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

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## Abstract

The distribution, diversity, abundance and influence of environmental variables on rotifers 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 in rotifer species 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 groups of organisms are used as bioindicators of aquatic health (Ma¨emets, 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 (Sla´decek, 1983; Marneffe *et al*., 1998). According to Duggan, 2001 rotifer bio-indicator could be used as potential scheme for lake trophic state. 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. Post restoration 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 an ecosystem, no attempt has been made to explore their diversity and analyze their relation to the environmental factors in such a dynamic 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 parameters) influencing their distribution, which in turn would aid in understanding and assessing the health of the lagoon.

**Materials and methods**

Situated in Odisha, spread over Puri, Khurda and Ganjam districts, along the east coast of India, between 19$^{o}$28' and 19$^{o}$54' NorthLatitude and 85$^{o}$06' and 85$^{o}$35' East Longitude, Chilika lagoon has water spread of 1165 km$^{2}$ (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 riverine system and seawater influx from Bay of Bengal through a channel.

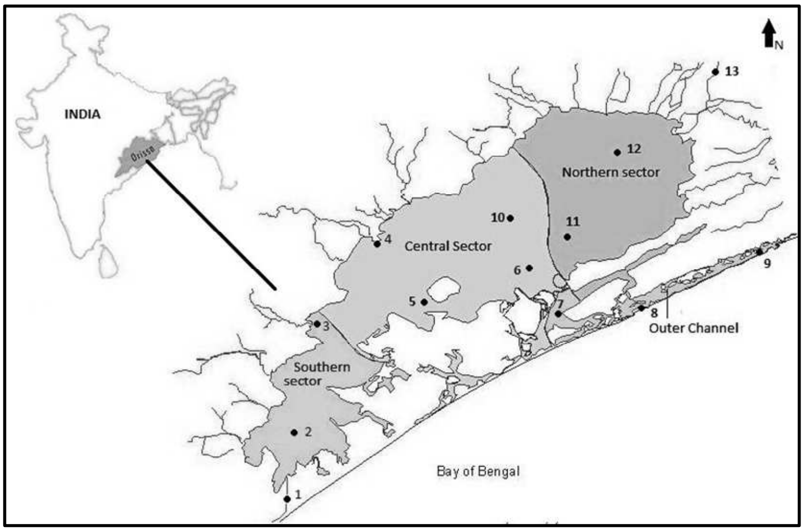

Fig.1.Map of Chilika lagoon indicating sampling stations and different ecological sectors.

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 complete 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 is 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 were captured under 10 to 60x magnification, using a Nicon 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 Sedgewick 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 $CO_2$, 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 6 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 correspondence 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).

## Result 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 very little variation 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 monsson (5.43- 27.93 ppt) to post mosnsoon period (0.07-10.83) being lowest during monsoon (0-10.67 ppt). There was considerable decrease in salinity (3.57) in Outer channel only during monsoon which otherwise remained highest (10.83-27.93 ppt) in all other seasons. Transparency was observed to vary much 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 in monsoon to 8733.33 ppm in pre monsoon. Silicate was found to be highest (12.83 ppm) during monsoon in Northern sector and least 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.

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. (ppm) | Free $CO_2$ (ppm) | Total hardness (ppm) | 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 |

Twenty three species of rotifers belonging to six families have been identified in the present study all being new records from the Chilika lagoon. The present study indicates 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 species of *Lecane* and two species of *Monostyla* (Table 2).

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 | *Hexarthra* sp. | | + | + | | + | + | | | + | | + | + |
| Conochilidae | *Conochilus dossuraius* | | + | + | | | + | | | + | | | + |
| Filiniidae | *Filinia longiseta* | | + | | | | | | | | | | |
| | *Filinia opoliensis* | | + | | | | | | | | | | |
| Testudinellidae | *Pompholyx sulcata* | | | | | | | + | | | | | |
| | *Testudinella patina* | + | + | + | | | | | + | | | | |
| Brachionidae | *Brachionus angularis* | | | + | | | + | | | | | | |
| | *Brachionus bidentata* | + | | | | | | | | | | | |
| | *Brachionus plicatilis* | | + | + | | + | | | + | | + | | |
| | *Brachionus falcatus* | + | + | + | | | | | | | | | + |
| | *Brachionus quadridentata* | + | | | | | | | + | | | | |
| | *Brachionus urceolaris* | | + | | | | + | | | | | | |
| | *Brachionus calyciflorus* | | | | | | + | | | | | | |
| | *Keratella tropica* | | | + | | | + | | | | | | + |
| | *Platyias patulus* | + | + | + | | | | | | | | | |
| Lecanidae | *Lecane batillifer* | + | | | | | | | | | | | |
| | *Lecane crepida* | | | | + | | | | | | | | |
| | *Lecane inopinata* | | | | + | | | | | | | | |
| | *Lecane leontina* | | + | + | | | | | | | | | + |
| | *Lecane styrax* | | + | + | | | | | | | | | |
| | *Lecane ungulata* | | | | | | | | | | | | + |
| | *Monostyla* bulla | + | | | + | | | | | | | | |
| | *Monostyla luna* | | | | + | | | | | | | | |

