

The first snapshot study on horizontal distribution and identification of five peritrich ciliates (Genus *Vorticella* Linnaeus and *Zoothamnium* Bory de St. Vincent) from the eastern Indian Ocean

MUNIR Sonia^{1, 2}, SUN Jun^{1, 2*}

¹Tianjin Key Laboratory of Marine Resources and Chemistry, Tianjin University of Science and Technology, Tianjin 300457, China

²Research Centre for Indian Ocean Ecosystem, Tianjin University of Science and Technology, Tianjin 300457, China

Received 4 July 2017; accepted 10 April 2018

© Chinese Society for Oceanography and Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract

Epipont peritrich ciliates are one of the most sessile protists that attached to the substrate of zooplankton communities especially copepods and crustaceans. Peritrich ciliates can be solitary or colonial form found from the coastal zones and embayment around the world. Present research report is the first snapshot study of the peritrich ciliates and the horizontal distribution in open waters from surface to 200 m depth in the eastern Indian Ocean. Recently, five peritrich ciliates, e.g., *Vorticella oceanica*, *Zoothamnium alternans*, *Z. alrasheidi*, *Z. pelagicum*, and *Z. marinum* were collected from plankton net tow samples during the cruise from April 10 to May 13, 2014. The characteristics of the peritrich ciliate were determined according to the shape of the zooids, the ciliary structure and the stalks. The morphometric shape, sizes and characters also explained by examination under light/scanning electron microscopy. *Vorticella oceanica* and *Z. pelagicum* showed their association with host such as diatom (i.e., *Chaetoceros coarctatus*) and copepod (*Oithona brevicornis*) including some individuals around the dinoflagellate species (*Ceratium tripose*). The distribution of these sessile ciliates was dominated by the *V. oceanica*, *Z. pelagicum* and *Z. marinum* at the southeast zone while the large colonies of *Z. alrasheidi* observed at the Bay of Bengal. This distribution can be influenced by substrate availability like diatom (*Ch. coarctatus*) and copepods (*O. brevicornis*).

Key words: *Vorticella oceanica*, *Zoothamnium alternans*, *Zoothamnium alrasheidi*, *Zoothamnium marinum*, *Zoothamnium pelagicum*, eastern Indian Ocean

Citation: Munir Sonia, Sun Jun. 2018. The first snapshot study on horizontal distribution and identification of five peritrich ciliates (Genus *Vorticella* Linnaeus and *Zoothamnium* Bory de St. Vincent) from the eastern Indian Ocean. Acta Oceanologica Sinica, 37(10): 79–85, doi: 10.1007/s13131-018-1303-4

1 Introduction

The class Oligohymenophora de Puytorac et al., 1974 and order Peritrichida has peritrich ciliates which characterized by its inverted bell shaped zooids, ciliary rows at the apical end and contractile stalks (Boltovskoy, 1999). Peritrich ciliates are both sessile and planktonic protist of marine and freshwater environment which have mostly epibiotic attachment with crustaceans, e.g., scallops, blue crabs and zooplankton such as copepods (Fernandez-Leborans and Tato-Porto, 2000; Song et al., 2002; Gilbert and Schröder, 2003; Clamp and Williams, 2006; Ji et al., 2015; Sun et al., 2016), Amphipod (Fenchel, 1965), also attached to green microalgae like *Chlorella* sp. (Karakashian and Karakashian, 1965) and *Ulva* sp. (Ji and Song, 2004), diatoms *Chaetoceros coarctatus* and *Licmophora* (Nagasawa and Warren 1996; Gómez, 2017), and *Cyanobacteria* (Hausmann and Walz, 2007). Some of them also have been seen in association with microsporidia and trypanosomatid parasites (Fokin et al., 2014), Proteobacteria in-

cluding *Archaea* (Schweikert et al., 2013) and other bacteria (Bauer-Nebelsick et al., 1996; Schuster and Bright, 2016). The epibiotic species of *Vorticella*, *Zoothamnium* and *Epistylis* have been found distributed in eutrophic biotopes such as coastal areas, e.g., Qingdao, China (Ji et al., 2009), Brazil (Regali-Selegim and Godinho, 2004), Chesapeake Bay (Utz and Coats, 2005), Gulf of Mexico (Ma and Overstreet, 2006), Kayamkulam estuary of Kerala (Chitra and Kumar, 2015) and in shallow-water sunken wood in the North Adriatic Sea (Schuster and Bright, 2016). Although this epibiosis has wide distribution, it is still less prevalent than other microzooplanktons with the regard to similar congeners. However, it is difficult to understand its ecological prevalence in marine ecosystem. Sessile ciliates have been reported worldwide but are unknown from the open sea, the eastern Indian Ocean. This baseline study on the distribution of peritrich ciliates and systematics is the key source for future research studies.

Foundation item: The NSFC Open Cruise for the Eastern Indian Ocean during March–May 2014; the National Natural Science Foundation of China under contract Nos 41876134, 41676112, 41276124 and 41406155; the University Innovation Team Training Program for Tianjin under contract No. TD12-5003; the Changjiang Scholar Program of Chinese Ministry of Education of China to Jun Sun.

