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Phytoplankton diversity in relation to the environment variables in the lagoon waters of Kavaratti Island, Lakshadweep Sea

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ABSTRACT
The present investigation is made on the Physico-chemical parameters and their influence on the diversity, community structure and abundance of phytoplankton in the Kavaratti Island of Lakshadweep Sea. Required water samples from the lagoon area were collected on monthly basis from January 2018 to December 2018. Statistical analyses were performed among the physico-chemical parameters such as temperature, pH, salinity, dissolved oxygen (DO), nitrate (NO_3), nitrite (NO_2), reactive silicate (RS), and inorganic phosphate (IP). The significant ($P < 0.05$) variation among seasons as well as a high influence of these parameters was observed on phytoplankton productivity. Totally, 47 species were identified, belonging to three different classes, Bacillariophyceae (72%), Dinophyceae (26%) and Cyanophyceae (2%). Throughout the study period, the occurrence of most dominant species was observed from class Bacillariophyceae. The phytoplankton species also showed significant changes according to seasonal variations as well as the nutrient availability. Phytoplankton attained their maximum population density during Summer Winter; whereas minimum population was observed during summer monsoon. Coscinodiscus granii, Coscinodiscus eccentricus, Biddulphia mobiliensis, Biddulphia sinensis, Pleurosigmae longatum, Rhizosolenia crassispina, Rhizosolenia cylindrus, Ceratium breve and Protoperidinium oceanicum were the most prevalent diatoms and dinoflagellates encountered in Kavaratti Island. The population density of phytoplankton ranged from 11260 to 24580 cells L^{-1}. The Canonical Correspondence Analysis (CCA) was used, to find out the seasonal relationship between phytoplankton and physicochemical parameters. The executed CCA results revealed that temperature, salinity, silicate, DO and IP have a higher influence on phytoplankton abundance. The study on phytoplankton diversity could be useful to understand the potential fishing season as well as location for the sustainable utilization fishery resource in the Kavaratti Island, Lakshadweep Sea
Keywords: Temperature, Salinity, Dissolved Oxygen, Phytoplankton

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INTRODUCTION

Coral lagoons are considered to be the most productive biologically diverse and complex ecosystems of the marine environment. Hence, they are referred to as the marine tropical rainforest (1, 2, 30, 41). Recently, the influence of environmental variables on planktonic communities has been the topic of ecological studies which has specifically focused on planktonic species diversity and distribution (5, 7, 28, 61). Phytoplankton is the primary source of a food chain, which contributes to the major fishery resource around the world. They are responsible for the biological community and regulate the food web in the aquatic ecosystem (19-20). Also phytoplankton is responsible for maintenance of oxygen in the water during photosynthesis (32). They play a crucial role in mitigating the climate change and global warming as they effectively fix the atmospheric CO_2 for the production of energy at base level (52). Phytoplankton community structure, composition and species diversity in aquatic ecosystem are determined by several physico-chemical parameters (Sin et al., 1999). Spatial and temporal variations in phytoplankton distribution are widely affected by the changing hydro-chemical and physical factors such as temperature, salinity, pH, nitrate, nitrite, ammonia, silicate and IP. The influence of these factors on phytoplankton community alters species composition and their diversity in the marine ecosystem (17, 34). Generally, shallow water and estuaries show seasonal fluctuations among variables depending on the regional rainfall, tidal inflow and various abiotic and biotic processes, which play a substantial role in nutrient cycle (11).

The relationship between phytoplankton and nutrients is highly dynamic and has always been the major focus among researchers to explicate experimental ecology (9). Recently, various anthropogenic activities have increased, which in turn enhance the nutrient concentration thus, leads to high productivity (bloom) in some locations of the coastal environment (44). Availability of nutrient plays an important role in phytoplankton diversity that reflects the environmental condition of the ecosystem (16, 49, 57). These dramatic changes in physico-chemical parameters exhibit differential effect in distribution and abundance of many phytoplankton species, ultimately indicating the quality of water (54). Phytoplankton species can be very sensitive to slight modification in its environment and hence, it provides good insight about water quality before it reaches to extreme visible condition like eutrophication (8). Monitoring the seasonal changes in phytoplankton diversity and its community structure provides the better understanding about the state of coastal waters and they are considered as one of the most important biological elements that provide the ecological status of the sea (6, 32). Significant work has been done in relation to seasonal variation on phytoplankton species composition in the different coastal ecosystem of India (37, 50, 56, 58).

