# Primary Production Determination in the South China Sea, Area I: Gulf of Thailand and East Coast of Peninsular Malaysia

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**ABSTRACT**

Primary production in the Gulf of Thailand and the East Coast of Peninsular Malaysia was determined from *in situ* fluorescense, light intensity in September-October, 1995 cruise, and from the uptake of radioactive carbon incubation in the October, 1996 cruise. The primary production rate was found to be 0.20–0.61 and 0.29–0.47gC/m$^2$/day for the Gulf of Thailand and the East Coast of Peninsular Malaysia, respectively. At nearshore stations, higher rate of primary production was found at sea surface, and it gradually decreased with depth. However, at offshore stations, where subpycnocline chlorophyll maximum was found, the rate was increased again at this layer

**Key words** : Primary production, South China Sea, Gulf of Thailand, Eeat coast of Penin sular Malaysia

## Introduction

"Primary production limits the trophic potential of the world ocean and thus a biological limitation of future population growth of humankind" (Russell-Hunter, 1970). A broad picture of primary production over most region of the world's ocean is now available and generally considered a key characteristic of marine ecosystem and has major implications for water quality (Bermal *et al*., 1995). However, few studies of the variability of primary production have been conducted over an annual cycle in the sea because of the size of the area and the time scales. In addition, the Gulf of Thailand and the East Coast of Peninsular Malaysia are a major and rapidly developing commercial fishing site and supports a fishery, but lack of knowledge of the levels of annual primary production is particularly evident for this area.

In order to determine the extent to predict trends of primary production have occurred, some functional relationship between biological and physical factors which are the biomass of phytoplankton, light intensity at that time and the relative importance of light decrease with depth (Berman *et al.*, 1995). This study was described to estimated the distribution of the primary production in the Gulf of Thailand and in the East Cost of Peninsular Malaysia.

## Materials and Methods

The location of the stations (60 stations) was shown in Fig. 1. Seawater samples were collected from several levels of depth (from sea surface to bottom). Data collection (total alkalinity, light intensity and *in situ* fluorescense) was divided into two cruises. The 1$^{st}$ cruise, on MV SEAFDEC in September-October 1995, which seawater samples were collected from all 60 stations in the Gulf of Thailand and the East Coast of Peninsular Malaysia. The 2$^{nd}$ cruise, on MV Platoo in October 1996, which samples were collected from only 15 stations in the Gulf of Thailand and only 5 station for $^{14}$C. incubtion (station-7, 15, 21, 27, and 35). According to the two cruises were during the beginning of the North-East Monsoon, the primary production of the Gulf of Thailand and the East Coast of Peninsular Malaysia were extrapolated by using the data between the two cruises.

***Primary production***

Seawater samples from the $2^{nd}$ cruise were collected for radioactive bicarbonate incubation using $^{14}C$ technique. Each sample was transferred into 500ml glass bottles (4 bottles of light glass which one of them is control, and 1 bottle of dark glass from each level of depth). Each bottle except control was innoculated with 2.52μCi of $^{14}C$. All of bottles were incubated *in situ* at their original depth for 3 hours, and took away from sunlight before filtered by syring filtration with GF/F membranes. Membranes were kept frozen in scintillation vials until they were determined by the GC-9A, Shimadzu, β-scintillation counter.

***Total alkalinity***

50ml of filtered seawater from 60 stations (Fig.1) on the 1st cruise was mixed with 10ml of 0.015N HCl. The final pH of the solution was measured by pH-meter, Fisher Scientific model 1002. Total alkalinity was computed, and then the carbonate alkalinity and total carbon dioxide were calculated by

carbonate alkalinity (meq/l) = total alkalinity-0.05
total carbon dioxide (meq/l) = 0.96*carbonate alkalinity

***Light intensity***

Light intensity in water column from 60 stations (Fig.1) was measured in lux by an underwater lux meter, Alec Electronics model SPI-9W.

***In situ fluorescense***

*In situ* fluorescense in volt of 60 stations (Fig.1) was recorded every one meter depth by Sea Tech submersible fluorometer.

***Chlorophyll-a***

*In situ* fluorescense can be converted to photosynthetic pigment concentration by correlated linearly with the actual chlorophyll concentration by spectrophotometry on cruise.

***Primary production calculations***

Equation for primary production is based on radioactive carbon technique by Parson *et al.* (1984)

$$\text{Primary production (mgC/m}^3\text{/hr)} = (R_S - R_B) * W / R * N \quad \textbf{(1)}$$

where $R$ = total activity of 2.52 μCi of $^{14}C$ solution (dpm)
$N$ = number of hours of sample incubation (hr)
$R_S$ = the light bottle count (dpm)
$R_B$ = the dark bottle count (dpm)
$W_{\text{(the concentration of total carbon dioxide in mgC/m3)}}$ = 12,000*TC
TC = total carbon dioxide (meq/l)

***Light-Depth curve***

The data of light (lux) and depth (m) from the 1st and 2nd cruise were combined and correlated linearly, then used for Light-Depth (L-D) relationship. The relationship was separated into 2 equations at the arbitrary pycnoclinal depth of 39m (Fig.2). From 0-38m depth, there was very low concentration of phytoplankton and thus allowed light to penetrate to the pycnocline. Because of thick layer of phytoplankton limited light penetration, so light intensity rapidly decreased below the pycnocline.

