

Implementing the Ballast Water Management Convention in Shipping Practice: Emerging Threats, Operational Issues and Solutions

Michael Boviatsis, Dionisios Polemis and Vasileios Tselentis

Department of Maritime Studies, University of Piraeus, Piraeus 18534, Greece

Abstract: Since the new BWM (Ballast Water Management) Convention entered into force in 2017, the ballast water should be cleansed of any harmful aquatic organisms, pathogens, wastes or even bacteria before being released into a new aquatic environment. For this purpose, the ships are required to carry (i) a BMW plan with detailed descriptions upon the implementation of the Convention's requirements, (ii) a ballast water record book, clearly stating the release spots and stations of ballast water, and (iii) an International Water Management Certificate, stating if the ship should abide the D-1 or D-2 standards. The research questions of this paper are, (i) should these standards apply when ballast water is released into more aggressive aquatic environments than the one where the outgoing ballast was collected? (ii) how will a port authority be able to enforce the Convention's rules when the water release happens in open waters and how can a vessel be criminalized? (iii) are the Port Facilities prepared and equipped in a global spectrum with the necessary tools to handle the ships' demand for wastewater unloading? (iv) how can the emerging operational issues be dealt with effectively?

Key words: BWM Convention, BWM plan, BWM record book, BWM aquatic(bio) map.

1. Introduction

Since the introduction of steel ships, water has been used as a ballast to stabilize vessels at sea. Ballast water is used to maintain safe operating conditions during a trip. This practice reduces pressure on the hull, provides transverse stability, improves propulsion and flexibility, and compensates for weight changes at various cargos, including fuel and water consumption [1].

While ballast water is essential for safe and efficient modern shipping operations, it can inflict severe ecological, economic and health damages due to the many marine species carried on ship ballast tanks. These include bacteria, germs, small invertebrates, eggs, cysts and larvae of various kinds [2].

In addition, transferable species can survive to create a breeding population in the host environment, making them invasive, competing with other species and

multiplying in proportions of pests.

To counter those threats, the BWM (Ballast Water Management) Convention was implemented in 2017 to regulate ballast water discharge and reduce the risk of transferring invasive aquatic species into the sea. Today, all ships in operation must manage their ballast water discharges according to a ship-specific ballast water management plan to comply with the discharge standards. Early compliance with the regulation should begin with a holistic approach of selecting a type-approved BWTS (Ballast Water Treatment System) as a primary disinfection medium and the effective use of treatment chemicals to keep the ballast water tanks and system in control. Every detail matters when complying with the ballast water discharge standards.

Additionally, the loading of seawater into the ballast tanks over time results in the accumulation of mud and silt, along with invasive species. If left untreated, the heavy sedimentation layer formed in the ballast tanks

Corresponding author: Michael Boviatsis, Ph.D. candidate, research fields: maritime law, maritime regulations, maritime policy.

may significantly reduce the disinfection efficacy of the ballast water treatment, resulting in operational challenges. For ships using electro-chlorination systems, releasing chlorinated ballast water into the sea can negatively impact the marine ecosystem and risk facing non-compliance with the discharge standards [3].

2. The Emerging Threats

Scientists first recognized the signs of the introduction of alien species after the mass appearance of *Odontella* algae (*Biddulphia sinensis*) in the North Sea in 1903. But by the 1970s, the scientific community began to analyze the problem in detail. In the late 1980s, Canada and Australia were among the countries with issues with invasive species and raised their concerns with the IMO (International Maritime Organization) MEPC (Marine Environment Protection Committee) [4].

The problem of invasive species in ships' ballast water is mainly due to the increased volume of trade and traffic in recent decades, and, as maritime trade volumes continue to grow, the problem may not yet have reached its peak. Nevertheless, the consequences in many parts of the world have been devastating. Moreover, quantitative data show that bio-invasions continue to grow alarming, and new areas are constantly being introduced [5].

The spread of invasive species is now recognized as one of the greatest threats to the ecological and economic sustainability of the planet. These species cause enormous damage to the biodiversity and precious natural wealth of the land. Moreover, the direct and indirect effects on health are becoming increasingly severe, and the damage to the environment is often irreversible [6].

Some examples of invasive species related to ballast water are (i) freshwater zebra mussel, (ii) sea walnut, (iii) green crab. A detailed analysis of those species is listed below.

