Rec. zool. Surv. India: Vol. 120(2)/133-140, 2020
DOI: 10.26515/rzsi/v120/i2/2020/144245

ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

Diversity of Ctenophores in the Sundarban Mangroves, Northern Indian Ocean

Jasmine Purushothaman*, Alfisa Siddique, Aishee Bhowal and Kailash Chandra

Zoological Survey of India, Protozoology Section, M Block, New Alipore, Kolkata – 700053;
Email: jasbose@gmail.com, alfisas44@gmail.com, ashleyaishee93@gmail.com, kailash.chandra61@gov.in

Abstract

Four species of ctenophore viz., *Pleurobrachia globosa* Moser, 1903; *Pleurobrachia pileus* (O. F. Müller, 1776); *Beroe ovata* Bruguière, 1789 and *Beroe gracilis* Künne, 1939 were collected from the mangrove estuarine waters of Sundarban during winter monsoon survey conducted in January 2018. Of these species, *Beroe gracilis* Künne, 1939 is a new record from Bay of Bengal, Northern Indian Ocean. *Pleurobrachia pileus* was found to cause a swarm in Sundarban waters. The present study provides the description and distribution of four ctenophore species recorded in the study area.

Keywords: Bay of Bengal, *Ctenophora, Beroe gracilis, Beroe ovata, Pleurobrachia pileus, Pleurobrachia globosa*

Introduction

Gelatinous zooplankters are a diverse group of organisms that are often active, swarming predators in the marine pelagic ecosystem (Harbison *et al.*, 1978; Oliveira *et al.*, 2014; Purcell, 2005). Jellyfishes and ctenophores are the two major groups of gelatinous zooplankton (Madin & Harbison, 2001). Ctenophores have eight "comb rows" of fused cilia arranged along their sides and the synchronized beating of cilia propels the animal through water. They are transparent, soft and bioluminescent marine organisms with biradial symmetry (Pang & Martindale, 2008). They play a significant role in the pelagic food web as they feed on fish eggs and larvae, and compete with juvenile fish for food by preying on smaller zooplankton such as copepods (Lalli & Parsons, 1997). Ctenophores are exclusively marine, distributed in all oceans, seas and brackish water, mostly seen in pelagic to bathypelagic waters. Ctenophores are usually associated with echinoderms, sponges, and cnidarians (Mills, 1996). The first report of a ctenophore in Indian waters was given by Annandale & Kemp (1915) who recorded *Pleurobrachia globosa bengalensis* in the Bay of Bengal. To date, 12 species of ctenophores have been recorded from Indian waters (Venkatraman & Raghunathan, 2015; Venkatraman & Wafar, 2005), with *P. globosa* being the only species reported from Sundarban coastal waters.

This paper presents the detailed description of all the ctenophore species recorded from Sundarbans with the hydrographical observations and also provides the first record of *Beroe gracilis* from the northern coastal waters of Bay of Bengal.

Material and Methods

The survey was conducted along the coastal waters of Sundarban Mangroves, Matla Channel (Sundarbans, West Bengal) to Mori Ganga Channel (Sagar Islands, West Bengal) of Bay of Bengal during winter monsoon season between 9 a.m. and 10 a.m in January 2018 (Figure 1). Among the five sampling stations; Station 1 (21°46' 10.7" N, 88° 37' 44.8" E) and Station 2 (21°48' 28.1" N, 88° 34' 04.8" E) were in the Matla Channel, Station 3 (21°42' 18.1" N, 88° 30' 51.0" E) and Station 4 (21°39' 18" N, 88° 28' 13.9" E) were in the Thakuran Channel and Station 5 (21°37' 35.9" N, 88° 26' 15.4" E) was in the Jagaddal Creek. Sampling was carried out using Fishery trawler/dinghy boat. Surface (0 m)

* *Author for correspondence*

Article Received on: 01.05.2019 Accepted on: 06.08.2019

and sub-surface (10 m, 20 m) water and zooplankton samples were collected from each station. The zooplankton samples were collected by WP (working party) plankton net with mesh size 300 µm and a mouth diameter of 60 cm, attached with a digital flow meter to record the amount of water filtered through the net. The WP plankton net was towed at two knots speed for 15 minutes and the volume of water filtered was calculated. Other than WP plankton net, a scoop-net was also used due to ctenophores ranging in size from 2 mm to 10 cm. Environmental parameters were recorded at each station from surface and sub-surface depths. The mean value of all physico-chemical parameters, station-wise, are provided in Table 1. Environmental parameters (sea surface temperature, salinity and dissolved oxygen) were measured in-situ with the aid of a WTW Portable Multiparameter from surface and sub-surface depths. For analysis of nitrate concentration and chlorophyll *a* concentration in seawater, water samples were collected using Niskin sampler and brought to the laboratory for spectrophotometric analysis. Photographs of live samples were taken in situ and identified up to order level. The ctenophore specimens were also photographed under a stereo zoom microscope (Leica M125C) and subsequently identified up to species level based on available literature (Annandale & Kemp 1915; Greve 1975; Künne 1939; Liley 1958; Moser 1903). The sorted specimens were preserved in 4% neutral formaldehyde solution for further analysis. The mesozooplankton and ctenophore abundance were calculated by finding the ratio between the total number of organism to the volume of water filtered and expressed as individuals per metre cube (ind/m^3) while, the percentage composition of each taxonomic group was calculated by finding the ratio between the number of specimens in that group to the total number of specimens from all the groups and multiplying the result with 100 and expressed as % (Goswami 2004). Fixation led to slight morphological distortion and shrinkage of the collected specimens. The voucher specimens were deposited in the collections of Zoological Survey of India National Zoological Museum collections with registration numbers (WN-CTEN-001, WN-CTEN-002, WN-CTEN-003, WN-CTEN-004).

