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Environmental gradients regulate the spatial variations of phytoplankton biomass and community structure in surface water of the Pearl River estuary

Li Gang [a], Lin Qiang [a], Lin Junda [b], Song Xingyu [a], Tan Yehui [a], Huang Liangmin [a,*]

[a] Key Laboratory of Tropical Marine Bio-resources and Ecology, South China Sea Institute of Oceanology, CAS, Guangzhou, Guangdong 510301, China
[b] Vero Beach Marine Laboratory, Florida Institute of Technology, Vero Beach, FL 32963, USA

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ABSTRACT

Regulations of estuarine environmental gradient on phytoplankton communities were evaluated about the Pearl River estuary during June 25 to July 2 of 2009 (wet season) and January 11 to 16 of 2010 (dry season). Downstream increase of salinity was 0.19 and 0.23 per km in wet and dry seasons; whereas the decrease of $NO_3^- + NO_2^-$ content was 0.57 and 5.54 μmol L^{-1} per km, of PO_4^{3-} was 0.013 and 0.014 μmol L^{-1} per km and of SiO_3^{2-} was 1.05 and 2.89 μmol L^{-1} per km. Chl *a* biomass decreased from 11.3 to 1.94 μg L^{-1} and from 12.5 to 2.04 μg L^{-1} in wet and dry seasons, respectively; while total phytoplankton abundance decreased from 2.42×10^6 to 3.05×10^5 cells L^{-1} and from 1.59×10^6 to 0.32×10^5 cells L^{-1}, with the dominating groups changing from diatoms and chlorophytes to solely diatoms. In particular, the nutrient PO_4^{3-} was found to limit the growth of phytoplankton in wet season, but not in dry season. Our results also indicate that chlorophytes are more sensitive to salinity changes than other species in this estuary.

1. Introduction

Dramatic environmental gradients due to the land-derived inputs or/and tide-induced exchanges with open-seawater often prevail in estuaries, affecting phytoplankton physiology [1], altering their biomass and communities [2–4] and influencing estuarine primary production [5,6]. The land-derived outflows of freshwater can osmotically stress the growth of phytoplankton cells, and even lead to cell death and ultimately change the species composition [2,7]. Such inputs can also result in light-limitation, reducing phytoplankton photosynthesis [1,8]. On the other side, the inputs of nutrients have also been observed to stimulate phytoplankton growth [9], increase estuarine productivity [8], and even lead to the developments of massive algal blooms [10,11]. In some cases, negative influences are neutralized by positive ones, raising no significant effects [12]. Estuarine environmental factors e.g. salinity and nutrients often vary markedly in spatial and temporal scales, resulting in the great changes in phytoplankton biomass and species composition and thus the primary production [3,13].

Pearl River estuary (PRE) is situated in subtropical water, at northern part of the South China Sea (SCS). It mainly consists of 3 tributaries and forms 8 outlets before entering the SCS [13]. Distinct wet (April to September) and dry seasons (October to next March) prevail in the PRE due to the influences of southwest and northeast monsoons, respectively [14]. The year-averaged rainfall of this area ranges from 1600 to 2300 mm, 80% of which incurs in wet season, with river discharge being as high as 8×10^3 m^3 s^{-1} [14,15]. In contrast to wet season, less river-discharges in dry season give ways to the great intrusions of saline-water, resulting in the higher salinity and lower nutrients [16] and thus the alterations of phytoplankton productivity and species compositions [3,13]. Moreover, it is noteworthy that the environment are threatened by rapid industrialization and urbanization around the this estuary over the past two decades [17], with annual drainages of 20 and 40 million tons of waste- and sewage-waters [14], leading to a frequent occurrence of harmful algal blooms (HABs) [11]. Therefore, extensive studies have been carried out in this estuary, including the characterization of hydrodynamics [e.g. 16–18], investigation of chemical environments [e.g. 19–22], depiction biological features [e.g. 3,23] and analysis of relationships of biotic and abiotic properties [e.g. 13,24–26]. However, the studies are scarce to focus on the seasonal comparisons of the changes in environments and phytoplankton biomass as well as community structure [3,13], thus still limiting our knowledge on primary production of the PRE. In this paper, we show the spatial and temporal changes of environmental factors (salinity, temperature and nutrients) and phytoplankton biomass and communities in wet and dry seasons, and analyze the relationships of dominating groups with environmental factors.

* Corresponding author.
E-mail address: hlm@scsio.ac.cn (L. Huang).

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2. Materials and methods

2.1. Study area and sampling protocol

Two cruises from June 25 to July 2 of 2009 (wet season) and from January 11 to 16 of 2010 (dry season) were conducted to investigate the environments, phytoplankton biomass and community structure along and across the PRE (Fig. 1). A total of 22 stations were occupied in each cruise, with 16 down the estuary and 6 across the outer-estuary (Fig. 1). At each station, profiles of temperature and salinity were measured using a multi-parameter water quality monitor Sonde (YSI 6600, Yellow Springs Instruments, USA). After this, surface water sample was collected with a 5 L acid-cleaned (1 N HCl) polycarbonate container. The collected samples were treated within 5 min for determinations of the nutrient content and phytoplankton biomass as well as dominating groups as described below.

