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Observations on bio-optical properties of a phytoplankton bloom in coastal waters off Cochin during the onset of southwest monsoon

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A phytoplankton bloom dominated by *Chaetoceros* spp. was detected in the Arabian Sea, off Cochin coast during May 2009 coinciding the onset of southwest monsoon with an average chlorophyll *a* concentration of 8.42 mg m^{-3} at four stations (A, C, D & E) of total 7 stations studied in coastal waters situated between latitudes 9º54'-10º02' N and longitudes 76º05'-76º12' E. All the stations were resampled after seven days and found that the average chlorophyll *a* concentration at the bloom stations has decreased to 2.91 mg m^{-3}. The inherent optical properties (chlorophyll *a*, specific phytoplankton absorption coefficient, chlorophyll scattering coefficient) of water were analyzed from the study area. The physico-chemical parameters like dissolved oxygen, pH, turbidity and nutrients were estimated for surface waters in these stations using standard methods. The phytoplankton of the study area was identified and their density was recorded. The phytoplankton community composed primarily of diatom *Chaetoceros* sp. in all the stations, with a percentage composition greater than 55 at the bloom. The highest phytoplankton density recorded was 4,89,578 cell no./l at station D. Samples from the bloom showed higher specific phytoplankton absorption coefficient [$a^*_c(\lambda)$] than other stations. $a^*_c(435)$ varied from 4.11 to 5.68 m^2mg^{-1} and a^*_c (665) from 1.45 to 1.80 m^2mg^{-1}. A survey on purse seine fishery showed a higher pelagic catch in close proximity to the bloom area during this period. Further investigation of absorption properties of blooms using remote sensing at complex case II waters is needed to interpret bio-optical properties as well as fisheries. The present study is the first attempt of this kind off Cochin coast.

Keywords: bloom, phytoplankton, specific absorption coefficient, Cochin coast

Introduction

The phytoplankton blooms are incidence of proliferation of microalgae in an aquatic environment. They can be quick events that begin and end within a few days or they may stay for several weeks; they can occur on a relatively small scale or cover hundreds of square kilometres of the ocean's surface[1]. Blooms are events of rapid production and accumulation of phytoplankton biomass that are usually responses to changing physical forcing originating in the coastal ocean (tides), the atmosphere (wind) or on the land surface (precipitation and river runoff)[2]. The excessive growth of an alga during a bloom usually causes water discolouration, depending on the predominant species.

The Arabian Sea is highly influenced by monsoon systems like south west monsoon (June – September) and north east monsoon (December-February). This affects availability of nutrients, distribution pattern of phytoplankton and also the fishery along the coast of India. The reports of algal blooms indicate their predominance along the west coast of India especially the southern part[3]. Several studies have reported the occurrence of phytoplankton bloom along Kerala coast[3,4,5,6]. Event of blooms along Cochin coast is also very prevalent[7,8,9]. The influence of bloom on the fishery of Kerala coast has been studied[5,10].

The present study reports observations and findings of an algal bloom observed during May 2009 in the Arabian sea, off Cochin coast. Analysis of *in-situ* water column measurements contributes to our knowledge of the optical characteristics of the phytoplankton community involved. The possible effect of bloom on pelagic fishery of the close by area has been studied.

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Materials and Methods

Sampling was conducted at seven stations in the coastal waters off Cochin area monthly for a period from March 2009 to May 2009. Stations A, B, C, D, E, F and G were located between latitudes 9º54'-10º02' N and longitudes 76º05'-76º12'E (Fig:1). All the stations were resampled after seven days. At each station, surface water samples were collected using

