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An Assessment of Progress in the Implementation of the BWM Convention on Ships as an Important Element in Protecting Aquatic Ecosystems

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Abstract: The purpose of this study was to assess progress in the implementation of rules for the control and handling of ballast water and sediments, regulated by the International Convention on the Control and Handling of Ship Ballast Water and Sediments (BWM Convention). The survey was conducted in 2018-2019 among seafarers responsible for handling ballast tanks. Analysis of the survey data revealed that despite the introduction of water treatments, ballast water continues to be a vector for the transfer of non-native organisms. This is due to the low effectiveness of the methods used, and the fact that 8% of the respondents answered that no BWT systems were used on the ships they manage. Despite this, some seafarers (4.7%) indicated that increasing environmental awareness and adherence to BWM principles should result in improved protection of aquatic ecosystems. Therefore, the global problem concerning the transport of non-native organisms via ballast water has still not been solved effectively. In the near future, improved BWT systems should be introduced, which after proper training of the crew will act as a barrier to the transfer of non-native organisms in ballast water.

Keywords: ballast water, foreign species, BWM convention, ballast water treatment, sea transport

1. Introduction

The chemical composition of water is shaped by natural phenomena and, to a large extent, depends on the structure of the catchment area, soil and rock environment, and the level of pollution in the area of the water's origin (Pyłka-Gustowska 2000). The chemical composition has been significantly affected by the development of the economy and maritime transport. Aquatic and terrestrial areas used by port infrastructure to enable maritime transport are subject to a strong anthropogenic influence (Directive 2002/413/EC of 30 May 2002). The continuous flow of ships arriving and departing from many different environments provides a basis for the transmission of marine organisms in ballast tanks (David & Gollasch 2018, Gollasch & David 2019). These organisms have a major impact on the environment surrounding the ports which has led to many studies on the composition of species in the ships' ballast waters (Zvyagintsev & Selifonova 2010, Butron et al. 2011, Carney et al. 2011) and ballast water treatment systems (Albert et al. 2013). Under favourable environmental conditions, e.g. temperature, suitable substrate and salinity, non-native species transported in ballast water may establish and spread in the ecosystems surrounding the port where ballast water was exchanged (Ojaveer et al. 2016, Normant-Saremba et al. 2017, David et al. 2019, Gollasch & David 2019).

The problem of uncontrolled movement of aquatic organisms and pathogens from ballast water as a result of international maritime transport has resulted in the creation of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Rastegary 2017), or the Ballast Water Management convention. Drafted in 2004 under the supervision of the International Maritime Organisation (IMO), and ratified on the 8th of September 2016, the document became a legal instrument which covers all elements of international shipping (Rastegary 2017, David & Gollasch 2018, Gollasch & David 2019). According to the principles of the Convention, as of the 7th of September 2017, all shipowners who have ships designed or constructed to carry ballast water, are obliged to comply with it. Under the BWM regulations, ships are required to carry out an inspection on the basis of which they can receive an International Ballast Water Management Certificate and to have an approved Ballast Water Management Plan (BWMP) and a Ballast Water Record Book (BWRB) (International Convention for the Control and Management of Ships' Ballast Water and Sediments, Rahman 2017, Gollasch & David 2019, Kuroshi et al. 2019).

The BWM Convention also forced ship masters to remove ballast water at a distance of at least 370 km from the coast, to clean the ballast tanks more frequently and introduce various ballast water treatment systems. The water treatment systems recommended by IMO that meet the Convention's D-2 norm are based, among other things, on the use of UV radiation, filtration, water heating, biodegradation, and chemical disinfection, often working in combination with one another (BWM Convention, Kuroshi et al. 2019).

The aim of this work is to assess the progress in the implementation of the principles of Control and Management of Ships' ballast water and sediment regulated by the BWM Convention and the attitude of seafarers, who are responsible for managing the exchange of ballast water, towards the new regulations.

