33	75.67	1.87	200.67	0.06	0.08	0.05	12.83
Post monsoon	Southern	8.97	10.73	27.17	86.33	7.13	0.67	104.00	0.00	2733.33	5.94	0.03	0.20	2.57
	Central	8.88	4.88	26.25	87.75	8.55	0.80	104.50	0.00	1150.00	2.70	0.04	0.43	4.36
	Outer Channel	8.70	10.83	24.97	67.33	7.47	1.07	98.67	2.67	2216.67	5.99	0.04	1.47	4.67
	Northern	7.60	0.07	25.17	61.33	5.60	0.80	74.67	6.67	90.67	0.10	0.19	2.27	8.35

Table 2. Seasonal distribution of rotifer species in different sectors of Chilika lagoon.

Family	Genus/ Species	Northern sector			Central sector			Southern sector			Outer Channel			
		Pr	M	Po	Pr	M	Po	Pr	M	Po	Pr	M	Po	
Hexarthridae	<i>Hexarthra</i> sp.		+	+		+	+			+		+	+	
Conochilidae	<i>Conochilus dossuraius</i>		+	+			+			+			+	
Filiniidae	<i>Filinia longiseta</i>		+											
	<i>Filinia opoliensis</i>		+											
Testudinellidae	<i>Pompholyx sulcata</i>							+						
	<i>Testudinella patina</i>	+	+	+					+					
Brachionidae	<i>Brachionus angularis</i>			+			+							
	<i>Brachionus bidentata</i>	+												
	<i>Brachionus plicatilis</i>		+	+		+			+		+			
	<i>Brachionus falcatus</i>	+	+	+									+	
	<i>Brachionus quadridentata</i>	+							+					
	<i>Brachionus urceolaris</i>		+				+							
	<i>Brachionus calyciflorus</i>						+							
	<i>Keratella tropica</i>			+			+							+
	<i>Platyias patulus</i>	+	+	+										
	Lecanidae	<i>Lecane batillifer</i>	+											
<i>Lecane crepida</i>						+								
<i>Lecane inopinata</i>						+								
<i>Lecane leontina</i>			+	+									+	
<i>Lecane styrax</i>			+	+										
<i>Lecane ungulata</i>													+	
<i>Monostyla bulla</i>		+				+								
<i>Monostyla luna</i>						+								

Note: Pr= Premonsoon, M= Monsoon and Po= Post Monsoon

species of *Lecane* and two species of *Monostyla* (Table 2).

The images of some of the identified species are shown in Fig. 2. Filiniidae was represented by two species *Filinia longiseta* and *Filinia opoliensis*. Two species, *Testudinella patina* and *Pompholyx sulcata* were found under Testudinellidae. Conochilidae and Hexarthridae were represented by single species *Conochilus dossuraius* and *Hexarthra* sp., respectively.

The abundance (no. m⁻³) of the rotifers varied between the sectors ranging between 942 in outer channel to 7349 in central sector (Fig. 3). The sector wise order in abundance of rotifers (no. m⁻³) was much higher and differed from that reported by Mohanty *et al.* (2009) as 90 no. m⁻³

in the outer channel to 813 no. m⁻³ in Southern sector although collected with a mesh of 40 micron. The present study indicated higher abundance and diversity in Northern sector, except the high abundance of Lecanidae (4323 no.m⁻³) in Central sector and least in outer channel (942 no.m⁻³).

Northern sector was dominated by Filiniidae and Brachionidae. Although Southern sector showed high abundance of Testudinellidae and Brachionidae, their presence was recorded only during monsoon (Table 2). Of all the sectors, the outer channel showed least abundance with presence of only Brachionidae and Lecanidae. The saline or brackish water species like *Brachionus plicatilis* and *Brachionus falcatus* observed from outer channel and Southern sector during post