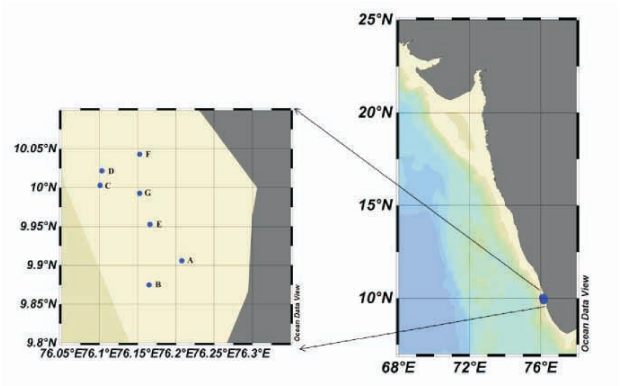

Fig 1. Study area showing station locations off Cochin coast

Hydro-Bios Niskin plastic water sampler of 2.5 L. Aliquots were filtered, under low vacuum (<10 cm Hg), through GF/F (Whatman) glass filters to concentrate the particles for pigments determination. Filters were analysed for chlorophyll *a* in flourometer as per EPA method 445.0 using Welshmeyer filter kit. Flourometric chlorophyll standards from Turner Designs were purchased from Sigma. The samples were analysed within 3 or 4 hours after collection. Chlorophyll specific absorption coefficient and scattering coefficient of chlorophyll were analysed through UV/VIS spectrophotometer using 1 cm cell. The optical density (OD) was measured in the spectral range 400 to 700 nm with an interval of 1 nm against the cell containing 90% acetone as blank[11]. The OD at 750 nm was subtracted from the entire spectrum and converted to absorbance unit as,

$$a_c(\lambda) = 2.303\ OD_c(\lambda)\ 100 \qquad [m^{-1}]$$

Chlorophyll specific absorption coefficient (a*c) was estimated for the spectral range 400 to 700 nm using the measured chlorophyll concentration (Cc) [11] and the spectral absorption coefficient[12].

$$a^*c(\lambda) = 0.06\ C_c^{0.62}\ ac(\lambda) \qquad [m^2\text{-}mg^{-1}]$$

The scattering coefficients of chlorophyll were then calculated over the spectral range 400-750 nm according to standard methods[13]

$$b_c(\lambda) = 0.3\ C_c^{0.62}\ (550/\lambda) \qquad [m^{-1}]$$

The nutrients (nitrite, silicate and phosphate) of surface waters were estimated as per the standard methods[14]. Dissolved oxygen was estimated by the Winkler method. The turbidity and pH of surface waters were also recorded. The quantitative and qualitative analysis of the phytoplankton was done in a Sedwick-Rafter plankton counting chamber and microscopically analysed. The phytoplanktons of the study area were identified as per standard references[15,16]. The numerical density was expressed as number of cells L^{-1}.

An attempt has been made to estimate the spatial distribution of bloom by using satellite images (MODIS). The catch from nine purse seiners in close proximity of the bloom area was recorded. Phytoplankton of the bloom samples was identified and their density was recorded.

Results and Discussion

A phytoplankton bloom was detected in the Arabian Sea, off Cochin coast during May 2009 coinciding with the onset of southwest monsoon (Fig:2). During the survey, high concentration of chlorophyll *a* was observed at stations C (7.5 mg/L), D (7.14 mg/L) and E (7.74 mg/L) on May 25, 2009.

Fig 2. Chaetoceros sp. dominant bloom observed during the cruise on 23.05.'09 off Cochin at station D

The same stations were sampled on June 1st, 2009 (7 days later) and found that chlorophyll *a* concentration diminished as at stations C (6 mg/L), D (0.54 mg/L) and E (3.18 mg/L) at the surface waters. An average chlorophyll *a* concentration of 8.42 mg m^{-3} recorded at four stations (A, C, D & E) on 23rd May '09 was decreased to 2.91 mg m^{-3} after seven days (Fig:3). The samples from the bloom showed

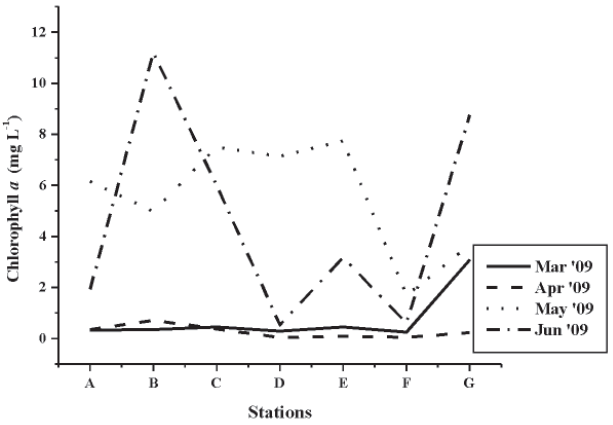

Fig 3. Chlorophyll a concentration at the stations studied (A, B, C, D, E, F & G) during the study period (March'09 to June '09)

higher specific phytoplankton absorption coefficient [$a^*_c(\lambda)$] than other stations (Fig.4). $a^*_c(435)$ varied from 4.11 to 5.68 m^2mg^{-1} and a^*_c (665) from 1.45 to 1.80 m^2mg^{-1}. The stations A, C, D and E where bloom was present in May 2009 indicated higher scattering

