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The implementation of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 in China: challenges and prospects

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THE IMPLEMENTATION OF THE INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS, 2004 IN CHINA: CHALLENGES AND PROSPECTS

By

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): .....

(Date): 24 September 2019 .....

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Abstract

Title of Dissertation: **The Implementation of the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 in China: Challenges and Prospects**

Degree: **Master of science**

With the rapid development of the international shipping industry, the problem of alien marine invasion caused by ships' ballast water has brought significant impacts on the ecological environment, economic development, and human health. To this regard, the International Convention for the Control and Management of Ships' Ballast Water and Sediment (BWM Convention) was adopted by the International Maritime Organization in 2004 and came into force on September 8, 2017.

On October 22, 2018, China ratified the BWM Convention which entered into force on January 22, 2019. However, as ballast water control and management is still a new issue in China, there are still many problems to be explored and improved in the process of the implementation of the BWM Convention.

The research aims to study and analyse the challenges of implementing the BWM Convention in China by using qualitative research methodology that applies a combination of research methods (law, policy, management, science, and technology). Besides, a comparison method was conducted to compare the representative systems and measures in the ballast water management in the United States and Australia with China.

The main challenges were identified from the aspects of legislation, management system, and technology development. First, the legislative challenges are mainly reflected in the imperfect legal system, legal liability system, and public participation system. Moreover, the decentralized management of functional departments and the incomplete risk management system are considered to be the main defects of the management system. Besides, the insufficient basic research and infrastructure construction, the global technical problems in ballast water sampling and ballast water management system are also essential factors restricting the implementation of the BWM Convention in China.

Through an in-depth analysis of the causes of the above challenges and summarizing the advanced foreign experience that is worth learning from, this dissertation put forward relevant recommendations, hoping to provide some enlightenment for China to implement the BWM Convention better.

KEYWORDS: ballast water management, BWM Convention, Invasive alien species, D-1 standard, D-2 standard

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List of Abbreviations

AQIS	Australian Quarantine and Inspection Service
BWM Convention	International Convention for The Control and Management of the ships' ballast water and sediments, 2004
BWMS	Ballast water management system
CWA	The Clean Water Act of 1977
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
HAOP	Harmful Aquatic Organisms and Pathogens
IMO	International Maritime Organization
IOPP	International Oil Pollution Prevention Certificate
MARS	Maritime Arrivals Reporting System
MEPC	Marine Environmental Protection Committee
China MSA	Maritime Safety Administration of the People's Republic of China
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990
NBIC	National Ballast Information Clearinghouse
NBWMO	National Ballast Water Management Office
NISA	National Invasive Species Act
NPDES	National Pollutant Discharge Elimination System
PCWP	Law of Prevention and Control of Water Pollution
PSC	Port State Control
PSCO	Port State Control Officer
USCG	United States Coast Guard
VGP	Vessel General Permit

Chapter 1 Introduction

1.1 Research background

The shipping industry has developed rapidly with the prosperity of international trade, accounting for about 90% of world trade (ICS, 2019). However, at the same time, international shipping has also brought numerous problems of marine environment pollution. In order to ensure the safety of ships at sea, ships are loaded with a large amount of ballast water (Saglam & Duzgunes, 2018). However, ballast water has also become the primary carrier of invasive aquatic species (Rak et al., 2018). The Global Environment Facility has listed the invasion of alien species through ships' ballast water as one of the four significant threats to the global marine ecological environment (GEF, 2019). This issue has aroused the widespread concern of relevant international organizations and countries, and many measures have been taken to strengthen ballast water management.

1.1.1 Overview of ships' ballast water

Ballast water is defined in Article 1 (2) of the International Convention for the Control and Management of the ships' Ballast Water and Sediments, 2004 (BWM Convention) as: "water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship." In Article 1 (11) of the BWM Convention (2004), "Sediments" is defined as "matter settled out of ballast water within a ship". In other words, sediment is the material that the suspended matter in ships' ballast water forms solid and precipitates. Therefore, in this dissertation, the ballast water and its sediments will be collectively referred to as ships' ballast water.

Historically, people used solids as ballast in the era of wooden sailing boats. In the mid-19th century, as iron replaced wood in the shipbuilding, ships increasingly used ballast water because it could be loaded and unloaded more quickly and had better stability control (Bailey, 2015). Figure 1 shows the process of ballast water loading and discharging.

Figure 1. Schematic diagram of ship's ballast water loading and discharging. (Source: IMO, n.d.)

Today, ballast water has become an indispensable part of ships' navigation. However, it has also become the primary mediator for invasive aquatic (Rak et al., 2018). Depending on the size and use of ships, each ship can carry hundreds of liters of ballast water to more than 130,000 tons. One cubic meter of ballast water can hold up to 50,000 zooplankton samples or 10 million phytoplankton cells (Bobka, 2018). So, it is no exaggeration that thousands of different aquatic species can be transported through ballast water (Diasamidze & Shotadze, 2019). Therefore, when ships move more frequently between ports around the world, invasive aquatic species is carried from the original growth sea area to other areas through ballast water and may invade highly sensitive waters and damage local marine ecosystems.

After a brief introduction to ships' ballast water, the impacts of invasive aquatic species from ballast water will be discussed below.

1.1.2 The harm of invasive aquatic species from ballast water

By definition, when alien species establish populations outside their natural range that alter or threaten native biodiversity, they become invasive species (Havel et al., 2015). Invasive aquatic species may compete for resources with the native organisms, spread harmful aquatic organisms and pathogens (HAOP), and even lead

to the native species become extinct (Balaji et al., 2014). The negative effects of invasive aquatic species are mainly reflected in the following aspects:

1. **Impact on the ecological environment**

   Some alien species can establish new populations in the new environment, having a battery of effects on the food chain, population structure, and biodiversity of local marine species (Gallardo, Clavero, Sánchez & Vilà, 2016). It is almost impossible for many species to destroy them once they have invaded and taken root (Seebens et al., 2016). From a global perspective, many countries have suffered from the invasion of foreign organisms. A typical example is the invasion of the Laurentian Great Lakes by zebra mussels from the Black Sea (Ricciardi, 2007).

2. **Impact on the economy**

   Impact on the economy. Invasive aquatic species may threaten direct economic losses such as fisheries, aquaculture, and tourism, resulting in a decline in economic output, and may also cause indirect economic losses associated with the harmful effects of human health. In the Black Sea, an invasive comb is blamed for the collapse of a local fishery that costs millions of dollars a year (Shalovenkov, 2019).

3. **Impact on human health**

   Ballast water can transport virus and bacterial pathogens and cause the spread of diseases, posing a potential threat to human health. The invasion of four dinoflagellate species has resulted in the accumulation of toxins in local seafood, which produce and accumulate toxicity in the human body after consumption, leading to paralytic poisoning and even death. Moreover, some invasive marine species carried by ballast water are intermediate hosts for human parasites. The Chinese mitten crab, which has invaded the west coast of Europe and the United States, is an intermediate host for human liver fluke (Bax et al., 2003).

As mentioned above, the problem of invasive aquatic species in ballast water has aroused wide concern all over the world. As early as the 1990s, the United States, Australia, and other countries have taken unilateral actions to control and manage ballast water through their legislation (Verna & Harris, 2016). In addition, the issue of ballast water management has been on the agenda of many meetings of international organizations over the past 30 years. In 2004, the International Maritime Organization (IMO) adopted the BWM Convention, 2004, which came into force on September 8, 2017 (IMO, 2019).

1.1.3 The impacts of invasive aquatic species on China

China has 18,000 kilometers of coastline and about 3 million square kilometers of ocean, which is rich in marine biological diversity. As one of the largest trading countries in the world, China's ports have become the primary destination and transit center of international shipping. According to "Statistical Bulletin of the Development of the Transportation Industry in 2018", by the end of 2018, there were 5,734 berths for the production and use of coastal ports, including 2,007 berths of 10,000-ton class or above, with a cargo throughput of 9,463 million tons and foreign trade cargo throughput of 3,744 million tons (MOT, 2018).

Since the 1980s, with the rapid development of China's economy, a large number of ships' ballast water has been discharged in China's coastal ports. According to the statistics, billions of tons of ballast water that entered China's coastal waters and has been transferred from China to ports around the world. The annual direct economic losses caused by invasive aquatic species in China has reached 57.4 billion, and the indirect economic losses may be as high as 1,000 billion (Guo, 2019). Studies have shown that 30.5% of the primary way for alien species to enter China is due to shipping (Xiong, Shen, Wu, Lu, & Yan, 2017). In addition, another study has shown that there were 34 of the 43 marine invasive species detected (77.3%) introduced by ballast water (Zhan et al., 2017). One of the influences of invasive aquatic species on China is mainly reflected in the frequent occurrence of red tide disasters. Especially since 2010, the average annual red tide in the Bohai Sea has been more than 2200 square

kilometers (Zhan et al., 2017). In recent years, the invasive aquatic species in China has caused an irreversible impact on the marine ecological environment and seriously threaten the sustainable development of China's economy and society.

On October 22, 2018, China submitted an instrument of accession to the BWM Convention to the IMO, which has entered into force in China on January 22, 2019 (Gov, 2018). It has brought significant challenges and opportunities to China's ballast water management and even the entire shipping industry.

1.2 Aims and objectives

The BWM Convention has just come into force in China on January 22, 2019 (Gov, 2018), and there are still many problems to be explored and improved in this process. How to control and manage the ships' ballast water scientifically and effectively and how to deal with the challenges brought by the BMW Convention are the challenges that the competent authorities need to solve urgently. The primary aim of this dissertation is to take the legislation, management system and technology as an entry point to study and analyse the challenges that the competent authorities may face in implementing the BWM Convention in China and propose forward corresponding solutions and suggestions. It is hoped to provide a reference for China to implement the BWM Convention better and improve ballast water management. The specific objectives are identified as below：

- The first is to study the current situation of ballast water management in China, analyse the problems and challenges in the process of implementing the BWM convention from the aspects of legislation, management, and technology, and analyse the causes of the problems.
- By analyzing the advanced systems and methods of ballast water management in the United States and Australia, to provide a new reference for improving China's ballast water management.

- From the perspective of government management, the corresponding recommendations are put forward at the legislative level, management level, and basic capacity building level, respectively.

1.3 Research questions

To this end, the specific research questions of the dissertation to be addressed include the following aspects:

- What are the defects of the current domestic legal system? How to improve it?
- How to improve the decentralized management mode and strengthen the collaboration of relevant departments?
- What are the defects and deficiencies in the current management system in China? How to improve it?
- What are the main technical barriers in China to implement the BWM Convention and what efforts should the competent authorities make in strengthening technical support and basic capacity building?
- What experiences can be learned from the United States and Australia in ballast water management?

1.4 Methodology

In order to achieve the aims and objectives of this research, this thesis adopted a qualitative research methodology.

The author extensively collected research data and materials from a wide range of literature sources, which provided substantial information towards the research. By analyzing and studying the professional opinions of different scholars in relevant fields, it was helpful to understand the history and current situations of ballast water management at a national and international level and to lay a solid foundation for this study. Besides, by using a combination of research methods from various disciplines,

including law, policy, management, science, and technology, a qualitative analysis was conducted in this research.

The research focused on the analysis of ships' ballast water and its harmful effects, the requirements of the BWM Convention, China's current legislation, management system, technological development and other elements for ballast water management. As a result, this study identifies the impacts of those factors on China's implementation of the BMW Convention, explores the main challenges faced by China in ballast water management and provide references for China to the better implementation of the BWM Convention.

Furthermore, this research adopted the comparison method to compare the ballast water management of the United States and Australia with that of China. From the comparison, some advanced experiences of foreign countries can be learned in the process of the implementation of the BWM Convention in China.

Moreover, when conducting research on relevant issues in Chapter 4.2.2 and 4.3.2, it was necessary to verify the accuracy of the information related ballast water risk assessment and ballast water sampling and testing technology in China. The author conducted an online interview with the director of the Hazardous Management and Anti-pollution Division of the China MSA.

According to the requirements of the World Maritime University Research Ethics Committee (REC), the application of the interview should be approved by the REC in advance. Nevertheless, due to time constraints, the researcher was unable to complete this process. By discussing with the supervisor, finally decided that the relevant contents of the interview could be cited.

In Chapter 1, the introduction of ballast water was given, and the effects of alien invasion caused by ballast water are expounded from the international and domestic levels. The next chapter will mainly explain how the international community responds to this problem.

Chapter 2 International response to ballast water management

The introduction of invasive aquatic species through ballast water is a global environmental problem, and many countries have paid an excruciating price for it (Gerhard and Gunsch, 2018). Some countries adopted unilateral actions and remarkable results have been achieved (Bailey, 2015). However, this issue is ultimately a global problem that requires concerted international action (Carney et al., 2017). The most significant achievement is the BWM Convention adopted in 2004, which provides an international uniform standard for ballast water management (Firestone and Corbett, 2005). This chapter will introduce the unilateral measures of ballast water management in the United States and Australia, and the highlight the BWM Convention.

2.1 Unilateral measures in major maritime countries

The United States and Australia as the most representative countries in ballast water management, in terms of legislation and management, have their characteristics.

2.1.1 The United States

The United States is one of the countries that has suffered the most prolonged and most losses from invasive aquatic species (Wei & Wang, 2014). Although the United States has not yet joined the BWM convention, the United States is one of the first countries in the world to legislate on ballast water management (Li, 2016).

2.1.1.1 The legislation progress

The Clean Water Act of 1977 is the fundamental law to control water pollution in the United States. It gave the Environmental Protection Agency (EPA) the power to develop ballast water management projects and regulations (Folkunger, 2010).

The first legislative action taken by the United States to address invasive aquatic species was the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) in 1990 (King & Tamburri, 2010). In 1993, the United States Coast Guard (USCG) issued and implemented the final rules for "Ballast Water Management for Control of Nonindigenous Species in the Great Lakes", which was written in Title 33 CFR Part 151, Subpart C (Buck, 2010). The key shift came in 1996, the Congress adopted the National Invasive Species Act (NISA), as an amendment to NANPCA, extended the management of ballast water to all ships in the U.S. waters and mandatory ballast water management report for all ships entering U.S. ports (McGee, 2002). In 2004, USCG issued a mandatory national ballast water management requirement, which was written in "Title 33 CFR Part 151, Subpart D". It marked the establishment of the national mandatory ballast water management program in the United States.

Furthermore, "Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters" was announced by the USCG in 2009 and took effect on June 2012. It required all vessels equipped with ballast water tanks operating in U.S. waters to use an USCG-approved ballast water management system (BWMS). The standard limited the concentration of biological organisms discharged in ballast water and imposed ballast water discharge regulation in two phases (King and Tamburri, 2010).

Moreover, in 2008, EPA first issued the Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP). VGP provided discharge requirements for different types of effluent, including ballast water. In 2013, the Final 2013VGP modified the contents of training and ballast water treatment (VGP, 2013). Currently, the 2013VGP has expired on December 19, 2018, and the Vessel Incidental Discharge Act authorized it to continue to be valid until the introduction of the new regulations (EPA, n.d.).

Another item worth mentioning is that, President Clinton issued Executive Order 13112 in 1999. It required the formation of the National Invasive Species Council, which was asked to develop a national invasive species management plan with specific goals and recommendations for actions (USDA, 1999).

2.1.1.2 Competent authorities

At the federal level, the EPA is authorized by the CWA to regulate the discharge of pollutants into U.S. waters, including ballast water. Besides, authorized by NANPCA in 1990, the USCG is responsible for ballast water management in the United States and has the authority to formulate relevant regulations and incorporated them into CFR (Buck, 2010).

2.1.1.3 The main features

First of all, the United States has enacted NISA as special legislation to prevent invasion of alien species. The NISA has played a fundamental role, providing strong support for the legal system of biological invasion in the United States (Liu, Lin, Wen & Lou, 2010). Further, the legislative structure is relatively complete. From the Clean Water Act to the USCG rules, a set of legal systems has been formed from top to bottom, from general to specific.

Besides, the United State has established the National Invasive Species Council, which is the central coordinating body at the federal level to prevent the invasion of alien organisms. It requires federal agencies to take coordinated actions to prevent the invasion of alien species and to take all necessary measures to control and minimize their impacts. Under the leadership and coordination of the NISC, various relevant federal agencies have greatly improved the efficiency of the prevention and control of invasive aquatic species.

Moreover, Ballast water management in the United States is stringent. First, the ballast water discharge standards in the first phase are equivalent to the D-2 standard in the BWM Convention, and the standards in the second phase are 1000 times stricter than the standard in the first stage. It can be said that the ballast water

discharge standards in the United States are the most stringent in the world (Li, 2016). Second, USCG required the type approval of the BWMS should adopt "Environmental Technology Verification" (ETV) standards (USCG, 2010). Since the ETV standards are stricter than G8 guidelines, it has brought some difficulties for the uniform and coordinated implementation of the BWM Convention (Čampara, Slišković, & Jelić Mrčelić, 2019). Third, the USCG imposes a maximum penalty of $35,000 for violations, which constitute a separate civil liability each day, and a class C felony for individuals who intentionally break the law (CFR, 2004).

Furthermore, the United States attaches importance to the integration of ballast water management information and data resources. In 1997, under the guidance of NISA, the USCG and the Smithsonian Environmental Research Centre jointly established the National Ballast Information Clearinghouse (NBIC). The main objective of NBIC is to analyse the patterns of transport and management of ballast water discharged in U.S. waters by collecting data and information from ballast water reports submitted by ships. NBIC has developed an online database with information and knowledge on ballast water open to coastal states and the public (NBIC, 2019). In addition, the United States has established the "Nonindigenous Aquatic Species Information Resource", which providing comprehensive information about alien aquatic organisms for biologists, inter-departmental organizations, and the public (USGS, n.d.).

In conclusion, the United States has a complete legal system and management system in ballast water management. In Chapter 2.1.2 will discuss the ballast water management in Australia.

2.1.2 Australia

According to statistics, about 150 million tons of ballast water is discharged into Australian ports every year (Tsamenyi, Kaye & Castle, 2003). Australia was one of the first countries in the world to introduce ballast water management guidelines (Wei & Wang, 2014). Over the years, Australia has developed mature experience in ballast water management.

2.1.2.1 Legislation

In early 1990, the Australian Quarantine and Inspection Service (AQIS) issued "Voluntary guidelines on ballast water management" to reduce the risk of harmful aquatic organisms being introduced into the Australian marine environment by ballast water (IMO, 2010).

In 2001, Australia began to implement mandatory ballast water management requirements officially. AQIS issued the "Australian Ballast Water Management Requirements", which required that all international vessels entering Australian ports or waters to exchange 95 percent of their volume of ballast water (Albert, Lishman & Saxena, 2013). In addition, the requirements include the use of the Decision Support System, to provide ships with a risk assessment of the potential introduction of invasive species into Australian waters (Rigby, Alan & Gustaaf, 2003).

On June 16, 2016, the Department of Agriculture and Water Resource and Department of Health co-administered the Biosecurity Act of 2015, which aims to manage biosecurity threats to plants, animals and human health in Australia to a low-risk level (Australian Government, 2018). Subsequently, the BWM Convention was ratified by Australia on June 7, 2017, and entered into force on September 8, 2017 (IMO, 2019), which has brought Australia in line with international ballast water management standards. Currently, the 7th edition of "Australian Ballast Water Management Requirements" has been updated to comply with the Biosecurity Act of 2015 and the BWM Convention (Australia Government Department of Agriculture, 2017).

2.1.2.2 Competent authorities

AQIS is an operational group within the Commonwealth Department of Agriculture, Fisheries and Forestry (now renamed the Department of Agriculture) (Australia Government, 2015). It is the principal agency for ballast water management in Australia. Since the early 1990s, AQIS has been actively working to create a national system to address the problem of invasive species (Wells & McDonald, 2010).