The overall equation for the depth 0-38m **(2)**

$L = -114.65\ Ln(D) + 426.16 \qquad r^2 = 0.5628$

The overall equation for the depth 39m-bottom

$L = -0.2633D + 19.524 \qquad r^2 = 0.6242$

where : L = light intensity (lux)
D = depth (m)

***Primary production–Light intensity curve***

Primary production and light intensity (P–I curve) was made by plotting primary production normalized to chl-a (as *in situ* fluorescense) against light intensity from the 1st cruise (Fig.3) and by the $r^2$ and subpycnocline chlorophyll maximum it was found that the relationship could also be separated into 2 groups at 39m.

The equation for the depth 0-39m **(3)**

$P = 3.6216\ Ln(L) - 5.8195 \quad r^2 = 0.6336$

The equation for the depth 40m-bottom

$P = 2.0891\ Ln(L) + 0.773 \quad r^2 = 0.5900$

where : P = primary production ($mgC/m^3/hr$)
L = light intensity (lux) at sample incubation depth

***Light-Time curve***

Light-time equation (L-T curve) was made from the time series of light at sea surface from 1st and 2nd cruise to integrate for daily primary production (Fig.4) and was separated to 2 groups.

Equation for time between 6 A.M.-12 Noon **(4)**

$L = 0.3217\ e^{0.5489t} \qquad r^2 = 0.8512$

Equation for time between 12 Noon -6 P.M.

$L = 140282\ e^{-0.4737t} \qquad r^2 = 0.7038$

where : L = light intensity (lux) at surface
t = time (6 A.M.-6 P.M)

***Estimation of daily primary production***

Photosynthetic rate in the incubated bottles was calculated for primary production rate using equation-(1) and extrapolated over the water column to obtain the rate per sq.m and integrated over 6 A.M. to 6 P.M. using the *in situ* biomass, light intensity (hourly light intensity profile) and time integrated daily primary production (assuming surface intensity to be 100%) by equation- (2), (3), and (4).

## Result

The range of daily primary production was 0.20–0.61 and 0.29–0.47 gC/ $m^2$/day in the Gulf of Thailand and the East Coast of Peninsular Malaysia, respectively. (Table 1) Depth integrated primary production in the Gulf of Thailand was very high at the east and the west cost (station-6 and 10, Fig.5). For the East Coast of Peninsular Malaysia, the primary production was high at station-66 (Fig 5).

The contribution of primary production at the same contour line on surface, depth-10, 20, 30, 40, and 50m was shown in Fig. 6-11.

The correlation between light intensity, chlorophyll-a, and daily primary production of nearshore and offshore stations was shown in Fig. 12-13. In which the data of light intensity and chlorophyll-a were reported from Snidvongs *et al.* (1995). At nearshore stations, daily primary production was highest at the surface or near-surface (2-6m depth) and generally decreased with depth (Fig. 12). At Offshore stations, daily primary production at subsurface decreased with reduced light penetration, but where subpycnocline chlorophyll maximum was found, it tended to increase and then declined rapidly as light attenuation deminished (Fig. 13).

The extent to daily primary production which changed as followed top-down in water column by distribution of chlorophyll-a was shown in Fig. 14.

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## Discussion

The contribution of daily primary production in the Gulf of Thailand and the East Coast of Peninsular Malaysia could be high, and it occurred along water column. Stations which would have the subpycnocline chlorophyll maximum, daily primary production was reached maxima also, because in daytime, when sunlight was generally abundant, the very low concentration of phytoplankton in the surface mixed layer allowed light to penetrate to the pycnocline, and the pycnocline light intensity was usually >10% of that at the surface (Snidvongs and Rochana-anawat, 1995), and that seemed to be sufficient for photosynthesis.

Berman *et al.* (1995) indicated that the variability of primary production in Lake Kinneret, Israel was highly correlated with covariation of 3 parameters: phytoplankton biomass, photic depth and surface irradiance, which similarity to this study. However, in this area the estimated of daily primary production was greatly due to chlorophyll-a concentration (Fig. 14).

The distribution and abundance of phytoplankton had been not obvious in this study. We claimed that the dominant species of phytoplankton in this area where subpycnocline chlorophyll maximum was approximate 25-50m (Snidvongs *et al.*, 1995) were diatom. Raymont (1980) described that the different species of phytoplankton may exhibit depth preferences within the Equatorial Pacific was present in the upper 100m, diatoms were mainly in the uppermost 25m or 50m layer. According to Boonyapiwat (1997), in this area, diatom was the main group of phytoplankton, and abundance near the west coast, lower past of the Gulf of Thailand and along the coast of Peninsular Malaysia. But, the abundance of blue green algae was near the east coast and offshore of the lower Gulf of Thailand, include offshore of the east coast of Peninsular Malaysia. We suggested that, all the areas abundance in phytoplankton species, they coincided with relative high level of daily primary production.

