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In situ study on photosynthetic characteristics of phytoplankton in the Yellow Sea and East China Sea in summer 2013

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ABSTRACT

In situ studies on photosynthetic characteristics of phytoplankton were important for the analysis of changes in community structure and for the prediction and control of algal blooms, but such studies of phytoplankton in offshore China were few. In this study, the detailed distribution of photosynthetic characteristics of phytoplankton in the summer of 2013 in the Yellow Sea and East China Sea was measured using Phyto-PAM (Pulse Amplitude Modulation). The phytoplankton community structure and the environmental parameters were also investigated to estimate the relationship between the distribution of the photochemical competence of phytoplankton and ecological factors. The total average F_v/F_m (the potential maximum quantum yield) value of phytoplankton in the Yellow Sea and East China Sea in summer 2013 was less than 0.5, reflecting that the photosynthetic activity of phytoplankton was relatively low. F_v/F_m of phytoplankton in summer was significantly positively associated with nitrate content (NO_2^-), which reflects relationship between metabolism and photosynthesis of phytoplankton: accompanied by NO_2^- metabolism, photosynthesis and photosynthetic capacity may be enhanced simultaneously, so the F_v/F_m value would increase with the NO_2^- released by phytoplankton. Through the in situ study on photosynthetic characteristics of phytoplankton in the Yellow Sea and East China Sea, we come to the conclusion that photosynthetic characteristics and activity of phytoplankton are influenced by its biological characteristics and surrounding ecological factors, such as irradiance, nutrients and phytoplankton community. Meanwhile, the thermally stratified structure and the movement of water masses, such as the Yangtze River diluted water, the Yellow Sea cold water mass and other different water system, also have an important impact on phytoplankton photosynthetic activity and characteristics. Greater understanding of the detailed photosynthetic characteristics of phytoplankton coupled with their community structure and the environmental parameters will encourage new researches and developments in studies of marine ecosystems.

1. Introduction

Phytoplankton is a basic link in the food chain and is the most important primary producer in marine ecosystems. Photosynthesis is the most critical process in the primary production of phytoplankton. Phytoplankton converts inorganic substances to organic matters and converts light energy to chemical energy through photosynthesis, providing energy sources for the entire aquatic ecosystem. Algal productivity accounts for about 45% of global gross primary productivity (Field et al., 1998).

Photosynthetic characteristics are the most fundamental and important physiological and ecological characteristics of algae. Research on phytoplankton photosynthetic capacity and characteristics improves our understanding of primary production and material circulation in the marine ecosystem and the population dynamics of phytoplankton (Jakob et al., 2005; Napoléon and Claquin, 2012; Strzepek and Harrison, 2004). Phytoplankton in different sea areas has different photosynthetic characteristics that are affected by nutrients, temperature, light and other environmental factors, which has important significance for their adaptation to the local living environment (Suggett et al., 2009). In the high nutrient low chlorophyll (HNLC) waters, the potential maximum quantum yields (F_v/F_m) of phytoplankton are very low, while after "iron fertilization" experiments in water, the photosynthetic capacity is significantly enhanced (Boyd et al., 2000; Kolber et al., 1994). Ice algae living in the arctic sea can reach the light saturation under a low light intensity condition (Mcminn and Hegseth, 2004) while diatoms in tropical and subtropical waters must live under a high light intensity condition in order to achieve a higher photosynthetic efficiency, because they have formed a strong photosystem protection mechanism (Wang et al., 2012). Diatoms living in the coastal waters (iron rich environment) and oceans (iron barren environment) have also been proved to have different mechanisms of photosynthesis. When the coastal diatoms

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move to ocean, they will regulate and reduce their light harvesting ability by reducing the activity of photosystem I and concentration of cytochrome *b6f*, which is conducive to their adaptation to the iron barren environment (Strzepek and Harrison, 2004). Phytoplankton can change the photosynthetic strategy to adapt to new environment, which influences the distribution and evolution of marine phytoplankton deeply.

Phytoplankton can consume absorbed light energy in three ways: photosynthesis, heat dissipation and re-releasing light energy in the form of chlorophyll fluorescence (Papageorgiou et al., 2007). The change of chlorophyll fluorescence is the embodiment of capacity and efficiency of phytoplankton photosynthesis, reflecting the influence of environmental factors on the photochemical reaction center activity and electron transport efficiency (Kromkamp and Forster, 2003). As the first trophic level in the ocean, marine phytoplankton is especially sensitive to the external environment and is able to make rapid and accurate responses to environmental factors that inhibit photosynthesis. The potential maximum quantum yield, F_v/F_m, is often used as an indicator of the influence of external stress on phytoplankton photosynthesis (Häder et al., 1998). It cannot only reflect effects of various external environmental factors on the photosynthesis of algae, but also help to explain the light adaptation mechanism of phytoplankton community in certain living environment. Different types of phytoplankton in different living conditions have different F_v/F_m values (Cermeño et al., 2005). According to the investigation of the tropical waters of Atlantic, the F_v/F_m of phytoplankton in eutrophic water is higher than that of the oligotrophic water (Babin et al., 1996). The value for algae is approximately 0.65 (Kolber et al., 1988), which is normally stable, but decreases significantly when algae are under stress. The measurement of F_v/F_m has contributed greatly to the study of aquatic photosynthesis and ecosystems (Bergmann et al., 2002).

