Studies on Phytoplankton Pigments: Chlorophyll, Total Carotenoids and Degradation Products in Vietnamese Waters

Nguyen Tac An, Hoang Trung Du

Institute of Oceanography, Vietnam, O1CauDa – Nhatrang - Vietnam

ABSTRACT

Distribution of phytoplankton pigments was investigated in the relation to Chlorophyll a (Chl-a) and light intensity in Vietnamese waters located at longitude 102E - 112W, latitute 23N - 7N. Over 200 samples collected at 58 stations were analyzed for pigments(Chlorophyll a, b ,c and carotenoids) and degradation products (Phaeophytill). Chlorophyll a was measured by fluorescence. Results show that average values in the seawater were 0.18 ± 0.04 mg.m^{-3}for Chl-a; 0.05 ± 0.01 mg.m^{-3} for Chl-b; 0.062 mg.m^{-3} for Phaeophytill. Higher value of Chl-a occurred at the thermocline but maxima were found at 75 or 50m depths. Average value of Carotenoids concentration was very low about 0.052 ± 0.12 mg.m^{-3}. The report used a model for the relationship between Chlorophyll a content and light intensity to estimate the primary production. Average value of primary production was about 9.04 mgC.m^{3}.day^{-1} at the surface and 2.63 mgC.m^{3}.day^{-1} at the bottom. The relationship between Chlorophyll and some environmental parameters such as temperature, salinity was examined. The effects of thermocline and halocline to the primary production were analyzed.

Introduction

Study on the content distribution of Chlorophylls a,b,c and Carotenoids of phytoplankton in the seawater is very necessary. On the one hand, the Chlorophyll content allows the studies and estimation on some characters of the physiological status of phytoplankton community and primary production of the waters. On the other hand, these are important parameters to assess the environmental quality of the waters.

Based on characters of chemical structure, the pigment system of marine phytoplankton are separated into four groups (Vedernhikov, 1988):

- Chlorophyll a,b,c
- Biliprotein (Phicoeritrin and Phicocianin)
- Carotene
- Xanthophyll

Actually in the research, two last groups Carotene and Xanthophyll are joined in one system called Carotenoids (Vedernhikov, 1988). Chlorophyll a and Carotenoids are the most important characters because they are present in most phytoplankton species and play the key role in the photosynthesis process of phytoplankton.

However, the contents of Chlorophylls a,b,c in different phytoplankton species are not identical and normally the ratio of Chlorophylls a,b,c are used to assess the quantitative distribution of phytoplankton in the waters. When the content of Chlorophyll a is defined much higher than the contents of Chlorophyll b,c the Cyanophyceae are dominant in the waters. When the content of Chlorophyll c is higher than that of Chlorophyll b the Diatomea is dominant (Cirenko, 1988). Some ratio indexes have been published and used in research, for example: for green algae, the ratio of Chlorophylls a:b is 0.43 ± 0.22; for

Diatomea, the ratio of Chlorophylls c:a is 0.62 ± 0.13; for Peridinhea, the ratio of Chlorophylls c:a is 0.86 ± 0.56; for Xrizomonad, the ratio of Chlorophylls c:a is 0.58 ± 0.46 and for Kriptomonad the ratio of Chlorophylls c:a is 0.51 ± 0.24. If the Phaephytill content is high and the Chlorophyll a content is negligible, it is proved that the phytoplankton is in the withered period, the suspended matters in this region are mainly detrit.

Usually, the pigment content of phytoplankton varies strongly and depends on ecological conditions, their physiological state, it is also an important information source to consider the production. Besides, it is also possible to use the measurements of pigment content to assess the biomass of phytoplankton with carbon dimension by experimental expression. The Chlorophyll a content in the phytoplankton is not high. Chlorophyll a makes up about 0.2-2.2% of dried weight of phytoplankton. Total Chlorophylls a,b,a contents range in 0.8-3.7% of dried weight, average value is 2.5% of dried weight (Parson, 1961 and Vinberg, 1960). According to the research of Foy (1987), the correlation coefficient between the phytoplankton biomass and Chlorophyll a is 0.77 and Carotenoi is 0.91.

The Vietnam sea region has characters of the tropical mesotrophic waters, receiving relatively high energy source of solar radiation that creates favorable conditions for the photosynthesis of phytoplankton. So, on the basis of measured data of the field survey in combination with using some mathematical models, the relationship, correlation between the production of the waters and the problems of marine biological resources are analyzed. The report focused on presentation of some investigated results on the distribution of Chlorophylls and carotenoids in Vietnamese waters collected during the survey of cooperated program of Fishery Ministry of Vietnam and SEAFDEC from 29 April to 31 May of 1999. Based on the data and some available methods are applied to assess the process of primary production and water quality of the coastal area.

Aims, Materials and Methods

1. Aims of project:

- To study on the Chl-a content distributed in Vietnamese waters.
- To assess the relationship of Chl-a and marine resources in the studied area.
- Based on data analysis and used the concentration of Chl-a and light quantum intensity to make a model which has been developed to estimate primary production.

2. Materials and Methods :

- Phytoplankton pigment investigations were conducted aboard the M/V SEAFDEC (from 29 April - 31 May 1999). The scientists were from Japan, Thailand, Malaysia and Vietnam.
- Water samples were collected by ICTD system equipped with 12 Niskin bottles (V=2.5-l). Light (photosynthetically available radiation, PAR). Water samples for pigment analysis were drawn from Niskin bottles tripped at the surface, 10m, 50m, halocline and bottom (0-1500m). The seawater was filtered through 0.45mm membrane filters in the lab of the ship at the moment. After that, samples were keeping in refrigerator and analyzed at laboratory of Institute of Oceanography for Chlorophyll a,b,c and their degradation products: Phaeophytill, Carotenoids. Samples were extracted in acetone solution (90%) and prevented light direction.

+ Chlorophyll a was analyzed by the luminescence spectrophotometer (Parsons R.T, Yoshiaki Maita, Carol M. Lalli, 1984).

+ Chlorophylls b,c were determined by UV-visible and Phaeophytill was measured by the fluorescence of sample before and after acidification. (Parsons R.T, Yoshiaki M., Carol M. L., 1984).

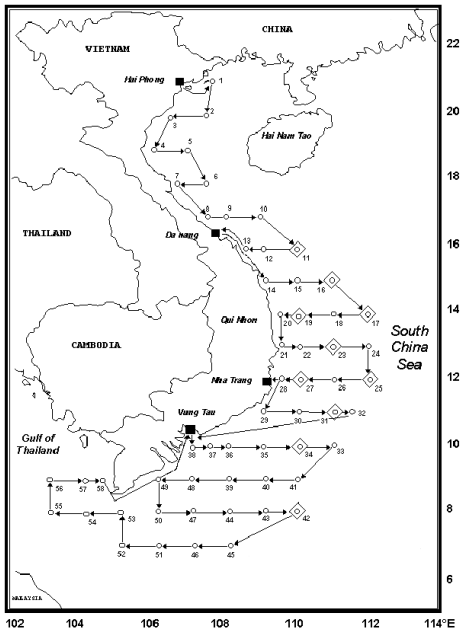
+ Total Carotenoids were measured by UV-visible spectrophotometer.

+ Light quantum intensity measurement : Datalogger, LI-1000, LI-COR, Inc.–with two sensors

In air	- LI-190SA Quantum Sensor (2p detecter), LI-COR, Inc.
Underwater	- LI-193SA Spherical Quantum Sensor (4p detecter), LI-COR, Inc.

Results

Survey was made at 58 stations which are given in the maps (Map1). The results of Chlorophylls a,b,c concentrations were analyzed in Table 1 that showed the average value of Chlorophyll a in the whole sea area of about 0.18 $mg.m^{-3}$, ranged from 0.02 to 1.41 $mg.m^{-3}$; Chlorophyll a concentration at: the surface was 0.14 $mg.m^{-3}$; 10m: 0.14 $mg.m^{-3}$; 50m: 0.20 $mg.m^{-3}$; the bottom: 0.25 $mg.m^{-3}$, ranged from 0.03 - 1.03 $mg.m^{-3}$ (Table1.1 and Table1.2).



Map.1. Location of survey stations.

Geographically the sea area was divided as follows: North Vietnam (I) including 1–7 stations; Centre Vietnam (II) including 8–32 stations; South Vietnam (III) including: 32-58 stations, and average values of Chlorophylls and primary productivity were calculated and compared.