2. Material and Methods

This study was based on surveys used to collect information from seafarers active in various posts. The surveys were carried out in 2018 and 2019, with 2000 questionnaires in total handed to seafarers in charge of the management of ballast tanks and related work. This group of respondents was chosen due to the nature of their work on the ship which was related to the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The study took into account only those questionnaires which included answers concerning ships with ballast tanks. After excluding documents not meeting the requirements, 1200 completed questionnaires were received. The questionnaire was divided into 2 parts. The first section concerned the current situation of the ships operation according to the type and size of ballast tanks, as well the Ships' region of operation in order to determine the significance of the ballast water problem. The second range of questions concerned seafarers' training and awareness of changes in legislation and the introduction of the International Convention for the Control and Management of Ships' Ballast Water and Sediments and their knowledge of potentially harmful organisms carried in ballast water (Appendix 1). The design of the survey also allowed for an examination of the seafarers' opinions and attitudes (such as their hopes and fears regarding the effectiveness of the introduced ballast water treatment solutions) to the new rules for the Control and Management of Ships' ballast water and sediments.

3. Results

3.1. Characteristics of the ships surveyed in terms of their use

The questionnaires were received from respondents who indicated that under the last three contracts they managed primarily seven types of ship, 50% of which were ships under 100 meters in length (600 ships), 33% were ships between 100 and 200 meters in length and 17% were ships over 200 meters (Fig. 1). The majority of the seafarers worked on ships operating exclusively in European areas (58% of all ships, including 600 ships under 100 metres and 96 ships between 100 and 200 metres long). In contrast, only 100 ships operated on the Europe-Asia-Africa-America route (10%) and 404 ships (32%) operated worldwide. Comparing the route of ships with the capacity of their ballast tanks, ships sailing exclusively in Europe accounted for as much as 71% of ships with ballast tanks no bigger than 5,000 m^3. On the other hand, ships sailing on routes between Europe and America, Europe and Africa or Europe and Asia had tanks between 5,000 m^3 and 20,000 m^3. In the case of ships sailing all over the world, the majority of them (as much as 90% of them) were ships with ballast tanks exceeding 20,000 m^3 (Fig. 2).

The results of the surveys showed that the larger the vessel is, the larger the ballast tanks are, which may lead to the increased number of non-native organisms being transported in ballast water.

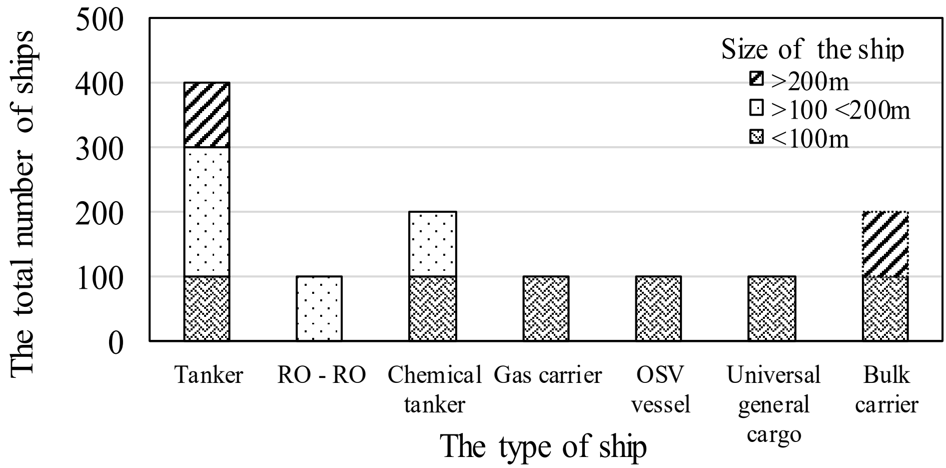

Fig. 1. Characteristics of the vessels mentioned in the survey in terms of type and length

