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Chapter 2

Checklist, Qualitative and Quantitative Analysis of Marine Microalgae from Offshore Visakhapatnam, Bay of Bengal, India for Biofuel Potential

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Abstract

Observation on the productivity parameters in relation to micro algal biodiversity helps to know the population in particular season and spatial. The study investigates in detail the seasonal and spatial variation of microalgae with special emphasis on their interrelationship of chlorophyll concentration. In order to obtain the information on distribution and abundance of Visakhapatnam Coast microalgae for isolation, fortnightly intervals samplings was carried out. Investigation has been made on the microalgae with special reference to the phylum Ochrophyta, Dinophyta, Chlorophyta, Euglenozoa, Haptophyta and Cyanophyta. Abundance of species under different season of pattern was Pre-monsoon>Post monsoon>Monsoon. The data evaluated from this study was used to prepare the checklist for marine microalgal diversity of Visakhapatnam offshore region.

Keywords: chlorophyll, microalgal abundance, checklist of marine algae, phytoplankton, Vizag coast, Bay of Bengal

1. Introduction

Andhra Pradesh is one of the six States/U.Ts of India adjoining the Bay of Bengal with a coastline of 974 km and the continental shelf area of 33, 227 sq. km. East coast India, surface currents skirting the coast move in a northerly direction during part of the year, and the opposite direction during the rest of the year [1]. Influx of untreated wastewaters into the aquatic bodies that are challenging the stability of nations [2]. Since in the middle of 19th century East coast of India, Visakhapatnam coastal waters pollution caused by the effluents from nearby industries, like steel

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plant, petroleum refinery, fertilizer plant and a lead and zinc smelter are discharged into a North-Western arm of the inner harbor through surface drain known as Meghadri gedda and city's domestic sewage drains directly into the Northern arm of the inner harbor [3]. Microalgal abundance and distribution critically depending on various physical, chemical and biological factors [4] and their ability to assimilate sufficient carbon, nitrogen and phosphorous, as well as minor nutrients, to ensure replication. Alterations in species richness are mainly due to the variability of abiotic factors, such as short-term climatic variations [5].

Multi-population microalgae and some native isolates i.e., *Tetraselmis* sp., *Chlorella* sp. were cultivated in open air pond in East cost of India proved the potential for biofuel production. Exploring microalgae diversity to find out the suitable season and spatial for microalgae isolation in Visakhapatnam coast since, the microalgae having wide application in biofuel and pharmaceutical. The research work from Andhra University, India revealed that Visakhapatnam coast is one of the potential sources for microalgae. Two years field work data from this study shows the relationship between the spatial and seasonal variations in Bay of Bengal, East Coast of India, and Visakhapatnam. Qualitative and quantitative analysis showed the feasibility to isolate the potential candidate strains for biofuels from the coastal water of Visakhapatnam.

2. Materials and methods

2.1. Description of the study area and physiography of sampling sites

Bay of Bengal, a semi-enclosed tropical basin, is a part of the northern Indian Ocean and experiences seasonal changes in circulation and climate due to the monsoons. Visakhapatnam is a coastal city located on the eastern seaboard of India between Chennai and Calcutta (latitude 17°38′N and 17°45′N and longitude 83°16′E and 83°21′E) surrounded on three sides by the overlapping mountain ranges, and the South-eastern city is safeguarded by the Bay of Bengal. The South-west monsoon starts late in June and lasts till early October. North-east monsoon closely follows the South-west monsoon and extends till December. Fourteen sampling stations were selected along the Visakhapatnam offshore line and surface water samples were collected at the 30–40 M depth line of the sampling point. Sampling sites and global positioning systems of sampling locations was represented in **Figure 1**. The sampling stations between Bheemunipatnam (station 1) and Coastal Battery (station 7) cover the area like waste water of shrimp culture ponds, seafood processing centers, shrimp hatcheries, fish cages cultures and sewage outfalls enter into the coastline. The sampling stations between Harbor (station 8) and Pudimadaka (station 14) cover the areas where the effluents from the major power plants such as Nuclear Power Corporation of India limited and East Coast Energy limited enter on the coastal line.

2.2. Sample collection and estimation of chlorophyll

A mechanized boat was used to get into the sea for sample collection. Physico-chemical examination of sea surface waters in relation to microalgal abundance from Bheemunipatnam (approximately 23 km northward from the Visakhapatnam port) to Pudimadaka (approximately

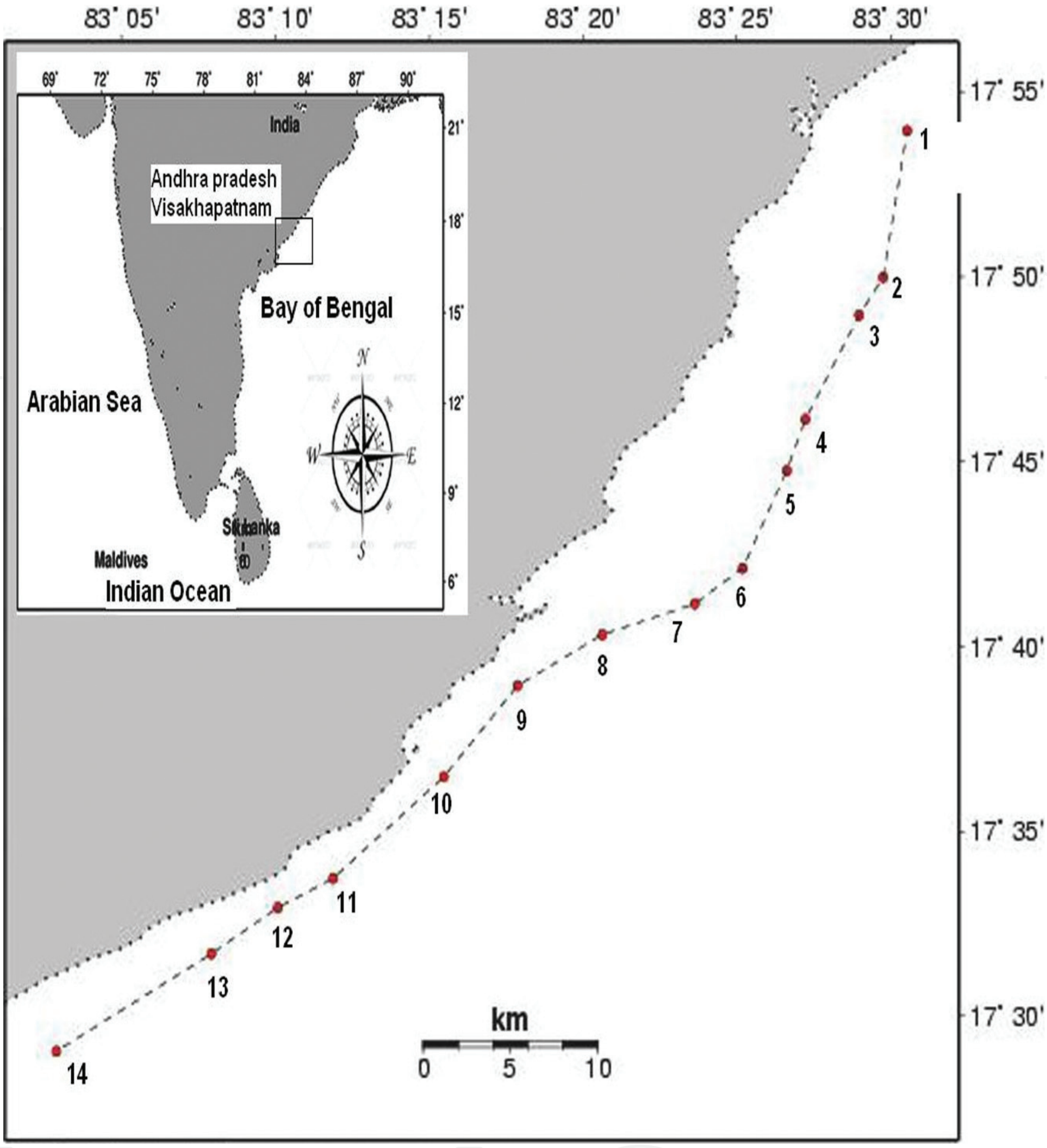

Figure 1. Map showing the sampling stations (1–14).