- Region I: Average value of Chlorophyll a in this area was about 0.24 $mg.m^{-3}$±0.09 (n=28), ranged from 0.11 to 0.36 $mg.m^{-3}$ (Fig.1), most of stations were deep from 26.5 to 80m in depth and the maximum of Chl-a content was recognized at bottoms where the depth of station is < 50m. We were two parameter Chlorophylls b, c were considered and the Chl b:a ratio was reported for marine green algae or the Chl c:a ratio for diatoms. Average value of Chl-b concentration was 0.043 $mg.m^{-3}$±0.071(n=23), ranged from 0 to 0.27 $mg.m^{-3}$. For Chl-c concentration: average value was 1.51 $mg.m^{-3}$±0.48(n=23). Ratio of Chl b:a is 0.18 and Chl c:a is 6.29.
- Region II: Average value of Chlorophyll a in this area was about 0.12 $mg.m^{-3}$±0.08(n=87), ranged from 0.04 to 0.31 $mg.m^{-3}$(Fig. 2). The content of Chl-a in different depths varied in the order 75m > 50m > 0m > 10m > 150m. It is possible that maximum Chlorophylls were caused by phytoplankton sinking from the surface water because their photosynthesis might not adapt to high light. Average value of Chl-b concentration was 0.05 $mg.m^{-3}$±0.06(n=58), ranged from 0 to 0.27 $mg.m^{-3}$. For Chl-c concentration: average value was 0.08 $mg.m^{-3}$±0.09(n=58).
- Region III: The results show that average value of Chlorophyll a in this area was about 0.26 $mg.m^{-3}$± 0.20 (n=101), ranged from 0.07 to 0.77 $mg.m^{-3}$ (Fig.3). Average value of Chl-b

Table 1.1. The results were analyzed seawater sample in Vietnamese waters.

Station	Depth (m)	Chlorophyll a (mg.m^{-3})					Phaeophytill (mg.m^{-3})					Primary production (mgC/m^3, day)			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940	0.03	0.04	0.07	0.01		0.01	0.01	0.02	0.01		2.66	3.48	2.55	
ST32	3897	0.05	0.03	0.07	0.01		0.01	0.01	0.02	0.00		4.43	2.63	3.47	
ST33	3385	0.05	0.09	0.12	0.02		0.02	0.01	0.05	0.01		3.74	3.11	1.12	
ST34	1614	0.04	0.04	0.12	0.01		0.02	0.02	0.05	0.01		3.47	2.39	3.01	
ST35	156	0.04	0.05	0.08	0.02		0.04	0.02	0.02	0.01		2.88	1.67	0.74	
ST36	45	0.10	0.05		0.16		0.04	0.02		0.06					
ST37	32	0.29	0.09		0.18	0.39	0.04	0.03		0.06	0.04	25.54	3.23	3.37	
ST38	21	0.64	0.46		1.20	1.41	0.16	0.09		0.15	0.13	56.83	79.83	15.6	12.66
ST39	62	0.07	0.03		0.33		0.01	0.01		0.11		6.22	1.02	2.69	
ST40	129	0.18	0.17	0.10	0.10		0.05	0.03	0.04	0.05		4.52	1.58	0.24	
ST41	1250	0.11	0.14	0.16	0.01		0.02		0.08	0.02	0.03				
ST42	654	0.12	0.15	0.54			0.04	0.03	0.11			10.66	13.09	12.85	
ST43	147	0.09	0.11	0.18	0.05		0.05	0.06	0.07	0.02		2.55	1.1	0.35	0.03
ST44	79	0.12	0.06	0.23	0.55		0.02	0.02	0.09	0.05					
ST45	61	0.06			0.16	0.09	0.02			0.07	0.04				
ST46	51	0.13			0.31	0.08	0.03			0.04	0.03				
ST47	42	0.05	0.06		0.26		0.02	0.02		0.10					
ST48	32	0.07	0.13		0.31	0.11	0.02	0.02		0.04	0.02				
ST49	20	0.23	0.09		0.17		0.02	0.02		0.03					
ST50	33	0.11	0.23		0.50		0.03	0.03		0.09		9.75	15.66	2.42	
ST51	44	0.12	0.11		0.42		0.03	0.04		0.14		10.66	9.03	7.94	
ST52	51	0.09	0.18		0.47	0.13	0.03	0.02		0.16	0.04	4.74	5.52	2.12	
ST53	34	0.09	0.92		0.62		0.15	0.18			0.21				
ST54	26	0.26	0.38		1.11		0.08	0.08		0.15		2.17	10.3	5.99	
ST55	70	0.10		0.76	0.38	0.20	0.03		0.11	0.12	0.08	8.88	13.29	14.43	1.82
ST56	57	0.10	0.12		0.59	0.20	0.04	0.06		0.23	0.07				
ST57	23	1.21	0.49		0.38	0.50	0.32		0.14	0.10	0.15	33.06	3.61	1.42	0.23
ST58	34	0.32	0.33		0.67		0.09	0.08		0.17					

Table 1.1. (Continued).

St	Depth (m)	Chlorophyll b (mg.m^{-3})					Chlorophyll c (mg.m^{-3})					Carotenoids(mg.m^{-3})			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940		0.007	0.046				0.003	0.006			0.040	0.008		0.001
ST32	3897		0.008	0.048	0.011				0.041			0.027	0.012	0.040	0.015
ST33	3385	0.117	0.005	0.046			0.162	0.044	0.053			0.023	0.004	0.036	0.075
ST34	1614	0.055	0.034	0.080			0.061		0.081			0.020	0.020	0.050	0.010
ST35	156	0.014	0.025	0.014	0.017		0.020	0.029	0.010	0.010		0.023	0.006	0.035	
ST36	45	0.042	0.033		0.093		0.036	0.026		0.083			0.080		
ST37	32	0.036	0.035		0.090		0.025	0.028		0.076			0.004	0.070	
ST38	21	0.340		0.017	0.597	0.038			0.013	0.714	0.017		0.026	0.008	
ST39	62	0.022					0.027						0.010	0.003	
ST40	129		0.007	0.034	0.003		0.028		0.027			0.010	0.008	0.042	0.035
ST41	1250	0.002	0.068				0.004	0.073	0.033			0.070	1.569		
ST42	654	0.008	0.039	0.064			0.004	0.049	0.144			0.001	0.024	0.012	
ST43	147	0.008	0.039	0.070	0.064		0.004	0.049	0.157	0.144		0.012	0.009	0.012	0.013
ST44	79	0.114	0.106	0.067	0.344		0.206	0.197	0.133	0.486			0.017	0.044	
ST45	61	0.034		0.006		0.046	0.039		0.004		0.046				0.010
ST46	51	0.028			0.034	0.028	0.035			0.028	0.060				0.011
ST47	42		0.006		0.117			2.36	0.162			0.102			
ST48	32	0.048			0.060	0.022	0.054			0.064		0.005	0.006		
ST49	20	0.060	0.049		0.046		0.064	0.123		0.126		0.026	0.003		
ST50	33	0.069	0.144		0.082		0.150	0.247		0.151					0.027
ST51	44	0.109	0.044		0.522		0.128	0.042		0.610			0.015		
ST52	51	0.028				0.104	0.025					0.004	0.111	0.016	0.113
ST53	34	0.030	0.026		0.154		0.012			0.163		0.046			0.046
ST54	26	0.035			0.077		0.030	0.071		0.078			0.020		
ST55	70	0.009		0.043	0.096	0.037			0.018	0.095	0.028	0.006	0.02	0.172	
ST56	57	0.019			0.102	0.078	0.003			0.064	0.093	0.005	0.222	0.014	0.177
ST57	23	0.074	0.119		0.035	0.050	0.050	0.094		0.026	0.061	0.005	0.172		
ST58	34	0.027	0.017		0.133		0.011	0.010		0.140		0.033	0.029		

Table 1.2. The results were analyzed seawater sample in Vietnamese waters.

St. No.	Depth (m)	Chlorophyll b (mg.m^{-3})					Chlorophyll c (mg.m^{-3})					Carotenoids(mg.m^{-3})			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST31	2940		0.007	0.046				0.003	0.006			0.040	0.008		0.001
ST32	3897		0.008	0.048	0.011				0.041			0.027	0.012	0.040	0.015
ST33	3385	0.117	0.005	0.046			0.162	0.044	0.053			0.023	0.004	0.036	0.075
ST34	1614	0.055	0.034	0.080			0.061		0.081			0.020	0.020	0.050	0.010
ST35	156	0.014	0.025	0.014	0.017		0.020	0.029	0.010	0.010		0.023	0.006	0.035	
ST36	45	0.042	0.033		0.093		0.036	0.026		0.083			0.080		
ST37	32	0.036	0.035		0.090		0.025	0.028		0.076			0.004	0.070	
ST38	21	0.340		0.017	0.597	0.038			0.013	0.714	0.017		0.026	0.008	
ST39	62	0.022					0.027						0.010	0.003	
ST40	129		0.007	0.034	0.003		0.028		0.027			0.010	0.008	0.042	0.035
ST41	1250	0.002	0.068				0.004	0.073	0.033			0.070	1.569		
ST42	654	0.008	0.039	0.064			0.004	0.049	0.144			0.001	0.024	0.012	
ST43	147	0.008	0.039	0.070	0.064		0.004	0.049	0.157	0.144		0.012	0.009	0.012	0.013
ST44	79	0.114	0.106	0.067	0.344		0.206	0.197	0.133	0.486			0.017	0.044	
ST45	61	0.034		0.006		0.046	0.039		0.004		0.046				0.010
ST46	51	0.028			0.034	0.028	0.035			0.028	0.060				0.011
ST47	42		0.006		0.117			2.36	0.162			0.102			
ST48	32	0.048			0.060	0.022	0.054			0.064		0.005	0.006		
ST49	20	0.060	0.049		0.046		0.064	0.123		0.126		0.026	0.003		
ST50	33	0.069	0.144		0.082		0.150	0.247		0.151					0.027
ST51	44	0.109	0.044		0.522		0.128	0.042		0.610			0.015		
ST52	51	0.028				0.104	0.025					0.004	0.111	0.016	0.113
ST53	34	0.030	0.026		0.154		0.012			0.163		0.046			0.046
ST54	26	0.035			0.077		0.030	0.071		0.078			0.020		
ST55	70	0.009		0.043	0.096	0.037			0.018	0.095	0.028	0.006	0.02	0.172	
ST56	57	0.019			0.102	0.078	0.003			0.064	0.093	0.005	0.222	0.014	0.177
ST57	23	0.074	0.119		0.035	0.050	0.050	0.094		0.026	0.061	0.005	0.172		
ST58	34	0.027	0.017		0.133		0.011	0.010		0.140		0.033	0.029		

Table 1.2. (Continued).

