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Diversity and distribution of tintinnids in Chilika Lagoon with description of new records

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ABSTRACT

The diversity and distribution of tintinnids in Chilika Lagoon has been studied with description of new records. The study revealed presence of 27 species belonging to eight genera and five families of which, 26 species are new records from the lagoon. The distribution pattern of tintinnids in the lagoon showed their presence along the central sector, southern sector and outer channel, except the northern sector of the lagoon. The distribution pattern in the lagoon indicated their existence along low saline areas, despite being mostly marine in habit.

Keywords: Chilika Lagoon, *Codonellopsis* sp., Species distribution, Tintinnids, *Tintinnopsis* sp.

Introduction

Tintinnids (Kofoid and Campbell, 1929) are eukaryotic micro-zooplankton, which are heterotrophic, mostly feeding on algae and bacteria (Dolan and Pierce, 2013). These are widely distributed protozoan ciliates, found mostly in marine and also in freshwater environments. Tintinnids play important role in the aquatic food chain. They are herbivores and consume high percentage of the daily primary production (Heinbokel and Beers, 1979) and act as food for higher zooplankters such as copepods, small crustaceans, cnidarians, tunicates, rotifers, ostracods, cladocerans, molluscs and fish larvae (Dolan and Pierce, 2013). These ciliates have been studied from the begining of plankton research (Haeckel, 1873; Daday, 1887). The earliest work on zooplankton of Chilika Lagoon mostly focused on large sized zooplankton belonging to the groups, rotifers and copepods (Jhingran, 1963). Later researchers (Patnaik, 1973; Srichandan *et al.*, 2012) studied other groups like cladocerans, annelids and decapods along with smaller groups like tintinnds. These studies dealt with genera *viz*., *Tintinnopsis, Cyttarocyclis* and *Codonella* (Patnaik, 1971). A recent study by Srichandan *et al.* (2012) on the summer distribution of zooplankton of Chilika Lagoon described the presence of three species of tintinnids in the lagoon namely, *Tintinnopsis sacculus, Tintinnopsis tocantinensis* and *Favella philippinensis*. However, Chilika being a large coastal lagoon, connected with the Bay of Bengal through a channel, mostly brackish in nature, with its outer channel being mostly saline throughout the year, is expected to have higher diversity of tintinnids than that already reported. Available literature does not indicate any concerted effort to focus studies on this group in the lagoon. Hence in the present study an attempt was made to investigate the diversity and distribution of order Tintinnina in the lagoon.

Materials and methods

Study area

Chilika is Asia's largest brackishwater lagoon with a water spread of 1165 km^2 (Annandale *et al.*, 1916). The lagoon is shallow with water depth between 0.38 and 4.2 m. It is situated in Odisha State, along the east coast of India, between lat. 19◦ 28'-19◦ 54' N and long. 85◦06'-85◦35' E. The spatial and temporal changes in salinity gradients, due to freshwater flow from the riverine system and seawater influx from Bay of Bengal, give Chilika Lagoon unique characteristics of an estuarine ecosystem. It is designated as a Ramsar site since 1981 (Balachandran *et al.*, 2005). The lagoon has been classified into four broad ecological zones based on salinity gradient and depth *viz*., the southern zone (saline), central zone (brackish), northern zone (freshwater) and the outer channel (saline) (Balachandran *et al.*, 2005). The present study was based on samples collected from twelve stations located in these four zones of the lagoon (Fig. 1) Stations 1, 2

