Estuarine, Coastal and Shelf Science 89 (2010) 234–244

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Spatial–temporal distribution of phytoplankton pigments in relation to nutrient status in Jiaozhou Bay, China

Peng Yao [a,b], Zhigang Yu [a,*], Chunmei Deng [c], Shuxia Liu [a], Yu Zhen [d]

[a] Key Laboratory of Marine Chemistry Theory and Technology, Ministry of Education, College of Chemistry and Chemical Engineering, Ocean University of China, Qingdao 266100, China
[b] Department of Chemistry, University of York, York YO10 5DD, UK
[c] Key Laboratory of Marine Spill Oil Identification and Damage Assessment Technology, State Oceanic Administration, Qingdao 266033, China
[d] Key Laboratory of Marine Environment and Ecology, Ministry of Education, College of Environmental Science and Engineering, Ocean University of China, Qingdao 266100, China

ARTICLE INFO

Article history:
Received 15 January 2010
Accepted 9 July 2010
Available online 15 July 2010

Keywords:
phytoplankton
HPLC
pigments
nutrients
Jiaozhou Bay

ABSTRACT

We conducted studies of phytoplankton and hydrological variables in a semi-enclosed bay in northern China to understand the spatial–temporal variability and relationship between these variables. Samples were collected during seven cruises in Jiaozhou Bay from November 2003 to October 2004, and were analyzed for temperature, nutrients and phytoplankton pigments. Pigments from eight possible phytoplankton classes (Diatoms, Dinoflagellates, Chlorophyceae, Prasinophyceae, Chrysophyceae, Haptophyceae, Cryptophyceae and Caynophyceae) were detected in surface water by high performance liquid chromatography (HPLC). Phytoplankton pigment and nutrient concentrations in Jiaozhou Bay were spatially and temporally variable, and most of them were highest in the northern and eastern parts of the sampling regions in spring (May) and summer (August), close to areas of shellfish culturing, river estuaries, dense population and high industrialization, reflecting human activities. Chlorophyll *a* was recorded in all samples, with an annual mean concentration of 1.892 $\mu g\,L^{-1}$, and fucoxanthin was the most abundant accessory pigment, with a mean concentration of 0.791 $\mu g\,L^{-1}$. The highest concentrations of chlorophyll *a* (15.299 $\mu g\,L^{-1}$) and fucoxanthin (9.417 $\mu g\,L^{-1}$) were observed in May 2004 at the station close to the Qingdao Xiaogang Ferry, indicating a spring bloom of Diatoms in this area. Although chlorophyll *a* and other biomarker pigments showed significant correlations, none of them showed strong correlations with temperature and nutrients, suggesting an apparent de-coupling between the pigments and these hydrological variables. The nutrient composition and phytoplankton community composition of Jiaozhou Bay have changed significantly in the past several decades, reflecting the increasing nutrient concentrations and decline of phytoplankton cell abundance. The unchanged total chlorophyll *a* levels indicated that smaller species have filled the niche vacated by the larger species in Jiaozhou Bay, as revealed by our biomarker pigment analysis.

1. Introduction

Jiaozhou Bay is a typical semi-enclosed small water body, connected to the North Yellow Sea of China through a narrow mouth (~2.5 km). It is surrounded by Qingdao City (population 9×10^6), has a surface area of about 390 km^2 and an average water depth of about 7 m. More than 10 small seasonal rivers enter the bay, the largest of which is Dagu River, with an annual average water discharge of $5.35 \times 10^8\ m^3$ and sediment load of 95.92×10^4 ton (Table 1, Liu et al., 2005b). Most of these rivers, however, have become discharge trenches for industrial and domestic wastes from Qingdao City and important external sources of nutrients entering the bay, especially with the advance of regional population and economic development (Shen, 2001; Liu et al., 2005b).

Jiaozhou Bay is a region in China subject to extensive marine research. Phytoplankton investigations and nutrient concentration measurements in Jiaozhou Bay can be traced back to the 1930s and 1960s (Jin, 1939; Shen, 2001), respectively. The balance of nutrient concentrations and structures has changed notably in the bay since the 1960s (Zhao et al., 2005a). In addition, the community composition, cell abundance and dominant species of phytoplankton in the bay have changed significantly over the past decades (Liu, 2004). The changes in nutrient regime and phytoplankton population structure are attributed to the substantial impacts from the surrounding area, such as increased human

* Corresponding author.
E-mail address: zhigangyu@mail.ouc.edu.cn (Z. Yu).

0272-7714/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2010.07.003

Table 1
Hydrological parameters and nutrient transport fluxes of the major rivers emptying into Jiaozhou Bay (modified from Liu et al., 2005b).

	Length (km)	Drainage area (km^2)	Water discharge ($10^8\ m^3\ yr^{-1}$)	Sediment load (10^4 ton yr^{-1})	Ammonium (10^6 M yr^{-1})	Nitrate (10^6 M yr^{-1})	Nitrite (10^6 M yr^{-1})	Phosphate (10^6 M yr^{-1})	Silicate (10^6 M yr^{-1})
Dagu River	179	5634.2	5.35	95.92	12.0	9.51	0.19	0.21	45.3
Baisha River	35	202.9	0.29	0.51	1.11	7.62	0.41	0.036	1.24
Moshui River	42.3	356.2	0.29	4.76	17.9	6.38	0.009	1.41	8.21
Yang River	41	87.2	0.56	25.8	0.89	4.76	0.041	0.009	2.58
Licun River	14.5	108	0.11	2.94	1.84	0.039	0.015	0.83	3.87

activity, changing water circulation and increased aquaculture in this region (Liu et al., 2005b).