St.	Depth (m)	Chlorophyll b (mg.m^{-3})					Chlorophyll c (mg.m^{-3})					Carotenoids(mg.m^{-3})			
		0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom	Cline layer	0m	10m	50m	Bottom
ST1	34		0.165		0.028		0.471	0.178		0.022					
ST2	29				0.009		0.417					0.009			0.022
ST3	28	0.195	0.002				0.204			0.500		0.009	0.024		0.019
ST4	26	0.059	0.033		0.023		0.058	0.018	0.004			0.020	0.023		0.032
ST5	58		0.011	0.186	0.022		0.107	0.047				0.008	0.011		0.031
ST6	80		0.013	1.061	0.038		0.011					0.010	0.009		0.034
ST7	40	0.640	0.103							0.025			0.002		0.011
ST8	45				0.006								0.007		0.004
ST9	75	0.021	0.030		0.048		0.022		0.056	0.072		0.002	0.001	0.024	0.012
ST10	107	0.178	0.169	0.243				0.158	0.287			0.010	0.010	0.020	0.080
ST11	847	0.014		0.016	0.040		0.024	0.007	0.030	0.010				0.005	
ST12	105	0.048					0.037	0.014				0.004	0.003	0.007	
ST13	42				0.010			0.031	0.013				0.021	0.001	
ST14	36	0.009										0.029	0.020	0.002	
ST15	412	0.022		0.005			0.095		0.001			0.015	0.014	0.016	0.013
ST16	1230														
ST17	2100		0.023	0.075	0.06		0.006	0.013	0.088			0.010	0.018		
ST18	2200			0.010	0.020			0.204		0.328					
ST19	653	0.029					0.034	0.004		0.801		0.006	0.013	0.014	0.004
ST20	143		0.233	0.006	0.022		0.066	0.276				0.020		0.020	0.045
ST21	134	0.035			0.002							0.021	0.027	0.027	0.005
ST22	1920	0.008		0.002	0.074		0.007		0.008	0.231				0.016	
ST23	2703	0.006	0.138	0.015	0.013			0.131		0.022		0.012		0.011	
ST24	3332	0.011	0.019	0.005	0.228		0.007	0.030		0.325		0.011	0.005	0.027	
ST25	4117		0.138		0.032		0.046	0.153	0.004	0.038		0.042			0.002
ST26	2889	0.006	0.025	0.012	0.009		0.002	0.143	0.010	0.011		0.020		0.017	0.020
ST27	1734	0.055	0.017	0.061	0.015		0.143	0.152	0.196	0.144					
ST28	110	0.050	0.036	0.021	0.083		0.187	0.033	0.019	0.095			0.010	0.011	
ST29	72	0.114	0.009	0.011	0.033		0.127	0.003		0.010		0.005	0.007	0.028	0.040
ST30	648	0.088		0.004	0.064		0.081			0.072				0.092	0.015

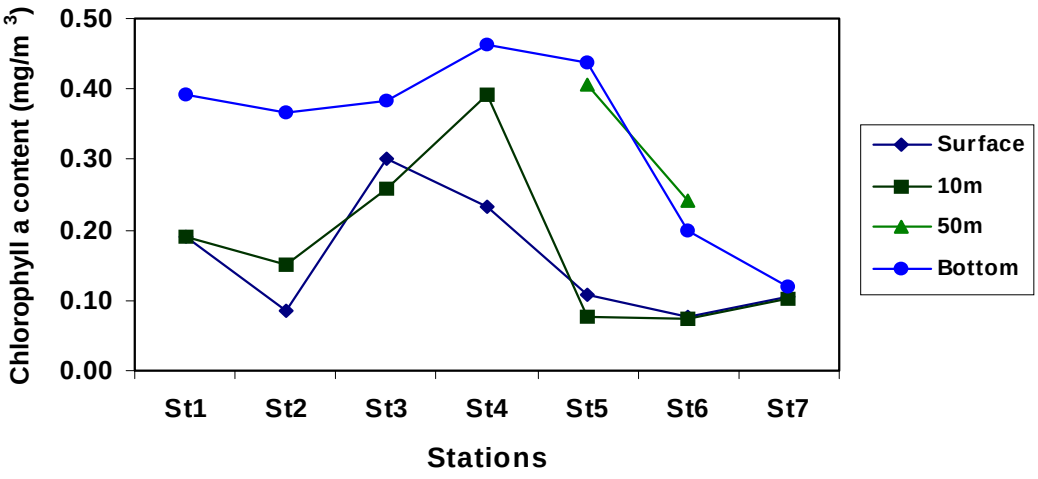


Fig. 1. Distribution of Chlorophyll a in seawater of region I.

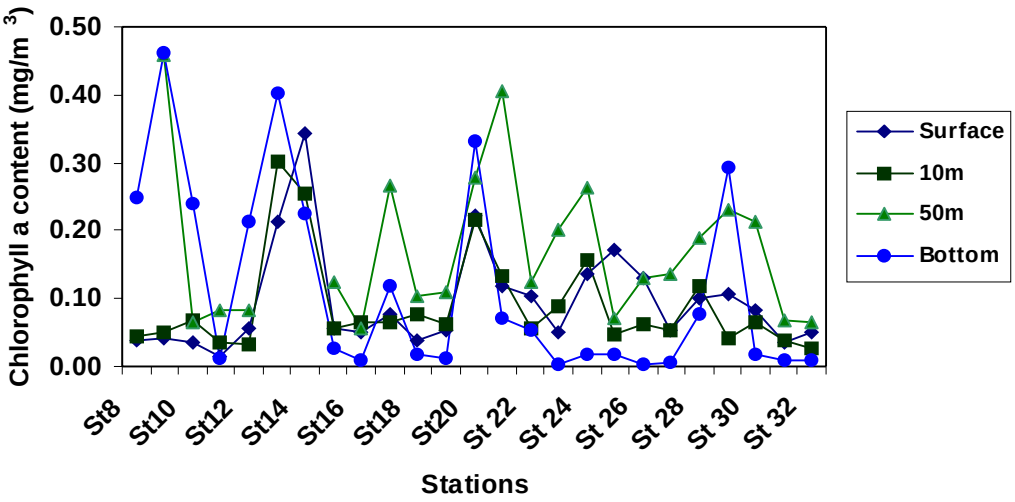


Fig. 2. Distribution of Chlorophyll a in seawater of region II.

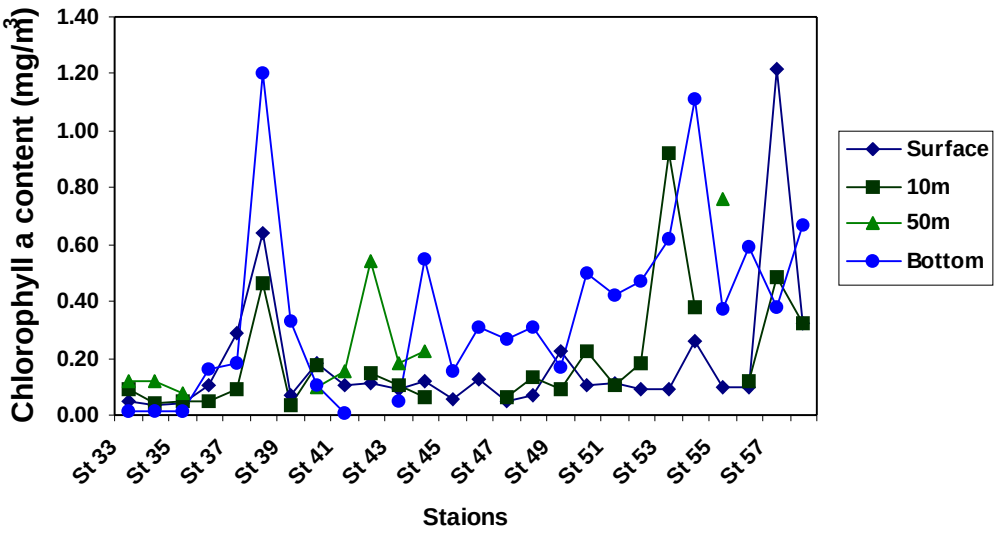


Fig. 3. Distribution of Chlorophyll a in seawater of region III.

concentration was 0.07 $mg.m^{-3}$±0.1(n=90), ranged from 0 to 0.6 $mg.m^{-3}$. For concentration of Chl-c: the average value was 0.09 $mg.m^{-3}$±0.12(n=90) ranged from 0 to 0.33 $mg.m^{-3}$. The values in the South Vietnam sea were higher than in the other parts perhaps because they relate to near shore waters and many river mouths entering into the sea.

