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Research paper

The impact of different pollution sources on modern dinoflagellate cysts in Sishili Bay, Yellow Sea, China

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ABSTRACT

The spatial distribution of dinoflagellate cysts in the surface sediment of Sishili Bay, Yellow Sea, China, was studied, with the purpose of understanding the impact from nutrient enrichment and industrial pollution. Thirty-five dinoflagellate cyst taxa belonging to 15 genera and 3 unknown cysts were identified and quantified at 22 sampling sites. Autotrophic cysts (e.g., *Spiniferites bentori* var. *truncata*) and heterotrophic cysts (*Brigantedinium* sp.1 and *Quinquecuspis concreta*) dominated the sediment samples. The spatial distribution of cyst abundance showed a significant positive correlation with increased nutrients, but was negative to heavy metal pollution. The highest cyst abundance (with an average of 539 cysts g^{-1} DW) occurred in Zone A, corresponding to nutrient enrichment caused by domestic sewage discharge. In contrast, the lowest cyst abundance (with an average of 131 cysts g^{-1} DW) occurred in Zone E, impacted heavily by the industrial pollution. The abundance of autotrophic cysts decreased dramatically in Zone E compared with heterotrophic cysts and showed a sensitivity to industrial pollution. How heavy metals affect physiological mechanisms in autotrophic and heterotrophic cysts differentially is in need of in-depth study.

1. Introduction

Sishili Bay (SB) is located in the northern Yellow Sea, China, and is surrounded by the city Yantai (Fig. 1). Over the last two decades, SB has been developed as an important harbor and coastal aquaculture base by the local government. The aquaculture area covers 70% of the bay and has provided more than 1.5 million tons of seafood for the market over the last 5 years (Yantai Statistics Bureau, 1985–2008). However, the increased population, marine aquaculture production, freight ships and sewage discharge along the Yantai coastline have significantly impacted the SB marine ecosystem (Yantai Statistics Bureau, 1985–2008) (Fig. 2). Domestic sewage and industrial waste water increased almost three-fold during 1995–2007 from 8.5×10^7 tons to 22.1×10^7 tons. As a result, increased red tides and jellyfish blooms indicated the deterioration of the SB ecosystem over the last 10 years (Wu et al., 2001; Chi, 2008; Dong et al., 2010). Thus, it is important to understand the impact of different sources of pollution on the SB ecosystem ahead of development of the policy on environmental protection and restoration.

Phytoplankton, as the most important primary producers in marine ecosystems, are sensitive to environmental changes, as indicated by the fluctuation of taxon composition and abundance. The fossil phytoplankton assemblages in the sediment have been used as proxies for past environmental changes (e.g., temperature, salinity and eutrophication) (McMinn and Wells, 1997; Matsuoka, 1999, 2001; Shin et al., 2010; Tuovinen et al., 2010; Wang et al., 2011). About 200 marine dinoflagellate taxa can produce cysts that sink to the seabed to serve as benthic resting stages, and their abundance and composition have been used to predict red tides (Anderson et al., 1982; Siringan et al., 2008), reflect pollution loads and indicate temperature change and hydrodynamic signals (Matsuoka, 1999, 2001; Dale, 2001, 2009; Pospelova et al., 2005, 2008). Thus, dinoflagellate cysts have been applied widely in the study of modern and past environments as an effective biological indicator.

Dale (2001, 2009) pointed out that dinoflagellate cysts showed different responses to nutrient enrichment and industrial pollution, respectively. The nutrient enrichment can increase the abundance of cysts in the sediment. For example, Pospelova et al. (2005) compared the spatial distribution of cysts from several polluted estuaries in the northeast coast of USA, and found that cyst abundance increased progressively with distance from the major sources of nutrient enrichment. However, the industrial pollution might decrease the cyst abundance or change the ratio between heterotrophic and autotrophic cysts (Sætre et al., 1997; Matsuoka, 2001; Dale, 2009). For example, Sætre et al. (1997) found that cyst abundance in sediment cores declined with increased pollution and suggested that industrial

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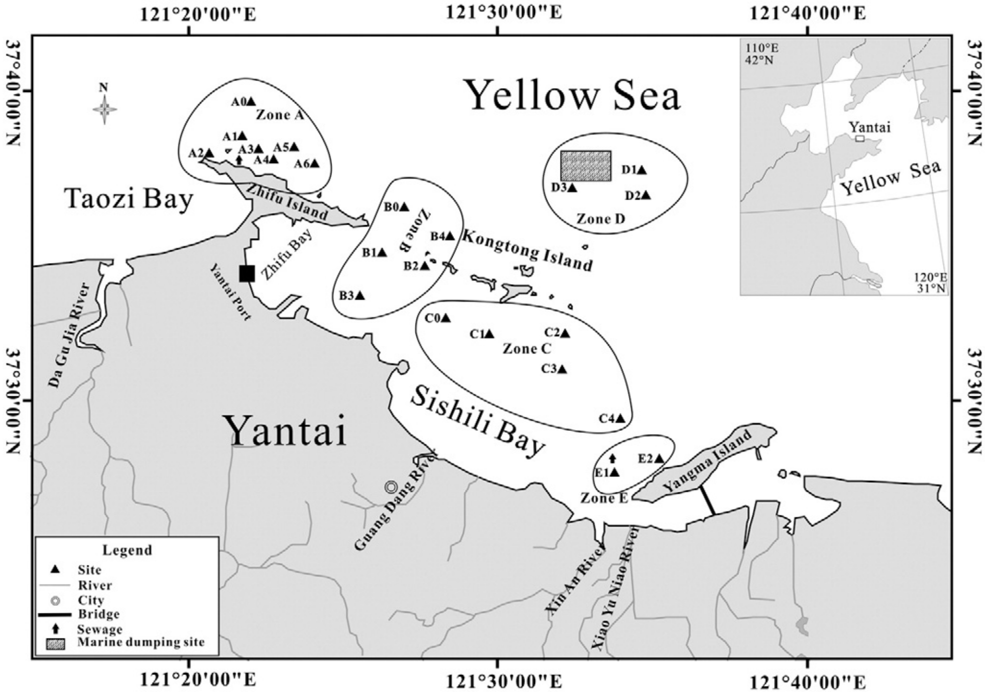