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

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

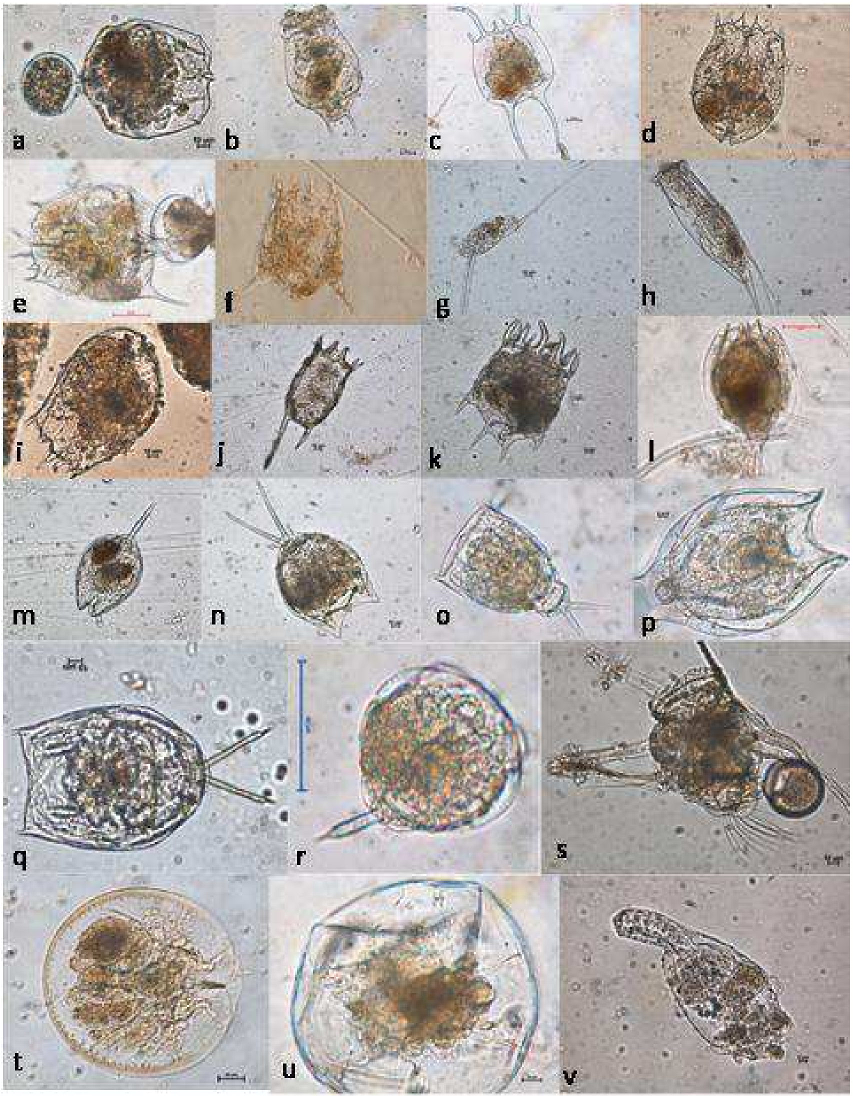

Fig. 2. (a) *Brachionus anguilaris* (b) *B. bidentata*, (c) *B. falcatus*, (d) *B. plicatilis*, (e) *B. quadridentata*, (f) *B. clyciflorus* (g) *Filinia longiseta*, (h) *F. opoliensis,* (i) *B. urceolaris*,(j) *Keratella tropica*, (k) *Platyias patulus*, (l) *L. inopinata*, (m) *L. leontina,* (n) *L.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

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 finer 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.$m^{-3}$).

