



Variation in photosynthetic activity of phytoplankton during the spring algal blooms in the adjacent area of Changjiang River estuary



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ABSTRACT

Nine cruises were undertaken in the adjacent area of Changjiang River estuary from late March to May in 2011 to investigate the variation in photosynthetic activity (F_v/F_m) of surface water during algal blooms. The time series covered the period from *Skeletonema* sp. bloom to *Prorocentrum donghaiense* bloom. The results showed that F_v/F_m ranged from 0.17 to 0.73. Temperature, turbidity and nutrients were the primary influencing factors on F_v/F_m and F_v/F_m showed a strong diel periodicity. Additionally, the change in F_v/F_m during *Skeletonema* sp. and *P. donghaiense* bloom was similar. F_v/F_m increased to more than 0.60 before bloom initiation, and then chlorophyll *a* (Chl *a*) concentration rocketed and the bloom broke out. F_v/F_m was above 0.6 during bloom development and declined to below 0.6 when bloom dissipated. F_v/F_m increasing to higher level occurred several days prior to significant increases in Chl *a* and outbreak of bloom, indicating F_v/F_m can be used to predict onset of algal blooms.

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1. Introduction

The Changjiang River ranks the third in length and the fourth in solid discharge in the world (Tian et al., 1993). Being the largest river in China, it discharges into the East China Sea and plays a fundamental role in the continental inputs to the East China Sea and the Pacific Ocean (Chai et al., 2006).

The rapid development of the economy and increase in the population in the drainage basin have significantly affected the river, and consequentially affected the aquatic ecosystem in the Changjiang River estuary and adjacent coastal waters (Zhou et al., 2008). Nitrate concentrations inshore increased nearly 9-fold since the early 1960s. Also, soluble reactive phosphorus concentrations have increased about 3- to 4-fold since the 1960s (Chai et al., 2006). As a result, eutrophication has become increasingly serious and harmful algal blooms (HABs) have been of more frequent occurrence in the adjacent East China Sea. HABs frequently occur in a region bounded by 28–31.5° N and 121.5–123.5° E during April–August (Zhang, 2008). *Skeletonema costatum* and

Prorocentrum donghaiense are the most representative bloom species. *P. donghaiense* blooms often occur after *S. costatum* blooms.

Quantification of chlorophyll *a* (Chl *a*) concentrations and algal cell density has conventionally been used for accurate detection of bloom-forming algal biomass. In terms of early detection and regulation of harmful algae, it is advisable to evaluate the growth potential or bloom-forming probability before any blooms appear. The maximum photochemical efficiency of photosystem II (F_v/F_m) is an index of the photosynthetic activity, allowing for rapid, sensitive, and non-invasive assessment of the physiological status of phytoplankton communities (Geider et al., 1993; Olaizola et al., 1996; Richardson et al., 2003; Goto et al., 2008; Martin et al., 2010). Boyd and Abraham (2001) showed that the changes in F_v/F_m were the first indication of a response by the algal assemblage to iron enrichment, and occurred several days prior to other increases in phytoplankton properties such as Chl *a*, growth rate, or cell size.

Over the last three decades, many investigations of nutrients and phytoplankton biomass in Changjiang River estuary and its adjacent area have been carried out (Gu et al., 1981; Huang et al., 1986; Shen and Hu, 1995; Shen et al., 1999; Shi et al., 2003; Zhou et al., 2008; Li et al., 2009; Liu et al., 2013), whereas there was a lack of research on F_v/F_m . The current study aimed to investigate the variation in bulk community values of F_v/F_m during the spring algal blooms in the adjacent area of Changjiang River estuary.

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Environmental parameters, such as temperature, light, nutrient, salinity and phytoplankton community composition, are the primary influencing factors on F_v/F_m and can reflect the status and characteristic of a bloom. Accordingly, these parameters were also measured.

2. Material and methods

2.1. Field survey

Sampling was conducted during nine cruises from late March to May in 2011 in the adjacent area of Changjiang River estuary, between 28 and 30.5° N (Fig. 1; Table 1). Surface water was collected using 30 l Niskin bottles for measurements of F_v/F_m and Chl *a*.

Data of sea surface temperature, salinity, nutrients, phytoplankton community composition and Secchi depth are from an ongoing project supported by National Basic Research Program of China (973 Program) (No. 2010CB428701).

2.2. Dark adaptation experiments

F_v/F_m has shown strong diel periodicity in past studies (Boy and Abraham, 2001; Bergmann et al., 2002; Almazán-Becerril and García-Mendoza, 2008). Two on-deck dark-adapted experiments were performed to determine the time that allows phytoplankton to repair damage due to the sun. For each experiment, 5-l

Table 1
Information of field survey in the spring of 2011 in the adjacent area of Changjiang River estuary.