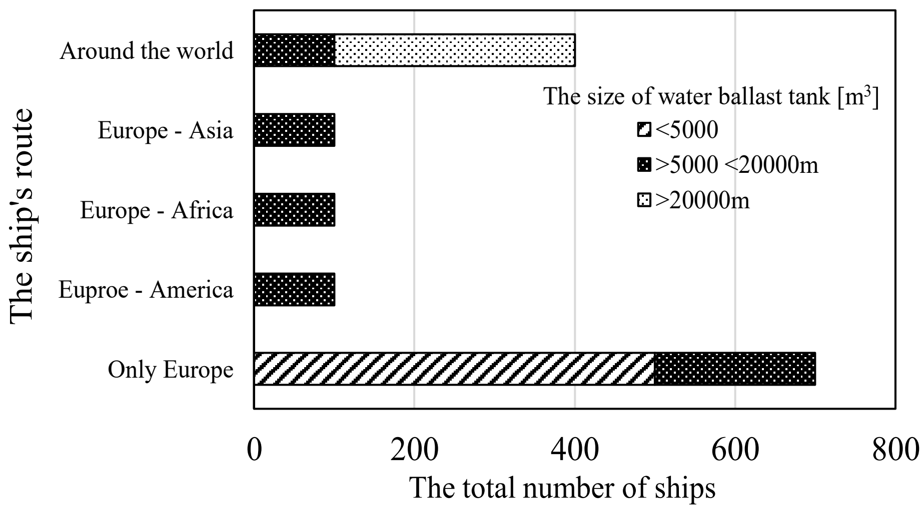

Fig. 2. Characteristics of the vessels mentioned in the survey in terms of routes and ballast tank volume

3.2. Assessment of seafarers' awareness of changes in legislation under theInternational Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention)

As many as 15% of the seafarers surveyed were not familiar with the recommendations of the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The group of respondents who did not attempt to learn the BWM (Ballast Water Management) principles, in force since September 2017, were made up of seafarers who were not in charge of water treatment management (most often a seaman or a third officer). At the same time, half of all respondents negatively commented on the introduction of additional recommendations with regard to the control and management of the vessel's ballast water and sediments. As many as 20% of the 1200 respondents were not adequately trained for the proper treatment of ballast water and its sediments or were not sure whether they had received such training. Of all the seafarers who were familiar with the BWM rules, as much as 90% considered the threat of non-native species being transferred to new areas as still apparent. In the multiple choice question, they most frequently indicated that the threats to new habitats from ballast tanks were microorganisms (83%),_shellfish (66%), protozoa (50%) and parasites (50%). On the other hand, 10% of the same group of respondents stated that with the correct operation of the ballast water treatment method (BWT), the waters from ballast tanks do not pose a threat in terms of the transmission of non-indigenous aquatic species (Fig. 3).

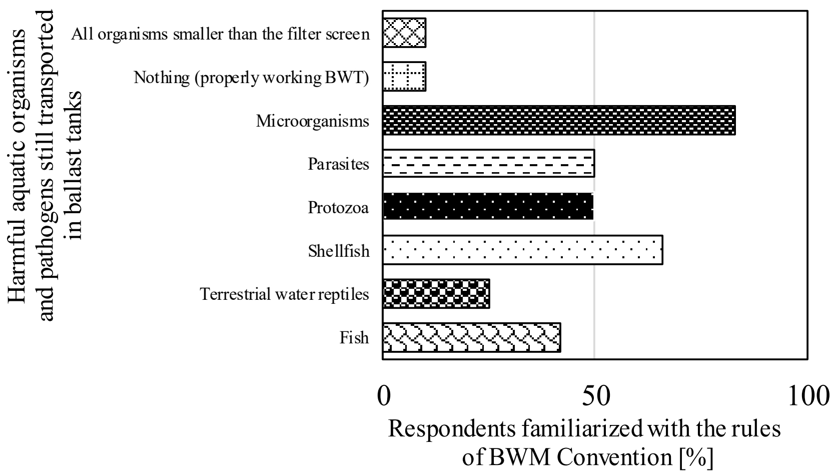

Fig. 3. Potentially harmful groups of aquatic organisms and pathogens transported in ballast tanks in the opinion of the surveyed seafarers familiar with the BWM Convention rules