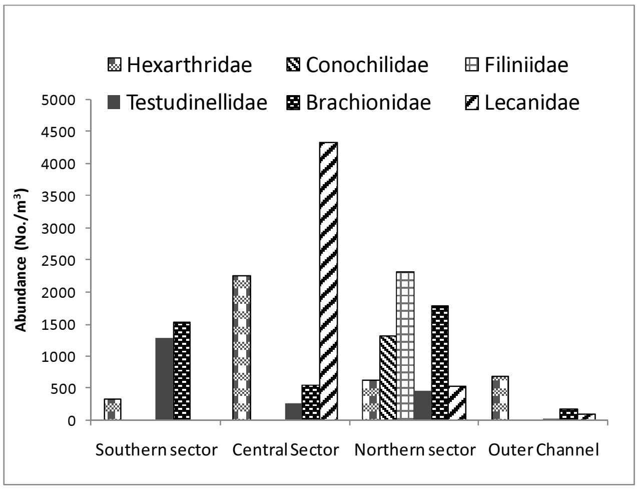


Fig. 3. Sector wise abundance of rotifers in Chilika lagoon during 2012-2013.

Northern sector was dominated by Filinidae 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 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 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.

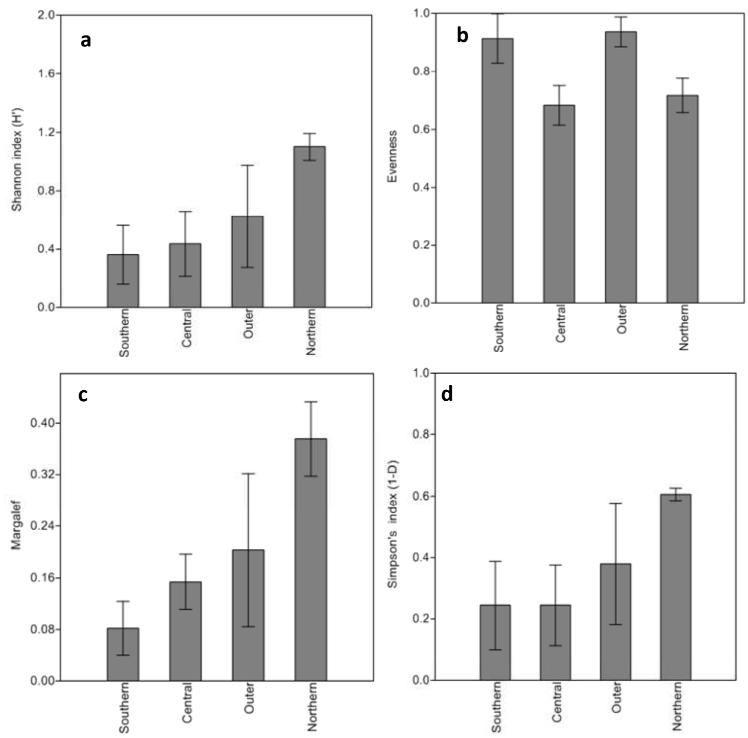


Fig. 4. Diversity indices (a) Shannon (H') index, (b) Evenness, (c) Margalef,s richness index (d) Simpson's dominance (1-D) index with standard error calculated along the sectors of the lagoon. Whiskers from the box indicate variability outside the upper quartiles.

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 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 (Sla´decek, 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).

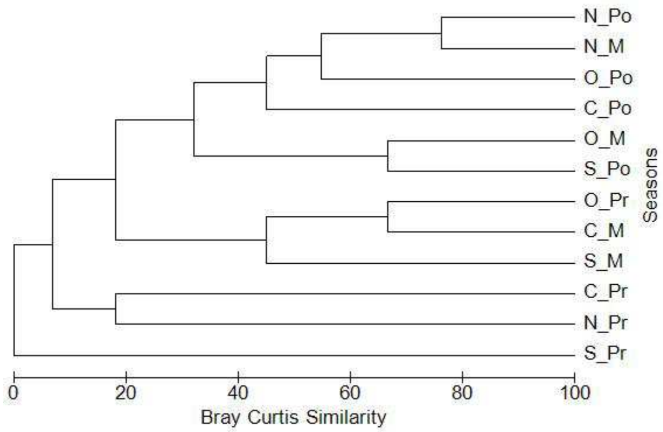


Fig. 5. Cluster analysis of lagoon based on distribution of rotifer species along the sectors of different seasons. Sectors indicated as, Northern- N, Southern- S, Central- C, Outer channel- O and seasons as pre monsoon (Pr), monsoon (M) and post monsoon (Po).

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 ($^{o}$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).