The Gulf of Thailand and the East Coast of Peninsular Malaysia is one of the world's most primary production (Lursinsub, 1985), and it is base of the pyramid which supports a large commer-

Table 1. Depth integrated daily primary production at various stations in gC/m²/day

| Station | P(gC/m²/day) | Station | P(gC/m²/day) | Station | P(gC/m²/day) |
|---|---|---|---|---|---|
| 1 | 0.26 | 28 | 0.42 | 57 | 0.35 |
| 2 | 0.39 | 30 | 0.25 | 58 | 0.35 |
| 3 | 0.36 | 31 | 0.23 | 59 | 0.42 |
| 5 | 0.35 | 32 | 0.24 | 61 | 0.39 |
| 6 | 0.56 | 34 | 0.31 | 62 | 0.44 |
| 7 | 0.52 | 35 | 0.29 | 63 | 0.42 |
| 9 | 0.45 | 36 | 0.56 | 65 | 0.40 |
| 10 | 0.61 | 38 | 0.22 | 66 | 0.47 |
| 11 | 0.50 | 39 | 0.20 | 68 | 0.37 |
| 13 | 0.44 | 40 | 0.21 | 69 | 0.29 |
| 14 | 0.39 | 42 | 0.25 | 70 | 0.39 |
| 15 | 0.39 | 43 | 0.43 | 72 | 0.35 |
| 17 | 0.28 | 45 | 0.31 | 73 | 0.40 |
| 18 | 0.47 | 46 | 0.31 | 74 | 0.30 |
| 19 | 0.58 | 49 | 0.41 | 76 | 0.29 |
| 21 | 0.33 | 50 | 0.38 | 77 | 0.31 |
| 22 | 0.34 | 51 | 0.49 | 78 | 0.41 |
| 23 | 0.24 | 53 | 0.43 | 80 | 0.33 |
| 25 | 0.25 | 54 | 0.33 | 81 | 0.38 |
| 26 | 0.29 | 55 | 0.35 | | |

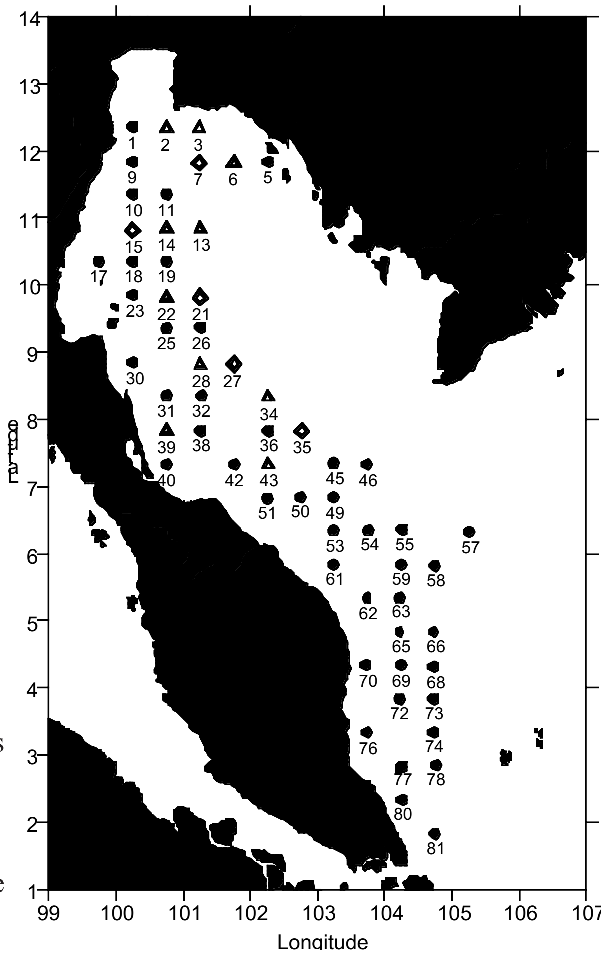


Fig.1. The location of 60 stations to previous study
circele = stations in the first cruise
triangle = stations in the and second cruise
diamon = stations in the first, second cruise and carbon - 14 incubation