*Corresponding author, E-mail: phytoplankton@163.com

2 Materials and methods

During springtime (April 10 to May 13, 2014), a total of 44 plankton net-hauled samples were collected from 200 m depth to the surface between the 10°N–5°S and 80°–95°E transect across the eastern Indian Ocean (Fig. 1). Samples were preserved by adding 2% formalin in 1 L Polycarbonate bottles. Only 3 mL of subsamples were used from each bottle and examined under the light

microscope (Motic, AE2000) at 200× and 400× magnification. All light microscopic images captured using the Motic camera (2506, 5.6M) and scanning electron micrographs captured under the scanning electron microscopy (JEOL TM-5006). The sizes measured on the ocular micrometer scale under light microscope. The number of zooids separately counted by following the method of Liu et al. (2015) and converted into ind./m³.

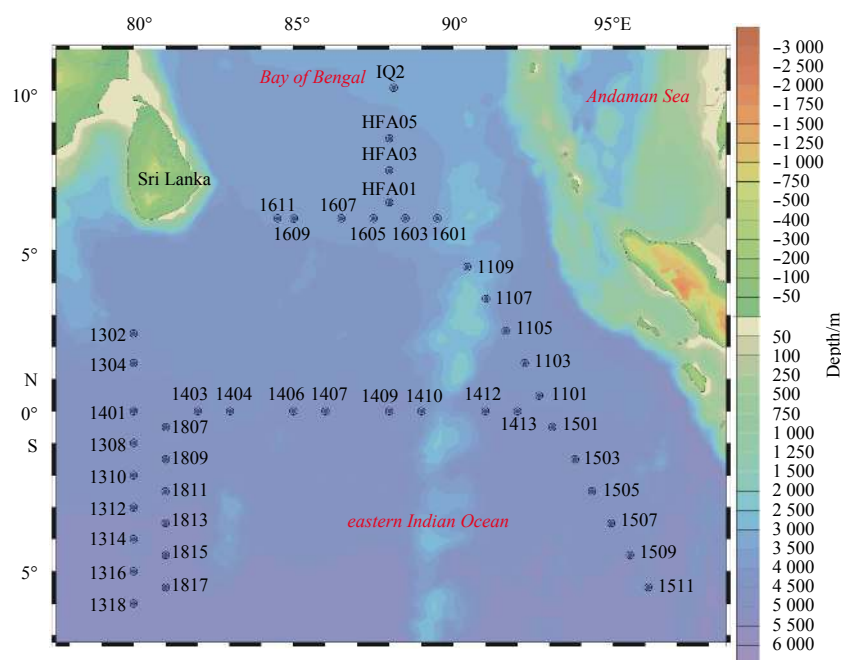


Fig. 1. Map showing the sampling area and stations across the Bay of Bengal, and the eastern Indian Ocean.

3 Results and discussion

Recently, a total of five species of peritrich ciliates (*Vorticella oceanicum*, *Zoothamnium alternans*, *Z. alrasheidi*, *Z. marinum* and *Z. pelagicum*) were collected from the open oceanic sampling sites at 200 m depth in the eastern Indian Ocean. Only *V. oceanicum* and *Z. pelagicum* are planktonic, free-floating Protista (Gómez, 2017). The *Z. alternans*, *Z. alrasheidi*, *Z. marinum* are mostly colonies former ciliates (Ji et al., 2009). During this study, *V. oceanicum* and *Z. pelagicum* although have specific host association with diatom *Ch. coarctatus* (Figs 2a, b), dinoflagellates species, *Ceratium tripose* (Fig. 2c) and zooplankton such as copepods (i.e., *Oithona brevicornis*, Figs 2d, e).

Systematics and classification

Class Oligohymenophora de Puytorac et al., 1974

Subclass Peritrichia Stein, 1859

Order Sessilida Kahl, 1933

Family Vorticellidae Ehrenberg, 1838

Genus *Vorticella* Linnaeus, 1767

Genus *Zoothamnium* Bory de St. Vincent, 1826

Family Vorticellidae

Vorticellidae family has been subjected to the taxonomic revision since 1838 by several authors (Ehrenberg, 1838; Song, 1991; Sommer, 1951; Stiller, 1971; Corliss, 1979; Kent, 1880–1882; Kahl, 1935; Lynn, 2008). Vorticellidae classified into two genera, *Vorticella* and *Zoothamnium* which have similar morphological characters, such as on the base of zigzag stalked with bell-shaped

zooids and infraciliature structures. So far, more than 100 species of genus *Vorticella* and 70 species of genus *Zoothamnium* have been described (Song et al., 2009).

Genus *Vorticella*

The genus *Vorticella* is unique with its single cell having the contractile stalks. It can be differentiated to the other colony forming cells having elongated stalked ciliates *Zoothamnium* (Ehrenberg, 1838). *Vorticella* is widely distributed in coastal localities of China, Japan, Austria (Ji et al., 2005). *Vorticella oceanica* Zacharias, 1906 in association to *Ch. coarctatus* has been reported from Japan (Nagasawa and Warren, 1996), South Atlantic (Boltovskoy, 1999) and Brazil (Dias et al., 2006). This is the first record on the distribution of *V. oceanica* with attachment to *Ch. coarctatus* Lauder from the eastern Indian Ocean (Figs 2a, b).