As shelf seas of the Western Pacific, the Yellow Sea and East China Sea are some of the largest shelf seas in the world with complex hydrological characteristics, which is under the combined effects of the Kuroshio, Taiwan warm current, the Yangtze River diluted water, the Yellow Sea cold water mass and other different water systems (Mi et al., 2012). In recent years, ecological environment of the Yellow Sea and East China Sea has been increasingly widespread concerned, because of the decline of fishery resource, frequent occurrences of red tides and jellyfish blooms (Tang et al., 2005). Current researches on phytoplankton in the Yellow Sea and East China Sea pay more attention to the structure and size fraction, influence factors of algal blooms, temporal and spatial variation of primary productivity and chlorophyll *a* concentration, while the research on the photosynthesis of phytoplankton and its influence factors has not been reported yet. In modern studies of phytoplankton photosynthesis, in vivo fluorescence measurements have been widely used because they are convenient, rapid and non-invasive, and they allow for higher spatio-temporal resolution investigations (Fu et al., 2013). In order to fully understand marine ecosystems in the Yellow Sea and East China Sea, it is necessary to properly understand the photosynthetic competence and photosynthetic physiological states of phytoplankton in detailed spatio-temporal distribution. So in the present study, we measured the detailed distribution of photosynthetic characteristics of phytoplankton in the Yellow Sea and East China Sea in summer (June and August) for the first time. At the same time, we also measured the physicochemical and biological factors (water temperature, irradiance, nutrients, phytoplankton species and chlorophyll *a* concentration) and have estimated the relationship between the distribution of photosynthetic characteristics and environmental factors based on the results obtained.

2. Materials and methods

2.1. Sampling time and stations

Sampling of the Yellow Sea (32–37°N) and East China Sea (27–32°N) for measurements of F_v/F_m was carried out from June 15 to 29, August 16 to 31 in 2013. Specific sampling stations were shown in Fig. 1. There were 41 sampling stations in June and 32 in August.

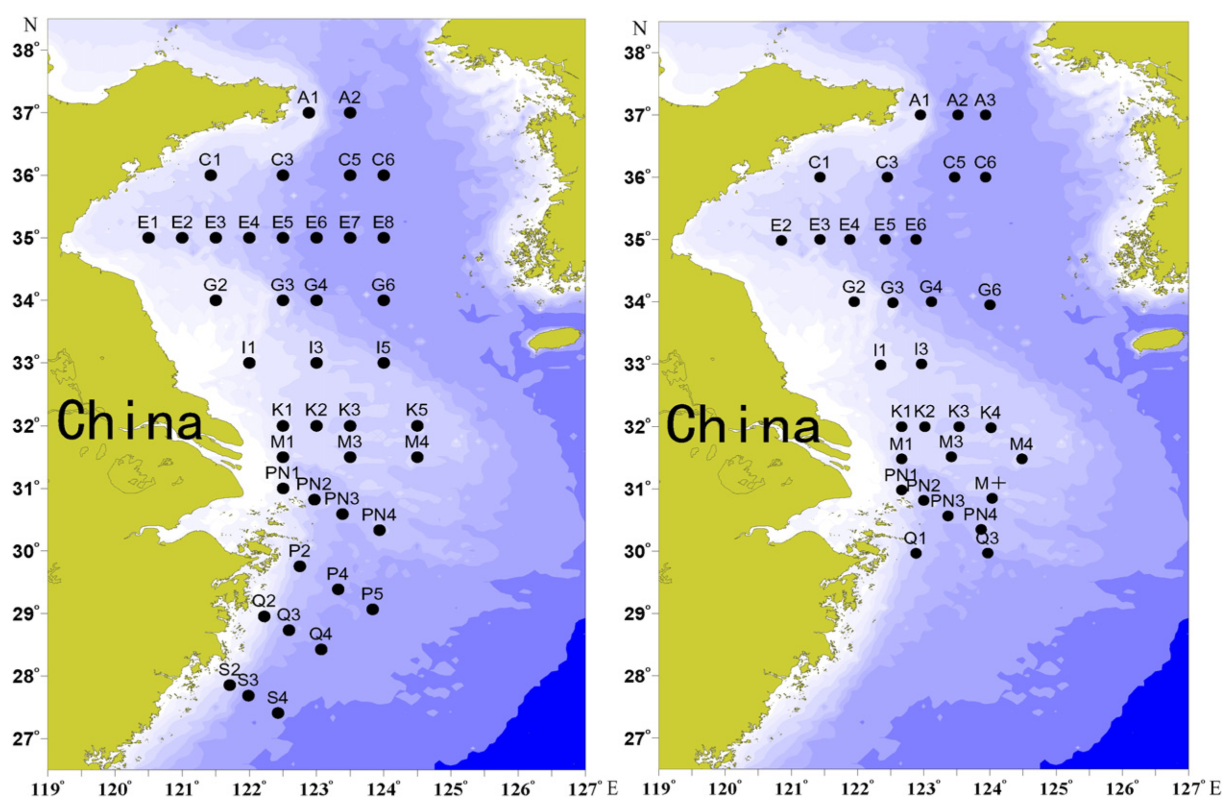

Fig. 1. Sampling stations in the Yellow Sea and East China Sea in June and August.