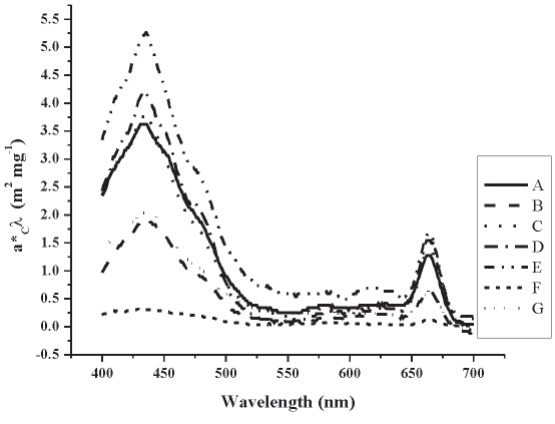

Fig 4. Chlorophyll specific absorption coefficient [$a^*_c(\lambda)$] at the stations studied (A, B, C, D, E, F & G) on 23.05.'09 off Cochin

coefficients of chlorophyll [$b_c(\lambda)$] (Fig.5). LAC MODIS/Aqua image shown in figure 6, shows a relatively high concentration of chlorophyll *a* off Cochin coast on 28th May (not sampled *in situ*) with a considerable increase from 12th May (not sampled *in situ*). Phytoplanktons require a wide range of chemical elements but the two essential ones are

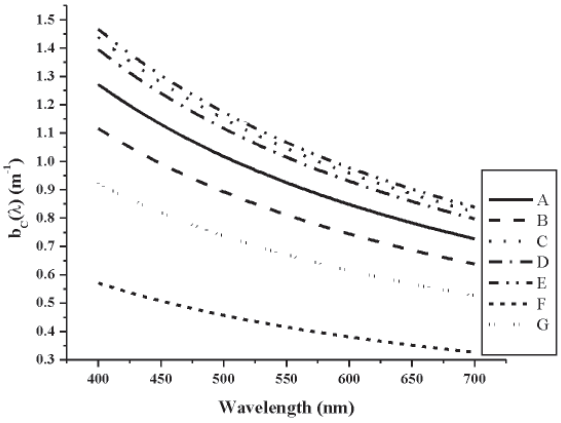

Fig 5. Scattering coefficients of chlorophyll [$b_c(\lambda)$] at the stations studied (A, B, C, D, E, F & G) on 23.05.'09 off Cochin

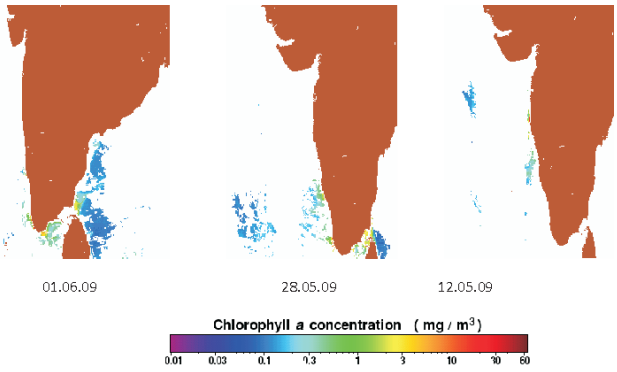

Fig 6. LAC MODIS/Aqua image

nitrogen and phosphorous[17]. In the present study, a positive correlation was found between phytoplankton and nutrients analysed (nitrite, phosphate and silicate). The lowest values of nitrite (0.001 ppm), phosphate (0.004 ppm) and silicate (0.001 ppm) were recorded in the months of March and April 2009 concurring with the pre-monsoon period. All the nutrients anlaysed showed an increase in concentration during the bloom as nitrite (0.038ppm), phosphate (0.383 ppm) and silicate (0.542 ppm) (Fig:7, Fig. 8). Increase in nutrient concentration can be due to river-inflow and upwelling usually prevailing during monsoon.