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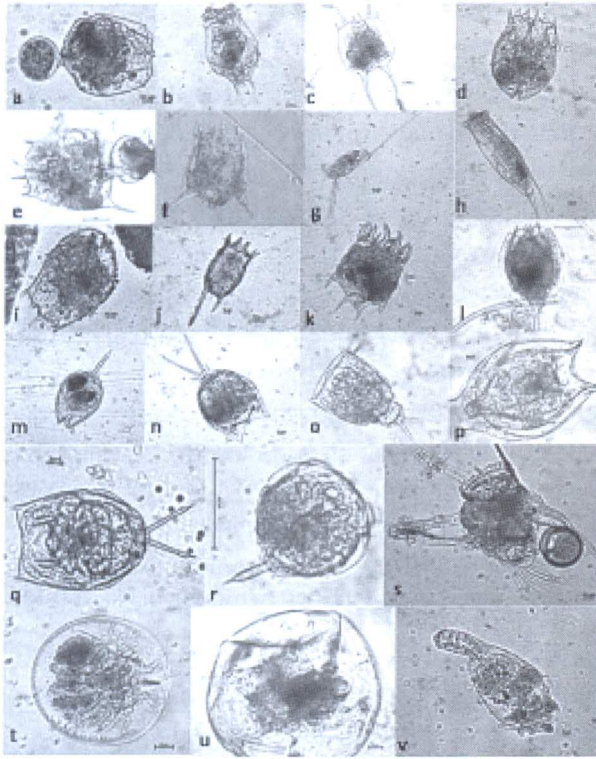


Fig. 2. (a) *Brachionus angularis* (b) *B. bidentata*, (c) *B. falcatus*, (d) *B. plicatilis*, (e) *B. quadridentata*, (f) *B. clyciflorus* (g) *Filinia longiseta*, (h) *F. opoliensis*, (i) *B. urceolaris*, (j) *Keratella tropica*, (k) *Platylas patulus*, (l) *L. inopinata*, (m) *L. leontina*, (n) *L. styrax*, (o) *L. crepida*, (p) *Lecane batillifer*, (q) *L. ungulata*, (r) *Monostyla bulla*, (s) *Hexarthra* sp. (t) *Testudinella patina*, (u) *Pompholyx sulcata*, (v) *Conochilus dossuraisii*.

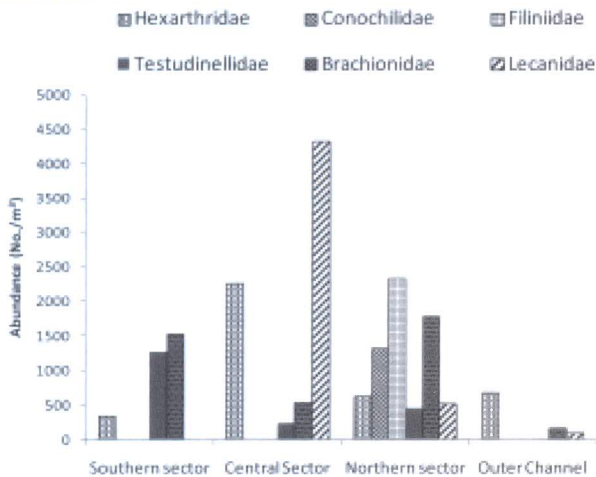


Fig. 3. Sector wise abundance of rotifers in Chilika lagoon during 2012-2013.

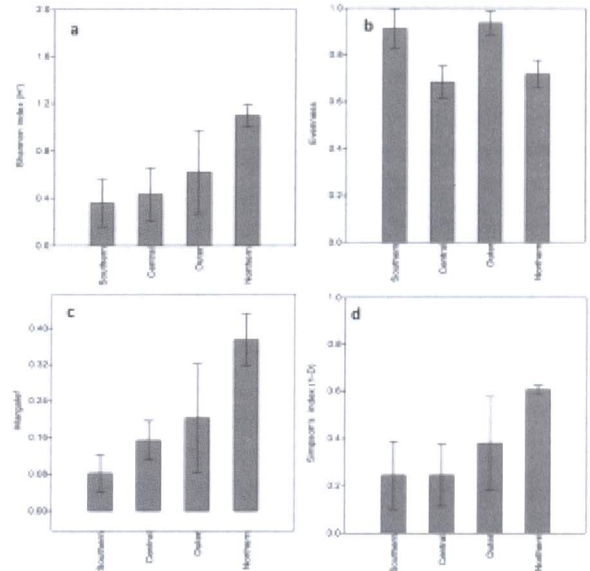


Fig. 4. Diversity indices (a) Shannon (H') index, (b) Evenness, (c) Margalef's richness index (d) Simpson's dominance (1-D) index with standard error calculated along the sectors of the lagoon. Whiskers from the box indicate variability outside the upper quartiles.

