SEASONAL VARIATION OF *IN SITU* PHYTOPLANKTON PHOTOSYNTHETIC PROPERTIES IN NHA TRANG BAY

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Abstract

Photosynthetic properties are essential for the evaluation of phytoplankton photosynthetic efficiency as well as their physiological status in different waters. The present study measured in situ minimum and maximum fluorescence (Fo, Fm), variable fluorescence (Fv), and photosynthetic efficiency (Fv/Fm) in Nha Trang Bay to estimate seasonal phytoplankton community responses to different environmental conditions. Photosynthetic efficiency of in situ phytoplankton in Nha Trang Bay varied from 0.03 to 0.55 among stations and sampling times. Stations near the shore (Cape Chut) and estuary had higher Fv/Fm values than offshore stations. Seasonal and spatial variation of photosynthetic efficiency along the transect from the river mouth to the open ocean reflected the impact of river inputs on phytoplankton communities. In situ measurements indicate the impacts of complex environmental conditions in Nha Trang Bay (e.g., light intensity and nutrients) on the physiological status and photosynthetic efficiency of phytoplankton.

Keywords: Fm; Fo; Fv/Fm; Physiological status; Phytoplankton photosynthetic efficiency.

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1. INTRODUCTION

Photosynthesis is an important activity in nature, as life on earth depends on its production. In marine ecosystems, phytoplankton are an important component of the marine food web, serving as major primary producers responsible for half of the primary production on earth (Kirchman, 2011). Primary production by phytoplankton in aquatic systems has been intensively estimated globally via production of photosynthetic activities (e.g., oxygen and CO_2). Primary production at sea depends on the health of phytoplankton communities, and the health of phytoplankton communities in turn depends on environmental conditions. Primary production estimation is essentially a measurement of photosynthetic activity, which includes measurements of variable fluorescence (Fv) and photosynthetic efficiency (Fv/Fm) (Falkowski et al., 2004).

Phytoplankton abundance and photosynthetic activity in marine ecosystems are influenced by various environmental factors, including pollutants from human activities. Phytoplankton health can be accessed via photosynthetic efficiency, which indicates the phytoplankton physiological state (e.g., Falkowski et al., 2004; Thornton, 2012, and references therein). Moreover, the photosynthetic activity of phytoplankton varies depending on phytoplankton composition and environmental conditions such as nutrients, light intensity, and temperature (Kirk, 2011; Kolber & Falkowski, 1993; Li et al., 2023). Therefore, the photosynthetic capacity of phytoplankton can be used as an indicator to evaluate the environmental state of the waters (Tan et al., 2019).

When a chlorophyll molecule in a plant cell is illuminated by light, it re-emits the light as chlorophyll fluorescence. This fluorescence can be used as an indicator for photosynthetic energy conversion and is characterized by a few parameters, including minimum and maximum fluorescence (Fo, Fm). In the photosynthetic system PSII of a plant cell, the minimum fluorescence can be measured in dark mode when all reaction centers are open. The maximum fluorescence is recorded when a high intensity pulse is applied and all reaction centers of the PSII are closed. Measuring Fm and Fo is essential for the quantification of photosynthetic processes during the light period. Variable fluorescence, (Fv) = Fm – Fo, is then denominated as the maximum variable chlorophyll fluorescence yield in the dark-adapted state. The ratio Fv/Fm is expressed as the photosynthetic efficiency of the PSII.

The fluorescence method of measuring the parameters Fo, Fm, Fv, and Fv/Fm has been applied in studying the effects of different environmental conditions on the growth and photosynthetic activity of phytoplankton in various bodies of water such as the Black Sea, the Mediterranean Sea, the Baltic Sea, the Norwegian Sea, lakes Baikal and Issyk-Kul (Antal et al., 1999, 2001), the Changjiang River Estuary (Li et al., 2023), and the southern Atlantic Ocean (Singh et al., 2022). By assessing photosynthetic efficiency versus underwater photosynthetic radiation, these studies showed that the photosynthetic ability and physiological state of phytoplankton in different environmental regions, climates, and hydrological conditions were correlated (Antal et al., 1999, 2001). In addition, Manzello et al. (2009) used fluorescence measurements in natural conditions to study and monitor photosynthetic performance and coral bleaching. In another application, Sven et al. (1998) used in vivo fluorescence measurement to study the photosynthetic ability of seagrass.

