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Spatial and Diurnal Variability in Primary Productivity and Composition of Phytoplankton in the Coastal Waters of South Andaman.

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Abstract: ***The present study was aimed at analyzing the spatial and diurnal variability of the phytoplankton composition and abundance in the coastal waters of South Andaman. Phytoplankton are responsible for one quarter of the world's plant photosynthesis and play a vital role in the process of primary production. Diel variation in primary production, standing stock, composition and species diversity was observed. The current study suggests the richness of different phytoplankton species at a particular period, along with a distinct dominance of selective species. It also shows high primary productivity (Chl-a) and species diversity (H') in a particular area (Chatham) along with high Biological Oxygen Demand (BOD) values, while another location (Science Center) shows low primary productivity with low BOD. Higher species diversity and equitability of phytoplankton species was observed at Chatham specifically during night. High Species richness and low equitability in the phytoplankton population was recorded, could be due to the dominance of few opportunistic species like Protoperidinum sp. and Gymnodinium sp.***

Keywords: Diurnal Variation, Phytoplankton Composition, South Andaman, Coastal

I. INTRODUCTION

Coastal ecosystems are one of the highly productive zones characterized by land-ocean boundary, with high nutrient and organic matter input (form both natural and anthropogenic sources) and shallow depth. Terrestrial derived nutrients and organic matter from land run-offs from both natural and anthropogenic sources influence the local microalgal community [1]. Coastal phytoplankton which forms the base of the food chains [2], [3], are primarily responsible for the production and flow of organic matter through the food webs; directly or indirectly sustaining the higher trophic levels [4] and the biogeochemical cycles [5]. Phytoplankton communities are highly dynamic and respond quickly to the sudden changes in the abiotic (e.g., nutrient flow, turbidity, stratification and tidal oscillations) and biotic (trophic interactions such as competition and grazing pressure) factors in the marine environment [6]-[8]. These microalgae play a primary role in global productivity and contribute to ~ 40% of the total global carbon fixed [9]. In oceanic waters, more than 95% of the primary production is by phytoplankton community [10]. Thus, ecological studies on local and global scales are important steps towards understanding the broader interactions within the food web and environmental fluctuations [11]. Major works have been carried out on distribution patterns of phytoplankton in Indian Ocean and Bay of Bengal. Remarkably, studies pertaining to the Andaman Sea are very limited to the previous works of [12]-[15].

II. MATERIALS AND METHOD

A. Study area

The present study was carried out during January to March, 2010 from three distinct coastal regions around Port Blair: Carbyn Creek (SS-1), Science Center (SS-2) and Chatham Jetty (SS-3) (Fig. 1), to estimate primary productivity and to understand the diel variation in the species composition in relation to various physico-chemical parameters. Carbyn's Creek has the presence of mangroves and relatively polluted due to high human interference, shipping activities and drainage. The oil slicks are common in this area, and another sampling location (11°38'N, and 92°44'E) was chosen from this region. Science Center (11°39'N, 92°45'E) is comparatively less polluted and almost free from the influence of anthropogenic activities like shipping, drainage etc. This area is rocky and gets completely submerged during high tide. Chatham jetty (11°40'N & 92°43'E) is largely influenced by the shipping and other anthropogenic activities with frequent oil slicks and waste from shipping activities.

B. Sampling

Day and night sampling was carried out for a period of three months from January to March, 2010, to establish a relationship between the diurnal variation in water parameters, phytoplankton diversity and primary productivity. Estimating the concentration of Chlorophyll-*a* (Chl-*a)* remains the most common method for assessing algal biomass. The concentration of chlorophyll-a has also been shown to relate to primary productivity [16] and can be used to assess the physiological health of algae by examining its degradation product, phaeophytin. This degradation product has been shown to contribute 16-60% of the Chl-*a* content in seawater and freshwater. Water samples were collected for analysis of Chl-*a*, Phaeophytin (Phae), phytoplankton abundance and diversity along with other hydrographic parameters such as Dissolved Oxygen (DO), BOD, salinity, pH and temperature. Water samples for phytoplankton count were collected in 250 ml bottles by filtering 50 liters of water, using phytoplankton scoop net (45µ). For Chlorophyll, 5 liters of water was filtered and collected in the 500ml bottles. For DO and BOD water samples were collected in 300 ml DO bottles separately. For BOD, the bottles were immediately stored in dark condition and left for incubation for a period of 3 to 4 days. After incubation the samples were fixed with Winkler B and Winkler A and subsequently titrated against Sodium Thiosulphate. BOD values were calculated from the difference in initial and final DO values. Estimation of DO and BOD was done following Winkler's Iodometric Titration method [17]. Temperature was measured by using mercury thermometer (°C). Atago Refractometer was used to measure the salinity (‰). The pH of the water was measured using Hamilton gel-plast electrode pH meter. For the estimation of primary productivity water samples (5 liters) were filtered through Whatman glass fiber filters (47µm), under a vacuum through a Millipore filter unit. The pigment was then extracted in 10ml of 90% acetone solution under dark and cold conditions, for about 18-20 hours. Chlorophyll concentration in acetone extract (mg/L≡mg/m³) was determined by using spectrophotometer, at different absorption wavelength (750nm, 664nm, 647nm, 630nm for chlorophyll). For phaeophytin, after measuring the absorption wavelength values for chlorophyll the sample extract was acidified, to allow corrections for phaeophytin, with 1.2M HCl and measured at wavelengths 750 nm & 665 nm [18].

C. Quantification

For phytoplankton taxonomy and cell counts, 500 ml water samples were fixed with a few drops of Lugol's iodine, preserved in 10% buffered formaldehyde, and then stored in dark and cool conditions until the time of analysis. Prior to microscopic analysis, samples were concentrated to 25ml by siphoning the top layer with a tube covered with a 10µm Nytex filter on one end. Sample concentrates were transferred to a 1 ml capacity Sedgwick-Rafter [19] and counted using a Nikon Inverted microscope (Model Eclipse TS 100) at 10X magnification. When used under a low magnification light microscope, each of the grid squares equates to 1µ litre of liquid. The direct estimate of phytoplankton cell density as a measure of standing crop is established usually by using this method. The phytoplankton identification was done upto the genus level as finer structures are undetectable under bright field microscopy. Species Identification was done according to the manual Identifying Marine Phytoplankton [20]. The results are expressed as numbers of Cells L^{-1}.