2.2. Nutrient measurements

To determine the nutrient concentrations, surface water was pre-filtrated through a Whatman GF/F filter (25 mm in diameter) to remove suspended particles; the filtration was then dispensed into an 80 ml polycarbonate bottle, frozen and stored at −20 °C for later analysis. The frozen samples were taken back to laboratory after the cruise, thawed and concentrations of nitrate + nitrite ($NO_3^- + NO_2^-$), reactive phosphate (PO_4^{3-}) and silicate (SiO_3^{2-}) were analyzed using a nutrients-autoanalyzer (Quickchem 8500, Lachat Instruments, USA) [27]. This equipment with the analytical error of less than 10% has been calibrated against CSK standard solutions before the nutrient measurements.

2.3. Chl a determination

Chlorophyll *a* (Chl *a*) concentration was determined by filtrating 300–500 ml surface water onto a Whatman GF/F filter (25 mm in diameter). The filter was wrapped in an aluminum foil, frozen immediately and stored at −20 °C for later extraction and measurement. The frozen filter with phytoplankton cells was put into a 15 ml tube and thawed; and 10 ml 90% acetone (v/v) was added, sonicated and extracted in darkness for 24 h at 4 °C conditions. After 10 min of centrifugation, fluorescence of the supernatant was measured with a Turner Designs Model 10 Fluorometer; and Chl *a* concentration was calculated according to Parsons et al. [28].

2.4. Species analyses

Compositions of phytoplankton assemblages were analyzed through fixing surface water samples with Lugol's solution to a final concentration of 1.5% [28]. After one liter fixed water being settled for 24 h and concentrated to 30 ml by gently removing the supernatant, the examination and numeration analyses of phytoplankton species in a 0.5 ml subsample were carried out under an inverted microscope [29].

2.5. Statistical analysis

Paired *t*-test was used to determine the significant differences ($p < 0.05$) of biological and environmental factors between the wet and dry seasons; a Kendall's τ test was used to establish the correlation between the environmental and biological factors.

3. Results

Surface seawater salinity (SSS) increased dramatically downstream by 0.19 per km from 0.13 to 24.81 in wet season and by 0.23 per km from 1.72 to 32.79 in dry season (Fig. 2A); whereas the temperature (SST) changed less i.e. from 28.15 to 29.46 °C and from 15.64 to 17.46 °C, respectively (Fig. 2A). Dissolved oxygen (DO) increased by 0.042 mg L^{-1} per km from 1.28 to 6.90 mg L^{-1} in wet season (Fig. 2A). At stations located in outer-estuary, SSS indicated a clear decrease of 23.19 to 16.54 from southwest to northeast in wet season, but not in dry season (i.e. 31.24 to 32.40); while no clear spatial variations were observed in SST and DO (Fig. 2B). Moreover, the SSS was lower and the SST was higher in wet season, as compared to dry season (Fig. 2).

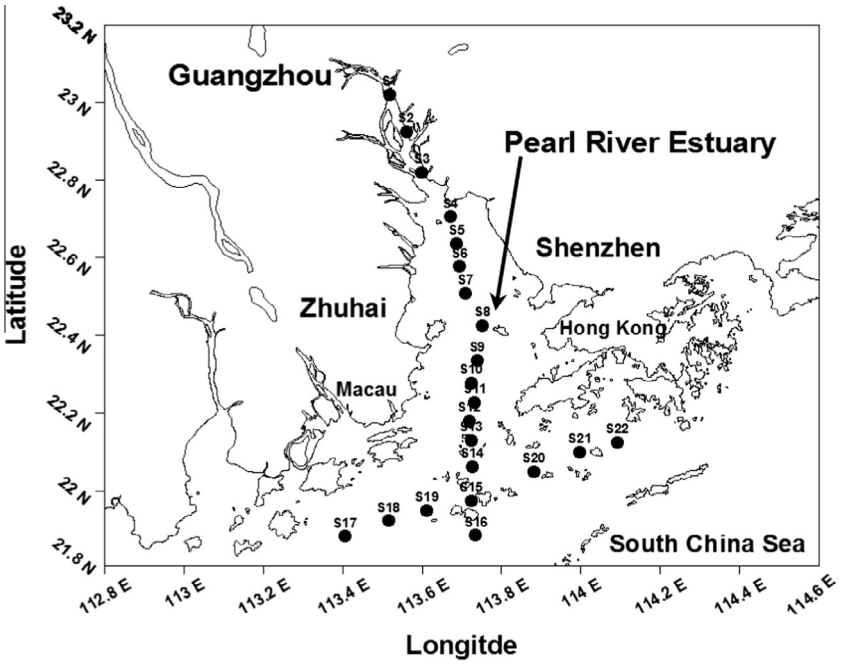

Fig. 1. Map of Pearl River estuary, indicating the sampling sites for the cruise periods of June 25 to July 2 of 2009 (wet season) and January 11 to 16 of 2010 (dry season).