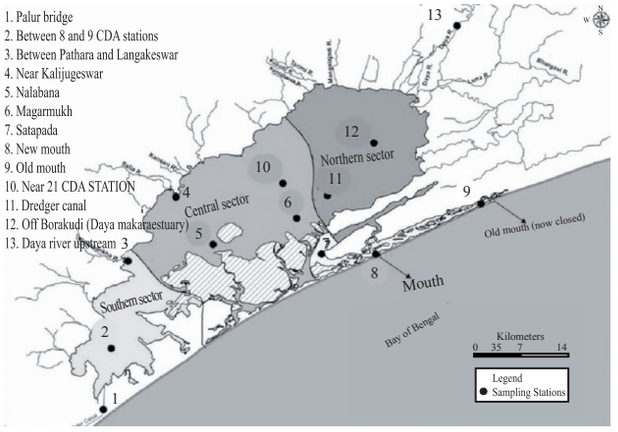


Fig. 1. The study area with sampling stations indicated

and 3 are situated in the southern sector of the lagoon. Station 1 is connected to the sea through Palur Canal and thus has continuous seawater influx. Station 4, 5, 6 and 10 are located in the central sector which has lesser saline influence. The northern and central part of the lagoon is densely covered with macrophytes, which grow luxuriantly in the post-monsoon period and which start decomposing in the summer with the increased salinity (Pal and Mohanty, 2002; Panigrahi, 2006). Stations 7, 8 and 9 are located in the outer channel, station 8 being in the 'new mouth' (an artificial opening to the sea which was created in September 2000 to restore the ecology of the lagoon) and station 9 in the 'old mouth' (natural opening to sea, which is closed due to siltation). Station 11 and 12 are located in the northern sector, wherein station 12 is in a freshwater zone.

Sample collection

Plankton samples were collected from July 2012 to June 2013 using plankton net made of No. 19 grade cloth (74 micron mesh) with 0.5 m diameter mouth. The net was hauled horizontally for a distance of 10 m in all the stations. Immediately after collection, the samples were fixed and preserved in 4% formalin. The samples were viewed and images were captured, using a Nikon Eclipse 50i microscope having image processing features.

Identification

The samples were identified by following the descriptions of Daday (1887); Brandt (1906); Meunier (1919); Kofoid and Campbell (1929) and Hada (1938), based mainly on the shape of the lorica, presence or absence of agglomerated particles, spiral structures, presence or absence of collar and their ornamentation, shape and size of the oral or aboral flare. The basic structures of ciliates of the order Tintinna are shown in for general understanding of the taxonomic features. These consist of an encasing lorica with oral and aboral end (Daday, 1887). The lorica is a protective case, which is either transparent or ornamented (Kofoid and Campbell, 1929). The pedicel at the bottom of the lorica holds the oral cilia, together with the micro and macronucleus (Dolan, 2013). The upper end of the body is more or less broad and is surrounded by peristomial collar. The collar may sometimes be hyaline with spiral structures or with semicircular windows. The aboral end may be closed or open and with large flares. The basic measurements of the tintinnids used in this paper are TL - total length, OD - oral diameter, AD - aboral diameter, CL - collar length, BL - bowl length andMT - maximum transdiameter, L/OD - ratio of lorica diameter to oral diameter.

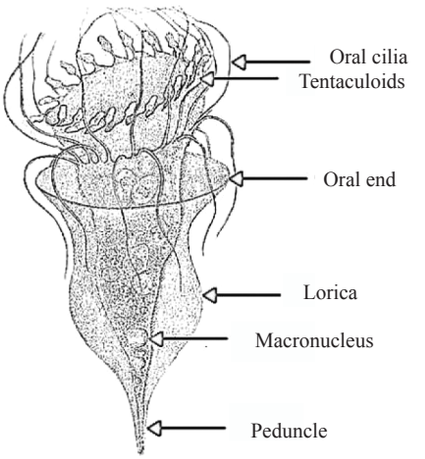


Fig. 2. Generalised diagram illustrating tintinnid (Haeckel, 1873)