2.1 Freshwater Zebra Mussel

Dreissena polymorpha, commonly known as the zebra mussel, lives in freshwater and is native to southern lakes in Russia and Ukraine. The zebra mussel has become an invasive species that is frequently spreading via ballast water. In North America, Great Britain, Ireland, Italy, Spain, and Sweden, the species has invaded native habitats. The mussels take oxygen and food from the water, limiting the resources available for native species and disrupting local ecosystems. Zebra mussels can have a significant impact on algae in the habitats they invade [7]. Invasive zebra mussels, often in monotypic populations, have been shown to damage abiotic components found in invaded habitats such as boats, waterways, harbors, water treatment plants, and power plants [8].

2.2 Sea Walnut

Mnemiopsis leidyi, commonly known as the sea walnut, is a ctenophore species in the class Tentaculata. This species is native to the eastern coast of North and South America. Currently, *Mnemiopsis leidyi* has become invasive through the transfer of ballast water to the Black, Azov, Aegean and Marmara Seas, west coast of Sweden, and the Southern and Northern Baltic Sea [9]. This carnivorous species feeds on zooplankton, crustaceans, fish eggs and larvae. Some individuals are known to consume individuals of their own species. Specifically, *Mnemiopsis* sp. has become an ecological problem for local fisheries because they have been linked to the diminishing zooplankton population [10].

2.3 Green Crab

Carcinus maenas, commonly known as the green crab, is native to the Baltic Sea and the northeastern Atlantic Ocean. This species has become invasive to North America, South Africa, South America, Asia, and Australia. This widely spreading invasive species is often distributed by ship ballast water [11]. *C. maenas* is a voracious predator to many species such as worms, mollusks, oysters, and clams. The

competitiveness and efficiency of this species out-competes native crabs and lobsters. Specifically, the green crab disrupts eelgrass beds, often home to diverse fish populations. For aquaculture and fishing industries, *C. maenas* poses a particular threat due to its appetite for valuable farmed mollusks [12].

Preventing the transfer of invasive species and coordinating a timely and effective response to invasions requires cooperation and collaboration between governments, the economic sector, non-governmental organisations and international treaty organizations. The United Nations Convention on the Law of the Sea (Article 196) provides the global framework by requiring States to work together to prevent, reduce and control marine pollution, including the deliberate or accidental introduction of a specific part of the marine environment, which can cause significant and harmful changes in it [13].

3. The BWM Convention

The IMO has been at the forefront of the international effort, committing itself to tackle the transport of IAS (infiltrating aquatic species) via shipping. In 1991, the MEPC adopted international guidelines to prevent the introduction of unwanted marine organisms and pathogens from ship ballast water and sediment discharges (MEPC resolution.50 (31)), while the UNCED (United Nations Conference on Environment and Development), held in Rio de Janeiro in 1992, recognized the issue as a significant international concern [14].

In November 1993, the IMO Assembly adopted Resolution A.774 (18) based on the 1991 Guidelines, requesting the MEPC to review the Guidelines and to develop legally binding provisions. In addition, the organization adopted Resolution A.868 in November 1997 (20)—Guidelines for the control and management of ballast water in ships to minimize the transport of harmful aquatic organisms and pathogens, calling on its Member States to use these new guidelines when addressing the issue of IAS [15].

After more than 14 years of complex negotiations between the IMO Member States, an international convention on the control and management of ballast water and sediment (BWM) was adopted by consensus during a diplomatic conference held at the IMO headquarters in London. On February 13, 2004, the Secretary-General of the IMO stated that the new Convention would be an essential step in protecting the marine environment for this and future generations. “Our duty to our children and their children cannot be exceeded. I am sure we would all like them to inherit a world of clean, productive, safe and secure seas - and the outcome of this conference, by eliminating an increasingly and more serious threat, will be necessary to ensure this” [16].

The BWM Convention entered into force on September 8, 2017. The Convention requires all ships to implement a BWM plan. All vessels must carry a ballast water logbook and are required to perform ballast management procedures to a given standard. The contracting parties to the contract can take additional measures subject to the criteria set out in the agreement and the IMO guidelines [17].

