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Regional differences in decadal changes of diatom primary productivity in the eastern Chinese shelf sea over the past 100 years

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ABSTRACT

Contradicting findings were observed when decadal changes of primary productivity in the eastern Chinese shelf sea were learnt through examination of sediment cores (Lv, 2007; Zhou, 2007; Jin, 2009; Zhao, 2010; Yang et al., 2012). This inconformity may imply the regional differences of decadal environmental changes in different types of seas. To verify the possible regional differences, we examined sediment cores collected in different types of seas in the eastern Chinese shelf sea. ^{210}Pb activity in the sediment was used to estimate sediment rate, while biogenic silica (BSi) was applied to indicate diatom paleoproductivity. And then the decadal change trends of diatom primary productivities (DPP) over the past 100 years in different areas were achieved. Subsequently, the differences in these DPP changes and the possible controlling mechanism were also discussed. Results reveal the presence of regional differences in DPP decadal changes in the eastern Chinese shelf sea. In all coastal seas, DPP followed similar trends before the 1980s; after the 1980s, DPP increased obviously in Shandong coastal waters where no large river mouth exists nearby, but decreased in the Yangtze River estuary. By contrast, in open waters, DPP in the past 100 years followed almost opposite trends against that in Shandong coastal waters. The differences in DPP changes between coastal and open sea areas before the 1980s could be attributed to the distinct influence mechanism of Pacific Decadal Oscillation (PDO) on DPP variation. However, the regional differences of DPP changes after the 1980s were probably attributed to the differences in influence type and intensity of human activities. Summarily, the disproportion of the influence of human activities and PDO could induce regional differences in DPP decadal changes in the Chinese shelf sea. These actual and probably general existences of regional differences prompt us to comprehensively assess long-term environmental changes in the complex shelf seas, rather than rebuild paleoenvironmental change patterns by using only one or limited sediment cores.

1. Introduction

Ecological environment has experienced decadal and multi-decadal changes in the North Pacific (Chavez et al., 2003; Overland et al., 2008; Zanchettin, 2012; Litzow et al., 2014). Based on fish catches and primary productivity investigation, regime shift has been observed in California and Japan (Rebstock, 2002; McGowan et al., 2003; Tian et al., 2008; Ichii et al., 2015). And in most cases, Pacific Decadal Oscillation (PDO) and human fishing are considered as the important controlling factors of the shift (Hare and Mantua, 2000; Patterson et al., 2013; Litzow et al., 2014; Boulton and Lenton, 2015). However, in Chinese shelf sea, an important marginal sea of the Northwest Pacific, environmental changes could not be directly investigated in decadal scale because of lack of survey data. In Chinese shelf sea, continuous and systematic field investigations were mainly conducted after the 1980s (Lin et al., 2005) and focused on estuary and adjacent coastal seas (Zhou et al., 2008). And these shortages in systematicness of survey time and study areas limit our understanding of decadal environmental changes, especially before the 1980s.

Previous studies used paleoenvironmental indicators, such as biogenic silica (BSi), phytoplankton fossils and lipid biomarkers in sediment cores to rebuild or indicate changes in primary productivity or phytoplankton biomass in Chinese shelf sea (Jia et al., 2000; Li, 2001; Jin et al., 2009; Liu et al., 2011; Guo et al., 2015).

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However, contradicting results were obtained even in adjacent study seas. For example, scientists studied decadal changes in primary productivity in the Changjiang River estuary and adjacent seas by using BSi in sediment cores. However, some scientists believed that BSi and primary productivity are relatively higher in about 1960s – 1980s than that after the 1980s and before the 1950s (Lv, 2007; Jin, 2009; Yang et al., 2012), while Zhou (2007) and Zhao (2010) reported almost opposite trends in the same estuary. Considering these contradicting findings, we remain perplexed with the environmental evolution in this area. Coincidentally, the phenomenon that long-term environmental changes perform distinctly in adjacent seas has also been observed in northeast Asian marginal seas (Kang et al., 2012) and Louisiana continental margin seas (Sampere et al., 2011).

Topography and current are complex in continental shelf seas and their environment could be affected not only by adjacent marine environment but also by terrestrial ecological environments nearby (Syvitski et al., 2005; Halpern et al., 2008; Pan et al., 2014; Wu et al., 2016). Marine environment changes in different regions could not follow the same pattern even in the same shelf sea. Moreover, inconsistent results reported by previous studies may imply the presence of regional differences in decadal environmental changes. However, these differences have not been systematically investigated, especially in the Chinese shelf sea. This limitation restricts studies to elucidate decadal environmental changes and the underlying controlling mechanism in the Chinese shelf sea.

In the past, many previous studies rebuilt or indicated long-term environment changes in shelf seas by only one or limited number of sediment cores (Zimmerman and Canuel, 2000; Douglas et al., 2007; Rabalais et al., 2007; Badejo et al., 2014; Wang et al., 2015). If regional differences in marine environmental changes are common in shelf seas, as predicted, then previous reconstruction of the paleoenvironment that ignored regional differences in environmental changes would yield imprecise results.