Kavaratti lagoon of Lakshadweep archipelago is endowed with higher dynamics of zooplankton diversity and composition, as well as the higher rate of primary productivity and which depends up on the depth and area of this lagoon (25). Lakshadweep archipelago of India consists of several small oceanic islands and coral lagoons between latitude 10–12◦N and longitude 72–74◦E in the Arabian Sea. Atolls are another highly productive major type of coral reef ecosystem and characterized with prominent canter lagoon which shows distinctive peculiarities compared to the surrounding oceans in their autotrophic abundance (23, 38). The primary production rate of macro algae and Sea grass in the lagoon of these islands was several times higher than that of phytoplankton productivity (15). The present study is made to understanding the seasonal change in environmental parameters and their influence on phytoplankton productivity. This will also aid in assessing the water quality in the studied locations. Hence, the present study aims to find out the seasonal variation in phytoplankton diversity, composition and their abundance in response to various environmental parameters.

MATERIAL AND METHODS

Description of the study area

The Lakshadweep archipelago located in the Arabian Sea comprise a group of 11 inhabited Islands, 17 uninhabited Islands, 6 submerged sand banks and 3 coral reefs environments situated between 8 - 12°N latitude and 71°45 -73°45 E longitude. Kavaratti island is the capital of Union Territory of Lakshadweep, a perfect atoll based island, located along latitude 10°33' N and longitude 72°36'E. The lagoon of the atoll is oriented in north to south direction and the coral reef on the east and west (Fig. 1). It is approximately 4,500 m long and 1200 m wide with an average depth of 2 m.

Data collection

Estimation of nutrients

Niskin water sampler (1 litter capacity) was used to collect surface water during 2018 at Kavaratti lagoon, the Lakshadweep. Collected samples were immediately kept in icebox and transported to the laboratory for the further analyses. The seawater samples were filtered using a Millipore filtering system through whatman membrane filter paper of 0.45 µ porosity. The quantity of the dissolved nutrients of Ammonia-N, Nitrite-N, Nitrate-N, Phosphate-P, Silicate-Sio_3 present in the filtered water samples were determined, following the standard methods as described by (24).

Enumeration of phytoplankton

Phytoplankton samples were collected from the surface water column at monthly intervals by towing a phytoplankton net (0.35 m mouth diameter) made of bolting silk (No.30, mesh size 48 µm) attached with a calibrated digital flow meter (General Oceanics Inc, Florida). Thereafter phytoplankton samples were preserved in 4 %formalin in filtered seawater for the qualitative analyses and species level identification. For the quantitative analysis, the settling method as described by (60) was followed. The cells count and species were identified based on standard taxonomic keys according to (62) and also as per the standard methods given in (14, 2). Before the microscopic analyses, samples were concentrated to 5 to10 ml by siphoning out the top layer with a tube covered with a 10 µm Nytex filter on one end. The required sample concentrates were transferred to a 1 ml capacity Sedgwick-Rafter counter and counted using a Nikon Binocular Dissection Microscope (Model: Nikon SMZ 1500) at 200× magnification. The total number of phytoplankton present in the collected sample was calculated by the following formula.

$N (n \times v / V) \times 1000$

where N is the total number of phytoplankton cells per litre of water filtered, n is an average number of phytoplankton in 1 ml of sample, v is the volume of phytoplankton concentrates, V is the volume of total water filtered. Species diversity index (53), species richness (22) and evenness index (42) of phytoplankton were calculated by using the following respective formulae.

a. Shannon-Wiener diversity index H′ = s i=1 Pi log2 Pi where, S = total number of species, Pi = ni/N for the ith species, ni = number of individuals of a species in sample, N = total number of individuals of all species in sample. H′ = species diversity in bits of information per individual, where the value of H′ is dependent upon the number of species present, their relative proportions, sample size (N), and the logarithmic base. The choice of the base of logarithm is very important. In the present study, log2 has been used as per the practice in India.

b. Species richness (SR) = (S − 1)/log N where, S = number of species representing a particular sample, N = natural logarithm of the total number of individuals of all the species within the sample.

c. Species evenness or equality J ′ = H′ /log2S where, J′ = species evenness, H′ = species diversity in bits of information per individual, (observed species diversity). S = total number of species.

Estimation of Chlorophyll 'a'

The Chl-a concentration was calculated by adopting the following formula as described by (45):

Pigment (mg/m3) = C/V

where V = volume of seawater filtered in 1 l. C = value obtained from the following

equation: C(Chl − a) = 11.64 E 663 − 2.16 E 645 + 0.10 E 630

In order to eliminate the turbidity, the OD values of the acetone extracts (C value) were subtracted from absorbance at 750 nm.