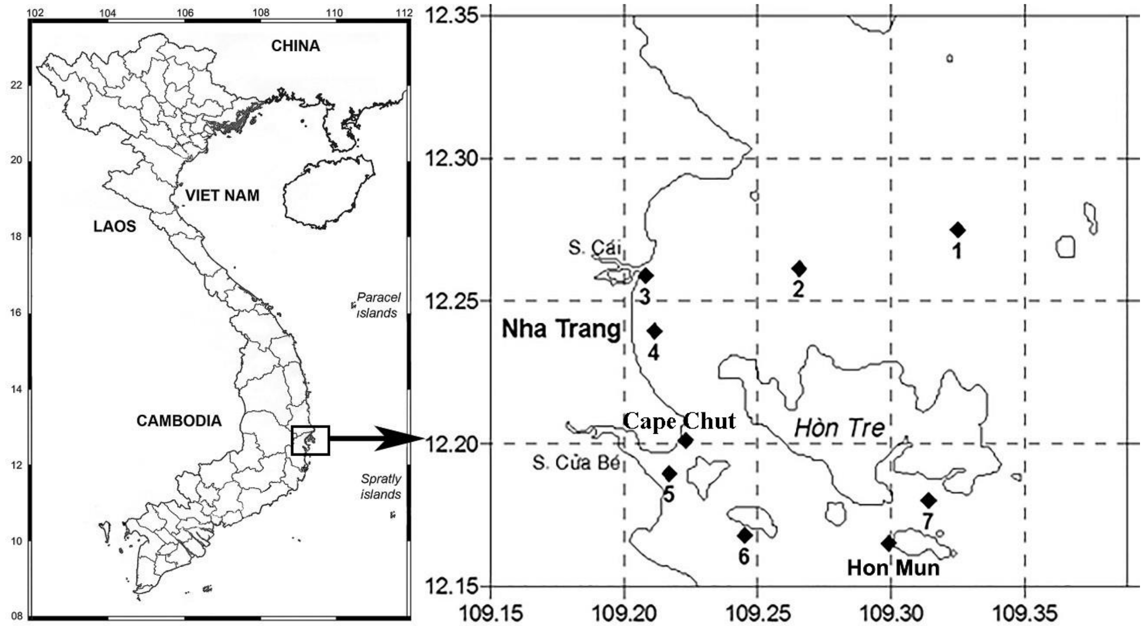
Previous studies on photosynthetic efficiency (Fv/Fm) in Nha Trang Bay found similar values of 0.44 and 0.49 ± 0.14 in the 1998 dry and 2004 rainy seasons, respectively (Il'yash et al., 2004; Il'yash & Matorin, 2007). These reports were limited to a single measurement per season but provide a valuable overall estimate of the photosynthetic efficiency of phytoplankton in Nha Trang Bay. Tran et al. (2022) measured photosynthetic efficiency of phytoplankton in Nha Trang Bay under various laboratory conditions. They showed that there were varied responses of phytoplankton depending on location, light, and nutrient regimes within 3 to 4 days of the experiments. This limited research, however, did not provide information on how phytoplankton Fv/Fm changes seasonally.

In the present study, in situ minimum and maximum fluorescence and photosynthetic efficiency of phytoplankton were measured in Nha Trang Bay using a fluorometric technique in both rainy and dry seasons from 2012 to 2013. These in situ measurements provide a basic assessment of the physiological status of phytoplankton communities in Nha Trang Bay in terms of monthly variations as well as an estimate of the impact of the river on the physiological states of the phytoplankton.