40 km southward from the Visakhapatnam port), on the East Coast of India, was carried out at fortnightly intervals for a period of 2 years (February 2011 to January 2013) at 14 selected stations, along the Visakhapatnam offshore region. Samples were collected using clean plastic buckets from the surface sea water and transferred into 1 L amber color plastic bottles and stored in refrigerator until further analysis. The water sample free of zooplankton is filtered through Millipore (0.45 μm, 47 mm) filter paper and the pigments chlorophyll 'a', 'b' and 'c' are extracted from the phytoplankton by using 90% acetone.

2.3. Collection of microalgae and identification

One hundred liters of sea surface water at each station was collected and filtered through cone-shaped phytoplankton net of 20-μm mesh size, made by bolting silk and concentrated to

500 ml was transferred into pre-cleaned polyethylene bottles. The filtrate was preserved in 3% neutralized Lugol's iodine solution. All the water samples were filtered with 60-μm size zooplankton net in order to remove the zooplankton and debris. The filtrate was collected into five liters capacity Polyethylene Terephthalate (PET) jar and kept undisturbed for 2 days to achieve complete sedimentation. After sedimentation of phytoplankton, the supernatant solution was siphoned out to concentrate the volume to accurately about 100–200 ml. Concentrated samples were examined under bright field, dark ground illumination and phase contrast at ×200, ×400 and ×1000 magnifications with the help of Axio scope A1 and Primo Vert (Carl Zeiss, Germany) microscopes. Identification of microalgae was done using an inverted research microscope based on standard keys [6–15] and current taxonomical details were been updated according to World Register of Marine Species and Algaebase (2015).

3. Results

3.1. Chlorophyll 'a'

In the year 2011–2012, the highest and lowest mean chlorophyll 'a' recorded in station 13 (PRM) and station 9 (MON) were 4.81 ± 2.86 and 0.68 ± 0.36 μg l^{-1}, respectively. During the post monsoon period, the maximum and minimum chlorophyll 'a' recorded was 1.82 ± 1.53 and 0.85 ± 0.55 μg l^{-1} respectively at station 9 and station 7 (**Figure** 2**a**). In the year 2012–2013, the highest and lowest mean chlorophyll 'a' recorded in station 9 (MON) and station 3 (PRM) were 3.76 ± 1.92 and 1.54 ± 1.04 μg l^{-1}, respectively. During the post monsoon period, the maximum and minimum chlorophyll 'a' recorded was 2.66 ± 1.79 and 1.92 ± 1.34 μg l^{-1} respectively at station 7 and station 2 (**Figure** 2**b**). In the both sampling years, two way ANOVA showed significant differences between the season ($p < 0.001$) but not between the stations.

3.2. Chlorophyll 'b'

In the year 2011–2012, the highest and lowest mean chlorophyll 'b' recorded in station 5 (PRM) and station 7 (POM) were 3.15 ± 2.28 and 0.70 ± 0.51 μg l^{-1}, respectively. During the monsoon period, the maximum and minimum Chlorophyll 'b' recorded was 1.99 ± 1.58 and 0.99 ± 0.48 μg l^{-1} respectively at station 4 and station 8 (**Figure** 3**a**). In the year 2012–2013, the highest and lowest mean chlorophyll 'b' recorded in station 6 (MON) and station 11 (PRM) were 4.14 ± 2.73 and 1.50 ± 1.35 μg l^{-1}, respectively. During the post monsoon period, the maximum and minimum chlorophyll 'b' recorded was 2.51 ± 1.79 and 1.69 ± 0.73 μg l^{-1} respectively at station 7 and station 13 (**Figure** 3**b**). In the both sampling years, two way ANOVA showed significant differences between the season ($p < 0.001$) but not between the stations.

3.3. Chlorophyll 'c'

In the year 2011–2012, the highest and lowest mean chlorophyll 'c' recorded in station 6 (PRM) and station 12 (POM) were 3.52 ± 2.3 and 0.96 ± 0.61 μg l^{-1}, respectively. During the monsoon

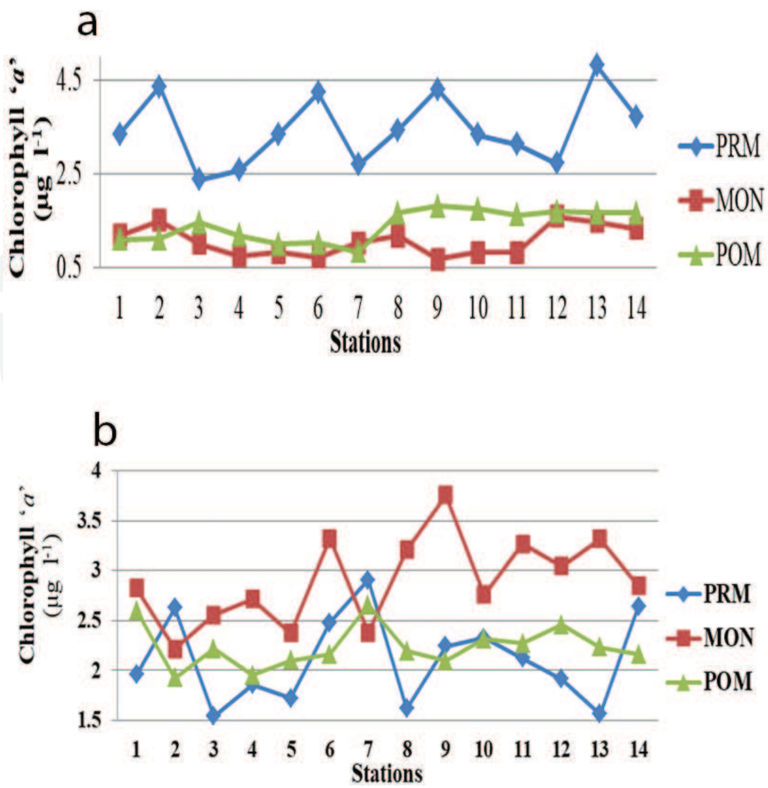

Figure 2. Seasonal and spatial variations in chlorophyll '*a*' (a) for the sampling year 2011–2012 and (b) for the sampling year 2012–2013.

period, the maximum and minimum chlorophyll 'c' recorded was 2.81 ± 2.13 and 1.49 ± 0.83 µg l^{-1} respectively at station 13 and station 6 (**Figure 4a**). In the year 2012–2013, the highest and lowest mean chlorophyll 'c' recorded in station 6 (MON) and station 4 (PRM) were 5.34 ± 1.31 and 1.52 ± 1.11 µg l^{-1}, respectively. During the post monsoon period, the maximum and minimum chlorophyll 'c' recorded was 3.91 ± 2.09 and 2.91 ± 1.31 µg l^{-1} respectively at station 7 and station 13 (**Figure 4b**). In the both sampling years, two way ANOVA showed significant differences between the season ($p < 0.001$) but not between the stations.