Vorticella oceanica Zacharias, 1906

Description and distribution: *Vorticella oceanica* Zacharias, 1906 was observed with numerous single cells with cylindrical and somewhat elongated zooids that are attached to contractile stalks (Figs 3a, b). Single contractile vacuole (CV) is about 8 μm that are positioned to the ventral position with greenish granules on zooids pellicle. These zooids are attached to the diatom species *Ch. coarctatus* Lauder (Figs 2a, b). The zooids were measured up to 25–50 μm in size (Table 1). Zooids have middle ciliated rows along the oral cavity (Figs 3b–d). In the eastern Indian Ocean, these specimens were found high in cell numbers, e.g., 21–190 ind./m³ and distributed from the sampling sites at the southeast transect (Stas 1310, 1809, 1815, 1410 and 1511) and the Bay of Bengal (Stas 1609 and 1109) of this study area (Table 1)

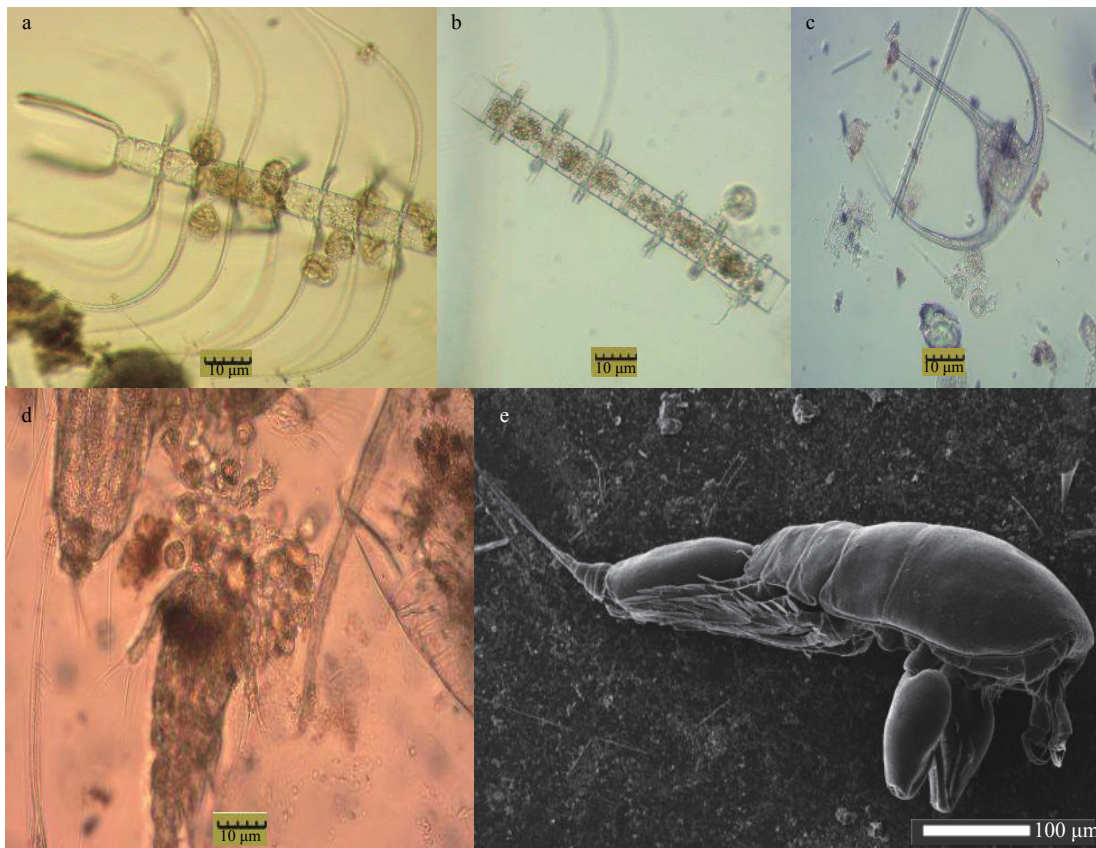


Fig. 2. Light micrographs of *Vorticella oceanica* attached to diatom (*Chaetoceros coarctatus*, a and b) and dinoflagellates (*Ceriatum tripose*, c), some colonial zoothamnium species *Z. pelagicum* attached to the copepods (d), and SEM image of copepod species (*Oithona brevicornis*, e).

when temperature and salinity were recorded up to 22.25–24.11°C and 34.9 respectively.

Genus *Zoothamnium*

The genus *Zoothamnium* is colonized form of stalked type ciliates with cylindrical, vase shape and elongated zooids. These zooids connected to each other with smooth, long branch stalks and stalks disc. The species of *Zoothamnium* are complex in the external morphological traits, but the modern silver-impregnation techniques helped scientists to identify more than 70 species from this genus and many taxonomic reworks have been taken into consideration (Ji and Song, 2004; Ma and Overstreet, 2006; Ji et al., 2009). Some of them are reported from the South China Sea (Ji et al., 2009). Only one species, *Zoothamnium pelagicum* is a planktonic species which reported from the open sea, Mediterranean Sea (Gómez, 2017). Four species, i.e., *Z. alternans*, *Z. alrasheidi*, *Z. marinum* and *Z. pelagicum* are reported for the first time from the eastern Indian Ocean (Figs 4 and 5).

