Plant Science Research

ISSN 0972-8546

Diversity of *Ceratium* along Astaranga coastal water, Bay of Bengal, Odisha

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ARTICLE INFO

Article history:
Received : 09 December 2016
Accepted : 18 December 2016

Keywords:
Ceratium
Bay of Bengal
Astaranga
Physicochemical parameters

ABSTRACT

Ceratium spp. are important marine phytoplankton of phylum Myzozoa. They are the primary producers in sea ecosystem and also act as biological indicators of the water. The present study was carried out in Astaranga coastal water of Bay of Bengal during winter season to study the diversity of *Ceratium* spp. found in the study area. Physicochemistry of the water was also studied to relate with *Ceratium* diversity. In all nine different *Ceratium* spp. namely *C. azoricum*, *C. contrarium*, *C. declinatum*, *C. furca*, *C. fusus*, *C. longirostrum*, *C. lunula*, *C. macroceros*, and *C. trichoceros* were recorded. Their diversity in the water during the season could be related to high nutrient and salt concentration and also could be the reason of clear water condition in the locality.

The Bay of Bengal (BoB) connects a number of rivers along Odisha coast and receives about 6.6% of total global river fluxes. Nutrients are injected to the mouth of the Bay of Bengal through river discharge, which significantly affects the growth of phytoplankton. In marine ecosystem physical processes such as upwelling, down welling and terrestrial run off play significant role in nutrient composition in continental shelf, which affects the phytoplankton distribution and abundance (Platt *et al.,* 2005). Since it is known that the coastal marine environments are experiencing dinoflagellate blooms causing red tides (Reynolds, 2006), study on entire phytoplankton distribution and hydrology in the ecosystem is essential and interesting.

The phytoplankton *Ceratium* (dinoflagellate) comes under the microplankton group (20-200µm). It is a common and widespread mixotrophic genus among marine plankton. *Ceratium* spp. have significant role in marine environment as they are the primary producer community and also act as the biological indicator of water masses (Ibrahim, 2014). High population density of the genus causes red tides, which in turn cause nutrient and oxygen depletion. The photosynthetic cells contain chromatophores (yellow, brown yellow or green), which is distributed in cell cytoplasm. Body contains two valves i.e. epi-theca and hypo-theca bearing the horns. Most species have three horns but some have two or single horn also. The horns help the organism to float in the water column. *Ceratium* can produce resting cysts that may remain dormant within the sediments during unfavourable condition (Moreira *et al.,* 2015).

Significant work has been done on phytoplankton diversity and distribution at different areas of the coastal environment. Some of the noteworthy studies include reports on Northern Arabian Sea (Sarangi *et al.,* 2005), Gulf of Aquaba (Al Qutob *et al.,* 2002), coastal waters of Pakistan (Naz *et al.,* 2012), Bay of Bengal water (Gomes *et al.,* 2000; Paul *et al.,* 2007), Palk Bay, South east coast of India (Sridhar *et al.,* 2006), Eastern Indian Coast (Choudhury and Pal, 2010) and coastal water of Chennai (Subramanian and Mahadevan, 1999). Study on *Ceratium* diversity and its relation to water quality is scantily available, though some reports are available from the Red sea (Ibrahim, 2014), Southeast Brazil (Moreira *et al.,* 2015), South Africa (Hart

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and Wragg, 2009) and Central Europe (Padisak, 1985). However *Ceratium* records of BoB are not found. This work presents the *Ceratium* diversity along coastal water of Astaranga providing a check list of species recorded.

The present study was carried out in coastal waters of Astaranga during winter season (December 2015-February 2016). Sampling was done from the coast (19°56’55.40”N and 86°23’36.70”E) to 10 km (19°51’35.34”N and 86°22’51.93”E) in the sea at 9.00-10.00 AM covering eleven different stations in a transect with about 1 km between the stations. Surface water samples were collected for analysing various water quality parameters like sea surface temperature (SST), pH, dissolved oxygen (DO; modified Winkler’s method), salinity (argentometric), silicate (silico-molybdic method), total phosphate (perchloric acid digestion) and nitrate (Azo-dye method) (Strickland and Parsons, 1972). Plankton samples were collected by filtering water through a plankton net (50µm pore size) and preserved immediately in 5% formaldehyde (Fig. 1). Measurement of *Ceratium* cell size was carried out by using ocular micrometer. For taxonomic identification photographs of the organisms were taken by the help of light microscope (Magnus MLX with camera at 10x40 zoom). Onsite measurement of SST was done by using a digital thermometer and pH by Systronic water analyser. The water samples for DO were fixed on site after sampling. The reported taxa are those recorded from all the 11 sampling site of the transect.