3.4. Seasonal mean value chlorophyll 'a, b, c'

The seasonal mean value for chlorophyll 'a, b, c' for the both sampling year was represented in **Table 1**. The seasonal mean value for chlorophyll 'a' varied between 1.07 ± 0.86 µg l^{-1} (MON) and 3.46 ± 2.05 µg l^{-1} (PRM) in the year 2011–2012. In the year 2012–2013, seasonal mean value fluctuated between 2.11 ± 1.83 µg l^{-1} (PRM) and 2.9 ± 1.47 µg l^{-1} (MON). The highest annual mean value 2.42 ± 1.46 µg l^{-1} was recorded in 2012–2013 and lowest annual mean value 1.98 ± 1.35 µg l^{-1} was recorded in the sampling year 2011–2012. In the year 2011–2012, the highest and lowest seasonal mean chlorophyll 'b' recorded in pre-monsoon and post monsoon was 2.76 ± 1.2 and 1.13 ± 1.07 µg l^{-1}, respectively. In the year 2012–2013, the highest and lowest mean chlorophyll 'b' recorded in monsoon and post monsoon was 3.07 ± 1.33 and 2.07 ± 0.96 µg l^{-1}, respectively. The highest and lowest annual average of chlorophyll 'b' was

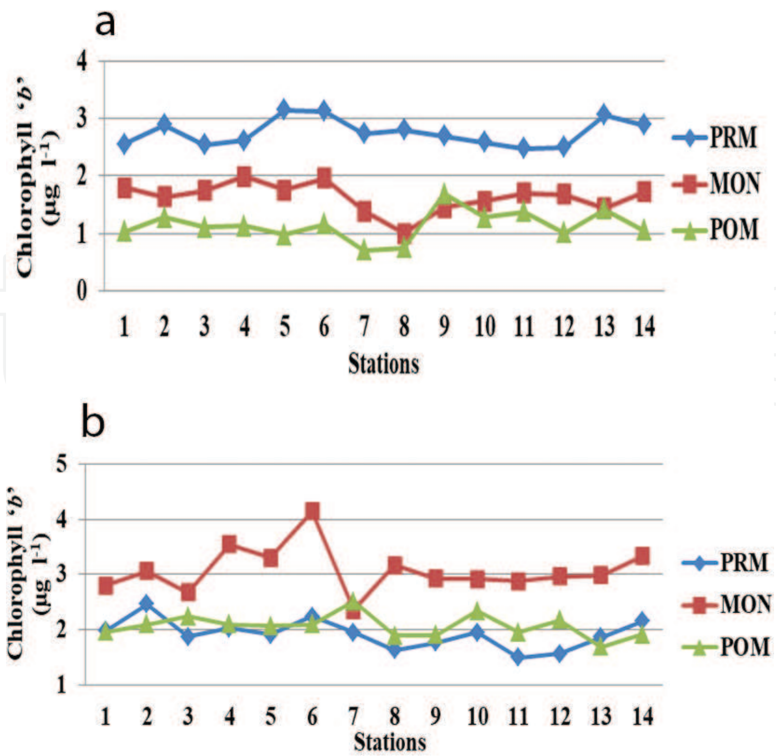

Figure 3. Seasonal and spatial variations in chlorophyll '*b*' (a) for the sampling year 2011–2012 and (b) for the sampling year 2012–2013.

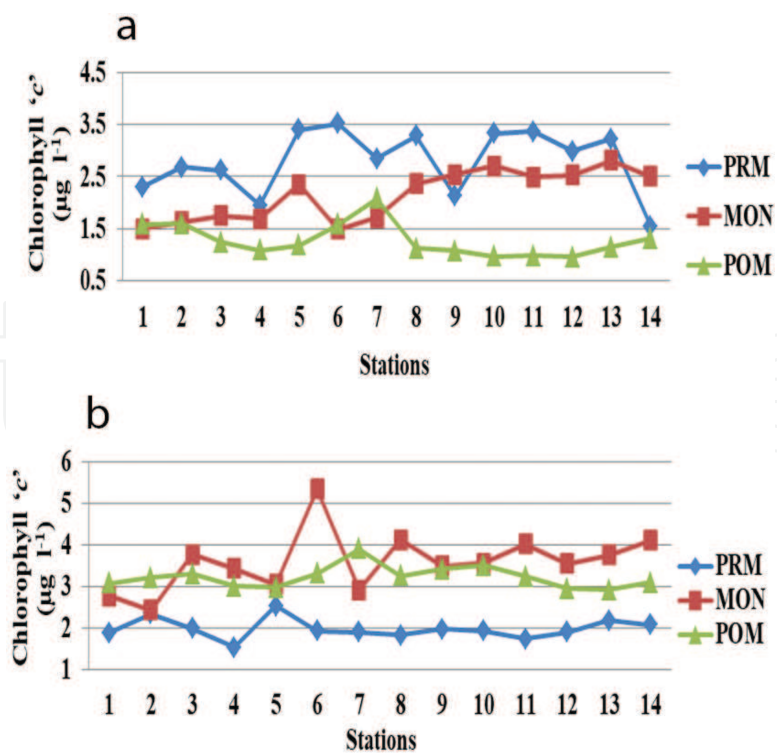

Figure 4. Seasonal and spatial variations in chlorophyll '*c*' (a) for the sampling year 2011–2012 and (b) for the sampling year 2012–2013.

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Chlorophyll	Pre-monsoon (n = 112)		Monsoon (n = 112)		Post monsoon (n = 112)		Annual (n = 336)	
	2011–2012	2012–2013	2011–2012	2012–2013	2011–2012	2012–2013	2011–2012	2012–2013
Chlorophyll '*a*' (μg l^{-1})	3.46 ± 2.056	2.11 ± 1.83	1.07 ± 0.86	2.9 ± 1.47	1.41 ± 1.11	2.24 ± 1.07	1.98 ± 1.35	2.42 ± 1.46
Chlorophyll '*b*' (μg l^{-1})	2.76 ± 1.2	1.92 ± 1.14	1.63 ± 1.28	3.07 ± 1.33	1.13 ± 1.07	2.07 ± 0.96	1.84 ± 1.6	2.35 ± 1.14
Chlorophyll '*c*' (μg l^{-1})	2.80 ± 1.619	1.98 ± 1.21	2.15 ± 1.75	3.59 ± 1.81	1.28 ± 1.02	3.22 ± 1.18	2.08 ± 2.81	2.93 ± 1.41

Table 1. Analytical mean values (mean ± standard deviation) of chlorophyll a b c for the sampling years 2011–2012 and 2012–2013.

2.35 ± 1.14 and 1.84 ± 1.6 μg l^{-1} in 2012–2013 and 2011–2012, respectively. In the year 2011–2012, the highest and lowest seasonal mean chlorophyll 'c' recorded in pre-monsoon and post monsoon was 2.80 ± 1.62 and 1.28 ± 1.02 μg l^{-1}, respectively. In the year 2012–2013, the highest and lowest mean chlorophyll 'c' recorded in monsoon and pre monsoon was 3.59 ± 1.81 and 1.98 ± 1.21 μg l^{-1}, respectively. The highest and lowest annual mean value of chlorophyll 'c' was 2.93 ± 1.41 and 2.08 ± 2.81 μg l^{-1} in 2012–2013 and 2011–2012, respectively.

3.5. Microalgal diversity

Microalgae characteristics were given in **Table 2**. A total of 191 species of microalgae were identified from the 14 study sites along the Visakhapatnam offshore region, Bay of Bengal. Of these, 131 species were recorded under Ochrophyta division (68.58%) (127 species are diatoms (40.84% Centrales, 25.65% Pennales), 3 species belong to silicoflagellates 1.57% and 1 species in Eustigmatophyceae 0.52%), 35 species (18.3%) belong to dinophyta, 11 species (5.76%) belong

Division	Characteristics				
	Class	Family	Genus	Species	% of species
1. Ochrophyta	4	38	66	131	68.5
2. Dinophyta	1	7	10	35	18.3
3. Cyanophyta	1	6	8	11	5.76
4. Chloropyta	3	5	5	7	3.66
5. Euglenozoa	1	2	2	4	2.09
6. Haptophyta	2	2	3	3	1.57
Total	12	59	91	191	100
Centrales	1	21	33	78	40.84%
Pennales	1	15	30	49	25.65%
Dictyochaceae	1	1	2	3	1.57%
Monodopsidaceae	1	1	1	1	0.52

Table 2. Characteristics of microalgae for the both sampling years.

to cyanophyta, 7 species (3.66%) belong to chlorophyta, 4 species (2.09%) belong to euglenozoa and 3 species (1.57%) belong to haptophyta. The community composition of phytoplankton was dominated by Centrales, which represented by 21 families with 33 genera. *Chaetoceros* (15 species), *Bacteriastrum* (5 species), *Coscinodiscus* and *Thalassiosira* (6 species) genus were encountered with more than five species and *Rhizosolenia* and *Triceratium* genus were recorded with four species under centric diatoms. Pennate diatoms were recorded with 30 genera and 49 species. In pennate diatoms, maximum four species were recorded under the same genus of *Pleurosigma* and three species were encountered in each genus of *Nitzschia, Amphora, Diploneis* and *Fragilariopsis*. In Dinophyta, 7 families and 10 genera were recorded, maximum number of species found in the genus were *Neoceratium* (8), *Protoperidinium* (8) *Prorocentrum* (3) and *Dinophysis* (4). In Cyanophyta, six families and eight genera were recorded. *Trichodesmium*, *Lyngbya* and *Schizothrix* genus were encountered with two species and remaining genera was observed with single species. In the division of Chlorophyta, 3 classes, 5 families and 5 genera were recorded, in this division species two species was encountered with *Tetraselmis* and *Dunaliella* genus. The division Haptophyta was observed with 3 species and 3 genera. In the Euglenozoa division, 2 genera with 4 species were noted and Silicoflagellates was observed with 2 genera and 3 species. During the course of study phytoplankton showed distribution pattern as: Centric diatoms>PennateDiatoms>Dinophyta>Cynophyta>Chloropyta>Euglenozoa>Haptophyta.