Estimation of primary productivity

The total primary productivity of the water column was estimated by the light and dark bottle method explained by (59). It was expressed in mg C/m^2/ day and calculated by the following formula:

$$Grossphotosynthesis\ (mgC/m3/hr)\ =\ 605\ \times f\ [VLB - VDB]\ /N \times PQ$$

605 = The factor value used to convert oxygen value into carbon value. Where f = Dissolved oxygen (ml)/the quantity of sodium thiosulphate (ml) used in the titration. VLB = Volume of Light Bottle. VDB = Volume of Dark Bottle. N = incubation period in hours. PQ = photosynthetic Quotient = 1.25

Statistical analyses

To assess the relationship between phytoplankton population abundance and with various inorganic nutrients, Pearson's correlation matrix was calculated by using statistical package SPSS (version 16.0). Two-way analysis of variance (ANOVA) for phytoplankton abundance for stations 1–3 was also calculated to understand the significance of differences of biodiversity indexes between temporal and spatial variations.

RESULTS

Environmental Variables

The water temperature at Kavaratti Island is presented in table 1.Temperature is an important factor which plays a major role in marine ecosystem and responsible for the changes in crucial factors of dissolved gases, productivity, salinity and alkalinity in the sea water. In Kavaratti coast, the water temperature was found to be varied between 24 ºC and 31ºC. The minimum was found during November 2019 (winter monsoon), while the maximum was found during March 2019(summer winter). The assessed salinity level of the Kavaratti coast was found to be varied between 30 and 34psu and the minimum values in October (summer winter) and maximum values in April (winter monsoon) 2019. The pH value was found to be above 8 and the values were varied between 8.1 and 8.4. The maximum was observed during March (summer winter) while the minimum was observed during November 2019(winter monsoon). The amount of dissolved oxygen was found to be varied between 5.9 and 6.9 mg/l. The maximum dissolved oxygen was observed during October 2019 (winter monsoon) while the minimum was observed during February2019 (winter). The TSS value was found to be varied between 3100 and 5200 mg/l. The maximum was observed during November 2019 (winter monsoon), while the minimum was observed during April 2019 (summer winter).

In Kavaratti coast, the nitrate concentration was found to be varied between 6.42 and 9.52µmol/l. The minimum level of nitrate was recorded during July' 2019 (Summer Monsoon), while the maximum level was recorded during October 2019 (Winter Monsoon). The ammonia concentration was found to be varied between 0.04 and 0.18 µmol/l. The minimum value was recorded during December 2019 (Winter Monsoon), while maximum value was recorded during April 2019 (Summer Monsoon). The total nitrogen concentration was found to be varied between 14.64 and 29.57 µmol/l. The minimum value was recorded during April 2019 (Summer Winter), while the maximum value was recorded during November 2019 (Winter Monsoon).

The total phosphorous concentration was found to be varied between 1.36 and 1.89 µmol/l (Fig. 2). The lower value was recorded during July 2019 (Summer Monsson), while the higher value was recorded during October 2019 (Winter Monsoon). The silicate concentration was found to be varied between 34.56 and 62.84 µmol/l. The minimum value was recorded during May 2019 (Summer Winter) and the maximum value was recorded during November 2019 (Winter Monsoon). N/P ratio: The ratio of

Nitrogen-N to Phosphorus-P was observed to be in the range of9.81 to 18.06 and showing seasonal similarity with nutrients.

Species abundance and composition

In Kavaratti station, the phytoplankton abundance ranged from 11260 to 24580 cells/l with minimum and maximum values in July (SM) and April (SW) 2019 respectively (Fig. 2). Among the 39 species of phytoplankton recorded (Table 2), 27 species were found with diatoms belonging to the family Bacillariophyceae with 71%, 10 were found with dinoflagellates (26%) and 1 species of Cyanophyceae (3 %) were observed (Fig. 3). The species of *Coscinodiscus granii, Coscinodiscus eccentricus, Biddulphia mobiliensis, Biddulphia sinensis, Pleurosigma elongatum, Rhizosolenia crassispina, Rhizosolenia cylindrus* were the dominant among the diatom group. *Ceratium breve* and, *Protoperidinium oceanicum* were the dominant species among the dinoflagellates.

Chl- 'a' and primary production

The level of Chl-'a' concentration revealed a significant seasonal variation (Fig. 4) and the values were found to have varied from 0.016 to 0.125 mg/m^{3}with highest during summer winter and lowest during summer monsoon. The variation of primary productivity levels was observed from 0.72 to 3.35 mg, C/m^2 /day, with maximum and minimum during summer winter and winter monsoon respectively (Fig. 5).

Diversity indices

The species diversity indices Shannon–Wiener diversity (H′), species richness index (J') and evenness index (J′) were considered as explanatory variables of dynamics of phytoplankton levels which are interrelated with observed indices (Table 3). The H′ index varied between 3.075 and 3.412. The minimum and maximum levels were recorded during July (SW) and February (W) respectively. The species richness ranged from 3.131 (July (SW)) to 4.255 (February (W)). The species evenness varied from 0.9665 to 0.9959 with minimum and maximum values during June, (SM) and April (SW) respectively.

