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Distribution and diversity of phytoplankton in Kadalundi estuary, southwest coast of India

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Original Article

Abstract

Phytoplankton samples collected from ten stations in the Kadalundi estuary during July 2018 to June 2019 were studied. A total of 87 species of phytoplankton belonging to 60 genera, 46 Families, 33 Orders, 8 Classes and 5 Phyla were recorded. Among them, 43 species belonged to the Phylum Bacillariophyta (Diatoms), followed by 24 species under Miozoa (Dinoflagellates), 9 species under Charophyta (green algae), 6 species under Chlorophyta (green algae) and 5 species under Cyanobacteria (Blue-green algae). Among the species, *Tripos furca* contributed maximum with 7%, followed by *Trieres chinensis* (6%), *Skeletonema costatum* and *Tripos muelleri* (5% each) and the rest of the species contributed less than 5% each. An average density of 25130 cells/m^3 was recorded from the study area with a maximum of 25% in September and a minimum of 1.7% in July. Station wise concentration varied from 9% to 11%. In all the stations, diatoms dominated and it varied from 51% at station 7 to 66% each at stations 3 and 10. Diversity studies were carried out using PRIMER software. The Pielou's evenness index, Shannon-Wiener's index and Simpson index did not show significant variation between months. The taxonomic diversity index and average taxonomic distinctness were the highest in July and lowest in March. In the dendrogram, the highest similarity in species composition and abundance were recorded between November and December and the similarity was low between July and September.

Keywords*: Phytoplankton, species distribution, abundance, diversity, Kadalundi*

Introduction

Phytoplankton play a significant role in maintaining the carbon budget of the atmosphere and seawater besides helping mitigate global warming. Inventorying of biodiversity, especially that of phytoplankton, which lies at the lowest level in the food chain, is invaluable for the sustainable utilization of the biological resources in this ecosystem. Several researchers have studied the distribution and abundance of phytoplankton in different water bodies in India (Gopinathan *et al*., 1994; Perumal *et al*., 1999; Thillai Rajasekar *et al*., 2005; Rajkumar *et al*., 2009; Subrat *et al*., 2009; Prabhahar *et al*., 2011; Babu *et al*., 2013; Dayala *et al*., 2014; Bipin *et al*., 2014; Minu *et al*., 2014; Baliarsingh *et al*., 2015; Roshith *et al*., 2018; Mayura *et al*., 2018; Jaishinimol and Tresa, 2019; Pranab *et al*., 2019). Kadalundi estuary, located in the Kadalundi-Vallikunnu Community Reserve, which lies overlapping Kozhikode and Malappuram districts in the northern part of Kerala, is known for its rich biological diversity. It is endowed with dense mangrove forests and mudflats with a large number of avian fauna, including several migratory species. Phytoplankton diversity and abundance in the Kadalundi estuary were earlier reported by Ali *et al.* (2019). Other than this, there is no information available on phytoplankton from this ecosystem based on a systematic study, covering the entire water body of the Community Reserve. Hence, studies were carried out extensively by regularly collecting samples from ten stations in the estuary covering the entire stretch of the Kadalundi-Vallikunnu Community Reserve, starting from the estuarine barmouth on the west to the Kottakadavu Bridge, which is the eastern boundary of the Reserve.

Material and methods

Phytoplankton samples were collected at a monthly interval from ten stations in the Kadalundi estuary from July 2018 to June 2019. The locations of sampling stations are given in Fig. 1

and the geographical coordinates of these stations are given in Table 1. The locations of stations concerning mangrove area, sand bar and land area are also indicated in Fig. 1. The stations were selected in a way representative of the whole Reserve.

Table 1. Geo locations of sampling stations

Stations	Coordinates
Station 1	11° 07'33.30"N, 75°49'34.26"E
Station 2	11° 07'47.70"N, 75°49'41.58"E
Station 3	11° 07'30.00"N, 75°49'49.44"E
Station 4	11° 07'50.64"N, 75°49'51.24"E
Station 5	11° 07'43.74"N, 75°49'54.78"E
Station 6	11° 07'49.98"N, 75°50'15.72"E
Station 7	11° 07'56.16"N, 75°50'10.14"E
Station 8	11° 08'1.08"N, 75°50'4.56"E
Station 9	11° 08'3.00"N, 75°49'59.40"E
Station 10	11° 08'6.42"N, 75°50'20.88"E

Fig. 1. Map showing the sampling stations.