3.5.1. Seasonal variations in qualitative abundance of microalgae

Seasonal variation in microalgae qualitative abundance was given in **Table 3**. Seasonal fluctuations of species composition in both sampling years varied from 150 (MON) to 161 (PRM). The species from phylum Ochrophyta fluctuated between 103 (PRM 2012–2013) and 115 (PRM 2011–2012). Centric diatoms varied between 66 (POM) and 70 (PRM) in the total of 78. Pennate

Division	2011–2012			2012–2013		
	PRM	MON	POM	PRM	MON	POM
1. Ochrophyta	115	106	107	110	103	107
2. Dinophyta	23	27	26	26	28	28
3. Cyanophyta	11	9	9	10	9	8
4. Chlorophyta	6	7	6	7	4	5
5. Euglenozoa	4	3	2	3	3	3
6. Haptophyta	2	3	2	2	3	2
Total	161	155	154	158	150	153
Centrales	69	68	68	70	67	66
Pennales	42	36	38	37	33	38
Dictyochaceae	3	1	2	2	2	2
Monodopsidaceae	1	1	1	1	1	1

Table 3. Quality abundance of microalgae.

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diatoms ranged from 33 (MON) to 42 (PRM) from the total of 46. Dinoflagellate showed the variation between 23 (PRM) and 28 (MON) species in the total of 35. Cyanobacteria found to be low in post monsoon (8) and high during pre-monsoon (11) in the total of 11. In the division of haptophyta, species abundance fluctuated between 2 and 3 during pre-monsoon and monsoon, respectively and chlorophyta species ranged from 4 to 7 during monsoon and pre-monsoon, respectively.

3.5.2. Seasonal variations in qualitative abundance of microalgae

Checklists (species composition) of microalgae on the Visakhapatnam offshore region were summarized in Appendix A. The samples of all station were pooled for seasonal distribution analysis into samples of three season (pre-monsoon, monsoon and post monsoon) which helped in obtaining information about the distribution and species composition (or) diversity of the sea surface water. Abundance of phytoplankton during the study period (191 species) was reported along the Visakhapatnam Coast throughout the sampling years. Six divisions of microalgae Ochrophyta, Dinophyta, Cyanophyta, Chlorophyta, Euglenozoa and Haptophyta were recorded. The class Bacillariophyceae and Coscinodiscophyceae comprised of 36 families, 63 genera and 124 species. Altogether 191 species of microalgae belonging to the classes of Bacillariophyceae, Coscinodiscophyceae, Dinophyceae, Euglenophyceae, Chlorodendrophyceae, Chlorophyceae, Eustigmatophyceae, Dictyophyceae, Prymnesiophyceae, Pavlovophyceae, Trebouxiophyceae and Cyanophyceae were identified. Of these, *Tetraselmis gracilis, Dicrateria inornata, Thalassiosira subtilis, Chaetoceros muelleri, Chaetoceros diversus, Skeletonema costatum, Thalassiosira subtilis* and *Asterionella inflata* were considered important species based on the order of their abundance and frequency of occurrence. Present study indicates that the diatoms are the dominant group followed by the dinoflagellates and others.

4. Discussion

Microalgal diversity is extremely important to analyze the status of an ecosystem. Local microalgae species have a competitive advantage under the local geographical, climatic and ecological conditions [16]. The levels of chlorophyll are the proof of photosynthetic activities and there was a distinct seasonality observed in the levels of phytoplankton biomass at the study sites. Total phytoplankton representing the maximum concentration of chlorophyll '*a*' was recorded along the Visakhapatnam Coast during pre-monsoon (2011–2012) and monsoon (2012–2013). Surface phytoplankton abundance (as chlorophyll '*a*' concentration) levels, reached up to 4.81 μg l^{-1}, occurred in pre-monsoon, with the further smaller peaks in post monsoon and monsoon periods of the sampling year 2011–2012. In the year 2012–2013, peak chlorophyll levels reached up to 3.76 μg l^{-1}, in monsoon. Highest chlorophyll '*a*' concentration was reported during pre-monsoon (2011–2012) coincided with the period of upwelling and in the year 2012–2013, and the monsoon coincided with large scale mixing between surface river waters and deeper nutrient rich bottom waters [17]. The annual average (13.4 μg l^{-1}) chlorophyll '*a*' was reported for the entire euphotic zone of EEZ of Arabian Sea and it ranged from 0.1 to 96.4 μg l^{-1} [18]. Chlorophyll '*a*' was found between 3.31 and 99.12 μg l^{-1} in surface water off Gopalpur, East coast of India, Bay of Bengal [19] and varied between 0.21 and 30.82 μg l^{-1} off Mangalore, West Coast of India [20] and the highest value 8.28 μg l^{-1} was observed during the post monsoon off Cape Comorin [21]. In the present work, the higher concentration of chlorophyll '*b*' was recorded during monsoon, 2012–2013 and the West coast also recorded the highest concentration of chlorophyll '*b*' (20.41 μg l^{-1}) during the monsoon [22]. Relatively high chlorophyll '*b*' indicates the presence of ultra or nano-planktonic microalgae coming under the class Chlorophyceae/Euglenophyceae/Prochlorophyceae [23].

Chlorophyll '*c*' was recorded in lower concentrations during the pre and post monsoon season (2012–2013) and the same pattern was also observed in West Coast of India [22]. Lowest chlorophyll and DO concentrations were recorded during pre-monsoon period (2012–2013) has clearly indicated that plankton growth during pre-monsoon was reduced because of oxygen demand by the organic matter in the period of May and June [24]. The highest seasonal average of chlorophyll '*a*', '*b*' and '*c*' in all stations were recorded during the monsoon of 2012–2013 due to the nutrient rich land runoff water in to the coastal areas. Monsoon rains and associated land runoff and nutrient loading determines the balance of organic to inorganic loadings which act as major factors controlling community responses of microalgae [25].

Earlier studies have reported that the nutrient supply could have significant effect on community composition of phytoplankton [26]. The nitrogen limitation is known to have a significant effect on phytoplankton composition. To determine the growth of phytoplankton, nutrients are the primary factors. The highly seasonal nature of monsoon rains might have increased the concentration nutrients (nitrite, nitrate and silicate) in monsoon period. The recorded low values during pre- and post-monsoon period may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and the dominance of neritic seawater having a negligible amount of nitrate [27]. In East Coast of India, Bay of Bengal a total number 249 species of phytoplankton comprising of 131 species of dinoflagellates, 111 species of diatoms and 7 species of cyanobacteria were recorded during 2004 [28]. In 2012, EEZ micro algae distributed studies reported 71 species, 30 genera with 22 families under Bacillariophyceae and 88 species of dinoflagellates encountered with 22 genera and 18 families [29]. In Cyanophyceae, 3 genera with 4 species and in Dictochophyceae one species were also reported in their studies.