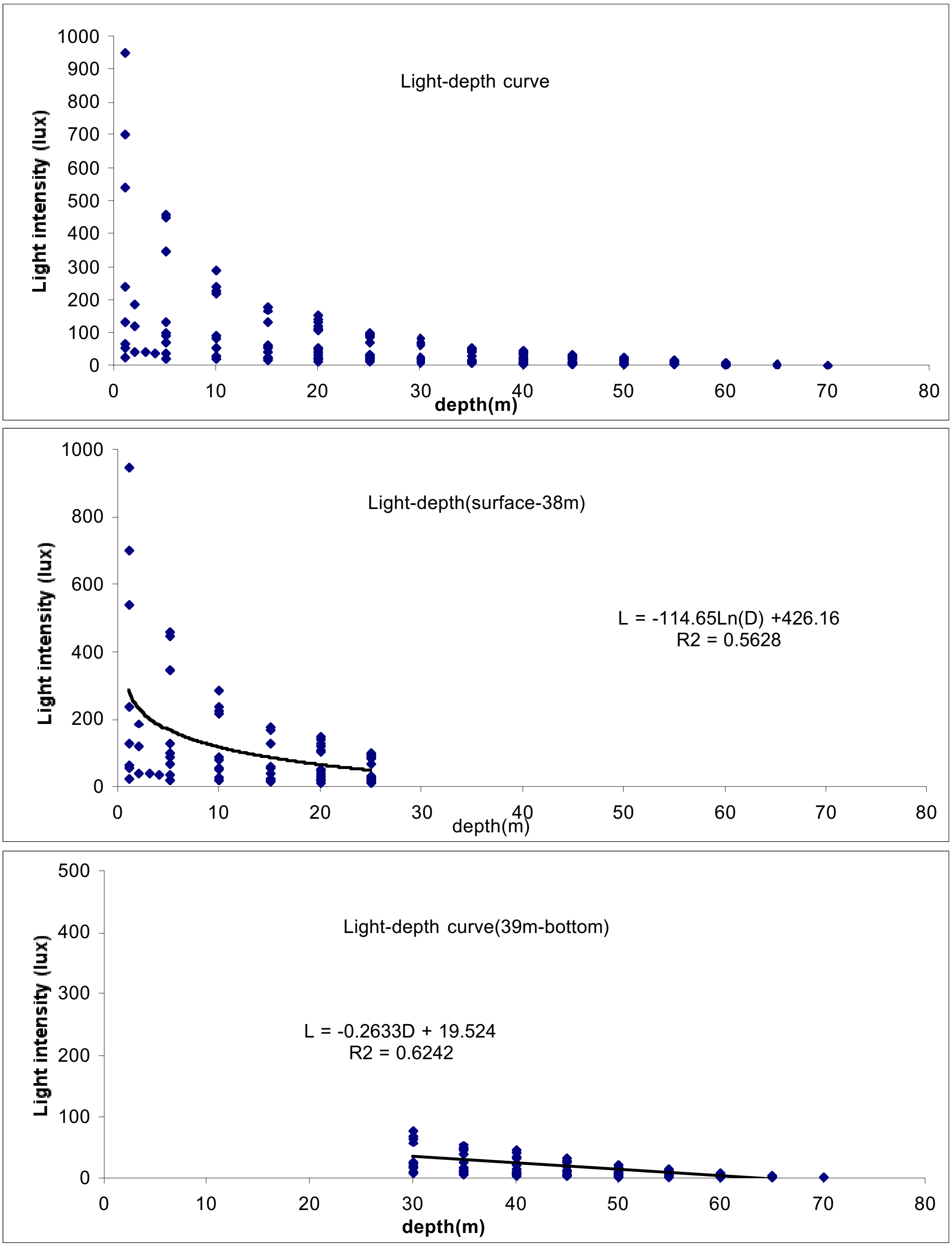


Fig. 2. Light-depth relationship and 2 equations that seperated at 38m
L = Light intensity (lux), D = Depth (m)

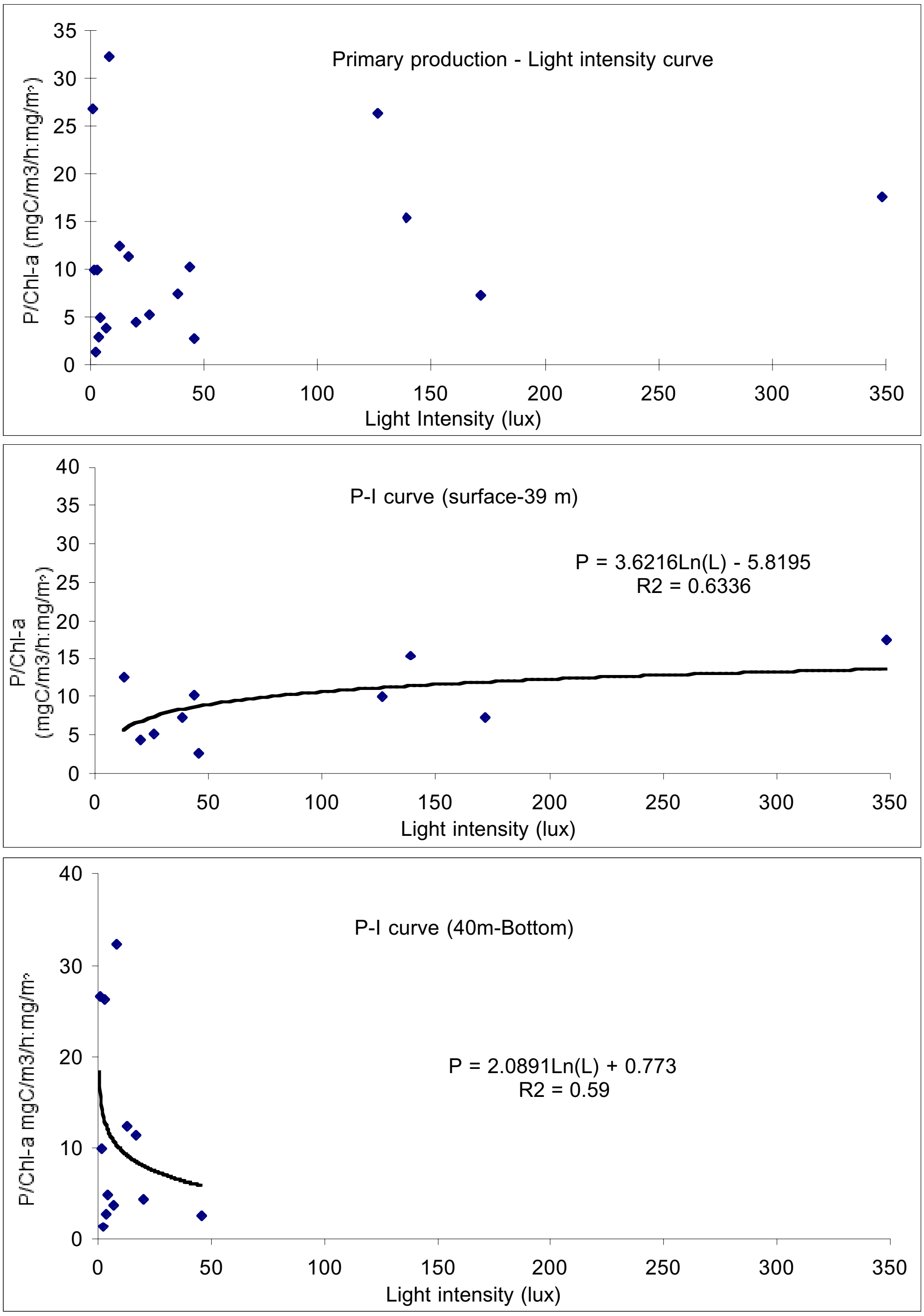


Fig. 3. Primary production normalized to biomass - light intensity relationship and 2 equations that separated at 39m