The total number of Phytoplankton present in a liter of water Sample can be calculated using the formula:

$N = ({}^{n \times v}/_{V}) \times 1000$

Where,

N=total number of phytoplankton Cells L^{-1} of water filtered.
n=average number of phytoplankton cells in 1 ml of plankton sample.
v=volume of plankton concentrates (ml)
V=volume of total water filtered (L).

D. Data Analysis

The biological diversity in an ecosystem are quantified and expressed in terms of community composition, species richness and evenness. Diversity indices are mathematical measures of species diversity in a community. Diversity indices provide more information about community composition than simply species richness. The two main factors taken into account when measuring diversity are richness and evenness. Richness (D) is a measure of the number of different kinds of species present in a particular area. Diversity depends not only on richness, but also on evenness. Evenness (E) compares the similarity of the population size of each of the species present. This is a measure of the relative abundance of the different species making up the richness of an area. Species richness and evenness were calculated using the following equations:

$E = H' / \log_2 S$	Reference [21]	(1)
$D = S-1/\log_e N$	Reference [22]	(2)

Where:

S	no. of species
D	species richness
E	evenness of species/ equitability
H′	species diversity

III. RESULT AND DISCUSSION

A. Hydrographic parameters and Phytoplankton abundance

Maximum value of chlorophyll (7.307 mg/l) was observed in the night samples at SS-3 during January while minimum values (0.02 mg/l) were obtained at SS-2 during March at night. Higher values of phaeophytin (7.435 mg/l) was recorded in the night samples at SS-3 during January while minimum values (0.06 mg/l) were recorded during March at day, in SS-3 (Fig: 2(a), (b)).The consecutive values for DO and BOD during January were (4.1 ml/l) and (2.7 ml/l) (Fig. 2 (c), (d)). Total phytoplankton counts varied from 0.23 X 10^5-20.64 X 10^5 (Table. 1). Maximum population (20.64 X 10^5) was recorded at Chatham area (SS-3) during January night (Table. 1). A total of 62 species of phytoplankton was recorded during the study period from all stations (Table 3). A total of 19 species of Phytoplankton were recorded in the day samples during January (SS-1). Gymnodinium sp., Nitzschia longissima, and Pleurosigma sp. were the abundant while other unidentified dinoflagellates, also contributed to the total population In the night samples a total of 16 species, dominated by Pleurosigma sp., Nitzschia longissima sp., Rhizosolenia sp. followed by Pseudonitzschia sp. were obtained. At SS-2 in day samples, composition was dominated by Gymnodinium sp., followed by Hemilaimus sp., Chaetoceros sp., Neostreptotheca sp. followed by others. In the night samples Gymnodinium sp. was most abundant, while other major populations were Ceratium sp., Hemilaimus sp., Maguinea sp. Day samples from SS-3, the composition was dominated by Gymnodinium sp., followed by Rhizosolenia sp., Protoperidinium sp., Ceratium sp. etc followed by others. At night the composition was composed of Chaetoceros sp., Rhizosolenia sp. and Bacteriastrum sp., Pleurosigma sp. and Ceratium sp. followed by others. During February, at Station SS-1 the day samples, maximum number of the Protoperidinium sp., was recorded followed by Chaetoceros sp., Fragillaria sp., Pleurosigma sp., Nitzschia sp., Diplonoeis sp. followed by others. While the night samples had higher abundance of Gymnodinium sp., Nitzschia longissima, Pseudonitzschia sp. etc followed by others. At SS-2, in day samples Gymnodinium sp., Cocconoeis sp., Dinobryon sp., Striatella sp.were the more widely distributed species. While at night, Gymnodinium sp., Gyrodinium sp., unidentified dinoflagellates, etc formed the part of the composition, with not much variation in number of species. At SS-3 in day samples Chaetoceros sp., Bacteriastrum delicatum, Rhizosolenia sp., Pseudonitzschia sp., Ceratium sp. etc. were abundant, while in the night samples few numbers of species was obtained, and was represented by Protoperidinium sp., Pleurosigma sp.and Cocconoeis sp. In March, Station SS-1 in day samples, Gymnodinium sp., Nitzschia sp., Pleurosigma sp., Thalassiothrix sp., and other unidentified Dinoflagellates formed the major population of phytoplankton while at night SS-1, was dominated by Pseudonitzschia, Fragillaria, Coscinodiscus etc. At SS-2 day samples were dominated by, Gymnodinium sp., Chaetoceros sp., Trichodesmium sp. and Protoperidinium sp.). At night, Gymnodinium sp., Bacteriastrum furcatum, Dinophysis sp., Campylodiscus sp.were the major species. At SS-3, day samples showed a high abundance of Chaetoceros, followed by Pseudonitzschia and Ceratium. At night, species such as, Coscinodiscus sp., Guinardia sp., Thalassiosira sp.etc. were mostly abundant.

B. Diversity Indices

SS-1 showed moderate values of primary productivity. SS-2 showed low primary productivity, species diversity and total phytoplankton count. Whereas, SS-3 showed relatively high species composition compared to the other two stations. The richest sample in terms of species (29) was observed at SS-3 during night in January. Species diversity (H') values ranged from 1.3 to 4.2. Higher Species Diversity (4.2), high values of species richness (D=5.1) was recorded when the evenness of the species distribution was low (E=0.5) was recorded during January, night at SS-3 (Fig.3 (a), (b)). In general, the BOD level of SS-3, was higher during the sampling period, followed by SS-1 and SS-2 (Fig. 2(d)). Higher chlorophyll values observed at SS-3, suggest high primary productivity, along with relatively higher species diversity (H′=4.2) in conformation with high biological oxygen demand; suggesting SS-3 as more productive among the three areas investigated in this study (Fig. 5).