2.1.2.3 The main features

First, the complete legislation system provides strong support for ballast water management in Australia. There are more than 600 laws and regulations related to the ocean in Australia, which cover all aspects, including the protection of marine biodiversity and the marine environment (Zhan, 2015).

In addition, Australia has a strict ballast water reporting system. Australia classifies ballast water as high-risk ballast water and low-risk ballast water and proposes different ballast water management measures. According to the "Australian Ballast Water Management Requirements", all the vessels intending to discharge ballast water in Australian waters must submit a Ballast Water Report through Maritime Arrivals Reporting System (MARS) at least 12 hours before arrival. Ballast water reports will be risk assessed by MARS and automatically generate the Biosecurity Status Document (Australian Government Department of Agriculture, 2017).

Moreover, Australia's ballast water management standards have been in line with international conventions. Although Australia has adopted unilateral measures for ballast water management, after its accession to the BWM Convention, the relevant ballast water management standards have gradually become consistent with the BWM Convention. For example, Australia is phasing out ballast water exchange in accordance with the BWM Convention schedule and requires that all ballast water be managed using one of the approved methods of ballast water management (Australian Government, 2017).

Furthermore, the standards of the penalty are detailed and specific. Under the Biosecurity Act 2015, Australia has specific penalty standards for different types of violations of ballast water management regulations, such as failure to submit a ballast water report, illegal discharge of ballast water and sediment, and failure to have a Ballast Water Management Plan or certificate. Moreover, specific conditions applicable to the Criminal Code are also provided in the corresponding provisions.

In summary, the United States and Australia have a mature legal system and management system for ballast water management, which is of great reference significance. In the next section will turn to the introduction of the BWM Convention.

2.2 Overview of the BWM Convention, 2004

The international community first proposed that the management of ships' ballast water can be traced back to the IMO International Conference on Marine Pollution in 1973 (IMO, 1973). After a long process of consultation, discussion, and preparation, IMO finally adopted the BWM Convention on February 13, 2004 (IMO, n.d.). After the accession of Finland in 2016, the BWM Convention came into force on September 8, 2017. So far, 81 countries have ratified to the BWM Convention, and their combined merchant fleets account for about 80.76% of the world's total tonnage (IMO, 2019). In this section, the primary structure and contents of the BWM Convention will be highlighted.

2.2.1 The main structure

The BMW Convention consists of 22 articles dealing with the general rights and obligations of Parties, with supplementary regulations in the annex mainly dealing with technical requirements. Article 2 (2) of the BWM Convention provides that the annex has the same legal nature as the provisions of the Convention (BWMC, 2004). While the central part of the Convention deals with the general principles guiding its application, the annex details the mechanisms by which they apply (Tsimplis, 2004).

In order to facilitate the implementation of the BWM Convention, IMO has also developed 14 sets of guidelines (G1-G14) attached to the BWM Convention to provide technical guidance for the Parties (see Figure 2). Although most of the guidelines are not mandatory, they are still important manuals for the governments to implement the BWM Convention (Zink, 2015).

Resolution	Title	Status
MEPC.152(55)	Guidelines for sediment reception facilities (G1)	
MEPC.173(58)	Guidelines for ballast water sampling (G2)	
MEPC.123(53)	Guidelines for ballast water management equivalent compliance (G3)	
MEPC.127(53)	Guidelines for ballast water management and development of ballast water management plans (G4)	
MEPC.153(55)	Guidelines for ballast water reception facilities (G5)	
MEPC.288(71)	2017 Guidelines for ballast water exchange (G6)	Revokes MEPC.124(53)
MEPC.289(71)	2017 Guidelines for risk assessment under regulation A-4 of the BWM Convention (G7)	Supersedes MEPC.162(56)
MEPC.174(58)*	Guidelines for approval of ballast water management systems (G8)	Revokes MEPC.125(53)
MEPC.279(70)*	2016 Guidelines for approval of ballast water management systems (G8)	Supersedes MEPC.174(58)
MEPC.169(57)	Procedure for approval of ballast water management systems that make use of active substances (G9)	Revokes MEPC.126(53)
MEPC.140(54)	Guidelines for approval and oversight of prototype ballast water treatment technology programmes (G10)	
MEPC.149(55)	Guidelines for ballast water exchange design and construction standards (G11)	
MEPC.209(63)	2012 Guidelines on design and construction to facilitate sediment control on ships (G12)	Revokes MEPC.150(55)
MEPC.161(56)	Guidelines for additional measures regarding ballast water management including emergency situations (G13)	
MEPC.151(55)	Guidelines on designation of areas for ballast water exchange (G14)	

Figure 2. List of Guidelines of the BWM Convention
(Source: IMO, 2018)

2.2.2 The main contents

The BWM Convention aims to prevent, minimize and ultimately eliminate the transfer of harmful aquatic organisms and pathogens by establishing standards and procedures for the management and control of ships' ballast water and sediment (BWMC, 2004). What follows are the main requirements of the BWM Convention.

1. **General requirements**
   - The Article 3 of the BWM Convention (2004) provides that the Convention should apply to vessels flying the flag of the Party and vessels not flying the flag of the Party but operating within the waters under the jurisdiction of the Party.
   - Article 4 provides the responsibilities of the Party include two aspects. One is to take adequate measures to ensure that vessels flying the flag of the Party comply with the requirements of the Convention; the other is to

formulate national policies, strategies or precise implementation plans to meet the requirements of the BWM Convention.

2. **Requirements for flag States**
    - Regulation D-3 requires that the competent authority approves the BWMS following G8. Also, Regulation D- 3.2 further provides that using active substances should be subject to basic and final approval by IMO before type approval by the flag state authority.
    - The competent authority should approve the Prototype Ballast Water Treatment Technologies following G10.
    - Examination and approval of the Ballast Water Management Plan by the competent authority.
    - Under Annex E-1, the competent authority or its designated surveyor or recognized organization should inspect the ship and issues an International Ballast Water Management Certificate (BWMC, 2004).
3. **Requirements for port States**
    - Article 5 provides that port State should ensure that adequate sediment reception facilities are provided at ports and terminals where ballast tanks are cleaned or repaired.
    - Port State should conduct PSC inspection of ships, including verifying that ships have valid certificates, checking Ballast Water Record Book, and sampling and testing ballast water (Article 9).
    - According to Regulation B-4.2, port State should designate an appropriate area for ballast water replacement of the ship under the requirements of G14 where the waters are not suitable for ballast water exchange.
    - Regulation A-4 and G7 provide that port State may exempt ships from ballast water management requirements in its jurisdiction based on the results of the risk assessment.
    - Additional measures for emergencies may be proposed for ships by the Party following Regulation C-1 and G13 of the Convention (BWMC, 2004).

4. **Requirements for vessels**
    - Vessels are required to install BWMS within a specified time to meet D-2 standards according to the year of construction and the size of the ballast tank.
    - Vessels must have an approved Ballast Water Management Plan, Ballast Water Record Book, and International Ballast Water Management Certificate.
    - Officers and crews should be familiar with the specific duties of the ships they serve to carry out ballast water management, and with the Ballast Water Management Plans (BWMC, 2004).

2.2.3 Ballast water management methods

Article 1 of the BWM Convention (2004) defines "ballast water management" as the single or integrated use of mechanical, physical, chemical and biological methods to remove, harmless disposal, or avoid loading and discharging ballast water and sediment containing HAOP.

According to the requirements of the BWM Convention and its guidelines, ballast water can be managed in three ways (see Figure 3):

1. Ballast water exchange, in line with D-1 standard;
2. Ballast water treatment by BWMS, subject to D-2 standard;
3. Ballast water isolation, such as discharging ballast water to onshore reception facilities, or no discharge of ballast water (Du, Qian and Guo, 2009).

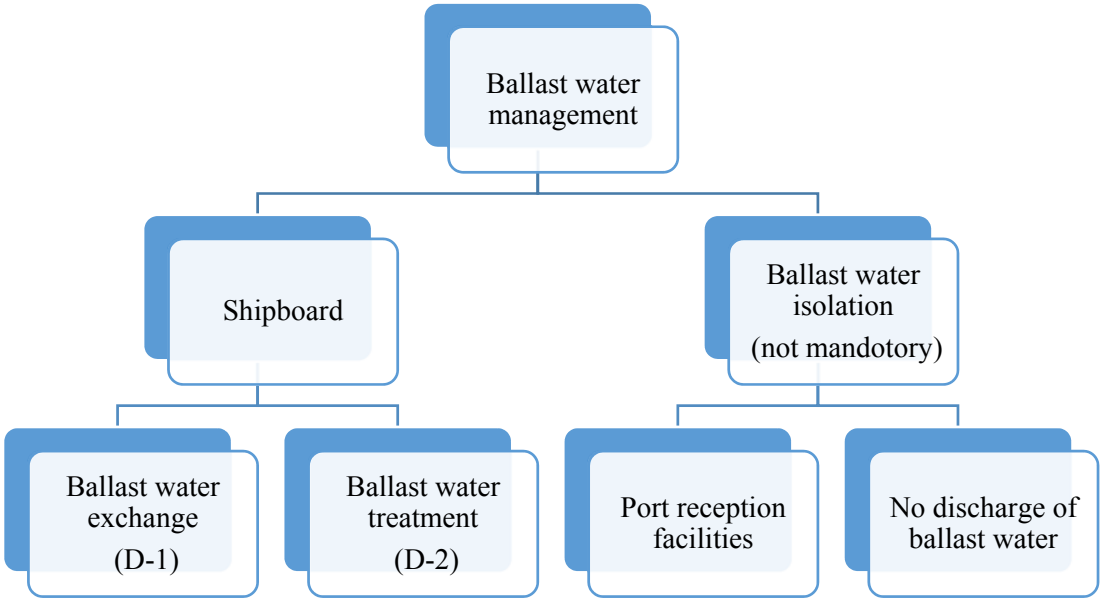

Figure 3. Diagram of ballast water management methods
(Source: Du, Qian and Guo, 2009; Tsolaki and Diamadopoulos, 2010)

2.2.3.1 Ballast Water Exchange Standard (Regulation D-1)

Regulation B-4 requires ships to exchange ballast water at least 200 nautical miles from the nearest land and at least 200 meters deep. D-1 standard requires that the ballast water exchange rate should reach 95% of the ballast water volume, or the replacement ballast water shall at least three times the volume of the ballast tank. (BWMC, 2004). G6 provided three accepted approaches of ballast water exchange, as shown in Figure 4. In addition, G11 provides the standard for the ship's design and construction of ballast water exchange to meet the D-1 standard (IMO, 2006).

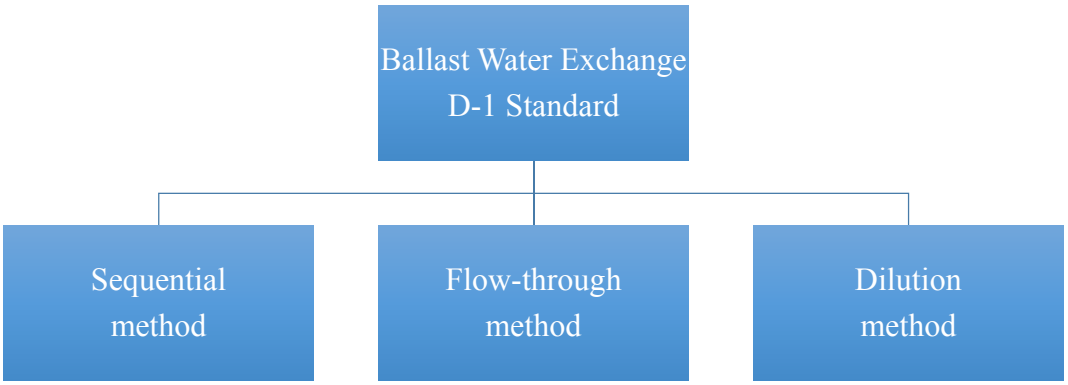

Figure 4. Three accepted methods of ballast water exchange
(Source: Based on Guidelines for ballast water exchange (G6), 2017)

2.2.3.2 Ballast Water Performance Standards (Regulation D-2)

Since ballast water exchange affects the stability and safety of ships, D-1 Standard is only a transitional management measure (Li &Huang, 2018). The ultimate aim of the BWM Convention is to require vessels to implement ballast water treatment to meet the D-2 standard. D-2 standard provides the maximum concentration of visible organisms and microorganisms in the discharged ballast water (see Table 1)

Table 1

Ballast Water Performance Standards of the BWM Convention

Organisms	**Discharge standards**
Organisms minimum size ≥ 50μm	< 10 viable organisms /m^3
10μm ≤Organisms minimum size < 50μm	< 10 viable organisms/ ml
Toxicogenic Vibrio cholerae (01 and 0139)	< 1 cfu* /100 ml or < 1 cfu /gram wet weight zooplankton samples
Escherichia coli	< 250 cfu /100 ml
Intestinal Enterococci	< 100 cfu /100 ml

Note. cfu* = colony forming unit.

(Source: Based on Regulation D-2 of the BWM Convention, 2004)

In order to meet D-2 standards, ships must install and use BWMS approved by the competent authority to treat ballast water. Most treatment methods need to be combined and applied to different stages of the treatment process (David and Gollasch, 2015). Table 2 shows the three stages of BWMS ballast water treatment and the primary technologies.

Table 2

The three stages of BWMS ballast water treatment and the main technologies

	Treatment			
Pre-treatment	Chemical	Physical	Biological	Residual control
Filtration	Chlorination	UV radiation	Bioaugmentation with microorganisms	Chemical reduction (Neutralisation)
Hydrocyclone	Electrochlorination	Deoxygenation		
Coagulation	Ozonation	Inert gas or Nitrogen injection		
Flocculation	Chlorine dioxide	Ultrasonic treatment		
	Peracetic acid	Cavitation		
	Other active substances	Fine filtration		
		Heat		

Source: (David & Gollasch, 2015)

Moreover, according to Regulation B-3 of the BWM Convention (2004) on the implementation date of D-2 standard, ships will gradually apply D-2 standard according to the year of construction and the size of ballast tanks. However, before the BWM Convention entered into force, specific dates for phased implementation had already passed. To this end, at the MEPC 71st session in 2017, IMO adopted the draft amendment to Regulation B-3 of the BWM Convention (IMO, 2017). In 2018, the new implementation schedule was adopted by Resolutions MEPC.297 (72) and MEPC.298 (72) (see Figure 5).

The new schedule requires that new ships built after 8 September 2017 must comply with D-2 standard, existing vessels built before 8 September 2017 will be determined according to the date of the International Oil Pollution Prevention Certificate (IOPP) renewal survey. The D-2 standard will take full effect from 2024 (IMO, 2018), and existing ships must conform to D-1 before the date of their D-2 compliance (IMO, 2018).

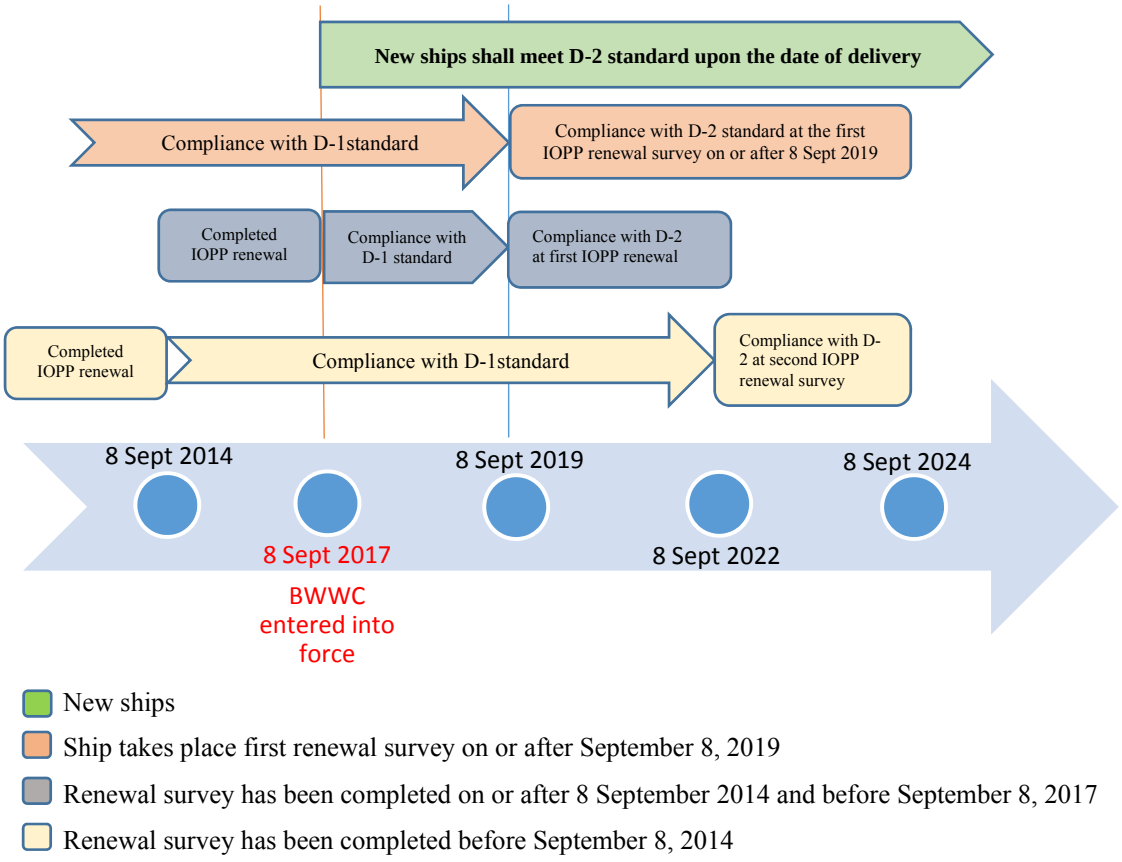

Figure 5. Summary of the new timeline for compliance of the D-2 standard (Source: Based on Resolution MEPC. 297 (72) and MEPC.298 (72), 2018; Čampara, Frančić, Maglić & Hasanspahić, 2019)

To sum up, Chapter 2 provided the international community's approaches to ballast water management through an introduction to unilateral measures by the United States and Australia and the contents of the BWM Convention. In chapter 3, the implementation status of the BWM Convention in China will be highlighted from the aspects of legislation, management system, and technological development.

Chapter 3 The implementation of the BWM Convention, 2004 in China: an overview

On October 22, 2018, China officially submitted to IMO the instrument of China's accession to the BWM Convention, which entered into force in China on January 22, 2019 (GOV, 2018). Before the entry into force of the Convention, China has put ballast water management into practice, laying a foundation for implementing the BWM Convention. This chapter will describe the current status of China's implementation of the BWM Convention.

3.1 Domestic legislation

In order to implement the BWM Convention, the first step is to translate its requirements into domestic legislation. In this section, an introduction to the legislative implementation of the BWM Convention will be given, together with the relevant provisions of ballast water management in other domestic laws.

3.1.1 Legislative transformation of the BWM Convention

Under Article 1 (1) of the BWM Convention, Parties are required to give full effect to the provisions of the BWM Convention and its annexes. Article 4 (2) requires Parties, in line with their capabilities and conditions, to develop national policies, strategies or programs for ballast water management that contribute to the achievement of the objectives of the convention (BWMC, 2004). Thus, China has an obligation to enact legislation to bring the requirements of local law into line with the content of the Convention. On January 11, 2019, the Maritime Safety Administration of the People's

Republic of China (MSA) issued the "Measures for the Supervision and Administration of Ships' Ballast Water and Sediment Management (Trial)" (hereinafter referred to as the "Measures"). These Measures were officially implemented on January 22, 2019 and the Experience-Building Phase [1] is till December 31, 2023 (MSA, 2019).