When asked (a multiple choice question) about the time and place of changing the water in the ballast tanks, the surveyed seafarers most often indicated ports (50%), open waters (41.7%) and at the time of unloading (41.7%). At the same time, only 8.3% indicated places specially designated by the administration (e.g. Norway has specially designated areas where ballast water should be changed before it is emptied in a Norwegian port). In the respondents' answers to the question about the applied methods of ballast water treatment before its release, mixed systems which combine mechanical and chemical processes were mentioned most often (42%), biological and physical methods were indicated much less frequently (17% each) and only 8% of the respondents indicated an answer suggesting no treatment of ballast water (Fig. 4).

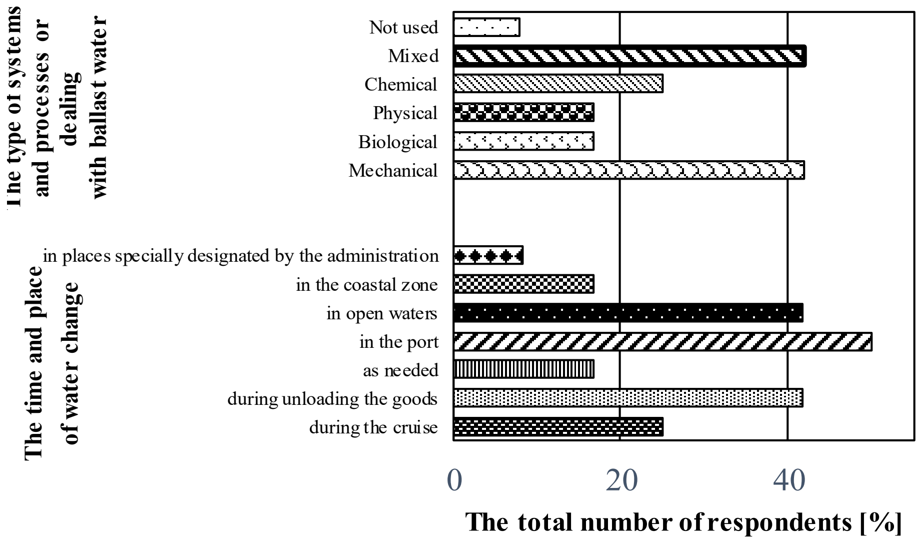

Fig. 4. Responses of respondents concerning treatment systems and processes and the place and time of ballast water exchange

3.3. Seafarers' hopes and concerns about the requirements of the BWM Convention

Out of 1,200 respondents, 600 did see a chance for the complete elimination of the transfer of harmful aquatic organisms and pathogens by using appropriate ballast water treatment systems (Fig. 5).

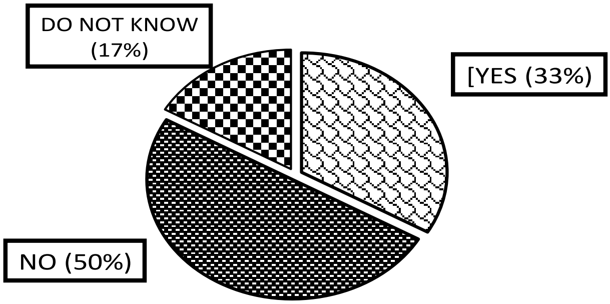

Fig. 5. Responses concerning the chance for complete elimination of the transfer of harmful aquatic organisms and pathogens with ballast water

Considering possible problems with the application of the new ballast water rules, as much as 40% of all seafarers were concerned about the increased number of duties by insufficiently trained crew. Almost as much as 35% declared the possibility of bypassing the regulations due to the overly complicated operation of ballast water treatment systems. 17% of respondents indicated economic issues, the long time needed to adjust ships to the new requirements, and additional problems during inspections as main concerns (Fig. 6).