Microalgal population (Diatoms>Dinoflagellates>Cyanophyta>Chlorophyta) pattern of this record was similar to that reported from Coastal waters off Rushikulya estuary, East Coast of India [30, 31]. Eurythermal and euryhaline nature of diatoms in all the three season leads to their dominance [32] and have been observed to bloom regularly along the Indian Coast during June to October [33, 34]. Dominance of diatom over dinoflagellates coincides to the report from Indian coastal water [35–37] and world oceans [38, 39]. A cosmopolitan genus such as *Chaetoceros* was dominant with 15 species followed by other major genera such as *Coscinodiscus* (6 species), *Nitzschia* (3 species) and *Rhizosolenia* (4 species) in this study. *Oscillatoriaceae* and *Phormidiaceae* were the dominant family in Cyanophyceae class with 3 species and followed by *Schizotrichaceae* (2 species) and the trend was similar to the studies in the same coast [40, 41]. Epiphytic cyanobacteria, *Dactylococcopsis* and *Synechococcus* and 17 genera belonging to chlorophyceae including *Oocystis, Chlorella vulgaris* was recorded in Palk Strait [42] and a total 44 species of Cyanobacteria from Tamilnadu [43] and Kerala [44].

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Seasonal succession of phytoplankton population indicated that dinoflagellates mainly *Neoceratium* and *protoperidinium* as well as silicoflagellates; *Dictyocha* were dominant population in pre-monsoon periods. In diatoms *Rhizosolenia, Guinardia, Thalassiosira, Chaetoceros and Asterionella* genus were relatively more dominantly throughout the sampling years. The same sequences in the phytoplankton abundance were reported at East Coast India [45] and from Pakistan 15 species in *Navicula* was reported [46]. Generally, *Skeletonema costatum* found to be dominant in this Coast coincides was agree with earlier studies [45, 47, 48]. *Chaetoceros* species have contributed high in total population of centric diatoms and it is coincided by the findings during pre-monsoon periods [45, 49]. In Sundarbans also diatom reported as dominant group in the overall phytoplankton group and *Skeletonema* and *Chaetoceros* are more abundant species East Coast of India [50].

In the current study, genus *Asterionella* and *Fragilariopsis* were observed throughout the year but the highest numbers were observed in the months of April and June 2013. *Asterionella japonica* bloom and discoloration Off Waltair, East coast [51] and north western Bay of Bengal [52] strongly supporting our findings. *Pleurosigma* species with five different classes was reported as dominant species in Nizampatnam, East Coast of India [53]. The maximum numbers of diatoms recorded in post monsoon period was only five numbers more than that of pre-monsoon. In waters off Visakhapatnam Coast, some genera of green algae under the division of Chlorophyta i.e. *Chlorella*, *Tetraselmis*, and *Dunaliella* were recorded throughout in both samplings years. Prasinophyceae and Trebouxiophyceae classes were found predominantly along with some prokaryotic and eukaryotic picoplankton species in the same Coast [54]. Highest number of species under chlorophyta was recorded during pre-monsoon periods like cyanophyceae. In contrary, Southwest Coast of India had recorded that the cyanophycean and chlorophycean species distributed during the monsoon period of the years 2006–2008 [22]. As like as centric diatoms, cyanophyta also showed a maximum number of species during pre-monsoon period, however, the maximum values were obtained for dinoflagellates during monsoon period. The annual mean water temperature 29°C for both sampling years supported for the abundance of flagellates throughout the year. The abundance of flagellate species was commonly occurring at higher water temperatures [55]. In the Visakhapatnam coastal waters, Haptophyceae and Prasinophyceae classes were most abundant [56] and 17 species of flagellates represented by 6 diverse groups in the same coastal waters [57]. *Dictyocha fibula* was recorded during monsoon periods of both the sampling years except during post monsoon (2011–2012) and the same sequence were reported the lower abundance of oceanic species *Dictyocha fibula* during pre- and post-monsoon [58].

5. Conclusion

Chlorophyll concentrations and diversity of microalgae in Visakhapatnam offshore region studied in detail for a period of 2 year (2011–2012 and 2012–2013). Our results revealed that the diatoms were found to be dominant with number of species in Visakhapatnam offshore waters, Bay of Bengal. From this study, we had found the suitable spatial and season to get sea water to isolate particular species of microalgae and which is use full for shrimp hatchery in that coastal zone. And another advantages of this study was pin point spatial of this coastal area may help to isolate microalgae can be grown in open pond without any major contamination to produce biomass for biodiesel production.

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A. Species composition of microalgae along the Visakhapatnam offshore region

	CENTRIC DIATIOMS Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: Coscinodiscophyceae (Round & Crawford in Round, Crawford & Mann, 1990)**	**2011–2012**			**2012–2013**		
S. No	**Family**	**S. No**	**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
1	*Bellerocheaceae* (Round and Crawford in Round *et al*. 1990)	*1*	*Bellerochea malleus* (Brightwell) Van Heurck 1885	+	+	+	+	+	+
2	*Biddulphiaceae* (Kutzing, 1844)	2	*Biddulphia biddulphiana* (Smith) Boyer, 1900	+	+	—	+	+	+
3	*Chaetocerotaceae* (Ralf in Pritchard, 1861)	3	*Bacteriastrum comosum* (Pavillard, 1916)	+	+	+	+	+	+
		4	*Bacteriastrum delicatulum* (Cleve, 1897)	+	+	+	+	+	+
		5	*Bacteriastrum furcatum* (Shadbolt, 1854)	+	+	+	+	+	+
		6	*Bacteriastrum hyalinum* (Lauder, 1864)	—	+	+	—	+	—
		7	*Bacteriastrum elongatum* (Cleve, 1897)	+	+	+	+	+	+
		8	*Chaetoceros affinis* (Lauder, 1864)	+	+	+	+	+	+
		9	*Chaetoceros atlanticus* (Cleve, 1873)	+	+	+	+	+	+
		10	*Chaetoceros lauderi* (Ralfs in Lauder, 1864)	+	+	+	+	+	+
		11	*Chaetoceros compressus* (Lauder, 1864)	—	+	—	—	+	—
		12	*Chaetoceros muelleri* (Lemmermann, 1898)	+	+	+	+	+	+

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	CENTRIC DIATIOMS Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: Coscinodiscophyceae (Round & Crawford in Round, Crawford & Mann, 1990)**	**2011–2012**			**2012–2013**		
S. No	**Family**	**S. No**	**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		13	*Chaetoceros tortissimus* (Gran, 1900)	—	+	+	+	—	+
		14	*Chaetoceros curvisetus* (Cleve, 1889)	+	+	+	+	+	+
		15	*Chaetoceros decipiens* (Cleve, 1873)	+	+	+	+	+	+
		16	*Chaetoceros diadema* (Ehrenberg) Gran, 1897	—	—	+	—	+	—
		17	*Chaetoceros diversus* (Cleve, 1873)	+	+	+	+	+	+
		18	*Chaetoceros didymus* (Ehrenberg, 1845)	+	—	—	+	—	—
		19	*Chaetoceros laevis* (Leuduger-fortmoral, *1892)*	+	+	+	+	+	+
		20	*Chaetoceros lorenzianus* (Grunow, 1863)	—	+	+	+	+	+
		21	*Chaetoceros messanense* (Castracane, 1875)	+	+	—	+	+	—
		22	*Chaetoceros paradoxus Var. eibenii* (Grounow) Grounow, 1896	+	+	—	+	—	—
4	*Coscinodiscaceae* (Kutzing, 1844)	*23*	*Coscinodiscus curvatulus* (Grunow in Schmidt, 1878)	+	+	+	+	+	+
		24	*Coscinodiscus granii* (Gough, 1905)	+	+	—	+	+	—
		25	*Coscinodiscus radiatus* **(**Ehrenberg, 1840)	+	+	—	+	—	—
		26	*Coscinodiscus centralis* (Ehrenberg, 1844)	+	+	+	+	+	+
		27	*Coscinodiscus jonesianus* (Greville) Ostenfeld	—	—	+	—	+	+
		28	*Coscinodiscus perforatus* (Ehrenberg, 1844)	—	—	+	—	+	+
5	*Corethraceae* (Lebour, 1930)	*29*	*Corethron hystrix* (Hensen, 1887)	+	+	+	+	+	+
		30	*Corethron inerme* (Karsten, 1905)	+	+	+	+	+	+
6	*Gossleriellaceae* (Round in Round *et al*. 1990)	*31*	*Gosleriella tropica* (Schutt 1892)	+	—	—	+	—	—
7	*Heliopeltaceae* (Smith, 1872)	*32*	*Actinoptychus campanulifer* (Schmidt, 1875)	+	+	+	—	+	+
8	*Hemiaulaceae* (Heiberg, 1863)	*33*	*Hemiaulus hauckki* (Grunow) ex van Heurck, 1882	+	+	+	+	+	+
		34	*Hemiaulus membranaceus* (Cleve, 1873)	+	—	—	+	+	—

