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What has happened to the benthic mollusks of the Yellow Sea in the near half century? Comparison on molluscan biodiversity between 1959 and 2007

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ABSTRACT

In recent years, the ecological environment in the Yellow Sea has changed greatly, as it has been influenced by climate change and various human activities. In this study, molluscan biodiversity at 42 sampling sites sampled in July 1959 and June 2007 were compared. The result showed that biomass of mollusks changed slight ($p=0.981$; 4.92 g/m^2 *vs* 4.88 g/m^2), while abundances were higher in 2007 ($p=0.038<0.05$; 81.79 ind/m^2 *vs* 45.10 ind/m^2), and the number of species ($p=0.021<0.05$), Margalef's species richness ($p=0.005<0.01$), and Shannon–Wiener index ($p=0.006<0.01$) was higher in 1959. The sites in the Yellow Sea Cold Water Mass occupied area, which were dominated by cold water species, were clustered together by the agglomerative classification method and the community there was rather stable, whilst great changes have occurred for the communities sited in the coastal waters. It is indicated that molluscan communities of the Yellow Sea were in undisturbed condition in 1959 ($W=$ 0.051), but were severely impacted in 2007 ($W=$ -0.058) resulting from the abundance/biomass comparison (ABC) method. Though the abundance increased, the biodiversity decreased and the community structure changed greatly. Generally, temperature, water depth, and salinity were major factors that affected the distribution of mollusks in the Yellow Sea.

1. Introduction

The habitat of neritic communities is affected by various threats and has become degraded, and related ecosystems have experienced tremendous changes (Halpern et al., 2008; Hoegh-Guldberg and Bruno, 2010; Jackson et al., 2001; Lotze et al., 2006; Worm et al., 2006). Nearshore marine benthic communities have been significantly threatened by human activities; thus, their habitat degradation rate is even astonishing (Ellingsen, 2002; Gray, 1997; Snelgrove, 1997, 1999). Aquaculture, trawl fisheries, chemical contamination, and sewage discharge are the major human activities that affect biodiversity (Fraschetti et al., 2011).

The Yellow Sea is an epicontinental sea in the Northwest Pacific Ocean, and it is affected by coastal water, the Yellow Sea Cold Water Mass (YSCWM), the Yellow Sea Warm Current, and the subtropical East China Sea. Because of the specialization and complexity of ecosystem conditions in the Yellow Sea, the composition of biota in this area is unique. The warm temperate and Indian-West Pacific species are abundant, and cold water originated species are also present. These faunal features are fully represented in the composition of molluscan fauna (Tchang et al., 1963; Xu and Zhang, 2011; Zhang and Xu, 2014; Zhang et al., 2012). The biota of the Yellow Sea belong to the Yellow Sea Warm Temperate Biota Province of the North Pacific Temperate Biota Region (Liu, 2008, 2013; Liu and Xu, 1963).

The coasts of the Yellow Sea are very densely populated and industrialized areas, at approximately 600 million people around this area (Park et al., 2011), and the high socio-economic development both in China and Korea has significant effects on the state of the Yellow Sea (Liu et al., 2003; Wang et al., 2013). Environmental features have undergone significant changes in the Yellow Sea during the last century because of global climate change and various anthropogenic activities. Especially, after the 1980s, the environment of the Yellow Sea has been severely affected by intensive human activities of aquaculture, sewage discharge, fishery, and so on (Li et al., 2013; Strokal et al., 2014; Tang, 2004). Chemical biogenic elements of nutrient such as, dissolved inorganic nitrogen, dissolved organic nitrogen, and N:P ratios exhibited an uptrend, because of sewage discharge, terrestrial runoff, atmospheric input and so on (Lin et al., 2005; Liu et al., 2003; Wang et al., 2003). The seawater temperature (Cai et al., 2006; Lin et al., 2005; Park et al., 2011) and salinity (Lin et al., 2005) increased obviously because of global warming, while dissolved oxygen, chlorophyll a, primary production, P and Si concentrations decreased (Lin et al.,

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2005). The marine ecosystem in the Yellow Sea was degrading, as the environmental changes affected the productivity and biomass yields (Lin et al., 2005; Liu and Wang, 2013), caused eutrophication and marine ecological disasters (Dong et al., 2010; Liu et al., 2009; Sun et al., 2008; Xu et al., 2013), destroyed marine biological resources (Tang, 2009) and severely threatened the biodiversity (Du et al., 2012; Zhang et al., 2015a, 2012).

Benthic mollusks are sensitive to environmental changes as they have a long life cycle and poor mobility; thus, they have long been used as a biological indicator of environmental change (Taylor et al., 1971). Because of their large biomass and high habitat density, mollusks play an important role at the bottom food chain. Changes in the ecological environment caused by anthropogenic activities or natural factors will usually induce changes in the survivability of benthic mollusks; therefore, changes in the composition and number of mollusks are always observed. The present study aimed to detect what kind of changes have happened to the biodiversity of benthic mollusks over nearly a half century under environmental pressures, by quantitative comparison of the differences in the biodiversity and community structure of benthic mollusks in the Yellow Sea between the data in 2007 and 1959. Therefore, the changes on the species composition, distribution features, biodiversity, and community structure of benthic mollusks in the two years were quantitatively analyzed, as well as the main environmental variables to determine their distribution pattern and community classification.

