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Temporal variation of picoplankton in the spring bloom of Yellow Sea, China

Yuan Zhao [a], Li Zhao [a,b], Tian Xiao [a,*], Chenggang Liu [c], Jun Sun [d], Feng Zhou [e], Sumei Liu [f], Lingfeng Huang [g]

[a] Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
[b] Graduate University, Chinese Academy of Sciences, Beijing 10086, China
[c] Key Laboratory of Marine Ecosystem and Biogeochemistry, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China
[e] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China
[f] Key Laboratory of Marine Chemistry Theory and Technology Ministry of Education, College of Chemistry and Chemical Engineering, Ocean University of China, Qingdao 266100, China
[g] Department of Oceanography, Xiamen University, Xiamen 361005, China
[d] College of Marine Science and Engineering, Tianjin University of Science and Technology, Tianjin 300457, China

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ABSTRACT

Temporal variation of *Synechococcus*, picoeukaryote and heterotrophic bacteria abundance and depth integrated biomass during three spring blooms in 2007 and 2009 were investigated in the Yellow Sea, China. *Synechococcus* and picoeukaryote responded differently to different types and course of spring blooms. During the diatom blooms of 2007 and Bloom B20 in 2009, *Synechococcus* and picoeukaryote abundances decreased sharply during the bloom period. However, during a mixed dinoflagellate and diatom bloom of Bloom B23 in 2009, *Synechococcus* and picoeukaryote increased in abundance and biomass along the bloom. During all three spring blooms, heterotrophic bacteria biomass had a similar increasing trend. Ciliate and heterotrophic nanoflagellate grazing could be responsible for *Synechococcus* and picoeukaryote abundance and biomass decrease during the spring blooms.

1. Introduction

Marine picoplankton refer to a functionally diverse group of organisms which are microscopic in size (≤2 μm in diameter), but very abundant in the marine water column. Picoplankton include cyanobacteria of the genera *Synechococcus* (Johnson and Sieburth, 1979; Waterbury et al., 1979) and *Prochlorococcus* (Chisholm et al., 1988), a great diverse assemblage of picoeukaryote and heterotrophic bacteria which do not carry out oxygenic photosynthesis. Picoplankton have drawn much research attention due to its essential role in oceanic processes such as carbon production, biomass and energy transfer (Stockner, 1988; Li et al., 1983; Azam et al., 1983). Cyanobacteria are very important primary producers among autotrophic picoplankton. Generally, *Synechococcus* are present in inshore or coastal waters (Jochem, 1988) and can account for 20% of marine total biomass and 60% of total primary productivity (Caron et al., 1991). In some marine environments, picoeukaryote are major contributors in terms of biomass (Worden et al., 2004). Heterotrophic bacteria play an indispensable role in the carbon flux in aquatic ecosystems. They are decomposer of organic material, as well as utilizer of dissolved organic carbon (DOC) in marine ecosystems (Lefèvre et al., 1996; Hansell and Carlson, 1998). Thus heterotrophic bacteria are at the foundation of the microbial loop (Fuhrman and Azam, 1980).

Spring phytoplankton bloom is one of the most important seasonal patterns in pelagic food webs (Townsend et al., 1994). The Yellow Sea, located between mainland China and the Korean peninsula, is a typical semi-closed marginal sea of the Pacific Ocean, with depths ranging from 90 m in the central trough to less than 20 m within 50 km off the coast. Several typical hydrological features are present in the Yellow Sea. In spring, with a strong activity of tidal mixing, surface water of the Yellow Sea is rich in nutrients. Together with seasonal warming and the seasonal onset of higher light availability, those conditions would trigger the spring phytoplankton bloom.

The picoplankton distribution during spring phytoplankton bloom was investigated in several marine environments and different patterns were observed. On the one hand, an abrupt abundance decrease for *Synechococcus* and/or picoeukaryote followed by their abundance increase was observed during phytoplankton blooms in mesocosm and field investigations (Cunliffe et al., 2009; Larsen et al., 2004; Martinez-Martinez et al., 2006;

* Corresponding author. Tel./fax: +86 532 82898586.
E-mail address: txiao@qdio.ac.cn (T. Xiao).

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Šimek et al., 1995). On the other hand, autotrophic picoplankton (*Synechococcus* and picoeukaryote) could maintain a "bloomer growth strategy with higher abundance and biomass during bloom than non-bloom conditions" (Mackey et al., 2009). The dissolved organic carbon (DOC) released from phytoplankton is an important carbon source for heterotrophic bacteria in the ocean (Azamet al., 1983). It was commonly observed that heterotrophic bacteria had higher abundance and biomass during bloom than non-bloom conditions (Martinez-Martinez et al., 2006; Larsen et al., 2004; Hyun and Kim, 2003).

Researches focused on the distribution of picoplankton during Yellow Sea spring bloom are very limited (Cho et al., 1994; Hyun and Kim, 2003). In this paper, we report investigations on picoplankton distribution in the Yellow Sea conducted during 2007 and 2009 spring blooms.

2. Materials and methods

2.1. Cruise description

In 2007 and 2009, two survey cruises were conducted in the central Yellow Sea (33.5–37.5°N, 121–124.5°E) to observe the spring bloom. On the basis of 9 years historical data (1998–2006), seawater chlorophyll *a* concentration >4 mg m^{-3} was set as the bloom criterion.