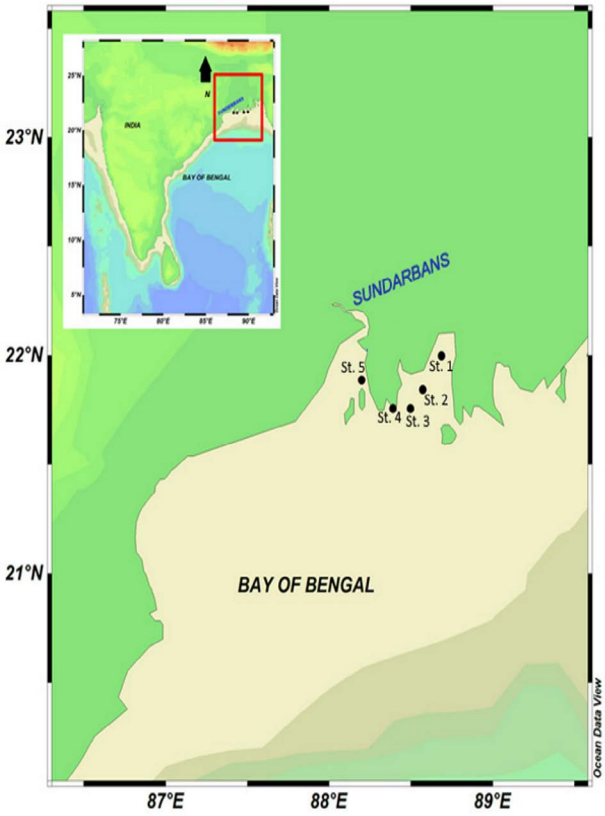

Figure 1. Map showing the study area.

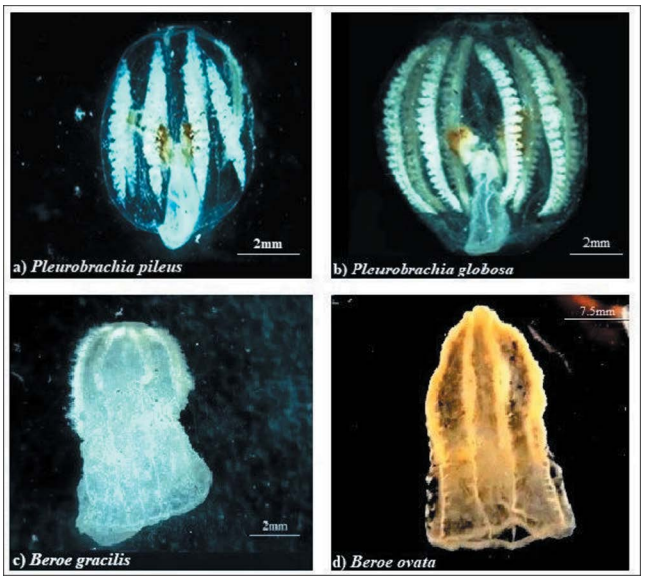

Figure 2. Collected ctenophore species of Sundarbans, Bay of Bengal, Northern Indian Ocean. **(a)** *Pleurobrachia pileus*; **(b)** *Pleurobrachia globosa*; **(c)** *Beroe gracilis*; **(d)** *Beroe ovata.*

Results

During the winter monsoon season of 2018, we have identified four species of ctenophores from the Sundarban mangrove waters. The species *Beroe gracilis* is reported for the first time from Bay of Bengal. Four species of ctenophores were recorded from five sampling stations.

Pleurobrachia pileus and *Pleurobrachia globosa* were recorded from all the five stations (Figure 1) that covered the areas of Matla Channel (Stations 1 and 2), Thakuran Channel (Stations 3 and 4) and Jagaddal Creek (Station 5). But *Beroe ovata* and *Beroe gracilis* were found only in stations 3 and 4. A very important observation in this regard is the sheer overwhelming number of individuals of genus *Pleurobrachia* in comparison to genus *Beroe* in the sampling stations (Figure 3). This can be attributed to the swarm of *Pleurobrachia pileus* and *Pleurobrachia globosa* in the station 3, contributing 3000 ind/m^3 and 1348 ind/m^3 respectively, in contrast to 40 ind/m^3 of *Beroe ovata* and 200 ind/m^3 of *Beroe gracilis* in the ctenophore swarm stations.