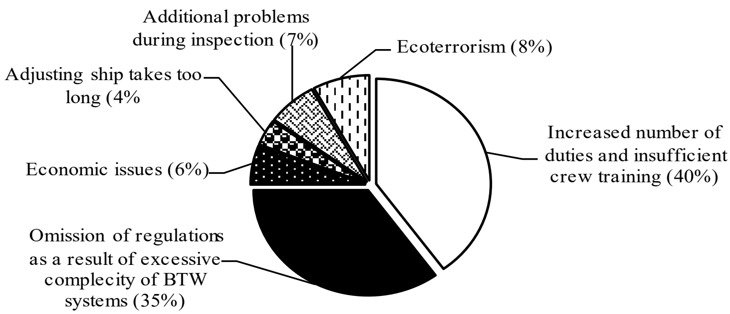

Fig. 6. Seafarers' concerns about the possibility of problematic situations arising from the introduction of new restrictions under the BWM Convention

A large group of respondents (80%) expressed confidence in the provisions for permanent prevention and final elimination of the transmission of harmful aquatic organisms and pathogens (Fig. 7). Some seafarers indicate that increasing environmental awareness and compliance with the BWM principles will lead to improved protection of aquatic ecosystems. However, as many as 33% of seafarers do not see any positive aspects in the introduction of new regulations in ballast water management (Fig. 7).

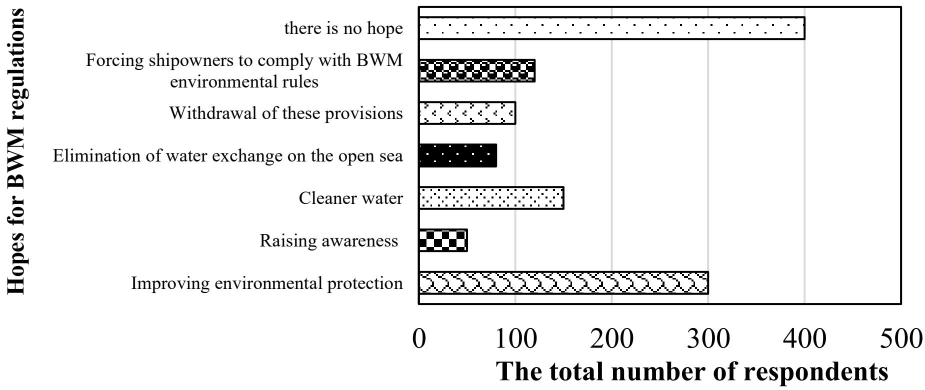

Fig. 7. Hopes of seafarers associated with the introduction of new restrictions on board the ship in accordance with the BWM Convention

4. Discussion

Globally, legislative work on regulations for the management of Ships' ballast water has been forced by the growing problem of non-native species being transported to new environments (Directive 2002/413/EC of 30 May 2002, HELCOM, International Convention for the Control and Management of Ships' Ballast Water and Sediment). According to information collected by HELCOM, 118 non-native species have been introduced into the Baltic Sea in the last 100 years (Fig. 8). Of these, as many as 90 have settled there permanently (HELCOM List of non-indigenous and cryptogenic species in the Baltic Sea).

This problem is not unique to the Baltic Sea, since as many as 7,000 species (Carlton 1999) are transferred in this way between ports around the globe. In the neighboring North Sea, as many as 150 non-native aquatic animal species have been identified (Gollasch et al. 2009), making it an area highly affected by the introduction of non-native species (Vila et al. 2010). It should be noted that the ports in the Baltic and North Sea are intensely connected via international maritime traffic, which may enhance the transfer and easy acclimatization of non-native species. However, the problem of ballast water transfer of allochthonous organisms does not only affect European ports, but also ports across the entire world (Ng et al. 2015, Kim et al. 2016, Kiu & Hall 2018, Li et al. 2018). That is why the problem of microorganisms that migrate to new environments in this way has been increasingly often researched (Atlung et al. 2012, Delacroix et al. 2013, Ziegler et al. 2018, Hess-Erga et al. 2019, Petersen et al. 2019).