Results and discussion

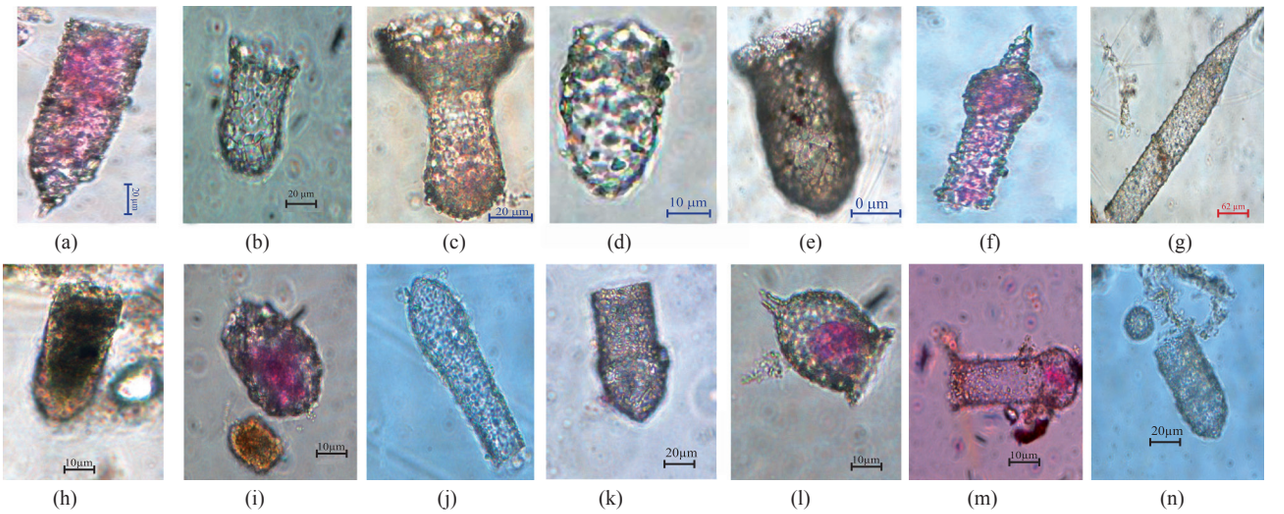
The species recorded and their distribution along the sampling stations are shown in (Table 1, Fig. 3; 4),) The study revealed presence of 27 species of tintinnids belonging to eight genera and five families. Of the 27 species identified, 26 are new records from Chilka Lagoon. The seasonal changes in the salinity gradient are shown in Table 2. The stations showed lower salinity in the month of October 2012 due to monsoon inflow and in June highest salinity was recorded. As reported by Godhantaraman (2002) as well as Dolan and Pierce (2013), the present study also revealed that *Tintinnopsis* of Codonellidae family formed the most diverse (14 species) and also the most widely distributed genera (occurring in all stations except station 12) in Chilika Lagoon.

Connection of the lagoon to the sea through station 8 (new mouth) and also the highest number of tintinnid

Table 1. Distribution of tintinnids in Chilika Lagoon

Family/ Species	Stations										
	1	2	3	4	5	6	7	8	9	10	11
Codonellidae											
Tintinnopsis compressa						+	+	+	+		
Tintinnopsis cylindrica				+			+	+	+		
Tintinnopsis directa	+		+	+		+	+	+	+		
Tintinnopsis filakinensis								+			
Tintinnopsis fimbriata							+	+			
Tintinnopsis gracilis		+	+					+			
Tintinnopsis karajacensis	+						+	+			
Tintinnopsis nucula							+				
Tintinopssis parvula							+				
Tintinnopsis radix							+	+			+
Tintinnopsis rotundata	+							+			
Tintinnopsis spiralis			+						+		
Tintinnopsis tocantinensis	+		+					+	+	+	+
Tintinnopsis tubulosa		+							+		
Codonellopsidae											
Codonellopsis ostenfeldi								+			
Stenosemella nivalis							+	+	+		
Stenosemella ventricosa							+	+			
Ptychocylididae											
Favella adriatica							+				
Favella campanula	+						+		+		
Favella ehrenbergii			+				+		+	+	
Tintinnidae											
Dadayiella bulbosa								+			
Eutintinnus fraknoi								+			
Eutintinnus apertus								+			
Eutintinnus elongatus								+			
Leprotintinnus nordqvistii							+	+	+		
Leprotintinnus simplex							+	+			
Metacyclididae											
Metacyclis tropica							+				