P = P/Chl-a, L = Light intensity

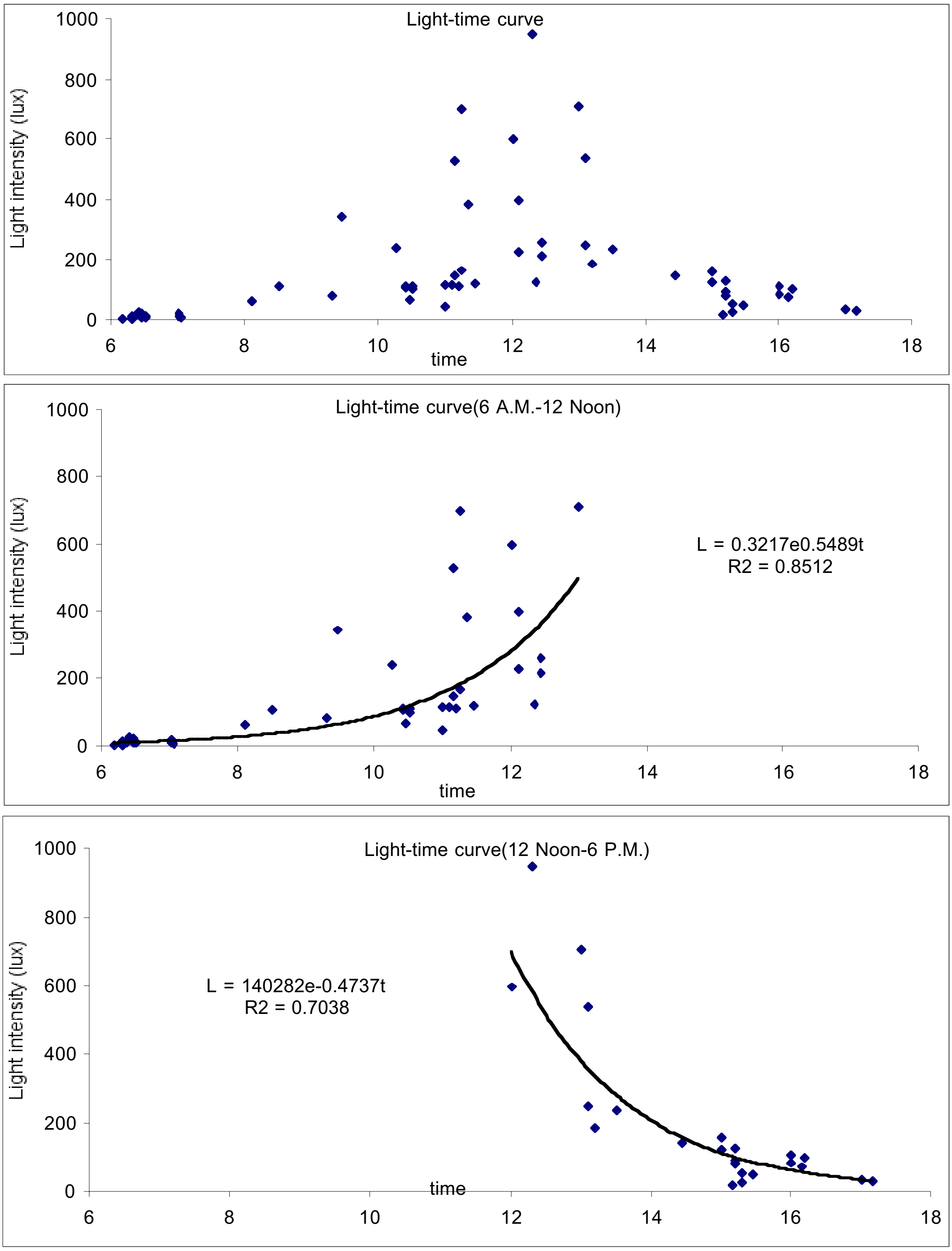


Fig. 4. Light - time relationship and 2 equations that seperated at noon
L = Light intensity (lux), t = time (6 A.M.-6 P.M.)