Zoothamnium alternans Claparède et Lachmann, 1859

Zoothamnium alternans is cosmopolitan species and widely distributed in coastal areas of Qingdao, China (Ji et al., 2006), Gulf of Mexico (Ma and Overstreet, 2006). *Zoothamnium alternans* was described on the base of alternatively branched colony with large macro and microzooids that contain large telotrochs on the main stem and the J-shaped macronucleus (Song et al., 2009). Similar characteristics were observed for the species collected from the eastern Indian Ocean (Figs 4a–c).

Description and distribution: Each colony of *Zoothamnium alternans* is comprised of more than 30 to 50 zooids. The zooids were measured up to 30–87 μm in size. These zooids are at-

tached with the smooth and long stalks (57–85 μm) which hinder with the large telotrochs (103 μm) located at the main trunk region (Figs 4a–c and Table 1). Zooids are mostly subglobular in shape, with ciliary rows, many greenish food-vacuoles, parallel silver lines, and contractile vacuoles (Figs 4a, b). This species often has long cilia (19 μm), contractile vacuole (8 μm) and peristomial lips (5 μm) (Fig. 4c). The specimens were collected from the sampling sites (Stas 1109, 1304 and 1807) that are located at the south-eastern part of the study area. The colonies were observed with maximum abundance (60 ind./ m^3) and have total numbers of zooids (560 m^{-3}) when temperature and salinity were recorded up to 22.25–24.11°C and 34.9 respectively.

Zoothamnium alrasheidi Ji et al., 2009

Description and distribution: *Zoothamnium alrasheidi* were observed in the foliiform, giant and leaf-shaped colonies. Each colony is comprised of more than 50 to 100 zooids. The zooids were measured up to 37–40 μm in size. These zooids are attached with the smooth, long stalks (73 μm) without any telotrochs (Fig. 4d). Zooids are bottle shape with ciliary rows (Fig. 5d). The specimens were collected from the sampling site (Sta. 1609) located to the Bay of Bengal. More than three colonies were observed with a high abundance (58 ind./ m^3) and total number of zooids (1 948 m^{-3}) (Table 1) during the low temperature and high salinity (23.35°C, 34.64).

Zoothamnium marinum Kahl, 1933

Zoothamnium marinum was the first described by Kahl in 1933. According to the original description, *Z. marinum* has the umbellate zooids with stalks devoid of any infraciliature and silverlines structures. This species can be differentiated with elong-