The "Measures" is a normative document, consisting of seven chapters of 32 articles and three Appendixes. Its primary purpose is to prevent HAOP from ships' ballast water and sediments from causing pollution and damage to the marine environment, human health, resources and property in China's waters (“Measures”, 2019). Its main contents are consistent with the requirements of the BMW Convention, which are described further on:

1. **Scope of application:** international vessels sailing, berthing, and operating in waters under Chinese jurisdiction. Not applicable to domestic vessels, including vessels sailing between the mainland and ports of Hong Kong, Macao, and Taiwan, as well as fishing boats, military vessels, and government vessels (Article 2).
2. **Competent authority:** Article 3 of the “Measures” (2019) provides that the MSA should be responsible for the supervision and management of the national ballast water and sediment management. Further, MSA authorities at all levels should be specifically responsible for the supervision and administration of the ships’ ballast water and sediment management within their respective jurisdictions (“Measures”, Article 3, Para.2)
3. **System management:** Article 4 requires shipping companies belonging to Chinese vessels to incorporate ballast water and sediment management into the safety management system (“Measures”, 2019).

[1] Experience-Building Phase: According to IMO Resolution MEPC.290 (71) “The Experience-Building Phase (EBP) Associated with the BWM Convention”, during the EBP, the Port State will not penalize ships that do not meet the requirements of the D-2 standard with some specific requirements, but this does not affect the Port State’s penalties for vessels that do not meet the prerequisites for environmental protection purposes (IMO, 2017).

4. **Certificate Instruments:** Article 5 requires the ship to be issued by the competent authority or its authorized ship inspection agency the International Ballast Water Management Certificate, the Ballast Water Management Plan, and the Ballast Water Record Book, the "Type Approval Certificate for Ballast Water Management System" or its copy (“Measures”, 2019).
5. **Discharge standards:** The requirements for ballast water exchange stipulated in Article 8 are basically in line with the BWM Convention D-1 standards. Article 9 provides that the ballast water discharge standards should contain the same amount of viable aquatic organisms as the D-2 standards in the BWM Convention.
6. **Reporting requirements:** According to Article 11, the discharge of ballast water from ships should be reported to the local maritime administrative agency 12 hours in advance.
7. **Equivalent conformity**: Ships applying for equivalent conformity should submit the following materials:
    - Preventive measures to reduce the transfer of ballast water and the introduction of HAOP;
    - Operational plan for regular cleaning of sediments in ballast tanks.
8. **Vessel exemption**: Article 22 provides for the circumstances under which ships may apply for exemption:
    - Ships sailing in waters delimited by other countries for mutual exemption;
    - Ships operating only in jurisdictional waters and on the high seas;
    - Ships that only use drinking water as ballast water;
    - Unmanned barge;
    - Ships used to search, rescue, and remove contaminants.
9. **Supervision and management**: Article 26 provides the supervision and inspection of vessels entering Chinese waters, including certificate documents, crew's familiarity with ballast water management operations, operation conditions of BWMS, ballast water sampling and testing.

Following an examination of the contents of the new national legislation adopted specifically in furtherance of the BWM Convention, the next section will turn to other domestic laws related to ballast water management.

3.1.2 Existing legal basis

Before China acceded to the BWM Convention, the legislation that referred to ships' ballast water mainly included:

1. **Marine Environmental Protection Law, 1999 as amended.** It is China's general law on marine environmental protection, which aims to protect and improve the marine ecological environment. There are two provisions of the law directly relating to ballast water. Article 62 provides that no ship or related operation shall discharge ballast water into the ocean in violation. Article 70 requires ships to comply with relevant regulations and procedures before discharging ballast water. This law did not provide specific requirements for ballast water management, but it defined the scope of responsibilities of various competent authorities.
2. **Frontier Health and Quarantine Law, 1986 as amended.** The primary purpose of the law is to protect human health and prevent infectious diseases from being introduced from abroad or from within China. Article 18 mandates frontier health and quarantine authorities to implement sanitary supervision of inbound and outbound vehicles, including supervision and inspection of ballast water treatment.
3. **Regulation on the Prevention and Control of Marine Pollution from Vessels, 2010.** The regulation is based on the Marine Environmental Protection Law. Its aim is to prevent and control pollution of the marine environment by ships and their related operations. Under Article 15, ballast water discharged by ships in sea areas under China's jurisdiction should meet the requirements of China's laws and regulations, international treaties concluded and relevant standards.

4. **Rules for implementing Frontier Health and Quarantine Law, 1989, as amended.** Article 78 provides that ballast water loaded from cholera epidemic areas is not allowed to be discharged without disinfection. Any unlawful discharge of ballast water without authorization should be punished in accordance with the provisions of Articles 109 and 110.
5. **Water Pollution Prevention and Control Law, 2008 as amended.** Article 59 of provides that a vessel on an international voyage entering Chinese inland rivers should use ballast water treatment devices or take equivalent measures to manage ballast water. Otherwise, it is forbidden to discharge ballast water. Also, penalties are imposed on ships that discharge ballast water that does not comply with Article 90.
6. **Administrative Measures for Entry-Exit Inspection and Quarantine of International Navigation Vessels, 2003.** Article 14 provides that when an international navigation vessel goes through the entry inspection and quarantine procedures, the ship or its agent should submit a "ballast water report form" to the inspection and quarantine institution. When ballast water comes from an epidemic area, the corresponding sanitary decontamination treatment should be implemented before discharge (Article 25). During the period of stay at the port, the ship should not discharge ballast water without the permission of the inspection and quarantine institution (Article 29).
7. **Provisions on the Prevention and Administration of Marine Environmental Pollution by Ships and Related Operations in 2010, as amended.** Articles 9 and 12 respectively require vessels to discharge ballast water with the permission of the maritime administrative authority, in compliance with relevant operational procedures, and comply with the provisions of laws, administrative regulations, relevant standards, and concluded international treaties.

8. **Water Pollution Prevention and Control Action plan, 2015.** It aims to strengthen the prevention and control of water pollution and ensure national water security. Section 1, paragraph 4 of the "Plan" requires that international vessels sailing in Chinese waters carry out ballast water exchange or install BWMS.

In summary, prior to the promulgation of the "Measures", existing laws in China concerning ballast water management were scattered in different legal provisions, most of which were relatively broad, and no specific standards were put forward for ballast water management.

3.2 Institutions

At present, the management of ballast water in China is a decentralized management model. The management authority is dispersed in multiple departments, and each department manages the work related to ballast water according to its own duties.

What follows is the organizational structure of the relevant departments (see Figure 6) and a description of the role of each authority given powers regarding ballast water management.

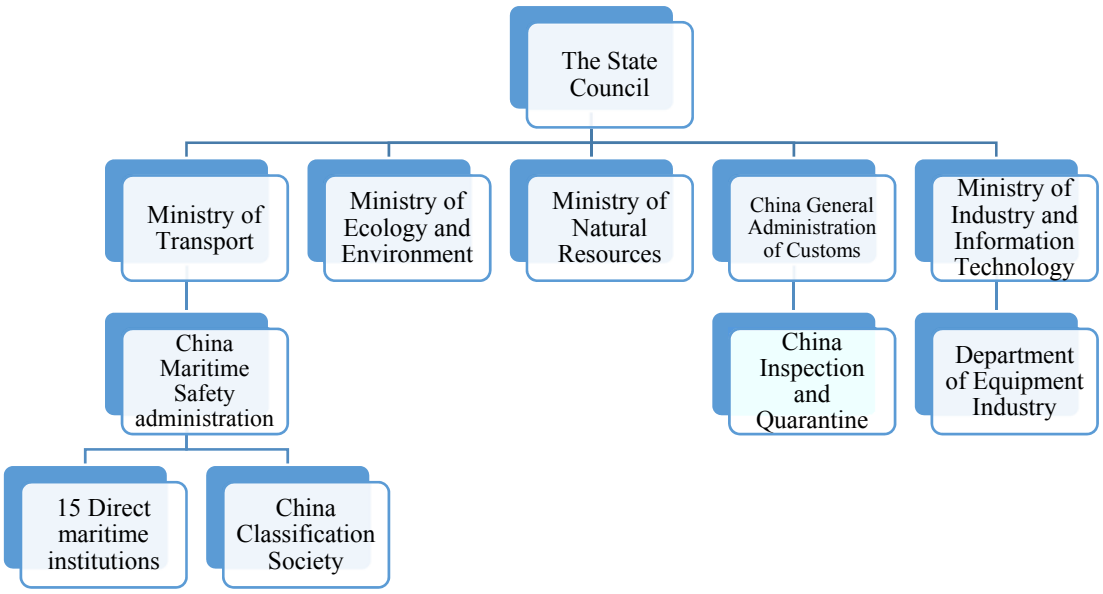

Figure 6. Diagram of the organization structure of departments involved in ballast water management in China
(Source: Created by author)

1. **China Maritime Safety Administration.** It is an administrative institution lying directly under the Ministry of Transport and implements a vertical management system[2]. According to Article 3 of the "Measures" (2019), MSA is the competent authority for the supervision and management of ship ballast water and sediment. Based on departmental functions, MSA is responsible for organizing the implementation of international maritime conventions and fulfilling the regulatory obligations of flag State, port State, and coastal State (MSA, 2014). Therefore, MSA is the competent authority for the implementation of the BWM Convention.

[2] According to document [1999] No. 90 issued by the State Council's General Office, the Ministry of Transport has set up direct maritime institutions in the coastal provinces, cities and major inter-provincial river trunk lines and important port cities. Currently, there are fifteen direct maritime institutions under the vertical management of the China MSA.

2. **Ministry of Ecology and Environment**. It undertakes the responsibility for marine environmental protection, delivers guidance, coordination and supervision of the national marine environmental protection work (MEE, 2018). Besides, the local bureaus of ecology and environment are responsible for examining and approving the environmental protection acceptance of the ports in the jurisdiction, which requires the construction of ballast water reception facilities (MEE, 2017).
3. **Ministry of Natural Resources.** It is responsible for monitoring and evaluation of ocean and other natural resources, including of marine ecological early warning and monitoring, disaster prevention, risk assessment and hidden danger detection and treatment (MNR, 2018).
4. **China Inspection and Quarantine**. Article 78 of the Rules for implementing Frontier Health and Quarantine Law (2016) requires that ballast water from an epidemic area must be discharged after disinfection by the inspection and quarantine department. After the ship arrives at the port, it needs to go through the quarantine formalities with the inspection and quarantine department first.
5. **Department of Equipment Industry, Ministry of Industry and Information Technology.** According to Section 1 (4) of the Water Pollution Prevention and Control Action Plan, its functions involve the management and technological innovation development of the BWMS manufacturing industry.
6. **China Classification Society**. It is authorized by China MSA to carry out type approval of BWMS as well as inspection and certification of Chinese flag ships (MSA, 2012).

To sum up, the above five departments have different responsibilities in ballast water management. Although China MSA is the central department to implement the ballast water convention, China's ballast water management needs to rely more on the coordination and cooperation between departments. In the next section, the progress in China's management system of ballast water is described.

3.3 Progress of the management system

Before the BWM Convention came into force in China, China has made many preparations to implement the Convention.

1. **Policy research and development**

   From 2005 to 2010, the China MSA developed the "Prospects and Countermeasures Research Report on China's Accession to the BWM Convention". From 2010 to 2012, China MSA launched the "Strategy and Countermeasure of the Implementation of the BWM Convention Research Project", which prepared the "China Ballast Water Convention Research and Implementation Work Plan" (Hebei MSA, 2015). In 2015, China MSA carried out research on the BWM Convention D-2 performance standard and conducted a comprehensive survey on the progress of stakeholders in the whole shipping industry (Fei, 2015).

   In 2017, Hebei MSA, appointed by the China MSA, specifically undertook the compliance tracking and research work of the BWM Convention and established the BWM Convention Research Studio (Zhang & Zhu, 2019). Hebei MSA has thus researched the norms and standards of the BWM Convention, PSC inspection, ballast water sampling and testing technology. Also, the “Technical Requirements for Sampling and Testing of Ballast Water” and “Technical Requirements for Port Reception Facilities for Ships’ Ballast Tank Sediments” are being developed (MOT, 2018). In addition, in accordance with the requirements of IMO Resolution MEPC.291 (71), China MSA commissioned Dalian Maritime University to carry out on-site inspection, sampling testing, laboratory testing and data collection of ballast water management during the Experience-Building Phase running from August 1, 2019 solstice to December 1, 2021 (“Measures”, 2019).

2. **In the field of ecology**

In 2010, China established the China Invasive Alien Species Database, covering animals, plants, and microorganisms (Xian, Chen, Zhao & Wan, 2013). So far, the Ministry of Ecology and Environment has released a total of four batches of "China's Natural Ecosystems of Invasive Alien Species List" (MEE, 2017). There are monitoring and research institutes in the coastal provinces of China concerned with biological invasion (Fei & Zhu, 2018). Moreover, China began to carry out ballast water biology surveys in 1980. At present, 27 studies of ballast water biology have been carried out in 19 ports in China (Wu et al., 2017).

3. **Type of approval for Ballast Water Management System (BWMS)**

In 2012, China MSA promulgated the “Interim Provisions on the Application of Ships' Ballast Water Management System”, which clearly defined the BWMS declaration process and standardized the type approval work of China's BWMS (MSA, 2012). In the same year, CSS compiled the Guidance for Type Approval of BWMS (2012), which was revised into the 2017 version following the revised G8 guidelines in 2017 (CSS, 2017).

4. **Port State Control (PSC)**

As a member of the Tokyo MOU, after the BMW Convention entered into force in China, the relevant requirements of the BWM Convention and its guidelines become the primary basis for the PSC inspection (CSS, 2018). On January 22, 2019, the Hebei MSA carried out the first national BWM Convention PSC. The PSC officers inspected the ship's certificates, instruments, BWMS, and crew's operational capabilities, and carried out the ballast water sampling and testing (Zhang & Zhu, 2019). Additionally, since January 22, 2019, Shanghai MSA has commissioned Shanghai Ocean University Ballast Water Testing Laboratory to test nearly 50 ships entering ports. Shenzhen MSA has received pre-discharge reports from several ships and conducted ballast water sampling and testing on some of them (Li, 2019).

5. **The publicity of the BWM Convention**

China Classification Society has issued and revised the "Guidelines for the Preparation of Ship Ballast Water Management Plan", "Guidelines for Shipborne Ballast Water Management Inspection and Certification", "Guidelines for Type Approval of Ship Ballast Water Management System". It also set up the BWM Convention implementation external service team to provide personalized service and relevant training for ships (Wang & Zhang，2017). In addition, the BWM Convention Research Studio has compiled and published three books on ballast water and filmed the first publicity video of the BWM Convention in China (Hebei MSA, 2018).

6. **International cooperation**

From 2000 to 2004, China participated in the first phase of the GloBallast project as one of the six pilot countries. As an experimental base, Dalian carried out education popularization, risk assessment, port biological investigation, personnel training. It has accumulated valuable experience for ballast water control and management in China (Li, 2013). Also, China has actively participated in international negotiations, participated in IMO conferences, and submitted more than ten proposals to MEPC (Hebei MSA, 2015). Moreover, China has also organized and participated in the China-ASEAN Maritime Consultation Mechanism (GOV, 2013), China-South Korea bilateral ballast water exemption project (IMO,2019), and China-Denmark ballast water management seminar and other international corporations (Hebei MSA, 2018).

The above is a summary of the progress of China's system of ballast water management. Next, an introduction will be given in terms of the development of China's science and technology.

3.4 Technology development

1. **Ballast Water Management System (BWMS)**

   So far, China's ballast water management technology goes hand in hand with other advanced manufacturers in the world and steadily advances in global competition (Liu et al., 2019). As of January 2019, MSA has approved 17 Ballast Water Management Systems in China. Four of them that make use of active substances have obtained the basic approval of IMO, and two have obtained the final approval (IMO, 2019). Besides, two Ballast Water Management Systems from two companies have received type approval from the USCG (USCG, 2019).

2. **Ballast water testing laboratory**

   At present, there are a limited number of laboratories engaged in ballast water detection and research in China (Li, 2019). Among them, the most representative is the Shanghai Ocean University ships' ballast water testing laboratory. It has been approved by the USCG (SHOU, 2019). Besides, China is building the first national ballast water testing center. It will become the first ballast water and sediment testing center integrating ballast water testing, scientific research, training and prediction (Hebei MSA, 2018).

3. **Ballast water rapid testing equipment**

   In 2007, China MSA carried out an engineering feasibility study on the procurement of ballast water rapid testing equipment (Hebei MSA, 2018). Besides, China successfully developed the first hand-held ballast water rapid detection equipment with completely independent intellectual property rights, which broke the technical monopoly and technical barriers in related fields (COSCO Shipping, 2019).

This chapter reviewed the current status of ballast water management in China. The next chapter will focus on analyzing the challenges of implementing the BWM convention in China from the perspectives of legislation, management, and technology.

Chapter 4 The challenges in implementing the BWM Convention in China

China's ballast water management is booming with the entry into force of the BWM Convention in China. However, In the early stage of the implementation of the BWM Convention, there are still many problems to be explored and improved. This chapter will elaborate on the challenges of legislation, management system, and technology, respectively.

4.1 Legislation perspective

China's legislation relative to the prevention and control of the invasive aquatic species from ballast water started relatively late, and there are various degrees of defects in the legal system, legal responsibility system and public participation system. The discussion below will focus on these three aspects.

4.1.1 The legal system

Judging from the current legislative situation in China, the legal system for ships' ballast water management is not perfect. As one of the countries in the world that suffered the most from invasive aquatic species, the issue has taken great significance in recent years. This being said, domestic legislation on marine ecological invasion has lagged behind. The existing legal system seems insufficient to comprehensively address the problem (Yu, 2014).

4.1.1.1 Lack of specific legislation to prevent biological invasion

First of all, the imperfection of the legislative system is reflected in the imprecise legislative purpose. The invasion of alien species has been considered as one of the five major threats to marine ecosystem functions and biodiversity (Hewitt & Campbell, 2007). The invasion of alien species is not a traditional problem of marine pollution, but rather a biosecurity issue, and constitutes a harm to the status of marine ecosystems, marine organisms' survival and human health (Bai, 2012). Therefore, the core of ballast water management should first recognize that invasive aquatic species are biological pollutants, which are different from traditional pollutants. Their harm to biosecurity and biodiversity will far outweigh the long-term impact of being classified as ordinary waste pollutants (Cohen & Foster, 2000; Zhang et al., 2009). To this end, the relevant legislation should take the protection of the ecological environment and marine biodiversity as the legislative purpose of preventing the invasive aquatic species (Li, 2013). The lack of specific legislation for biological invasion will restrict the effectiveness of the management and control of invasive aquatic species, thus affecting the protection of marine biodiversity and biosecurity (Xu, 2014).

In comparison, both the United States and Australia, have adopted special laws for biological invasion (See Table 3). Those countries' legislative purposes seek macroscopic biosecurity with a view to solving the problem of invasive aquatic species carried by ballast water. However, so far, China has not established a specific law to prevent the invasion of alien species (Mo, 2017). Even after the BWM Convention came into force in China on January 22, 2019, the China MSA issued the "Measures for the Supervision and Administration of Ships' Ballast Water and Sediment Management (Trial)" (hereinafter referred to as the "Measures") (MSA, 2019). The "Measures" clearly provided for the specific ballast water discharge standards to make up for the gap in the regulations governing ballast water management in China（Liu & Maes, 2011). However, the "Measures" is only based on the implementation of the BWM Convention by specific standards, whose legislative purpose is not at the height of comprehensive prevention and control of invasive alien species.