In the present study (January to March) an alternative dominance of diatoms such as Chaetoceros sp., Pleurosigma sp., Pseudonitzschia sp., Nitzschia sp., Rhizosolenia sp. and Dinoflagellates like Gymnodinium sp., Protoperidinium sp., Ceratium sp.was observed. Maximum number of diatom species was observed compared to the dinoflagellates (Table. 3). Species number (S) was higher in day samples than at night at each station (Fig. 4). Higher species diversity and evenness correlated with maximum number of species in this study. Species richness was high (D=5.1) in the samples where single species Protoperidinium was dominant where equitability was low (E=0.5) as expected in an eutrophic environment like Chatham where opportunistic species like Protoperidinum sp. and Gymnodinium sp. take advantage of the frequent changes of the environmental conditions and rapidly multiply in numbers. Lack of stability and time for diversification are the possible reasons for low diversity of coastal plankton communities. More intensive studies on phytoplankton bloom, primary productivity in relation to seasonal, diurnal variations in relation to nutrient availability should be carried out from this area to understand the pattern of variation and dominance of phytoplankton species and the reason to understand the reason for the dominance of few species at any particular time in the studied area.

IV. CONCLUSION

During the study Chatham was found to be more productive among the other three stations along with high BOD, investigated during this study. Diurnal variations in primary productivity and population density was noticed. An alternative spatial dominance of diatom species such as Protoperidinium, Gymnodinium & Chaetoceros during day & night as observed, which could be due to the nutrients available in this area and for which intensive study is required. Equitability in phytoplankton population was low in this study area which could be due to the opportunistic species take advantage of frequent changes in the environmental conditions & multiply in numbers. This study thus shows that phytoplankton communities respond greatly to subtle changes in the environmental parameters. Since, phytoplankton form the base of the food chain, it has a direct effect on the higher trophic levels. Longer time series, studies are required in these areas along with other hydrographic parameters to ascertain the reasons behind such variations.

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Table. 1. Total Phytoplankton count (Cells L^{-1}) at the three study study sites for 3 months.

Area	January	February	March
SS-1(D)	1.59×10^5	1.76×10^5	1.7×10^5
SS-2(D)	3.21×10^5	0.35×10^5	0.69×10^5
SS-3(D)	3.21×10^5	2.84×10^5	7.61×10^5
SS-1(N)	$1,53 \times 10^5$	0.23×10^5	0.95×10^5
SS-2(N)	0.69×10^5	1.44×10^5	1.14×10^5
SS-3(N)	1.29×10^5	20.64×10^5	1.14×10^5

Table. 2. Average values of Chl a, DO, BOD for the month of January, February and March

Area	Chl-a (mg/l)	DO (ml/l)	BOD(ml/l)	Temperature (º C)	S‰	pH
SS-1 (D)	1.374	3.4	1.6	30.2	33.0	7.4
SS-2(D)	0.089	4.6	1.1	30.2	34.3	7.6
SS-3(D)	1.054	4.1	2.6	28.3	35.3	7.7
SS-1(N)	0.099	2.8	1.4	29.7	38.3	7.0
SS-2(N)	0.152	3.8	1.1	29.0	37.7	7.5
SS-3(N)	2.697	4.0	2.3	28.3	34.7	7.4

Table 3. Phytoplankton species recorded during the study period from all stations.

Species	SS-1		SS-2		SS-3	
	D	N	D	N	D	N
Amphora sp.	+	+	-	-	+	+
Asterionellopsis glaciaris	+	+	+	+	+	-
Asterionellopsis karina	-	-	-	+	-	-
Bacteriastrum delicatum	+	+	-	-	+	-
Bacteriastrum furcatum	+	+	+	+	-	+
Bacteriastrum hyalinum	+	+	-	-	+	-
Bacillaria paradox	-	-	-	-	-	+
Biddulphia sp.	-	+	+	-	+	+
Campylodiscus sp.	+	+	+	+	+	-
Ceratium furca	+	-	-	-	-	-
Ceratium sp.	+	+	+	+	+	+
Chaetoceros sp.	+	+	+	+	+	+
Cocconoeis sp.	+	+	+	+	+	+
Coscinodiscus sp.	+	+	+	+	+	+
Cylindrotheca closterium	+	+	+	+	+	+
Cymbella sp.	-	+	-	+	-	-
Diatoma sp.	-	-	+	-	-	-
Dictyocha sp.	+	+	-	+	-	-
Dinophysis sp.	+	+	+	+	-	+
Dinobryon sp.	-	-	+	-	-	-

Diplonoeis sp.	+	+	-	-	+	+
Eucampia sp.	+	-	-	-	-	-
Fragillaria sp.	+	+	+	+	+	+
Fragilariopsis sp.	-	-	-	-	-	-
Grammatophora sp.	-	+	+	+	-	-
Gonolauyx sp.	-	-	+	+	+	+
Guinardia sp.	+	+	-	+	+	+
Gymnodinium sp.	-	+	+	+	+	+
Gyrosigma sp.	+	+	+	+	+	+
Haslea trompii sp.	+	-	+	-	+	-
Hemilaimus sp.	+	+	+	+	-	-
Leptocylindricus sp.	+	+	+	+	+	-
Licomorpha sp.	-	+	+	-	-	+
Maguinea fusiformis sp.	+	-	+	+	+	+
Melosira sp.	+	+	+	-	+	+
Navicula sp.	-	+	+	+	+	+
Neostreptotheca	+	-	+	-	+	+
Nitzchia longissima	+	+	-	-	+	+
Nitzchia sp.	+	+	-	-	+	-
Nostoc sp.	+	-	-	-	+	-
Noctiluca sp.	+	+	-	+	-	+
Odontella sp.	+	-	-	-	-	-
Oscillatoria sp.	-	-	-	-	+	-
Peridinium sp.	+	+	+	+	+	-
Plagiotropis gausii	-	+	-	-	-	-
Planktonella sol	+	-	-	-	-	-
Pleurosigma sp.	+	+	+	+	+	+
Pleurosigma directum	-	+	-	+	+	-
Prorocentrum sp.	-	-	-	-	-	+
Protoperidinium sp.	-	+	+	+	+	-
Pseudoguinardia sp.	-	-	+	-	+	-
Pseudonitzchia sp.	+	+	-	+	+	+
Rhizosolenia sp.	+	+	+	+	+	+
Skeletonema sp.	+	-	-	-	-	-
Straustrum sp.	-	+	-	-	-	-
Striatella sp.	+	-	+	+	+	-
Surirella sp.	-	+	+	+	+	-
Thalassionema sp.	-	+	+	+	+	+
Thalassiothrix sp.	+	+	+	-	-	-
Trichodesmium sp.	-	-	+	+	+	+
Triceratium sp.	-	-	-	+	-	+
Ulothrix sp.	-	-	-	-	+	-
unidentified dinoflagellates	+	-	-	+	+	-