'+' indicates 'present', blank cells indicates 'not recorded'



(a) (b) (c) (d) (e) (f) (g)

(h) (i) (j) (k) (l) (m) (n)

Fig. 3. (a) *Tintinnopsis cylindrica,* (b) *T. directa,* (c) *T. compressa,* (d) *T. rotundata,* (e) *T. filakinensis* , (f) *T. tocantinensis,* (g) *T. radix,* (h) *T. karajacensis,* (i) *T. nucula,* (j) *T. tubulosa,* (k) *T. parvula,* (l) *T. fimbriata,* (m) *T. spiralis,* (n) *T. gracilis*

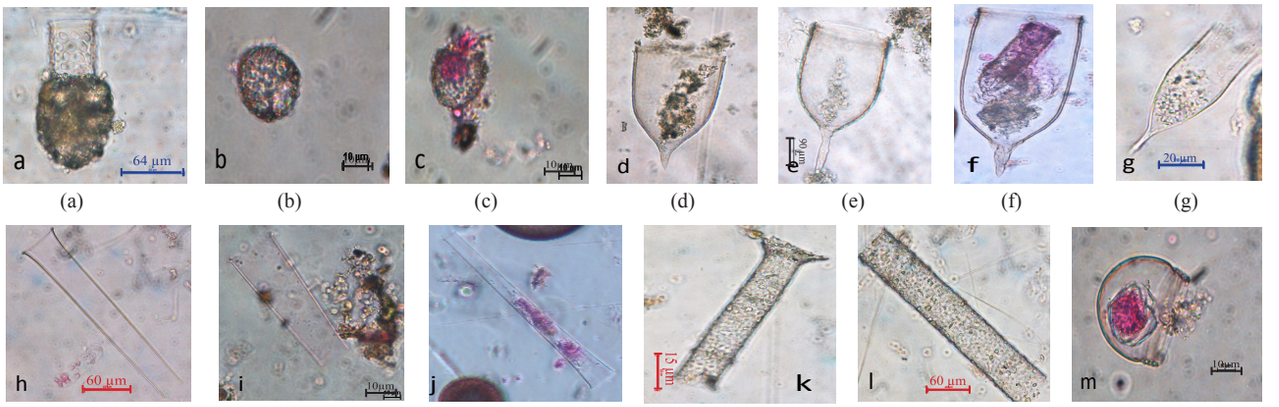


Fig. 4. (a) *Codonellopsis ostenfeldi,* (b) *Stenosemella nivalis,* (c) *S. ventricosa,* (d) *Favella adriatica,* (e) *F. campanula,* (f) *F. eherenbergii,* (g) *Dadayiella bulbosa,* (h) *Eutintinus franknoi,* (i) *E. apertus,* (j) *E. elongatus,* (k) *Leprotintinnus nordqvistii,* (l) *L. simplex,* (m) *Metacylis tropica*

species recorded from this station (Table 1) indicated that tintinnids might be entering the lagoon from the Bay of Bengal (salinity 33 - 34 ppt) under tidal influence. These tintinnids being marine, were expected to be restricted to the higher saline stations *viz.,* 7 (1.2-33.6 ppt), 8 (5.3-33.1 ppt) and 9 (4.2-30.7 ppt). But the study revealed their presence with good diversity in stations 2 (11.3-18.9 ppt), 3 (9.2-22.2 ppt), 4 (6.3-21.4), 6 (0.7-33.4 ppt) and 11 (0- 33.1) having low salinity range (Table 2).