Samples were collected using a manually operated canoe during morning hours from each station by filtering 50 l of water through a 20 μ sieve and the samples were preserved in 2% formalin (Lars and Malte, 2010). In the laboratory, each sample was allowed to settle for 24 hours and later, the supernatant was siphoned off from the top to concentrate the sample up to 10 ml. One ml of sample from this concentrate in triplicate was used for identification and counting under an inverted microscope. The total number of phytoplankton cells present in one litre of water was calculated using the formula, N=nv/V; where N is the total number of phytoplankton cells per litre of water filtered, n is the average number of phytoplankton cells in 1 ml of sample and v is the volume of plankton concentrate (ml) and V is the volume of water filtered (l).

Species wise identification of phytoplankton was done using standard publications (Subrahamanyan, 1946; Desikachary, 1959; Gopinathan, 1984; Tomas, 1997; Santhanam *et al.*, 1987; Venkataraman, 1939). Data were analysed on a geo-spatiotemporal scale for qualitative and quantitative interpretations. Conventional diversity indices like Shannon diversity index (H'), Margalef's richness index (d) and Pielous evenness index (J') were derived to compare the phytoplankton diversity between months. New diversity indices have statistical support to compare the biodiversity within different months and they were derived using the average taxonomic distinctness index (Δ+), the taxonomic diversity index (Δ) and variation in taxonomic distinctness (Lambda+). To compare the diversity between months, a dominance plot was drawn by ranking the species in decreasing order of abundance. The similarity in species composition was studied by calculating the Bray-Curtis coefficient. The similarity was taken as 100% when the two samples are similar and as 0 when the two samples are dissimilar. In hierarchical agglomerative clustering, the Bray-Curtis similarity was used to construct the map. All the univariate and multivariate analyses for the diversity profile were done using the PRIMER (v.6) software package developed by the Plymouth Marine Laboratory, UK (Clarke and Gorley, 2006).

Results and discussion

A total of 87 species of phytoplankton belonging to 60 genera, 46 families, 33 orders, eight classes and five phyla were recorded from the study area (Table 2). Phylum Bacillariophyta (Diatoms) was dominant with 43 species (34 genera, 25 families, 20 orders), followed by 24 species (13 genera, 13 families and 7 orders) under the Phylum Miozoa (Dinoflagellates), nine species (four genera, two families and two orders) under the Phylum Charophyta (green algae), six species (five genera, three families and two orders) under Chlorophyta (green algae) and five species (four genera, three families and two orders) under Cyanobacteria (Blue-green algae). Earlier, Ali *et al.* (2019) recorded 24 species of phytoplankton from the same ecosystem. This difference in the number of species recorded during different studies from the same ecosystem may be due to the difference in mesh size of the plankton collection net used and the number of stations covered for sampling. Ali *et al.* (2019) used a net having a mesh size of 48 μ while we used a 20 μ mesh net for collection from 10 stations. Ali *et al.* (2019) covered only three stations. The dominance of diatoms was recorded in both studies. Another study carried out by Perumal *et al.* (2009) recorded 85 species from the Kaduviyar estuary on the southeast coast of India, which is comparable with that of the present study. From the

Table 2. List of phytoplankton species recorded from Kadalundi estuary in the present study