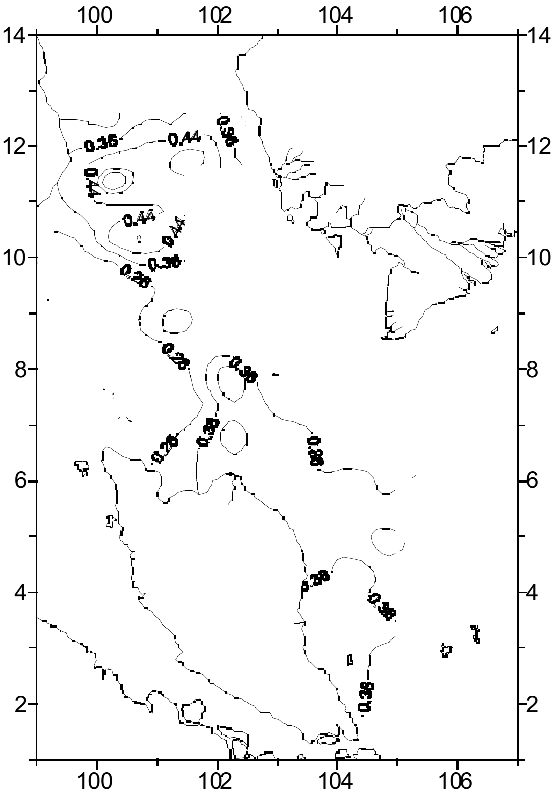


Fig. 5. Depth Integrated Primary production ($gC/m^2/d$)