(+) indicates species was recorded during the period of study

(-) absence of species during the period of study

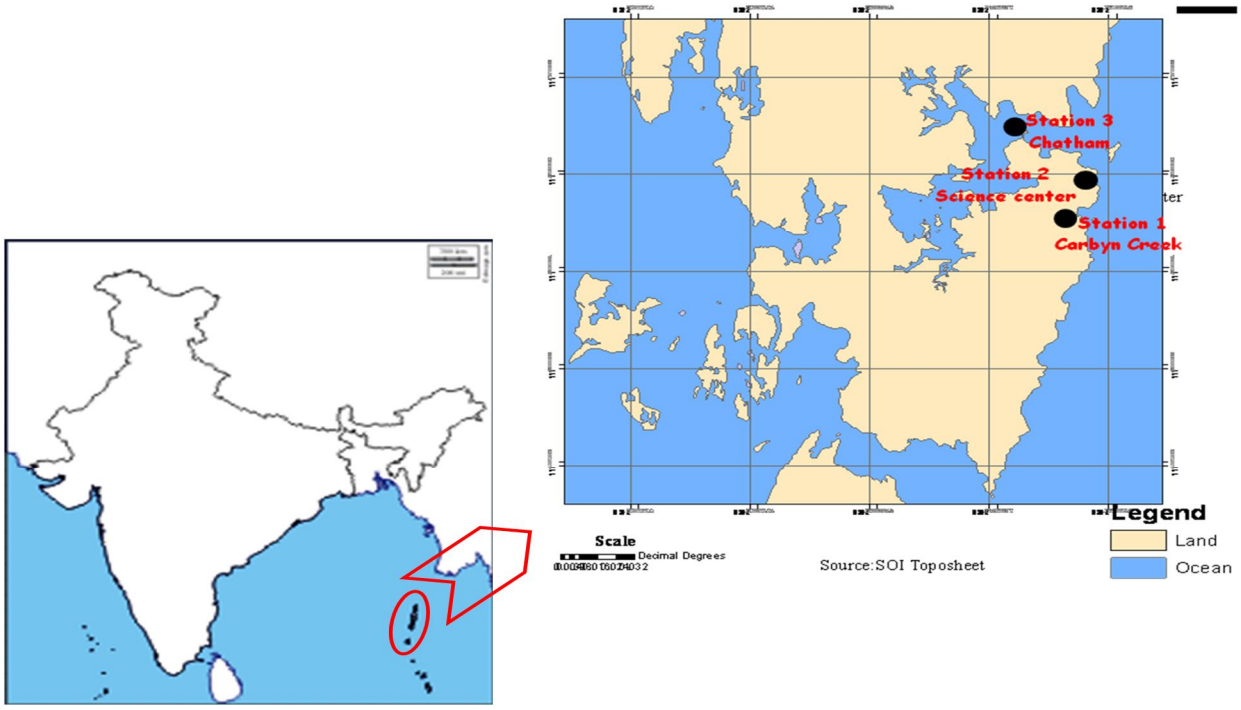
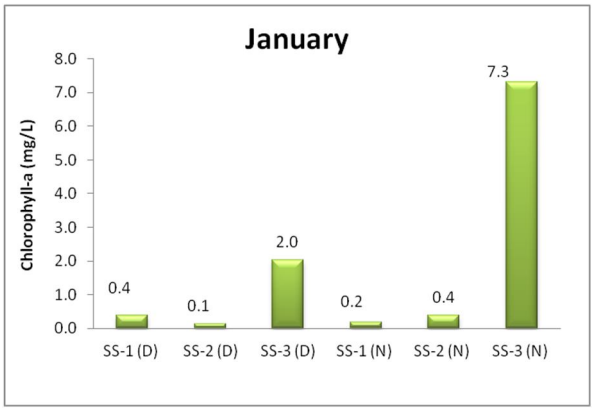
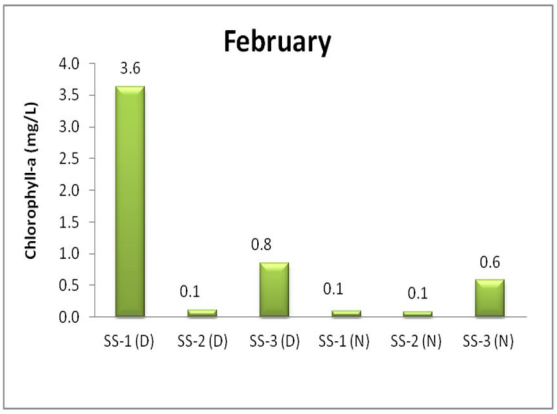
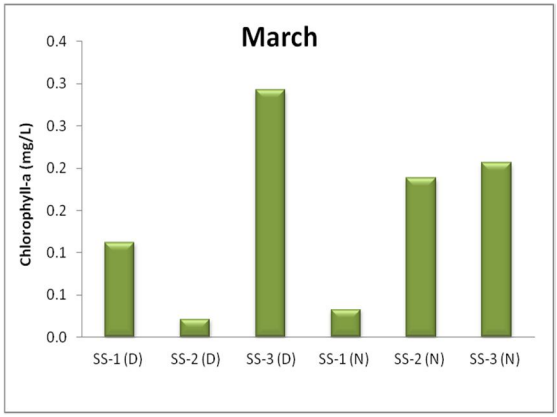


Fig 1: Map of South Andaman with the three study location Station 1(SS-1), Station 2 (SS-2), Station 3 (SS 3).