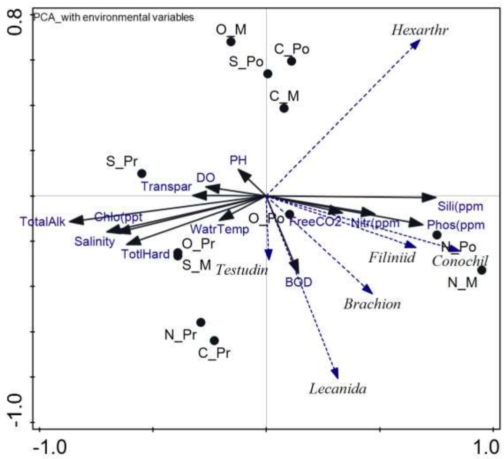


Fig. 6. PCA to analyze the variation along the sectors of the lagoon in species composition and environmental parameters. Sectors based on seasons represented by closed circles, species by dashed arrows and environmental parameters by solid arrows. Eigen values of the first two axes= 0.31 and 0.29

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 (ppm), Silicate- silica (ppm) and Free $CO_2$ (ppm). Lecanidae was influenced by water temperature ($^oC$) and total hardness (ppm). The parameters influencing the Brachionidae were salinity (ppt), 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.

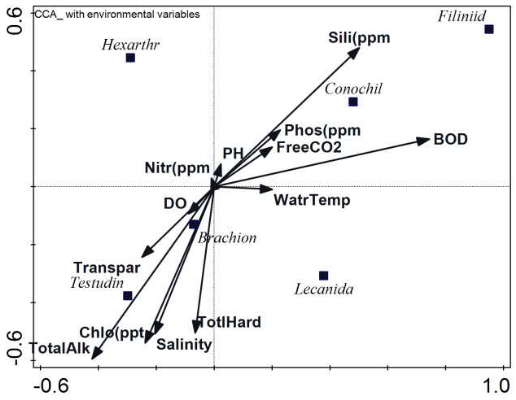


Fig. 7. Ordination diagram based on CCA on rotifer groups of Chilika with respect to environmental variables. Species are represented by black arrows and species by black squares Eigen values of the first two axes= 0.34 and 0.33.

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 being a brackish water lagoon harbors vast diversity of rotifers of which twenty three have been reported here. The rotifer population and species distribution highly dependent on the environmental factors of the lagoon, specifically the salinity, transparency, silicate and total hardness.


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## References


Annandale, N., Ghosh, E., Eliot, C., Bhattacharya, D. R., Kemp, S. W. 1916. The fauna of Chilika lake. *Mem. Ind. Mus.*, 1003 pp.

APHA, AWWA and WEF. 2005. Standard Methods for the Examination of Water & Wastewater. 21st ed. *American Public Health Association. Washington, D. C.*

Balachandran, S., Rahmani, R. A. and Sathiyaselvam, P. 2005. Habitat evaluation of Chilika Lake with special reference to birds as bio-indicators, Govt. of Orissa, Bhubaneswra, p. 1-140.

Battish, S. K., 1992. Freshwater Zooplankton of India. *Oxford and IBM Publications*. 233 p.

Branco, C. W. C., Suzuki, B. K. and Paggi, S. J. 2005. Rotifers from a humic coastal lagoon of Rio de Janeiro state, Brazil. *Studies on Neotropical Fauna and Environment*. **40** (3): 255-265.

Castro, B. B., Antunes, S. C., Pereira, R., Soares, A. M. V. M. and Goncalves, F. 2005. Rotifer community structure in three shallow lakes: seasonal fluctuations and explanatory factors, *Hydrobiologia*. **543** (1): 221–232.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, **18**: 117-143.

Clarke, K. R., Gorley, R. N. 2006. PRIMER v6: User Manual/Tutorial. *PRIMER-E, Plymouth*.

Duggan, I. C., Green, J. D., Shiel, R. J. 2001. Distribution of rotifers in North Island, New Zealand and their potential use as bio-indicators of lake trophic state. *Hydrobiologia*, **446/447**: 155-164.

Fontaneto, D., De Smet, W. H. and Ricci, C. 2006. Rotifers in saltwater environments, re-evaluation of an inconspicuous taxon. *Journal of the Marine Biological Association of the United Kingdom*, **86**: 623–656.

Gannon, J. E. and Stemberger, R. S. 1978. Zooplankton (especiallycrustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*, **97**:16–35.

Herzig, A. 1987. The analysis of planktonic rotifer populations: A plea for long–term investigations. *Hydrobiologia*, **147**:163–180.

Hoai, L. T., Rougier and C., Lasserre, G. 1997. Tintinnids and rotifers in a northern Mediterranean coastal lagoon. Structural diversity and function through biomass estimations. *Mar Ecol Prog Ser*., **152**: 13-25.