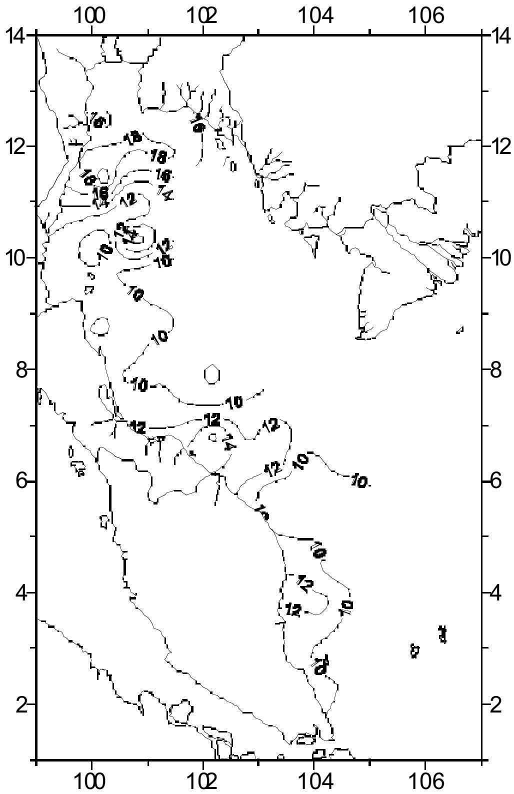


Fig. 6. Distribution of daily primary production at surface in $mgC/m^3/day$

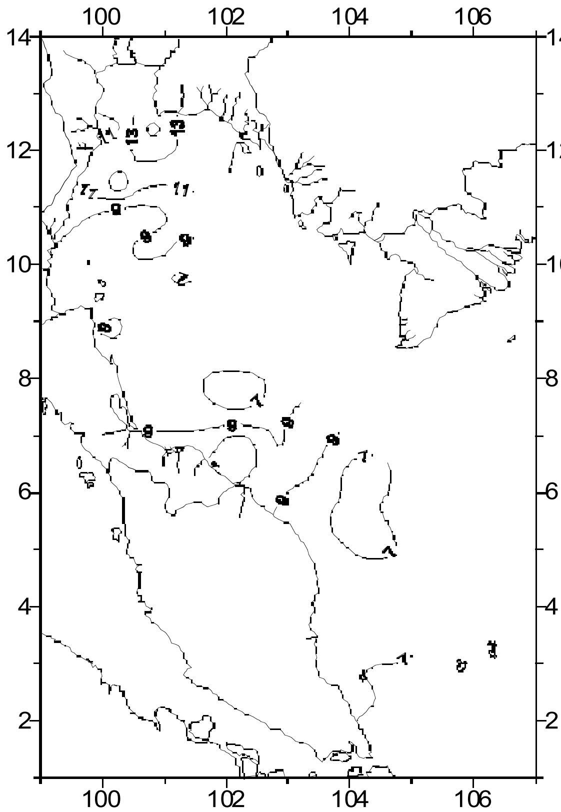


Fig. 7. Distribution of primary production at 10 m in $mgC/m^3/day$

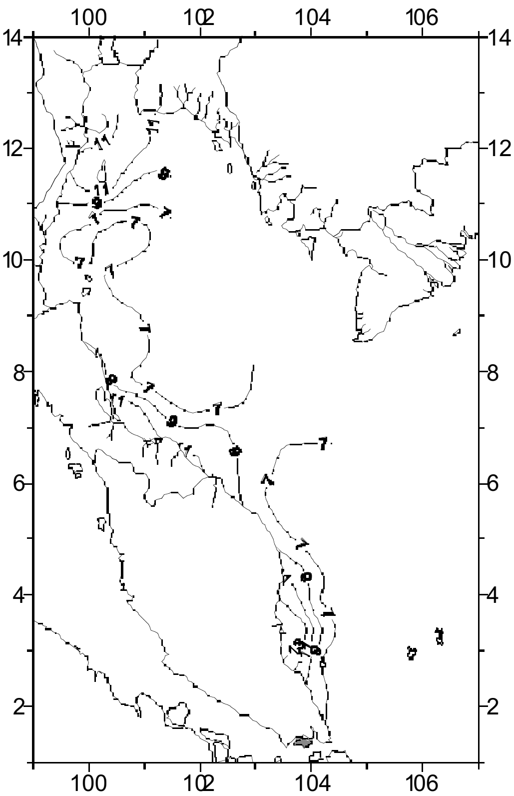


Fig. 8. Distribution of primary production at 20 m in $mgC/m^3/day$

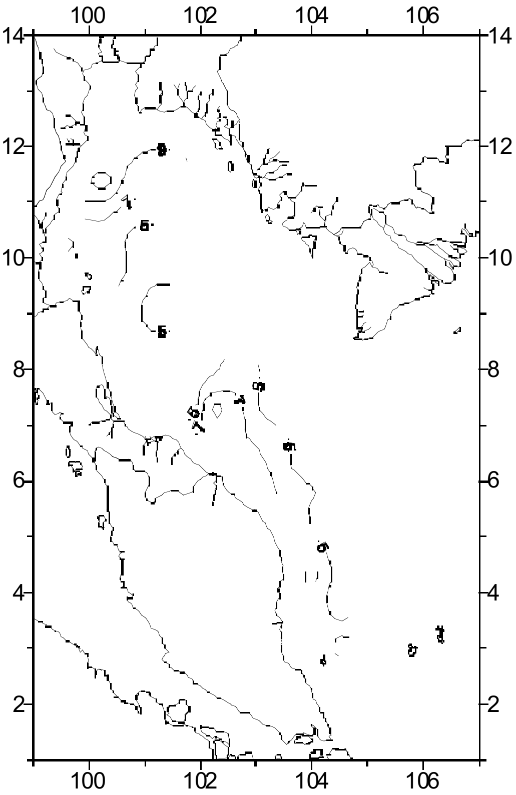


Fig. 9. Distribution of primary production at 30 m in mgC/$m^3$/day

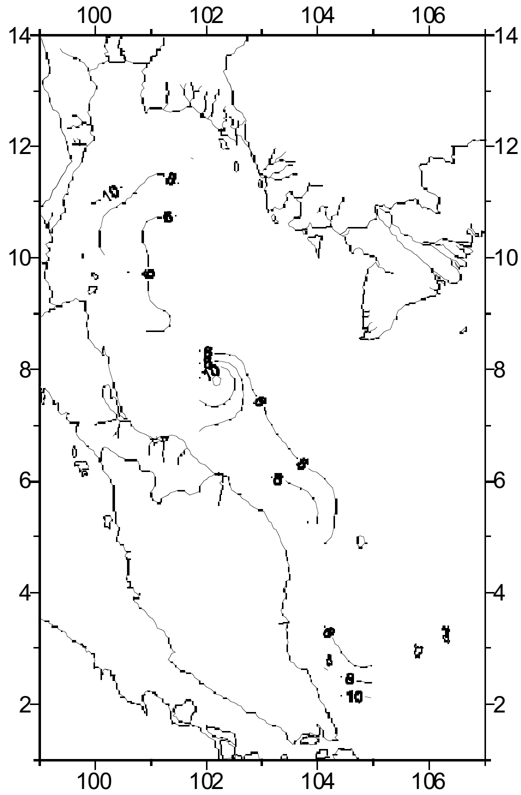


Fig. 10. Distribution of primary production at 40 m in mgC/$m^3$/day

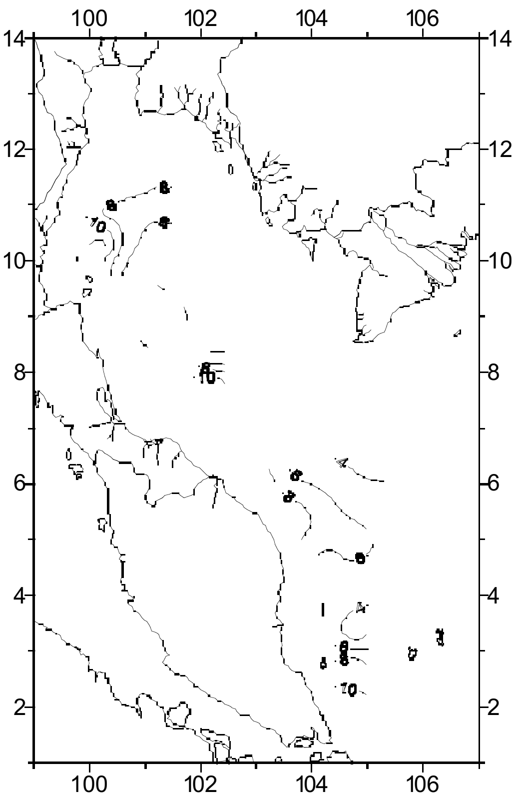


Fig. 11. Distribution of primary production at 50 m in mgC/$m^3$/day

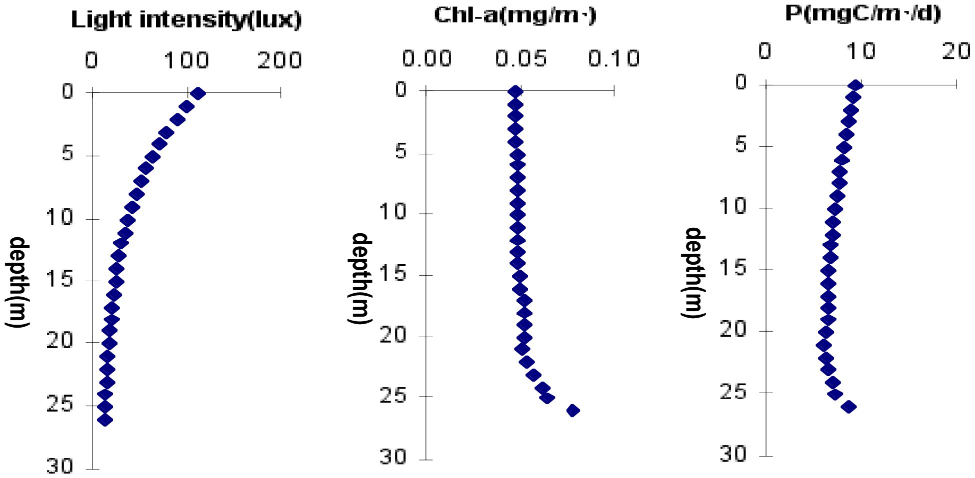


Fig. 12. Vertical distribution of light, chl-a (from Snidvongs et al., 1995) and daily primary production at station 39 (nearshore station) in September 15, 1995 at time 10.45 A.M.

