Rapid evaluation of photosynthetic activity of phytoplankton by pulse amplitude modulated (PAM) fluorescence in coastal waters

HITOSHI TAKAMARU, TAKASHI YOSHIKAWA, NEELAM RAMAIAH, SHIGENOBU TAKEDA AND KEN FURUYA
Department of Aquatic Bioscience, The University of Tokyo, Bunkyo-Ku, 113-8657, Japan

***KEY WORDS*: PAM, NPQ, phytoplankton fluorescence, primary production, Otsuchi Bay**

INTRODUCTION

Coastal waters undergo considerable changes in environmental conditions due to shallow topography, physical processes and human interferences viz., anthropogenic input and aquaculture practices. Evaluation of primary production of considerable variability in such an environment is a major challenge. The conventional bottle incubation is time consuming and laborious thus limiting spatio-temporal coverage. Bio-optical approaches such as active fluorescence (by PAM[1-3] and FRRF-fast repetition rate fluorometry[4,5]) and natural fluorescence (passive fluorescence) are recent alternate techniques adopted to determine the primary production. These approaches enable rapid and continuous measuremnt. However, quantification of various bio-optical parameters is needed. Among them, the non-photochemical quenching (NPQ) of in vivo fluorescence is important. PAM allows the quantification of the photochemical efficiency of photosystem II and relative electron flow rates[6]. We used PAM to evaluate the seasonal variations in NPQ and maximum quantum yield to determine the primary production in Otsuchi Bay, a subarctic ria in the northeastern Japan.

MATERIALS AND METHODS

Samples were collected during spring (17 to 29 May 2000), summer (4 Jul to 4 Aug 2000) and winter (19 Feb to 9 Mar 2001). Six stations were selected in Otsuchi Bay, five located in the inner bay and one at the bay mouth. Photosynthetic rate (P^B) was obtained from the P-E curves using ^{14}C uptake measurements[7] at 21 light intensities up to 2500 μmol m^{-2} s^{-1}. Light absorption co-efficient of phytoplankton (a*) was estimated by the quantitative filter technique (QFT)[8]. PAM measurements were made using the fluorometer (OS5-FL and AMF, Opti Science, UK) after dark adaptation of the samples for 15 minutes. Ancillary data on water temperature, salinity and irradiance were monitored continuously in the central part of the bay.

RESULTS

NPQ obtained after dark adaptation of the samples varied considerably between 0 and 0.34 during spring. In summer and winter, the NPQ was less variable in a narrow range of 0 and 0.2. ETR, electron transport rate calculated from NPQ and a* was between 0.5 and 3 μmol electrons (mgChl a)$^{-1}$ s^{-1} with relatively higher values during the diatom dominated spring and winter seasons.

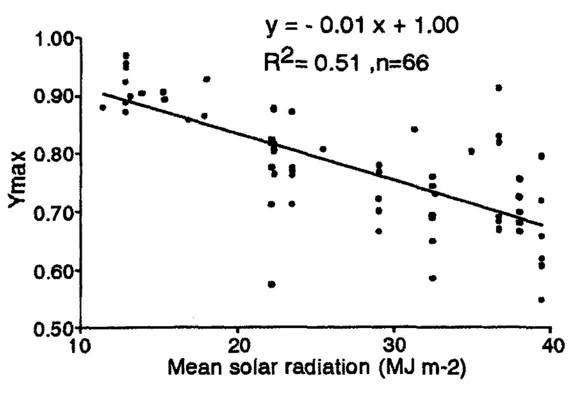

Fig.1. Relationship between Y_{max} and irradiance

Maximum quantum yield (Y_{max}) showed a significant negative correlation ($P<0.001$) with mean irradiance of past five days, indicating photo-acclimation of Y_{max} (Fig. 1). ETR showed significant correlation with P^B (Fig. 2). The good correlation found at both 1- and 7.5-m depths in winter and spring and at a 7.5-m depth in summer shows P^B is estimated from ETR. However, surface population in summer showed poor correlation, although the correlation is significant ($p<0.001$). The correlation of each obaservation was good, but the slope was highly variable between days.