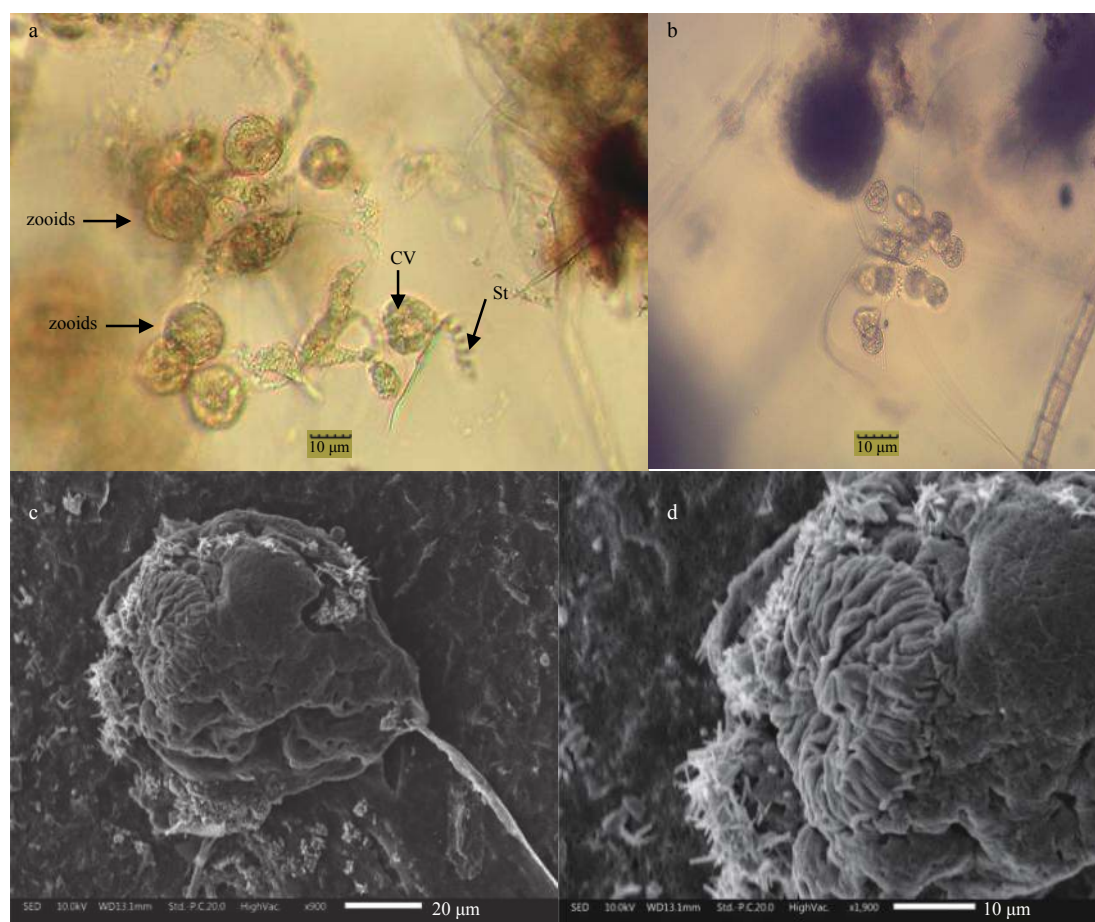


Fig. 3. Light and scanning electron micrographs of *Vorticella oceanica*. a. Zooids are rounded with contractile stalk (St) (black arrows) and central contractile vacuoles (CV) (black arrow); and b–d. LM and SEMs micrographs of single zooids with ciliary structure.

Table 1. Morphometric data, numbers of the zooids as per m^3 and the distribution of five peritrich ciliates in the eastern Indian Ocean

Taxa	Size of zooids	Zooids per m^3	Stations	Plates
<i>Vorticella oceanica</i>	25–50 μm ($n=10$)	21–190	1310, 1809, 1609, 1815, 1410, 1511	Figs 2a, b; Figs 3a–d
<i>Zoothamnium alternans</i>	30–87 μm ($n=20$ –30)	65–560	1109, 1304, 1807,	Figs 4a–c
<i>Zoothamnium alrasheidi</i>	37–40 μm ($n=40$ –100)	91–1 980	1609	Fig. 4d
<i>Zoothamnium marinum</i>	30–55 μm ($n=24$ –40)	18–485	1304, 1308, 1807	Fig. 4e
<i>Zoothamnium pelagicum</i>	20–35 μm ($n=30$ –40)	21–827	1304, 1307, 1310, 1807	Figs 5a–f

ated zooids, single peristomial lips, and c-shaped macronucleus with single contractile myomere at the apical region of infundibular area of the oral cavity. Recently this species was reported from the littoral zones of Qingdao and South China Sea. This species was redescribed on the basis of transversely silverlines in the zooids between the peristomial lip and trochoband area (Ji et al., 2009).

Description and distribution: *Zoothamnium marinum* is elongated bell shaped and umbrella shaped colonies, consisting of no more than 24 zooids (Fig. 4e). The zooids were measured up to 30–55 μm in size. These colonies were collected from the sample sites (Stas 1304, 1307 and 1807), located at southeast part of the study area. The total colonies ranged into maximum abundance as 9–21 ind./ m^3 per colonies and total salinity observed from the ranges as 23.35–24.32°C and 34.64–35.00 respectively.

***Zoothamnium pelagicum* Du Plessis, 1891**

Zoothamnium pelagicum was first described from the Mediterranean Sea by Du Plessis in 1891. Later this species also been reported from the same region (France and Spain) and South Atlantic Ocean (Gómez, 2017). *Zoothamnium pelagicum* has been classified as planktonic sessilid ciliates species, which are mostly associated to diatoms, *Cyanobacteria* and some bacteria (Laval-Peuto and Rassoulzadegan, 1988). This species has close resemblance with *Z. alternans*, *Z. niveum* and *Z. plumula* (Ji et al., 2015; Sun et al., 2016). This is the first report of *Z. pelagicum* (Figs 5a–f) in the eastern Indian Ocean.

Description and distribution: *Zoothamnium pelagicum* has inverted bell shaped zooids which consist more than 100 zooids in one colony (Figs 5a–h). Zooids with peristomial lips (PL) and ciliary rows are shown in Fig. 5c. Each zooid was measured as 20–35 μm in size and attached to stalks disc. The stalks are