2. MATERIALS AND METHODS

Samples were collected in 2012 and 2013 near the surface (1 m) and the bottom (1 m above the sea floor) of the water column at nine stations in Nha Trang Bay (Figure 1). Seawater samples were kept cool and in the dark in a cooled box filled with seawater at ambient temperature and then transported to the laboratory within a maximum of 2 hours. Minimum fluorescence (Fo), maximum fluorescence (Fm), variable fluorescence (Fv = Fm – Fo), and photosynthetic efficiency (Fv/Fm) were measured using a Turner Designs 10-AU fluorometer (Turner Designs, USA). Photosynthesis was inhibited with 3-(3,4-dichlorophenyl)-1,1-dimethylurea (TCI America, Japan), as described in Samuelsson and Öquist (1977) and Parkhill et al. (2001). Additional measurements of Fv/Fm in phytoplankton smaller than 20 µm were conducted in June, August, and November 2012 and in March 2013. Seawater was gently passed through a sieve with a mesh size of 20 µm, and water below the sieve was collected for Fv/Fm measurements of all phytoplankton smaller than 20 µm. At all sampling times, Fo, Fm, and Fv/Fm were measured for the entire plankton community.

In Khanh Hoa Province, the dry season is from January to August and the rainy season is from September to December. Total rainfall is distributed as approximately 30% in the dry season and 70% in the rainy season. Rainfall during the 2012 dry season was higher than in a normal year by 10% and occurred mainly in April and May (Khanh Hoa Statistics Office, 2013).



(a) (b)

Figure 1. Map of Vietnam showing (a) Nha Trang Bay and (b) sampling stations

Samples of major nutrients, Si-SiO_3, N-NH_4/NH_3, N-NO_3, and P-PO_4, were collected at the same layers and stations in May, June, August, and November, and analyzed at the Institute of Oceanography using current standard methods (APHA, 2005). Dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) were measured for each sample. Chlorophyll-*a* was extracted with 90% acetone, measured with a spectrophotometer, and calculated using formulas in Jeffrey and Humphrey (1975). Other physiochemical parameters (depth, temperature, and salinity) were measured at all stations with a SBE 19plus V2 CTD profiler (Sea-Bird, USA). Ocean Data View software (Schlitzer, 2016) was used for constructing temperature-salinity (T-S) graphs, and Microsoft Excel was used for plotting and correlation calculations. One-way ANOVA with the nonparametric Kruskal-Wallis test was used for analyzing differences among stations and sampling months.

3. RESULTS

3.1. Environmental setup

Environmental parameters showed little variation (Table 1) but were influenced by wet and dry seasons, upwelling, and riverine inputs. Temperatures varied strongly in June and August during the dry southwest monsoon season, when coastal upwelling occurred. Lower temperatures (ca. 21°C–23°C) were observed in subsurface layers during these months (Table 1, Figure 2). Dissolved phosphate and nitrogen concentrations did not differ seasonally, but chlorophyll-*a* concentration was high in November during the wet season.

Table 1. Variation of environmental parameters in Nha Trang Bay in 2012

Month (season)	T (°C)	S (psu)	DIN (μM)	SRP (μM)	DISi (μM)	Chl-a (μg/L)
May (dry)	27.5 ± 1.7	33.6 ± 0.2	3.2 ± 0.4	0.4 ± 0.1	17.7 ± 16.2	0.4 ± 0.2
	(26.0–29.6)	(33.5–33.9)	(2.8–3.9)	(0.3–0.5)	(7.4–46.1)	(0.2–0.7)
June (dry)	26.9 ± 2.1	33.7 ± 0.3	4.7 ± 0.9	0.3 ± 0.2	15.3 ± 7.5	0.6 ± 0.4
	(22.6–28.7)	(33.3–34.0)	(3.9–6.6)	(0.2–0.8)	(9.4–28.2)	(0.1–1.3)
August (dry)	25.7 ± 2.3	33.7 ± 0.3	3.5 ± 0.7	0.2 ± 0.02	11.8 ± 2.1	0.6 ± 0.4
	(21.5–28.7)	(33.1–34.1)	(2.7–4.7)	(0.17–0.21)	(9.5–14.5)	(0.2–1.3)
November (rainy)	28.1 ± 0.23	32.1 ± 0.6	2.7 ± 0.04	0.3 ± 0.1	14.4 ± 8.7	1.1 ± 0.4
	(27.9–28.4)	(31.3–32.8)	(2.6–2.7)	(0.2–0.5)	(7.0–28.2)	(0.6–1.7)

Notes: (T) temperature, (S) salinity, (DIN) dissolved inorganic nitrogen, (SRP) soluble reactive phosphorus, (DISi) dissolved silica, (Chl-a) chlorophyll-*a* concentration. Numbers in parentheses are ranges.

