Acta Ecologica Sinica 36 (2016) 133–140

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Effects of tide and water masses on the distribution of zooplankton in different parts of Hangzhou Bay

Dongrong Zhang [a,b], Zhaoli Xu [a,*], Qian Gao [a], Jiajie Chen [a]

[a] East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Shanghai 200090, China
[b] College of Marine Sciences, Shanghai Ocean University, Shanghai 201306, China

ARTICLE INFO

Article history:
Received 13 May 2014
Received in revised form 13 January 2015
Accepted 14 March 2015

Keywords:
Tide
Water mass
Hangzhou Bay
Distribution
Dominant species

ABSTRACT

Based on the data collected from three oceanographic surveys in the east area of north (NE) (121.67°E–121.87°E, 30.68°N–30.83°N), the east area of south (SE) (121.60°E–121.85°E, 29.95°N–30.24°N), and the west area of north (NW) (121.31°E–121.56°E, 30.58°N–30.77°N) Hangzhou Bay during the autumn of 2009, 2011 and 2012, we analyzed the distribution patterns and composition of dominant zooplankton species in the three areas. The effects of the tide, water masses, and environmental factors on the distribution patterns of zooplankton were explored as well. The results indicated that the total biomass increased gradually from nearshore to offshore in the NW, while the total abundance increased from offshore to nearshore. In the NE, the total biomass increased from offshore to nearshore, however the peak abundance occurred in the central survey waters. In the SE, both total biomass and total abundance increased from offshore to nearshore. The average biomass of zooplankton in the NW, NE and SE was 70.78 mg/m^3, 84.10 mg/m^3, and 580.58 mg/m^3, respectively. The average abundance in the three areas was 47.98 ind/m^3, 98.89 ind/m^3, and 578.88 ind/m^3, respectively. The analysis of variance shows that there was a significant difference in the zooplankton abundance in the different parts of Hangzhou Bay; and there was a significant difference in dominant species in the three areas as well. The primary dominant species in the NW were *Tortanus vermiculus*, *Labidocera euchaeta* and *Paracalanus aculeatus* in the NE; and *Labidocera sinilobata* in the SE. The difference in zooplankton distribution in the three areas may be majorly influenced by the runoff strength of the Yangtze River and Qiantang River, seawater invasion from the East China Sea, and the difference of tidal currents between the north and south parts. The association between the distribution of zooplankton and environmental parameters, which was calculated by the stepwise regression analysis, indicates that temperature and salinity are the two major factors that influence the distribution pattern of zooplankton in the three different parts of Hangzhou Bay.

1. Introduction

The Hangzhou Bay is located in the East China Sea, immediately south of the Changjiang (Yangtze River) Estuary. The west area of north Hangzhou Bay (NW) is situated in the mouth of Qiantang River, and the salinity of this area (salinity ranges 7.2–9.1) was relatively low because of the runoff strength of the Qiantang River [1]. While the east area of north part (NE), with higher salinity (12.1–18.8) is close to the mouth of Hangzhou Bay, which was influenced by the Yangtze River diluted water and the sea water of the East China Sea. The east area of south Hangzhou Bay (SE), with the highest salinities (12.7–21.8), was adjacent to Jintang Island, mainly influenced by the water masses of the East China Sea. Besides, as a macro-tidal bay, its tidal system is asymmetry, the flood currents from northwest Pacific Ocean propagate mainly along the northern Hangzhou Bay for convergence, while ebb currents disperse southeastwards for divergence [2].

Some studies on the distribution and diversity of zooplankton in the Hangzhou Bay have been reported. In the 1980s, Zhu [3] had made a comprehensive study on the ecological characteristics of zooplankton communities in the Hangzhou Bay. In the north shore of Hangzhou Bay sea near Shanghai Petrochemical Plant, Chen et al. [1] analyzed the biomass, species composition and community structure of zooplankton. Ji et al. [4] discussed the ecological characteristics of zooplankton from multiple perspectives in Jinshan–Three-Island sea area of Shanghai. In Yangshan Islands sea area of Hangzhou Bay, Xu et al. [5] studied the distribution characteristics of zooplankton. Chen et al. [6] discussed the effects of Yangshan Project in Hangzhou Bay on the distribution of zooplankton biomass in the adjacent waters. However, previous studies on zooplankton are generally limited to local waters of Hangzhou Bay. The effects of tide and water masses on the distribution of zooplankton in different parts of Hangzhou Bay are still elusive to us. Tide and water masses were considered to be important factors influencing the distribution of zooplankton in bays and estuaries. For example, in the southern Europe Mondego estuary, Marques et al. [7] pointed out that zooplankton species composition in different seasons

* Corresponding author.
E-mail address: xiaomin@sh163.net (Z. Xu).

http://dx.doi.org/10.1016/j.chnaes.2015.12.007
1872-2032/© 2015 Published by Elsevier B.V.

was significantly different, and the estuarine community was strongly dependent on allochthonous events, such as tidal exchange and river inflow. Morgan et al. [8] found that in estuaries and coastal waters, the fluctuations of physical and chemical characteristics of water at different temporal and spatial scales had an impact on the distribution and community composition of zooplankton. Zervoudaki et al. [9] found that salinity and ecosystem types were the important factors to control the biomass proportion of copepod species in estuarine waters.

To explore the possible influence of the tide and water masses on the distribution of zooplankton in Hangzhou Bay, we made investigations on the zooplankton communities in three different areas, including the NW, the NE, and the SE of Hangzhou Bay. The resulting information would enrich our understanding on the relationship between zooplankton communities and tidal, water masses in different parts of the estuary, the Gulf of China.