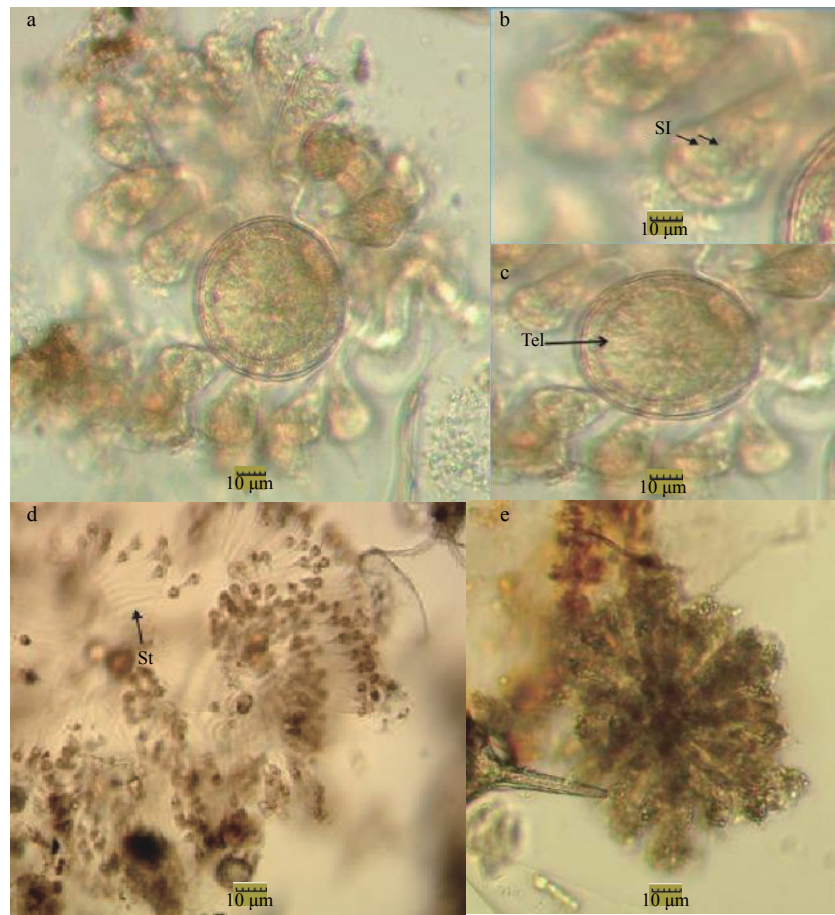


Fig. 4. Light micrographs of *Zoothamnium altranans* (a–c), *Zoothamnium alrasheidi* (d) and *Zoothamnium marinum* (e). a. Colony form of *Z. altranans* with zooids and teletoms attached to the zigzag stalked; b. silverlines in zooids (SI) and greenish food vacuoles (black arrows); c. large teletrochs (Tel), black arrow; d. colony form with leaf-like zooids in *Z. alrasheidi*; and e. elongated zooids in *Z. marinum*.

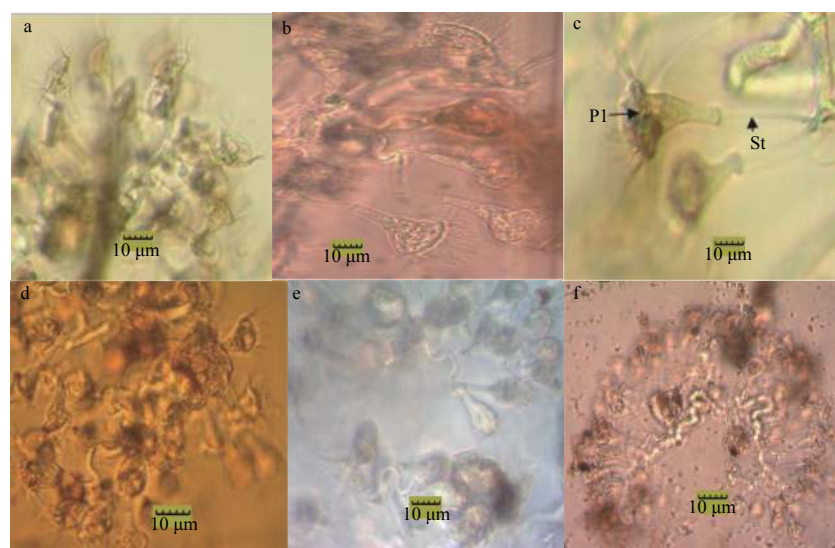


Fig. 5. Light micrographs of *Zoothamnium pelagicum* showing the bell-shaped zooids in colony form. c. Peristomial lip (Pl, black arrow); d. c-shaped macronucleus; and e–f. colonies with zigzag, smooth and elongated stalks (St).

smooth, elongated and 2 µm in width (Figs 5c–f and Table 1). This species were collected from the sampling sites located to southeast zone (Stas 1304, 1307, 1310 and 1807) and the Bay of

Bengal (Sta. 1609) of the sampling area. Each colony was observed with high abundance 19–50 ind./m³ per colonies and total numbers of zooids are 827 ind./m³. Temperature and salinity was

observed to be 24.25°C and 34.92 respectively.

Conclusion: The current study highlights the first report on the horizontal distribution and systematic studies of five peritrich sessilid ciliates (*Vorticella* and *Zoothamnium*) from the eastern Indian Ocean. The *Vorticella oceanica* and *Zoothamnium pelagicum* are two major species which were observed with planktons, such as diatom (*Chaetoceros coarctatus*) and copepods (*Oithona brevicornis*). These planktonic ciliates are the source of nutrients recovered from the ecosystem. Most sessilid ciliates can increase high filtration rates and produce high biomass similar to other microzooplankton. This baseline study can play an important role in future research.

Acknowledgements

The authors appreciate the support of the captain and crew of R/V *Shiyan 1* and other participants, Ding Changling, Zhai Weidong, Wu Libin, Su Hongfei, Song Yongjun for trawling and sampling in the eastern Indian Ocean.