The average Chlorophyll a content for individual region varied in following order: III > I >II, it represents that there was highest value in the South Vietnam sea. The concentration of Chlorophylls in different depths varied in the order 75 > 50 > 0 > 10 > over 150m. The above results show that the Chlorophyll a content in offshore region of the South China Sea (Vietnamese waters, Area IV) was lower than in nearshore region which related the source of nutrients inputted from rivers (Table1.1).

The results of Phaephytill and Carotenoids are shown in Tables 1 - 58, the average value of Phaeophytill in studied area was about 0.062 $mg.m^{-3}$. The Phaeophytill concentration was lowest at offshore station, especially, at some nearshore stations the phytoplankton was determined to be in withering stages. Average value of Carotenoids concentration was very low about 0.052 $mg.m^{-3}$± 0.12. At many stations the Carotenoids content could not be determined (Table1.2).

Phytoplankton pigments depend upon the ecological and environmental factors. Therefore, a quantitative analysis of Chlorophylls is main information to estimate the primary production. According to Herman the irradiance of light intensity was decreased at different depths. The profile of light quantum I (z) was measured by the equation over depths (z):

$$I(z) = I(z-1)*Exp^{-K(z)} \qquad (1)$$

- z is depth of station (unit - m)
- Kz : is decreasing coefficient : Kz = 0.18 when z £ 12m
  = 0.03 + 0.05*Chl-a when z > 12.

Our numerical model is based on the construction of production profile from the relationship between photosynthesis and light. In our representation, the dependence of primary production P(I) per unit mass of Chlorophylls (mgC[mgC Chl a]$^{-1}$h-^{1}) on available light is given by photosynthesis light saturation curve (Jassby, Platt, 1976; Platt, Jassby, 1976; Chalker, 1980):

$$P(I) = Pm\tanh(aI/Pm) - R \qquad (2)$$

- I is the irradiance (PAR- photosynthetically active radiation) -$w.m^{-2}$.
- a is the initial slope of light saturation curve - mgC[Chl a]$^{-1}$. $W^{-1}.m^{2}.h^{-1}$
- Pm is the assimilation number - mgC[Chl a]$^{-1}.h^{-1}$
- R is measure of dark respiration mgC[Chl a]$^{-1}.h^{-1}$. The magnitude of R is generally » 0.1 in our self water and small enough to be ignored in equation (2). According to Herman *et al.*, 1981; Herman, Platt, 1983 the validity of a and Pm was used in tropical sea that is Pm=3.7; a =0.08.

Absolute production profile in units of ($mgC.m^{-3}.h^{-1}$) is obtained by multiplying the production P(I) of equation (2) by the Chlorophyll a profile (units of $mgC.m^{-3}$) as measured with the pump profile and is given by:

$$Pv(z) = P(z) \,.\, B(z) \qquad (3)$$

- B(z) : is the Chlorophyll concentration and z is the depth in meters. The daily profile, Cd in unit of ($mgC.m^{-3}.d^{-1}$), can be obtained by integrating equation (4) over time t:

$$Cd(z) = \int_{0}^{24hr} Pv(z,t)dt \qquad (4)$$

The equation of I (z) was measured based on the data of light quantum intensity. From the model production curve Pv (z) of equation (3), we measured the primary production at layers to

collect samples and analyzed Chlorophyll (Table1.1).

- Region I: Average value of primary production at: the surface was about 9.57mgC.m^3.day^{-1}±3.66, ranged from 6.75 – 15.8 mgC.m^3.day^{-1}; 10m layer: 5.42 mgC.m^3.day^{-1}± 1.29, ranged from 3.58 – 6.56 mgC.m^3.day^{-1}.
- Region II: Average value of primary production at: the surface was about 4.73mgC.m^3.day^{-1}±5.24, ranged from 0.33 – 15.08 mgC.m^3.day^{-1}; 10m layer: 2.0 mgC.m^3.day^{-1}± 1.42, ranged from 0.47 – 3.96 mgC.m^3.day^{-1}; 50m layer: 1.02 mgC.m^3.day^{-1}± 0.09.
- Region III: Average value of primary production at the surface was about 11.88 mg C.m^3.day^{-1} ±14.75, ranged from 2.17–56.8 mgC.m^3.day^{-1}; 10m layer: 10.44 mgC.m^3.day^{-1}± 19.14, ranged from 1.02 – 79.83 mgC.m^3.day^{-1}; 50m layer: 4.86 mgC.m^3.day^{-1}± 5.11, ranged from 0.24 – 15.60 mgC.m^3.day^{-1}.

The results of primary production measured by the above model showed that the primary production in region III was highest, average value varied in order III > I > II. The region III is euphotic waters, because it is nearby a mouths of Me Kong Delta. The waters were provided nutrients from the runoff river entering the sea. The phytoplankton growth rates depend on the nutrient recycling processes and light intensity of regions.

Discussion

The distribution of Chlorophyll a was analyzed at the depths of different transects: - the transects perpendicular to the coastline (5 transects) and the transect parallel to the coastline.

- Transect I: including 4 stations (T21, T22, T23, T24) (Fig. 4.1) located from 13°N latitude 109°30' E to 111°59' longitude. The temperature was measured from the depths of 0m to 1500m where it was approximately 3°C. The Chlorophyll a content ranged from 0.05 to 0.33 mg.m^{-3}, average value was 0.14 ± 0.10 mg.m^{-3} and the highest value was found at St 20 located near the coastline in this transect. The distribution pattern of Chlorophyll a was changed in different layers while the light intensity decreased with the depths.

- Transect II: including 4 stations (T28, T27, T26, T25) (Fig. 4.2) located from 12°N latitude – 109°30'E to 111°59' longitude. This region has slope topography and very deep bottom (ranged from 110m – 4200m). Chlorophyll a contents in this transect ranged from 0.01 – 0.19 mg.m^{-3}, average value was 0.08 ± 0.06 mg.m^{-3}.

- Transect III: including 5 stations (T38, T37, T35, T35, T34) (Fig. 4.3) located in southeastern part of Vietnam which is very rich of marine resources. The coastal zone of this area has developed mangrove forests and large estuaries. The Chlorophyll a content at each station was different between the coastal stations and offshore stations, the average value was 0.29 ± 0.41 mg.m^{-3}, ranged from 0.04 – 1.41 mg.m^{-3}.

- Transects IV and V: including 13 stations (Fig. 5). Almost stations are located at shallow waters, the depth is < 150m (depths ranged from 20 – 50m). This region is influenced by runoff of Maekong river into the sea through many estuaries. Its ecology is very particular and biodiversity is very abundant: estuaries, tidal flats, and mangroves. Therefore, the variation of Chlorophyll a distribution in the seawater is very complex. The freshwater input into the region causes the variation of salinity. This effects to the vertical distribution of phytoplankton species. Simultaneously, the nutrient contents also change strongly and depend upon each period of the river. Although, the seawaters is impacted from out side, the Chlorophyll a concentration in transects IV, V is not different, it still keeps the dimension: the shorter distance to the coastline the region has, the higher Chlorophyll a concentration it has, the value of Chlorophyll a at transect IV ranges from 0.03–0.33 mg.m^{-3} ; transect V ranges from 1.01–1.11mg.m^{-3}.

-Transect VI: is parallel with the coastline (Fig. 5) and located from 16°N – 9°N latitude on 110°E longitude, the stations are outspread in many different regions, but the observed results showthat the Chlorophyll a concentration in depths was changed little between surface and the weakest light intensity layer. The vertical distribution of Chlorophyll at stations is rather homogeneous. Therefore, at offshore stations (about 120km far from the continent), the Chlorophyll content is stable and is not effected by the impacts from the coastal zone, the average value is 0.08 ± 0.03 $mg.m^{-3}$.