Several articles (such as 2 and 9) and the Annex (Section B and D) of the BWM Convention refer to guidelines to be developed in Resolution 1 of the Organization and the Conference, calling on the IMO to establish these guidelines urgently and to adopt them as soon as possible and, in any case, before entry into force of the Convention, to facilitate the universal and uniform application of the instrument [18].

Initially, MEPC, at its fifty-first meeting in April 2004, approved a program to develop guidelines and procedures for the uniform implementation of the BWM Convention listed in Resolution 1 of the Conference, including additional instructions required but not included in the resolution. The program was further extended to the fifty-third session of the MEPC in July 2005 to develop and adopt 14 sets of guidelines, the last of which was adopted by MEPC Resolution.173 (58) in October 2008. Some of the

guidelines have been revised since their initial approval and have access to various other relevant guidance documents [19].

During the development process of the Convention, significant efforts were made to develop appropriate standards for BWM (Annex, Section D). These are the ballast water exchange standard and the ballast water performance standard. Vessels performing ballast water exchanges must do so with a ballast volume efficiency of 95%, and ships using a BWM system must meet a performance standard based on agreed organisms per unit volume [3].

According to Regulation D-3 of the BWM Convention, BWM systems used to comply with the Convention must be approved by management, considering the guidelines for the approval of BWM systems (G8). The guidelines (G8) were revised in 2016 and became mandatory codes for BWM systems (BWMS code) [20].

Regulation D-3 also stipulates that ballast management systems using active substances to comply with the Convention must be approved by the IMO by the approval procedure for BWM systems (G9). Procedure (G9) consists of a two-step process—essential and final approval—to ensure that the BWM system does not pose excessive environmental risks, human health, property or resources.

A technical team of experts has been set up under the auspices of GESAMP to review the proposals submitted for the approval of ballast management systems using Active Substances. The GESAMP-BWWG (GESAMP Working Water Group) reports to the Agency on whether such a proposal poses excessive risks by the criteria set out in Procedure (G9) [21].

The contract requires review to determine if there are appropriate technologies to achieve the standard. Accordingly, the MEPC conducted a series of such revisions and agreed that appropriate technologies were in place to meet the standard contained in Regulation D-2 of the BWM Convention [19].

The adoption of all the necessary guidelines for the

uniform implementation of the BWM Convention and the approval and certification of modern ballast water treatment technologies have posed severe obstacles to the ratification of the instrument, and some other countries have stated their intention to accede to this Convention in the near future [22].

4. The Extent of the Impact of Ballast Water on a Region

Ballast water does not affect only the maritime sector or the environment in general but also the everyday lives of the habitats near the affected areas. The outcome of this phenomenon is that the affected ecosystem is drastically changed, with severe environmental, health and even economic consequences. In several countries, introduced, microscopic, “red-tide” algae have been absorbed by filter-feeding shellfish, such as oysters. When eaten by humans, these contaminated shellfish can cause paralysis and even death [23]. Studies revealed that in North America, the introduced European Zebra Mussel had infested over 40% of internal waterways, and over US \$5 billion has been spent on control measures since 1989. The list goes on, with hundreds of examples of significant ecological, economic and human health impacts across the globe. It is even feared that cholera may be transported in ballast water. In addition, hundreds of other organisms carried in ballast water cause problematic ecological effects outside of their natural range around the world [18].

The outcome of ballast water can be successfully summarized in the below-mentioned categories: (i) the extermination of the species populating the area before the “new-transferred” via ballast water species emerge, (ii) the gradual denaturation of the local and regional biodiversity, leading to the destruction of vast ecosystems, (iii) direct impact of public health, with the proliferation of many hostile bacteria and other hostile microorganisms to human health, (iv) severe impact on local economies, such as fisheries, tourism attractions and other human coastal activities, (v) finally, direct

effects on coastal industries that use water extraction and water-based resources as material for their production [22].

5. Present Issues and Proposed Solutions

As discussed above, the BWMS is currently expanding rapidly. Still, there are many cases where there is an overload internally on shipping companies, upon handling the newly required processes, or even externally when inspections are carried out, or external stakeholders are included as part of the process. To whitewash the amount of operation required, an option would be for these standards not to be applied when ballast water is released into more aggressive aquatic environments than when the outgoing ballast was collected. For this plan to be implemented, we need a global map describing, analysing and marking the aggressiveness of biodiversity at a regional level. By utilizing a “bio-map” such as this, we will considerably simplify the operational processes by creating a filter before the initiation of each BWM process evaluating if the utilization of the BWM process will be impactful [3].