Table 2. Seasonal changes in salinity (ppt) of Chilika Lagoon

Stations	Salinity (ppt)			
	Oct 12	Dec 12	Mar 13	Jun 13
1	6.1	11.7	17.6	33.2
2	15.2	11.3	13.6	18.9
3	10.7	9.2	10.5	22.2
4	6.4	6.3	9.0	21.4
5	10.6	8.1	8.9	23.9
6	0.7	1.9	13.7	33.4
7	1.2	3.1	24.2	33.6
8	5.3	8.9	30.2	33.1
9	4.2	20.5	29.4	30.7
10	0.1	3.2	8.0	32.6
11	0.0	0.2	15.8	33.1
12	0.0	0.0	0.5	0.8

This indicated that tintinnids might be tolerant to low salinity range in the lagoon. Station 10 and 11 supported very few species of tintinnids, being mostly freshwater, except during summer seasons. Although tintinnids were distributed in almost all the stations of the lagoon, none of them were recorded from station 12, which is completely freshwater in nature due to the western catchment of Daya and Makara rivers and station 5 with macrophyte infestation causing low dissolved oxygen and having lower salinity range (8.1- 23.9 ppt) throughout the year. Importance of tintinnids in the food chain as prey for suspension feeding zooplankton, benthic invertebrates, and fishes has already been studied (Lebour, 1918; Omori, 1974; Hopkins, 1987). Large tintinnids feeding on smaller tintinnids (Lebour, 1922; Robertson, 1983; Verity, 1986) was evident from the present study. *Favella eherenbergii* with a hyaline lorica was observed to feed on smaller tintinnids like *Tintinnopsis rotundata*, *T. cylindrica* and *T. tocantinensis* (Fig. 4f). Tintinnids have been recorded from the guts of many fish species of clupeids (Detwyler, 1970). Two species of tintinnids *viz*., *T. tocantinensis* and *T. cylindrica* were also recorded from the gut of *Nematalosa nasus* during investigations on feeding biology in a concurrent study during the same period. The distribution of tintinnids although reported to be cosmopolitan (Kofoid and Campbell, 1929), Pierce and Turner (1993) clearly indicated that the variation in the distribution of tintinnids is dependent on various biotic and abiotic factors. The distribution of tintinnids in Chilika Lagoon and the factors affecting their distribution are to be further investigated. As the lagoon is a dynamic water body and has both freshwater and saline water sectors, it is bestowed with huge diversity of both flora and fauna. Further detailed study on diversity, abundance and assemblage of tininnids is needed to understand the role of tintinnids in the complex food chain and in the composition of planktonic assemblage of the lagoon.

Description of newly recorded tintinnids from the lagoon

The description of the newly recorded species, from the lagoon based on their diagnostic characters are discussed in the following section.

Family: *Codonellidae* (Kent, 1880).
Tintinnopsis cylindrica (Daday, 1887)

Diagnostic characters: Cylindrical in shape to its two third length and blunt in the rear quarter, tapering into a pointed process towards the aboral end. The oral end smooth and transversely truncate (Fig. 3a). The specimen from Chilika Lagoon measured 149.47µm in TL and 43.36 µm in OD, while Daday (1887), reported 180 µm (TL) and 45 µm width for the species.

Tintinnopsis directa (Hada, 1932)

Diagnostic characters: Lorica with a sub-cylindrical body, slight oral flare and a globose aboral end. Oral rim irregular and body wall coarsely agglomerated. The species differs from other species of *Tintinnopsis* in having a globose aboral end. The specimen measured 84.68 µm TL, 41.23 µm OD and 44.65 µm in MT (Fig. 3b).

Tintinnopsis compressa (Daday, 1887)

Diagnostic characters: Lorica has wide flaring collar at the aboral end with marked constriction at the neck which then widen into a bowl. Flare almost twice the size of the bowl and wall of the lorica agglomerated. The specimen measured 90.11 µm in TL, 66.50 µm in OD and 37.12 µm in MT (Fig. 3c). This species differs from *T. filakinensis* in having a large flare and comparatively smaller bowl.