	CENTRIC DIATIOMS Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: Coscinodiscophyceae (Round & Crawford in Round, Crawford & Mann, 1990)**	**2011–2012**			**2012–2013**		
S. No	**Family**	**S. No**	**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		35	*Hemiaulus sinensis* (Greville, 1865)	+	+	+	—	+	+
		36	*Eucampia cornuta* (Cleve) Grunow, 1883	+	+	+	+	+	+
		37	*Eucampia zodiacus* (Ehrenberg, 1839)	+	+	+	+	+	+
		38	*Erataulina pelagic* (Cleve) Hendey, 1937	+	+	+	+	+	+
9	*Hemidiscaceae* (Hendey, 1937)	*39*	*Actinocyclus octonarius* var. crassus (Smith) Hendey, 1954	+	+	—	+	+	—
		40	*Actinocyclus ehrenbergii* (Ralfs in Pritchard, 1861)	+	—	+	+	—	+
		41	*Hemidiscus cuneiformis* (Wallich, 1860)	+	+	+	+	+	+
		42	*Palmeria hardmaniana* (Greville, 1865)	+	+	+	+	+	+
10	*Hyalodiscaceae* (Crawford in Round *et al*. 1990)	*43*	*Podosira stelliger* (Bailey) Mann, 1907	+	+	+	+	+	+
11	*Leptocylindraceae* (Lebour, 1930)	*44*	*Leptocylindrus danicus* (Cleve, 1889)	+	+	+	+	+	+
		45	*Leptocylindrus minimus* (Gran, 1915)	+	+	+	+	+	+
12	*Lithodesmiaceae* (Round in Round *et al*. 1990)	*46*	*Lithodesmium undulatum* (Ehrenberg, 1839)	—	+	+	—	+	+
		47	*Ditylum brightwellii* (West) Grunow, 1885	+	+	+	+	+	+
		48	*Ditylum sol Grunow* (Grunow) De Toni, 1984	+	+	+	+	+	+
		49	*Paralia sulcata* (Ehrenberg) Cleve, 1873	+	—	+	+	—	+
13	*Melosiraceae* (Kutzing 1844)	*50*	*Melosira moniliformis* (Muller) Agardh, 1824	+	+	+	+	+	+
		51	*Melosira nummuloides* (Agardh, 1824)	+	+	+	+	+	+
14	*Rhizosolenia* (De Toni, 1890)	*52*	*Rhizosolenia castracanei* (Peragallo, 1888)	+	+	+	+	+	+
		53	*Rhizosolenia crassa* (Schimper, 1905)	+	+	+	+	+	+
		54	*Rhizosolenia imbricate* (Brightwell, 1858)	+	+	+	+	+	+
		55	*Rhizosolenia formosa* (Peragallo, 1888)	+	+	+	+	+	+
		56	*Proboscia alata* (Brightwell) Sundstrom, 1986	—	+	+	—	—	+

	CENTRIC DIATIOMS Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: Coscinodiscophyceae (Round & Crawford in Round, Crawford & Mann, 1990)**	**2011–2012**			**2012–2013**		
S. No	**Family**	**S. No**	**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		57	*Guinardia flaccid* (Castracane) Peragallo, 1892	+	+	+	+	+	+
		58	*Guinardia striata* (Stolferfoth) Hasle, 1996	+	+	+	+	+	+
		59	*Dactyliosolen fragilissimus* (Bergon) Hasle, 1966	+	+	+	+	+	+
15	*Skeletonemaceae* (Lebour, 1930)	60	*Skeletonema costatum* (Greville) Cleve, 1878	+	+	+	Contd. +	+	+
16	*Stephanodiscaceae* (Glezer and Makarova, 1986)	61	*Cyclotella striata* (Kutzing) Grunow, 1880	+	+	+	+	+	+
17	*Stephanopyxidaceae* (Nikole in Round *et al*.1990)	62	*Stephanopyxis palmeriana* (Greville) Grunow, 1884	+	+	+	+	+	+
18	*Streptothecaceae* (Crawford,1990)	63	*Helicotheca tamesis* (Shrubsole) Richard, 1890	+	—	+	+	—	+
19	*Thalassiosiraceae* (Lebour 1930)	64	*Thalassiosira longissima* Baltica (Grunow) Ostenfeld 1901	+	+	+	+	+	+
	Thalassiosiraceae (Hasle, 1973)	65	*Thalassiosira eccentric* (Ehrenberg) Cleve, 1903	+	+	+	+	+	+
		66	*Thalassiosira subtilis* (Ostenfeld) Gran 1900	+	+	+	+	+	+
		67	*Thalassiosira leptopus* (Grunow ex Van Heurck) Hasle & Fryxell, 1977	+	+	+	+	+	+
		68	*Thalassiosira anguste-lineata* (Schmidt) Fryxell & Hasle, 1977	+	+	+	+	+	+
		69	*Thalassiosira oceanica* (Halse, 1983)	+	+	+	+	+	+
		70	*Planktoniella sol* (Wallich) Schutt, 1892	+	+	+	+	—	+
20	*Lauderiaceae* (Schutt) Lemmermann, 1899	71	*Lauderia annulata* (Cleve, 1873)	+	+	+	+	+	+
21	*Triceratiaceae* (Schutt) Lemmermann, 1899	72	*Triceratium favus* (Ehrenberg, 1839)	+	+	+	+	+	+
		73	*Triceratium robertsianum* (Graville, 1863)	+	+	+	+	+	+
		74	*Triceratium reticulum* (Ehrenberg, 1844)	+	—	+	+	—	+
		75	*Triceratium alternans* (Bailey) Mann, 1907	+	+	+	+	+	+

	CENTRIC DIATIOMS Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: Coscinodiscophyceae (Round & Crawford in Round, Crawford & Mann, 1990)**	**2011–2012**			**2012–2013**		
S. No	**Family**	**S. No**	**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		76	*Odontella longicruris* (Greville) Hoben, 1983	+	+	+	+	+	+
		77	*Odontella mobiliensis* (Bailey) Grunow, 1884	+	+	+	+	—	—
		78	*Odontella sinensis* (Greville) Grunow, 1884	+	+	+	+	+	+
			Class 1, Families 21, Genera 33 and Species 78.	69	68	68	70	67	66

	Pennate Diatoms Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: *Bacillariophyceae* (Haeckel, 1878)**	**2011–2012**			**2012–2013**		
S.No	**Family**	**S.N**	**Species**	**PRM**	**MON**	**PRM**	**MON**	**PRM**	**MON**
1	*Amphipleuraceae* (Grunow, 1862)	*1*	*Amphiprora gigantea* (Grunow, 1860)	+	+	+	+	+	+
		2	*Amphiprora alata* (Ehrenberg),1845	+	+	—	+	—	+
		3	*Frustulia specula* (Amosse, 1932)	+	+	—	—	+	—
2	*Bacillariaceae* (Ehrenberg, 1831)	*4*	*Nitzschia longissima* (Brebisson, in Kutzing) Ralfs, 1861	+	+	+	+	+	+
		5	*Nitzschia macilenta* (Gregory, 1857)	+	+	+	+	+	+
		6	*Nitzschia sigmoidea* (Nitzsch) W. Smith 1853	+	+	+	+	+	+
		7	*Ceratoneis closterium* (Ehrenberg, 1839)	+	+	+	+	+	+
		8	*Bacillaria paxillifera* (Muller.) Hendey, 1951	—	—	+	—	+	+
		9	*Pseudonitzschia australis* (Frenguelli, 1939)	+	+	+	+	+	+
		10	*Pseudonitzschia pungens* (Grunow ex cleve) Hasle, 1993	+	+	+	+	+	+
		11	*Tryblionella compressa* (Bailey) Poulin, 1990	+	+	+	+	+	+
3	*Catenulaceae* (Mereschkowsky, 1902)	*12*	*Amphora laevis* (Gregory, 1857)	—	+	+	—	+	+
		13	*Amphora delphineiformis* (Levkov, 2009)	+	+	+	+	+	—
		14	*Amphora obtusa* (Gregory, 1857)	+	+	+	+	+	+
4	*Cocconeidaceae* (Kutzing, 1844)	*15*	*Cocconeis placentula var. euglypta* (Ehrenberg) Grunow, 1884	+	+	—	+	—	—