(a)







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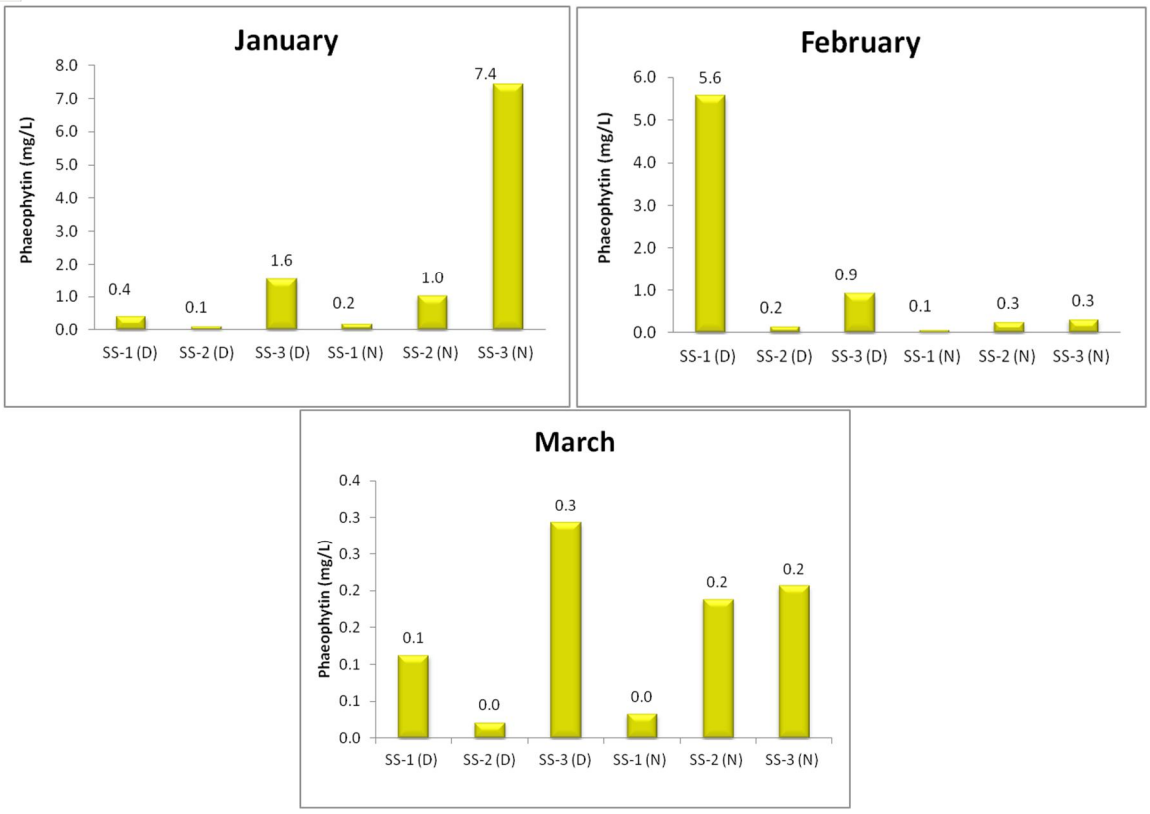

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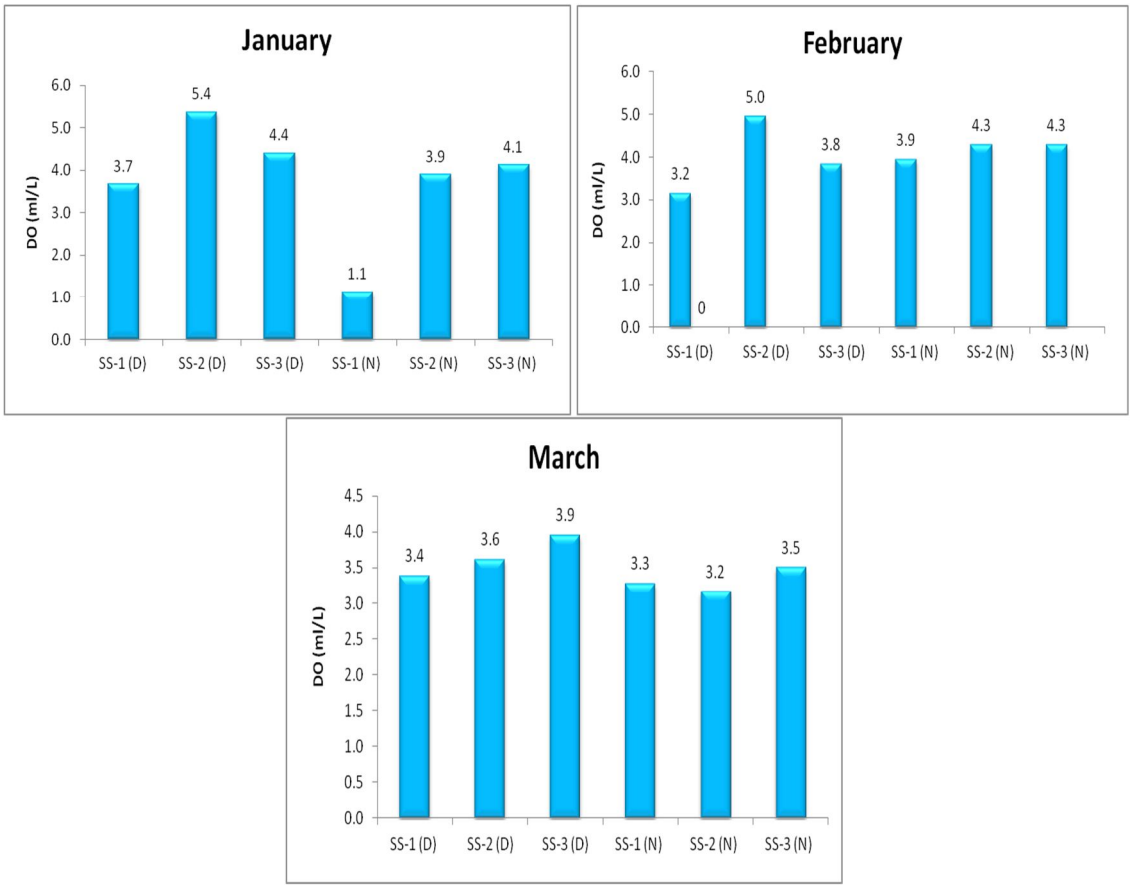