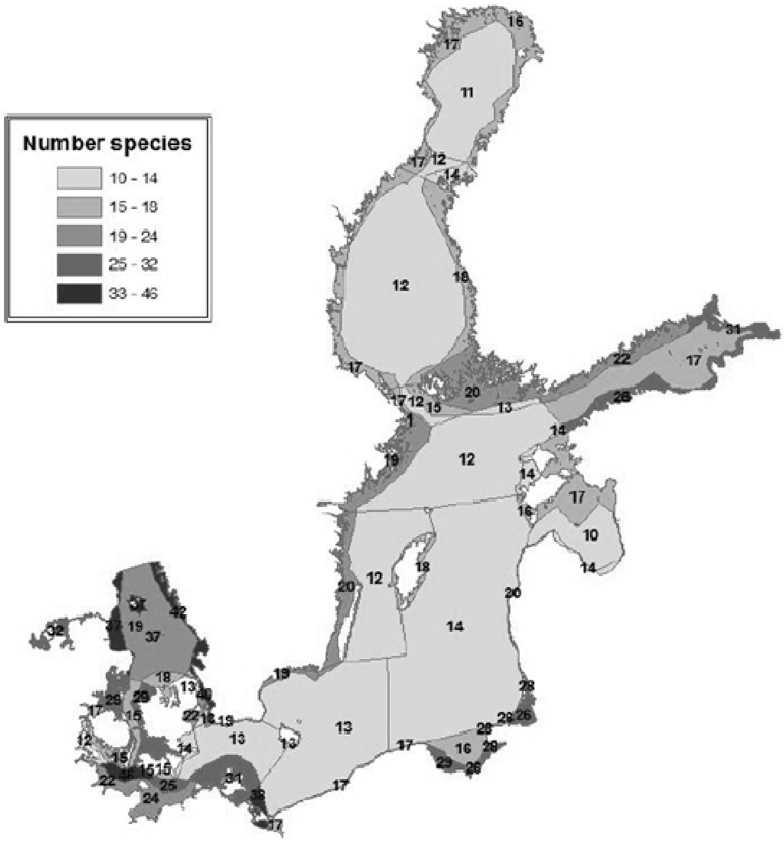

Fig. 8. Number of observed non-indigenous species in the Baltic Sea coastal and offshore areas. Source: HELCOM List of non-indigenous and cryptogenic species in the Baltic Sea

It is difficult to unequivocally determine the distribution of the populations of non-native animals carried by individual vessels. The abundance of organisms in the ballast water of ships sailing between the same ports varies depending on the season, the presence of organisms in the vicinity of the ship, and the security measures used on the ship (Golasch et al. 2000). In addition, different species have different tolerances to ballast tank conditions. Some can survive in ballast tanks for several days (Flagella et al. 2007) and therefore can be relocated to ports in close proximity to the point of departure. According to Carlton (1999), short-range vessels are a major vector for the transfer of non-native organisms. Some of these organisms, due to their shorter routes, may become invasive in marine and estuarine habitats, with negative ecological, economic and human health impacts (Anil et al. 2002) and effects on biodiversity and ecosystem services (Stachowicz et al. 2007). However, long-range vessels do not pose less of a threat to the transfer of allochthonous organisms to new environments. Although most of them are not able to survive long voyage times, those that manage to adapt to the adverse conditions in ballast tanks (especially microorganisms of unknown potential) become resistant and increase their survival capacity. Such adaptability may pose a much greater threat in terms of gaining the capacity to facilitate invasions than the mere transfer of non-native yet non-invasive organisms to new ecosystems (Gollasch et al. 2000, Gollash et al. 2009, Ng et al. 2015, Kim et al. 2016, Hess-Erga 2019). This situation makes ship passage routes a key element in combating the problem of transferring organisms to new ecosystems.