The salinity-temperature (S-T) diagram of the transect from the Cai River (Station 3) to open water (Station 1) reflects variations in river discharge over time (Figure 2). The middle station (Station 2) was in the transitional zone between the river and open water during most of the study period. During the wet season (November), warmer and less saline water was observed, indicating a stronger influence of the Cai River (Figure 2). In March, the bay was strongly influenced by cooler and less saline surface water from the northern part of the South China Sea (Figure 2).

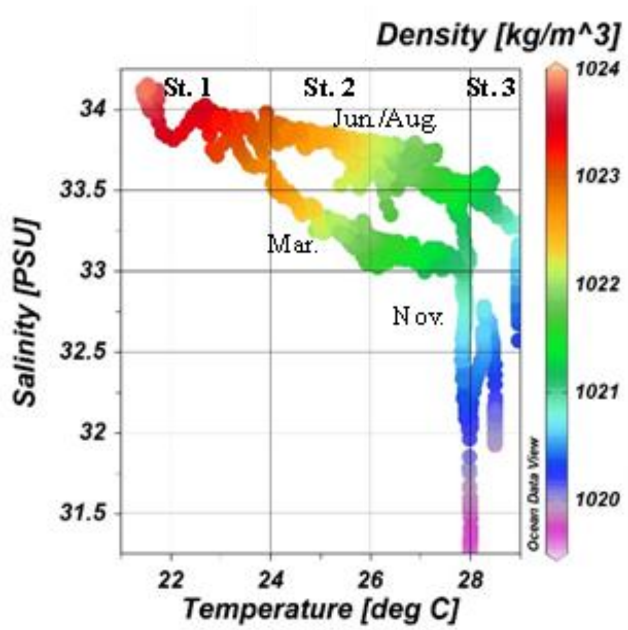


Figure 2. Salinity-temperature diagram of the transect from the Cai River mouth (Station 3) to ocean water (Station 1) in Nha Trang Bay in 2012

Notes: S-T is characterized by station number (St.) and sampling month (e.g., June, Aug.).

3.2. In situ photosynthetic efficiency of phytoplankton

Minimum (Fo) and maximum fluorescence (Fm) varied among sampling times (Table 2) and stations (Appendix, Table A1). These values were usually highest at Cape Chut station and lowest at Stations 1 and 7 far from shore. Strong positive correlations between Fv/Fm and chlorophyll-*a* were found in all months (Figure 3, $p < 0.05$), except May 2012.

Table 2. Variation of average Fo, Fm, and Fv/Fm (±*SD*) in Nha Trang Bay in 2012–2013

Month	Season	Fo	Fm	Fv/Fm
March, 2012	Dry	25.9 ± 0.3	26.7 ± 0.1	0.03 ± 0.02
April, 2012	Dry	29.5 ± 1.3	30.1 ± 1.3	0.02 ± 0.00
May, 2012	Dry	27.3 ± 7.2	33.7 ± 17.5	0.16 ± 0.14
June, 2012	Dry	42.2 ± 15.0	69.8 ± 39.7	0.32 ± 0.21
July, 2012	Dry	29.0 ± 1.4	47.8 ± 2.7	0.39 ± 0.06
August, 2012	Dry	35.4 ± 13	53.3 ± 29.6	0.28 ± 0.13
November, 2012	Rainy	44.8 ± 7.7	77.3 ± 19.2	0.41 ± 0.09
March, 2013	Dry	34.3 ± 4.5	52.3 ± 6.5	0.34 ± 0.04