The water quality of Astaranga coastal water showed significant variation during the study period. SST varied from 24.27-25.52°C with an average of 24.65°C. The surface water was moderately alkaline (pH 7.58) with a narrow pH range. This indicated efficient utilization of dissolved CO_2 for phytoplankton production. On the other hand, DO ranged from 2.88-4.32mg/l with an average of 3.73 mg/l showing sub-optimal aerobic condition. This may be attributed to a good amount of dissolved organic carbon (DOC) drifted from the terrestrial system. As the water had a high transparency the DOC is probably the primary driving force for high *Ceratium* density. Salinity varied from 32.86-35.02psu with an average of 34.06psu showing high saline condition. Nutrients like phosphate, silicate and nitrate concentrations of the study site were 77-138µg/l with an average of 112.82µg/l, 8.6-22.3µg/l with an average of 13.8µg/l and 1866.7-2746.9µg/l with an average of 2298.9µg/l, respectively (Table 1).

Table 1

The physicochemistry of surface water of Astaranga coast of Bay of Bengal

	SST(°C)	PH	Salinity (psu)	DO (mg/l)	Phosphate (µg/l)	Silicate (µg/l)	Nitrate (ig/l)
Max	25.52	7.64	35.02	4.32	138	22.3	2746.9
Min	24.27	7.48	32.86	2.88	77	8.6	1866.7
Aver	24.65	7.58	34.06	3.73	112.82	13.80	2298.9
Stdev	0.26	0.05	0.65	0.33	16.78	3.04	208.46

Note: The data points are the means ±standard deviation of 33 replicates of 11 stations located at a transect of 10km.

A total of 9 *Ceratium* spp. viz., *C. azoricum*, *C. contrarium*, *C. declinatum*, *C. furca*, *C. fusus*, *C. longirostrum*, *C. lunula*, *C. macroceros*, and *C. trichoceros,* as detailed below, were reported during the study (Fig. 2).

1) *Ceratium azoricum* Cleve : Apical horn is very short and centrally placed. Antapical horn is relatively short, continuously curved and directed anteriorly. Right antapical horn is closely positioned to the cell body. Widest point of the cell is adjacent to the antapical horns. Chromatophore small, numerous, disc shaped and distributed in periphery. Cell length is about 140-146µm and width about 142-148µm.

2) *Ceratium contrarium* (Gourret) Pavillard: Cell body is subtrapezoidal with nearly flat and oblique posterior margin. Apical horn is very long and straight. Proximal parts of the antapical horn forms a shallow notch between them and are generally parallel to each other. Antapical horns are often undulating. Widest point is adjacent to the antapical horns. Parietal dark brown chromatophores present in the body as well as in the horns. Cell length is about 340-350µm and width about 265-270µm.

3) *Ceratium declinatum* (Karsten) Jørgensen: Cell body is subtriangular and longer than the width. Apical horn is moderately long. Proximal part of the antapical horns are directed laterally, distally they bend continuously and are directed anteriorly. Widest point is adjacent to the cingulum or to the antapical horns. One or two parietal chromatophores containing carotenoides and xanthophylls as accessory pigments. Cell length is about 190-210µm and width about 125-135µm.

4) *Ceratium furca* (Ehrenberg) Claparède & Lachmann: Cells contain two robust antapical horns, which are unequal

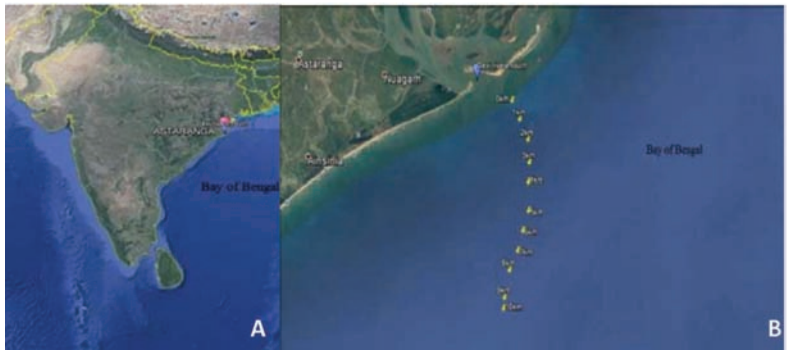

Fig. 1. Satellite imagery of (A) BoB coast and the (B) the sampling sites of the study area in a transect up to 10 km.