Table 3

Comparison of legislation on alien biological invasion in the United States, Australia and China

Country	**Legislation on alien biological invasion**
The United States	National Invasive Species Act of 1996
Australia	Biosecurity Act of 2015
China	Does not exist

(Source: Created by author)

Similarly, in addition to the "Measures", other legal provisions concerning ballast water management are only scattered sporadically in several existing laws in China mentioned in Chapter 2. These legal provisions are fragmented, and legislative purposes are not the same (Kuang, 2010). For example, the Marine Environment Protection Law aims to prevent pollution from ships' garbage and sewage, where ballast water is considered a common pollutant. The Frontier Health and Quarantine Law is aimed mainly to prevent the spread of disease caused by ballast water. These laws do not cover the objectives, procedures, and means of preventing the invasive aquatic species. So, it can be seen that China's existing environmental legislation does not take biodiversity conservation as the legislative purpose of preventing the invasive aquatic species. It cannot play a comprehensive role in effectively solving the problem of ballast water (Du & Li, 2013).

In the above analysis, the lack of special legislation on biological invasion is one of the main reasons leading to the imperfection of the legal system of ballast water management in China. Besides, lower-level legislation will be mentioned below as another essential element.

4.1.1.2 Lower hierarchy of legislation

According to the Legislation Law of the People's Republic of China (2015), there are three levels of national legislation as follows:

- National laws adopted by the National People's Congress and its standing committee.
- Administrative regulations adopted by the State Council.
- Local regulations; Departmental rules adopted by the ministries of the State Council.

Besides, the administrative organs may, in accordance with their duties, formulate normative documents. Normative documents are not strictly legislative, but they are universally binding and can be applied repeatedly (Wang, 2010). The "Measures" is a normative document issued by the China MSA, which has a lower legal hierarchy (see Figure 7). Although it is legally binding on relevant departments and industries, however, as a non-legislative document, it cannot directly create rights or obligations and legal consequences independently and cannot create mandatory measures and sanctions (Song & Liu, 2011). Although the relevant legal provisions mentioned above are scattered at various legislative levels, there is a lack of coordination and unity among the provisions. In the absence of a particular law on biological invasion as its superior law, the relevant legal basis is not sufficient, which may easily lead to confusion in law enforcement.

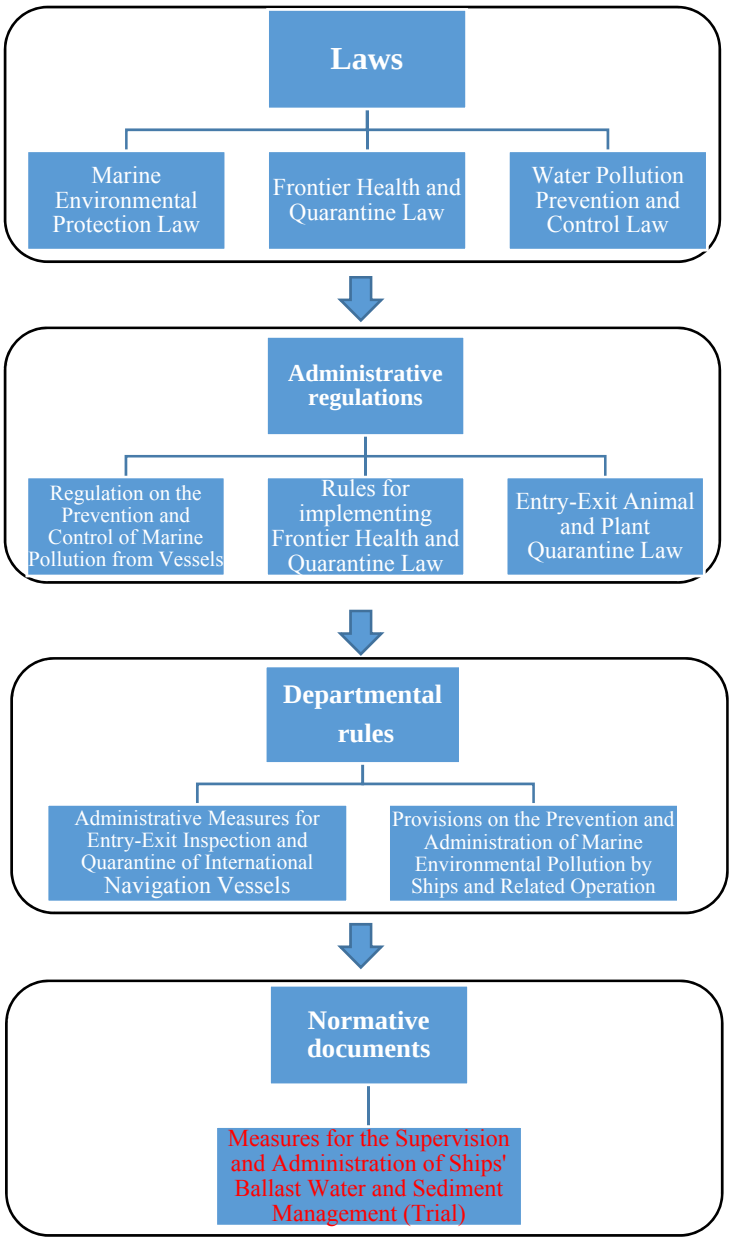

Figure 7. The hierarchy of the Chinese legislation related to ballast water management
(Source: Created by author)

This section analysed the problems existing in the legal system of ballast water management in China. The next subchapter will highlight the problems existing in the legal liability system of ballast water management.

4.1.2 The legal liability system

For centuries, legal systems around the world have recognized the polluter/user-pays principle that those who cause significant and foreseeable harm to others should be held liable for the damage (Percival, 2010). The fundamental purpose of legal liability[3] setting is to punish the offenders, thereby reducing or eliminating illegal acts. However, China's current domestic laws still have defects in the liability system for illegal acts caused by ballast water.

So far, the existing laws in China have rarely directly mentioned the legal liability for the harm caused by ballast water. According to Article 14 of the Administrative Punishment Law (1996), normative documents should not establish administrative penalties. Due to the "Measures" is a normative document meaning that the relevant legal liability provisions can only refer to the superior law.

However, as shown in Appendix 1, the relevant provisions of superior laws are scattered among various laws and regulations, so the relevant legal liability provisions are not uniform. Besides, the violations of the BWM Convention are also complex and diverse; the extent of the damage is also different. Overly broad and decentralized standards may make it difficult for relevant departments to enforce the law. In contrast, Australia has very detailed penalties for violations of ballast water management regulations, which cover the entire process of ballast water management and clearly distinguish different penalties for violations.

In addition, Article 8 (3) of the BWM Convention (2004) provides that the penalties prescribed by the law of the country concerned should be sufficiently severe. Most of the legal liability involved in the violation of ballast water management in China's current laws are an administrative liability, mostly based on fines, and the amount of fines is relevant low. Appendix 1 also shows that the penalties for ballast water management provided by the relevant laws in China are much lighter than that

[3] Legal liability in China includes criminal liability, administrative liability and civil liability.

of the United States and Australia, the deterrent effect of the law would be greatly reduced.

Besides, the damage caused by the invasive alien species is often catastrophic or even irreversible. It is necessary to adopt strict penalties (Bai, 2012). However, the relevant laws in China do not mention criminal liability on this issue. Although Article 338 of the Criminal Law of the People's Republic of China (2017) lists the acts that seriously pollute the environment as a criminal offence as below:

> Whoever discharges or treats wastes, toxic substances or other harmful substances containing pathogens of infectious diseases and thus seriously pollutes the environment shall be sentenced to fixed-term imprisonment of not more than three years or criminal, shall be punished with a fine or a single penalty; if the consequences are especially serious, shall be sentenced to fixed-term imprisonment of not less than three years but not more than seven years and shall also be fined (Chapter 6, translated by author).

However, the definition of pollution as "serious" and "especially severe" in the above provision is vague. The pollution degree caused by invasive aquatic species is difficult to qualitatively measure, resulting in practical implementation difficulties (Li, 2019). Compared with the United States and Australia, both of them specify the criminal liability in the corresponding penalty provisions.

Furthermore, from the perspective of one of the ways to realize legal liability, namely compensation, the existing legal system lacks specifications for ecological compensation. Generally, the legal means to compensate for environmental harm caused by human behavior are mostly through the environmental tort theory in civil law. But this theory has the "innate" deficiency in dealing with the ecological damage caused by invasive alien species (Shen, 2010). The damage caused by ballast water is the result of unintentional introduction, and not easily discovered in a short time. It is

hard to find a specific responsible person. So, it may not be adequately compensated or cannot be compensated at all. Therefore, the traditional legislation and theory of civil compensation can no longer meet the demand for compensation when ecological damage is restored, it must be addressed through new legislation.

In summary, China's current legal liability system for ballast water is not perfect. Although China is currently in the Experience-Building Phase period and ships meeting relevant provisions are exempted from punishment, a complete legal liability system is an essential prerequisite for the implementation of the BWM Convention. In addition, the public participation system is also another weakness of China's legislation system, which will be discussed in the next section.

4.1.3 The public participation system

Public participation as an essential part of the supervision mechanism is still very imperfect in China. Because it is challenging to achieve full control of marine ecological disasters by relying solely on the power of the government, which requires the broad participation of the relevant public (Zhao, 2013). According to Article 2 of the Constitution of the People's Republic of China, 1982 as amended, people manage state affairs, economic and cultural undertakings, and social affairs through various channels and forms in accordance with the law. Article 4 of the Marine Environmental Protection Law (2017) provides that all units and individuals have the obligation and right to report and lodge complaints against units and individuals that pollute and damage the environment. These legal provisions are the basic legal guarantee for the public to supervise environmental protection; however, they are too general and do not clarify the specific forms and procedures for the public to participate and supervise. Thus, the exercise of public participation rights has not yet obtained sufficient legal protection, resulting in the actual difficulty of the public to participate in environmental protection supervision effectively (Canfa, 2006).

Additionally, the lack of awareness of civil rights is a significant factor in hindering public participation. On the one hand, due to the tradition of the history of China's feudal system, coupled with the long-term implementation of the planned

economy at the beginning of the founding of the country, the "government-led" management model has been deeply rooted in the hearts of the people. For a long time, Chinese citizens have fallen into a misunderstanding about the concept of participating in marine environmental protection, namely, “marine environment depends on the government” (Shi, 2013). Therefore, the awareness of Chinese citizens’ rights is generally weak. The public does not understand or care about the fundamental rights and obligations of participating in marine environmental supervision and management. On the other hand, for a long time, there has been a lack of public education on the prevention of invasive aquatic species. So, people do not have a good understanding of its harm, and do not pay enough attention to the protection of the marine environment (Shen, 2011). In particular, ballast water management is highly technical and requires a high level of relevant knowledge. However, the popularization and education of relevant knowledge for the public are not in place at present. In addition to the stakeholders related to ballast water management, most people in China are unfamiliar with ballast water. Due to the lack of environmental awareness and knowledge, the public lack sufficient knowledge and skills to participate in the management of the marine environment (Ge, Bi, & Wang, 2009).

To sum up, in this section, the current legislative problems in China have been evaluated. Next, the management challenges will be analysed and identified.

4.2 Management system perspective

The prevention and control of the invasive aquatic species need not only a unified and coordinated leadership mechanism, but also a complete control and management system (Wan, Chen, & Sperling, 2018). Next, the problems existing in the current management system of ballast water in China will be discussed from these two aspects.

4.2.1 Departmental functions

Although the “Measures” provides that China MSA is the competent authority for the supervision and management of ballast water in compliance with the BMW Convention. However, due to the objective "cross-border" characteristics in the field of marine environment management, diverse competent departments have different demands for division function (Zhang, 2017). In particular, ballast water management is a very complex work, with significant industry attributes and department characteristics, involving many departments in the management system. For example, MSA of the Ministry of Transport is responsible for the supervision and management of ships’ ballast water; after the ballast water is discharged into the sea, it turns to the charge of the Ministry of Natural Resources; in case of epidemic diseases, they should be under the control of the General Administration of Customs; if it causes environmental problems, it should be under the charge of the Ministry of Ecology and Environment; the marine equipment involved belongs to the Ministry of Industry and Information Technology.

Due to different management purposes, each department only pays attention to a particular aspect of ballast water management, and the work focus and information mastery are quite different (Du & li, 2013). The communication between departments cannot be smooth, lacking a comprehensive, complete, and coordinated management model, which is easy to form management crossover or management loopholes. Therefore, decentralized management does not fit well with the overall characteristics of marine ecosystems (Dang, Yin & Sun, 2004). It is challenging to take concerted action to achieve the overall goal of integrated ballast water management.

In addition, China has not set up a special coordination mechanism to manage and control ballast water. The above-mentioned competent departments are only different in the division of management, but no leadership relationship between them. However, there is no comprehensive mechanism to coordinate the work of various departments. MSA has undertaken significant work in the management of ballast water. But due to its limited functions, it is impossible to achieve overall coordination between departments.

In 2018, China carried out the 8th government institutional reform, transferring the responsibility for marine environmental protection undertaken by the former State Oceanic Administration to the Ministry of Ecology and Environment (GOV, 2018), whose purpose is to unify the responsibilities of ecological protection and the responsibilities of marine environmental protection. However, no precise functional arrangement has been made to deal with the invasive aquatic species. Moreover, in 2010, the State Council established the “China National Committee for Biodiversity Conservation (CNCBC)” to coordinate national biodiversity conservation work (CNCBC, n.d.). However, it has not paid enough attention to ballast water management.

The development of a national strategy for responding to alien invasions depends to a large extent on the coordination between the various departments (Tamelander et al., 2010). Therefore, it is necessary to comprehensively coordinate the national management work to prevent invasive alien species by drawing on the United States' "unified and coordinated comprehensive management model".

The above is an analysis of the problems existing in the management mechanism of related departments of ballast water management in China. The next subchapter will give a discussion of the challenges of the management system.

4.2.2 Lack of ballast water risk management system

Ships' ballast water management based on risk management can predict the possible invasion risk through risk assessment and monitoring, and then adopt a series of measures to minimize risks. For the established invasion, emergency measures can be taken to minimize the impact and loss (Zhang, Zhang & Li, 2008). Guidelines for Risk Assessment Under Regulation A-4 of the BWM Convention (G7) provide fundamental principles and general methods for ballast water risk assessment (IMO, 2007), and Guidelines for Additional Measures Regarding Ballast Water Management Including Emergency Situations (G13) provide risk assessment methods and implementation procedures for introducing additional measures for ballast water management, including emergency situations (IMO, 2007).

The following will respectively discuss the shortcomings of China's risk management from three aspects of risk assessment, monitoring and early warning, and emergency management.

4.2.2.1 Risk Assessment

Recent studies have shown that prevention is a management policy with the most significant net benefits in the term in preventing biological invasion (Wu, Chen, Wang, Lin, & Xue, 2017; Lodge et al., 2016). The risk assessment not only provide scientific decision-making reference for countries to formulate mutual exemption agreements for ballast water discharge, but also prevent the possible invasion hazards in advance and take targeted measures (David et al., 2015).

So far, in addition to the risk assessment based on mutual exemption agreement with South Korea, China has not fully carried out the risk assessment of ballast water management (Zhang, personal communication, August 02, 2019)[4]. At present, the initial assessment of potential risks is mainly based on ballast water reporting system and PSC inspection. In particular, as one of the risk assessment methods, ballast water sampling and testing still have challenges in the practice, which will be discussed in Chapter 4.3.2.

China started relatively late on the study of risk assessment of invasive alien species caused by ballast water (Li et al., 2019). The relevant research is not mature and has not been fully applied in practice. Besides, current studies lack a comprehensive and systematic understanding of the invasion mechanism and impact of alien species (Xiong et al., 2017). Most of the current ballast water risk assessment methods only focus on the analysis in the field of ecology. Less attention is paid to the source of ballast water in the field of marine traffic, such as the volume of discharge, location, time. The risk assessment mechanism for loading, carrying, and discharge of HAOP has not been established (Li & Huang, 2018).

[4] The information given by Zhang C.C. is also to be found at (Li, Wen, Tian & Zhang, 2018; Zhang, Zhang, Li, Du & Tian, 2018).

Moreover, risk assessment requires a large amount of basic data, including marine environmental parameters, species information, trade characteristics, ballast water loading and discharge times and port information (Zhang, Wang & Zhang, 2009). However, the systematic and continuous investigation of marine organisms in different parts of China has been problematic for a long time, making it difficult to verify the origin of the majority of the species recorded in China's sea areas (Yang et al., 2011). Although a database of alien species has been initially established in China, however, there is still no comprehensive information service platform for marine risk management (Xu et al., 2015). Problems such as inconsistent data, unshared information, and lack of authority make these databases not play a full role.

In this regard, China still has a gap compared with developed countries such as the United States and Australia. These two countries have established the integrated information system of risk management with a high degree of informatization, which combines with the ballast water reporting system to conduct data collection and risk assessment of ships arriving at the ports. However, although there is a "Comprehensive Services Platform of China MSA" is used for collecting ballast water reports, apart from being used for collecting data, the platform does not be used for integrating, analyzing and using data.

4.2.2.2 Monitoring and early warning

Article 6(1) of the BWM Convention (2004) provides that the competent authorities of each contracting state shall monitor the effectiveness of ballast water management in waters under its jurisdiction. The invasion of marine organisms has a process from quantitative change to qualitative change. In order to understand the invasion status, it is necessary to establish a specific dynamic tracking and monitoring of alien marine species and focus on monitoring and controlling the discharge and disposal of ballast water from ships in ports (Liu, Wu & Xue, 2013). Also, establish an early warning system to provide decision-making for relevant component authorities (Wang et al., 2014).

However, China's marine ecosystem has various types and complex environment, so it is relatively difficult to monitor the invasion of alien species (Li et al., 2019). There is less attention has been paid to forecasting, monitoring, and early control of invasive aquatic species, as well as a lack of necessary data and management system (Liu et al., 2013). At present, a preliminary offshore marine monitoring network has been formed in China's coastal areas. However, the central monitoring objects are red tide, offshore oil spill, and other marine environmental risks (Xu et al., 2015). Invasive species along China's coastline have not been adequately studied and monitored (Wan, Chen, & Sperling, 2018).

4.2.2.3 Emergency management

In recent years, in the general sense of "emergency management", people are most concerned about the safety of people and ships, oil and chemicals and other toxic and harmful substances leakage and other issues in China. However, the impact of ships' ballast water on the marine environment is often ignored (Zhang, Wang & Zhang, 2009). At present, there is no regulations on marine biological invasion emergency management in China. Although within the overall framework of the Marine Environmental Protection Law and the Emergency Response Act, the State Council has issued the National Emergency Plan for Environmental Emergencies. However, existing regulations generally make relevant provisions for oil spills or chemical spills. In practical, ballast water disposal is rarely used as a single emergency objective but is usually combined with emergency responses to above marine accidents (Zhang, 2009). There is no specific emergency management system for marine biological invasion caused by ballast water (Pang, Liu & Zhu, 2015).

Besides, the emergency management of marine species invasion often requires the close cooperation of different departments. Due to the lack of unified emergency management coordination and command mechanism in various government departments in China for a long time, it is difficult for cross-government administrative departments to interact. A complete emergency rescue system for dealing with sudden marine environmental incidents has not been formed yet (Yang, 2010).

Furthermore, the research on the emergency management of marine biological invasion is still an emerging topic in China, there are few pieces of research on the emergency response mechanism and rapid response system when invasive species are discovered (Pang et al., 2015). By contrast, Australia has a relatively mature approach in dealing with marine alien invasion emergencies. It has developed a perfect and operable emergency management plan, a strict identification standard for marine biological invasion emergencies, a hierarchical emergency response organization framework, and emergency response programs are rigorously designed (Zhang, 2012).

