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Seasonal variations of phytoplankton assemblages and its relation to environmental variables in a scallop culture sea area of Bohai Bay, China

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ABSTRACT

Seasonal variations of phytoplankton assemblages were examined in a scallop culture sea area of Bohai Bay (China) with regard to some major physical and chemical variables. Samples were collected at three stations from July 2011 to September 2013. A total of 134 species belong to 4 phyla were identified, of which 104 were diatoms, 27 were dinoflagellates, 1 was euglenophyte and 2 were chrysophytes. The cells abundance in autumn (55.44×10^3 cells/L) was higher than that in summer (6.99×10^3 cells/L), spring (3.46×10^3 cells/L) and winter (2.69×10^3 cells/L). The Shannon-Wiener diversity index was higher in summer (3.06), followed by spring (3.02) and winter (2.91), and low in autumn (1.40). Results of canonical correspondence analysis showed that phosphate, salinity, temperature, silicate and DIN/SiO_2 ratio were the most important environmental factors influencing the variation of phytoplankton community structure. It is suggested that eutrophication resulted from scallop culture would cause a potential red tide risk.

1. Introduction

Over the past 20 years, mariculture industry has developed rapidly throughout the world. China is one of the countries where mariculture practiced very well. To mention, the yield of shellfish aquaculture, mainly filter-feeding bivalves, reached 11 million tons in 2010 (Li et al., 2014). Scallop aquaculture is an important investment of which >60 thousand ha aquaculture area and 700 thousand tons yield production were undertaken. Scallop aquaculture scale in China has topped the world. As one of the main mariculture areas in China, Bohai Bay is the main spawning and feeding site not only for many economically important fish and shrimp, but also shellfish, particularly scallop (Xu et al., 2010). In Bohai Bay, the scope of scallop culture reached 69 thousand tons in Shanhaiguan and Funing and 230 thousand tons in Xinkaikou respectively in 2010 (Fig. 1).

Bohai Bay is a shallow semi-enclosed bay with an area of 1.6×10^4 km^2 and an average depth of only 12.5 m (Peng et al., 2012). It is located in the western region of Bohai Sea (117°32′–122°08′E, 37°07′–40°55′N) and impacted by the intrusion of the Yellow Sea Warm Current (YSWC) in winter (Fig. 1). More than 40 rivers flow into Bohai Sea among which Yellow River, Haihe River, Luanhe River and Liaohe River are the four major ones (Fig. 1). There are abundant marine resources, flourishing industry and agriculture around Bohai Bay. With the rapid industrialization and urbanization in recent years, the recipients of industrial and sanitary wastewater and the input of artificial fertilizer have made more and more eutrophication events in Bohai Bay (Guo et al., 2014). The seawater quality of Bohai Bay is deteriorated gradually (Peng et al., 2009). Some research have indicated that nitrogen and phosphorus concentrations in Bohai Sea have changed notably over the last 30 years (Jiang et al., 2005; Wang and Li, 2006; Yu et al., 2000). As nutrient conditions change, the phytoplankton community structure change correspondingly. Therefore, phytoplankton community structure in Bohai Bay has been changed significantly in recent decades.

The production of scallop aquaculture mainly depends on their consumption of primary producers. Phytoplankton is the foundation of the marine ecosystem, it is very important for fishery resources such as scallop production (Xu et al., 2010). Because phytoplankton is the primary producer and the main energy source for higher consumers, the population dynamics of phytoplankton affect the growth and survival of fish, shrimp, shellfish and their larvae directly or indirectly (Wang et al., 2001). However, primary productivity in the Bohai Sea has decreased from 1980s to 1990s with the more and more severe eutrophication (Tang et al., 2003). Moreover, the phytoplankton community structure has changed gradually from a diatom dominated type to a diatom and dinoflagellate co-dominated type since the 1980s (Sun et al., 2002). Changes in primary productivity and the phytoplankton community