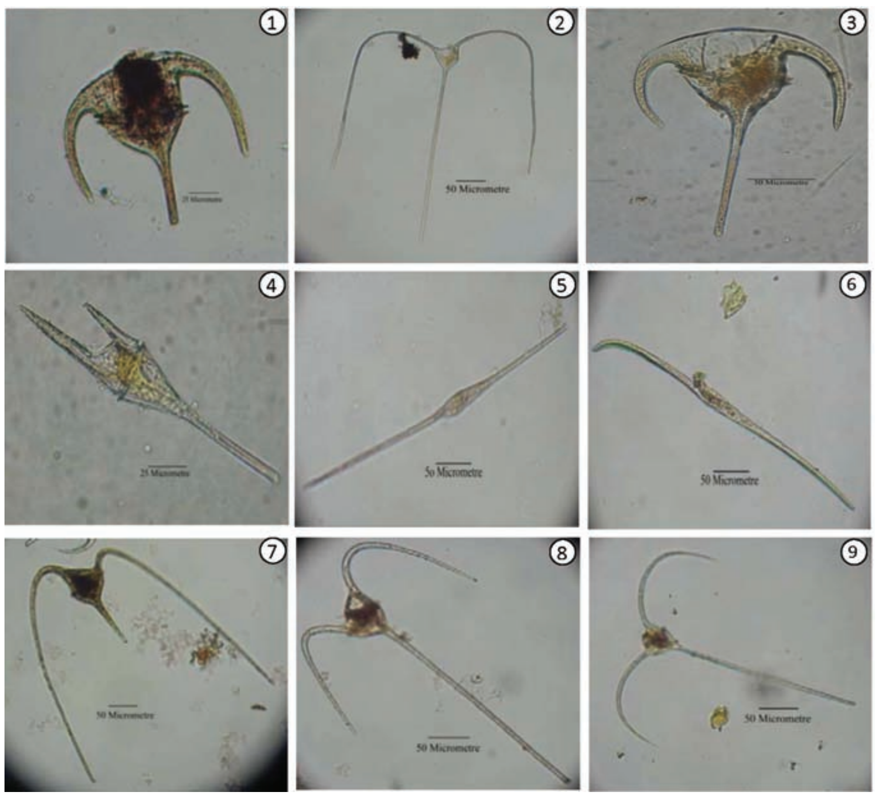

Figure 2. Light micrograph of 1) *Ceratium azoricum,* 2) *Ceratium contrarium,* 3) *Ceratium declinatum,* 4) *Ceratium furca,* 5) *Ceratium fusus,* 6) *Ceratium longirostrum,* 7) *Ceratium lunula,* 8) *Ceratium macroceros,* and 9) *Ceratium trichoceros* distributed in the Astaranga coast of BoB.

and slightly divergent from each other. Left antapical horn is longer than the right one. Epitheca tapers in to a long apical horn. Hypotheca between the horns is prominently inclined towards the cingulum. Chromatophores numerous, yellow brown, peripherally distributed in the cell. Measured cell length is about 185-198 µm and width about 32-37 µm.

5) *Ceratium fusus* (Ehrenberg) Dujardin : Cell is spindle shaped and long in size. Epitheca tapers to form a long apical horn and hypotheca tapers to form the long left antapical horn. Apical and left antapical horns are equal or subequal in length and slightly curved. A reduced right antapical horn may be present. Chromatophores are numerous, yellow brown chloroplast performing photosynthesis. Cell length is about 400-410 µm and width about 20-25 µm.

6) *Ceratium longirostrum* Gourret: Cell is needle shaped with epitheca tapering to form a long apical horn and hypotheca a left antapical horn. Horns are equal or subequal; apical horn is slightly curved and left antapical horn curved prominently. Thin and crowded chromatophores present in the body. Cell length is about 400-410 µm and width about 18-22 µm.

7) *Ceratium lunula* Schimper ex Karsten: Cell body is robust almost triangular in shape with prominently long and curved horns. Posterior margin of the cell is slightly flat and oblique. Apical horn is straight and positioned centrally, slightly inclined to the right and significantly shorter than the antapical horns. Small, angular, yellowish chromatophores are scattered about the amyloid body. Cell length is about 370-400 µm and width about 195-205 µm.

8) *Ceratium macroceros* (Ehrenberg) Vanhöffen: Cell body is subquadrangular with nearly flat and oblique posterior margin. Apical horn is very long and almost straight. The antapical horns are divergent after bending downward. Proximal parts of the antapical horns are directed posteriorly, forming a deep notch between them. Chromatophores are yellowish brown, numerous and discoidal. Cell length is about 400-420 µm and width about 260-270 µm.

9) *Ceratium trichoceros* (Ehrenberg) Kofoid: The cell body is subtrapezoidal with nearly flat and oblique posterior margin. Apical horn is very long and straight. Antapical horns are parallel to each other and are often undulating. Chromatophores are golden brown in colour. Cell length is about 300-310 µm and width about 245-253 µm.

In the locality diversity of *Ceratium* indicated nutrient rich condition during winter. Ibrahim (2014) reported that *Ceratium* diversity increased in nutrient rich waters elsewhere. Light availability was maximum in the photic zone and salinity concentration was also higher in the study site reaching up to 35.02 psu. Abundance of *Ceratium* spp. in the study area indicated clear water condition. Similar results were reported by Padisak (1985) and Buck and Zurek (1994). Species diversity and abundance of *Ceratium* at SST i.e., 24.65°C and DO i.e., 3.73mg/l revealed that they can survive in low temperature and low oxygen level. On the other hand, oxygen depletion in the water could be related to oxygen utilisation through metabolic activity that was driven by DOC as reported in Albert Falls (Hart and Wragg, 2009).

Acknowledgement

The authors thank ISRO, Govt. of India, for providing financial assistance under MOP-3 and the Heads of the Department of Botany and Zoology for the laboratory facilities to carry out this reserch.

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