Another aspect regarding how a port authority will be able to enforce the Convention’s rules when the water release is implemented has already been handled initially by the US coast guard and gradually by other authorities in similar cases to ballast water. Namely, US Coast Guard has developed a process of notifying a source of pollution, such as oil or other waste, investigating the maritime routes of all passing ships in the area and locating the liable vessel. As it is known, oil and other wastes have individual characteristics that make them distinct from all others. The same applies to the ballast water, especially when the BWM processes require sampling, as already analyzed above. Even if the illegal spilling of ballast water is implemented in open waters, the same process as with oil spills is utilized, namely, when the ballast water carrying malicious microorganisms enters the EEZ (exclusive economic zone) of a country, this state can criminalize the act under the National or International Legislation

(e.g. UNCLOS Article 204) [24].

Presently, ships may be subject to port State control in any port or offshore terminal of a Party to the BWM Convention. This inspection may include verifying that there is onboard a valid Certificate and an approved ballast water management plan; inspection of the ballast water record book; and/or sampling of the ship’s ballast water, carried out in accordance with the Guidelines for ballast water sampling (G2). However, the time required to analyse the samples shall not be used as a basis for unduly delaying the operation, movement or departure of the ship [25].

To the question, if the Port Facilities are prepared and equipped in a global spectrum with the necessary tools to handle the ships’ demand for wastewater unloading, the answer becomes complicated. The ports’ most efficient method to address this issue is proactiveness and adaptation [26].

Precisely, the ports could measure the volume of required actions before these materialize and install the proper quantity of equipment to respond to demand and avoid conjunctions. Additionally, other equipment, such as secondary tanks, pumps from cargo handling or even installed temporarily to supportive ships, such as tugs, can reciprocate to sudden spikes in demand for ballast water treatment [27].

The abovementioned plan of creating an aquatic map, stating the level of threat that the local microorganisms pose to other marine environments, can only be achieved through a coordinated action plan of IMO involving all member states (BWM Convention members and non-members). Specifically, each member state should provide sufficient data from their sovereign biodiversity areas. All those data should be collected and evaluated from the same working group, which will compare the aggressiveness of each nation’s biodiversity, as depicted by each respective national data gathered. Based on this method, an international “bio-map” evaluating the biodiversity aggressiveness status of each region can be created, adding to the operational efficiency and effectiveness of BWM

methods and processes [28].

Another issue is that ships usually send their treated ballast water samples to an onshore lab for certification to comply with the D-2 standard. The scenario a vessel manager would least hope for is receiving a non-compliance lab result due to high biological “off-spec” readings. If the lab report indicates non-compliance, the vessel manager will risk spending unnecessary resources and time on re-deploying the process again. To avoid this instance, Ballast Water Test Kits have been designed to be used on the vessel for routine indicative and operational testing and used to supplement 3rd party laboratory verification analysis [29].

6. Conclusion

Ballast water is essential for safe and efficient modern shipping operations. Still, it creates at the same time severe ecological problems due to the multitude of marine species carried in ships’ ballast water. The ballast water includes bacteria, microbes, small invertebrates, eggs, cysts and larvae of various species.

When ballast water is loaded, many microscopic organisms and sediments are introduced into the ship’s ballast tanks, with the majority of them being able to survive in those tanks. However, if suitable conditions exist in the region where those microorganisms are released, they will start to reproduce, harm the existing biodiversity and become invasive species. Potentially, these microorganisms can (i) exterminate the native species, (ii) destroy the local and regional biodiversity, (iii) harm the public health, (iv) inflict damage to regional economies, and (v) negatively affect coastal industries and endeavours.

The international reaction to this phenomenon was the initiation of the BWM Convention, which regulated the operational processes required for ballast water handling and the instalment of D-1, D-2 and D-3 standards. But an outcome of the rapid expansion of the BWM Regulation was the lack of equipment and proper organization from port authorities and other

stakeholders to satisfy the present demands from ship-owners. Some viable options to limit the current market demand for the port authorities to evaluate and invest in the proper equipment are modifying the existing supportive equipment in port authorities and utilizing tugs and other supporting ships. Additionally, with the coordinated effort from all nations, a “biodiversity” map may be drafted, evaluating the biodiversity aggressiveness status of each region, thus providing a filter before the initiation of each BWM process, assessing if the utilization of the BWM process will be impactful.