Phylum Bacillariophyta	*Pleurosigma elongatum*	*Phalacroma* sp.
Amphora lineolata	*Pleurosigma normanii*	*Podolampas bipes*
Asterionellopsis glacialis	*Proboscia alata*	*Podolampas spinifera*
Asteromphalus flabellatus	*Guinardia cylindrus*	*Podolampas* sp.
Bacillaria paxillifera	*Neocalyptrella robusta*	*Prorocentrum* sp.
Bacteriastrum sp.	*Skeletonema costatum*	*Pyrophacus* sp.
Cerataulus heteroceros	*Ardissonea formosa*	
Biddulphia mobilensis	*Thalassionema nitzschioides*	Phylum Cyanobacteria
Biddulphia biddulphiana	*Thalassiosira subtilis*	*Dolichospermum affine*
Trieres chinensis	*Thalassiothrix longissima*	*Dolichospermum circinale*
Chaetoceros indicus	*Triceratium* sp.	*Nodularia* sp.
Chaetoceros peruvianus	*Triceratium alternans*	*Oscillatoria limosa*
Coscinodiscus centralis		*Trichodesmium erythraeum*
Coscinodiscus gigas	Phylum Miozoa	
Coscinodiscus marginatus	*Tripos furca*	Phylum Chlorophyta
Cyclotella striata	*Tripos fusus*	*Parapediastrum biradiatum*
Cylindrotheca closterium	*Tripos longipes*	*Pediastrum duplex*
Diploneis puella	*Tripos longirostrus*	*Monactinus simplex*
Ditylum sp.	*Tripos lunula*	*Tetradesmus lagerheimii*
Eucampia zodiacus	*Tripos minutus*	*Tetradesmus dimorphus*
Grammatophora undulata	*Tripos trichoceros*	*Volvox* sp.
Gyrosigma acuminatum	*Tripos muelleri*	
Gyrosigma sp.	*Dinophysis* sp.	Phylum Charophyta
Hemiaulus sinensis	*Dinophysis caudata*	*Cosmarium costatum*
Leptocylindrus minimus	*Gonyaulax spinifera*	*Cosmarium bioculatum*
Paralia sulcata	*Karenia brevis*	*Cosmarium baileyi*
Navicula distans	*Gymnodinium* sp.	*Cosmarium* sp.
Navicula elongata	*Noctiluca scintillans*	*Desmidium grevillei*
Nitzschia frigida	*Ornithocercus* sp.	*Desmidium swartzii*
Nitzschia longissima	*Protoperidinium biconicum*	*Staurastrum alternans*
Pseudo-nitzschia seriata	*Protoperidinium depressum*	*Staurastrum paradoxum*
Planktoniella sol	*Peridinium* sp.	*Zygnema conspicuum*

Mahanadi estuary, Subrat *et al.* (2009) recorded 77 species of phytoplankton, which is lower than that of the present study while Dayala *et al.* (2014) identified 120 species of phytoplankton from the Cochin estuary. Thus, the number of phytoplankton species differs in different ecosystems, which may be due to the variations in physicochemical characteristics of water in different water bodies and natural distribution. The relationship between phytoplankton and different environmental characteristics has been confirmed by many researchers (Devassy and Goes, 1988; Baliarsingh *et al.*, 2015; Roshith *et al.,* 2018; Dayala *et al.,* 2014; Pranab *et al.,* 2019; Murulidhar and Murthy, 2015; Bipin *et al.,* 2014).

Quantitatively, Bacillariophyta contributed a maximum (59%), followed by Miozoa (39%), Cyanobacteria (1%) and Chlorophyta and Charophyta together contributed 1%. Thus, diatoms dominated qualitatively as well as quantitatively among the phytoplankton. The dominance of diatoms among phytoplankton was recorded earlier by several researchers (Subramanyan *et al.,* 1975; Gopinathan and Rodrigo, 1991; Rajkumar *et al.*, 2009; Madhu *et al.*, 2010; Robin *et al.*, 2010; Babu *et al.*, 2013; Dayala *et al.*, 2014; Minu *et al.*, 2014; Dinesh *et al.*, 2017; Roshith *et al.*, 2018; Asha *et al.*, 2018; Ali *et al.*, 2019). Among diatoms, *Trieres chinensis* and *Skeletonema costatum* dominated (9% each), followed by *Biddulphia mobilensis* (8%), *Paralia sulcata* (5%) and other species constituted less than 5% each. Dayala *et al.* (2014) also observed *S. costatum* as the most dominant species among diatoms from Cochin estuarine system. Among all the phytoplankton species recorded during the study period, *T. furca* contributed a maximum of 7%, followed by *T. chinensis* (6%), *S. costatum* and *T. muelleri* (5% each) and the rest of the species contributed less than 5% each.