Though ctenophore forms 42% of the mesozooplankton community in Sundarbans, other mesozooplankton groups such as Copepoda, Chaetognatha, Decapoda, Ostracoda, Appendicularia also contributed to the mesozooplankton diversity. Apart from ctenophores, copepods were found to be the second most abundant with an average of 48.40% of the total mesozooplankton composition, followed by chaetognaths, with an average of 3.35% of the total mesozooplankton composition (Figure 4).

Various environmental parameters were recorded in the ctenophore sighting stations (Table 1) of Sundarbans. The average Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Dissolved Oxygen (DO), Chl *a* and Nitrate concentration values were 19.22 °C, 24.63 PSU, 5.39 ml/l, 0.64 µg/l and 3.73 µM respectively in the ctenophore sighting stations. In Sundarbans, ctenophore abundance was high in the stations of low sea surface temperature, low dissolved oxygen and less biological productivity, i.e., low nitrate concentration and low *Chlorophyll a.* The systematics, description, diagnosis and distribution of each species recorded are also included.

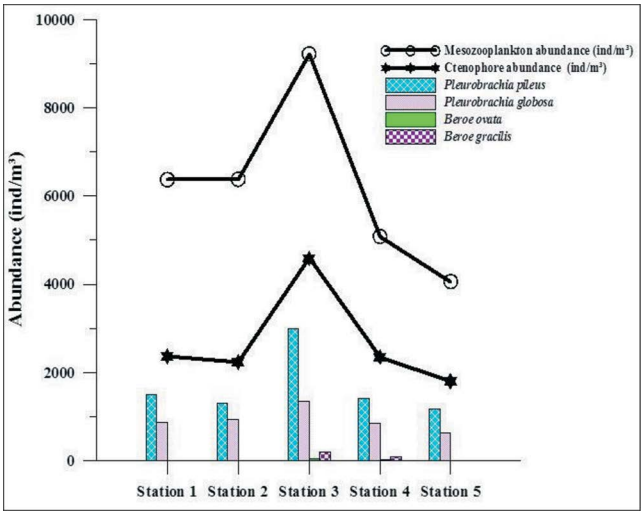

Figure 3. Comparison between Mesozooplankton abundance and Ctenophore abundance in the selected study sites of Sundarbans.

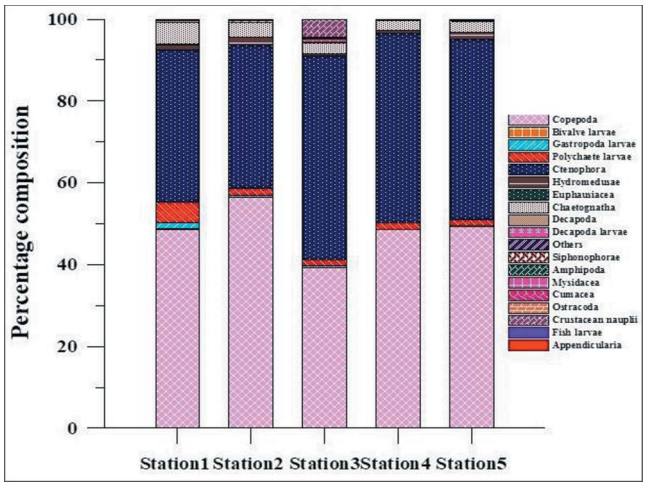

Figure 4. Percentage composition of mesozooplankton groups observed in the selected study sites of Sundarbans.

Systematics

Phylum CTENOPHORA Eschsholtz, 1829
Class TENTACULATA Mills, 1998
Order CYDIPPIDA Gegenbaur, 1856
Family PLEUROBRACHIIDAE Chun, 1880
Genus ***Pleurobrachia*** Fleming, 1822

1. *Pleurobrachia globosa* Moser, 1903

1903. *Pleurobrachia globosa* Moser, *Die Ctenophoren der Siboga Exped.* XII. E.J. Brill, Leiden, 32 pp.

Material examined: WN-CTEN-001; 5 specimens, Matla Channel: Surface water, 10 m (21°46' 10.7" N, 88° 37' 44.8" E and 21°48' 28.1" N, 88° 34' 04.8" E); Thakuran

Channel: Surface water, 20 m (21°42' 18.1" N, 88° 30' 51.0" E), Surface water, 10 m (21°39' 18" N, 88° 28' 13.9" E); Jagadhhal Creek: Surface water and 10 m (21°37' 35.9" N, 88° 26' 15.4" E), Sundarbans, West Bengal, India, 19.1.2018, 20.1.2018, 21.1.2018. Coll. Jasmine P. and Party.

Description: The body is elliptical and globular with dimensions 7-12 mm in height and 5-10 mm in width (Figure 2b). About 15-30 cilia present on each comb plate (which run from the oral to aboral pole). Presence of a pair of tentacles. The tentacular sheath is yellowish in colour. Each tentacle possesses further branches and sub-branches. The comb plates start from the aboral pole and end almost near the oral pole, traversing the entire length of the body (Annandale & Kemp, 1915; Moser, 1903).