References

- Bauer-Nebelsick M, Bardele C F, Ott J A. 1996. Redescription of *Zoothamnium niveum* (Hemprich & Ehrenberg, 1831) Ehrenberg, 1838 (Oligohymenophora, Peritrichida), a ciliate with ectosymbiotic, chemoautotrophic bacteria. *European Journal of Protistology*, 32(1): 18–30, doi: [10.1016/S0932-4739\(96\)80036-8](https://doi.org/10.1016/S0932-4739(96)80036-8)
- Boltovskoy D. 1999. South Atlantic Zooplankton. Leiden: Backhuys Publishers
- Chithra P, Kumar R S. 2015. Preliminary studies on epibiotic protista in the mangrove ecosystem of Ayiramthengu, Kerala coast. *Journal of the Marine Biological Association of India*, 57(2): 90–94
- Clamp J C, Williams D. 2006. A molecular phylogenetic investigation of *Zoothamnium* (Ciliophora, Peritrichia, Sessilida). *The Journal of Eukaryotic Microbiology*, 53(6): 494–498, doi: [10.1111/jeu.2006.53.issue-6](https://doi.org/10.1111/jeu.2006.53.issue-6)
- Corliss J O. 1979. The Ciliated Protozoa: Characterization, Classification, and Guide to the Literature. New York: Pergamon Press, 1–453
- de Puytorac P, Batisse A, Bohatier J, et al. 1974. Proposition d'une classification du phylum Ciliophora Doflein, 1901 (Réunion de Systematique, Clermont-Ferrand). In: *Comptes Rendus des Séances de l'Académie des Sciences*. Paris: Gauthier-Villars, 278: 2799–2802
- Dias R J P, D'Ávila S, D'Agosto M. 2006. First record of epibionts peritrichids and suctorians (Protozoa, Ciliophora) on *Pomacea lineata* (Spix, 1827). *Brazilian Archives of Biology and Technology*, 49(5): 807–812, doi: [10.1590/S1516-89132006000600015](https://doi.org/10.1590/S1516-89132006000600015)
- Ehrenberg C G. 1838. Die Infusionsthierchen als Vollkommene Organismen. Leipzig: L Voss, 1–612
- Fenchel T. 1965. On the ciliate fauna associated with the marine species of the amphipod genus *Gammarus*. J. G. Fabricius. *Ophelia*, 2(2): 281–303, doi: [10.1080/00785326.1965.10409605](https://doi.org/10.1080/00785326.1965.10409605)
- Fernandez-Leborans G, Tato-Porto M L. 2000. A review of the species of protozoan epibionts on crustaceans: I. Peritrich ciliates. *Crustaceana*, 73(6): 643–683, doi: [10.1163/156854000504705](https://doi.org/10.1163/156854000504705)
- Fokin S I, Schrällhammer M, Chiellini C, et al. 2014. Free-living ciliates as potential reservoirs for eukaryotic parasites: occurrence of a trypanosomatid in the macronucleus of *Euplotes encysticus*. *Parasites & Vectors*, 7(1): 203
- Gilbert J J, Schröder T. 2003. The ciliate epibiont *Epistylis pygmaeum*: selection for zooplankton hosts, reproduction and effect on two rotifers. *Freshwater Biology*, 48(5): 878–893, doi: [10.1046/j.1365-2427.2003.01059.x](https://doi.org/10.1046/j.1365-2427.2003.01059.x)
- Gómez F. 2017. Motile behaviour of the free-living planktonic ciliate *Zoothamnium pelagicum* (Ciliophora, Peritrichia). *European Journal of Protistology*, 59: 65–74, doi: [10.1016/j.ejop.2017.03.004](https://doi.org/10.1016/j.ejop.2017.03.004)
- Hausmann K, Walz B. 2007. *Zoothamnium pelagicum*: Ein sessiler, kolonialer Ciliat lebt vereint zu Gruppen. *Mikrokosmos*, 96: 217–222
- Ji D D, Kim J H, Shazib S U A, et al. 2015. Two new species of *zoothamnium* (Ciliophora, Peritrichia) from Korea, with new observations of *Z. parahentscheli* Sun et al. 2009. *Journal of Eukaryotic Microbiology*, 62(4): 505–518, doi: [10.1111/jeu.2015.62.issue-4](https://doi.org/10.1111/jeu.2015.62.issue-4)
- Ji D D, Song W B. 2004. Notes on a new marine peritrichous ciliate (Ciliophora: Peritrichida), *Zoothamnopsis sinica* sp. n. from north China, with reconsideration of *Zoothamnium maximum* Song, 1986. *Acta Protozoologica*, 43(1): 61–71
- Ji D D, Song W B, Al-Rasheid K A S, et al. 2005. Taxonomic characterization of two marine peritrichous ciliates, *Pseudovorticella clampi* n. sp. and *Zoothamnium parabuscula* n. sp. (Ciliophora: Peritrichia), from North China. *Journal of Eukaryotic Microbiology*, 52(2): 159–169, doi: [10.1111/jeu.2005.52.issue-2](https://doi.org/10.1111/jeu.2005.52.issue-2)
- Ji D D, Song W B, Warren A. 2006. Redescriptions of Three Marine Peritrichous Ciliates, *Zoothamnium alternans* Claparède et Lachmann, 1859, *Z. sinense* Song, 1991 and *Z. commune* Kahl, 1933 (Ciliophora, Peritrichia), from North China. *Acta Protozoologica*, 45(1): 27–39
- Ji D D, Xu H L, Choi J K, et al. 2009. Taxonomic characterization of three marine peritrichous ciliates from China: *Zoothamnium alrasheidi* spec., *Z. marinum* Kahl, 1933 and *Z. vermicola* Precht, 1935 (Ciliophora: Peritrichia). *Acta Protozoologica*, 48(2): 171–183
- Kahl A. 1933. Ciliata libera et ectocommensalia. In: Grimpe G, Wagler E, eds. *Die Tierwelt der Nordund Ostsee*. Leipzig: Akademische Verlagsgesellschaft, 147–183
- Kahl A. 1935. Urtiere oder Protozoa I: Wimpertiere oder Ciliata (Infusoria) 4. Peritricha und Chonotricha. In: Dahl F, ed. *Die Tierwelt Deutschlands*. Jena: G Fischer, 651–805
- Karakashian S J, Karakashian M W. 1965. Evolution and symbiosis in the genus *Chlorella* and related algae. *Evolution*, 19(3): 368–377, doi: [10.1111/evo.1965.19.issue-3](https://doi.org/10.1111/evo.1965.19.issue-3)
- Kent W S. 1880–1882. A Manual of the Infusoria: Including a Description of All Known Flagellate, Ciliate, and Tentaculiferous Protozoa, British and Foreign, and an Account of the Organization and Affinities of the Sponges. London: David Bogue
- Laval-Peuto M, Rassoulzadegan F. 1988. Autofluorescence of marine planktonic Oligotrichina and other ciliates. *Hydrobiologia*, 159(1): 99–110, doi: [10.1007/BF00007371](https://doi.org/10.1007/BF00007371)
- Liu H J, Huang Y J, Zhai W D, et al. 2015. Phytoplankton communities and its controlling factors in summer and autumn in the southern Yellow Sea, China. *Acta Oceanologica Sinica*, 34(2): 114–123, doi: [10.1007/s13131-015-0620-0](https://doi.org/10.1007/s13131-015-0620-0)
- Lynn D H. 2008. The Ciliated Protozoa. Characterization, Classification and Guide to the Literature. 3rd ed. Dordrecht: Springer
- Ma H W, Overstreet R M. 2006. Two New Species of *Epistylis* (Ciliophora: Peritrichida) on the Blue Crab (*Callinectes sapidus*) in the Gulf of Mexico. *Journal of Eukaryotic Microbiology*, 53(2): 85–95, doi: [10.1111/jeu.2006.53.issue-2](https://doi.org/10.1111/jeu.2006.53.issue-2)
- Nagasawa S, Warren A. 1996. Redescription of *Vorticella oceanica* Zacharias, 1906 (Ciliophora: Peritrichia) with notes on its host, the marine planktonic diatom *Chaetoceros coarctatum* Lauder, 1864. *Hydrobiologia*, 337(1–3): 27–36
- Regali-Selegim M H, Godinho M J L. 2004. Peritrich epibiont protozoans in the zooplankton of a subtropical shallow aquatic ecosystem (Monjolinho Reservoir, Sao Carlos, Brazil). *Journal of Plankton Research*, 26(5): 501–508, doi: [10.1093/plankt/fbh055](https://doi.org/10.1093/plankt/fbh055)
- Schuster L, Bright M. 2016. A Novel Colonial Ciliate *Zoothamnium ignavum* sp. (Ciliophora, Oligohymenophorea) and its Ectosymbiont *Candidatus Navis piranensis* gen. nov., sp. nov. from Shallow-Water Wood Falls. *PLoS One*, 11(12): e0162834
- Schweikert M, Fujishima M, Görtz H D. 2013. Symbiotic associations between ciliates and prokaryotes. In: Rosenberg E, DeLong E F, Lory S, et al., eds. *The Prokaryotes: Prokaryotic Biology and Symbiotic Associations*. Berlin, Heidelberg: Springer, 427–463
- Sommer G. 1951. Die peritrichen Ciliaten des großen Plöner Sees. *Acta Hydrobiologica*, 44: 349–440
- Song W B. 1991. Contribution to the commensal ciliates on *Penaeus*