Statistical analyses

Correlation coefficient

The phytoplankton abundance exhibited positive correlation with Chl-a, (Table 4).The biological factors such as Chl-a, primary productivity and phytoplankton abundance were found have significant negative correlation with TSS, ammonia, total nitrogen and total phosphate. Ammonia exhibited significant negative correlation with phytoplankton at $P < 0.01$ level (Table 4).

Canonical Correspondence Analysis of phytoplankton and environmental parameters

Important environmental variables responsible for the phytoplankton community changes were identified with CCA are represented in Fig. 6. During summer axis 1 and 2 explained 71% of the variabilityin the species environment bi-plot (Fig. 6). DO, TP, and nitrate had positive correlation in axis 1 and highly associated with *Triposfurca, Protoperidinium pedunculatum, Dinophysis miles, Dinophysis caudate, Synedra nitzschioides, Protoperidinium oceanicum, Mastogloia rostrate, Asteromphalus flabellatus, Asterionella japonica,* and *Pleurosigma* maximum canonical values (3.177, 1.967, 1.257, 1.436, 1.386, 1.187, 1.167, 1.025, and 1.019 respectively).

DISCUSSION

The dynamics of phytoplankton are the net result of a complex interplay of physical, chemical and biological processes (10). In the last few decades, there has been much interest to study different factors influencing the development of phytoplankton communities, primarily in relation to physico-chemical factors (40, 26, 18). It is because of the succession pattern of phytoplankton communities in relation to nutrient variation which helps in understanding the ecosystem functioning as suggested by (35) and (7). In the present investigation, a remarkable biodiversity changes could be observed with seasonal time scales. It was also noticed that, the dynamics of hydrological conditions combined with hydrographical and nutrient dynamics controlling the biological productivity of the Kavaratti. The phytoplankton abundance is not only controlled by environmental conditions but also by the predators of the food web.

The correlation analyses showed significant negative correlation of phytoplankton population with certain nutrient concentrations. It is a common phenomenon that nutrient availability largely determines the diversity of phytoplankton. Fluctuations of primary productivity and nutrients are controlling the dynamics of phytoplankton (4).From the statistical perspective, it could be understood that, ammonia would function as the limiting nutrient than nitrate. Phosphate play vital role in the phytoplankton growth. Ammonia and silicate concentration are the essential for development and growth of the diatoms. Similarly, changes in physico-chemical parameters of the water column due to various factors that significantly influence the phytoplankton population (10). Whenever the diatom population flourished, a drop in the nutrient levels could be observed in the surface waters. The fluctuation in nutrient concentration was mainly due to influx of fresh water from the land during monsoon rainfall but this is absent in the atoll based island ecosystem.

As far as Lakshadweep Sea is concerned, the nutrients are influenced by the localized current and have control over the phytoplankton species diversity (39, 46, 31) which is coincided with the observations of the present study. Since this water current during the monsoon enhances the nutrient concentration, the productivity also found to have increased during this period.

N/P ratio

In aquatic systems, nitrogen or phosphorus is the most common limiting nutrient since other minerals required for growth may be present in abundance (49, 64). Generally, nitrogen (N) limitation prevails in most of the marine ecosystems (21, 27). Changes in nutrient supply are often reflected in their ratios (65). Hence, the elemental ratios (nitrogen to phosphate) of coastal environment can be used as indicators of the status of nutrient loading or to predict productivity (13). The calculated N: P ratio could be used to predict the phytoplankton abundance and assemblages and to understand of the ecology of the phytoplankton (Jane 2007). Generally, if the ratio of nitrogen and phosphorous exceeds 15:1, the available phosphorous is said to limit organic carbon production. If the N/P ratio value below 15:1, then nitrogen is the limiting nutrient (47). Based on the N/P ratio obtained from the present study, N/P ratio was remained above 15 in Kavaratti. According to the N/P ratio of the present study, phosphorous was the limiting nutrient in Island. Generally, ammonia is known to suppress the uptake of nitrate and other nutrients by phytoplankton when its concentration exceeds 1 µg at N/l (36). Further, it was unique to observe that ammonia was remained above 1 µg at N/l in majority cases. The correlation study revealed that the nitrogenous nutrients were found to be limiting factor for the phytoplankton productivity.