Tintinnopsis rotundata (Kofoid and Campbell, 1929)

Diagnostic characters: Tintinnid with agglomerated lorica, has short rounded vial shape and an uneven oral rim. The aboral end is curved or sometimes semicircular. Specimen from Chilika measured 35.10 µm in TL, 18.58 µm in OD and 20.79 µm in MT (Fig. 3d). This species differs from *T. beroidea* and *T. cylindrica* in having a round aboral end instead of pointed.

Tintinnopsis filakinensis (Al-Yamani *et al.,* 2011)

Diagnostic characters: Has a large pot shaped lorica. The aboral end tapering bluntly into either pointed or sometimes rounded end. The oral end with large, wide and campanulate flare. Wall of the lorica densely agglomerated. The specimen from Chilika measured 154.88 µm in TL and 107.16 µm in OD (Fig. 3e).

Tintinnopsis radix (Imhof, 1886)

Diagnostic characters: This trunk shaped species has an elongated and tubular lorica and a cylindrical bowl with smooth oral rim. Aboral region tapering into a horn. The lorica wall thin and with faint spiral structures. The specimen measured 93.68 µm in TL, 11.97 µm in OD and the aboral horn length was 14.92 µm. The L/OD ratio was 7.82 µm (Fig. 3g). The species differs from *T. kofoidi* in the aboral region, which is gradually tapering and also in the fragile construction of the lorica. The species has less contraction at the aboral region, and also differs in the shape of lateral opening in the aboral horn.

Tintinnopsis karajacensis (Brandt, 1896)

Diagnostic characters: Cylindrical bowl with rounded aboral end. Lorica capsular and is coarsely agglomerated. The species differes from *T. rotundata* in the presence of spiral structures towards 1/3rd of the oral end. The species from Chilika measured 81.06 µm in TL, 36.11 µm in OD and 40.87 µm in MT (Fig. 3h).

Tintinnopsis nucula (Fol, 1884)

Diagnostic characters: Flask shaped, slightly elliptical lorica having more or less oval bowl. The oral end with a low collar. Body covered with agglomerated particles. The body converges towards the oral end with its MT at 1/3rd of the aboral end. The species differs from other species of tintinnids in its typical flask shaped structure and in the absence of constriction at the neck. The specimen from Chilika measured 56.47 µm in TL and 19.49 µm in OD and 39.33 µm in MT (Fig. 3i).

Tintinnopsis tubulosa (Levander, 1900)

Diagnostic characters: Lorica with cylindrical collar and rounded bowl, collar narrowing towards the oral end. Lorica thin and lightly agglomerated. MT towards the aboral end. The specimen from Chilika measured 88.67 µm in TL, 16.15 µm in OD and the MT measured 26.96 µm (Fig. 3j). The species differs from *T. pistillum*, which has a conical aboral end.

Tintinnopsis parvula (Jorgensen, 1912)

Diagnostic characters: Lorica cylindrical with bowl either forming a cone or rounded aboral end. The lorica agglomerated and the bowl shape varied individually. The specimen from Chilika measured 188.80 µm in TL, 52.97 µm in OD and 59.35 µm in MT (Fig. 3k). The species differs from *T. lobiancoi* in having a continuous bowl than a continuous lorica.

Tintinnopsis fimbriata (Meunier, 1919)

Diagnostic characters: The lorica agglutinated with a bowl, which has its maximum width at two third of the oral end, narrowing into a neck. The oral end has undefined oral edge with irregular extensions like fringes forming a broken flare. The aboral end with a horn. The specimen from Chilika measured 43.91 µm in TL, 27.64 µm in OD. The aboral horn measured 8.85 µm (Fig. 3l).