(d)

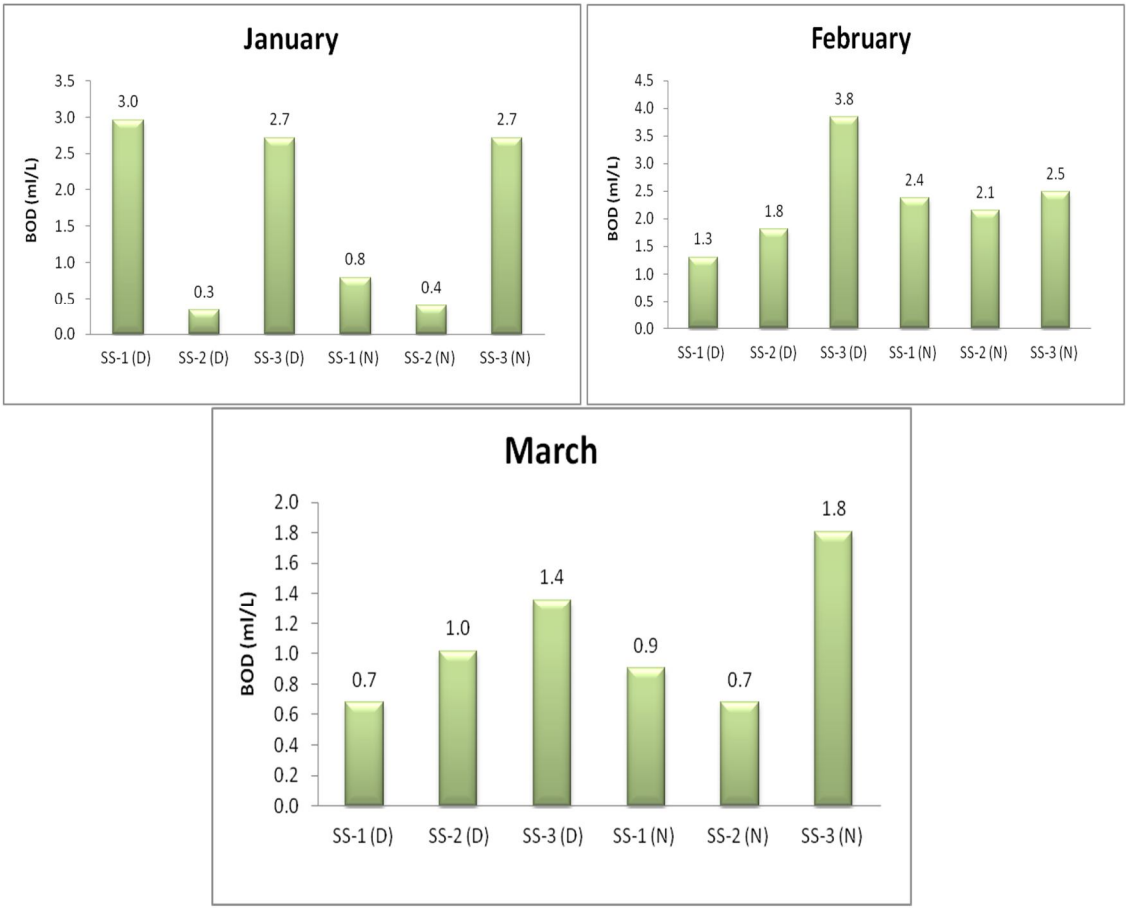
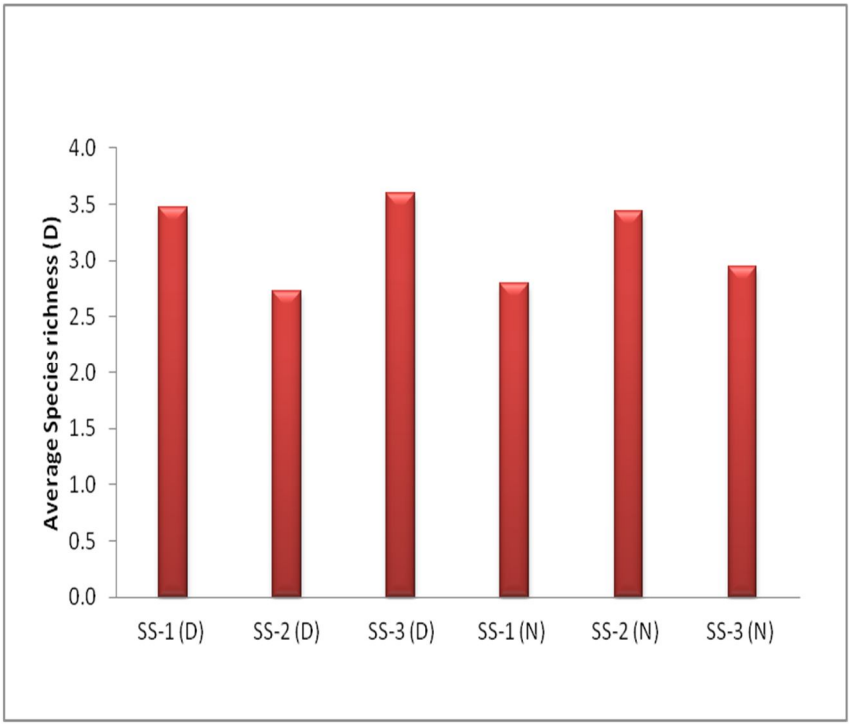


Fig 2: Variations in hydrographic parameters (a) Chlorophyll-a, (b) Dissolved Oxygen (DO) (c) Phaeophytin (d) Biological Oxygen Demand (BOD)for the month of January, February, March.