Previous studies of phytoplankton species in Jiaozhou Bay mostly relied on net sampling and subsequent light microscopic cell counting, which is time-consuming and costly, if larger numbers of samples need to be processed, and requires expertise in taxonomic identification. Most importantly, smaller phytoplankton species cannot be identified under light microscopy, since they lack taxonomically useful external morphological features, which may cause the underestimation of the biomass of the primary producers. It has been observed that the maximum cell abundance in Jiaozhou Bay has decreased from $10^8 - 10^9$ cells L^{-1} in the 1980s to the 10^7–10^8 cells L^{-1} in the 1990s (Liu et al., 2008), whereas total chlorophyll *a* levels have, on average, remained largely unchanged at around 3.55 $\mu g\ L^{-1}$ without significant difference over time (Zhao et al., 2005a). Smaller species have undoubtedly occupied the niches vacated by larger species in the bay (Zhao et al., 2005a). Therefore, microscopic observations are no longer suitable for the comprehensive understanding of the phytoplankton community composition in Jiaozhou Bay.

An alternative to microscopy is the use of characteristic pigments as chemotaxonomic markers of individual phytoplankton groups (Wright and Jeffrey, 2006). Many pigments are limited to particular classes or even genera, allowing the classification of the phytoplankton at the taxonomic rank of class or better, especially for small eukaryotic cells (Suzuki et al., 1997). In the last decade, understanding of phytoplankton community structure and abundance in the water column has been greatly aided by developments in high performance liquid chromatography (HPLC) pigment analysis.

The aim of this study was to describe the spatial and temporal distribution of phytoplankton pigments and community composition in Jiaozhou Bay. In addition, the relationships of phytoplankton pigments with hydrological and nutrient concentrations were studied in order to link the chemical analyses with the biology of the bay, which is of importance for future management decisions.

2. Materials and methods

2.1. Sampling

Sampling was carried out with "Diaoxie 32" at bimonthly intervals from December 2003 to October 2004 (plus May 2004). Samples were collected at 18 stations located in the middle part and the inlet of Jiaozhou Bay (Fig. 1). In April 2004, no samples from stations 16–18 were collected due to bad weather conditions. At each station, subsurface water was collected at 0.5 m depth with a prewashed plastic bottle. After collection, water temperatures were measured immediately on board using a mercury thermometer. The water depth of the sampling stations was recorded by ship-based depth measuring instrumentation. All the samples were transported to the laboratory after each cruise for further treatment. A 250 mL subsample was filtered through a pre-cleaned, 0.45 μm pore size, acetate cellulose filter (Xidoumen, Hangzhou, China) that had been presoaked in diluted hydrochloric acid (ca. pH = 2) overnight and then rinsed with Milli-Q water (Millipore Corporation, USA), for nutrient measurements. The filtrates were poisoned by addition of chloroform (ca. 1.0×10^{-3} v/v). For each sample, half of the filtrates were stored at −20 °C pending nitrate and phosphate measurements, and the other half of the filtrates were kept at room temperature until silicate analysis. A 1000 mL subsample was pre-filtered over a 200 μm silk sieve to remove larger zooplankton, and then filtered through a GF/F filter (Whatman International Ltd., Maidstone, UK), under gentle vacuum pressure (less than 0.03 MPa) and dim light, for analysis of phytoplankton pigments. The filters were wrapped in aluminum foil and stored at −80 °C until analysis by HPLC.

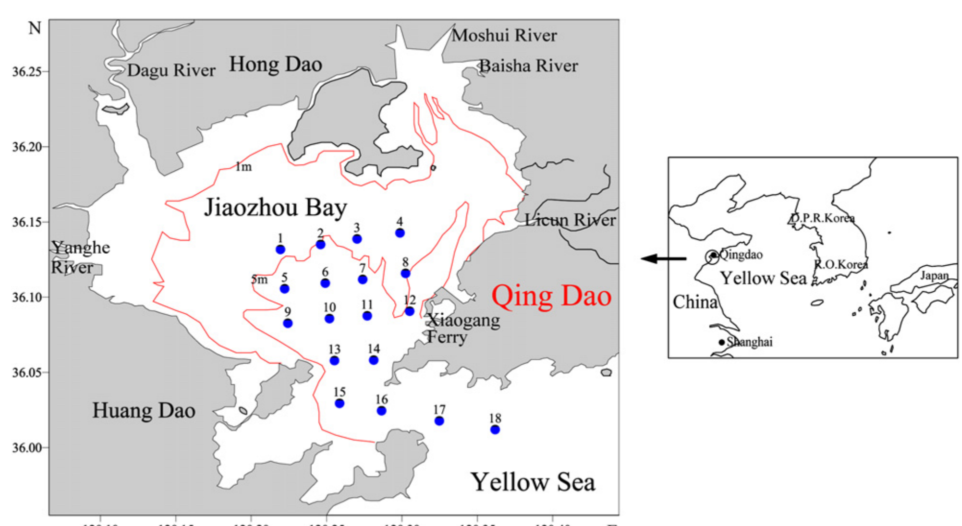

Fig. 1. The sampling stations in the Jiaozhou Bay, China during the seven cruises from December 2003 to October 2004.