Tintinnopsis spiralis (Kofoid and Campbell, 1929)

Diagnostic characters: Lorica cylindrical, elongated, campanulate and scarcely agglomerated. Suboral flare towards the oral end and a blunt posterior end. The lorica wall with 10-12 spiral turns. The specimen from Chilika measured 94 µm in TL, 36.02 µm in oral dimater and 44.36 µm in MT. The species differs from *T. karajacensis* and *T. loricata* in having an oral flare and spiral structures.

Tintinnopsis gracilis (Kofoid and Campbell, 1929)

Diagnostic characters: Finger shaped tintinnid with a tubular bowl which can be slightly swollen towards the end. The lorica wall thick and lightly agglomerated but with no spiral structures. The specimen from Chilika measured 101.77 µm in TL, 59.45 µm OD with an L/OD ratio of 1.72 (Fig. 3n). The species differs from *T. karajacensis* and *T. turgida* in having a pointed aboral region instead of round.

Family*: Codonellopsidae*
Codonellopsis ostenfeldei (Schmidt, 1902)

Diagnostic characters: Lorica with a round bowl and sub-cylindrical collar. Bowl with dense agglomerated particles and collar slightly flared upwards. Spiral lines and 10-12 fenestrae present on the collar but absent on the upper turns of the oral ends. Specimen from Chilika measured 125.22 µm in TL, 42.93 µm in OD, MT of the bowl 73.43 µm and 43.45 µm in collar length (Fig. 4a). The species differs from other species of *Codonellopsis* in having number of spiral structures with fenestrae on the collar.

Stenosemella nivalis (Meunier, 1910)

Diagnostic characters: The agglomerated lorica globose, rounded or slightly tapering towards the aboral end. The shoulder squarish and the oral end encircled with a small but prominent collar. The specimen from Chilika measured 22.70 µm in TL and the MT was 23.72 µm. The collar measured 2 µm in length with OD 9.60 µm (Fig. 4b). The specimen is smaller and stouter when compared to the species *Stenosemella ventricosa*.

Stenosemella ventricosa (Jorgensen, 1924)

Diagnostic characters: Lorica ovate and the body covered with agglomerating particles. The oral end with a very low collar with the shoulder sloping outward. Aboral end more conical. The specimen from Chilika measured 26 µm in TL and 12.80 µm in OD and MT measured 25.30 µm (Fig. 4c). According to Hada (1932), the species has a lorica length of 1.7-2 OD with MT of 1.5-1.7.

Family: Ptychocylididae
Favella adriatica (Imhof, 1886; Jorgensen, 1924)

Diagnostic characters: Lorica hyaline, widely campanulate, with a thick wall. The oral end with a rim with primary reticulations. Single walled mouth/or with two annuli. The aboral end with short, thick and undulated caudal horn. According to Jorgensen (1924), the specimen measured 120-145 µm in TL and 100-113 µm or smaller in OD. The present study recorded a TL of 134-140 µm and OD of 88-100 µm (Fig. 4d).

Favella campanula var. composite (Schmidt, 1902; Jorgensen, 1924)

Diagnostic characters: The lorica hyaline and slightly campanulate. The collar had slightly flaring oral lip with single annulus. The aboral end conical which tapers to a horn. The horn with a long pedicel had wings that varied in size with individuals. The specimen from Chilika which is a variance of *F. campanula* measured 247 µm in TL, 112 µm in MT, 108 µm in OD and the pedicel measured 72 µm (Fig. 4e). The species differs from *var. composita* in having a longer pedicel and single annuli.

Favella ehrenbergii (Claparede and Laachmann, 1858; Jorgensen, 1924)

Diagnostic characters: Elongated lorica hyaline and slightly campanulate. The oral end with large pedicel and flaring lips. Its pedicel attached to the bottom by wings. The aboral end with an aboral horn with spiral turns. The lorica are found engulfed in other tintinnid species like *T. tocantinensis* and *T. cylidrica.* The specimen from Chilika Lagoon measured 307.97 µm in TL, 120.03 µm in OD and the length of aboral horn was 33.19 µm (Fig. 4f). The species differs from other species of *Favella* in having a more cylindrical bowl.