Above analysed results show that transects (I, II, II, IV) are perpendicular to the coastline. The depths increase from the coast to offshore and the Chlorophyll a distribution is comparative in almost transects (at near shore stations, the concentration is higher than at the offshore ones). According to the data collected in 1986 (Table 3) (Nguyen Tac An and Vo Duy Son,1999.), the average value of Chlorophyll a in offshore is 0.37 $mg.m^{-3}$; in 1999, the value is 0.18 ± 0.04 $mg.m^{-3}$ which is smaller than other regions of the coastal zone. The variation of Chlorophyll a depends on depths of stations (the maximum value is often reached at the photosynthesis layers where the light intensity is approximately 25% of light intensity in surface).

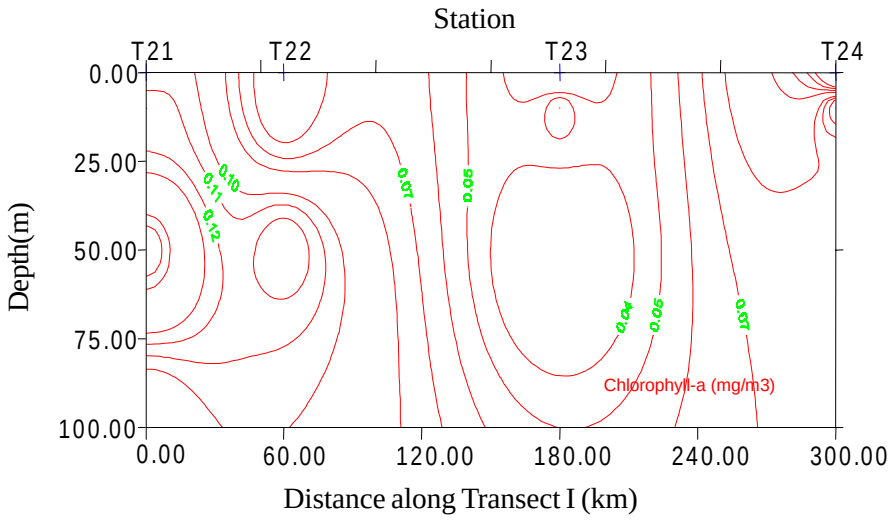


Fig. 4.1. The verticle profile of chlorophyll a from transects I.

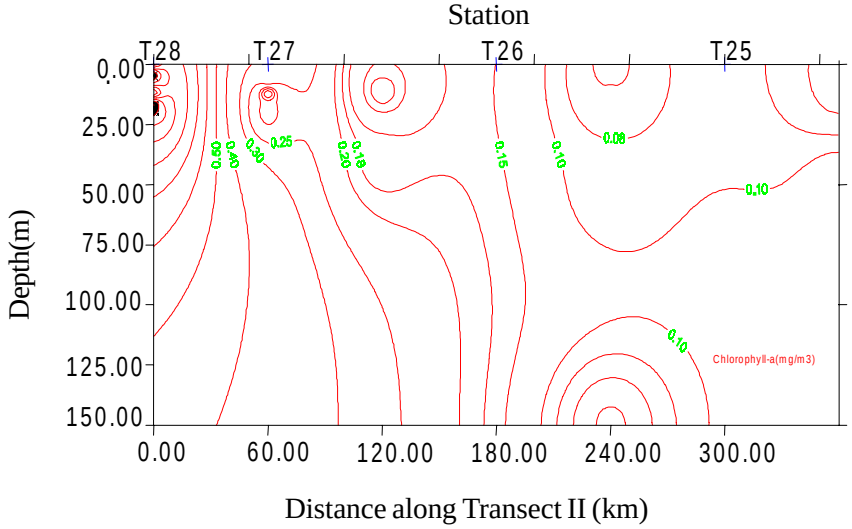


Fig. 4.2. The verticle profile of chlorophyll a from transects II.

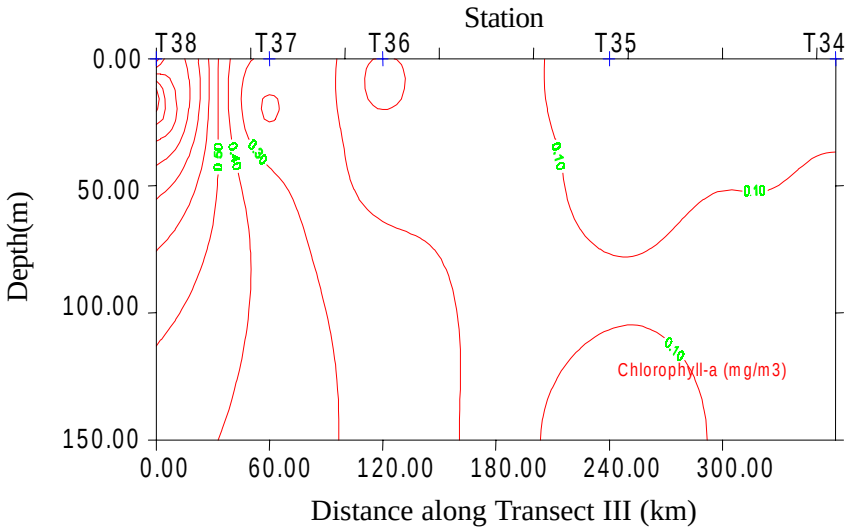


Fig. 4.3. The verticle profile of chlorophyll a from transects III .

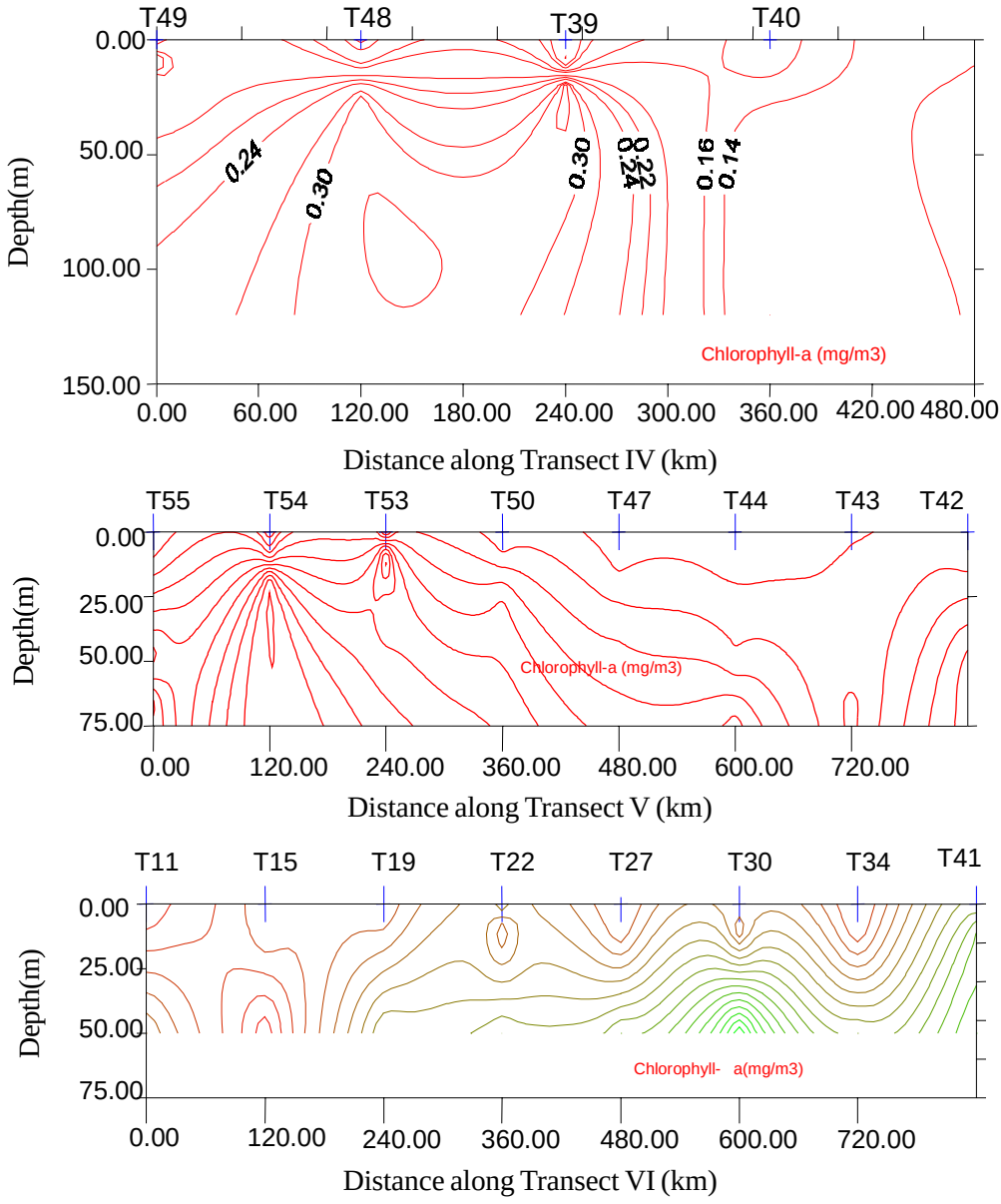


Fig. 5. The verticle profile of chlorophyll a from Transects IV,V and VI.

Table 3. The results studied in offshore of Vietnam in 1986.