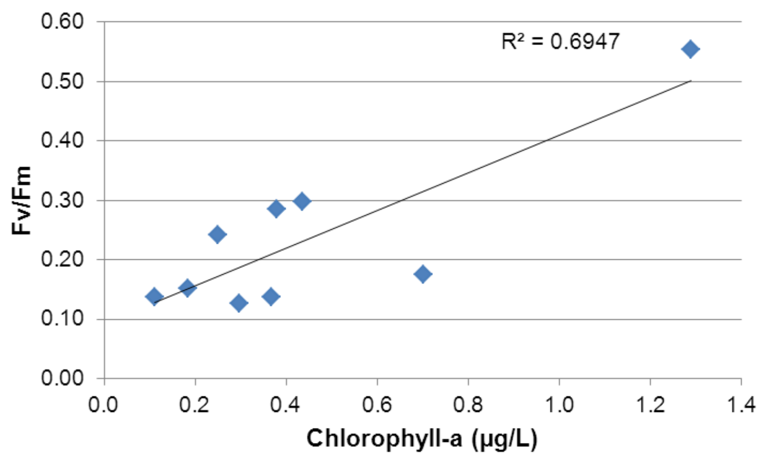


Figure 3. Correlation between Fv/Fm and chlorophyll-*a* along the Cai River to open water transect in 2012

Photosynthetic efficiency (Fv/Fm) ranged from 0.02 to 0.55 and varied highly among stations and sampling months (Figure 4). Higher Fv/Fm values were observed at Cape Chut, a coastal station, and lower values at open water stations (Stations 1 and 7) (Appendix, Table A1, $p < 0.05$, Kruskal-Wallis test). Among the sampling months, the average Fv/Fm was high from June to the end of the year and low from March to May 2012 (Figure 4). There were significant variations of Fv/Fm among sampling months

(ANOVA, p = 0.0003) and stations (ANOVA, p = 0.027). The post-hoc tests confirm November as having the highest Fv/Fm during the sampling period, and higher Fv/Fm values were observed at Cape Chut station than offshore at Station 1. Fv/Fm of the phytoplankton size class smaller than 20 µm was lower than that of entire phytoplankton population samples in November 2012 ($p < 0.001$) and March 2013 ($p < 0.01$), whereas there were no differences in June and August 2012.

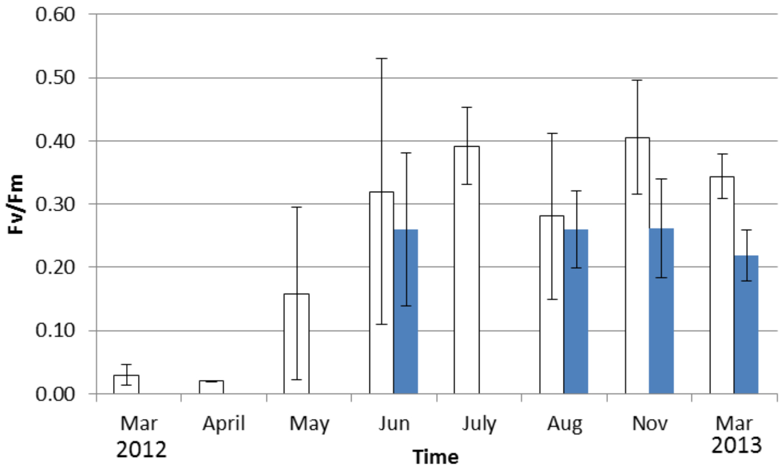


Figure 4. Monthly average (± *SD*) of in situ phytoplankton photosynthetic efficiency (Fv/Fm) in Nha Trang Bay

Notes: All phytoplankton (empty bars) and the phytoplankton size class < 20 µm (solid bars).

There were seasonal variations in Fv/Fm along the transect from the Cai River mouth to the open water (Stations 3, 2, and 1). During June and August, Fv/Fm decreased from the river to open water but was almost the same among stations in May and November (Figure 5).

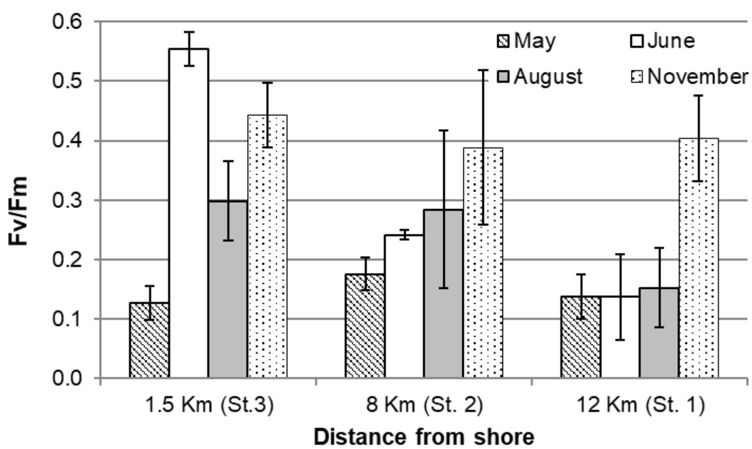


Figure 5. Monthly variation in photosynthetic efficiency (Fv/Fm) along the transect from the Cai River to open water in 2012

A positive correlation was found between photosynthetic efficiency and nutrient concentrations, but it varied with sampling month, e.g., R^2 = 0.72 in May and R^2 = 0.47 in June.