Diagnosis: Specimens range from 7-10 mm in diameter, length 12-16 mm from oral to aboral end, with comb plate arising from the oral pole and ending at the aboral pole, each of which possess about 20-30 cilia on them (Figure 2b).

Distribution: East Coast of India (Ennur Backwater, Chilka Lake) (Annandale & Kemp, 1915), Sundarbans (Choudhury *et al.,* 1987), Arabian Sea (Coast of Goa) (Goswami, 1982). *Elsewhere*: Bermuda and New York waters (Grice & Hart, 1962).

2. *Pleurobrachia pileus* (O. F. Müller, 1776)

1776. *Beroe pileus* Müller, O. F. Hafniae, *Typiis Hallageriis*, 1-274.
1860. *Pleurobrachia rhododactyla* Agassiz, L. *Contrib. Nat. His. U.S.A.* Vol. 3, Boston. 301 pp.

Material examined: WN-CTEN-002; 5 specimens, 4-7 mm in diameter, length 10-16 mm from oral to aboral end. Matla Channel: Surface water, 10 m (21°46' 10.7" N, 88° 37' 44.8" E and 21°48' 28.1" N, 88° 34' 04.8" E); Thakuran Channel: depth 0 m, 20 m (21°42' 18.1" N, 88° 30' 51.0" E), Surface water, 10 m (21°39' 18" N, 88° 28' 13.9" E); Jagaddal Creek: Surface water and 10 m (21°37' 35.9" N, 88° 26' 15.4" E), Sundarbans, West Bengal, India, 19.1.2018, 20.1.2018, 21.1.2018. Coll. Jasmine P. and Party.

Description: Body oval or spherical in shape. Oral surface is wider than the aboral surface. Presence of eight ciliary comb plates equal in length, beginning from aboral pole ending at three-quarters of its length towards the oral pole. The comb plates are opalescent with transparent ectomesoderm; tentacles, sheaths, and stomodeum make be milky or pale orange. Length fluctuates between 10-25 mm. Tentacle sheath is distant from stomodeum. Contractile tentacles which may be fifteen to twenty times longer than the body length, they can retract into the tentacle sheaths (Moser, 1903). The unique features of *Pleurobrachia pileus* are: it is spherical i.e. its length and width are almost equal. The comb plates run three-quarters the distance between the oral and aboral pole, the tentacular sheath has an orangish hue.

Diagnosis: Specimens range from 4-7 mm in diameter, 10-16 mm in length from oral to aboral end. Eight ciliary comb plates begin from aboral pole and end at three quarters of its length towards the oral pole. Tentacular sheath varies from the stomodeum (Figure 2a).

Distribution: North-western Bay of Bengal, off Rushikulya estuary (Srichandan *et al.,* 2015), south-eastern Arabian Sea, Kanyakumari to off Kollam (Peter *et al.,* 2018). *Elsewhere:* East Adriatic Sea (Gamulin, 1979), North Atlantic and the coastal waters of NW Europe

Table 1. Details of the stations and environmental characteristics observed in the sampling stations of Sundarbans.

Station No.	Location	Station	Latitude	Longitude	SST (°C)	SSS (PSU)	DO (ml/l)	Chl *a* (µg/l)	Nitrate (µM)
Station 1	Sundarbans	Matla Channel	21°46' 10.7" N	88° 37' 44.8" E	18.89	24.38	4.92	0.66	3.45
Station 2	Sundarbans	Matla Channel	21°48' 28.1" N	88° 34' 04.8" E	19.25	24.70	5.42	0.54	4.37
Station 3	Sundarbans	Thakuran Channel	21°42' 18.1" N	88° 30' 51.0" E	19.18	24.85	5.42	0.59	3.97
Station 4	Sundarbans	Thakuran Channel	21°39' 18.0" N	88° 28' 13.9" E	19.57	24.64	5.42	0.73	3.66
Station 5	Sundarbans	Jagaddal Creek	21°37' 35.9" N	88° 26' 15.4" E	19.22	24.57	5.78	0.70	3.18

(Greve, 1975; Liley, 1958), Black Sea (Mutlu & Bingel, 1999), Kiel Bight (Schneider, 1987).

Remark: Most of these specimens were obtained from swarm stations (Thakuran Channel). More than 600 specimens per 500 ml of sea water were obtained, but only 5 specimens have been preserved in the museum collections for further study. Abundance of *P. pileus* was reported as a swarm and according to the local fishermen this causes a huge menace to the fishery community by clogging the fishing nets as well as causing skin irritation.

Class NUDA Mills, 1998
Order BEROIDA Eschscholtz, 1829
Family BEROIDAE Eschscholtz, 1825
Genus ***Beroe*** Browne, 1756

3. *Beroe gracilis* Künne, 1939

1939. *Beroe gracilis* Künne, C. *Zoologischer Anzeiger*, 127: 172-174.

Material examined: WN-CTEN-004; 5 specimens. The samples were collected from the Thakuran Channel (Stations 3 and 4): Surface water, 10 m (21°42' 18.1" N, 88° 30' 51.0" E; 21°39' 18" N, 88° 28' 13.9" E), Sundarbans, West Bengal, India, 20.1.2018. Coll. Jasmine P. and Party.