Month wise distribution and abundance

An average density of 25130 cells/m^3 was recorded from the area. The values ranged from 5150 cells/m^3 in July 2018 to 76650 cells/m^3 in September 2018. In another study, Geetha and Kondalarao (2004) reported mean densities of phytoplankton ranging from 1 to 367 nos. /l from the coastal waters of the east coast of India, while Robin *et al.* (2010) noticed very high densities of phytoplankton (330 to 5928 cells/l) from different stations along the coast of Kerala. The low density of phytoplankton observed during the present study may be due to several environmental issues prevailing in this ecosystem. The major environmental issues in this water body are plastic pollution, dumping of slaughterhouse and human wastes, coconut husk retting, water quality problems and sand mining (Ali *et al.*, 2019; Bindu and Jaypal, 2016). The sand bar formation at the barmouth restricts the water exchange/ water flow between the estuary and the adjacent Sea, affecting the nutrient exchange and phytoplankton abundance in the estuary. The month-wise distribution of phytoplankton in the study area during the present study is depicted in Fig. 2.

The minimum values of phytoplankton during July (1.7%) and August (1.8%) may be due to the turbid condition of water caused by heavy land run-off during the massive flood that occurred in this area in 2018. The rainfall received in the study area during July, August, September, October and November 2018 were 726mm, 754mm, 50mm, 256mm and 49mm respectively (IMD, 2018). After the turbulence caused by the flood, the condition in the estuary improved with nutrient-rich water and the highest concentration of phytoplankton was

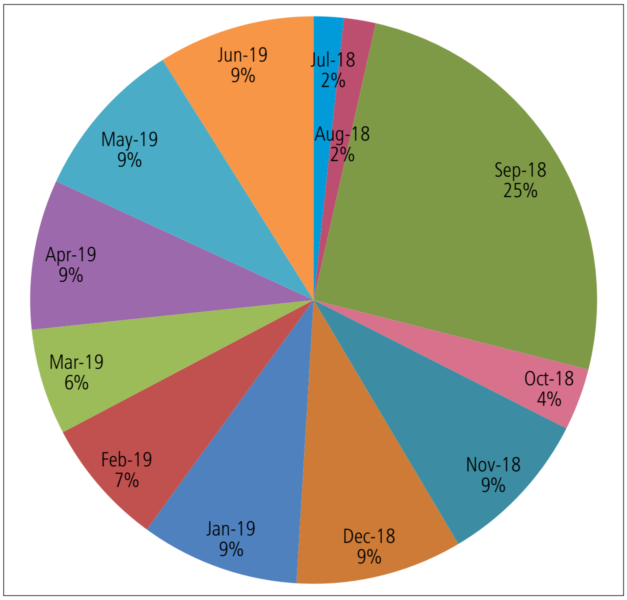

Fig. 2. Monthwise distribution of phytoplankton in Kadalundi estuary

noticed in September 2018 (25%). Again, in October 2018, with the onset of the northeast monsoon and associated changes, the density decreased and contributed only 4%. After October, there were not many variations till June and fluctuated between 6% and 9%. Ali *et al.* (2019) also noticed the minimum values of phytoplankton during July in the Kadalundi estuary.

The month-wise distribution of different phyla in the area during the study period is depicted in Fig. 3. Phylum Bacillariophyta (diatoms) dominated in all months except September 2018 and January 2019. During September and January, Miozoa (dinoflagellates) dominated and the dominance was more pronounced during September. During September, the abundance was due to the blooming of the dinoflagellates, *Tripos* spp.,