Since, the inorganic nutrients are the primary foodstuff of phytoplankton, high abundance of phytoplankton causes low nutrients level in the water column and vice versa. Similar values were reported from the Kavaratti Island (48) and Parangipettai coast (63). It is a common phenomenon that the diatoms are playing major role on contribution of primary productions in coastal waters, which subsequently being transferred through copepods to fish (34). *Biddulphia mobiliensis, Biddulphia rhombus, Chaetoceros densus, Coscinodiscus ecentricus* and *Skeletonema* sp were found to be the dominant species among the diatom group. Generally, diatom communities are influenced by environmental perturbations with monsoonal system that influence the niche opportunities of species (12). The Shannon diversity index (H') indicated the lowest phytoplankton composition stability during the monsoon season, whereas the highest heterogeneity was observed during summer. The species richness index (SR) was found higher during summer as reported elsewhere with a maximal species richness of the phytoplankton community (42). Maximum species evenness was recorded during winter monsoon season as reported by (43).

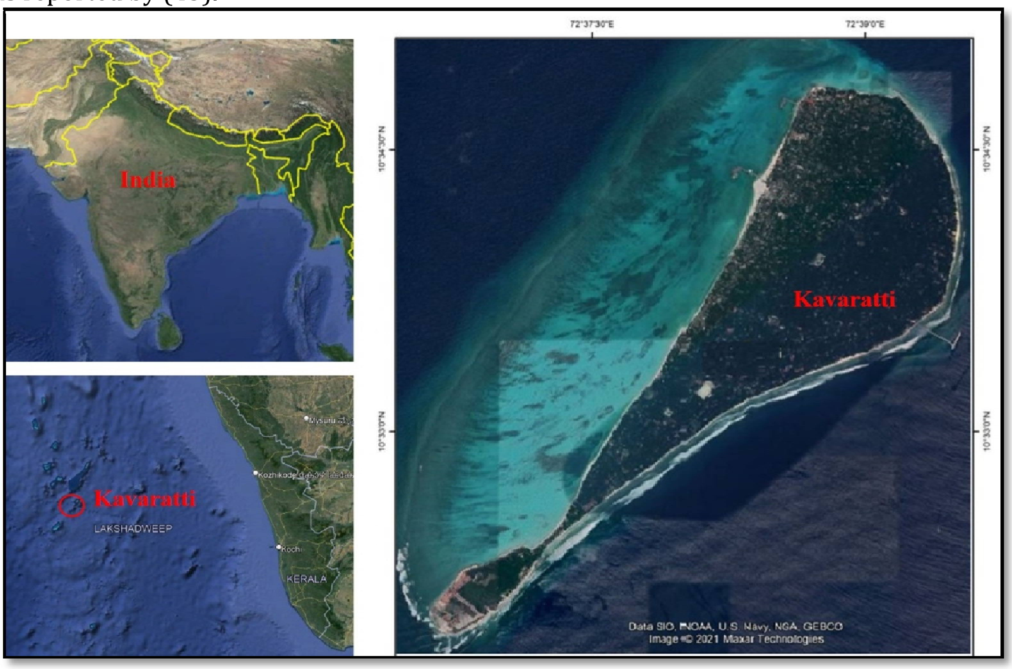

Fig.1 Map showing the study area in the Lakshadweep Sea

Table.1Variation of physiochemical parameters in Kavaratti Lagoon

	WINTER		SUMMER WINTER			SUMMER MONSOON				WINTER MONSOON		
	JANUARY	FEBURAY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
TEMPERATURE	28	27	31	30	29	28	30	29	27	25	24	25
SALINITY	33	33	34	34	33	32	32	33	32	30	31	31
PH	8.2	8.3	8.4	8.3	8.3	8.2	8.2	8.3	8.3	8.2	8.1	8.2
DO	6.5	5.9	6.1	6.5	6.1	6.5	6.4	6.3	6.3	6.9	6.7	6.8
TSS	3400	3200	4200	3100	3400	4400	5100	4800	4500	4800	5200	4200
NO3	7.56	7.46	8.23	8.46	7.56	8.42	6.42	7.48	8.20	9.52	8.74	7.95
NH_3	0.06	0.06	0.05	0.04	0.06	0.09	0.06	0.08	0.07	0.08	0.15	0.18
TN	18.62	21.59	17.31	14.64	16.48	22.59	23.79	19.41	18.42	27.61	29.57	24.64
TP	1.80	1.63	1.43	1.49	1.50	1.76	1.36	1.43	1.84	1.89	1.64	1.74
SILICATE	46.27	51.62	48.97	47.18	34.56	48.86	53.93	56.13	46.21	51.74	62.84	61.05