4. DISCUSSION

The results show that photosynthetic efficiency was low in the open water in Nha Trang Bay (Stations 1 and 7) and high in the coastal area (Cape Chut, data not shown). This reflects the impact of nutrient limitation on phytoplankton in the open water (Doan et al., 2012). At Cap Chut, there was nutrient supply from direct discharge from Chut communities, port activities, and Bao Dai tourist business services (Phan et al., 2016). The ammonium values (which are included in DIN) were always high at Cap Chut during the study period (Table 1). In Nha Trang Bay, the variation of Fv/Fm (Figure 5) is likely due to nutrient availability at near and far shore stations (nutrient data not shown).

Previous photosynthetic efficiency measurements of 0.44 were made in March 1998 in both the north and south portions of Nha Trang Bay (Il'yash et al., 2004) and 0.49 ± 0.14 in the rainy season during October and November 2003 (Il'yash & Matorin, 2007). They also reported lower values in the waters between Hon Tre and Cape Chut. Although these results were measured in the dry and rainy seasons of years with low rainfall (1998 and 2003), the values are comparable to our measurements. Generally, the variation of Fv/Fm in Nha Trang was lower than the optimum growth condition of approximately 0.65–0.70 (Juneau & Harrison, 2005; Suggett et al., 2009). These values in Nha Trang Bay, however, may reflect the sum of the responses of different phytoplankton species of the entire community. In N and P nutrient limitation experiments on 14 phytoplankton species, Tan et al. (2019) found Fv/Fm to range from 0.43 to 0.72, depending on species and available nutrient concentration.

Along the transect from the Cai River mouth to open water (Stations 3, 2, and 1), the photosynthetic efficiency of phytoplankton in May and November mostly had the same values in the transect and slightly higher values in the middle of Nha Trang Bay (Station 2). During the months of the dry season (June and August), photosynthetic efficiency decreased gradually from the river mouth to the open water. These findings are similar to those of previous studies from November 2003 (Il'yash & Matorin, 2007) and March 1998 (Il'yash et al., 2004). During the dry season, photosynthetic efficiency was high at the coast and river mouth regions along the Cai River transect and decreased toward the open ocean, while in the rainy season, photosynthetic efficiency values were high along the whole transect. The distribution of Fv/Fm values in May 2012, when there was a total rainfall of about 92 mm (Khanh Hoa Statistics Office, 2013), was similar to that of the November rainy season, but with lower values.

The variation of photosynthetic efficiency was high among the stations in June (Figure 5). The lowest value was at the bottom layer of the open water at Station 1 (Appendix, Table A1) due to the depth of this station of approximately 30 m, with < 10% of surface PAR and a low temperature of about 22°C. Moreover, nitrate concentration at this station was lower than at other stations (data not shown). These conditions could largely influence the photosynthetic capacity of phytoplankton. High Fv/Fm values (e.g., > 0.65) are usually found in nutrient-rich waters (e.g., upwelling), whereas low values are found in oligotrophic waters (Falkowski & Kolber, 1995). In the Indian Ocean, Wang et al. (2024) found that DIN to be positively correlated with Fv/Fm. In contrast, the Fv/Fm ratio at station Cape Chut was relatively high. Photosynthetic efficiency at this station did not vary much among the study months, which demonstrated the stable and suitable ecological conditions for the growth of phytoplankton. An overall positive correlation between phytoplankton biomass (chlorophyll-*a* concentration) and Fv/Fm was found at all stations, especially along the Cai River transect (Figure 3). However, in June, there was not always high chlorophyll-*a* associated with high photosynthetic efficiency (data not shown). At the bottom layers of Stations 1 and 2 in June, relatively high chlorophyll-*a* (1.10 and 0.54 µg/L, respectively) was not associated with high Fv/Fm (0.03 and 0.21, respectively). This can be related to the physiological status or species composition of the phytoplankton at those layers and stations. Both higher temperature stress and species composition had direct and indirect impacts on Fv/Fm (Wang et al., 2024). However, at the bottom layer of the open water station (Station 1), photosynthetic efficiency was twice as high as the surface value, perhaps because of the upwelling activities of the southwest monsoon (21°C and salinity 34.1 psu). In the upwelling area, higher nutrient supply can support phytoplankton communities to grow better and healthier than in the surface water, even at low light, as previously reported by Cullen and Renger (1979). In the tropical and subtropical North Pacific, Fujiki et al. (2013) also found that phytoplankton communities below the chlorophyl maximum layer had high potential photosynthetic performance capacity and were able to grow in very low ambient light.