Long – Lat.	P(mgC/m^3,day)	Chlorophyll (mg/m^3)			Assimilation Coefficient
		a	b	c	mgC/mgChl a.day
4^{O}5'N-106^{O}05'7E	0.31	0.22	0.029	0.174	1.39
9^{O}39'N-108^{O}32'E	0.24	0.16	0.048	0.263	1.46
10^{O}15'5N-107^{O}05'3E	1.65	1.24	0.180	0.950	1.33
9^{O}52'N-107^{O}00E	1.1	0.54	0.103	0.555	2.03
9^{O}51'N-107^{O}00E	1.6	0.74	0.131	0.711	1.16
9^{O}45'N-107^{O}09E	0.98	0.43	0.061	0.406	2.26
8^{O}47'N-107^{O}01E	0.13	0.09	0	0.128	1.31
9^{O}04'N-108^{O}44E	0.07	0.08	0.015	0.115	0.86
9^{O}51'N-107^{O}01'3E	3.1	0.73	0.127	0.684	4.25
13^{O}24'N-110^{O}050'7E	0.07	0.08	0.202	0.446	0.85
17^{O}40'N-116^{O}25E	0.08	0.05	0	0	0.84
19^{O}35'N-119^{O}15'E	0.25	0.12	0.006	0.034	2.17

Data in Table 3 show that the Chlorophyll a in off shore is continuous data, but the results reflect characteristics of ecology areas: in off shore of Vietnam sea. The Chlorophyll a is much lower than the other regions such as: the coastal zone, upwelling region, Coral reefs. The result studied in Vietnam seawaters in the stage 1979 - 1998 showed that Chlorophyll a concentration is higher in the cultural area, shallow waters. Averaged value in shallow waters is ranged from 0.29 - 6.10mg.m^{-3}; in near shore is ranged from 0.07 - 1.65 mg.m^{-3}; in the off shore is very lower which were ranged from 0.02 - 0.40 mg.m^{-3}. The Chlorophyll content distributed from 140m to 160m depth in off shore. In the coastal waters, the Chlorophyll a concentration is maximum in 5 -15m depth with light intensity is about 1000 -4000 lx which is useful for the photosynthesis phytoplankton or on thermocline layer and halocline. On the other hand, Chlorophyll is not factor that effects to the marine resources, but it relates to the biological production. Additionally, based on the result studied of Nguyen Tac An,1985 , the Chlorophyll concentration occupied about 0.14% of phytoplankton fresh weight. Average value of Chlorophyll a is about 0.18 mg.m^{-3}, ranged from 0.02 - 1.41 then biomass of phytoplankton is about 128 freshmg.m^{-3}, ranged from 14 - 1007 freshmg.m^{-3}.The results is agree with the data publishing by Sorokin Yu.I. *et al,*1982 and Nguyen Tac An,1989. Biomass of phytoplankton in coastal waters is average value about 500 freshmg.m^{-3}, The primary production force is average value from 20 -40mgC.m^{-3}.day^{-1} and it is a base food strain for zooplankton developing. Usually, the pigment content of phytoplankton varies strongly and depends on ecological conditions, physiological state, it is also an important information source to consider the production. Based on the changes of phytoplankton pigment, the nutrient changes as well as the impacts of human activity to the seawaters are also known.

Comparison of the results of primary production measured by model and studied in 1986 shows that the primary production force in offshore is lower than in coastal zone. At the observed stations, Chlorophyll a reaches to maximum value at the deep layers while the primary production does not reach to maximum value, the maximum value is reached in the surface layer. At the surface, the nutrients are more often supplied from cycle of nutrient. Simultaneously, primary production value depends on the cycle nutrients of waters (in offshore, the nutrients depend on the internal waters). In offshore, the high primary production is only observed in upwelling region because of its specific characteristics. The upwelling only appears in certain periods of year. The primary production value is ranged from 0.3 - 79mgC.m^3, to help assessment assimilation coefficient which is range from 1 - 56mgC.mgChla^{-1}.day^{-1} (Nguyen Tac An,1989.)

The characteristics of vertical distribution of production depend on the phytoplankton distribution, solar radiation, thermocline layer, halocline layers and the processing supplement nutrients for the photosynthesis of phytoplankton. The distribution curve of primary production may have two maxima in water column: at surface or thermocline, because, the surface is supplemented by nutrients making

good conditions for the phytoplankton development. The phytoplankton community will photosynthesize maximally at certain daytime and depths in the water column corresponding to optimum conditions.

Conclusion

The concentration of phytoplankton Chlorophyll a (the main photosynthetic pigments) in the South China Sea, Area IV (Vietnamese Waters) was investigated from 29 April – 31 May, 1999. The analyzed results on the content of Chlorophyll a show that the average value of pigments of phytoplankton in the studied area was not high, ranged between 0.03-1.03 $mg.m^{-3}$. In all 58 stations from the north to the south, the Chlorophyll a contents at different depths: at

The contents of Chlorophylls were not much different between layers and have tendency of increase with depths. The Chlorophylls at the bottom were higher than at the surface 1.7 times.

- Region I: Average value of Chlorophyll a in this area was about 0.24 $mg.m^{-3}$± 0.09 (n =28), ranged from 0.11 to 0.36 $mg.m^{-3}$.
- Region II : Average value of Chlorophyll a in this area was about 0.12 $mg.m^{-3}$± 0.08(n = 87), ranged from 0.04 to 0.31 $mg.m^{-3}$. The content of Chl-a in different depths varied in the order 75m > 50m > 0m > 10m > 150m.
- Region III : The results show that average value of Chlorophyll a in this area was about 0.26 $mg.m^{-3}$± 0.20, ranged from 0.07 to 0.77 $mg.m^{-3}$.

  Contents of Phaeophytin and Carotenoids were negligible, the average values of Phaeophytin only reached to 0.06 $mg.m^{-3}$ and Carotenoids – 0.052 $mg.m^{-3}$ ± 0.12 .

The distribution of Chlorophyll a was analyzed at the depths of different transects: - the transects perpendicular to the coastline (5 transects) and the transect parallel to the coastline:

-Transect I,II,III,IV,V: the transects perpendicular to the coastline. The temperature was measured from the depths of 0m to 1500m where it was approximately 3°C. The Chlorophyll a content ranged at transect I: from 0.05 to 0.33 $mg.m^{-3}$, average value was 0.14 ± 0.10 $mg.m^{-3}$.At Transect II: ranged from 0.01 – 0.19 $mg.m^{-3}$, average value was 0.08 ± 0.06 $mg.m^{-3}$.; at transect III : the average value was 0.29 ± 0.41 $mg.m^{-3}$, ranged from 0.04 – 1.41 $mg.m^{-3}$. At Transect IV: ranges from 0.03 –0.33 $mg.m^{-3}$; transect V ranges from 0.01 –1.11$mg.m^{-3}$.

-Transect VI: the transect parallel to the coastline. The stations are outspread in many different regions, but the observed results show that the Chlorophyll a concentration in depths was changed little between surface and the weakest light intensity layer. The vertical distribution of Chlorophyll at stations is rather homogeneous, the Chlorophyll content is stable and is not effected by the impacts from the coastal zone, the average value is 0.08 ± 0.03 $mg.m^{-3}$.

A model is used in the report for the relationship between Chlorophyll a content and light intensity to estimate the primary production. Average value of primary production was about 9.04 $mgC.m^3.day^{-1}$ at the surface and 2.63 $mgC.m^3.day^{-1}$ at the bottom. Concretely, in the region III, the primary production was 9.03 $mgC.m^3.day^{-1}$ higher than the region I (6.63 $mgC.m^3.day^{-1}$) and region II (2.58 $mgC.m^3.day^1$)

The result studied for Chlorophyll concentration to estimate phytoplankton biomass and assessment a assimilation coefficient. Phytoplankton biomass is range from 14 - 1007 $freshmg.m^{-3}$ and assimilation coefficient is range from 1 -56$mgC.mgchla^{-1}.day^{-1}$

Our research results on the distribution of phytoplankton Chlorophylls contents and primary production in Vietnamese waters will be using basically to assessment fishery resources.

Propose

We would like the projects to supplement the detail data for fluorescense(digital data) and to help us could be comparison with the measurement result. We would like to co-operating with articipant in projects to discussion about our subject studied for us.

Acknowledgement

We would like express our sincere thanks to the leaders of Fishery Ministry of Vietnam, SEAFDEC, the Research Institute of Marine Products, Institute of Oceanography, Nhatrang and Our colleagues in other research agencies who participated in the program and the crew of M/V SEAFDEC ship for precious help in data collection and supply to complete the research.

References

An Nguyen tac *editor*. 1985. Primary production in the coastal zone in Vietnam. The Scientific Reports in 48.05.13 Project, 132 p.

An Nguyen Tac. 1989. Biological Production in coastal of Vietnam and ecological condition . Thesis of Doctor Science (Russian), 430 p.