In summary, after the analysis of the challenges faced by China in establishing a risk management system for ballast water management, the challenges of technology are also issuing to be faced in the implementation process, which will be discussed in the next section.

4.3 Technology perspective

Up to now, there is still no fully mature ballast water biological control and detection technology, which makes the implementation of the BWM Convention more difficult. Therefore, how to overcome the adverse impact of technical barriers in ballast water management process will be the challenge that must be faced in the implementation of the BWM Convention.

4.3.1 Basic research

The marine alien invasion caused by ballast water involves navigation technology, environmental science, marine ecology, physics, chemistry and other scientific fields (Shen, 2010). It is challenging to study and requires higher scientific research level. However, China's basic research on the invasion of alien organisms caused by ballast water started late and has a weak foundation. Compared with the United States, Australia, and other developed countries, China's research investment in ballast water is far from enough. At present, only a few universities and research institutes in China have researched ballast water management technology and policy,

with a total investment of less than 10 million yuan (USD1,411,700)[5] (Chen, 2017). Although some research results have been obtained, there is still a lack of practical application for these studies, and the data obtained are not systematically sorted out.

Furthermore, the research field of ballast water needs a large number of related professionals. Some scientific difficulties are still pending, which need more researchers to explore, research, and solve. China has relatively few scientific and technical personnel in the field of ballast water management, and its training is still in the initial stage (Heibei MSA, 2018). Therefore, it is necessary to accelerate the construction of ballast water research team to meet the future demand.

As analysed above, the late start of basic research, insufficient investment and lack of talents will make China passive in the implementation process. In the next subchapter, the ballast water sampling and testing technology is taken as an example to illustrate the challenges of technology faced by PSC inspection in China.

4.3.2 Ballast water sampling and testing in PSC inspection

According to Article 9 of the BWM Convention (2004), the Port State Control Officer (PSCO) should have the right to determine the ship's compliance of the BWM Convention through inspection certificates and Ballast Water Record Book and may take samples of ballast water during the inspection. In 2014, MEPC adopted the Guidelines for Port State Control (PSC) Under the BMW Convention by MEPC.252(67), which provides a four-step inspection method (see Figure 8) (IMO, 2014). Ballast water sampling is an indispensable step in the risk assessment of ballast water (Xu, Fu & Wu, 2016).

[5] Currency conversion as per Forex rates on September 18, 2019 (https://www.forex.com/en-uk/support/currency-converter/) ,1 RMB = 0.14117 USD

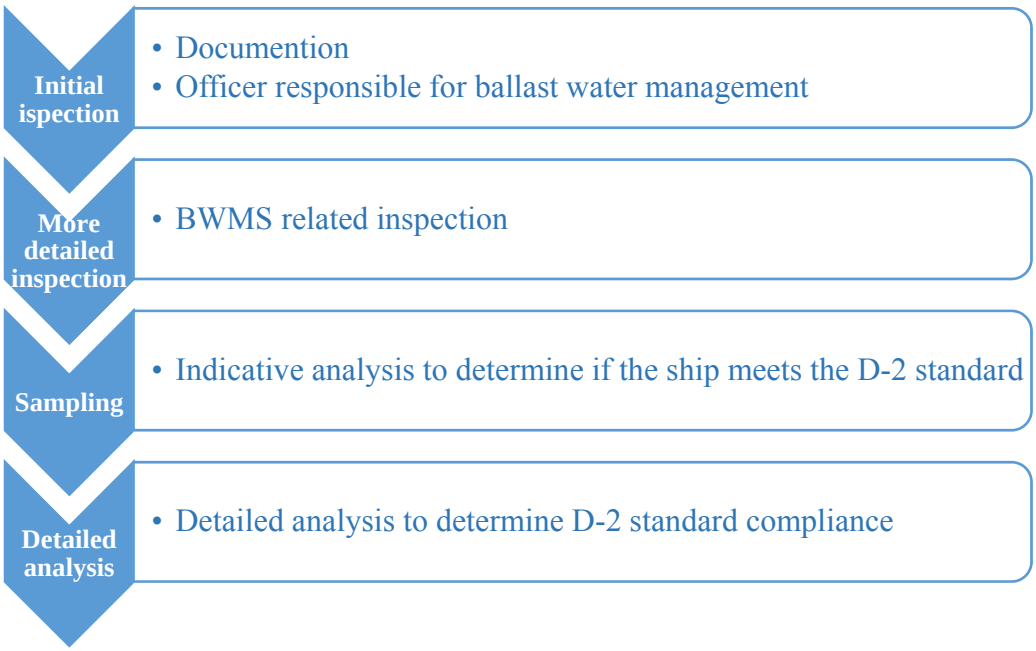

Figure 8. Diagram of Four-Step PSC inspection method
(Source: based on the IMO Resolution MEPC.252 (67), 2014)

When conducting PSC inspection, law enforcement authorities require fast, accurate and efficient ballast water biological testing technology support to avoid improper delay of ships (Liu, el at., 2018). However, so far, there is no standardized, reliable, and universally applicable sampling method (Yu, 2018). The selection of ballast water sampling points, determination of sampling principles, and index analysis methods have become the main problems faced by PSCO. First of all, different sampling and analysis methods are used in the BWMS type approval test and the ballast water sampling in the PSC inspection, which may lead to different conclusions (Fei, 2014). In other words, although the shipowner installed the BWMS with type approval certificate, the sampling inspection of PSC may be unqualified due to the differences in testing methods. Secondly, whether the ballast water sampled is representative is another problem. Different sampling methods may have different influences. Even same method is used, different detection results will be generated due to the differences in sampling points (Xu, Fu & Wu, 2016). Thirdly, studies have shown that a sample size of $1m^3$ is the best choice for PSC inspection, however, sampling a sample size of $1m^3$ takes at least 30 minutes (Hernandez et al., 2017). How

to carry such a large sample and reasonably arrange inspection time are also problems faced by PSCO.

China is also facing the above technical problems. At present, China's ballast water sampling and testing standards and procedures are in the process of being developed. The competent authorities are still studying the appropriate methods to determine whether the test is in compliance (Zhang, personal communication, August 16, 2019). Although IMO Guidelines for Ballast Water Sampling (G2) provide macro guidance for sampling work (IMO, 2008), its operability is not good, and there are still many improvements to be made (Kong et al., 2018). Therefore, in the absence of uniform standards, the sampling and testing of ballast water still faces many difficulties in practical application.

Moreover, the professional quality of PSCO directly determines the quality of law enforcement (Yu, 2018). So far, China's PSC inspection is still in the stage of testing and collecting information during the Experience-Building Phase, PSCO's related technical experiences are limited. Although China has conducted training on PSC inspection procedures and skills of the BWM Convention many times (Liu, Sun & Li, 2019). However, due to the high technical level of ballast water PSC inspection, involving a large number of complex technical principles and practical operations, the technical level of PSCO should be continuously enhanced.

In addition to ballast water sampling and testing, which are the significant technical challenges facing in China, BWMS, which will be discussed in the next section, is also a globally recognized technical challenge.

4.3.3 Industry concerns from Ballast Water Management System

This year (2019), is not only the time that the BWM Convention came into force in China, according to IMO Resolution MEPC.297 (72), this year also marks the end of the two-year buffer period for the BWMS mandatory installation (IMO, 2018). Data shows that by the end of 2018, 7.1 percent of the existing ships in the world had completed the installation of BWMS, and 92.9 percent of the ships were to be installed. From 2019 to 2024, about 30,000 existing ships will need to complete the installation

of BWMS (Guo, 2019). Thus, shipowners, shipyards, and BWMS manufacturers are facing opportunities and challenges.

4.3.3.1 For shipowners

BWMS is currently the primary means of carrying out ballast water management to meet D-2 standards (Qu, Xie & Chang, 2018). With the progress of biological control technology and the gradual maturity of supporting industries, 42 types of BWMS using active substances have been finally approved by IMO, and the competent authorities have approved 73 types of BMWS in various countries (IMO, 2017). However, in the process of use and installation of BWMS, shipowners, as major users, have encountered various risks and challenges (Zhong, 2017).

First of all, in order to fully implement the requirements of the BWM Convention, shipowners must invest a large amount of money to reconstruct and install BWMS, including equipment investment, alteration fees, dock repair fees, time loss. It is estimated that a 150,000-ton tanker refit with BWMS would cost about 8.5 million yuan (USD1,199,945)[6] in total (Yuan, Mao & Dang, 2017). Moreover, the operation and maintenance cost of some systems is even higher than the initial installation cost (King, Hagan, Riggio, & Wright, 2012). Under the current sluggish shipping situation, the new high cost will put a lot of pressure on the operation of shipowners. Therefore, some shipowners may delay the implementation or fail to comply with the BWM Convention, which will have a negative impact on the implementation of the Convention.

So far, there is not a single treatment technology in the existing BMWS that can be applied to all ships (Diasamidze & Shotadze, 2019). How to choose a proper BMWS is a very complicated problem, which is closely related to the shipping route, ship type, and the characteristics of BMWS (Wang et al., 2014). Moreover, the BMWS is in the research and development stage, and the practical application experience is not mature (Yuan, Mao & Dang, 2017). How to choose the system with the highest

[6] Currency conversion as per Forex rates on September 18, 2019 (https://www.forex.com/en-uk/support/currency-converter/) ,1 RMB = 0.14117 USD

safety performance and the best processing efficiency for the ship is a difficult problem for shipowners (Kong, el at., 2018). Further, the choice is made more difficult by the conflict between the requirements of the BWM Convention and those of the United States (Li, 2016).

In addition, the BMW Convention has relatively high technical and professional requirements for the implementation of the relevant provisions. It is necessary to provide specialized training in operation and knowledge for the seafarers. However, the training of ballast water treatment professional crews lacks the necessary professional training institutions, and the high training and personnel costs will make shipping companies discouraged (Zhong, 2017). In the absence of the adequate and professional crew, the full implementation of the Convention is a big challenge to shipowners.

4.3.3.2 For shipyards

According to the "Review of Maritime Transport 2018" published by the United Nations Conference on Trade and Development (UNCTAD), China has the largest number of ships in the world. It has 5512 Chinese flag merchant ships with a gross tonnage of more than 1,000 tons. (UNCTAD, 2018). On the one hand, the implementation of the BWM Convention will stimulate the growth of the shipbuilding business (Fang, 2018). On the other hand, the shortage of docks expected to be used for ship repair and modification will continue to exist in the next few years (Sun & Chen, 2018).

In addition, BMWS will have a considerable impact on ship construction. The volume of BWMS will have a significant impact on ships, which may bring safety risks to ships (Zhou el at., 2011). The modification of BWMS is different from the previous modification project, and the technical principle or structural arrangement adopted by different types of BMWS is different. It requires shipbuilders to have stronger technical capacity (Zhong, 2017). Besides, ballast water and sediment that needs to be treated during the ship repair process should also be discharged to shore

reception facilities and meet relevant discharge requirements (Hebei MSA, 2015). These are the problems that shipyards have to face.

4.3.3.3 For BWMS manufacturers

The entry into force of the BWM Convention will stimulate the demand for BWMS. According to statistics, the global market size of BWMS in 2016 is USD6.81 billion, which will reach USD26.71 billion by 2021. In the future, there will be about 32,000 existing ships in the world with BMWS for additional installation (Fan & Li, 2017). The high demand will have a great impact on the BMWS price, equipment supply chain, and BWMS installation plan. Since the large fleet size of China has created a vast BMWS market, many foreign BMWS manufacturers aim at the huge market potential of China and actively enter the Chinese market (Wang & Lu, 2012). The fierce competition will test the comprehensive capabilities of domestic manufacturers.

High requirements, difficulties, complex procedures, and stringent standards make the development of BWMS very difficult. At present, in terms of quantity, China's BWMS manufacturers have certain advantages. However, from the perspective of technical level, most of the equipment core components produced by Chinese manufacturers rely on imported accessories, with less independent research and development, and fewer manufacturers that can establish a global service network (Li, 2016). Moreover, BWMS technology is also updated continuously, once the update of a higher technical threshold, so China's BWMS manufacturers will face significant pressure.

Moreover, in the early years after the adoption of the Convention, the high cost of BWMS attracted substantial investment. However, after several years of development, various BMWS manufacturers have improved their production capacity, and the price of BMWS is also decreasing. The emergence of domestic BMWS has played a particular role in reducing the equipment price of other foreign manufacturers (Fei, 2014). Further, due to the delayed implementation of the D-2 standard, it is difficult for BMWS manufacturers to recover the costs in time. Some manufacturers

may face the risk of capital chain breakage (Chang & Liu, 2019). It can be said that the market space of BMWS in China is not optimistic, which has put forward the request to the competent departments to exert the BWMS market supervision responsibility.

In this chapter, China's main challenges in the implementation of the BWM Convention are analysed from the perspectives of legislation, management system, and technological development. In Chapter 5, the recommendations will be put forward.

Chapter 5 Recommendations

Ballast water management is still an emerging topic in China, the implementation of the BWM Convention relies on the close cooperation and effective cohesion of stakeholders such as the competent authority, shipowners, shipbuilders, and Ballast Water Management System (BWMS) manufacturers (Tian, el at., 2019). This chapter will make recommendations on the challenges in the implementation of the BMW Convention.

5.1 Improving the legal system

Laws and regulations are the basis of administration (Xu, 2016). The management of preventing and controlling invasive alien species must be improved at the legislative level as the first step.

5.1.1 Specialized legislation

As has been discussed in Chapter 4.1.1, China still lacks special legislation on prevent the invasive aquatic species. Although the introduction or modification of laws usually requires a complicated process and a long cycle (Kuang, 2010). In the long run, there is still an urgent need to develop a special law to extend the scope of China's existing legal system.

Before enacting the specific legislation, some legislative purpose needs to be changed first. China should upgrade the legislative purpose from the traditional environmental protection concept to a higher level of protecting ecological security and biodiversity. Only by taking the protection of ecological value as the goal of legislation to prevent and control invasive aquatic species is when this problem can

fundamentally be controlled and solved. Under this legislation purpose, through the formulation of the special law to clarify the legal principles, legal system and legal liability.

In this respect, the legislative systems of the United States and Australia are worthy of China's reference and learning. Special legislation on prevention and control of invasive alien species should be taken as the superior law to provide a comprehensive legal framework for ballast water management. Specific regulations on ballast water management may be written into the special legislation or in a separate legal form. In this way, the legal countermeasures and measures for comprehensive prevention and control of alien marine invasion will be improved.

5.1.2 Legal liability system

In order to comprehensively construct legal liability system for the prevention and control of invasive aquatic species, the legal liability needs to be further unified and clarified in the legislation. It is necessary to improve the administrative liability, criminal liability, and civil liability, respectively.

5.1.2.1 Administrative liability

As mentioned in Chapter 5.1.2, the description of legal liability in the current law is too general and scattered, which is difficult to conduct quantitative implementation. It is suggested to refine the administrative liability standards further. The administrative liability should clearly distinguish the measures and standards of different illegal violations, which will help law enforcement departments better perform their duties. In this regard, Australia has very detailed provisions on the penalty of violation of ballast water management, which is worth referencing. Besides, for the person who violates ballast water management, in addition to the conventional administrative punishment measures, the illegal cost can be increased through substantially increasing the amount of the fine.

Moreover, the administrative liability subjects should also include the civil servants of the competent authority who break the law. The civil servants who fail to perform their statutory duties in the administrative management of ballast water shall be given administrative penalties and sanctions.

5.1.2.2 Criminal liability

Due to the lack of specific quantitative standards for the degree of the marine environmental harm by invasive aquatic species, it is necessary to further clarify the criminal liability for ballast water management violations in relevant laws, so that the Criminal Law of China can be better applied. In this regard, the legislation of Australia provides a reference. Australia has made specific provisions on the "Strict liability offence" in the Biosecurity Act 2015, and corresponding provisions of the Criminal Law.

5.1.2.3 Civil liability

Due to the traditional civil compensation legislation has been difficult to apply to the ecological harm caused by the invasive alien species, it is necessary to supplement the relevant liability investigation and civil compensation mechanism in civil compensation legislation. When the risk of damage to the ecological environment is irreversible, the enterprise or individual causing the risk shall bear civil liability for the potential ecological damage (Bai, 2012). To this end, it is necessary to investigate the civil liability of the person responsible for potential environmental harm caused by the violation of the ballast water management regulations. The specific civil liability and compensation mode should be clarified, and the responsible person and relevant impact should be identified as early as possible in combination with the risk prevention and control emergency response mechanism. In addition, the compensation standards should be raised according to the degree of ecological environment harm and management costs.

5.1.3 Public participation system

In order to further improve the public participation system, it is necessary to legalize and institutionalize public participation to ensure its operability.

On the one hand, it is necessary to improve relevant legislation, which is the legal guarantee for public participation. Under the general framework of the constitution and relevant laws, the obligations and rights, and the ways and procedures involved in the public participation in the prevention and control of invasive aquatic species should be clarified clearly in the relevant legislation. Thereby, a smooth channel for public participation will be provided, enabling the public to achieve the right of participation and supervision.

On the other hand, it is necessary to strengthen publicity and education to raise public awareness of marine environmental protection. Popularizing and publicizing marine knowledge and enhancing people's awareness of marine protection are necessary conditions for guiding the public to participate in marine ecological management (Zhao, 2013). Through TV, newspaper, Internet and other media, the basic knowledge and prevention measures of ballast water should be publicized to the public, making the public realize the obligation and responsibility of protecting the marine ecological environment. In addition, the government can establish an online communication platform in response to public participation to improve the transparency of relevant information disclosure, public participation opinions and feedback, and implementation of decisions (Jin, Zeng & Zhao, 2011). Expanding public access to relevant information and establish a supervision and reporting mechanism to play the role of public supervision effectively are essential factors, to promote better implementation of the BMW Convention.

The above are some suggestions for improving the legal system of ballast water management. The next section will give some advices on the management system.

5.2 Enhancing management system

The effective implementation of the BWM Convention depends on the construction of a complete management system. In this section, recommendations will be made on the challenges mentioned in Chapter 4.2.

5.2.1 Establishing a National Ballast Water Management Office

In order to avoid overlapping powers and gaps in management between departments, it is necessary to establish a National Ballast Water Management Office (NBWMO) to unify the leadership and coordination of the national ballast water prevention and control work.

According to the current status of ballast water management in China and combined with the experience of the GloBallast program, the NBWMO should be composed of the China MSA of the Ministry of Transport, the Marine Ecological Environment Department of the Ministry of Ecology and Environment, the Marine Early Warning and Monitoring Department of the Ministry of Natural Resources, the China Inspection and Quarantine of the General Administration of Customs, the Equipment Industry Department of the Ministry of Industry and Information Technology.

The NBWMO should have an advisory and guidance function to guide and supervise the national ballast water management and provide a platform for cooperation and coordination among various departments. Its main responsibilities should include:

- The formulation, revision and implementation of the National Ballast Water Management Strategic Plan, identifying the phased objectives, specific action plans and steps and practical safeguards;
- Integration of the responsibilities and management resources of relevant departments, optimizing the allocation of resources;
- Regular evaluation of the effectiveness and implementation of ballast water management and technical standards;

- Establishment of a marine biological invasion management information sharing platform (Tang & Su, 2015), to achieve real-time sharing of cross-departmental resources and information.
- Establishment of a guarantee system for scientific research funds (Du & Li, 2013), to organize experts and scientific research institutions to carry out scientific research, and promote the transformation of scientific achievements into practical applications;
- Promotion of the training, education and publicity of information and knowledge related to invasive aquatic species;
- Coordination of the functions of various departments and conduction of emergency management, in the event of an emergency incident of ballast water.