The correlation between photosynthetic efficiency and nutrient concentrations differed among the sampling months, with positive correlations in May, June, and November and a negative correlation in August (data not shown). This may be a result of different impacts from nutrient inputs during the rainy season and upwelling activity of the southwest monsoon.

5. CONCLUSIONS

Photosynthetic efficiency of phytoplankton in Nha Trang Bay varied seasonally; it was generally low in the dry season and high in the rainy season. Evidence suggested that nutrient inputs from the shore or upwelling enhanced the Fv/Fm values. The Cai River transect in this study provided an example to explain variation of phytoplankton Fv/Fm in relation to river runoff (e.g., nutrient input). This year-long investigation of photosynthetic efficiency, together with other environmental parameters, provides valuable data for further studies of the phytoplankton communities in coastal and open waters.

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APPENDIX

Supplement Table.

Table A1. Photosynthetic efficiency (Fv/Fm) in Nha Trang Bay 2012–2013

Year	Date	Station	Layer	Size class	ID	Fv/Fm
2012	11/6/2012	3	surface	All	9M	0.405
2012	11/6/2012	3	surface	All	9M	0.481
2012	11/6/2012	2	surface	All	11M	0.377
2012	11/6/2012	2	surface	All	11M	0.239
2012	11/6/2012	2	bottom	All	11D	0.381
2012	11/6/2012	2	bottom	All	11D	0.556
2012	11/6/2012	1	surface	All	1BM	0.354
2012	11/6/2012	1	surface	All	1BM	0.511
2012	11/6/2012	1	bottom	All	1BD	0.379
2012	11/6/2012	1	bottom	All	1BD	0.372
2012	5/7/2012	1	surface	All	St 1A	0.164
2012	5/7/2012	1	surface	All	St 1B	0.111
2012	5/7/2012	3	surface	All	St 3A	0.147
2012	5/7/2012	3	surface	All	St 3B	0.106
2012	5/7/2012	2	surface	All	St 2A	0.156
2012	5/7/2012	2	surface	All	St 2B	0.195
2012	5/7/2012	4	surface	All	St 4A	0.034
2012	5/7/2012	4	surface	All	St 4B	0.022
2012	5/7/2012	5	surface	All	St 5A	0.243
2012	5/7/2012	5	surface	All	St 5B	0.086
2012	5/7/2012	6	surface	All	St 6A	0.223
2012	5/7/2012	6	surface	All	St 6B	0.214
2012	5/7/2012	7	surface	All	St 7A	0.028
2012	5/7/2012	7	surface	All	St 7B	0.037
2012	5/16/2012	Hon Mun	surface	All	Hmun	0.043
2012	5/16/2012	Hon Mun	surface	All	Hmun	0.026
2012	5/16/2012	Hon Mun	surface	All	Hmun	0.046
2012	5/16/2012	Cape Chut	surface	All	CapeChut	0.457
2012	5/16/2012	Cape Chut	surface	All	CapeChut	0.395
2012	5/16/2012	Cape Chut	surface	All	CapeChut	0.429

Notes: Size class: All = all phytoplankton; layer: surface (0.5 m below the water surface); bottom (1 m above the seabed).

Table A1. Photosynthetic efficiency (Fv/Fm) in Nha Trang Bay 2012–2013 (cont.)