	Pennate Diatoms Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: *Bacillariophyceae* (Haeckel, 1878)**	**2011–2012**				**2012–2013**	
S.No	**Family**	**S.N**	**Species**	**PRM**	**MON**	**PRM**	**MON**	**PRM**	**MON**
5	*Cymbellaceae* (Greville, 1833)	*16*	*Cymbella cymbiformis* (Agardh, 1830)	+	+	+	—	+	+
		17	*Cymbella cistula* (Ehrenberg) Kirchner, 1878	+	+	—	+	—	—
6	*Diploneidaceae* (Mann, 1990)	*18*	*Diploneis splendida* (Cleve, 1894)	+	+	+	+	+	+
		19	*Diploneis bombus* (Ehrenberg, 1953)	+	—	+	+	+	+
		20	*Diploneis littoralis* (Donkin) Cleve, 1894	+	—	+	+	+	+
7	*Rhaphoneidaceae* (Forti, 1912)	*21*	*Delphineis surirella* (Ehrenberg) Andrews 1981	+	+	+	+	+	+
		22	*Delphineis surirelloides* (Simonsenii) Andrews, 1977	+	+	+	+	+	+
8	*Fragilariaceae* (Greville, 1833)	*23*	*Tabularia fasciculata* (Agardh) Williams & Round, 1986	+	+	—	+	—	—
		24	*Synedra ulna* (Nitzsch) Ehernberg, 1832	—	—	+	+	—	+
		25	*Asterionellopsis glacialis* (Castracane) Round, 1990	+	—	+	+	—	+
		26	*Asterionella inflata* (Heib, 1863)	+	—	+	+	+	+
		27	*Fragilaria crotonensis* (Kitton, 1869)	+	+	+	+	+	+
		28	*Fragilariopsis oceanica* (Cleve) Hasle, 1965	+	+	+	+	+	+
		29	*Fragilariopsis doliolus* (Wallich) Medlin & Sims, 1993	+	+	+	+	+	+
		30	*Fragilariopsis kerguelensis* (O'meara) Husbedt, 1952	+	+	+	+	+	+
9	*Licmophoraceae* (Kutzing, 1844)	*31*	*Licmophora abbreviate* (Agarth, 1831)	+	—	+	—	—	+
10	*Lyrellaceae* (Mann, 1990)	*32*	*Lyrella hennedyi* (Smith) Stickle & Mann, 1990	+	+	+	—	+	+
		33	*Lyrella lyra* (Ehrenberg) Karajeva, 1978	+	+	—	+	—	+
11	*Naviculacaea* (Kutzing, 1844)	*34*	*Navicula semen* (Ehrenberg) 1843	+	+	+	+	+	+
		35	*Navicula peticolasii* (Peragallo, 1909)	+	—	+	+	+	—
		36	*Trachyneis aspera* (Ehrenberg) Cleve, 1894	—	—	+	—	+	+
		37	*Meuniera membranacea* (Cleve) Silva, 1996	+	+	+	+	—	+
		38	*Pleurosigma directum* (Grunow, 1880)	+	+	+	+	+	+
		39	*Pleurosigma elongatum* (Smith, 1852)	+	+	+	+	+	+

	Pennate Diatoms Phylum: Ochrophyta (Cavalier-Smith in Cavalier-Smith & Chao, 1996)		**Class: *Bacillariophyceae* (Haeckel, 1878)**	**2011–2012**			**2012–2013**		
S.No	**Family**	**S.N**	**Species**	**PRM**	**MON**	**PRM**	**MON**	**PRM**	**MON**
		40	*Pleurosigma normanii* (Ralfs in Pritchard 1861)	+	+	+	+	+	+
		41	*Gyrosigma balticum* (Ehrenberg) Robenhorst, 1853	+	+	+	+	—	+
12	*Phaeodactylaceae* (Lewin, 1958)	*42*	*Phaeodactylum tricornutum* (Bohlin, 1897)	+	+	+	+	+	+
13	*Striatellaceae* (Kutzing, 1844)	*43*	*Grammatophora marina* (Lyngbye) Kutzing, 1844	+	+	—	+	—	+
14	*Surirellaceae* (Kutzing, 1844)	*44*	*Surirella patella* (Kutzing, 1844)	+	—	+	—	—	+
15	*Thalassionemataceae* (Round and Crawford in Round *et al.* 1990)	*45*	*Thalassionema bacillare* (Heiden) Kolbe, 1955	+	+	+	+	+	+
		46	*Thalassionema nitzschioides* (Grunow) Mereschkowsky, 1902	+	+	+	+	+	—
		47	*Thalassionema frauenfeldii* (Grunow) Tempere & Peragallo, 1910	+	+	+	+	+	+
		48	*Thalassiothrix longissima* (Cleve & Grunow 1880)	+	+	+	+	—	+
		49	*Thalassiothrix heteromorpha* (Karsten, 1907)	+	+	—	—	+	—
	Class 1, Families 15, Genera 30 and Species 49			42	36	38	37	33	38

Phylum: Ochrophyta		**S. No**	**Species**	**2011–2012**			**2012–2013**		
				PRM	**MON**	**POM**	**PRM**	**MON**	**POM**
Family			**Class 1: Dictyochophyceae (Silva, 1980)**						
1	Dictyochaceae (Lemmermann, 1901)	1	*Dictyocha fibula* (Ehernberg, 1839)	+	+	—	+	+	+
		2	*Dictyocha staurodon* (Ehrenberg, 1844)	+	—	+	+	—	—
		3	*Octactis octonaria* Ehernberg Hovasse, 1946	+	—	+	—	+	+
2	Monodopsidaceae (Hibberd, 1981)		Class 2: Eustigmatophyceae (Hibberd & Leedale, 1971)						
		4	*Nannochloropsis gaditana* (Lubian, 1982)	+	+	+	+	+	+
	Families 2, Class 2, Genera 3 and Species 4			4	2	3	3	3	3

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	Phylum: Dinophyta (Round, 1973)		**Class: Dinophyceae (Fritsch in West & Fritsch, 1927)**	**2011–2012**			**2012–2013**		
	Family		**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
1	Ceratiaceae (Lindeman, 1928)	1	*Neoceratium breve* (Ostenfeld & Schmidt) Gomez, Moreira & Lopez-Garcia, 2010	+	+	+	+	+	+
		2	*Neoceratium furca* (Ehrenberg) Gomez, Moreira & Lopez-Garcia, 2010	—	+	+	+	+	+
		3	*Neoceratium karsteni* (Pavillard, 1907) Gomez, Moreira & Lopez-Garcia, 2010	—	+	+	—	+	+
		4	*Neoceratium macroceros* (Ehrenberg) Gomez, Moreira & Lopez-Garcia, 2010	—	+	—	+	+	—
		5	*Neoceratium teres* (Kofoid) Gomez, Moreira & Lopez-Garcia, 2010	+	—	—	+	+	+
		6	*Neoceratium tripos* (Muller) Gomez, Moreira & Lopez-Garcia, 2010	—	+	+	+	—	+
		7	*Neoceratium symmetricum* (Pavillard) Gomez, Moreira & Lopez-Garcia, 2010	—	+	+	+	+	+
		8	*Neoceratium horridum* (Gran) Gomez, Moreira & Lopez-Garcia, 2010	—	—	+	—	+	+
		9	*Ceratium seta* (Ehrenberg) Kent, 1881	+	+	+	—	—	+
		10	*Ceratium pacificum* (Wood, 1963)	+	—	+	+	+	—
		11	*Ceratium uteri* (Campbell, 1934)	—	+	+	+	+	+
2	Dinophysaceae (Butschli, 1885)	12	*Dinophysis caudata* (Saville-Kent, 1881)	+	+	+	+	—	+
		13	*Dinophysis dens* (Pavillard, 1915)	+	+	—	+	—	+
		14	*Dinophysis fortii* (Pavillard, 1923)	+	+	—	+	+	+
		15	*Dinophysis miles* (Cleve, 1900)	+	+	+	+	+	+
		16	*Ornithocercus magnificus* (Stein, 1883)	+	+	+	—	—	+
		17	*Ornithocercus thumii* (Schmidt) Kofoid & Skoggberg, 1928	+	—	+	+	+	+
3	Gymnodiniaceae (Lankester, 1885)	18	*Karenia brevis* (Davis) Hansen & Moestrup, 2000	+	+	+	+	+	+
		19	*Gymnodinium danicans* (Cambell, 1973)	+	+	—	+	—	+
		20	*Gymnodinium dentatum* (Larsen, 1994)	+	—	+	+	+	—
		21	*Akashiwo sanguine* (Hirasaka) Hansen & Moestrup, 2000	—	+	+	+	+	+
4	Protoperidiniaceae (Taylor, 1987)	22	*Protoperidinium thorianum* (Paulsen) Balech, 1974	+	+	+	+	+	+
		23	*Protoperidinium depressum* (Bailey) Balech, 1974	+	+	—	+	—	—
		24	*Protoperidinium elegans* (Cleve) Balech, 1974	+	+	+	+	+	—
		25	*Protoperidinium oceanicum* (VanHoffen) Balech, 1974	+	—	+	—	+	+