5.2.2 Developing a whole-process management system

In order to strengthen ballast water management, it is necessary to implement the whole-process control and management system including "risk assessment, early monitoring and warning, and emergency response management" according to the invasion route and invasion mechanism of marine organisms.

In this regard, firstly, it is necessary to carry out scientific ballast water ecological risk assessment classification for China's coastal waters, establish the relevant invasive species database for port waters, and establish the risk assessment index system. In addition, through identifying the risk factors of ballast water, a reasonable model to measure the ballast water risk should be established (Liu, Hu & Song, 2007). Additionally, other steps to quantify the possible impact of ballast water on the ecological environment, measures, and take actions to reduce risks accordingly.

Furthermore, the sooner invasive species are discovered, the better chance there is of containing and eliminating them (Du & Li, 2013). Through the construction of ballast water marine biological monitoring network system, the ballast water is classified and monitored, and the ship from the infected area or high-risk area is mainly tracked (Li & Huang, 2018). Based on the database of marine alien invasive

organisms, an early warning and decision system for alien marine organisms should be constructed. According to the results of the monitoring and risk assessment system analysis, the system should be combined with functional departments and expert opinions to make early warning decisions.

In terms of emergency management, there are usually two situations. One is that after the warning mechanism indicates that there is a high risk of ballast water, effective measures should be taken quickly to avoid the ship discharging high-risk ballast water. Another is for invasive species, scientific and valid removal measures should be taken to control the situation and minimize the harm, including chemical, physical, biological, mechanical and other control technologies (Hu el at., 2003). In order to achieve the above objectives, the emergency management mechanism of ballast water should be established as soon as possible, and the relevant emergency response plan should be drawn up (Zhang, 2012). Thus, the guiding principles and action guidelines of marine biological invasion emergency response work can be determined.

Moreover, the NBWMO should assume the leading function of emergency mechanism, coordinating all departments to make an emergency response. In practice, the existing "oil spill emergency response team" is responsible for the current emergency disposal of ships' ballast water (Zhang, el at., 2009). Because of the complexity of ballast water management, it is necessary to popularize and train the emergency team to master the methods of proper disposal of ship ballast water in an emergency. Besides, it is suggested to set up an expert team to provide technical support for ballast water emergency management.

After making some suggestions on the improvement of legislation and management system, how to strengthen the basic capacity building of China to implement the BWM Convention will be discussed in Section 5.3.

5.3 Strengthening the basic capacity

Ballast water management involves a wide range of subjects and requires high technical level. Therefore, in order to improve the efficiency of ballast water management and better implement the BWM Convention, the basic capacity building should not be ignored.

5.3.1 Support towards science and technology

The establishment of an efficient ballast water management system is inseparable from scientific guidance and technical support. The basic research of ballast water in China started late, so it needs the support of the theory, data, and technology.

The first action is to increase financial support for scientific research and technology research and development in the field of invasive aquatic species and ballast water, especially a special fund, should be established. Specific measures should be taken to encourage scientific research, to keep pace with international developments, and to broaden the scope and depth of scientific research, especially in the areas of ballast water risk assessment, monitoring and early warning, ballast water sampling and testing and other technical difficulties. Further, the expansion of ballast water testing laboratories should be accelerated. Based on existing laboratories, at least one testing laboratory with sufficient testing capacity should be authorized in each local jurisdiction (Yu, 2018).

In addition, China's marine biodiversity survey should be fully carried out. The NBWMO should develop a detailed biodiversity survey and research plan. On the basis of the original biological survey results, the survey of the status of every port area in China should be completed by regions and step by step. In this manner, an authoritative marine biological invasion database can be established. On this basis, a unified information sharing platform for marine alien species should be established by using big data technology to realize resource integration and data sharing, which can

provide data basis for ballast water risk assessment and designated ballast water exchange areas in various countries (Du, Qian & Guo, 2009).

5.3.2 Education and personnel training

At present, many organizations and individuals in China lack adequate understanding of marine ecological harm caused by ballast water (Xu et al., 2006). In addition to strengthening publicity and education to improve the public's awareness, key and targeted education and training should be provided to practitioners engaged in the shipping industry.

Most importantly, the quality of Port State Control Officers (PSCO) should be further enhanced. PSCO should actively explore the feasibility of further promoting PSC inspection, and study how to take samples appropriately based on the actual situation, to achieve a balance between sample representativeness and sampling efficiency (Yu, 2018).

Moreover, Article B-6 of the BWM Convention (2004) provides that senior and ordinary seafarers should be familiar with the specific duties of their ships in carrying out ballast water management, and with the Ballast Water Management Plan corresponding to their duties. The "Measures" also requires that ballast water management methods should be included in the safety management system. Shipowners should organize crew to study the BMW Convention and relevant guidelines and clarify relevant requirements. Shipping companies that have identified or installed BMWS should train the crew as soon as possible under the guidance of the manufacturer to master the use and maintenance methods.

In addition, emphasis should be placed on the cultivation and selection of scientific research personnel. To this end, the government authorities, industrial enterprises, and scientific research institutions should increase investment to train a group of professional talents proficient in ballast water management knowledge and research skills. For example, by increasing the setting of relevant specializations in colleges and universities, to inject continuous driving force into the cultivation of scientific research talents.

5.3.3. Providing support and guidance for industries

Due to the entry into force of the BWM Convention has great impacts on shipping industry, shipbuilding industry and BWMS manufacturing, the Chinese government should give adequate support and guidance to stakeholders.

First of all, the competent authorities should adopt active policies to guide the shipowners and shipbuilders to meet the challenges actively. Competent authorities should provide timely information support and policy guidance on the implementation of the BWM Convention, including the latest progress of the BMW Convention, technological development status of various countries, BMWS type selection and installation, so that they can formulate countermeasures as soon as possible. Also, the shipowner should be guided to determine the specific actions and timelines to install BWMS following the requirements of the BMW Convention.

The competent authorities also have responsibility for correctly guiding the direction of the BWMS industry. In the work of BMWS type approval and certification, the competent authorities should further strengthen their regulatory responsibilities. It is necessary to provide timely guidance and management for the critical technologies of ballast water treatment developed in China and promote the type approval both in the international and domestic level (Zhou el at., 2010). In addition, the competent authorities should maintain a good market order through active policy guidance, to avoid some BMWS manufacturers to take advantage to form a monopoly (Xue, 2018).

Furthermore, the competent authorities should further increase support for BMWS research and development. The development and application of BMWS with independent intellectual property rights should be encouraged. Necessary policy support to manufacturers with promising prospects to build competitive brands in the international market should be provided. At the same time, attention should be paid to the transformation of self-developed ballast water treatment prototype technology into a practical application (Fei & Zhu, 2018). The supervision and management of the transformation process of scientific and technological achievements into application fields should be standardized.

Chapter 6 Summary and Conclusions

6.1 Conclusions

With the rapid development of the international shipping industry, more and more attention has been paid to the harmfulness of HAOP from ships' ballast water. The international community has taken measures to deal with the threat from invasive aquatic species. On September 8, 2017, the BWM Convention entered into force, providing an international standard for the control and regulation of ballast water management. China is one of the world's major shipping countries, a large number of ships from all over the world discharged ballast water into Chinese waters, which has caused serious harm to China's marine environment. On January 22, 2019, the BWM Convention entered into force in China, China MSA as the component authority issued the "Measures for the Supervision and Administration of Ships' Ballast Water and Sediment Management (Trial)", which filled the blank of concrete specification of ballast water management in China. However, there are still many problems to be explored and improved in the process of implementation of the BWM Convention.

Starting from the introduction of ballast water and its hazards, this thesis briefly expounded the main contents of the BMW Convention and the main measures of unilateral countries taking the United States and Australia as examples. The current status of ballast water management in China has been studied from the perspectives of legislation, management system, and technology development. According to the comprehensive analysis, the main challenges to the implementation of the BMW Convention in China are reflected in the imperfect legal system, decentralized management departments, incomplete management system, and technology difficulties. By deeply analyzing the causes of the problems and absorbing the

management experience of the United States and Australia, some recommendations were put forward.

In terms of legislation, the concept of sustainable development and marine ecological protection should be established. It is necessary to introduce a special legislation on the invasion of marine aliens as soon as possible and step up efforts to improve the legal liability system and public participation system. In terms of management system, it is necessary to change the current decentralized management mode of various departments and establish a National Ballast Water Management Office to conduct unified leadership of ballast water management at the national strategic level. In addition, the whole process management system should be built with prevention, control and emergency management as the core. In terms of basic capacity building, it is necessary to strengthen China's scientific research on ballast water and invasive aquatic species and strengthen basic work such as biological investigation of China's port waters. Further, the government needs to increase investment to accelerate the training of talents in ballast water research and management, encourage technological innovation, and actively guide the healthy development of the shipping industry and BMWS-related industries.

To sum up, the entry into force of the BWM Convention in China has brought both opportunities and challenges to the government and the shipping industry. The Chinese government needs to strengthen international cooperation, and work together with stakeholders to continuously strengthen and improve the management of ballast water. This is of great significance for China to protect the marine ecological environment and promote the development strategy of building an ocean power.

6.2 Limitations and suggestions for further research

From the perspective of government management, this thesis analysed the challenges China faces in the process of implementing the BWM Convention only from three aspects of legislation, management system, and technological development. However, due to the issues involved in the implementation of the BWM Convention

are very complex, combining international standards, science, technology, socio-economic, and ecological environment, this research did not cover all aspects. Future studies should continue to supplement and improve the conclusion from other perspectives.

Moreover, due to limited time and approaches, the author only interviewed one person who works in China MSA, it was not available for the author to conduct questionnaire surveys or interviews from all the stakeholders. Therefore, this thesis lacks sufficient first-hand information, which may make some conclusions limited. The next step of the research should make up for these deficiencies.

References

Administrative Measures for Entry-Exit Inspection and Quarantine of International Navigation Vessels, China. (2003).

Albert, R. J., Lishman, J. M., & Saxena, J. R. (2013d). Ballast water regulations and the move toward concentration ‐ based numeric discharge limits. Ecological Applications, 23(2), 289-300.

Australian Government Department of Agriculture and Water Resources. (2017). Australian Ballast Water Management Requirements (Version 7). Retrieved from http://www.agriculture.gov.au/biosecurity/avm/vessels/ballast/australian-ballast-water-management-requirements

Australian Government Department of Agriculture and Water Resources. (2018). The Biosecurity Act 2015. Retrieved from http://www.agriculture.gov.au/biosecurity/legislation/biosecurity-legislation#about--our-biosecurity-legislation

Australian Government Department of Agriculture. (2019). Change of Department of Agriculture name and logo on AIMS directions. Retrieved from http://www.agriculture.gov.au/import/industry-advice/2019/91-2019

Australian Government. Department of the Environment and Energy. (n.d). Quick Domestic Ballast Water Risk Assessment Tool. Retrieved from http://www.agriculture.gov.au/biosecurity/avm/vessels/ballast#quick-domestic-ballast-water-risk-assessment-tool

Bai, J.Y. (2012). Zhongguo fangzhi Haiyang wailai wuzhong ruqin lifa zhi jiben yaunze tanjiu [The basic principles of China's legislation on the prevention and control of marine alien species invasion. Learning and Exploration]. *Xuexi yu tansuo*, (9), 88-92.

Bai, Y., & Liu, Z.Y. (2010). American legal system for prevention and control of ship source pollution and its enlightenment to China. Journal of Bohai University (Philosophy and Social Sciences Edition), 32(6), 96-99+.

Bailey, S. A. (2015). An overview of thirty years of research on ballast water as a vector for aquatic invasive species to freshwater and marine environments. Aquatic Ecosystem Health & Management, 18(3), 261-268.

Ballast water management for control of nonindigenous species in waters of the United States. 33C.F.R. § 151 (2004).

Ballast water management for control of nonindigenous species in waters of the United States. 33C.F.R. § 151.2080 (2004).

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., & Geeves, W. (2003). Marine invasive alien species: A threat to global biodiversity. Marine Policy, 27(4), 313-323.

Bobka, J. R. (2018). Defining unduly: Resolving inherent textual ambiguity in the IMO's ballast water management convention. Wm.& Mary L.Rev., 60, 267.

Boltovskoy, D., Correa, N., Cataldo, D., & Sylvester, F. (2006). Dispersion and ecological impact of the invasive freshwater bivalve limnoperna fortunei in the río de la plata watershed and beyond. Biological Invasions, 8(4), 947-963.

Buck, E. H. (2010). Ballast water management to combat invasive species.

Čampara, L., Slišković, M., & Jelić Mrčelić, G. (2019). Key ballast water management regulations with a view on ballast water management systems type approval process. NAŠE MORE: Znanstveno-Stručni Časopis Za More i Pomorstvo, 66(2), 78-86.

Canfa, W. (2006). Chinese environmental law enforcement: Current deficiencies and suggested reforms. Vt.J.Envtl.L., 8, 159.

Carney, K. J., Minton, M. S., Holzer, K. K., Miller, A. W., McCann, L. D., & Ruiz, G. M. (2017). Evaluating the combined effects of ballast water management and trade dynamics on transfers of marine organisms by ships. PloS One, 12(3), e0172468.

Central People's Government. (2018). China has formally acceded to the international convention on the management of ballast water for ships. Retrieved from http://www.gov.cn/xinwen/2018-10/27/content_5334949.htm

Chang, G.G., & Liu, S.L. (2019). Yazaishui xingneng biaozhun tuichi shengxiao de shengxian yu tiaozhan [Risks and challenges of delayed implementation of ballast water performance standards]. *Zhongguo haishi*, (1), 13.

Chen, S., & Uitto, J. I. (2003). Governing marine and coastal environment in china: Building local government capacity through international cooperation. China Environment Series, 6, 67-80.

Chen, X.S. (2017). Woguo jiaru yazaishui gongyue de jiyu he tiaozhan [Opportunities and challenges for China to accede to the ballast water convention]. *Shijie haiyun*, 40(12), 14-17.

China Classification Society (CSS). (2017). Chuanbo yazashui guanli xitong xingshi renke zhinan [Guidelines for type approval of ballast water management systems 2017]. Retrieved from http://www.ccs.org.cn/ccswz/font/fontAction!article.do?articleId=4028e3d653e5c87601542dc6e0620288

China Classification Society (CSS). (2018). Yazaishui shishi hangye zhinan 2018 [Industry guide for implementation of ballast water convention 2018]

China MSA. (2012). Guanyu banbu chuanbo yazaishui guanli xitong shenbao zanxing guiding de tongzhi [Notice on the Interim Provisions on the Application of Ships' Ballast Water Management System]. Retrieved from https://www.msa.gov.cn/html/xinxichaxungongkai/gkml/HSFG/bjGFXWJ/wf/20121201/6E08826A-670C-443B-AC76-F9633DE55EC4.html

China MSA. (2019). Jiaotong yunshubu haishiju guanyu kaizhan yazaishui guanli gongyue jingyan leiji gongzuo de tongzhi [Notice of MSA on experience accumulation of BWM Convention].

China MSA. (2014). Jiaotong yunshubu haishiju zhize. [The responsibility of China MSA] Retrieved from https://www.msa.gov.cn/html/haishizhichuang/MSAZZ/20141211/86183E24-A5E6-4476-9DB6-B954A3E287DE.html

China National Committee for Biodiversity Conservation. (n.d.). Jigou jieshao [Introduction of institution]. Retrieved from http://cncbc.mee.gov.cn/gjwyh/jgjs/

China State Shipbuilding Corporation LTD. (2018). Jiujiang jingmisuo shouge yazaishui xitong guoji biaozhun lixiang [Jiujiang precision institute's first international standard for ballast water system]. Retrieved from cssc.net.cn/component_news/news_detail.php?id=27021

Code of Federal Regulations. (1993). Title 33 Part 151 Subpart C—Ballast Water Management for Control of Nonindigenous Species in the Great Lakes and Hudson River. Retrieved from https://ecfr.io/Title-33/sp33.2.151.c#se33.2.151_11500

Cohen, A. N., & Foster, B. (2000). The regulation of biological pollution: Preventing exotic species invasions from ballast water discharged into California coastal waters. Golden Gate UL Rev., 30, 787.

Constitution of the People's Republic of China, 1982, as amended. Chapter 1. (2018)

COSCO Shipping Heavy Industry. (2019). Weihai keji yazaishui kuaisu jiance shebei shunli tongguo zhongyuan haiyun jituan keyan xiangmu yanshou [Weihai Technology Ballast Water Rapid Testing Equipment passed the acceptance of COSCO Shipping Group scientific research project]. Retrieved from http://chi.coscoshipping.com/art/2019/4/23/art_7984_98111.html

Dang, K., Yin, P.M., & Sun, P.T. (2004). Guoneiwai chuanbo yazaishui chuli jishu xianzhuang [Current status of ballast water treatment technology for ships at home and abroad]. *Hanghai jishu*, (2),64-66.

David, M. (2015). Vessels and ballast water. Global maritime transport and ballast water management (pp. 13-34) Springer.

David, M., & Gollasch, S. (2015). Ballast water management systems for vessels. Global maritime transport and ballast water management (pp. 109-132) Springer.

David, M., Gollasch, S., Leppäkoski, E., & Hewitt, C. (2015). Risk assessment in ballast water management. Global maritime transport and ballast water management (pp. 133-169) Springer.

Detailed rules for implementation of Frontier Health and Quarantine Law,1989 as amended, China. (2016).

Diasamidze, M., & Shotadze, A. (2019). Ballast water management and their system processing. Fundamental and Applied Researches in Practice of Leading Scientific Schools, 31(1), 58-60.

Du, L., Qian, C.X., & Guo, X.B. (2009). Chuanbo yazaishui guanli gongyue jiesho ji guojia duice [Introduction to the Convention on the management of ships' ballast water and national countermeasures]. *Zhongguo shuiyun (xiabanyue), 9(5), 98-99.*

Du, X., & Li, Z.W. (2013). Woguo haiyang shengwu ruqin yingdui xianzhuang ji duice [Current situation and countermeasures of marine biological invasion in China]. *Huanjing baohu,* 41(16), 50-51.

Du, Y., & Li, Z.W. (2013). Current situation and countermeasures of marine biological invasion in China. Environmental Protection, 41(16), 50-51.

Endresen, Behrens, H. L., Brynestad, S., Andersen, A. B., & Skjong, R. (2004). Challenges in global ballast water management. Marine Pollution Bulletin, 48(7-8), 615-623.

Fan, D.S. (2013). Woguo jiaru yazaishui gongyue de fenxi he duice yanjiu [Analysis and countermeasure research on acceding to BWM Convention in China]. (Master dissertation, Dalian Maritime University).

Fan, W., & Li, Y. (2017). Yazaishui gongyue dui chuanbo shichang de yingxiang [Impact of the BWM Convention on ship market]. *Zhongguo chuanjian* (9), 10-13.

Fang, F. (2017). Yazaishui guanli gongyue shishi yu yingxiang jiexi [Implementation and impact analysis of BWM Convention]. *Tianjin hanghai* (2).

Fei, S.S. (2014). Yazaishui gongyue shengxiao mianlin de nanti fenxi [Analysis of the difficulties facing the entry into force of the BWM Convention]. Zhongguo haishi, (7), 59-61.

Fei, S.S. (2015). IMO qidong yazaishui gongyue D2 biaozhun shishi yanjiu xiangmu [IMO launch research project of ballast water convention D2 standard implementation]. Zhongguo haishi, (4), 62-62.

Fei, S.S. & Zhu, X.M. (2018). Jiexi yazaishui gongyue lvyue zhunbei [A brief analysis of the provisions for the implementation of ballast water convention]

Fei, S.S., Zhang, S. H. (2009). Yazaishui guanli xitong xianzhuang he woguo shishi yazaishui gongyue de jianyi [J] [The present situation of ballast water management system and the suggestion of implementing ballast water convention in China]. *Hanghai jishu*, 2009 (1): 46-49.