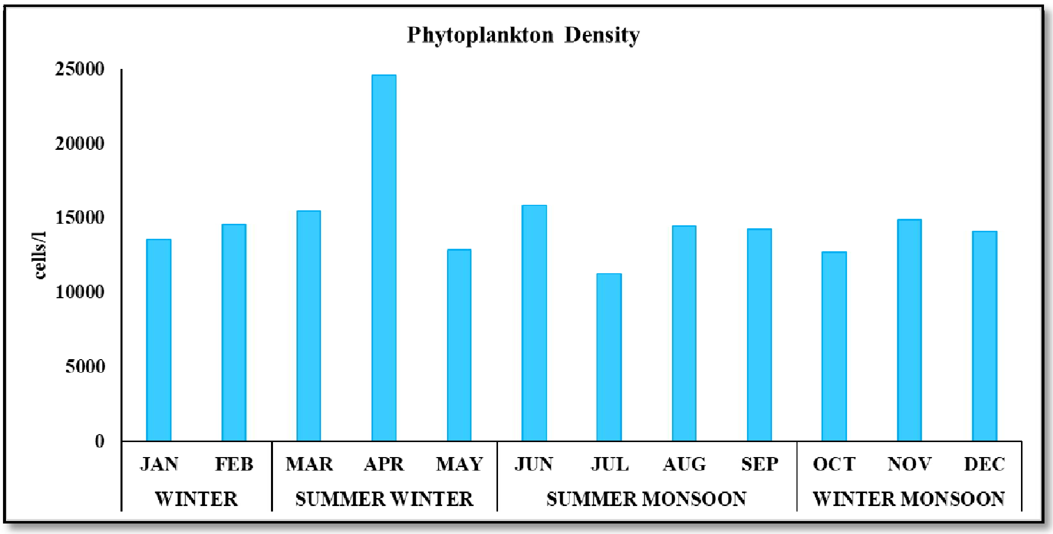

Fig.2. Seasonal variation of environmental indicators of Phytoplankton density

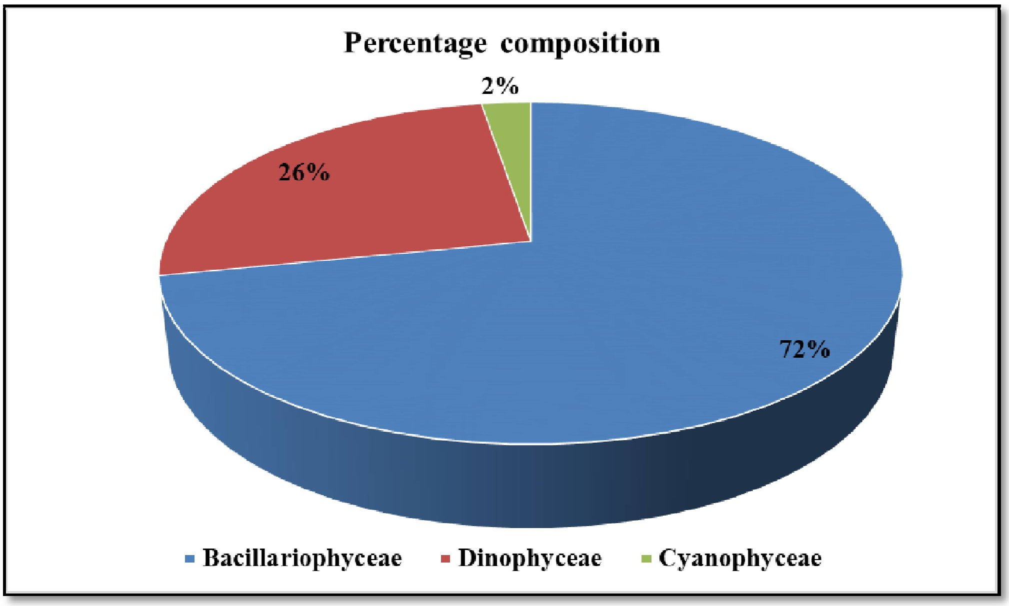

Fig.3. Percentage composition of phytoplankton community

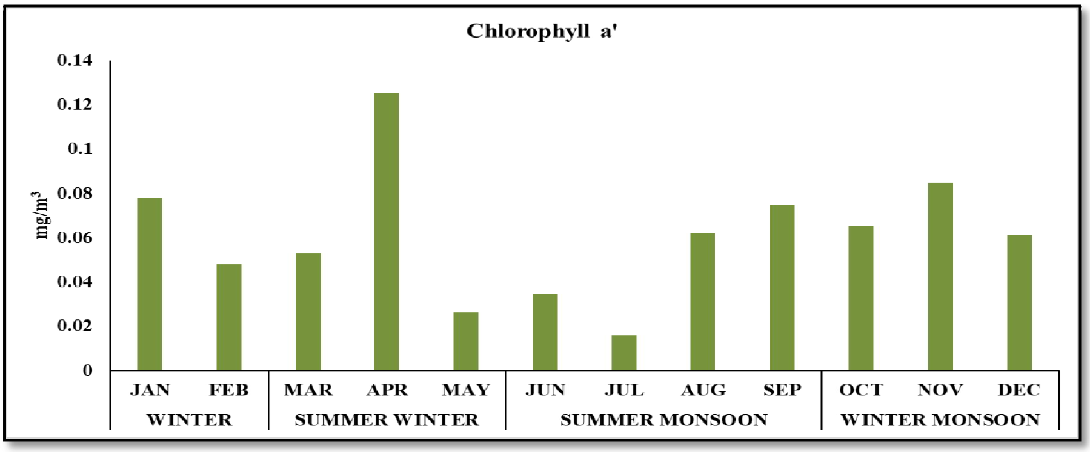

Fig.4 Seasonal variation of environmental indicators of Chlorophyll-a

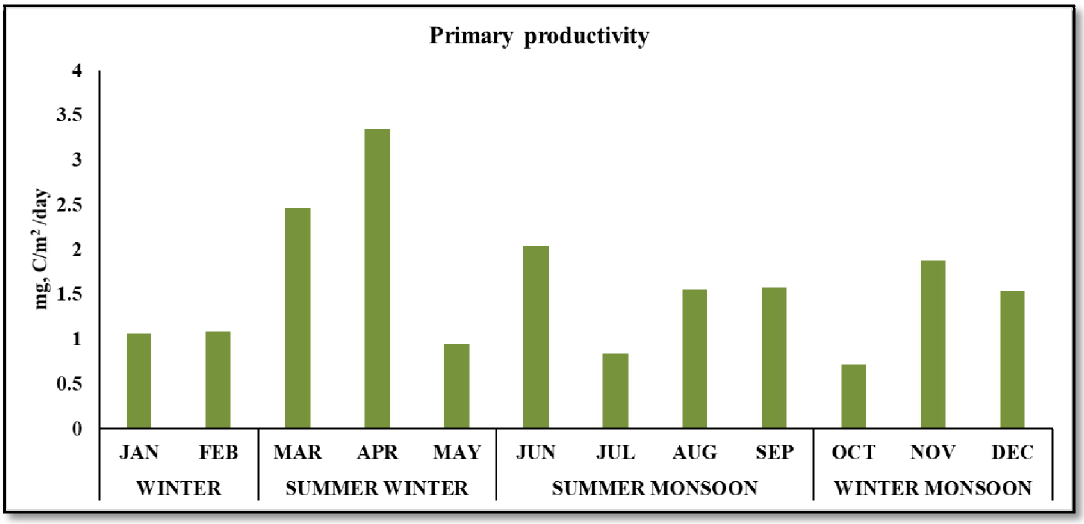

Fig.5 Seasonal variation of environmental indicators of Primary productivity

Table.2. Seasonal Variation of diversity indices in Kavaratti Lagoon

	Sample	S	N	d	J'	H'(loge)
WINTER	JAN	31	1358	4.159	0.99	3.4
	FEB	32	1458	4.255	0.9844	3.412
SUMMER WINTER	MAR	30	1547	3.949	0.99	3.367
	APR	33	2458	4.099	0.9665	3.379
	MAY	26	1285	3.492	0.9911	3.229
SUMMER MONSOON	JUN	29	1585	3.8	0.9959	3.354
	JUL	23	1126	3.131	0.9806	3.075
	AUG	27	1445	3.573	0.9858	3.249
	SEP	25	1427	3.304	0.9952	3.203
WINTER MONSOON	OCT	25	1270	3.358	0.9812	3.158
	NOV	28	1486	3.697	0.9867	3.288
	DEC	28	1411	3.723	0.9823	3.273

Table. 3 Pearson's correlations coefficient between physicochemical parameters and phytoplankton diversity