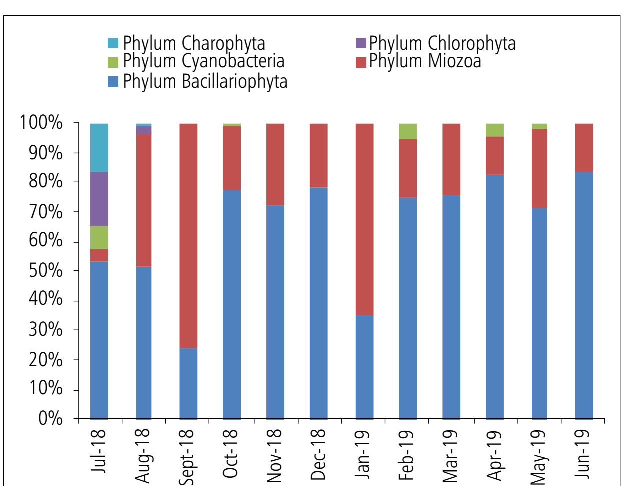

Fig. 3. Phylum-wise percentage composition of phytoplankton in different months in the study area

(*Tripos trichoceros*, *T. muelleri*, *T. furca*, *T. fusus*, *T. longipes* and *T. longirostrus*) and *Gymnodinium* spp. which together constituted 58% of the total phytoplankton recorded during September. During January also, the *Tripos furca*, *T. fusus*, *T. muelleri*, *T. longipes*, *T. lunula* and *T. longirostrus* were dominated, which formed 53% of the total phytoplankton recorded in January. Here, September and January fall during the end of the monsoon and post-monsoon seasons, respectively. Hence, the overall changes in the physicochemical characteristics of the ecosystem during the withdrawal of these seasons might have favoured the flourishing of the dinoflagellates during September and January in this estuary.

Season wise distribution showed a maximum of 38% during monsoon, followed by pre-monsoon and post-monsoon with 31% each. The highest density during monsoon in the present study was due to the maximum abundance during September 2018 as July and August showed the minimum values. The maximum cell density of phytoplankton in the monsoon was also recorded by Ajithamol *et al.* (2014) from the Manakudy estuary on the southwest coast of India. But in some other studies conducted in different ecosystems, phytoplankton showed the maximum during pre-monsoon (Asha *et al.*, 2018; Minu *et al.*, 2014; Baliarsingh *et al.*, 2015), summer (Thillai Rajasekar *et al.*, 2005; Prabhahar *et al.*, 2011; Perumal *et al.*, 2009; Dinesh *et al.*, 2017) or post-monsoon seasons (Dayala *et al.*, 2014; Mayura *et al.*, 2018). The unusual massive flood in August 2018 in this area might have brought out several changes in the water quality of this estuary which might have influenced the phytoplankton abundance and blooming in September.

Station wise distribution and abundance

The station wise density varied from 22529 cells/m^3 at station 7 to 27638 cells/m^3 at station 5 with an average of 25130 cells/m^3 in the study area (Fig. 4). Among the total phytoplankton, the percentage contribution by different stations ranged from 9% to 11% with the highest by stations 1, 3, 5 and 6 (11% each), followed by stations 2 and 9 (10% each) and the minimum of 9% contribution was made by stations 4, 7, 8 and 10 each. Thus, there was not much variation in phytoplankton density between stations and hence it is assumed that there was thorough mixing of water throughout the estuary. The species under the Phylum Charophyta belong to the group of green algae which thrive mainly in freshwater were observed only during the monsoon months of July and August during the present study and were found in all stations starting from station 10 (located upstream) up to station 1 (located at barmouth) which further ensures proper mixing in this estuarine environment.