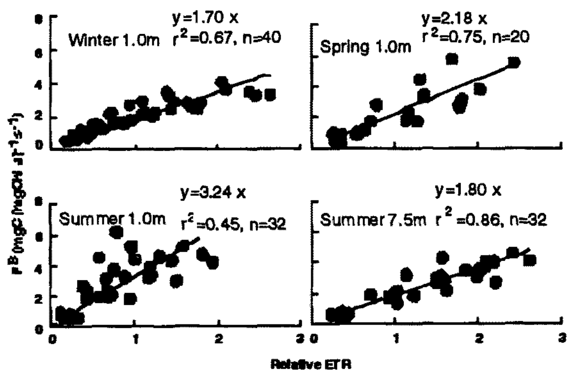

Fig. 2. Relationship between relative ETR and photosynthetic rate (P^B)

DISCUSSION

To date, only a few studies have used PAM for the estimation of photochemical efficiency of natural and cultured phytoplankton[1-3]. We applied this technique for quick and efficient evaluation of primary productivity in Otsuchi Bay for evaluation of the carrying capacity of which depends on the magnitude of primary production and material cycling[9]. From the present study, it was possible to predict the variations in Y from mean solar irradiance based on the relationship obtained between these two parameters. The photoacclimation of Ymax we observed was in accordance with that reported for the coral photosymbionts[10]. Higher variations in NPQ during spring coincided with the variations in phytoplankton biomass (in terms of chlorophyll *a*). This parameter could thus be used as a vital signal to determine the primary production in coastal waters. For robust interpretation of ETR as an indication of P^B further inverstigation is needed for the observed variations in the relationship between ETR and P^B in the surface populations in summer.

REFERENCES

1. Ting CS, Owens TG. Limitation of the pulse-modulated technique for measuring the fluorescence characteristics of algae*Plant Physiol.* 1992; **100**:367-373.

2. Kroon B, Prezelin BB, Schofield O. Chromatic regulation of quantum yields for photosystem II charge separation, oxygen evolution, and carbon fixation in Heterocapsa pygmaea (Pyrrophyta). *J. Phycol.* 1993; **29**: 453-462.

3. Hofstaart JW, Peeters JCH, Snel JFH, Geel C. Simple determination of photosynthetic efficiency and photoinhibition of *Dunaliella tertiolecta* by saturating pulse fluorescence measurements. *Mar. Ecol. Prog. Ser.* 1994; **103**: 187-196.

4. Lesser MP, Gorbunov MY. Diurnal and bathymetric changes in chlorophyll fluorescence yields of reef corals measured in situ with a fast repetition rate fluorometer. *Mar. Ecol. Prog. Ser.* 2001; 212: 69-77.

5. Suggett D, Kraay G, Holligan P, Davey M, Aiken J, Geider R. Assessment of photosynthesis in a spring cyanobacterial bloom by use of a fast repetition rate fluorometer. *Limnol. Oceanogr.* 2001; **46**: 802-810.

6. Schreiber U, Bilger W, Neubauer C. Chlorophyll fluorescence as a non-intrusive indicator for rapid assessment of *in vivo* photosynthesis. *Ecol. Stud.* 1994; **100**: 49-70.

7. Platt, T, Gallegos, CL W. G. Harrison (1980): Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. *J. mar. Res.*, **38**, 687-701.

8. Kishino, M., and Okami, N. (1986): Light utilization effiency and quantum yieled of phytoplankton in a thermally stratified sea. *Limnol. Oceanogr.*, **31**, 557 - 566.

9. Furuya K. Evaluation of biological productivity of lower trophic levels and carrying capacity of aquaculture areas. This volume, B-3-4.

10. Beer S, Ilan M. *In situ* measurements of photosynthetic irradiance responses of two Red Sea sponges growing under dim light conditions. *Mar. Biol.* 1998; **131**: 613-617.