Description: Body is barrel-shaped, oral-aboral ends are rounded, and very subtle lateral compression is evident in the tentacular plane. The comb plates, substomodeal and subtentacular which are equal in length run to three-fourths the body length, starting from the aboral pole to the oral pole. A wide semicircular mouth opening into a large pharynx, which covers almost all space of the inner part of the body. A row of macrocilia formed as a wideband on the oral part of the pharynx. The meridional canals lack branches. The four meridional canals meet the pharyngeal canal via the oral fork. The body has whitish to pink colouration with maximum height of 30 mm (Greve, 1975; Liley, 1958). Apical organ consists of a statolith at the middle and surrounded by unsplit aboral papillae with a smaller length than statolith dome.

Diagnosis: Specimens are 3-6 mm in diameter or width. Total length 9 mm from oral to aboral end, the width of the mouth is about 4.2 mm. The ctene plates in the subtentacular rows is 29 – 31 and the ctene plates in substomodeal are 36 – 39, the size of the statocyst dome is about 230 µm (Figure 2c).

Remarks: The specimens collected from this area are almost similar to those collected from Chilean waters (Oliveira *et al.,* 2014). The specimens of Künne (1939) and Wrobel & Mills (2003) are slender than the present specimens. The present specimens are characterized with broadband of macrocilia inside the oral part of the pharynx, which is same as described by Tamm & Tamm (1993). This species has not been reported by earlier workers from this region, so it may be an alien species. This is the first record of this species from the coast of Sundarbans, Bay of Bengal.

Other observation notes: The specimens observed were alive and active swimmers. The samples were collected from the same station having swarms of *Pleurobrachia pileus*.

Distribution: This is the first instance of sighting of this species from the Northern Indian Ocean, Bay of Bengal. *Elsewhere*: North Sea (Kunne, 1939), North Atlantic Ocean (Greve, 1975), Pacific Ocean (Wrobel & Mills, 2003) and Chilean waters (Oliveira *et al.,* 2014).

4. *Beroe ovata* Bruguière, 1789

1789. *Beroe ovata* Bruguière, J. G. *Histoire naturelle des vers. Chez Panckoucke*.
1860. *Idyiopsis affinis* Agassiz, L. *Contrib. Nat. His. U.S.A.* 3: 301.

Material examined: WN-CTEN-003; 2 specimens. Thakuran Channel: Surface water (21°39' 18" N, 88° 28' 13.9" E), Sundarbans, West Bengal, India, 20.1.2018. Coll. Jasmine P. and Party.

Description: Body appears like bell-shaped, elongated, cylindrical, slightly flattened, gradually tapering in a semicircular arc towards the aboral pole. Eight meridional canals associated with many diverticulae, forming a network. The wide side of four meridional canals is joined to paragastric canal via oral forks. The comb plates originating from the aboral pole end midway before reaching the oral pole. A narrow band of macrocilia situated inside the lips or oral portion. Body is pinkish, reddish brown or whitish in colour (Moser, 1903).

Diagnosis: Specimen oral diameter 1.5 cm, length 2.2 cm from oral to aboral end and width of 1.9 cm (Figure 2d).

Distribution: Indian waters (Ramakrishna & Sarkar. 1998). *Elsewhere:* Black Sea (Arashkevich, 2001; Finenko

et al., 2003), Atlantic Ocean (Mayer, 1912), coastal waters of the United States and Canada, Gulf of Mexico (Bayha 2006), Caspian Sea (Kideys *et al.,* 2004), Mediterranean Sea (Mills. 1996), Northern Adriatic Sea (Shiganova & Malej, 2008).

Remark: The specimen has shrunk in size due to preservation in formaldehyde.

Discussion

During the winter monsoon survey held in 2018, four species of ctenophore *viz.*, *Pleurobrachia globosa* Moser, 1903, *Pleurobrachia pileus* (O. F. Müller, 1776), *Beroe ovata* Bruguière, 1789, *Beroe gracilis* Künne, 1939 were observed in the mangrove estuarine area of Sunderbans, Bay of Bengal, India. Till date, only one species of ctenophore *P. globosa* has been recorded from Sundarban, (Choudhury *et al.,* 1987). *P. pileus* and *P. globosa* formed a swarm in Thakuran channel and more than 3000 ind/ m^3 were obtained and this swarm posed a threat to the fishing community as they clogged the nets and caused skin problems. *Beroe gracilis* was observed for the first time in our study from the coastal waters of northern Bay of Bengal. *B. gracilis* has been found to feed exclusively on *P. pileus* (Greve, 1970; Greve & Reiners, 1988). Presence of a few *B. gracilis* in the swarm of *P. pileus* could be related to its affinity towards the estuarine waters for its feeding purpose. *B. gracilis* has been found in the Atlantic and Pacific oceans (Kunne, 1939; Wrobel & Mills, 2003; Oliveira *et al.,* 2014) and also in the Dutch coastal waters (Kuipers *et al.,* 1990). Kuipers *et al.,* (1990) stated that the end of ctenophore *P. pileus* outburst in the western Wadden Sea led to the emergence of *B. gracilis*. The ctenophore swarm lead to a decrease in copepod population and ends with the predation of major swarm forming species *P. pileus* by *B. gracilis*, thereby shifting the balance in favour of copepods and phytoplankton. Further, the enrichment of inshore waters from rivers might have generated enough food sources for the ctenophores which lead them to migrate into river channels of Sundarbans.