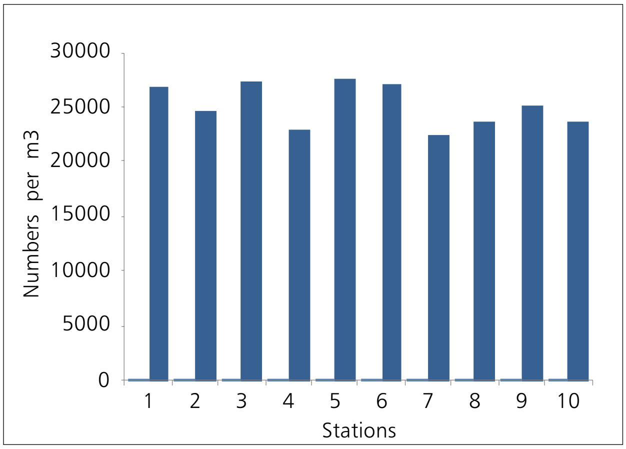

Fig. 4. Station wise distribution of phytoplankton in the study area

The station wise distribution of different phyla in the study area during the present study is depicted in Fig. 5. Phylum Bacillariophyta dominated in all stations during the study period and the percentage contribution varied from 51 at station 7 to 66 at stations 3 and 10. At stations 3 and 10, *S. costatum* contributed the maximum (9% at station 3 and 10% at station 10) among the total phytoplankton of the respective stations. The dinoflagellates (Phylum Miozoa) ranged from 29% at station 10 to 47% at station 8 and this abundance at station 8 was due to the highest contribution (11%) of *T. furca* among the total phytoplankton at this station.

Diversity

The diversity analysis to discern the species status for different months was carried out and the different indices along with some attributes of community structure are given in Table 3. The Margalef's richness index (d) varied from 6.09 in March to 9.69 in November. There was no particular trend in species richness and the values fluctuated between months. The

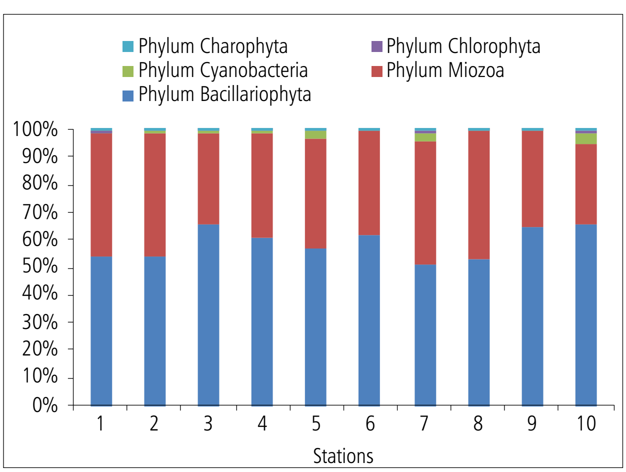

Fig. 5. Phylum-wise percentage composition of phytoplankton in different stations during the study period

Table 3. Diversity indices of phytoplankton in different months in the study area

Month	S	d	J'	H' (loge)	1-Lambda'	Delta	Delta+	Lambda+
Jul-2018	40	8.03	1.00	3.67	0.98	89.46	91.45	312.28
Aug-18	45	8.94	0.99	3.77	0.98	85.78	88.32	315.24
Sep-18	37	6.69	0.98	3.55	0.97	81.48	85.24	365.92
Oct-18	36	7.08	0.99	3.56	0.98	82.38	84.44	370.02
Nov-18	54	9.69	0.99	3.96	0.98	84.07	85.38	308.32
Dec-18	48	8.70	0.99	3.85	0.98	82.82	84.57	327.95
Jan-2019	43	7.99	0.99	3.72	0.98	81.48	84.39	386.80
Feb-19	43	7.96	1.00	3.74	0.98	83.30	85.09	318.38
Mar-19	31	6.09	0.99	3.41	0.97	80.44	83.15	472.49
Apr-19	41	7.75	0.99	3.66	0.98	83.08	85.39	325.39
May-19	44	8.13	0.99	3.75	0.98	83.31	85.39	310.23
Jun-19	44	8.11	0.99	3.75	0.98	81.81	83.76	322.82

Pielou's evenness index (J') which expresses the evenness of distribution of individuals among the different species did not show much variation and the values ranged from 0.98 to 1.00. The Shannon–Wiener's index (H') which is the most commonly used diversity measure varied from 3.41 to 3.96 indicating no considerable variation in species composition between months. However, the maximum species diversity index was noticed during the post-monsoon season which agrees with the observations of Baliarsingh *et al.* (2015) from coastal waters off Rushikulya estuary on the east coast of India. The Simpson index (1-Lambda') provided information on the dominance of species and it varied from 0.97 to 0.98.