So, confirming the existence of regional differences in decadal environmental changes will be beneficial to explaining the contradicting results in previous studies and also giving guidance to paleoenvironmental researches in the future. To verify regional differences in decadal environmental changes in Chinese shelf sea, we examined sediment cores from different types of seas in the eastern Chinese shelf sea in this study. ^{210}Pb and BSi were used to estimate sediment rate and reflect diatom paleoproductivity, respectively. The decadal diatom primary productivities (DPP) change trends were then constructed in different types of seas. The constructed trends were subsequently compared, and their regional differences were investigated.

2. Methods

2.1. Sample collection

The south Yellow Sea and adjacent East China Sea, locating in the eastern Chinese shelf sea, is a typical marginal sea of the Northwest Pacific Ocean. The Yellow Sea Coastal Current (YSCC), the Yellow Sea Warm Current (YSWC) and the West Korean Coastal Current (WKCC) are considered as the mainly current here (Fig. 1). And the Yangtze River also runs into the sea in this area. In the southeast seas, marine environmental changes exhibit oceanic characteristics because of the influence of YSWC, which is considered to originate from Kuroshio Current. By contrast, in the northeast and west regions, for near the land, marine environment is greatly affected by adjacent terrestrial environment and YSCC.

To compare decadal environmental changes trends in different types of seas, in April 2006 and March 2011, we collect sediments cores from four stations (Fig. 1). As envisaged, in station A7 and station B10, locating in open sea and near the initiation region of YSWC, environmental variation here follow the oceanic pattern. Station B19 and station H1-18 locate near shore, and ecological environment of nearby land is an important element in affecting their marine environment. Besides, station H1-18 is situated in the estuary of the Yangtze River, the third longest river in the world with annual runoff of 951.3 billion m^3 and drainage area of 1.8 million km^2, and its environment is also directly affected by the large river, while this is no large river in the vicinity of station B19. In the following sections, for ease of description, station A7 and station B10 are called as “the open sea”, station H1-18 is called as “the estuary” and station B19 is described as “the coastal sea with no large river nearby (CSNR)”.

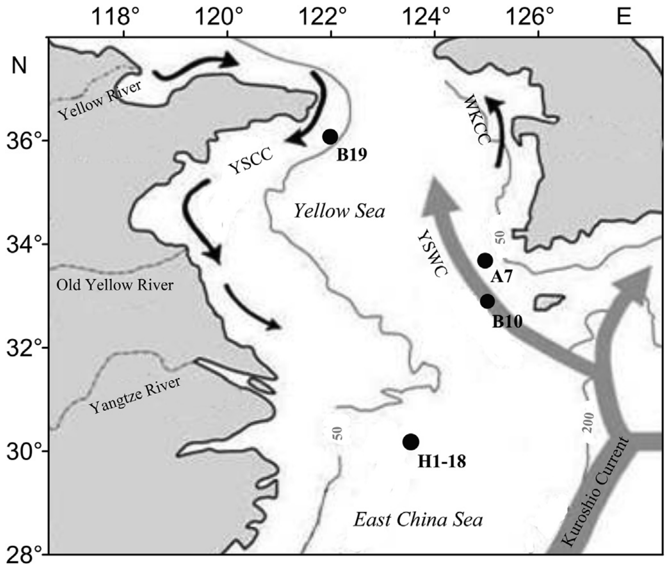

Fig. 1. Study areas and sampling stations. YSCC: the Yellow Sea Coastal Current; YSWC: the Yellow Sea Warm Current; WKCC: the West Korean Coastal Current.

Sediment cores were collected by a box sampler and were stored at about 4 °C prior to being cut in the laboratory. Subsamples were achieved at interval of 1 cm in the upper 15 cm length, and 2 cm in the other part. After drying to a constant weight at room temperature or 60 °C, necessary parameters of sediments were analyzed.

All collected sediment samples were gray, and all samples in core A7 and core B19 were silty clay, while in core B10 and core H1-18, sediments were clay and clayey sand respectively.

2.2. Chronological analysis of the sediment cores

Sediment rates were calculated based on ^{210}Pb (Goldberg, 1963), and the ages of the sediment cores were determined with the sediment rates and date beginning from the sample collection. The ^{210}Pb activity of core A7 was measured by a germanium detector manufactured by AMETEK Company at the Institute of Polar Environment, University of Science and Technology of China, Hefei, China (Zhou et al., 2012). The ^{210}Pb activity of core B19 and H1-18 were cited from Zhao et al. (1991) and Yang et al. (2012) respectively. The sediment rate of core B10 was cited from Zhao et al. (1991) and Li et al. (2002).

2.3. Determination of BSi in the sediments

BSi determination follows the method of Zhao et al. (2005). Briefly, dry sediment samples were ground and treated by H_2O_2 and hydrochloric acid to remove organic matter and carbonates. Subsequently, BSi in samples was extracted by Na_2CO_3 solution and

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