An Nguyen Tac. 1995. Biological productivity of Vietnam marine waters. *Collection of Marine Research Works*, Vol. VI, pp. 177 –184.

An Nguyen Tac and Vo Duy Son. 1989. Hydrographic and Biogeochemical Studies in the Mekong Delta, Vietnam. Biogeochemistry of River in Tropical South and South East Asia, pp.285–296.

An Nguyen Tac. 1989. Energy flow in the tropical marine shelf ecosystems of Vietnam, Marine Biology, No 2, pp. 9 -15.

Alex W. Herman, Trevor Platt. 1986. Primary production profiles in the ocean : Estimtion from a chlorophyll/ light model. *Oceanological Acta*, Vol 9, No 1, pp.31 – 40.

Andreu Morel. 1986. Chlorophyll –specific scattering coefficient of phytoplankton. A simplified theoretical approach. *Deep –Sea Research*. Vol 34, No 7, pp.1093 – 1105.

Cirenko L.A. 1980. The information value of Chlorophyll index. *Hydro biologica*l , Vol 4 No 24 . pp. 49 –53.

Foy R.H. A. 1987. comparison of Chlorophyll and carotenoid concentration as indicators of algal.*Freswater Biol* , Vol 17, No 2 .pp. 237 –250.

Huang Liangmin. 1988. Distribution of Chlorophyll a and estimattion of primary productivity in the waters around Nansha Islands. Proc. On marine biology of the South China Sea. pp.262–274

Parson T.R. 1961. On the pigment composition of eleven species of marine phytoplankters, J.*Fish. Res*, Board. Canada, Vol 18, No6, pp.1017 – 1025.

Parsons R.T, Yoshiaki Maita, Carol M. Lalli. 1984. Amanual of chemical and Biological Methods for seawater analysis, Pergamon Press, 169 p.

Raymont E.G. Jonh. 1983. Plankton and productivity in the oceans, Vol 1- Phytoplanton, 567 p.

Robert R. Bidigare, Tamara J.Frank,. 1986. Colleen Zastrow and James M.Brooks.The distribution of Algal chlorophylls and their degradation products in Southern Ocean. . *Deep –Sea Research*. Vol 34, No 7, pp. 923 – 937.

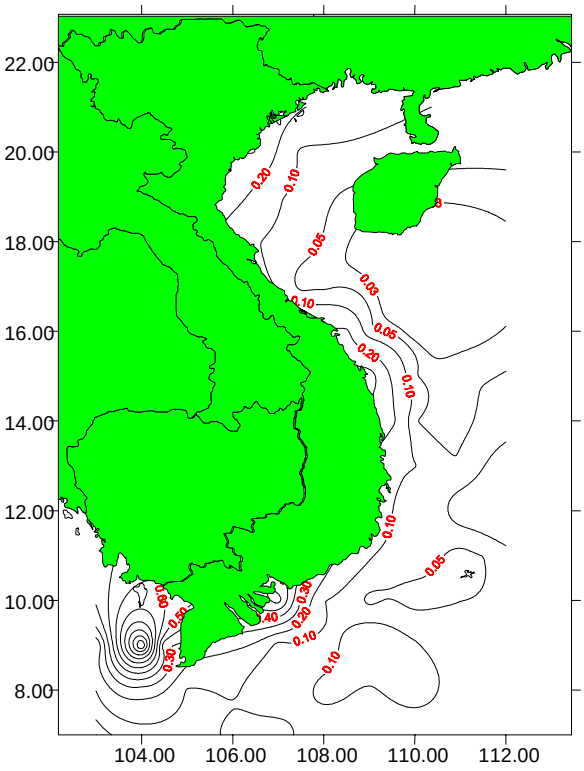
Sorokin Yu. I, Tyapkin V.S, An Nguyen Tac. 1982. Primary production of phytoplankton in the coastal waters of centre Vietnam. Marine Biology, No 6, pp.12 -17.

Vedernhikov V.I. 1988. Assimilation in index of phytoplankton, *Hydro Biological*. pp. 92-107.

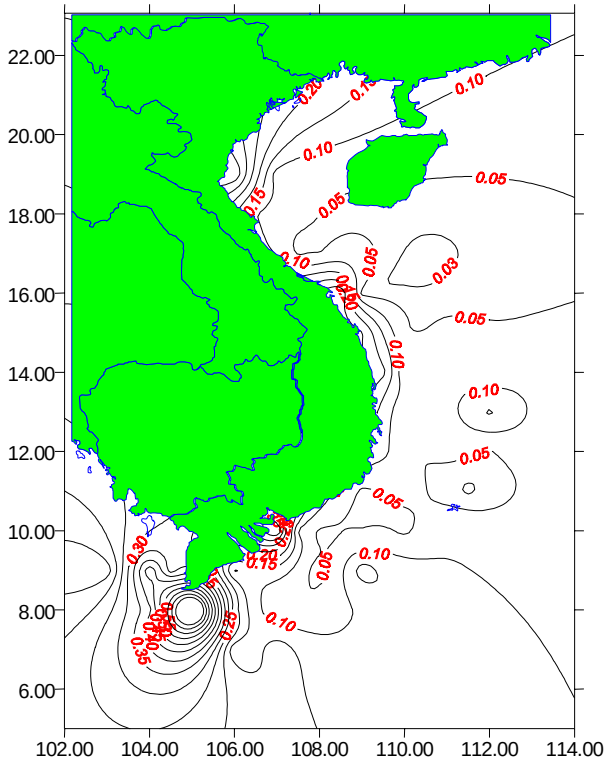
Vinberg G.G. 1960. The primary production in water body, Minks Press, 329 p.

Appendix

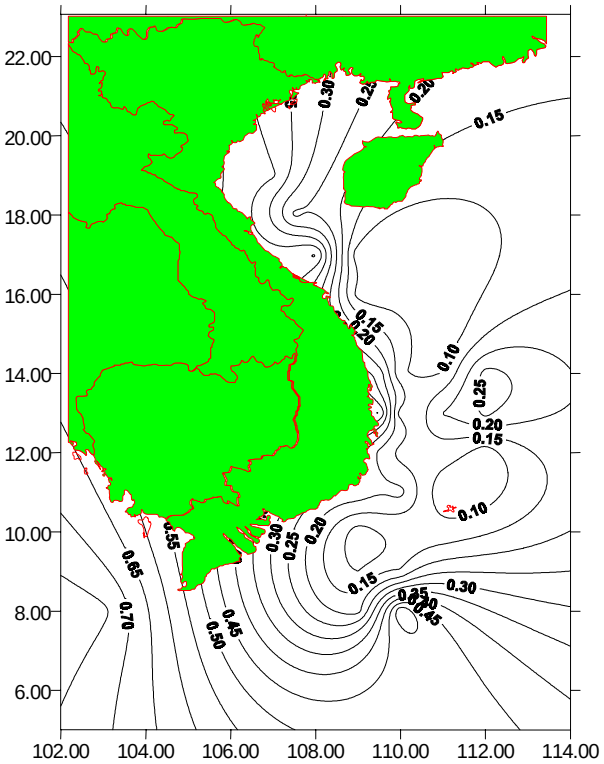
The maps of distribution Chlorophyll a and Phaeophytill



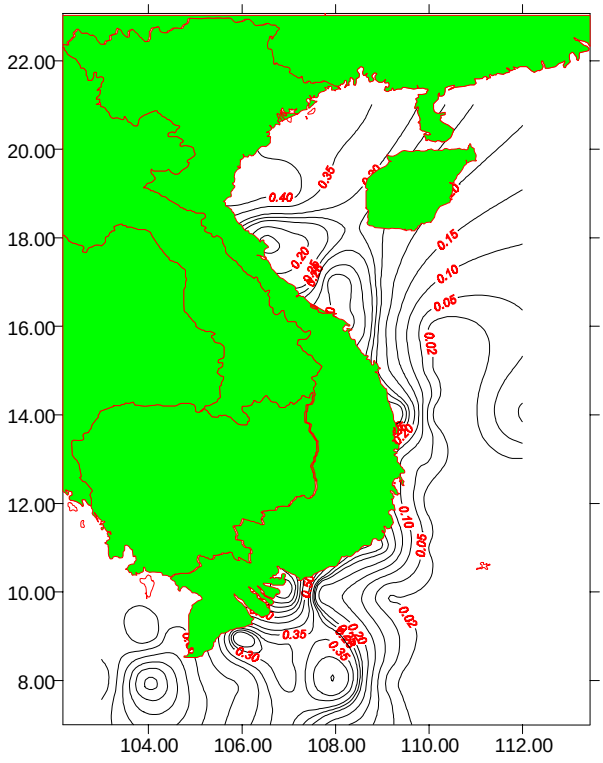
Distribution of Chlorophyll a at surdace layer. ($mg.m^{-3}$)