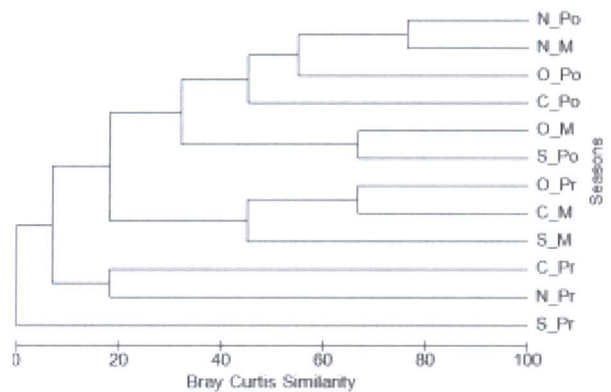


Fig. 5. Cluster analysis based on distribution of rotifer species along the sectors of the lagoon in different seasons. Sectors indicated as, Northern- N, Southern- S, Central- C, Outer channel- O and seasons as pre monsoon (Pr), monsoon (M) and post monsoon (Po).

monsoon period were possible entry from the Bay of Bengal as their presence in Bay of Bengal was reported by Mohapatra and Patra (2012). The diversity indices calculated across the sectors is represented in Fig. 4. The Shannon Diversity

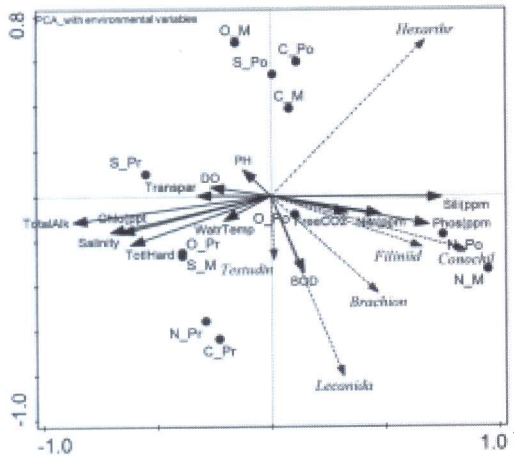


Fig. 6. PCA to analyze the variation along the sectors of the lagoon in species composition and environmental parameters. Sectors based on seasons represented by closed circles, species by dashed arrows and environmental parameters by solid arrows. Eigen values of the first two axes= 0.31 and 0.29

index ranged between 0.4 in southern sector to 1.2 in Northern sector (Fig. 4a). The Shannon index value in southern sector (0.4) and outer channel (0.65) remained low but exhibited higher evenness (Fig. 4b). Northern sector with high Shannon index, richness (Fig. 4c) and dominance (Fig. 4d) but lower evenness indicated seasonal variation in species abundance.

The evenness in species abundance was higher in southern sector and outer channel in spite of less diversity, but the outer channel was dominated by only a few groups of species. The central sector was low in both diversity as well as evenness. Northern sector being fresh water and Outer channel being saline; these sectors were different in their species distribution. Although the total abundance of rotifer in Central sector (7349 no. m⁻³) was higher than the Northern sector (6985 no. m⁻³), the Shannon diversity (H') index (0.8) and Simpson's Dominance (1-D) index (0.4) was lower than the Northern sector (H' = 1.2, 1-D=0.6). This indicated that the abundance of rotifers in central sector was dominated by a single