The newly introduced indices like taxonomic diversity index (Delta), average taxonomic distinctness index (Delta+) and variation in taxonomic distinctness (Lambda+) have the additional statistical framework for comparison of samples. The taxonomic diversity index was the maximum during July (89.46) and minimum in March (80.44). The average taxonomic distinctness was also the highest in July (91.45) and lowest in March (83.15). This indicates that the taxonomic distance between species was the maximum during July and minimum during March pointing out the availability of more closely related species during March compared to that of other months. The variation in taxonomic distinctness (Lambda+) varied between 308.32 during November and 472.49 in March, which indicates the divergent range in taxonomic distances between pairs of species in different months. Hence, the unevenness of the taxonomic tree structure was greater during March when compared to that of other months and the same remained the least during November. The change in phytoplankton density and species diversity in different months/seasons might be significant to varying water characteristics, which is confirmed by Dayala *et al.* (2014).

The dominance plot or K-dominance curve was constructed on the data sets to determine the biodiversity pattern (Fig. 6). The curve for November which lies on the lower side extends further and rises slowly due to the presence of more species. As the percentage contribution of each species is added, the curve extends horizontally, before reaching the cumulative 100%.

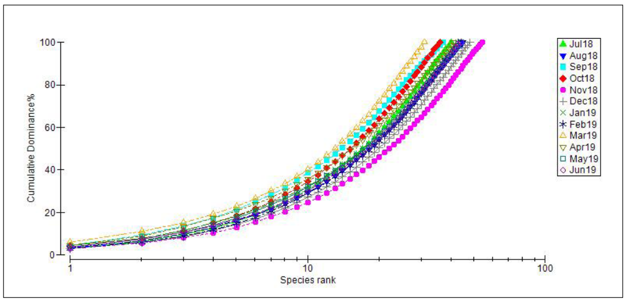

Fig. 6. Dominance plot of phytoplankton in Kadalundi estuary during the study period

The dendrogram shows the results of the hierarchical clustering by using the group average linking between months during the present study (Fig. 7). In this clustering, the entities are sequentially linked together according to their similarity producing a two-dimensional hierarchical structure. It revealed the separate grouping similarity in species composition and abundance of different months. In the present study, different clusters can be noticed in Fig. 7 and the maximum similarity was found between November and December with 85.12%. The minimum similarity was between July and September.

The present work is based on detailed studies on the assessment of phytoplankton in the Kadalundi-Vallikunnu estuarine system. It revealed the qualitative, quantitative and biodiversity aspects of phytoplankton from a spatiotemporal perspective. The turmoil of the massive flood that occurred in August 2018 and associated changes in water quality characteristics might have influenced the species composition and abundance of phytoplankton in this ecosystem during the study period. According to Robin *et al.* (2010), phytoplankton abundance, community structure and biomass could be controlled by spatial variability of nutrients and species-specific association concerning differences in the hydrographical conditions and anthropogenic inputs from point sources, which may support the present study also. Since phytoplankton acts as the primary link in the food chain of any aquatic ecosystem, this information on the species wise availability in different months can be used to correlate with the fishery in this ecosystem. It is noteworthy to mention here that the Potential Fishing Zone is an attribute of pigment characteristic of phytoplankton measured through remote sensing technique. Thus, the study on phytoplankton is essential and more concerted studies encompassing environmental variables have to be carried out in the Kadalundi estuary to arrive at more meaningful conclusions.

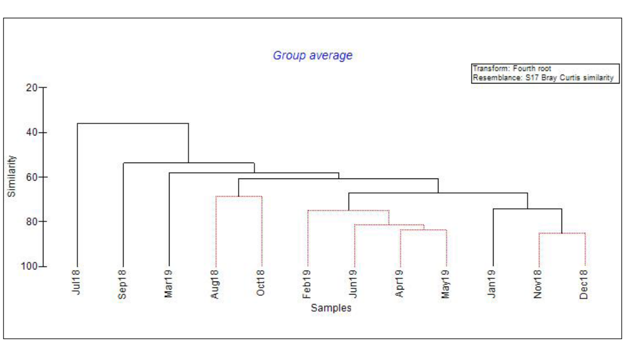

Fig. 7. Dendrogram of phytoplankton in different months in the study area

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