	Phylum: Dinophyta (Round, 1973)		Class: Dinophyceae (Fritsch in West & Fritsch, 1927)	2011–2012			2012–2013		
	Family		**Species**	**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		26	*Protoperidinium pellucidum* Bergh, 1881	—	+	+	—	+	—
		27	*Protoperidinium subinerme* (Paulsen) Loeblich III, 1970	—	+	—	+	+	—
		28	*Protoperidinium pallidum* (Ostenfeld) Balech, 1973	—	+	+	+	+	—
		29	*Protoperidinium pentagonum* (Gran) Balech, 1974	+	+	—	—	+	+
5	Phyrophacaceae (Lindemann, 1928)	30	*Pyrophacus steinii* (Schiller) Wall & Dale 1971	+	+	+	+	+	+
		31	*Pyrophacus horologium* (Stein, 1883)	+	+	+	—	+	+
6	Prorocentraceae (Stein, 1883)	32	*Prorocentrum lima* (Ehrenberg) Stein, 1878	—	+	+	+	+	+
		33	*Prorocentrum gracile* (Schutt, 1895)	+	+	+	+	+	+
		34	*Prorocentrum micans* (Ehrenberg, 1834)	+	—	+	—	+	+
7	Noctilucaceae (Kent, 1881)	35	*Noctiluca scintillans* (Macartney) Kofoid & Swezy, 1921	+	—	—	+	—	+
Class 1, Families 7, Genera 11, Species 35				23	27	26	26	28	28

	Phylum: Cyanobacteria (Stanier ex Cavalier-Smith, 2002)		Class: Cyanophyceae (Schaffner, 1909)	2011–2012			2012–2013		
S. No	**Family**			**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
1	Oscillatoriaceae (Engler, 1898)	1	*Lyngbya majuscule* (Harvey ex Gomont, 1892)	+	—	+	+	—	+
		2	*Lyngbya confervoides* (Agardh ex Gomont, 1893)	+	+	+	+	+	+
		3	*Oscillatoria princeps* (Vaucher ex Gomont, 1892)	+	+	+	+	+	—
2	Phormidiaceae (Anagnostidis & Komarek, 1988)	4	*Phormidium nigroviride* (Thwaites ex Gomont) Anagnostidis & Komarek, 1988	+	+	—	+	+	—
		5	*Trichodesmium thiebautii* (Gomont, 1892)	+	+	+	+	+	+
		6	*Trichodesmium erythraeum* (Ehrenberg ex Gomont, 1893)	+	+	+	+	+	+
3	Nostocaceae (Eichler, 1886)	7	*Anabaenopsis elenkinii* (Miller, 1923)	+	—	+	+	+	+
4	Schizotrichaceae (Elenkin, 1949)	8	*Schizothrix calcicola* (Agardh) Gomont ex Gomont, 1892	+	+	+	+	—	+

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	Phylum: Cyanobacteria (Stanier ex Cavalier-Smith, 2002)		**Class: Cyanophyceae (Schaffner, 1909)**	**2011–2012**			**2012–2013**		
S. No	**Family**			**PRM**	**MON**	**POM**	**PRM**	**MON**	**POM**
		9	*Schizothrix fuscescens* (Kutzing, 1843)	+	+	+	+	+	+
5	Synechococcaceae (Nageli, 1849)	*10*	*Synechococcus* sp. (Nageli, 1849)	+	+	—	—	+	+
6	Chroococcaceae (Hansgirg, 1888)	*11*	*Dactylococcopsis* sp. (Hansgirg, 1888)	+	+	+	+	+	—
Class 1, Families 6, Genera 8 and Species 11.				11	9	9	10	9	8

Phylum: Euglenozoa (Cavalier-Smith, 1981)			**Species**	**2011–2012**			**2012–2013**		
Family				PRM	MON	POM	PRM	MON	POM
	Class 1: Euglenophyceae (Schoenichen, 1925)								
1	Eutreptiaceae (Hollande, 1942)	1	*Eutreptia lanowii* (Steuer, 1904)	+	+	—	—	+	+
		2	*Eutreptia viridis* (Perty, 1852)	+	+	—	+	—	+
2	Euglenaceae (Dujardin, 1841)	3	*Euglena proxima* (Dangeard, 1901)	+	—	+	+	+	—
		4	*Euglena ascusformis* (Schiller, 1925)	+	+	+	+	+	+
Class 1, Families 2, Genera 2, Species 4				4	3	2	3	3	3

Phylum: Chlorophyta (Pascher, 1914)									
Family	Class 1: Chlorodendrophyceae (Massjuk, 2006)								
1	Chlorodendraceae (Oltmanns, 1904)	1	*Tetraselmis gracilis* (Kylin) Butcher, 1959	+	+	+	+	—	+
		2	*Tetraselmis chui* (Butcher, 1959)	+	+	+	+	+	—
	Class 2: Chlorophyceae (Wille in Warming, 1884)								
2	Dunaliellaceae (Christensen, 1967)	3	*Dunaliella tertiolecta* (Butcher, 1959)	+	+	+	+	+	+
		4	*Dunaliella salina* (Dunal) Teodoresco, 1905	+	+	+	+	+	+
3	*Chlamydomonadaceae* (Stein, 1878)	5	*Chlamydomonas reinhardtii* (Dangeard, 1888)	—	+	+	+	—	+
	Class 3: Trebouxiophyceae (Friedl, 1995)								
4	*Chlorellaceae* (Brunnthaler, 1913)	6	*Chlorella vulgaris* (Beijerinck, 1890)	+	+	+	+	+	+
5	Oocystaceae (Bohlin, 1901)	7	*Oocystis solitaria* (Wittrock, 1879)	+	+	—	+	—	—
Class 3, Families 5, Genera 5 and Species 7.				6	7	6	7	4	4

Phylum: Haptophyta (Cavalier-Smith, 1986)		Class: Prymnesiophyceae (Hibberd, 1976)						
1 Prymnesiaceae (Conrad ex O.C.Schmidt, 1931)	1	*Dicrateria inornata* (Parke, 1949)	+	+	+	+	+	+
	2	*Isochrysis galbana* (Parke, 1949)	+	+	—	+	+	+
		Class: Pavlovophyceae (Cavalier-Smith) Green & Medlin in Edvardsen *et al*., 2000						
2 Family: Pavlovaceae (Green, 1976)	3	*Diacronema lutheri* (Droop) Bendif & Veron, 2011	—	+	+	—	+	—
2 Family, 2 Class, 3 Genera and 3 Species			2	3	2	2	3	2

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