Relating the on-board operational challenges, the ballast tanks should be cleaned regularly to prevent heavy sedimentation. Each shipping company should comply with the ballast water discharge standard by treating chlorinated water before discharge. Additionally, the ballast water should be monitored by conducting biological sample tests during the voyage and before the next discharge, in order to comply with the regulatory framework.

The MEPC has recognized that challenges may be expected with the entry into force of an entirely new treaty. There may be a need for future improvements to the BWM Convention in the light of experience gained. MEPC 71 adopted an important MEPC resolution, on “the experience-building phase associated with the BWM Convention”.

This envisages a three-stage approach—data gathering; data analysis; and Convention review. Based on the experience and feedback gained, as well as the analysis of the data gathered, draft amendments to the Convention have been put forward presently for consideration at MEPC 79.

References

- [1] Gerharda, W., Lundgreenb, K., Drilletc, G., Baumlerd, R., Holbechb, H., and Gunsch, C. 2019. “Installation and Use of Ballast Water Treatment Systems—Implications for Compliance and Enforcement.” *Ocean & Coastal Management* 181: 104907.
- [2] Bax, N., Williamson, A., Aguerro, M., Gonzalez, E., and Geeves, W. 2003. “Marine Invasive Alien Species: A

- Threat to Global Biodiversity.” *Mar. Policy* 27: 313-23.
- [3] Chen, N., Yang, Z., and Luo, W. 2021. “The Working Principle of Ballast Water Management System.” In *Development and Implementation of Ship BWMS*. Singapore: Springer. ISBN: 978-981-33-6864-4.
- [4] Marine Environment Protection Committee (MEPC). 2022. Accessed December 22, 2021. <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-default.aspx>.
- [5] David, M., and Gollasch, S. 2019. “Risk Assessment for Ballast Water Management—Learning from the Adriatic Sea Case Study.” *Mar. Pollut. Bull.* 147: 36-46.
- [6] Endresen, Ø., Behrens, H. L., Brynstad, S., Andersen, A. B., and Skjong, R. 2004. “Challenges in Global Ballast Water Management.” *Marine Pollution Bulletin* 48 (7-8): 615-23.
- [7] Roberts, L. 1990. “Zebra Mussel Invasion Threatens US Waters: Damage Estimates Soar into the Billions for the Zebra Mussel, Just One of Many Invaders Entering US Waters via Ballast Water.” *Science* 249 (4975): 1370-2.
- [8] Minchin, D., Lucy, F., and Sullivan, M. 2002. “Zebra Mussel: Impacts and Spread.” In *Invasive Aquatic Species of Europe. Distribution, Impacts and Management*. Dordrecht: Springer, pp. 135-46.
- [9] Józwiak, Z. 2011. “Ships’ Ballast Water in the Southern Baltic Area.” In *Zeszyty Naukowe/Akademia Morska w Szczecinie*, pp. 38-46.
- [10] Holbech, H., and Pedersen, K. L. 2018. “Ballast Water and Invasive Species in the Arctic.” In *Arctic marine Resource Governance and Development*. Cham: Springer, pp. 115-37.
- [11] Cohen, A. N., Carlton, J. T., and Fountain, M. C. 1995. “Introduction, Dispersal and Potential Impacts of the Green Crab *Carcinus maenas* in San Francisco Bay, California.” *Marine Biology* 122 (2): 225-37.
- [12] Behrens Yamada, S., and Gillespie, G. E. 2008. “Will the European Green Crab (*Carcinus maenas*) Persist in the Pacific Northwest?” *ICES Journal of Marine Science* 65 (5): 725-9.
- [13] De Souza Rolim, M. H. F. 2008. *The International Law on Ballast Water: Preventing Biopollution*. Leiden, Netherlands: Brill.
- [14] McCammon, A. L. 1992. “United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, during 3-14 June 1992, and the 92nd Global Forum, Rio de Janeiro, Brazil, 1-14 June 1992.” *Environmental Conservation* 19 (4): 372-3.