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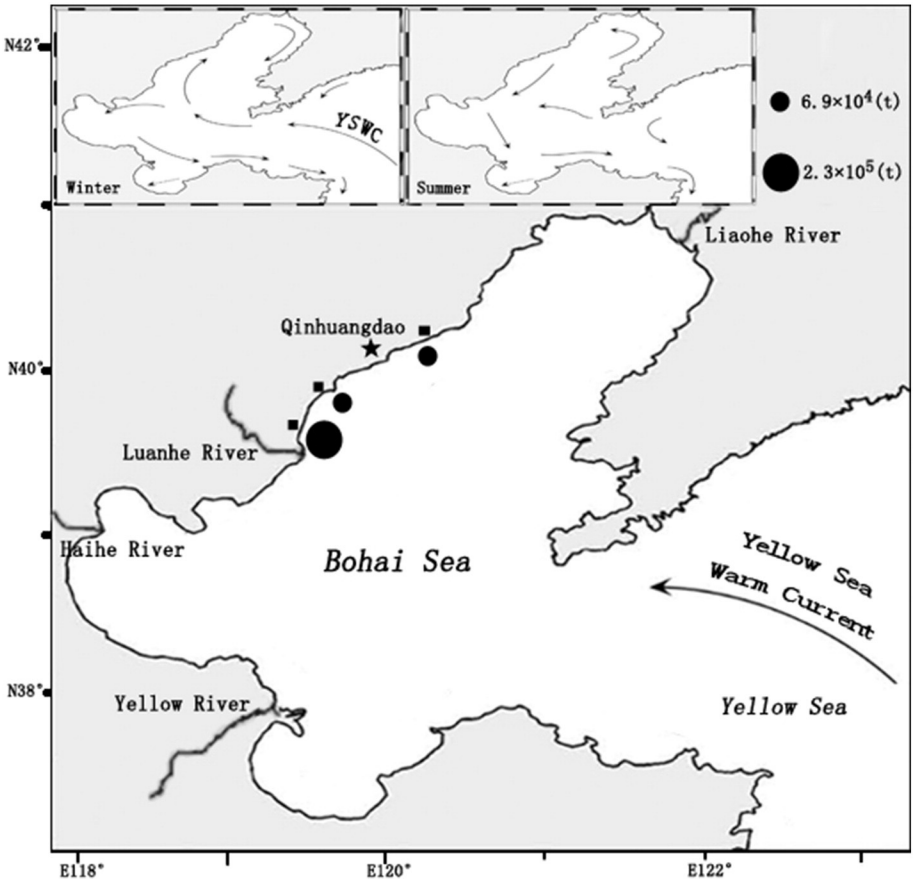

Fig. 1. The scope of scallop culture (●) and the flow condition in Bohai Bay. Figure adapted from Bian et al. (2016), based on data from Zhang et al. (2011).

structure in the Bohai Sea can affect the stability and function of the ecosystem (Huang et al., 1999).

Eutrophication of marine systems promotes the growth of phytoplankton and even leads to phytoplankton blooms (Byun et al., 2007). Phytoplankton blooms will cause catastrophic effects to aquaculture and significant losses in economies (Richlen et al., 2010). Harmful phytoplankton blooms, especially the toxic algal blooms, will potentially make shellfish contaminated with toxins, thus resulting in a series of health problems by human consuming (Flewelling et al., 2005). To develop a healthy scallop aquaculture rapidly, the efficient plans of pollution prevention and bloom controlling should be very necessary. Phytoplankton dynamics represents a useful indicator of water quality that can be used to monitor coastal pollution (Boyer et al., 2009). In addition, the phytoplankton blooms formation is mainly affected by the environmental factors (Paerl et al., 2011). Hence it is significant to understand the phytoplankton dynamics and its relationship with the environmental factors. However, there is little knowledge about the relationship between phytoplankton and the environmental factors in the scallop culture sea area of Bohai Bay. Therefore, the aim of this study is to investigate the species composition, abundance and seasonal variations of phytoplankton which play an important role in the scallop aquaculture (both beneficial and harmful), and to reveal the relationships between phytoplankton assemblages and the environmental factors and scallop culture in Bohai Bay.

2. Materials and methods

2.1. Field sampling and measurements

There were three sampling stations distributed uniformly in Bohai Bay (Fig. 2). The station 1 is located in Shanhaiguan (119°49′1.90″E, 39°57′1.80″N) and field observations were conducted in 2 and 6 nautical miles away from the shore. The station 2 and 3 are located in Funing (119°26′46.20″E, 39°41′55.20″N) and Xinkaikou (119°25′49.00″E, 39°34′16.00″N) respectively with the same observation sites as station 1. The scallop aquaculture is flourishing and has large-scale culture area in all of the three stations. Totally, eight field investigations were carried out from 2011 to 2013, including all the four seasons spring (March, April and May), summer (June, July and August), autumn (September) and winter (December). Water samples were collected from surface water (about 50 cm deep) from each sampling site for the determination of the phytoplankton species composition and abundance and the nutrient concentrations.

2.2. Phytoplankton analyses

For phytoplankton analyses 2 L of water was collected from each sampling site and fixed with 20 mL Lugol. Samples were stored in the dark and concentrated to 10–15 mL in the laboratory using sedimentation method. Phytoplankton species were identified and cell numbers were counted using a phytoplankton enumeration chamber under microscope (Olympus BX51, Olympus Corporation, Tokyo, Japan). In addition to light microscope, 10 μL of the acid-cleaned samples were placed on copper grids, air-dried and observed using a transmission electron microscope (TEM, JEM2100HC, JEOL Ltd., Tokyo, Japan) for the morphological observation and cell counting of the nano-diatoms (2–20 μm).

2.3. Environmental factors analyses

Physical parameters (temperature and salinity) were measured with a Model HQ30d multi-parameter meter (HACH, China) at the three stations in the sea.

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