The biological productivity of the Bay of Bengal is regulated by hydrological parameters (Prasanna Kumar *et al.,* 2010). During the winter monsoon, Northern Bay of Bengal is characterized with low sea surface temperature (SST) due to winter cooling, as there is a heat loss from the sea surface (Narvekar & Prasanna Kumar, 2006). Moreover, the sloping of isotherms reduces the ambient temperature further (Prasanna Kumar *et al.,* 2010). This complies well with the low SST (19.22 °C) observed in our study area. High sea surface salinity (24.63 PSU) was observed in ctenophore sighting stations. A similar range of sea surface salinity has been reported (Prasanna Kumar *et al.,* 2010) from the Bay of Bengal, during winter-monsoon season. Wang *et al.* (1995) observed a high abundance of ctenophores along the marine side of the estuary where salinity was high. A similar pattern of ctenophore migration has been observed in our study where ctenophores preferred to aggregate in areas of high salinity. Arai (1973) showed through an experimental study that *P. pileus* had a strong inclination to cluster at the interface of salinity discontinuities. This can explain the distribution of ctenophores in estuarine areas. The average SSS of northern coastal Bay of Bengal is generally less than 33 PSU (Akhil *et al.,* 2014).

Low Chl *a* (0.64 µg/l) and nitrate concentrations (3.73 µM) were observed in the presently studied stations. A similar result was obtained in the experimental study conducted by Deason & Smayda (1982) that revealed the depletion of phytoplankton abundance, Chl *a* and nitrate concentration in the microcosms caused due to ctenophores predation. The decreased nitrate content in surface waters suggests oligotrophic conditions in the northern Bay of Bengal (Prasanna Kumar *et al.,* 2010). Stratification of the water column with decreased wind mixing is also a source for low Chl *a* and Primary productivity as proposed by Prasanna Kumar *et al.* (2010). Gelatinous zooplankters such as ctenophores are more tolerant to low Dissolved Oxygen (DO) concentration than their zooplankton counterparts. Predation on zooplankton (like copepods) by ctenophores at hypoxic conditions is greater than under normoxic conditions while the mobility rate of copepods decreases significantly with drop in DO levels (Decker *et al.,* 2004). Such a difference in predation rate and prey escape under hypoxic conditions makes the prey more vulnerable to predation. The overwhelming abundance of ctenophores in our study area has affected the copepod population which leads to their less abundance. Apart from copepods, other taxa such as chaetognaths, amphipods, mysids etc. were also represented scarcely. A similar observation that copepod abundance decreases when the density of ctenophores increases were suggested by Purcell & Decker (2005).

So far, 12 ctenophore species have been reported from Indian waters (Venkatraman & Raghunathan,

2015; Venkatraman & Wafar, 2005), but most of the reports mentioned only the number of species, there is no valid species-specific record of ctenophores from the Bay of Bengal. Since the ctenophore community is highly sensitive to environmental variation, changes in their diversity and distribution can provide important evidence of environmental change. Future studies on ctenophores from the Bay of Bengal should be focused to construct a detailed checklist of their diversity. A continuous seasonal study should also be undertaken to understand the clear impact of environmental factors on the diversity and distribution of ctenophores along this region.

Acknowledgements

The authors like to thank DST SERB (sanction order number ECR/2017/000087) for the financial support provided to carry out the work. We are also thankful to CSIR [sanction letter number 09/1181(0003)/2017-EMR-I], for providing JRF fellowship to the second author.

References

Akhil, V. P., Durand, F., Lengaigne, M., Vialard, J., Keerthi, M. G., Gopalakrishna, V. V., Deltel, C., Papa, F. and de Boyer Montégut, C. 2014. A modeling study of the processes of surface salinity seasonal cycle in the Bay of Bengal. *J. Geophys. Res. Oceans*, **119**(6): 3926-47. https://doi.org/10.1002/2013JC009632.

Annandale, N. and Kemp, S. 1915. Ctenophora. *Mem, Indian Mus*., **5**: 55-63.

Arai, M. N. 1973. Behavior of the planktonic coelenterates, *Sarsia tubulosa, Phialidium gregarium*, and *Pleurobrachia pileus* in salinity discontinuity layers. *J. Fish. Res. Board Can*., **30**(8): 1105-1110. https://doi.org/10.1139/f73-181.

Arashkevich, E. 2001. Reproduction strategy of *Beroe ovata* (Ctenophora, Atentaculata, Beroida): A New Invader in the Black Sea, *Okeanologiya*, **41:** 116. Accessed 18 March 2019. Available from: http://faculty.washington.edu/cemills/Ctenolist.html.

Bayha, K. 2006. The molecular systematics and population genetics of four coastal ctenophores and scyphozoan jellyfish of the United States Atlantic and Gulf of Mexico. *Diss. Abst. Int*. Pt. B- Sci. & Eng., **66**: 3590.