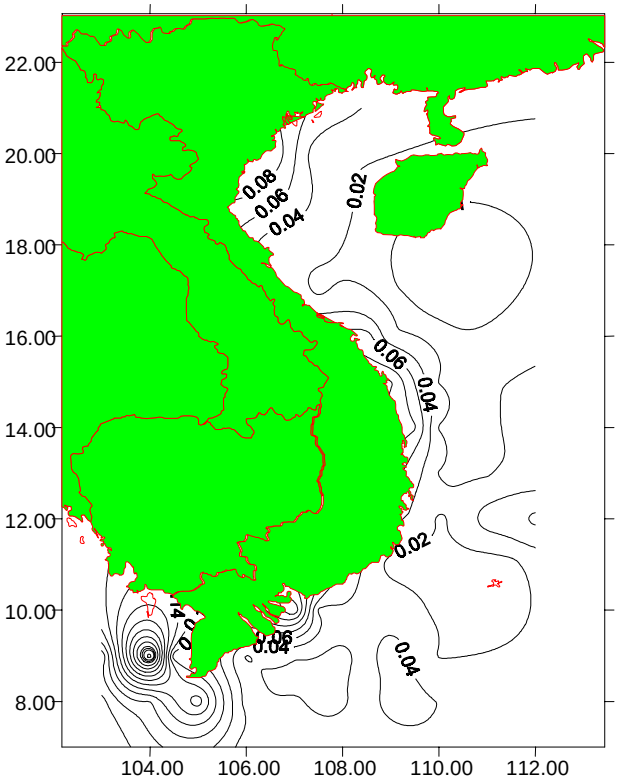
Distribution of Chlorophyll a at 10 m layer. ($mg.m^{-3}$)



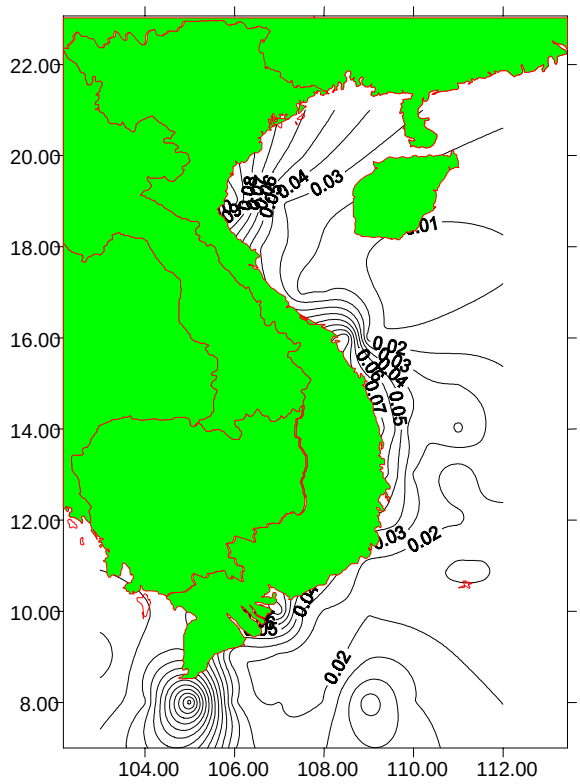
Distribution of Chlorophyll a at 50m layer. ($mg.m^{-3}$)



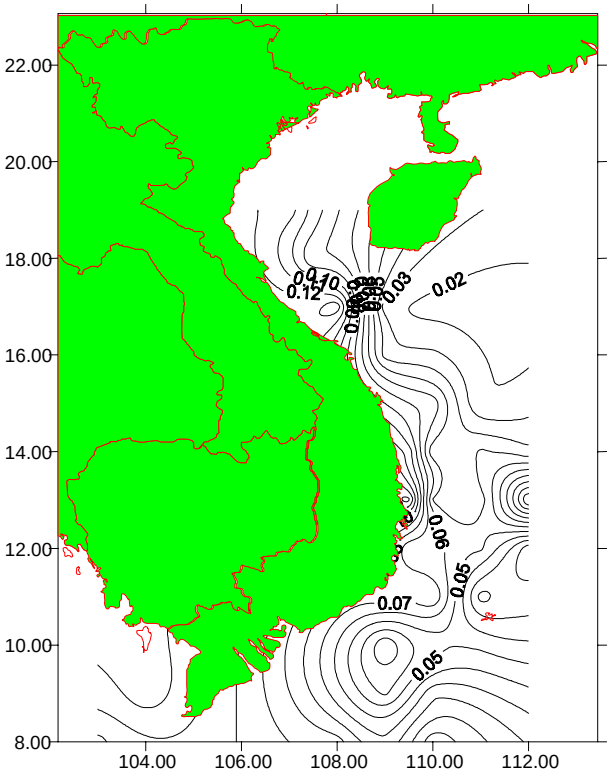
Distribution of Chlorophyll a at Bottom layer ($mg.m^{-3}$)



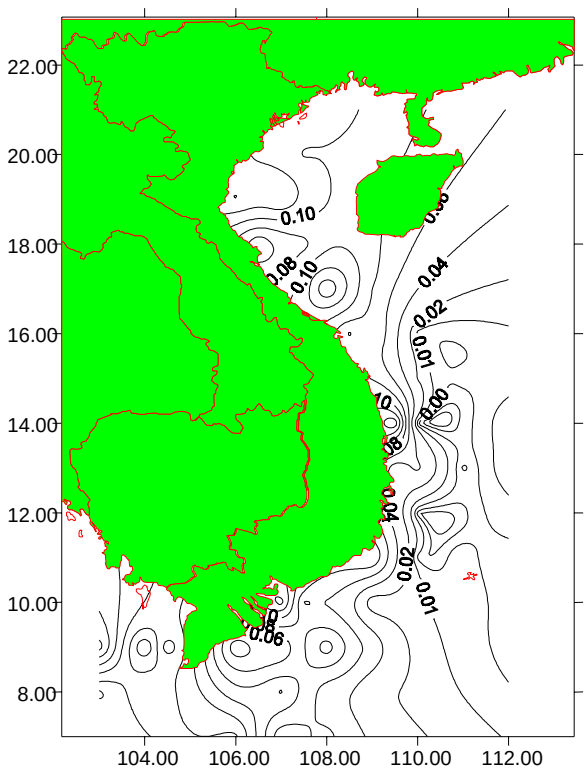
Distribution of Phaeophytill at surface layer. ($mg.m^{-3}$)



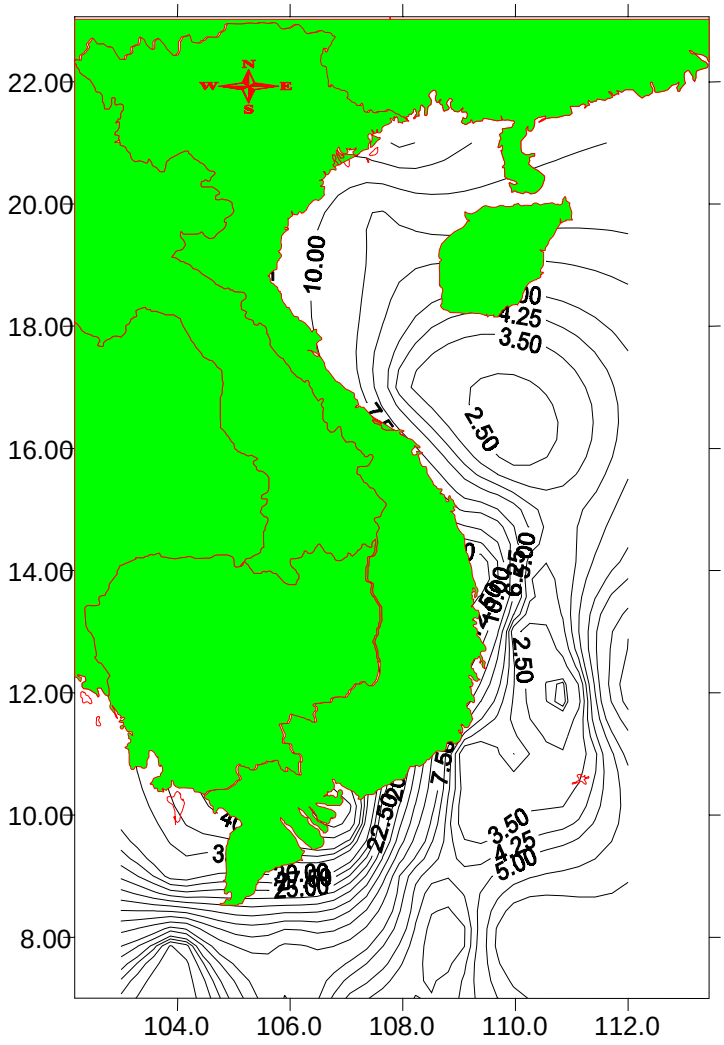
Distribution of Phaeophytill at 10m layer. ($mg.m^{-3}$)



Distribution of Phaeophytill at 50m layer. ($mg.m^{-3}$)



Distribution of Phaeophytill at Bottom. ($mg.m^{-3}$)



Map of primary production distribution on surface water. ($mgC.m^{-3}.day^{-1}$)