(a)



(b)

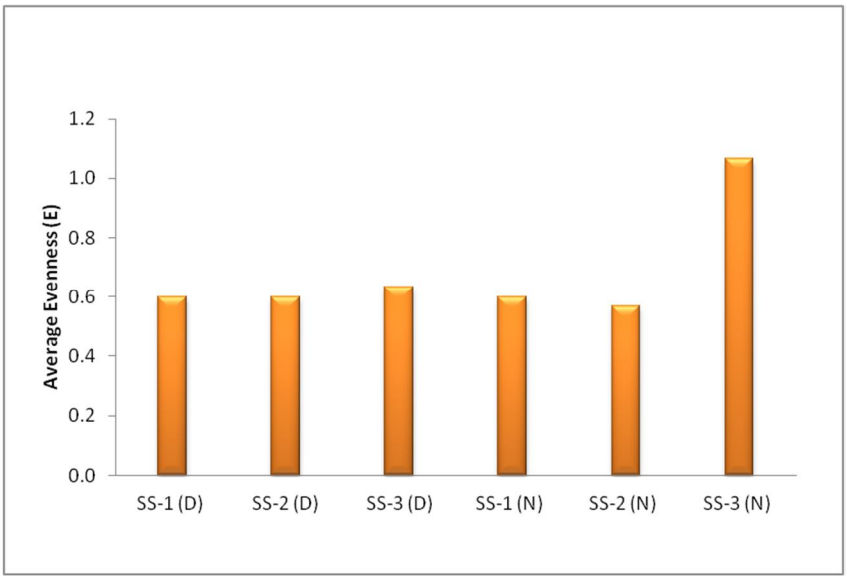


Fig.3. Variations in average (a) Species richness (D) and (b) Evenness (E) at all station from January to March.

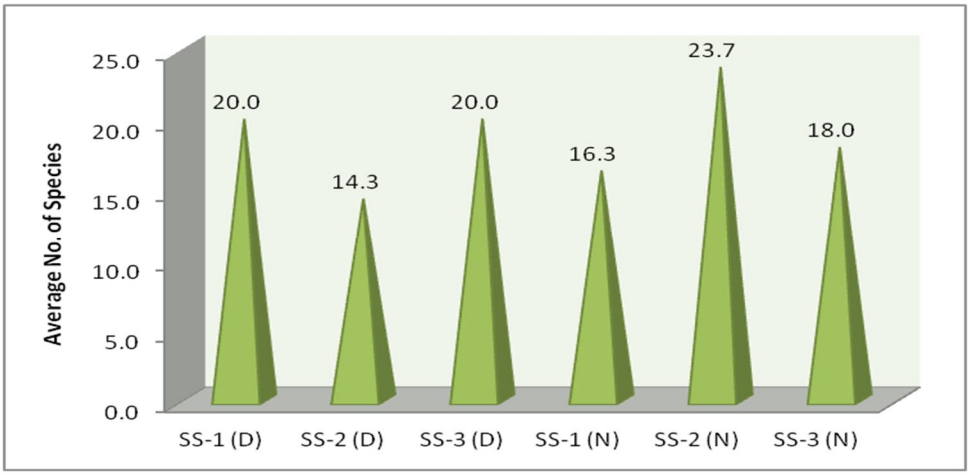


Fig. 4. Variations in average species number of phytoplankton species (S) at all station.

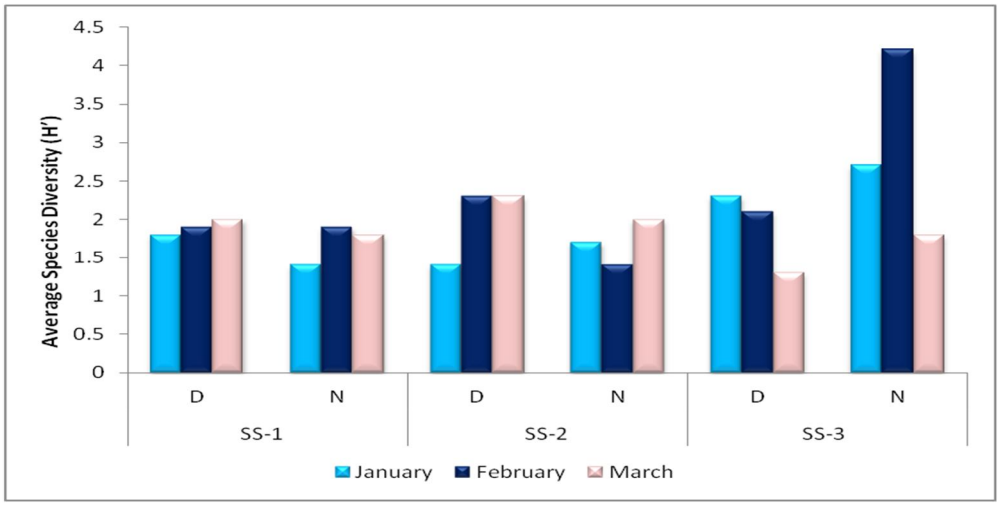
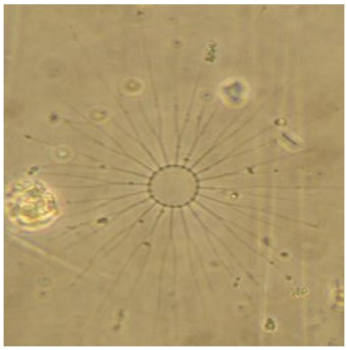
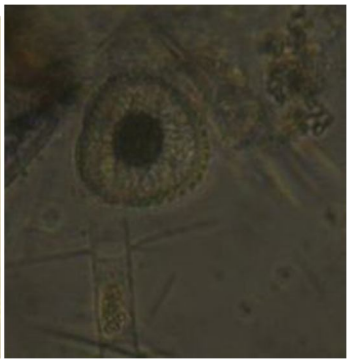
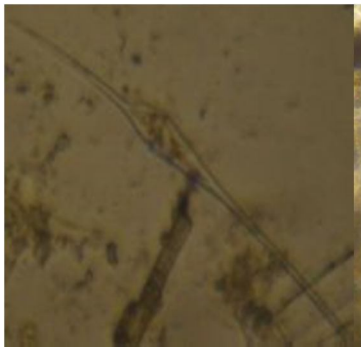