	TEMP	*SALI*	*PH*	*DO*	*TSS*	*NO_3*	*NH_3*	*TN*	*TP*	*SiO_3*	*Density*	*d*	*J'*	*H'*	*PP*	*Chl a'*
TEMP	1															
SALI	**0.831**	1														
PH	**0.693**	0.741	1													
DO	-0.604	-0.735	-0.733	1												
TSS	-0.313	-0.629	-0.450	0.434	1											
NO_3	-0.497	-0.403	-0.162	0.521	0.124	1										
NH_3	-0.758	-0.667	-0.624	0.601	0.439	0.211	1									
TN	-0.776	-0.878	-0.792	0.612	0.681	0.297	0.691	1								
TP	-0.706	-0.599	-0.409	0.494	0.007	0.569	0.312	0.356	1							
SiO_3	-0.522	-0.490	-0.516	0.501	0.596	0.108	0.722	0.719	0.034	1						
Density	0.264	0.484	0.259	0.023	-0.461	0.321	-0.223	-0.454	-0.159	-0.075	1					
d	0.105	0.536	0.208	-0.255	-0.710	0.076	-0.138	-0.318	0.026	-0.037	0.527	1				
J'	-0.095	-0.096	0.021	-0.272	0.205	-0.046	0.082	0.036	0.315	-0.234	-0.573	-0.156	1			
H'	0.107	0.546	0.244	-0.280	-0.663	0.155	-0.118	-0.361	0.082	-0.094	0.541	0.969	0.020	1		
PP	0.326	0.490	0.304	0.426	-0.213	0.316	-0.092	-0.398	-0.261	0.050	0.893	0.436	-0.335	0.513	1	
Chl a'	-0.182	0.131	-0.026	0.341	-0.245	0.511	0.022	-0.166	0.220	0.167	0.744	0.415	-0.500	0.406	0.612	1

Correlation is significant at the 0.05 level.
Abbreviations: Temp: Temperature, Sali: Salinity, DO: Dissolved Oxygen, NO_3: Nitrate, NH_3: Ammonia, TN: Total nitrogen, TP: Total phosphorus, SiO_3: Silicate, PP: primary productivity, Chla: Chlorophyll-a.

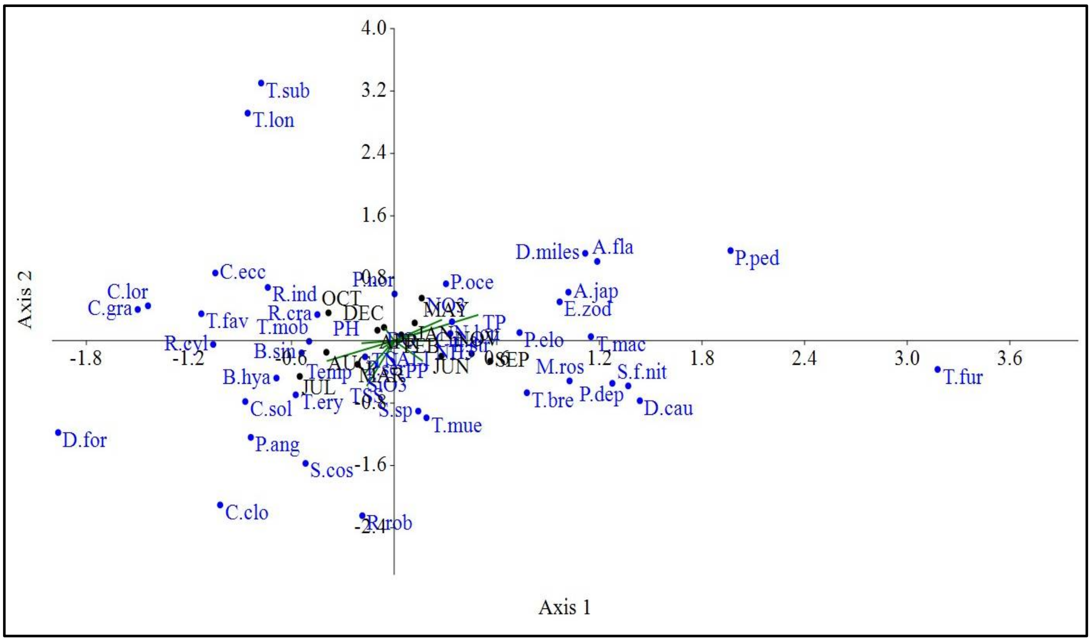

Figure 6. CCA biplot showing the seasonal variations between phytoplankton species and environmental parameters. Environmental variables are depicted by long arrows and species are given in code words. The correlation between species and environmental variables are explained by the length of the arrows

CONCLUSION

Phytoplankton diversity and their abundance showed a clear positive as well as negative relationship with physico-chemical parameters. Localized currents were found to be the main source of nutrients which help for the primary productivity in the Lakshadweep waters. Among the phytoplankton diversity, diatom species was recorded higher than the dinoflagellates. It was also found that the phosphate nutrient was insignificant in making the phytoplankton abundance in higher level in the Lakshadweep Sea as it was showing negative correlation and acting as a limiting factor. However, the present study substantiated that the diatom population flourished even if there was a drop in the nutrient levels especially phosphates but in contrast, the silicate is sufficiently available for the growth of diatoms. Since the phytoplankton are the base of the marine food web, and transferring energy to secondary and tertiary levels, this study could be useful to understand the potential fishing season as well as location for the sustainable utilization fishery resource in the Kavaratti Island, Lakshadweep Sea.

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