Year	Date	Station	Layer	Size class	ID	Fv/Fm
2012	6/30/2012	1	bottom	All	1D-A	0.051
2012	6/30/2012	1	bottom	All	1D-B	0.039
2012	6/30/2012	1	bottom	All	1D-C	0.008
2012	6/30/2012	1	surface	All	1M-A	0.199
2012	6/30/2012	1	surface	All	1M-B	0.057
2012	6/30/2012	1	surface	All	1M-C	0.154
2012	6/30/2012	3	surface	All	9M-A	0.565
2012	6/30/2012	3	surface	All	9M-B	0.522
2012	6/30/2012	3	surface	All	9M-C	0.575
2012	6/30/2012	2	bottom	All	11D-A	0.261
2012	6/30/2012	2	bottom	All	11D-B	0.152
2012	6/30/2012	2	surface	All	11M-A	0.247
2012	6/30/2012	2	surface	All	11M-B	0.236
2012	6/19/2012	Hon Mun	surface	All	Hmun	0.425
2012	6/19/2012	Hon Mun	surface	All	Hmun	0.558
2012	6/19/2012	Hon Mun	surface	All	Hmun	0.599
2012	6/19/2012	Cape Chut	surface	All	CapeChut	0.444
2012	6/19/2012	Cape Chut	surface	All	CapeChut	0.460
2012	6/19/2012	Cape Chut	surface	All	CapeChut	0.527
2012	8/17/2012	3	surface	All	9M	0.345
2012	8/17/2012	3	surface	All	9M	0.251
2012	8/17/2012	2	surface	All	11M	0.191
2012	8/17/2012	2	surface	All	11M	0.378
2012	8/17/2012	2	bottom	All	11D	0.149
2012	8/17/2012	2	bottom	All	11D	0.265
2012	8/17/2012	1	surface	All	1BM	0.200
2012	8/17/2012	1	surface	All	1BM	0.105
2012	8/17/2012	1	bottom	All	1BD	0.356
2012	8/17/2012	1	bottom	All	1BD	0.314
2012	8/17/2012	Hon Mun	surface	All	H.Mun-M	0.158
2012	8/17/2012	Hon Mun	surface	All	H.Mun-M	0.267
2012	8/17/2012	Hon Mun	bottom	All	H.Mun-Đ	0.239
2012	8/17/2012	Hon Mun	bottom	All	H.Mun-Đ	0.173

Notes: Size class: All = all phytoplankton; layer: surface (0.5 m below the water surface); bottom (1 m above the seabed).

Table A1. Photosynthetic efficiency (Fv/Fm) in Nha Trang Bay 2012–2013 (cont.)

Year	Date	Station	Layer	Size class	ID	Fv/Fm
2012	8/17/2012	Cape Chut	surface	All	CapeChut	0.536
2012	8/17/2012	Cape Chut	surface	All	CapeChut	0.566
2012	3/27/2012	Cape Chut	surface	All	CapeChut	0.041
2012	3/27/2012	Cape Chut	surface	All	CapeChut	0.019
2012	4/4/2012	Hon Mun	surface	All	Hmun	0.021
2012	4/4/2012	Hon Mun	surface	All	Hmun	0.019
2012	7/18/2012	Hon Mun	surface	All	Hmun	0.430
2012	7/18/2012	Hon Mun	surface	All	Hmun	0.321
2012	7/18/2012	Hon Mun	surface	All	Hmun	0.424
2013	3/23/2013	3	surface	All	9M	0.326
2013	3/23/2013	3	surface	All	9M	0.323
2013	3/23/2013	2	surface	All	11M	0.380
2013	3/23/2013	2	surface	All	11M	0.387
2013	3/23/2013	2	bottom	All	11D	0.392
2013	3/23/2013	2	bottom	All	11D	0.337
2013	3/23/2013	1	surface	All	1BM	0.369
2013	3/23/2013	1	surface	All	1BM	0.315
2013	3/23/2013	1	bottom	All	1BD	0.327
2013	3/23/2013	1	bottom	All	1BD	0.285

Notes: Size class: All = all phytoplankton; layer: surface (0.5 m below the water surface); bottom (1 m above the seabed).