Aquaculture and Fisheries xxx (2017) 1–6

Contents lists available at ScienceDirect

Aquaculture and Fisheries

journal homepage: www.keaipublishing.com/en/journals/aquaculture-and-fisheries/

The biological content of ballast water in China: A review

Huixian Wu [a, b], Chen Chen [a, b], Qiong Wang [a, b], Junda Lin [c], Junzeng Xue [a, b, c, *]

[a] Ballast Water Detecting Lab, Shanghai Ocean University, Shanghai 201306, China
[b] Key Laboratory of Exploration and Utilization of Aquatic Genetic Resources, Shanghai Ocean University, Ministry of Education, Shanghai 201306, China
[c] Department of Biological Sciences, Florida Institute of Technology, Melbourne, FL 32901, USA

ARTICLE INFO

Article history:
Received 11 October 2016
Received in revised form
11 January 2017
Accepted 13 March 2017
Available online xxx

Keywords:
Ballast water
Biological survey
China
Phytoplankton
Zooplankton
Bacteria

ABSTRACT

Species introduction through the release of ballast water has become one of the four major threats to marine biodiversity and ecosystem function worldwide. China is one of the top trading countries, yet little is known about exotic species in the ballast water of ships coming to her ports. Here we review the biological surveys of ballast water in major Chinese ports. Forty species of non-indigenous phytoplankton, belonging to 25 genera and five phyla, have been reported. The dominant species are diatoms and dinoflagellates. There are 17 red-tide causing species, five of which are noxious algae. Seventeen species of non-indigenous zooplankton have been reported, with most of them (11) being copepods. There are also 22 species of pathogenic bacteria, including *Vibrio alginolyticus, V. carchariae, V. parahaemolyticus, and V. vulnificus.* These studies show that species introduction through ballast water poses a potentially serious threat to the ecology and human health in China. More research, including collaboration with the international community, is urgently needed to address this problem.

1. Ports along coast of China

China has a coastline of more than 18,000 km, with an additional 14,000 km of coastline along its islands. Many ports have been established along the coast (Fig. 1). With rapid economic development since the 1980s, these ports have received large numbers of ships from all over the world, along with huge volumes of ballast water. According to data from the Transportation Ministry, the cargo-handling capacity of all Chinese harbors reached 12.75 billion tons in 2015, and the container-handling capability reached 212 million TEU. There were a total of 10721 coastal vessels and 2689 *trans*-oceanic vessels (Department of transportation, 2016).

2. The management of ballast water

The relevant laws and regulations governing ballast-water management in China include the Marine Environment Protection Law of the People's Republic of China (1999), the Frontier Health and Quarantine Law of the People's Republic of China (1986), and Regulations of the People's Republic of China on the Prevention of Vessel-Induced Sea Pollution (1983). Specifically, deballasting in Chinese ports has to be approved by the relevant authorities (No.70, Chapter Eight, Marine Environment Protection Law of the People's Republic of China, 1999). Nos. 18, 25 and 29 in Chapter Four of Frontier Health and Quarantine Law of the People's Republic of China (1986) specify the standards for regulation, inspection and treatment of pathogenic organisms in ballast water; and No.15, Chapter Three of Regulations of the People's Republic of China on the Prevention of Vessel-Induced Sea Pollution (1983) states that deballasting in China's seas has to comply with China's laws, regulations and the relevant international agreements China has signed. Deballasting management is administered by Maritime Safety Administration of the People's Republic of China (mainly focused on hydrocarbon products and dangerous chemicals, with increasing attention being paid to organisms) and the China Entry-Exit Inspection and Quarantine Bureau (covering ballast water from pathogen-infected regions).

3. Biological survey

Surveys of ballast water organisms began in 1980 (Xu, 1993; Table 1), with emphasis on pathogenic organisms in the early years. With the increasing trade, the survey frequency and scope have increased steadily over the years (Table 1). A total of 27 biological

* Corresponding author. Ballast Water Detecting Lab, Shanghai Ocean University, 999 Huchenghuan Road, Shanghai 201306, China.
E-mail address: jzxue@shou.edu.cn (J. Xue).