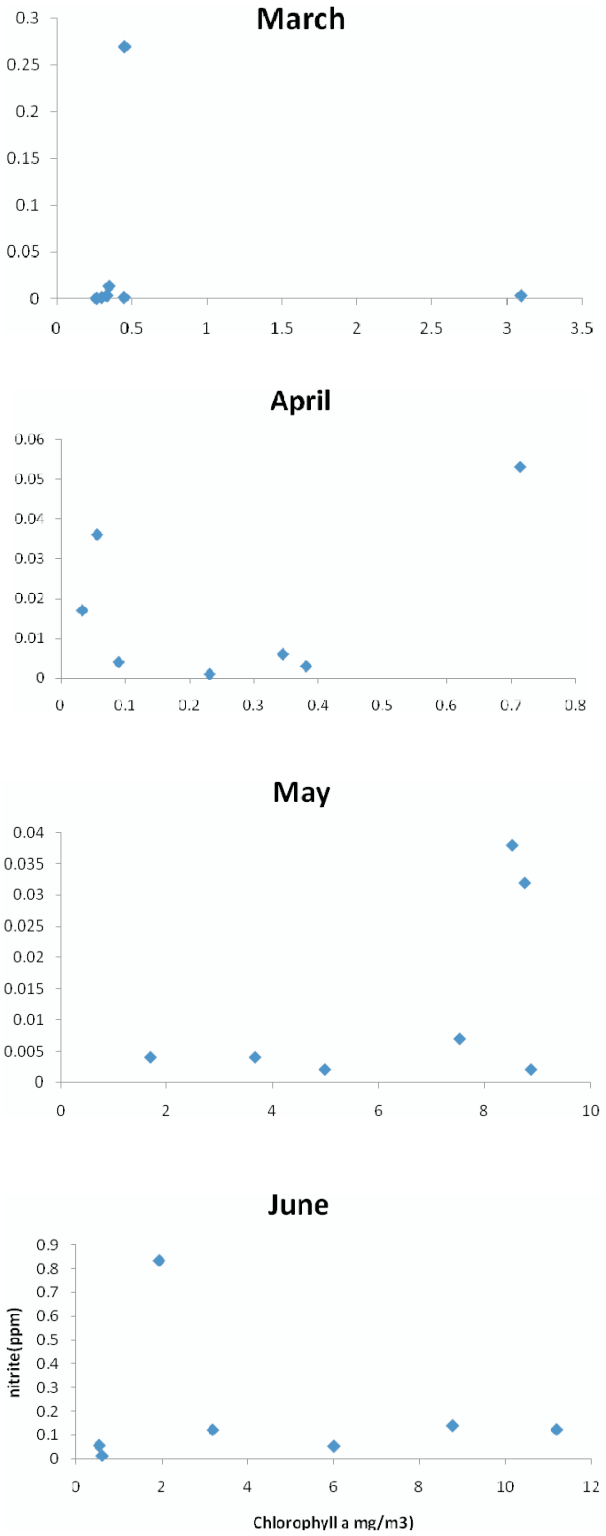

Fig 7. Pattern of variations of nitrites (in ppm) in relation to chlorophyll a (mg/m^{-3}) during the study period (March'09 to June '09)

The phytoplankton blooms are generally known to be sensitive to nutrient inputs. With the onset of the summer monsoon, under the influence of the south-westerly winds along the west coast the surface waters move away from the coast and are replaced by colder, nutrient-rich waters from the subsurface. This leads to phytoplankton blooms of mostly diatoms and dinoflagellates and increased productivity[10]. Nutrient rich waters caused by upwelling and river discharges usually lead to phytoplankton blooms in south west coast of India during south west monsoon months[3,18,19]. Of the three nutrients analysed, silicates (0.542 ppm) were in higher concentration than nitrite and phospahte during the bloom (Fig:7, Fig:8). This ascertains that the bloom is of a diatom as the cell walls of diatoms are made up of silica. Seven days after the bloom nitrites were in higher concentration (0.835 ppm) than phosphate and silicates (Fig7, Fig:8).