Choudhury, A., Bhattacharya, A.K., Ghosh, A., Jana, T.P., Chatterjee, P.K., Bhowmik, S.K., Santra, S.C., Dhara, K.K. and Jamadar, Y.A. 1987. Zooplankton Ecology Secondary Productivity in Deltaic Sundarbans. In: *A long term multidisciplinary Research approach and Report on Mangrove Ecosystem of Sundarbans*. Department of Marine Science, University of Calcutta: 35-51.

Deason, E. E. and Smayda, T. J. 1982. Experimental evaluation of herbivory in the ctenophore *Mnemiopsis leidyi* relevant to ctenophore-zooplankton-phytoplankton interactions in Narragansett Bay, Rhode Island, USA. *J. Plankton. Res*., **4**(2): 219-236. https://doi.org/10.1093/plankt/4.2.219.

Decker, M. B., Breitburg, D. L. and Purcell, J. E. 2004. Effects of low dissolved oxygen on zooplankton predation by the ctenophore *Mnemiopsis leidyi*. *Mar. Ecol. Prog. Ser*., **280**: 163-172. https://doi.org/10.3354/meps280163.

Finenko, G., Romanova, Z., Abolmasova, G., Anninsky, B., Svetlichny, L., Hubavera, E., Bat, L. and Kidneys, A. 2003. Population dynamics, ingestion, growth and reproduction rates of the invader *Beroe ovata* and its impact on plankton community in Sevastopol Bay, the Black Sea. *J. Plankton Res*., **25**(5): 539-549. https://doi.org/10.1093/plankt/25.5.539.

Gamulin, T. 1979. Zooplankton of the eastern Adriatic coast, *Acta. Biol*., **8**: 177-270. (in Croatian).

Goswami, S.C. 1982. Occurrence of swarms of *Sagitta enflata* (Chaetognatha) and *Pleurobrachia globosa* (Ctenophora) in the coastal waters of Goa. *Mahasagar*, **15**(3): 163-166.

Goswami, S.C. 2004. *Zooplankton Methodology, Collection and Identification - A field manual*. First Edition. National Institute of Oceanography, Dona Paula, Goa; p. 37.

Greve, W. 1970. Cultivation experiments on North Sea ctenophores, Helgoland. *Wiss. Meer*., **20**(1): 304. https://doi.org/10.1007/BF01609908.

Greve, W. 1975. Ctenophora. Fiches d'Identification du Zooplancton 146. *Cons. Int. Explor. Mer*., Kopenhagen: 6.

Greve, W. and Reiners, F. 1988. Plankton time-space dynamics in German Bight-a systems approach. *Oecologia*, **77**(4): 487-496. https://doi.org/10.1007/BF00377264. PMid: 28311268.

Grice, G.D. and Hart, A.D 1962. The abundance, seasonal occurrence, and distribution of the epizooplankton between New York and Bermuda. *Ecol. Monogr*., **32:** 287-309. https://doi.org/10.2307/1942377.

Harbison G.R., Madin, L.P. and Swanberg, N.R. 1978. The natural history and distribution of oceanic ctenophores. *Deep-Sea Res*., 25: 233-256. https://doi.org/10.1016/0146-6291(78)90590-8.

Kideys, A., Finenko, G., Anninsky, B., Shiganova, T. and Roohi, A. 2004. Physiological characteristics of the ctenophore *Beroe ovata* in Caspian Sea water. *Mar. Ecol*., **226:** 111. https://doi.org/10.3354/meps266111.

Kuipers, B. R., Gaedke, U., Enserink, L. and Witte, H. 1990. Effect of ctenophore predation on mesozooplankton during a spring