Family: Tintinnidae
Dadayiella bulbosa (Brandt, 1906)

Diagnostic characters: The body tumbler shaped with lorica slightly flaring towards the oral end. Bowl narrowest in the first anterior half, increasing to its largest width and then gradually tapering into a narrow longitudinal pedicel. Aboral region convex. Wall provided with longitudinal striae. The specimen from Chilika Lagoon measured 78.51 µm in TL, 24.53 µm in OD and 26.46 µm in MT. Length of the aboral horn was 14.54 µm (Fig. 4g). The species differs from D. ganymedes which has a knob at the end of the pedicel whereas D. bulbosa has a pointed pedicel.

Eutintinnus fraknoi (Daday, 1887)

Diagnostic characters: The lorica hyaline and elongated in shape, gradually slightly tapering towards the end. Both the oral ends more flared than the aboral ends. Daday (1887) reported a TL of 360-416 µm, OD of 54-72 µm and aboral end length of 36-45 µm for the species. The specimen from Chilika Lagoon measured 262.53 µm in TL, 92.04 µm in OD and 48 µm in aboral end diameter (AD) (Fig. 4h).

Eutintinnus apertus (Kofoid and Campbell, 1929)

Diagnostic characters: Lorica hyaline, tubular, sub-conical anteriorly and slightly concave posteriorly. The oral region very lightly flaring whereas the aboral region narrows abruptly. According to Kofoid and Campbell (1929), the species measured 89-108 µm in length and 2.2-3.2 µm in OD. The specimen from Chilika followed almost the same measurements and stood at 88 µm in length, 31 µm in OD and 19 µm in AD (Fig. 4i).

Eutintinnus elongatus (Jorgensen, 1924)

Diagnostic characters: Lorica tubular, long, slender and conically dilated slowly towards the mouth. The length of the species is much larger when compared to *Eutintinnus franknoi* and other species of *Eutintinnus*. It also has a narrower end. The specimen reported by Jorgensen (1924) measured 348-493 µm in length, 62-68 µm in OD and 35-42 µm in aboral end diameter. The specimen from Chilika Lagoon measured 372 µm in length, 64 µm in OD and 38 µm in AD (Fig. 4j).

Leprotintinnus nordqvistii (Brandt, 1906)

Diagnostic characters: Lorica with a tubular shaft and a large aboral flare. Shaft tapering and then expanding posterior to form a large aboral conical flare. Spiral structures of aggregated scare particles on the wall of the aboral flare. Brandt (1906) reported this species with length 110-200 µm and width 30-40 µm. The specimens from Chilika Lagoon measured 180 µm in TL, 41.71µm in width and 83.87 µm in OD (Fig. 4k). The species differs from all other *Leprotintinnus* species in having a large aboral flare.

Leprotintinnus simplex (Schmidt, 1902)

Diagnostic characters: This species has an elongated, tubular lorica with coarsely agglomerated body. The agglomeration is spirally arranged along the length of the body. Both the oral and aboral ends open and not flaring. The specimen from Chilika Lagoon measured 297.32 µm in TL and 58.19 µm in OD (Fig. 4l). The species differs from *Leprotintinnus nordqvistii* in absence of the large aboral flare.

Family: *Metacylidae* (Jorgensen, 1924)
Metacylis tropica (Duran, 1957)

Diagnostic characters: Lorica hyaline, globose and aborally convex. Length almost equal to width. Oral end having a neck with constriction forming 3 - 4 rings. The lorica attained its MT just below the constriction. The measurements from Duran (1957) showed a length range of 0.14 - 0.30 µm. The present study reports TL of 42.09 µm and OD of 42.95 µm. The MT was 49.11 µm just below the constriction (Fig. 4 m).

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