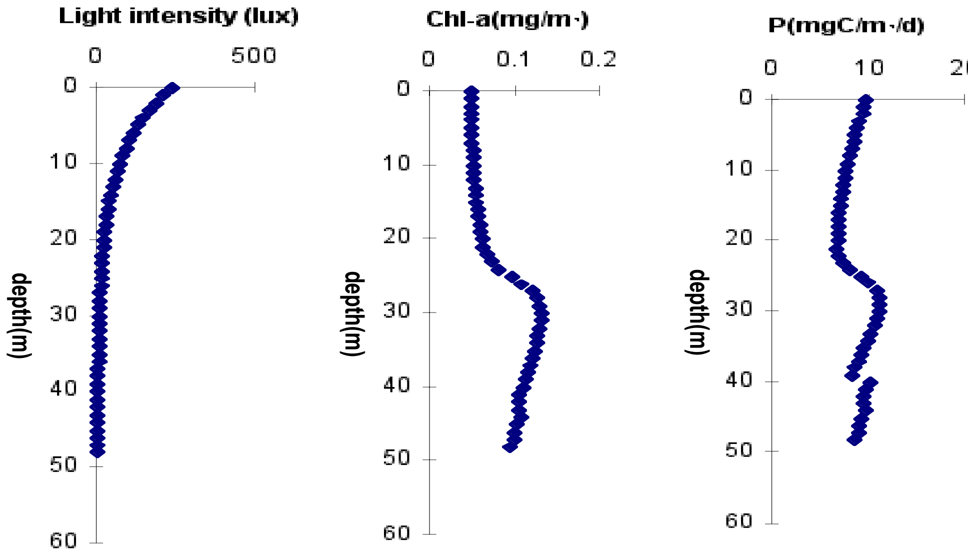


Fig. 13. Vertical distribution of light, chl-a (from Snidvongs et. al., 1995) and daily primary production at station 43 (offshore station) in September 17, 1995 at time 13.50 P.M.

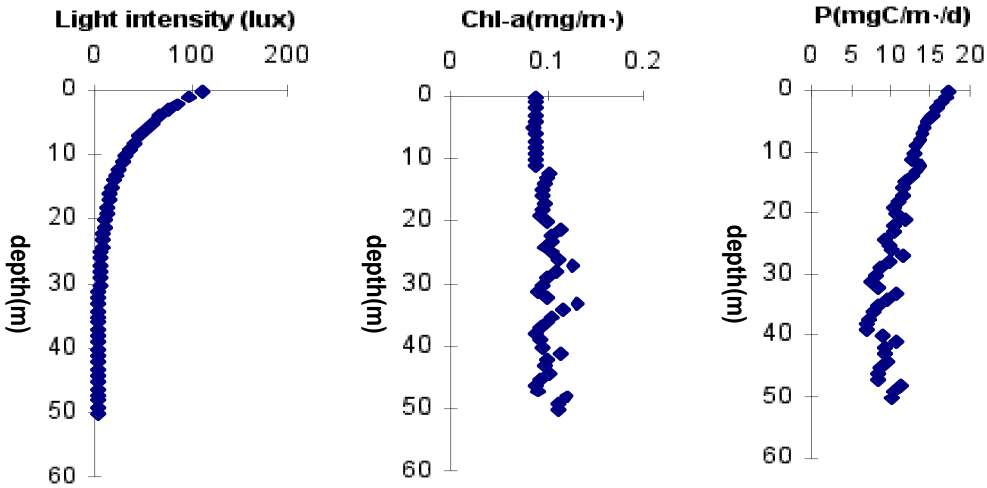


Fig. 14. Vertical distribution of light, chl-a (from Snidvongs et. al., 1995) and daily primary production at station 6 in September 6, 1995 at time 10.50 A.M.

cial fishery. The apparently high primary production does not imply the increasing marine population growth, because of the over fishing in this area. Careful management is a prerequisite to mantain future ecosystem.

## Summary


1) The variability in daily primary production is closely related to change in the phytoplankton biomass.
2) A factor in adequate light penetration which may become of significance in this is attennuation due to the contribution of daily primary production.


## Acknowledgement

The authors gratefully acknowledge the assistance of Dr. Anond Snidvongs, Department of Marine Science, Chulalongkorn University who collaborated in the study of the Gulf of Thailand and the East Coast of Peninsular Malaysia. And our sincere thanks due to SEAFDEC's Training Department in Thailand, the organization that funded this research, including Mr.Kijja Hutayon, the research scientist, Faculty of Science, Chulalongkorn University who counted samples by the GC-9A, Shimadzu, β - scintillation counter.

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