Firestone, J., & Corbett, J. J. (2005). Coastal and port environments: International legal and policy responses to reduce ballast water introductions of potentially invasive species. Ocean Development & International Law, 36(3), 291-316.

Folkunger, J. (2010). Regulations on ballast water & invasive species-a comparative approach.

Frontier Health and Quarantine Law, 1986 as amended, Cap 4, China. (2018).

Gallardo, B., Clavero, M., Sánchez, M. I., & Vilà, M. (2016). Global ecological impacts of invasive species in aquatic ecosystems. Global Change Biology, 22(1), 151-163.

Ge, B.F., Huang, Y.J., Ran, J.X., Zhang, M.J., & Lou, S.Z. (2013). Jinjing chuanbo yacangshui wailai shengwu ruqinxing chuanbo jiqi jianguan cuoshi yanjiu [Study on invasive spread of alien organisms in ballast water of inbound ships and its regulatory measures]. *Zhiwu jianyi*, 27(1), 86-89.

Ge, J., Bi, J., & Wang, S. (2009a). Public participation in china's environmental protection. Building Effective Governance for Water Environment Conservation In

GEF-UNDP-IMO GloBallast Partnerships. (2017). The GloBallast Story: Reflections from a Global Family. GloBallast Monograph No. 25. Retrieved from http://www.imo.org/en/OurWork/Environment/MajorProjects/Documents/Mono25_English.pdf

Gollasch, S., Hewitt, C. L., Bailey, S., & David, M. (2018). Introductions and transfers of species by ballast water in the Adriatic Sea. Marine Pollution Bulletin,

Guard, U. C. (2012). US coast guard: America s maritime guardian Lulu. com.

Guo, D.R. (2019). Qiantan yazaishui gongyue shengxiaohou de yingdui [Discussion on the countermeasures after the entry into force of the BWM Convention]. Zhongguo yuanyang haiyun February 2019: 72-74

Havel, J. E., Kovalenko, K. E., Thomaz, S. M., Amalfitano, S., & Kats, L. B. (2015). Aquatic invasive species: Challenges for the future. Hydrobiologia, 750(1), 147-170.

Hebei MSA. (2015). Yazaishui guanli ji shishi [The management and implementation of ballast water]. *Shanghai jiaotong daxue chubanshe*, 2 (1), 270-271.

Hebei MSA. (2015). Yazaishui guanli ji shishi [The management and implementation of ballast water]. *Shanghai jiaotong daxue chubanshe*, 2 (1), p 269.

Hebei MSA. (2018). Yingdui yazaishui guanli gongyue shengxiao ,tisheng woguo shuiyu shengtai huanjing baohu shuiping [The BWM Convention should be put into effect to improve the ecological environment protection level of China's waters]. Zhongguo haishi (9).

Hernandez, M. R., Johansson, M. L., Xiao, Y., Lewis, M. A., & MacIsaac, H. J. (2017). Modeling sampling strategies for determination of zooplankton abundance in ballast water. Marine Pollution Bulletin, 115(1-2), 80-85.

Hewitt, C. L., & Campbell, M. L. (2007). Mechanisms for the prevention of marine bioinvasions for better biosecurity. Marine Pollution Bulletin, 55(7-9), 395-401.

Hu, S.H., Wang, J.Q., Nie, Lei, & He, Q. (2003). Shengwu ruqin de weihai ji fangzhi cuoshi [The harm and control measures of biological invasion]. *Shengwuxue zazhi*, 20(5), 12-15.

Hulme, P. E. (2009). Trade, transport and trouble: Managing invasive species pathways in an era of globalization. Journal of Applied Ecology, 46(1), 10-18.

Ibrahim, A. M., & El-Naggar, M. M. (2012). Ballast water review: Impacts, treatments and management. Middle-East J Sci Res, 12(7), 976-984.

International Chamber of Shipping (ICS). (2016). ICS Annual Review 2019. Retrieved from http://www.ics-shipping.org/docs/default-source/resources/ics-annual-review-2019.pdf

International Maritime Organization (IMO). (2019). Current lists of Ballast Water Management Systems, which received Type Approval Certification, Basic and Final Approval. Retrieved from http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Documents/Table%20of%20BA%20FA%20TA%20updated%20January%202019.pdf

International Maritime Organization (IMO). (2019). Resolution MEPC. 74/4/15, Proposals for improving application of the same risk area approach for exemptions from ballast water management-submitted by China. London. Retrieved from https://docs.imo.org/Shared/Download.aspx?did=115392

International Maritime Organization (IMO). (2019). Status of IMO treaties. Retrieved from http://www.imo.org/en/About/Conventions/StatusOfConventions/Documents/Status%20-%202019.pdf

International Maritime Organization (IMO). (n.d.). Ballast Water Management. Retrieved from http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx

International Maritime Organization (IMO). (1973). Resolution 18, Research into the effect of discharge of ballast water containing bacteria of epidemic diseases. London: IMCO. MP/CONF/WP.29 Retrieved from http://www.imo.org/en/KnowledgeCentre/ReferencesAndArchives/IMO_Conferences_and_Meetings/MARPOL/MP_CONF_1973/Documents/WP.29.pdf

International Maritime Organization (IMO). (2004). International Convention for the control and management of ships' ballast water and sediments, 2004. London.

International Maritime Organization (IMO). (2006). Resolution MEPC. 153(55), GUIDELINES FOR BALLAST WATER RECEPTION FACILITIES (G5). London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-CommitteeMEPC)/Documents/MEPC.153(55).pdf

International Maritime Organization (IMO). (2006). Resolution MEPC.149 (55), Guidelines for Ballast Water Exchange Design and Construction Standards (G11). Retrieved from http://www.imo.org/blast/blastDataHelper.asp?data_id=16307&filename=149(55).pdf

International Maritime Organization (IMO). (2007). Resolution MEPC.161(56), GUIDELINES FOR ADDITIONAL MEASURES REGARDING BALLAST WATER MANAGEMENT INCLUDING EMERGENCY SITUATIONS (G13). London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee(MEPC)/Documents/MEPC.161(56).pdf

International Maritime Organization (IMO). (2007). Resolution MEPC.162(56), GUIDELINES FOR RISK ASSESSMENT UNDER REGULATION A-4 OF THE BWM CONVENTION (G7). London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-EnvironmentProtection-Committee-(MEPC)/Documents/MEPC.162(56).pdf

International Maritime Organization (IMO). (2008). Resolution MEPC. 173(58), GUIDELINES FOR BALLAST WATER SAMPLING (G2). London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-(MEPC)/Documents/MEPC.173(58).pdf

International Maritime Organization (IMO). (2014). Resolution MEPC. 252 (67), GUIDELINES FOR PORT STATE CONTROL UNDER THE BWM CONVENTION. London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-(MEPC)/Documents/MEPC.252(67).pdf

International Maritime Organization (IMO). (2017). Global treaty to halt invasive aquatic species enters into force. Retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/21-BWM-EIF.aspx

International Maritime Organization (IMO). (2017). Marine Environment Protection Committee (MEPC), 71st session – Media information. Retrieved from http://www.imo.org/en/MediaCentre/IMOMediaAccreditation/Pages/MEPC71PREVIEW.aspx

International Maritime Organization (IMO). (2017). Resolution MEPC. 290(71), THE EXPERIENCE-BUILDING PHASE ASSOCIATED WITH THE BWM CONVENTION. London. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-%28MEPC%29/Documents/MEPC.290%2871%29.pdf

International Maritime Organization (IMO). (2017). Resolution MEPC.288 (71), Guidelines for Ballast Water Exchange. Retrieved from http://www.imo.org/en/KnowledgeCentre/IndexofIMOResolutions/Marine-Environment-Protection-Committee-%28MEPC%29/Documents/MEPC.288%2871%29.pdf

International Maritime Organization (IMO). (2018). Guidelines and guidance documents related to the implementation of the international convention for the control and management of ships' ballast water and sediments,2004. Retrieved from http://www.imo.org/en/OurWork/Environment/BallastWaterManagement/Documents/Compilation%20of%20relevant%20Guidelines%20and%20guidance%20documents%20-%20May%202018.pdf

International Maritime Organization (IMO). (2018). Marine Environment Protection Committee (MEPC), 72nd session, 9-13 April 2018. Retrieved from http://www.imo.org/en/MediaCentre/MeetingSummaries/MEPC/Pages/MEPC-72nd-session.aspx

International Maritime Organization (IMO). (2018). Resolution MEPC.297(72), Amendments to regulation B-3. London.

International Maritime Organization (IMO). (2019) Status of Conventions, Retrieved from http://www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx

International Organization for Standardization (ISO). (2019). ISO/CD 23152. Retrieved from https://www.iso.org/standard/74745.html?browse=tc

International Organization for Standardization (ISO). (2019). ISO/NP 23314-2. Retrieved from https://www.iso.org/standard/77037.html

International Organization for Standardization (ISO). (2019). ISO/NP 23315-2. Retrieved from https://www.iso.org/standard/77039.html

Jin, L., Zeng, Y.H., & Zhao, S. (2011). Haiyang huanjing baohuzhong de gongzhong canyu wenti yu duice [Problems and recommendations of public participation in Marine environmental protection]. *Huanjing kexue yu guanli*, 36(12), 1-4.

King, D. M., & Tamburri, M. N. (2010). Verifying compliance with ballast water discharge regulations. Ocean Development & International Law, 41(2), 152-165.

King, D. M., Hagan, P. T., Riggio, M., & Wright, D. A. (2012). Preview of global ballast water treatment markets. Journal of Marine Engineering & Technology, 11(1), 3-15.

Kong, Q., Liu, J.F., Li, C., & Xu, F.L. (2018). Quanmian shishi chuanbo yazaishui gongyue cunzai de wenti fenxi [Analysis of the problems existing in the full implementation of the BMW Convention]. Guangdong zaochuan, (2018nian04yue), 81-82.

Kuang H. (2010). A comparative study on the prevention of invasive alien species from marine ballast water - legislation, trends and responses (Master's thesis, Dalian Maritime University).

Law of people's Republic of China on the Entry and Exit Animal and Plant Quarantine, China. (1991).

Li, L.N. (2016). Jiyu IMO yazaishui gongyue shengxiao beijing xia de woguo yazaishui lvyue duice yanjiu [Research on China's ballast water performance countermeasures based on the IMO Convention on Ballast Water]. Zhongguo Shuiyun, (10), 17-18.

Li, Q. (2018). Zhongguo zhengshi jiaru yazaishui gongyue [China officially joined the Ballast Water Management Convention on January 22, 2019, and we are ready to deal with the Ballast Water Management Convention]. Ship Standardization Engineer, 3-4.

Li, Q. (July 12, 2019). Woguo chuanbo yazaishui jiance de xinmingti [A new proposition of ballast water detection for ships in China]. *China Water Transport*. pp06. Retrieved from http://epaper.zgsyb.com/html/2019-07/12/content_33266.htm

Li, S.B. & Huang Y.Y. (2018). Guoji haishi zuzhi yazaishui gongyue lifa fazhan yanjiu [Research on the Legislative Development of the International Maritime Organization Ballast Water Convention]. *Shanghai haiyangdaxue xuebao*, (3), 18.

Li, S.J. (2013). Chuanbo yazaishui wailai shengwu ruqin de falv wenti yanjiu [Study on the invasion of alien organisms in ships' ballast water]. (Master's thesis, Dalian Maritime University).

Li, T., Wen, J.P.,Tian, Y.J.,& Zhang, B. (2018). Jiyu SRAfa de zhonghan chuanbo yazaishui shengwu ruqin fengxian yanjiu [Research on the risk of ballast water invasion of Chinese and Korean ships based on sra]. *Shanghai Haiyang daxue xuebao*, 27(3), 407-415.

Li, Y.E. (2017). Chuanbo yazaishui guanli qidai tongyi xingdong [Ships' ballast water management looks forward to unified action].*Zhujiang shuiyun*, (4), 33-33

Li, Z.J. (2019). Daxing tufaxing shuihuanjing wuran shigu falv zeren zhuijiu tizhi goujian yanjiu [Study on the establishment of legal liability investigation system for large sudden water environmental pollution accidents]. Huanjing kexue yu guanli, 44(02), 43-46.

Liu, F.M., Miu, J.L., Zheng, Z. (2007). Zhongguo wailai haiyang shengwu ruqin de xianzhuang, weihai, jiqi fangzhi duice [The present situation, harm and countermeasures of alien marine biological invasion in China]. *Haian gongcheng* (4).

Liu, L., Wu, H.X., Yuan, L., Wang, Q., & Xue, J.Z. (2018). Jiyu guoji gongyue yaoqiu de yazaishui shengwu jiance jishu [Biological detection technology of ballast water based on international convention]. *Shanghai Haiyang daxue xuebao*, 27(3), 460-467.

Liu, L.D., Sun, Y.J., Li, H. B. (2019). Yazaishui guanli gongyue PSC jiancha [J] [The BWM Convention PSC inspection]. *Shijie haiyun*, 2019, 42 (02) :13-18

Liu, M.H., Wang, N., Liu, T., & Ji, Z.Y. (2019). Chuanbo yazaishui chuli fangfa yanjiu jinzhan [Research progress on ballast water treatment for ships]. *Ziyuan jieyue yu huanbao* (2), 69-72.

Liu, N. (2013). China: Prevention of invasive species from ballast water. The International Journal of Marine and Coastal Law, 28(1), 171-187.

Liu, N., & Maes, F. (2011). Prevention of vessel-source marine pollution: A note on the challenges and prospects for chinese practice under international law. Ocean Development & International Law, 42(4), 356-367.

Liu, Y., Hu, L.L., & Song, C.W. (2007). Chuanbo yazaishui fengxian pinggu [Risk assessment of ships' ballast water]. *Zhongguo hanghai xuehui xueshu jiaoliuhui youxiu lunwenji.*

Liu, Y., Wu, H.X., & Xue, J.Z. (2013). Haiyang wailai wuzhong ruqin shengtaixue yanjiu [Ecological research on marine invasive alien species]. *Shenwu anquan xuebao*, (1), 8-16.

Lodge, D. M., Simonin, P. W., Burgiel, S. W., Keller, R. P., Bossenbroek, J. M., Jerde, C. L., . . . Wittmann, M. E. (2016). Risk analysis and bioeconomics of invasive species to inform policy and management. Annual Review of Environment and Resources, 41

Marine Environmental Protection Law, Cap 8. China. (2000).

Maritime Safety Administration of China. (2012). Guanyu banbu chuanboyazaishui guanlixitong shenbao zanxing guiding de tongzhi [Notice on Promulgating the Interim Provisions on the Application of the Ship Ballast Water Management System]. Retrieved from https://www.msa.gov.cn/html/xinxichaxungongkai/gkml/HSFG/bjGFXWJ/wf/20121201/6E08826A-670C-443B-AC76-9633DE55EC4.html

Maritime Safety Administration of China. (2014). Zhonghua renmin gongheguo haishiju (jiaotong yunshu bu haishiju) jianjie [Brief introduction of Maritime Safety Administration of the People's Republic of China]. Retrieved from https://www.msa.gov.cn/html/haishizhichuang/MSAZZ/20141211/86183E24-A5E6-4476-9DB6-B954A3E287DE.html

Maritime Safety Administration of China. (2019). Measures for the Supervision and Administration of the Management of Ships' Ballast Water and Sediments (Trial). Retrieved from https://www.msa.gov.cn/page/article.do?articleId=C7E6FEDF-DB0D-4C59-8285-C9BA350EB35A

McConnell, M. J. (2002). GloBallast legislative review 2002 Global Ballast Water Management Programme.

Measures for the Supervision and Administration of Ships' Ballast Water and Sediment Management (Trial), China. (2019)

Ministry of Ecology and Environment (MEE). (2017). Guanyu fabu zhongguo ziran shengtai xitong wailai ruqin wuzhong mingdan (disipi) [Announcement on the release of the list of alien invasive species in China's natural ecosystems (the fourth batch)]. Retrieved from http://sts.mee.gov.cn/swaq/lygz/201708/t20170828_420478.shtml

Ministry of Ecology and Environment (MEE). (2017). Principles for approval of environmental impact assessment documents of port construction projects (draft for comments). Retrieved from http://www.mee.gov.cn/gkml/hbb/bgth/201710/W020171027336556220357.pdf

Ministry of Ecology and Environment (MEE). (2018). Duties of the Ministry of Ecology and Environment. Retrieved from http://www.mee.gov.cn/zjhb/zyzz/

Ministry of Nature Resources (MNR). (2018). Haiyang yujing jiancesi [Department of Marine Early Warning and Monitoring]. Retrieved from http://www.mnr.gov.cn/jg/jgsz/nsjg/201809/t20180912_2188281.html

Ministry of Transport of China (MOT). (2018). Statistical Bulletin of the Development of the Transportation Industry in 2018. Retrived from http://xxgk.mot.gov.cn/jigou/zhghs/201904/t20190412_3186720.html

Ministry of Transport of China (MOT). (2018). Jiaotong yunshu bu guanyu xiada 2018nian jiaotong yunshu biaozhunhua jihua de tongzhi [Notice of the Ministry of Transport on the issuance of the 2018 Transportation Standardization Plan]. Retrieved from http://xxgk.mot.gov.cn/jigou/kjs/201806/t20180625_3036798.html

Mo, L.S. (2017). Yazaishui gongyue shengxiao gei woguo dailai de tiaozhan ji woguo de falv duice [The challenge brought by the entry into force of the BWM Convention and its legal countermeasures]. (Master dissertation, Dalian Maritime University).

National Ballast Information Clearinghouse. (2019). Welcome to the National Ballast Information Clearinghouse. Retrieved from https://nbic.si.edu/

Office of port of entry and exit of Shenzhen Municipal Poeple's Government. (2018). The world's first "Shared" ballast water emergency treatment test was held in Shenzhen. Retrieved from http://www.sz.gov.cn/szskab/xxgk/qt/gzdt/201806/t20180620_12203421.htm

One Hundred First Congress of the United States of America. (1990). Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Sec. 1002(b). Retrieved from https://www.congress.gov/bill/101st-congress/house-bill/5390/text.

One Hundred First Congress of the United States of America. (1990). Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, Sec. 1101(a). Retrieved from https://www.congress.gov/bill/101st-congress/house-bill/5390/text.

Pang, S.T., Liu, Y., & Zhu, Z.Y. (2015). Guoneiwai fangzhi wailai shengwu ruqin guanli celue yanjiu jinzhan [Research progress on management strategies of preventing alien species invasion at home and abroad]. *Nongxue xuebao* (12).

Peng, B. (2014). Qiantan yazaishui gongyue shishi yingdui cuoshi [Discussion on countermeasures of the BWM Convention implementation]. *Zhongguohaishi*, 2014 (3): 32-34.

Percival, R. V. (2010). Liability for environmental harm and emerging global environmental law. Md.J.Int'L L., 25, 37.

Provisions of the People's Republic of China on the prevention and administration of Marine environmental pollution by ships and related operations 2010, as amended, China. (2010)

Punishment Law of the People's Republic of China, 1996 as amended, China, (2017)

Qu, P.X., Xie, X., & Chang, Y.G. (2018). Chuanbo yazaishui quyang ji zhishixing fenxi chutan [Preliminary analysis of ballast water sampling and indicator]. Hanghai (1), 67-70.

Rak, G., Zec, D., Kostelac, M. M., Joksimović, D., Gollasch, S., & David, M. (2018). The implementation of the ballast water management convention in the Adriatic Sea through states' cooperation: The contribution of environmental law and institutions. Marine Pollution Bulletin,

Ricciardi, A. (2007). Are modern biological invasions an unprecedented form of global change? Conservation Biology, 21(2), 329-336.