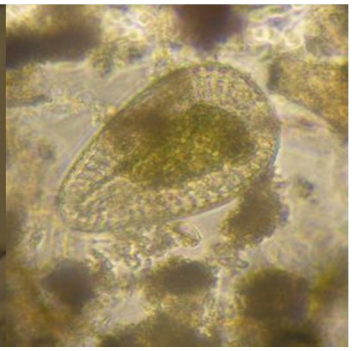
Fig. 5. Variations in species diversity (H') at all station for all months

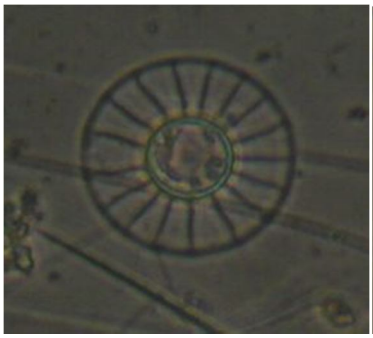
Plate.1

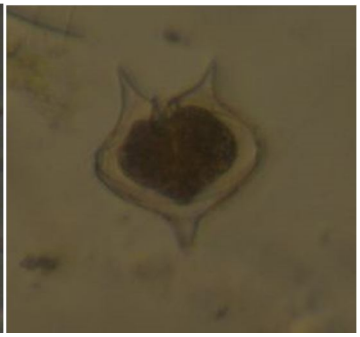

Bacteriastrum delicatum.

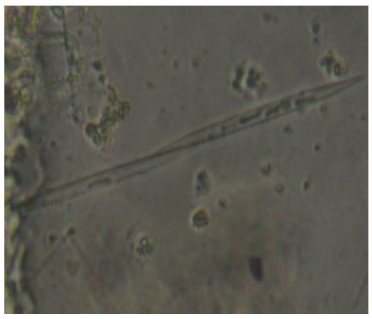

Campylodiscus sp.

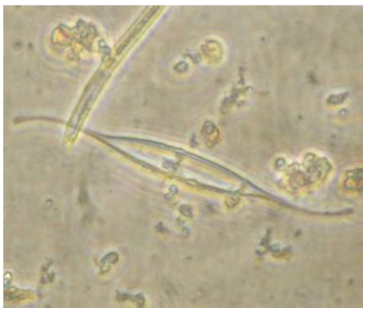

Ceratium sp.

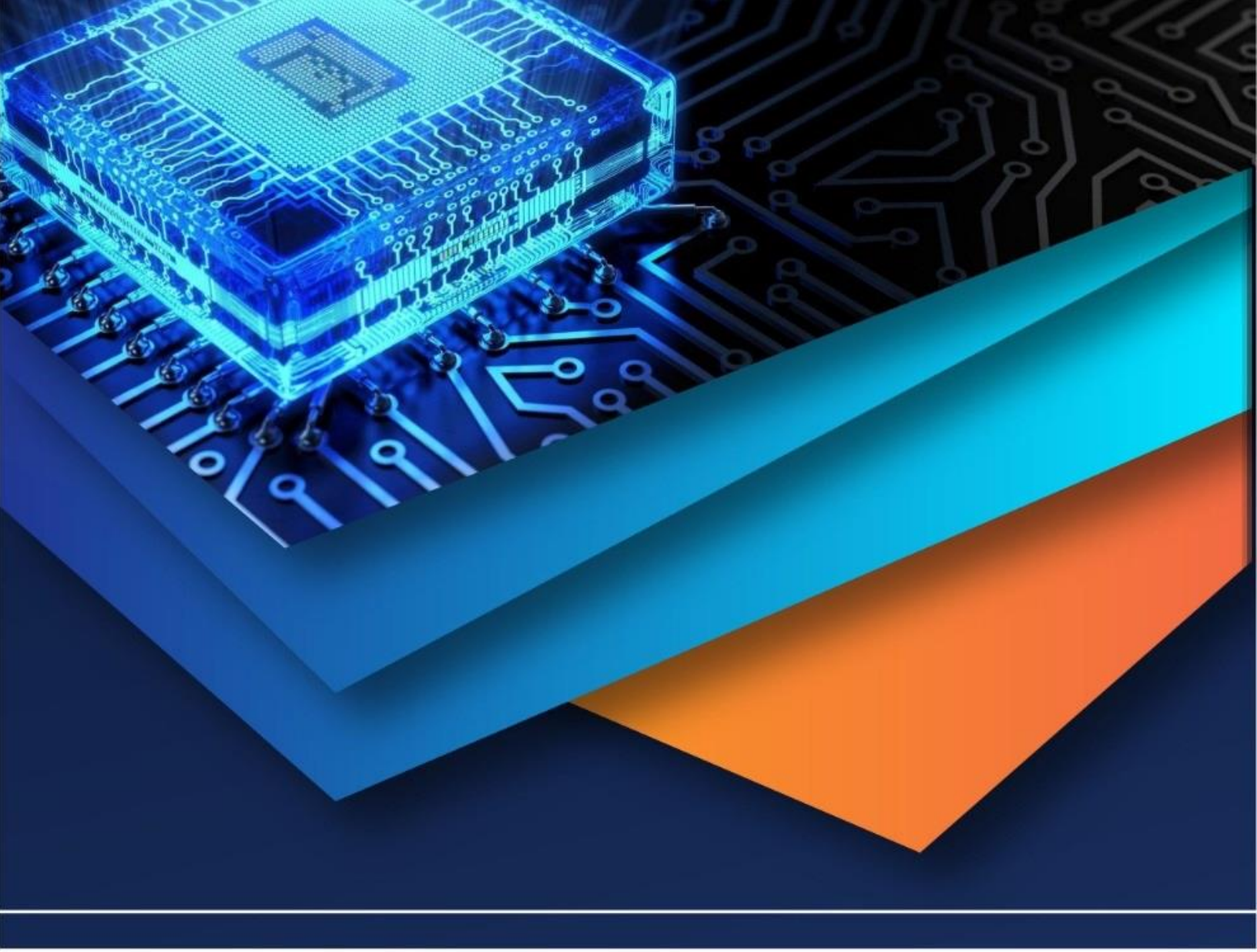

Surirella sp.


Planktoniella sol.


Protoperidinium sp.


Pseudonitzschia sp.


Nitzschia longissima



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