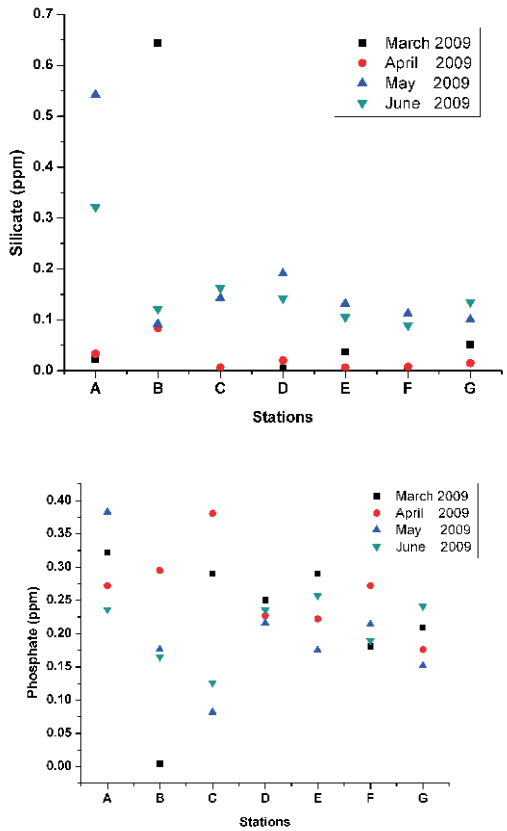

Fig 8. Pattern of variations of silicates and phosphate (in ppm) at the stations studied (A, B, C, D, E, F & G) off Cochin during the study period (March'09 to June '09)

Dissolved oxygen showed a slight increase in concentration during the months of May (5.18 mg/L) and June (5.11 mg/L) compared to pre-monsoon period (4.32 mg/L). River-inflow and wind-mixing might have contributed to this increase of dissolved oxygen. According to Padmakumar *et al*., 2010, the dissolved oxygen concentration was high in the bloom area (6.89 ml L^{-1}) due to the increased photosynthetic activity of the diatom cells[9].

A drastic increase in turbidity was noticed during the bloom (3.58 NTU in May and 3.84 NTU in June) corresponding to the onset of southwest monsoon. The pre-monsoon months showed very low turbidity to the tune of 0.82 NTU in March and 0.55 NTU in April. A slight dip in pH values were noted on the onset of monsoon. An average pH value of 8.19 during pre-monsoon period reduced to 7.85 during May and June. The reduction of pH is indicative of river run-off.

On analysing the phytoplankton abundance and species composition, 17 genus and several species of Bacillariophyceae (11 genera of Centrales and 6 genera of Pennales), 4 genera of Dinophyceae, one genus each of Cyanophyceae and Chrysophyceae were identified. The total phytoplankton community during this bloom was composed mainly of diatoms and was dominated by the diatom *Chaetoceros* spp. The other groups contributing considerably to the composition were Centrales (*Skeletonema costatum*) Pennales (*Nitzschia* sp., *Asterionella japonica*), Dinoflagellates (*Ceratium furca, Pyrophacus* sp.) and Blue green algae (*Oscillatoria* sp.) (Table 1). The highest phytoplankton density recorded was 4,89,578 cell no./L at station D. A survey on purse seine fishery showed a higher pelagic catch in close proximity to the bloom area during May '09 (Table 2). No adverse conditions were noted due to bloom as river-inflow, upwelling and wind-mixing contributed to slight

Table 1—Numerical density (no./L) of phytoplankton recorded during the cruise on 23.05.'09 off Cochin at seven stations studied

Phytoplankton	Stations						
	A	B	C	D	E	F	G
Diatoms							
Centrales							
Skeletonema costatum	9999	0	6000	43355	30015	2001	13340
Thalassiosira subtilis	2000	1000	0	1334	0	0	0
Coscinodiscus sp.	0	0	0	667	0	0	0
Laudaria annulata	2000	0	0	0	0	0	0
Leptocylindrus danicus	2000	0	0	0	0	0	0
Rhizosolenia sp.	0	0	0	0	0	0	3335
R. setigera	0	1000	1500	0	0	0	0
R. delicatula	13332	1000	3000	5336	0	2668	0
R. imbricata	3333	1000	3000	10005	2001	667	0
R. styliformis	667	0	0	0	667	0	0
R. stolterfothii	0	0	0	0	667	0	0
R. alata	8666	0	1500	667	1334	0	1334
Bacteriastrum sp.	0	0	0	4669	0	1334	667
B. hyalinum	667	0	0	667	667	0	0
B.delicatulam	4666	0	9000	2001	667	0	0
B.furcatum	0	0	0	0	0	667	667
Chaetoceros sp.	163317	97000	4500	270135	176755	90045	83375
C.decipiens	0	0	187500	0	0	0	0
C.curvisetus	19998	0	0	36685	0	10005	13340
Ditylum brightwellii	0	1000	0	0	667	0	667
Biddulphia sinensis	667	0	0	0	1334	0	0
B.mobiliensis	667	2000	1500	1334	1334	0	0
B.aurita	0	0	0	0	667	0	0
Hemidiscus sp.	0	0	0	0	667	0	0