Jhingran, V. G. 1963- *Report on the Fisheries of the Chilka Lake 1957-1960*. Cent. Inl. Fis. Res- Inst- Barrackpore, Bull No. **8**. 1- 113 p.

Ji, G., Wang, X. and Wang, L. 2013. Planktonic Rotifers in a Subtropical Shallow Lake: Succession, Relationship to Environmental Factors, and Use as Bioindicators, *The Scientific World Journal*, **2013**: 1- 14.

Kumar, A. 2004. Environmental contamination and bioreclamation. *APH Publishing*, pp. 495.

Lodi, S., Vieira, L. C. G., Velho, L. F. M., Bonecker, C. C., Carvalho, P., Bini, L. M. 2011. Zooplankton Community metrics as Indicators of Eutrophication in urban lakes. *Natureza & Conservação*, **9** (1): 1-6.

Ludwig, J. A. and Reynolds, J. F. 1988. Statistical Ecology: a Primer on Methods and Computing. *John Wiley and Sons, New York.*

Magurran, A. E. 1988. Ecological Diversity and its measurement. *Croom Helm Limited, London*.

Ma¨emets A. (1983) Rotifers as indicators of lake types in Estonia. Hydrobiologia, 104, 357–361.

Marneffe, Y., Comblin, S. and J. P. Thome. 1998. Ecological water quality assessment of the Bu¨tgenbach lake (Belgium) and its impact on the River Warche using rotifers as bio-indicators. *Hydrobiologia*, **387/388**: 459–467.

Mohanty, R. K., Mohapatra. A. and Mohanty, S. K. 2009.Assessment of the impacts of a new artificial lake mouth on the hydrobiology and fisheries of Chilika Lake, India. *Lakes and Reservoirs: Research and Management*. **14**: 231–245.

Mohapatra,S. and Patra, A. K. 2012. Studies on Zooplankton diversity of Bay of Bengal at Puri Sea shore in Orissa. *International Journal of Advanced Scientific and Technical Research*, **5** (2): 532-540.

Patnaik, S. 1973. Observations of the seasonal fluctuation of Plankton in Chilika lake. *Indian J. Fish.*, **20** (1): 43-55.

Saksena, D. N. 1987. Rotifers as Indicators of Water Quality. *Acta Hydrochimica et Hydrobiologica*, **15** (5): 481–485.

Segers, H. 2008. Global diversity of rotifers (Rotifera) in freshwater. *Hydrobiologia*, **595**: 49–59.

Shiel, R. J. 1995. A guide to identification of rotifers, cladocerans and copepods from Australian inland waters. *Co-operative Research Center for Freshwater Ecology. NSW. Albury*. pp. 144.

Sla´decek, V. 1983. Rotifers as indicators of water quality. *Hydrobiologia*. **100**: 169–201.

Srichandan, S., Baliarsingh, S. K., Panigrahy, R. C., Sahu, K. C. 2012. A Case Study on Summer Distribution of Zooplankton in Chilika Lagoon, East Coast of India. *International Journal of Life Sciences and Technology*, 5 (5): 29–36.

Starkweather, P. L. 1987. Rotifera. In T. J. Pandian and F. J. Vernberg (eds.), *Animal energetics. Vol. 1, Protozoa through Insecta*, Academic Press, Orlando, pp.159–183.

ter Braak, C. J. F. 1986. Canonical Correspondence Analysis: A new eigenvector technique for Multivariate Direct Gradient Analysis1. *Ecology*. **67** (5).1 986, pp. 1167-1179.

ter Braak, C. J. F. and Prentice, I. C. 1988. A theory of gradient analysis. *Adv. Ecol. Res*. **18**: 271–317.

ter Braak, C. J. F. 1994. Canonical community ordination. Part 1: Basic theory and linear methods. *Ecoscience*. **1**: 127–140.

ter Braak, C. J. F. and Verdonschot, P. F. M. 1995. Canonical correspondence analysis and related multivariate m ethods in aquatics ecology. *Aquat. Sci*. **57**: 255–289.

Walz, N. 1997. Rotifer life history strategies and evolution in fresh-water plankton communities. In B. Streit, T. Sta¨dler, and C. M. Lively (eds.), *Evolutionary ecology of freshwater animals*, Birkha¨userVerlag, Basel, pp. 119–149.

Ward, H. B. and G. C. Whipple. 1959. Freshwater Biology, Second Edition. *Wiley and Sons, Inc. New York*. pp. 589-596.