In 2007, a cruise was carried on from 30 March to 23 April. Seawater samples were collected from 32 stations (25 main-cruise stations and 7 anchor-stations) (Fig. 1). The ship track and station locations are displayed in Fig. 2. The cruise started from Transect A (Fig. 2A). When Transect G was completed, remote sensing detected high chl *a* concentration south of the study area which initiated the bloom tracking from St. F4 (Fig. 2B). Some stations were visited repeatedly as follows: A6-a→BM1-a→C4-a→D3-a→C4-b→BM1-b→A6-b→BM1-c→C4-c→D3-b (-a, -b, -c after the St.-name meaning the 1st, 2nd, 3rd time the vessel visited the stations respectively). After the bloom faded away, cruises went on as shown in Fig. 2C.

The main cruise survey conducted in 2009, initially set up non-bloom stations as reference. Then, two blooms were detected by remote sensing at St. B20 and St. B23 (Fig. 3). A drogue was released at each station in order to track the phytoplankton bloom development in a Lagrangian mode. The blooms were monitored for a period of 102 h (03:00 4 April–9:00 8 April) from St. B20 and 126 h (03:00 9 April–9:00 14 April) from St. B23. The B20 drogue drifted to southwest about 20 km from its initial position and the B23 drogue remained within a 7 km distance to its initial position (Fig. 4). Seawater samples were collected every 3 h during both blooms.

2.2. Sampling strategy

At each station, seawater samples were collected with 5 L Niskin bottles on a "Sea-Bird" CTD (Conductivity/Temperature/Depth) rosette sampler. In 2007, seawater samples were mainly collected from five depths (surface, 10 m, 30 m, 50 m and bottom).

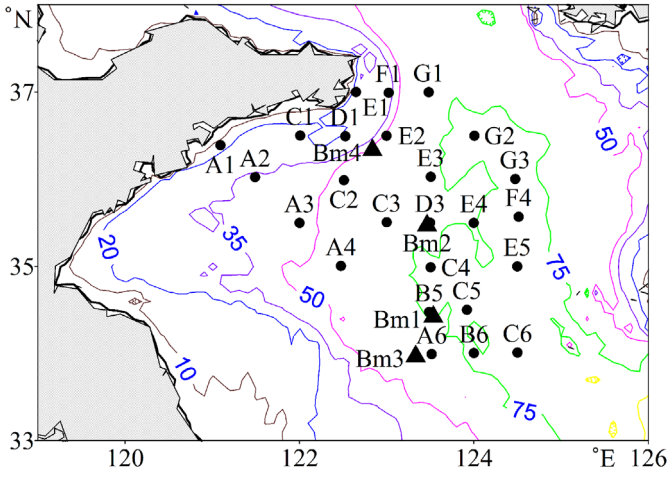

Fig. 1. Location of the sampling stations of the Yellow Sea Spring Bloom Cruise in 2007. (●: Main cruise stations, ▲: Anchor stations and contour-lines: isobath of the study area).

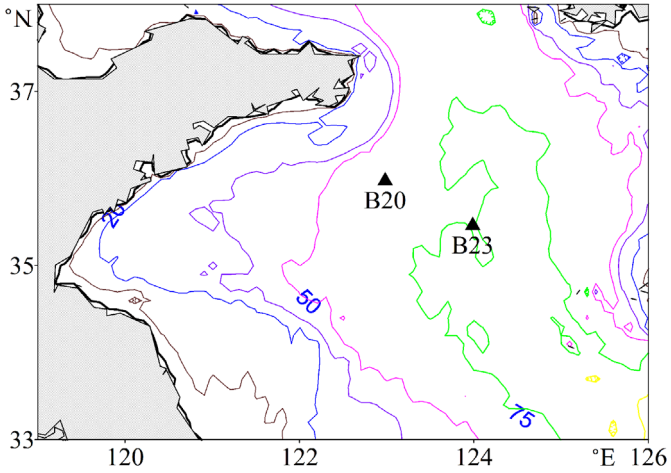

Fig. 3. Location of the bloom tracking stations in 2009 (contour-lines: isobath of the study area).

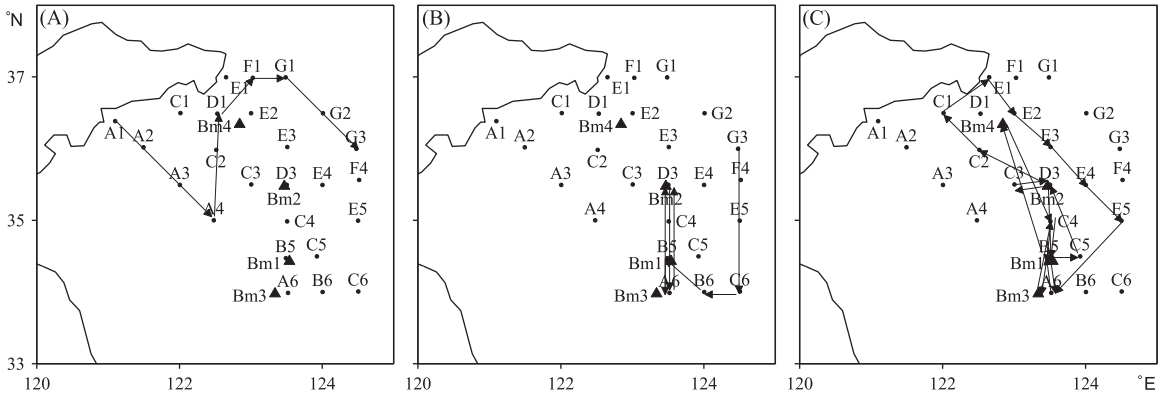

Fig. 2. Observation routes in 2007 (a) pre-bloom period; (b) bloom period and (c) post-bloom period.