Hemialus sp.	2666	0	0	0	0	0	0
Pennales							
Asterionella japonica	9999	1000	19500	40020	16675	0	10005
Grammatophora sp.	667	0	0	1334	0	0	0
Pleurosigma elongatum	667	0	0	0	0	0	0
P.directum	0	0	0	667	0	0	0
Amphiprora sp.	0	0	0	1334	0	0	0
Cylindrotheca closterium	1333	0	1500	0	1334	0	0
Nitzschia sp.	29997	2000	3000	6670	10005	13340	6670
N. longissima	0	0	4500	667	667	0	0
N. seriata	5333	0	3000	16675	10005	4669	6670
Dinoflagellates							
Prorocentrum micans	0	0	0	667	0	0	0
Ceratium fusus	0	0	0	667	0	0	667
C. tripos	667	0	0	0	0	0	667
C. furca	1333	2000	0	2001	0	0	667
C.inflatum	667	0	0	0	0	0	0
Pyrophacus sp.	2000	0	0	2001	667	0	667
Protoperidinium sp.	0	0	0	667	667	0	0
P.ovatum	0	0	0	667	0	0	0
P.leonis	667	0	0	0	0	0	667
Blue green algae							
Oscillatoria sp.	667	0	0	38019	10005	30015	0
Flagellates							
Dictyocha sp.	0	0	0	667	0	0	0
Others	667	0	3000	0	667	1334	2668
Total	**289309**	**109000**	**252000**	**489578**	**268134**	**156745**	**146073**

Table 2—Catch obtained in experimental purse seining during the bloom period near to the bloom area

Date	Fishing ground	Latitude (N)	Longitude (E)	Fish catch (Scientific name)	weight in kg
5/8/2009	Off Chettuva	10º 24.784'	075º48.111'	*Auxis rochei*	30
5/8/2009	Off Chettuva	10º 24.784'	075º48.111'	*Scomberoides tol*	10
5/23/2009	Off Cochin	09º58.490'	075º57.505'	*Alepes djedaba*	150
5/23/2009	Off Cochin	09º 58.490'	075º57.505'	*Auxis rochei*	250
5/23/2009	Off Cochin	09º56.900'	075º57.024'	*Auxis rochei*	500
5/23/2009	Off Cochin	09º56.900'	075º57.024'	*Euthynnus affinis*	250
5/25/2009	Off Cochin	09º49.999'	076º06.856'	*Alepes djedaba*	180
5/26/2009	Off Cochin	09º59.372'	075º52.625'	*Auxis rochei*	100
5/26/2009	Off Cochin	09º55.186'	075º56.439'	*Scomberoides tol*	60
5/26/2009	Off Cochin	09º55.186'	075º56.439'	*Auxis rochei*	75
5/27/2009	Off Cochin	09º54.071'	075º58.929'	*Parastromateus niger*	150
5/28/2009	Off Cochin	09º53.297'	075º54.853'	*Carangoides malabaricus*	14000
5/28/2009	Off Cochin	09º53.297'	075º54.853'	*Auxis rochei*	75

increase in dissolved oxygen. Higher DO concentrations during bloom has been recorded in previous studies[9]. Due to increase in DO, no anoxic condition was formed affecting fishery. In the present study, the fish catch during the pre-monsoon period were not economically feasible to the local fishermen. During the bloom the highest catch was of *Carangoides malabaricus* (14,000 kg) (Table 2).

Most of the major pelagic fisheries of south west coast of India like sardines, mackerels and anchovies are planktonivorous. They take advantage of the upwelling and higher primary productivity during southwest monsoon. Fairly high percentages in the catches of oil sardine, anchovies, perches, carangids and mackerels are noted during monsoon as they breed and spawn in these high productive areas[10].

The overall findings of this study revealed that an increase of influx of nutrients contributed to a single species proliferation, resulting in higher pelagic fishery. Further investigation of absorption properties of blooms using remote sensing at complex case II waters is needed to interpret bio-optical properties as well as fisheries.

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