Fig. 1. Map showing the sampling sites in Sishili Bay, Yellow Sea, China.

pollution could cause a shift toward more heterotrophic taxa. However, due to the limited number of case studies to date, it is still hard to define the changes to dinoflagellate cysts under industrial pollution conditions. In addition, nutrient enrichment and industrial pollution often occurred together in the coastal waters. For example, Matsuoka (1999, 2001) found that the relative proportion of heterotrophic dinoflagellate cysts in Yokohama Port, Tokyo Bay, Japan was mostly consistent with the trend of eutrophication and industrialization levels since the 1970s. Thus, it is necessary to do more case studies to understand the response of dinoflagellate cysts to industrial pollution.

In this study, we chose SB as a survey region, with the aim of finding out the relationship between the spatial distribution of dinoflagellate cysts and different pollutants. The cyst composition and abundance in the surface sediment of SB were surveyed at 22 sites, and these sites covered the sea areas impacted by nutrient enrichment and industrial waste water. The trophic types and abundance

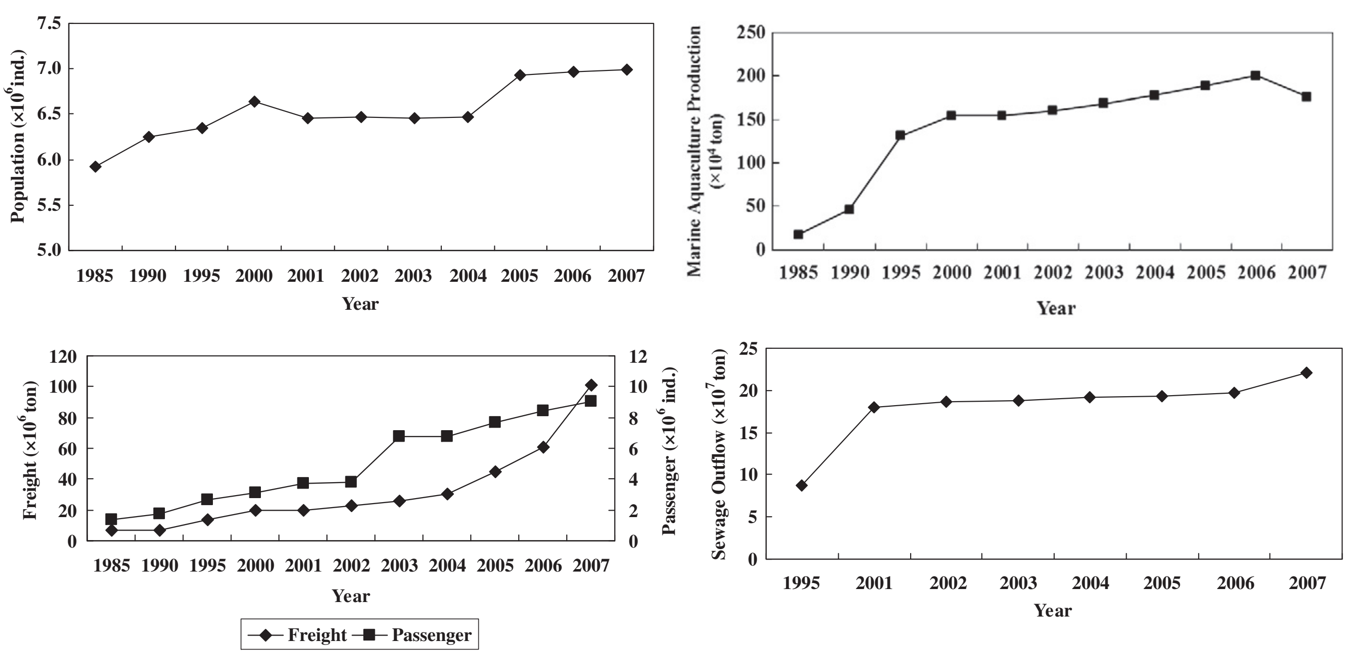

Fig. 2. The increased population, marine aquaculture production, freight ships and sewage outflow in Yantai (Yantai Statistics Bureau, 1985–2008).