Rigby Geoff, Alan Taylor & Gustaaf Hallegraeff. (2003). Fifteen Years of Managing Ballast Water to Minimise the Biological Threat to Australia's Marine Environment – Past, Present and Future, Maritime Studies, 2003:133, 21-30

Ruiz, G. M., Miller, A. W., Everett, R. A., Steves, B., Lion, K., Whitcraft, C., . . . Lipski, D. (2000). National ballast information clearinghouse interim report (october 2000). Results of the First Year of Data Management and Analysis: Shipping Industry Compliance with Mandatory Ballast Water Reporting Requirements Shipping Industry Compliance with Voluntary Ballast Water Management Guidelines,

Saglam, H., & Duzgunes, E. (2018). Effect of ballast water on marine ecosystem. Exergy for A better environment and improved sustainability 2 (pp. 373-382) Springer.

Seebens, H., Schwartz, N., Schupp, P. J., & Blasius, B. (2016). Predicting the spread of marine species introduced by global shipping. Proceedings of the National Academy of Sciences, 113(20), 5646-5651.

Shanghai Ocean University (SHOU). (2018). Chuanbo "gongxiangshi" yazaishui yijing chuli yanlian zai shenzhen juxing [A "Shared ballast water" emergency treatment drill was held in Shenzhen]. Retrieved from https://www.shou.edu.cn/2018/0625/c7082a223819/page.htm

Shanghai Ocean University. (2019). Shanghai haiyang daxue chuanbo yazaishui jiance shiyanshi huozhun wei USCG renke shiyanshi [Shanghai ocean university ship ballast water testing laboratory was approved by the USCG]. Retrieved from http://dwgk.shou.edu.cn/2019/0624/c1318a247807/page.htm

Shen, Y.Y. (2010). Research on the legal mechanism for preventing foreign invasion of ship ballast water (Master's thesis, Dalian Maritime University).

Shi, Y. (2013). Gongzhong canyu Haiyang huanjing wuran fangzhi de falv jizhi yanjiu [Research on the legal mechanism of public participation in the prevention and control of Marine environmental pollution]. (Doctoral dissertation, Harbin Engineering University).

Song, X.L., & Liu, Y.Y. (2011). Lun xingzheng guifanxing wenjian de quexian jiqi jiaozhi [On the defects and correction of administrative normative documents]. *Gansu zhengfa xueyuan xuebao*, (3), 152-157.

Sun, C.B., & Chen, Y. (2018). Quanqiu xiuchuan sheshi xuqiu jiang yinglai xianzhu zengzhang [The global demand for ship repair facilities will grow significantly]. *Chuanbo biaozhunhua yu zhiliang*, 279(06), 50-51.

Tamelander, J., Riddering, L., Haag, F., Matheickal, J., & No, G. M. S. (2010). Guidelines for development of a national ballast water management strategy GloBallast Partnerships Project Coordination Unit, International Maritime ….

Tang, Y., & Su, S. (2015). Fangkong chuanbo yazaishui zaocheng de shengwu ruqin de guanli wenti [The management of biological invasion caused by ship ballast water]. *Shanghai Haiyang daxue xuebao*, 24(1), 130-137.

The Central People's Government of the People's Republic of China. (2018). Zhongguo zhengshi jiaru guoji chuanbo yazaishui guanli gongyue [China has formally acceded to BWM Convention]. Retrieved from http://www.gov.cn/xinwen/2018-10/27/content_5334949.htm

The Central People's Government of the People's Republic of China. (2018). Guowuyuan jigou gaige fangan [State Council institutional reform plan]. Retrieved from http://www.gov.cn/xinwen/2018-03/17/content_5275116.htm

The Central People's Government of the People's Republic of China. (2013). Zhongguo dongmeng haishi cuoshang jizhi dijiuci huiyi zai shanghai zhaokai [The ninth meeting of China-ASEAN maritime consultation mechanism was held in Shanghai]. Retrieved from http://www.gov.cn/gzdt/2013-11/11/content_2525128.htm

The Central People's Government of the People's Republic of China. (2018). Institutional Reform Plan of the State Council. Retrieved from http://www.gov.cn/xinwen/2018-03/17/content_5275116.htm

Tian, W., Shen, H., Guo, J.F., Ding, H., Zhu, L., Li, X.D., Xu, J.X., Li, H. Guoji yazaishui guanli ji duice yanjiu [J][International ballast water management and countermeasures]. *Zhiwu jianyi*, 2019,33(04):1-6.

Tort Liability Law of the People's Republic of China, China, (2010).

Tsamenyi, M., Kaye, S., & Castle, A. (2003). Towards a Legal Framework for a Single National Ballast Water Management Scheme in Australia. Australian and New Zealand Maritime Law Journal, 19. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=edshol&AN=edshol.hein.journals.ausnewma17.4&site=eds-live&scope=site

Tsimplis, M. (2004). Alien species stay home: The international convention for the control and management of ships' ballast water and sediments 2004. The International Journal of Marine and Coastal Law, 19(4), 411-482.

Tsolaki, E., & Diamadopoulos, E. (2010). Technologies for ballast water treatment: A review. Journal of Chemical Technology & Biotechnology, 85(1), 19-32.

U.S. Department of Agriculture. (1999). Executive Order 13112 - Invasive Species Retrieved from https://www.invasivespeciesinfo.gov/executive-order-13112

United Nations Conference on Trade and Development (UNCTAD). (2018). Review of Maritime Transport. Retrieved from https://unctad.org/en/Publications Library/rmt2018_en.pdf

United States Coast Guard. (2010). Generic protocol for the verification of ballast water treatment technology. Retrieved from https://www.dco.uscg.mil/Portals/9/ETV%20EPA%20Report.pdf?ver=2018-05-22-081043-607

United States Coast Guard. (2019). BWMS APPROVAL STATUS. Retrieved from https://www.dco.uscg.mil/Portals/9/MSC/BWMS/BWMS_Approval_Status_9JUL19.pdf

United States Environmental Protection Agency. (2008). Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP). Retrieved from https://www3.epa.gov/npdes/pubs/vessel_vgp_permit.pdf

United States Environmental Protection Agency. (2013). Final 2013 VGP. Retrieved from https://www3.epa.gov/npdes/pubs/vgp_fact_sheet2013.pdf

United States Environmental Protection Agency. (n.d). Vessels-VGP. Retrieved from https://www.epa.gov/npdes/vessels-vgp

United States Geological Survey (USGS). (n.d.). ANS Task Force Experts Directory. Retrieved from https://anstaskforce.gov/experts/search.php

United States Geological Survey (USGS). (n.d.). NAS - Nonindigenous Aquatic Species. Retrieved from https://nas.er.usgs.gov/default.aspx

Wan, Z., Chen, J., & Sperling, D. (2018). Institutional barriers to the development of a comprehensive ballast-water management scheme in china: Perspective from a multi-stream policy model. Marine Policy, 91, 142-149.

Wang, D.S., Yin, Y.S., Zhang, L., & Dong, L.H. (2014). Zhongguo chuanbo yazaishui chuli xitong yanfa xianzhuang [Research and development of ballast water treatment system for ships in China]. *Zhongguo shuiyun (xiabanyue)*, 14(12), 135-137.

Wang, H.F., & Zhang, L. (2017). CCS wei yazaishui gongyue shishi tigong quanfangwei fuwu [CCS provides a full range of services for the implementation of the BWM Convention]. *Zhongguo chuanjian,* (9), 17-18.

Wang, M. (2005). Jiyu anji shebei de yazaishui guanli xitong yanjiu [Research on ballast water management system based on shore-based equipment].*2005nian chuanbo fangwuran xueshu nianhui lunwenji.*

Wang, T.Y., & Lu, H.M. (2012). Chuanbo yazaishui kongzhi he guanli xianzhuang de diaocha zongshu [Survey and summary of the current situation of ballast water control and management in ships]. *Zhongguo hanghai xuehui neihe chuanbo jiashi zhuanye weiyuanhui nianhui ji xueshu yantaohui.*

Water pollution prevention and control action plan, China. (2015)

Water Pollution Prevention and Control Law,2008 as amended, China. (2018)

Wei, Y., & Wang T.Y. (2014). Guanyu chuanbo yazaishui guanli xianzhuang de diaocha yu fenxi [Investigation and analysis of the status quo of ship ballast water management]. *Marine Development and Management*, 31(2), 78-83.

Wells, F. E., & McDonald, J. I. (2010). Actions to implement and complement the national system for the prevention and management of introduced marine pests in western australia Fisheries Research Division, Western Australian Fisheries and Marine

Wu, H., Chen, C., Wang, Q., Lin, J., & Xue, J. (2017). Zhongguo yazaishui shengwu neirong zongshu [The biological content of ballast water in China: a review]. *Aquaculture and Fisheries*, 2(6), 241-246.

Xian, X.Q., Chen, H., Zhao, J., & Wang, F.H. (2013) Zhongguo wailai ruqin wuzhong shujuku jianjie [Introduction to the database of invasive species in China]

Xiong, W., Shen, C., Wu, Z., Lu, H., & Yan, Y. (2017). A brief overview of known introductions of non-native marine and coastal species into china. *Aquatic Invasions,* 12(1)

Xiong, W., Shen, C., Wu, Z., Lu, H., & Yan, Y. (2017a). A brief overview of known introductions of non-native marine and coastal species into china. *Aquatic Invasions*, 12(1)

Xu, J.S. (2016). Woguo rujing chuanbo yazaishui guanli cunzai de wenti jiqi duice yanjiu [Study on the existing problems and countermeasures of ballast water management of inbound ships in China]. (Master's thesis, Suzhou University).

Xu, J.W., Fu, L.D., & Wu, G.T. (2016). Chuanbo yazaishui quyang tanjiu [Research on ships' ballast water sampling]. *Zhongguo shuiyun:xiabanyue* (6), 12-14.

Xu, Y., Liang, B., Yu, C.Y., Bao, C.G., Lan D.D., & Ma, M.H. (2015). Woguo Haiyang shengtai huanjing jiance yu fengxian guankong nengli yanjiu [Research on marine ecological environment monitoring and risk control capability in China]. *Haiyang kaifa yu guanli*, 32(5), 87-90.

Xue, M.G. (2018). Chuanbo yazaishui guanli gongyue shishi yu yingxiang [Implementation and impact of the BWM Convention]. *Tianjin hanghai* (2).

Yang, Z.J. (2010). Woguo Haiyang huanjing tufa shijian yingji guanlizhong cunzai de wenti ji duice [The problems and countermeasures of Marine environmental emergency management in China]. *Shandong nongye daxue xuebao (ziran kexue ban)*, 41(3), 420-423.

Yin, C.J. (2008). Tufaxing shuihuanjing wuran shigu falv zeren zhuijiu tanxi [Investigation and analysis of legal liability for sudden water environmental pollution accident]. *Heilongjiangsheng zhengfa guanli ganbu xueyuan xuebao*, (5).

Yu, Y.F. (2018). Gangkouguo jiandu jianchazhong yazaishui quyang de tiaozhan he duice [Challenges and countermeasures of ballast water sampling in port state supervision and inspection]. *Junmin liangyong jishu yu chanpin*, (2018nian 4yue), 268-268.

Yu, Y.H. (2014). Woguo chuanbo yazaishui de falv zhidu yanjiu [Research on the legal system of ship ballast water in China]. (Master's thesis, Harbin Engineering University).

Yuan, J., Mao, M.J., & Dang, K. (2017). Yazaishui gongyue shengxiao Beijing xia de yingyun chuanbo lvyue duice yanjiu [Research on the countermeasure of implementing the BWM Convention under the background of entering into force]. *Shuyan jishu yu guanli*, 34(11), 279-282.

Zhan, A., Ni, P., Xiong, W., Chen, Y., Lin, Y., Huang, X., . . . Gao, Y. (2017a). Biological invasions in aquatic ecosystems in china. *Biological invasions and its management in China* (pp. 67-96) Springer.

Zhan, X.W. (2015). Aodaliya youguan Haiyang ruqin wuzhong fangzhi de falv gizhi [Australian legal regulation on the prevention and control of marine invasive species]. *Zhongguo Haiyang daxue*,1-z.

Zhang, B. (2019, January 22). Hebei haishiju kaizhan quanguo shouci yazaishui gongyue gangkouguo jiandu jiancha gongzuo [Hebei Maritime Safety Administration carried out the nation's first "ballast water convention" port state supervision and inspection work]. *Zhongguo jiaotong xinwenwang.*Retrieved from http://www.zgjtb.com/2019-01/22/content_218140.htm

Zhang, B., & Zhu, F. (2019, January 1). Hebei haishi zhaokai yazaishui gongyue shishi dongyuan bushuhui [Hebei MSA held the BWM Convention implementation mobilization meeting]. *China water transport*. pp 02.

Zhang, B.& Zhang, L. (2018). Chuanbo yazaishui gangkou jieshou chuli sheshi yingyong yanjiu [Research on the application of ship ballast water port receiving and treatment facilities].

Zhang, C. H. (2012). Aodaliya fangfan yingdui Haiyang shengwu ruqin rufa shijian de zhuyao zuofa yu jingyan jiejian [The main methods and experience of Australia in preventing and dealing with marine biological invasion emergencies].*Zhongguo yingji guanli* (8), 50-54.

Zhang, D.F., Zhang, S.J., & Lu, Y.K. (2012). Chuanbo yazaishui chuli xitong jishu yanfa xianzhuang ji zhanwang [Research and development status and prospect of ballast water treatment system for ships]. *Shijie haiyun*, 35(9), 51-54.

Zhang, M. X. (2018). Responding to the entry into force of the Ballast Water Management Convention to improve the level of ecological environment protection in China's waters. *China Maritime Safety*,9,18-20.

Zhang, P. (2016). Seafarers' rights in china: Restructuring in legislation and practice under the Maritime Labour Convention 2006 Springer.

Zhang, S., Wang, H., & Zhang, S.H. (2009). Sheji chuanbo yazaishui ji chenjiwu chuzhi de yingji fanying gaishu [Overview of emergency response involving ballast water and sediment disposal on ships]. *Zhongguo haishi* (12), 35-39.

Zhang, S., Zhang, S.H., & Li, Y.L. (2008). Chuanbo yazaishui de fengxian guanli [The risk management of ships' ballast water]. *Shijie haiyun*, 31(3), 32-34.

Zhang, X. H. (2014). Yazaishui gongyue zhimen [The door of the BWM Convention]. *Zhongguo chuanjian* (7), 9-11.

Zhang, X.H., Zhang, Z.L., Li, S.W., Du, J., Li, P., & Tian, Z.G. (2018). Guoji chuanbo yazaishui guanli ji gongyue shengxiaohou jianyan jianyi jianguan cuoshi de sikao he jianyi [Thoughts and Suggestions on the management of international ship ballast water and the supervision measures of inspection and quarantine after the entry into force of the BWM Convention]. Shanghai haiyang daxue xuebao, v.27(03), 130-133.

Zhang, Y.Q. (2017). Haiyang qiangguo beijingxia woguo Haiyang guanli bumen de xietongwenti yanjiu –yi xietong zhengfu lilun wei shijiao [Research on the coordination of China's marine management departments under the background of maritime power -- from the perspective of collaborative government theory]. *Zhongguo Haiyang daxue xuebao (shehui kexue ban)* (4).

Zhao, J. (2013). Haiyang huanjing baohuzhong de gongzhong taidu yu xingwei fenxi [Analysis of public attitudes and behaviors in marine environmental protection]. *2013nian zhongguo shehuixue nianhui ji disijie Haiyang shehuixue luntan lunwenji.*

Zhong, Z.Y. (2017). Yazaishui gongyue de shishi dui hangyun qiye de yingxiang – fengxian yu tiaozhan [The impact of the implementation of the BWM Convention on shipping enterprises -- risks and challenges]. *Hanghai jishu*, (5), 67-71

Zhou, Z.S., Duan, G.J., Sun, Y.P., & He, S.H. (2011). Guoji chuanbo yazaishui he chenjiwu kongzhi yu gaunli gongyue lvyue duice yanjiu [Research on implementation countermeasures of International convention for control and management of ships' ballast water and sediment]. *Zhongguo haishi* (1), 34-36.

Zhou, Z.S., Lv, A.Q., Duan, G.J., Sun, Y.P., & He, S.H. (2010). Guoji chuanbo yazaishui he chenjiwu kongzhi yu guanli gongyue de lvyue duice yanjiu [Research on implementation countermeasures of the International convention for the control and management of ship's ballast water and sediment]. *Shuiyun kexue yanjiu* (4), 34-36.

Zink, A. (2015). The IMO's ballast water management convention of 2004: A decade of evolution and challenges. Ocean Yearbook Online, 29(1), 441-473.

Appendix

Appendix 1

Summary of penalties related to ballast water management in China, the United States, and Australia.

Country	Penalties	Sources of law
China	Discharging pollutants over the standards or the total volume control targets shall be fined not less than RMB20,000 but not more than RMB100,000 (USD 14,117) [1]. Those who refuse to make corrections may continue to be fined according to the original fine amount.	Articles 73, 74, 75 of the Marine Environmental Protection Law ,1999 as amended
	If the pollutant discharge is not reported as required or is fraudulent at the time of reporting, shall be imposed a fine of not more than RMB20,000 (USD2,823.4) [1].	
	Refuse to carry out inspection, or falsify when being inspected, a fine of less than RMB20,000 (USD2,823.4) [1].	
	If the vessel fails to keep a record of the disposal of pollutants on the vessel, a fine between RMB20,000 (USD2,823.4) and RMB100,000 (USD 14,117) [1] shall be imposed.	Article 59 of Regulation on the Prevention and Control of Marine Pollution from Vessels, 2010
	If an international navigation vessel that discharge ballast water not meeting the required standards in China's inland rivers shall be imposed a fine of not less than RMB10,000 (USD 1,411.7) [1].	Article 90 of Water Pollution Prevention and Control Law, 2008 as amended
	The illegal act of discharging ballast water without authorization is liable to a fine between RMB1,000 (USD141.17) and RMB10,000 (USD1,411.7) [1].	Articles 109 and 110 of the Rules for implementation of Frontier Health and Quarantine Law, 1989, as amended

Country	Penalties	Sources of law
The United States	The maximum penalty for a violation of the ballast water regulations is USD35,000 and constitutes a separate civil liability daily — moreover, a class C felony for individuals who intentionally break the law.	Section 2080 of Part 151 of Title 33 of CFR
Australia	Failure to give report shall be punishable by imprisonment for 2 years or 120 penalty units (USD17,243) [2], or both; Civil penalty: 120 penalty units (USD17,243) [2].	Chapter 5 of the Biosecurity Act 2015
	The offence of discharging ballast water shall be fined 2,000 penalty units (USD287,263) [2] and committed an offence of strict liability.	
	If do not have a ballast water management plan or certificate shall be fined 200 penalty units (USD28,726) [2].	
	Vessels do not have a ballast water management record system shall be fined 200 penalty units (USD28,726) [2]. If a ballast water management record fails to remain shall be fined 200 penalty units (USD28,726) [2] and committed an offence of strict liability.	
	The offence of disposing of sediment shall be fined 2,000 penalty units (USD287,263) [2] and committed an offence of strict liability.	

Note.

[1].Currency conversion as per Forex rates on September 18, 2019 (https://www.forex.com/en-uk/support/currency-converter/) ,1 RMB = 0.14117 USD; 1 AUD = 0.68396 USD.

[2]. According to the Crimes Amendment (Penalty Unit) Act 2017, 1 penalty unit = AUD 210 on or after July 1, 2017.