http://dx.doi.org/10.1016/j.aaf.2017.03.002

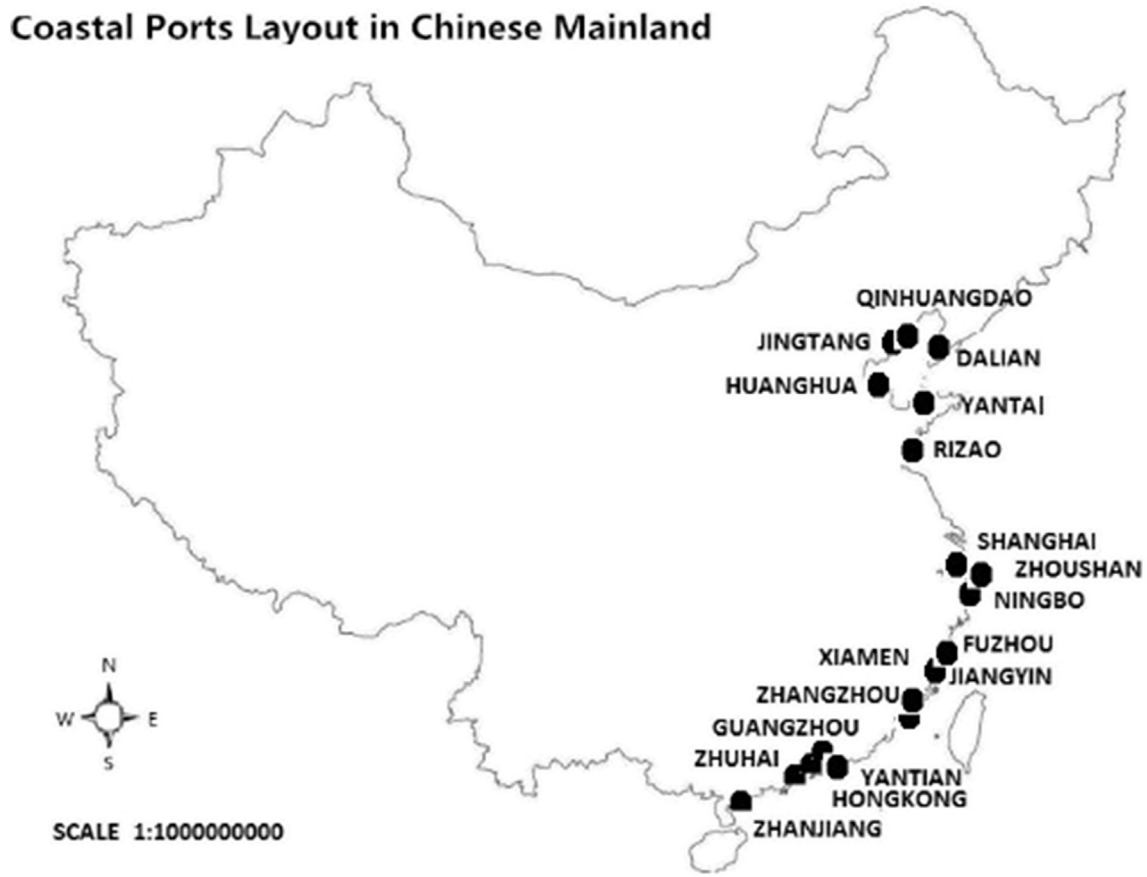

Fig. 1. Major ports along the mainland coast of China.

studies of ballast water were conducted at 19 ports. These surveys include microbial, planktonic and sedimentary assemblages. In addition, new technologies for investigating microbial communities are being explored, and the effects of ballast water exchange in the open ocean are being examined. The surveyed ships are mainly container ships, bulk carriers, oil tankers, dredging boats and car transport ships from Japan, South Korea, Southeast Asia, Taiwan, and other ports in China. Details of vessel selection, sampling and organism identification have been published elsewhere (Table 1).

Overall, 40 non-indigenous species of phytoplankton, belonging to 25 genera and five phyla, were found, including 21 species of Bacillariophyta, 13 species of Pyrrophyta, 13 species of Cyanophyta, and 2 species each of Chlorophyta and Chrysophyta (Table 2). There were 17 red-tide species (10 of Bacillariophyta, 6 of Pyrrophyta and 1 of Pyrrysophyta), with *Leptocylindrus danicus*, *Thalassiothrix frauenfeldii*, and *Cylindrotheca closterium* being the most common. Five of the red-tide species are toxic algae: *Dinophysis acuminata*, *Dinophysis caudata*, *Scrippsiella trochoidea*, *Pseudo-nitzschia delicatissima* and *Dictyocha fibula*.

16 non-indigenous species of zooplankton were found in these surveys (Table 3). Sixty-three percent of the species were copepods, including 4 each of Calanoida, Cyclopoida, and Harpacticoida. Other zooplankton included *Pontosphaera haeckele* and larvae of *Cultellus pellucidus*, *Cypris* sp., and Cyphozoan ephyra.

A total of 24 species of harmful microorganisms were found (Table 4). In the ports of Yantian and Zhuhai, *Vibrio alginolyticus*, *V. carchariae*, *V. parahaemolyticus*, and *V. vulnificus* were the dominant species. Also found were species of *Pseudomonas* and *Aeromonas*, which are important pathogenic species in aquaculture (Jia *et al.*, 2010).

There are geographic variations in the species composition of ballast water organisms among the Chinese ports. The next section reviews the results in-depth for each harbor.

3.1. Dalian

There have been 3 surveys at Dalian since 1980. The survey of 1980–1982 focused on microorganisms and included 401 samples from 210 ships. About 27% of the samples contained bacteria of the *E. coli* group (Xu, 1993). In April 2003, 10 ships arriving from both the Atlantic and Pacific were surveyed. The *E. coli* group was found in all the ships (Zhang et al., 2005). In addition, the non-agglutinable group and several other pathogenic organisms were detected. One species of calanoid copepod and 10 species of phytoplankton, with *Gonyaulax polyedra* as the dominant species, were also found (Zhang et al., 2005). In 2006, the ballast water plankton assemblage in a cargo ship that travelled between Dalian and Haikou was monitored daily. The rapid decrease in water temperature during the journey led to a dramatic decrease in biomass of phytoplankton and zooplankton, and the number of species and density of zooplankton decrease with the aging of the ballast water (Liu, Wang, Wang, Liu, *et al.*, 2011). In 2007–2008, 41 species of phytoplankton, mostly diatom with *Coscinodiscus* sp. as the dominant species, were found during surveys of ballast water in 2 ships from Malaysia and one ship each from Algeria, South Korea, Laizhou (China) and Dalian Bay (China) (Liu, Wang, Wang, Li, et al., 2011).

Please cite this article in press as: Wu, H., et al., The biological content of ballast water in China: A review, Aquaculture and Fisheries (2017), http://dx.doi.org/10.1016/j.aaf.2017.03.002