- orientalis*: II. (Ciliophora, Peritrichida). *Journal of Ocean University of Qingdao* (in Chinese), 21(4): 45–55
- Song W B, Al-Rasheid K A S, Hu X. 2002. Notes on the poorly-known marine peritrichous ciliate, *Zoothamnium plumula* Kahl, 1933 (Protozoa: Ciliophora), an ectocommensal organism from cultured scallops in Qingdao, China. *Acta Protozoologica*, 41(2): 163–168
- Song W B, Warren A, Hu X Z. 2009. Free-living Ciliates in the Bohai and Yellow Seas, China. Beijing: Science Press, 239–243
- Stiller J. 1971. Szájkoszorús Csillósok-Peritricha. *Fauna Hungariae*, 105: 1–245
- Sun P, Clamp J, Xu D P, et al. 2016. An integrative approach to phylogeny reveals patterns of environmental distribution and novel evolutionary relationships in a major group of ciliates. *Scientific Reports*, 6: 21695, doi: [10.1038/srep21695](https://doi.org/10.1038/srep21695)
- Utz L R P, Coats D W. 2005. Spatial and temporal patterns in the occurrence of peritrich ciliates as epibionts on calanoid copepods in the Chesapeake Bay, USA. *Journal of Eukaryotic Microbiology*, 52(3): 236–244, doi: [10.1111/jeu.2005.52.issue-3](https://doi.org/10.1111/jeu.2005.52.issue-3)