2. Materials and methods

2.1. Study area and sampling method

Sampling in the Hangzhou Bay was conducted during the autumn of 2009, 2011 and 2012 in three cruises of comprehensive oceanographic surveys in three different areas: the NE (121.67°E–121.87°E, 30.68°N–30.83°N), the SE (121.60°E–121.85°E, 29.95°N–30.24°N), and the NW (121.31°E–121.56°E, 30.58°N–30.77°N) of Hangzhou Bay. 12 stations were set up in each survey, except the NE which added the station 13 (Fig. 1). The zooplankton samples were vertically towed from the bottom to the surface with a standard large plankton net (diameter 50 cm, mesh fiber CQ14, mesh size 0.505 mm). The method of sample collection and handling was provided by the Marine Biological Survey of the Specification for Marine Monitoring [10]. Zooplankton samples were preserved in 5% formalin, and identified to species level under a stereomicroscope in the laboratory. The unit of biomass was mg/m^3 and the unit of abundance was ind/m^3. The temperature, salinity and depth of sea water were measured by the Conductivity–Temperature–Depth instrument.

2.2. Data processing

The dominance (Y) of each species was calculated with the following equations:

$$Y = (n_i/N) \times f_i. \quad (1)$$

where n_i is the total abundance of the species i occurring in each station (ind/m^3), N is the total abundance of all species occurring in each station (ind/m^3), and f_i is the frequency of the species i occurring in each station. The zooplankton species with $Y \geq 0.02$ was considered to be the dominant species [11].

To determine the potential influence of the distribution and abundance of dominant species on the zooplankton, each dominant species of abundance was valued as the independent variable, and the total abundance as the dependent variable, using P (<0.05) to filter out the dominant species which had significant contribution to the total abundance, while calculating the standardized regression coefficient β [12].

The spatial distribution map of stations, total biomass, total abundance and abundance of dominant species was drawn by the Surfer software. SPSS 16.0 software was used to analysis the variance of total biomass and total abundance. The stepwise regression was carried out

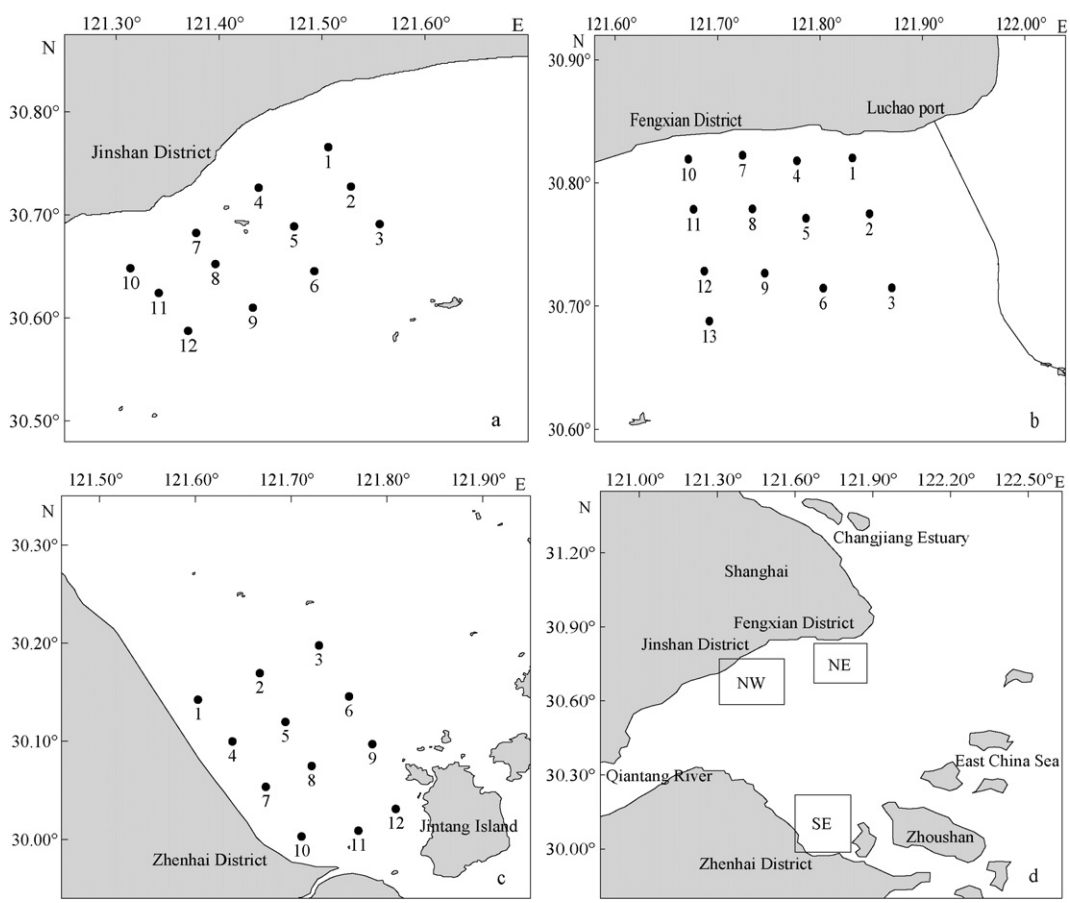

Fig. 1. Distribution of sampling stations in the Hangzhou Bay. a. The NW; b. the NE; c. the SE; d. sampling stations in different parts of Hangzhou Bay.