- [15] Drake, L. A., Bailey, S. A., Brydges, T., Carney, K. J., Ruiz, G. M., Bayly-Stark, J., Drillet, G., and Everett, R. A. 2021. “Design and Installation of Ballast Water Sample Ports: Current Status and Implications for Assessing Compliance with Discharge Standards.” *Marine Pollution Bulletin* 167: 112280.
- [16] IMO. 2020. Ballast Water Management Programme. Department of Economic and Social Affairs (un.org).
- [17] GARD. 2017. *Ballast Water Management—Are You Ready for 8 September 2017?*
- [18] David, M., Gollasch, S., Elliott, B., and Wiley, C. 2015. “Ballast Water Management under the Ballast Water Management Convention.” In *Global Maritime Transport and Ballast Water Management*. Dordrecht: Springer, pp. 89-108.
- [19] Outinen, O., Bailey, S. A., Broeg, K., Chasse, J., Clarke, S., Daigle, R. M., Gollasch, S., Kakkonen, J. E., Lehtiniemi, M., Normant-Saremba, M., and Ogilvie, D. 2021. “Exceptions and Exemptions under the Ballast Water Management Convention—Sustainable Alternatives for Ballast Water Management?” *Journal of Environmental Management* 293: 112823.
- [20] IMO. 2022. BWMS Code—Code For Approval of Ballast Water Management Systems—Resolution MEPC.300(72), Accessed March 17, 2022. [https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/MEPCDocuments/MEPC.296\(72\).pdf#:~:text=%22BWMs%20Code%20means%20the%20Code%20for%20Approval,relating%20to%20amendment%20procedures%20applicable%20to%20the%20Annex.%22](https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/MEPCDocuments/MEPC.296(72).pdf#:~:text=%22BWMs%20Code%20means%20the%20Code%20for%20Approval,relating%20to%20amendment%20procedures%20applicable%20to%20the%20Annex.%22).
- [21] GESAMP. 2022. “Ballast Water Management Working Group.” Accessed March 17, 2022. <http://www.gesamp.org/work/groups/34>.
- [22] Wang, Z., Nong, D., Countryman, A. M., Corbett, J. J., and Warziniack, T. 2020. “Potential Impacts of Ballast Water Regulations on International Trade, Shipping Patterns, and the Global Economy: An Integrated Transportation and Economic Modeling Assessment.” *Journal of Environmental Management* 275: 110892.
- [23] Gollasch, S., David, M., Broeg, K., Heitmüller, S., Karjalainen, M., Lehtiniemi, M., Normant-Saremba, M., Ojaveer, H., Olenin, S., Ruiz, M., Helavuori M., Sala-Pérez M., and Strake S. 2020. “Target Species Selection Criteria for Risk Assessment Based Exemptions of Ballast Water Management Requirements.” *Ocean & Coastal Management* 183: 105021.
- [24] Chen, Y. S., Kang, C. K., and Liu, T. K. 2022. “Ballast Water Management Strategy to Reduce the Impact of Introductions by Utilizing an Empirical Risk Model.” *Water* 14 (6): 981.
- [25] IMO. 2022. “Implementing the Ballast Water Management Convention.” Accessed May 7, 2022. <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Implementing-the-BWM-Convention.aspx>.
- [26] Boviatsis, M., and Daniil, G. 2022. “Legal Analysis of the US Supreme Court Position upon a Safe Berth

- Warranty and Evaluation of the UK Legal Position.” *TransNav, International Journal on Marine Navigation and Safety of Sea Transportation* 16 (1): 23.
- [27] Karlis, T., and Polemis, D. 2016. “Ship Demolition Activity: A Monetary Flow Process Approach.” *Pomorstvo* 30 (2): 128-32.
- [28] Boviatsis, M., Polemis D., and Tselendis V. 2021. “Practical Impediments to the Effective Utilization of Ballast Water Management Plan from Port facilities and Shipping practice.” In *Proceedings of the 17th Conference on Environmental Science and Technology*, 1-4 September 2021, Athens, Greece.
- [29] Liu, T. K., Wang, Y. C., and Su, P. H. 2019. “Implementing the Ballast Water Management Convention: Taiwan’s Experience and Challenges in the Early Stage.” *Marine Policy* 109: 103706.