Cruise	Date	Transect
1	3.29–4.02	ZC, ZB, ZA, RA, RB
2	4.09–4.10	RB, ZB, ZA
3	4.19–4.20	RB, ZB, ZA
4	4.28	ZA
5	5.02	ZA, ZB
6	5.04–5.07	RB, ZA, ZB, ZC, RA
7	5.13–5.15	RB, ZC, ZB, ZA, RA
8	5.22	ZA
9	5.25–5.27	RB, RA, ZB, ZC, ZA

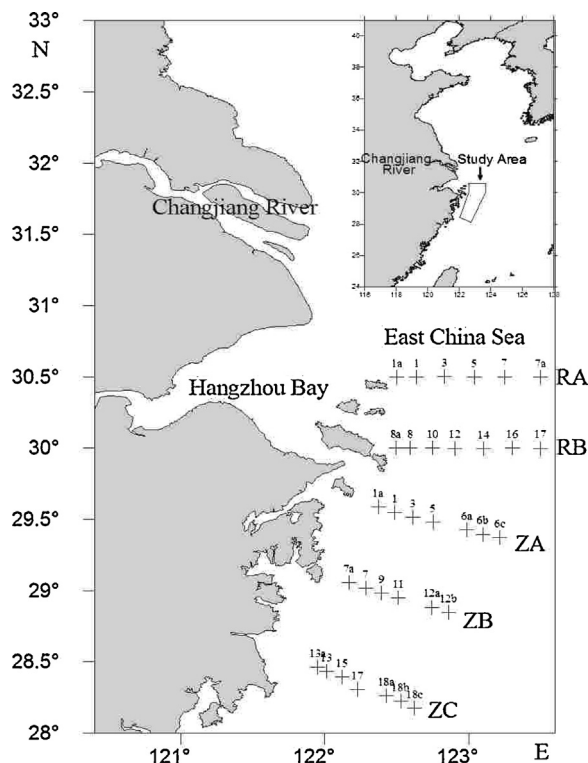


Fig. 1. Sample stations in the spring of 2011 in the adjacent area of Changjiang River estuary.

transparent polyethylene bottles were filled with surface seawater and incubated at ambient temperature and irradiation. At intervals, dark-adapted and non dark-adapted F_v/F_m was recorded to determine the extent and recovery time of photoinhibition of F_v/F_m . The first experiment was performed on April 28 at station za6b where *Skeletonema* sp. was dominated. The second was performed on May 5 at station zb9 where *P. donghaiense* was dominated.

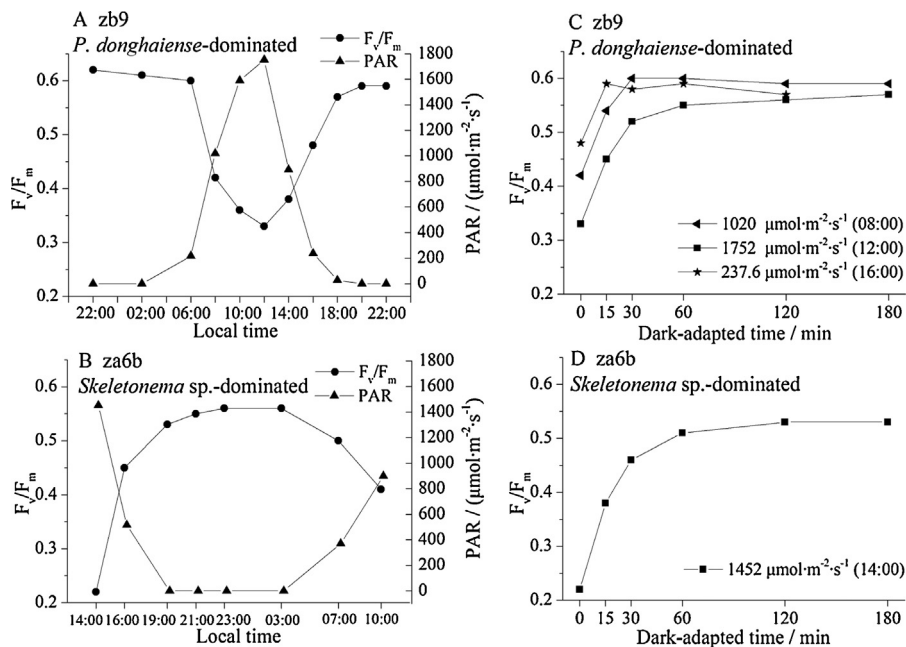


Fig. 2. Diel variations of F_v/F_m in surface water and recoveries of F_v/F_m after dark adaptation for *P. donghaiense*-dominated communities at station zb9 (A and C) and for *Skeletonema* sp.-dominated communities at station za6b (B and D). Incident irradiance was measured by a PAR sensor.

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