2. Materials and methods

2.1. Study area

This study examined mollusks collected in the Yellow Sea during the "National Comprehensive Oceanographic Survey" in 1959 and subsequent survey in 2007. In July 1959, two "Ocean 50" corers with a sampling area of 0.1 m^2, or one box corer with a sampling area of 0.25 m^2 were used to perform at one station. In June 2007, two samples of box corer of 0.1 m^2 at each station were used. Each investigation was carried out strictly according to the National Ocean Survey Specification. The locations of the stations

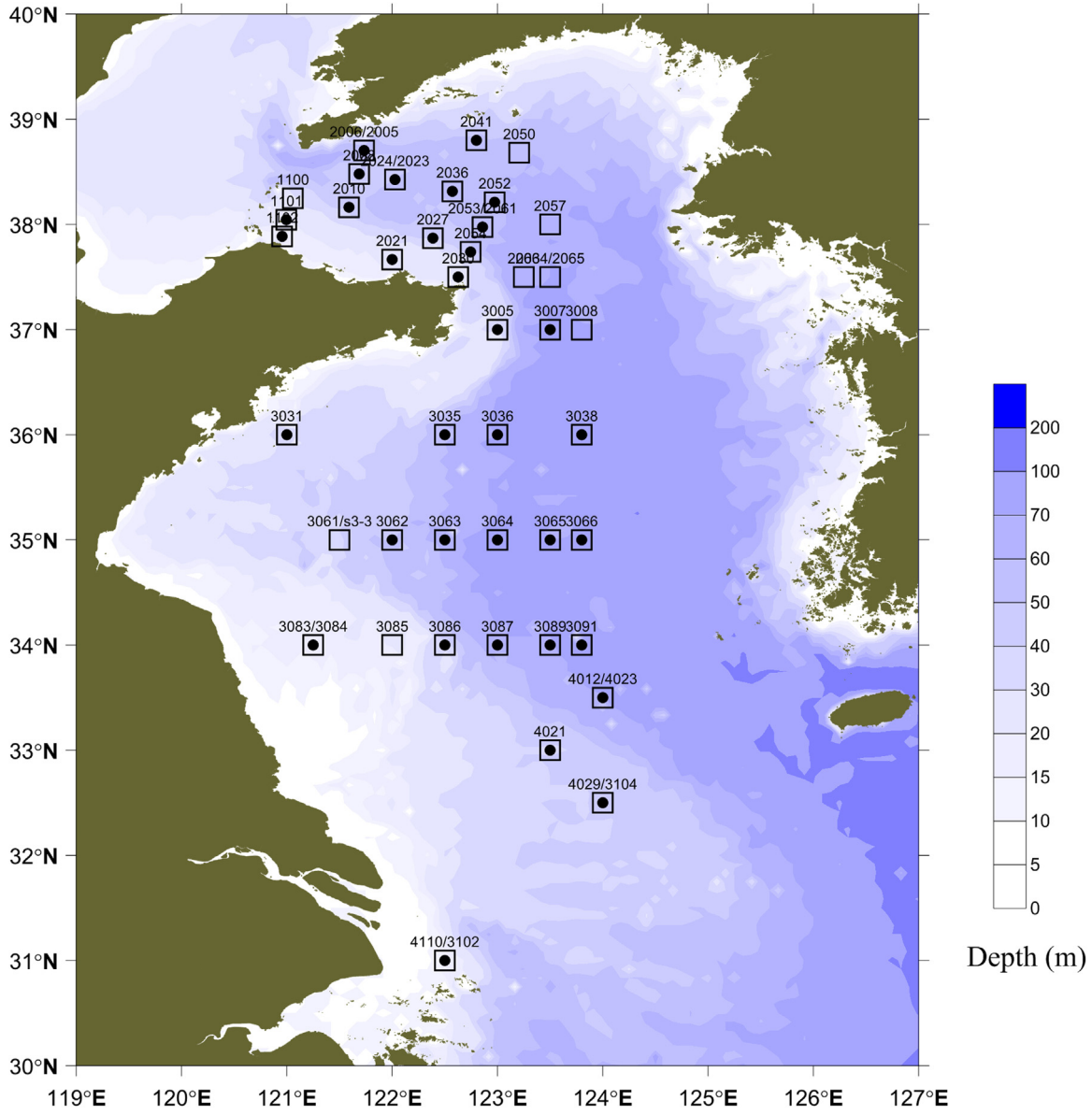

Fig. 1. Sampling area and locations of sampling sites of the Yellow Sea in June 1959 and July 2007. Sampling sites recorded complete environmental data were marked a dot in central. The bathymetry of the map is derived from the ETOPO1 data set, supplied by National Geophysical Data Center (http://www.ngdc.noaa.gov/mgg/global/).