outburst of *Pleurobrachia pileus*. *Neth. J. Sea Res*., **26**(1): 111-124. https://doi.org/10.1016/0077-7579(90)90061-K.
Künne, C. 1939. Die Beroe (Ctenophora) der südlichen Nordsee, *Beroe gracilis* n, sp. *Zool. Anz*., **127:** 172-174.
Lalli, C. and Parsons, T.R. 1997. *Biological oceanography: An introduction.* Butterworth-Heinemann, Second Edition, Elsevier, USA; 320 p. https://doi.org/10.1016/B978-075063384-0/50057-8.
Liley, R. 1958. Ctenophora. Fiches d'Identification du Zooplancton 82. Cons. *Int. Explor. Mer*, Kopenhagen: 5.
Madin, L.P. and Harbison, G.R. 2001. Gelatinous Zooplankton. In: Steele, J., Thorpe, S. and Turekian, K. (Eds.), *Encyclopedia of Ocean Sciences*, Academic Press. London: 1120-1130. https://doi.org/10.1006/rwos.2001.0198.
Mayer, A.G. 1912. *Ctenophores of the Atlantic coast of North America* (No. 162). Publs. Carnegie Inst. Washington, D.C.: 138. https://doi.org/10.5962/bhl.title.21926.
Mills, C.E. 1996. Medusae, siphonophores and ctenophores of the Alborán Sea, south western Mediterranean. *Sci. Mar*., **60**(1):145-163.
Mills, C.E. 1998. Phylum Ctenophora: list of all valid species names. Published by the author, web page established March 1998, last updated 12 June 2017.
Moser, F. 1903. *Die Ctenophoren der Siboga Expedition* XII. E.J. Brill, Leiden: 32. https://doi.org/10.5962/bhl.title.11348.
Mutlu, E. and Bingel, F. 1999. Distribution and abundance of ctenophores, and their zooplankton food in the Black Sea. I, *Pleurobrachia Pileus*. *Mar. Biol*., **135**(4): 589-601. https://doi.org/10.1007/s002270050660.
Narvekar, J. and Kumar, S. P. 2006. Seasonal variability of the mixed layer in the central Bay of Bengal and associated changes in nutrients and chlorophyll. *Deep Sea Res*. Part 1 Oceanogr. Res. Pap., **53**(5): 820-35. https://doi.org/10.1016/j.dsr.2006.01.012.
Oliveira, O.M.P., Feliu, G. and Palma S. 2014. *Beroe gracilis* (Ctenophora) from the Humboldt Current System: First occurrence of this species in the southern hemisphere. *Zootaxa*, **3827**(3): 397-400. https://doi.org/10.11646/zootaxa.3827.3.10. PMid: 25081170.
Pang, K. and Martindale, M.Q. 2008. Ctenophores. *Curr. Biol*., **18**(24): 1119-1120.https://doi.org/10.1016/j.cub.2008.10.004. PMid: 19108762.
Peter, S., Manojkumar, B., Pillai, D., Velusamy, A., Kamarudeen, B., Sreeparvathy, P. and Agnes, F. 2018. Distribution and Diversity of Gelatinous Zooplankton in the South Eastern Arabian Sea, Kanyakumari to off Kollam. *Vestn, Zool*., **52**(5): 379-388. https://doi.org/10.2478/vzoo-2018-0040.
Prasanna Kumar, S., Nuncio, M., Narvekar, J., Ramaiah, N., Sardesai, S., Gauns, M., Fernandes, V., Paul, J. T., Jyothibabu, R. and Jayaraj, K. A. 2010. Seasonal cycle of physical forcing and biological response in the Bay of Bengal. *Indian J. Mar. Sci*., **39**(3): 388-405.
Purcell, J. E. and Decker, M. B. 2005. Effects of climate on relative predation by scyphomedusae and ctenophores on copepods in Chesapeake Bay during 1987-2000. *Limnol. Oceanogr*., **50**(1): 376-387. https://doi.org/10.4319/lo.2005.50.1.0376.
Purcell, J.E. 2005. Climate effects on formation of jellyfish and ctenophore blooms: A review, *J. Mar. Biol. Ass. U.K*., **85**(3): 461-476. https://doi.org/10.1017/S0025315405011409.
Ramakrishna and Sarkar, J. 1998. Faunal diversity in India: Ctenophora. In: *Faunal diversity in India,* Alfred et al., (eds), ENVIS Centre, Zoological Survey of India, Calcutta.
Schneider, G. 1987. Role of advection in the distribution and abundance of *Pleurobrachia pileus* in Kiel Bight. *Mar. Ecol. Prog. Ser*., **41**(1): 99-102. https://doi.org/10.3354/meps041099.
Shiganova, T. and Malej, A. 2008. Native and non-native ctenophores in the Gulf of Trieste, Northern Adriatic Sea, *J. Plankton Res*., **31**(1): 61-71. https://doi.org/10.1093/plankt/fbn102.
Srichandan, S., Sahu, B. K., Panda, R., Baliarsingh, S. K., Sahu, K. C. and Panigrahy, R. C. 2015. Zooplankton distribution in coastal water of the North-Western Bay of Bengal, off Rushikulya estuary, east coast of India. *Indian J. Mar. Sci*., 44(4): 546-561.
Tamm, S.L. and Tamm, S. 1993. Diversity of macrociliary size, tooth patterns, and distribution in *Beroe* (Ctenophora). *Zoomorphology*, **113**(2): 79-89. https://doi.org/10.1007/BF00403086.
Venkataraman, K. and Raghunathan, C. 2015. Coastal and Marine Biodiversity of India. In: Venkataraman, K. & Sivaperuman, C. (Eds.), *Marine Faunal Diversity in India*. San Diego, Academic Press: 303-348. https://doi.org/10.1016/B978-0-12-801948-1.00019-7.
Venkataraman, K. and Wafar, M. 2005. Coastal and marine biodiversity of India. *Indian J. Mar. Sci*., **34**(1): 57-75.
Wang, Z., Thiébaut, E. and Dauvin, J. C. 1995. Spring abundance and distribution of the ctenophore *Pleurobrachia pileus* in the Seine estuary: Advective transport and diel vertical migration. *Mar. Biol*., **124**(2): 313-324. https://doi.org/10.1007/BF00347135.
Wrobel, D. and Mills, C. 2003. *Pacific coast pelagic invertebrates: a guide to the common gelatinous animals*. Sea Challengers and the Monterey Bay Aquarium, Monterey, California: 108.