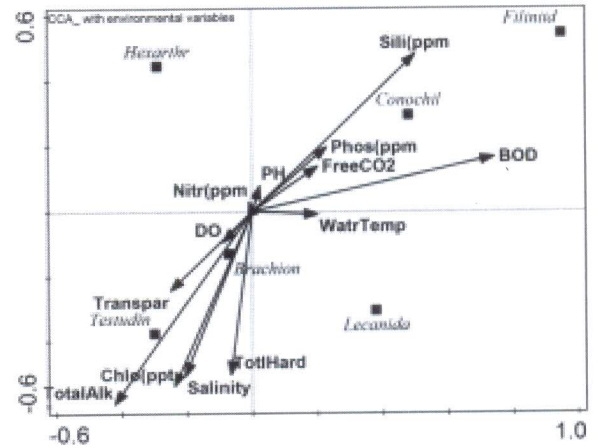


Fig. 7. Ordination diagram based on CCA on rotifer groups of Chilika with respect to environmental variables. Species are represented by black arrows and species by black squares Eigen values of the first two axes= 0.34 and 0.33.

species (*Lecane crepida*). Thus Northern sector is the most diverse and stable zone when considering rotifers. Although presence of species like *Brachionus angularis*, *Pompholyx sulcata* and *Filinia longiseta* are considered as indicators of eutrophy (Sladeczek, 1983 and Saksena, 1987). Lodi *et al.* 2011, reported that density and evenness of rotifers are to be considered along with species diversity as ecological indicators of eutrophication. The present study also looked at the variation in distribution of the rotifer species along the lagoon. Distribution of these rotifer species in different seasons of Chilika lagoon along the characteristic sectors is given in Table 2. In order to understand the degree of similarities or dissimilarities, if any, in distribution of the rotifer species between sectors and seasons, Bray Curtis similarity analysis (Clark, 1993) was performed using Primer-E6 software (Clark, 2006). The rotifer species in Chilika showed both seasonal as well as sector wise variation, based on their distribution pattern as indicated by cluster diagram (Fig. 5).

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The pre- monsoon period in all the sectors showed 80% dissimilarity with the monsoon and post- monsoon period in rotifer species distribution. This dissimilarity can be attributed to the changes in environmental parameters that occurred in each season as indicated by PCA analysis. The environmental parameters like Water temperature ($^{\circ}\text{C}$), pH, DO (mg/l), BOD (mg/l), transparency (cm) and silicate (ppm) varied the most and thus separated the pre- monsoon period from the rest of the seasons. Principal Component Analysis was performed to summarize the variation along the sectors of the lagoon by species composition and environmental parameters. Sixty one percent of cumulative variation was explained by first two axes of PCA and the eigen values were 0.31 and 0.29. The Northern and Central sectors were similar during monsoon and post-monsoon seasons, whereas species distribution differed in all the sectors during pre-monsoon period (Fig. 6).

In the Canonical Correspondence Analysis the first two ordination axes explained 67.31% cumulative species-environment variability (Fig. 7). The eigen values in first two axes were 0.34 and 0.33 indicating the variance explained was equal by both the axes. The analysis indicated that the Filiniidae and Conochilidae were influenced by levels of Phosphate-P, Silicate- silica and Free CO_2 . Lecanidae was influenced by water temperature and total hardness. The parameters influencing the Brachionidae were salinity, total alkalinity, transparency, DO and Total hardness. Testudinellidae was influenced by total alkalinity and transparency. Hexarthridae did not exhibit any specific relation with the environmental variable. However, further study with more environmental variables may reveal the parameters affecting this group individually.

From the canonical corespondence analysis the factors that commonly influenced all the rotifer groups include salinity, transparency, silicate and total hardness and thus were the most determining physico-chemical factors for the distribution of rotifers in Chilika lagoon. Further studies on their contribution to the planktonic community, other biotic factors and the functional role of these rotifers in the lagoon can be utilized to develop rotifer index to assess the trophic condition of the lagoon.

Conclusion

Chilika harbors high diversity of rotifers, of which twenty three have been newly reported. The rotifer population and species distribution are highly dependent on the environmental factors of the lagoon, specifically the salinity, transparency, silicate and total hardness.

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