The problem related to the transport of non-native organisms with ballast water has still not been successfully resolved despite numerous studies on their appearance and ecology in new areas (Gollasch 2006, Czerniejewski & Filipiak 2001, Bauer & Woog 2008, Alexandrowicz & Alexandrowicz 2010, Brandorff 2011, Burton et al. 2011, David et al. 2019, Gollasch & David 2019). This is indirectly confirmed by the results of our survey, which shows that half of the respondents not only did not see a chance to eliminate the transmission of harmful aquatic organisms via ballast tanks, but as many as 40% of all seafarers are afraid of the increased number of duties associated with the operation of BWT systems which have to be performed by undertrained crew members.

The introduction of regulations for the control and proper handling of ship ballast water and its sediments has resulted in various types of ballast water treatment systems. According to the BWM Convention, these processes are procedures, activities and mechanisms designed to reduce or eliminate, in whole or in part, the risks associated with the carriage of non-indigenous species in ship ballast water. Those processes that have been approved and permitted under regulations D-2 and D-3 of that Convention can be divided into physical and chemical. The physical methods of ballast water treatment include water filtration, ultraviolet light irradiation, ultrasonic wave action, and circulation based on the ballast transfer process, during which the volume of water pumped through the tank should be at least three times the tank volume (Misorz 2017). However, pumping through less than three times the volume may be accepted provided the ship can demonstrate that at least 95 per cent volumetric exchange is met (Resolution MEPC.173(58)). The BWM Convention stipulates that ballast water exchange should be carried out by sequential, flow-through or dilution methods. On the other hand, chemical methods for ballast water treatment include disinfection processes that require the use of chemicals or biocides, e.g., chlorination, ozonation, chemical removal of sulfites and bisulfites (Misorz 2017, Hess-Erga 2019, Jung et al. 2020).

Continuous work on improvement of ballast water treatment processes as a consequence of eliminating undesirable aquatic organisms and pathogens have resulted in the creation of various BWT systems (Rahman 2017, David & Gollasch 2018, Gerhard et al. 2019, Kuroshi et al. 2019). According to the surveys, the commonly used ballast water treatment processes are mechanical, biological, physical and chemical, most often used in combination. In addition to those mentioned in the survey, other systems are used worldwide, such as UV lamps, filtration, ballast water heating, deoxidation and ozonisation (Rahman 2017, David & Gollasch 2018, Wan et al. 2018, Gerhard et al. 2019, Gollasch et al. 2019, Kuroshi et al. 2019).

However, according to Gollach and David (2019), and as confirmed by our survey, none of the systems are fully effective, as viable organisms still appear in the ballast water. Moreover, respondents indicated that in 8% of cases no BWT systems are used on their ships. Furthermore, Drillet et al. (2016) believe that the standards for the efficient operation of these systems include testing only for selected indicator organisms (e.g. pathogenic microorganisms), which is insufficient to create a full characterisation of the burden to the aquatic environment. This problem was examined by Hess-Erga et al. (2019), who correctly pointed out the lack of effectiveness of single ballast water treatment systems in the face of the diversity of organisms living in the tanks. Legal guidelines for ballast water treatment omit organisms smaller than 10 μm, which creates the risk of a lack of control of the unpredictable presence of harmful microorganisms. Most ballast water treatment systems in use utilize mechanical separation or filtration followed by a combination of chemical or physical post-treatment of tank water. Unfortunately, the common use of electrochemical or UV treatment in such conditions is hampered by the varying environment of ballast tanks and organic biocompounds. Hess-Erga et al. point out that insufficient inactivation of this group of organisms inhabiting ballast tanks could lead to potentially dangerous ecological consequences, where the success of invasive species may be aided by the microbial community that enters new environments with them. Therefore, they point out the need for intensified research on microbial invasion patterns in terms of their impact on ecosystems. Jung et al. (2020) also noted that validated BWT have failed to treat ballast water with a high density of organic matter. They also pointed out that for such ballast water, it is recommended to filter the water from the tanks during de-ballasting rather than vessel ballasting. In addition, they argue that ballast water should be re-treated when stored for long periods of time, due to the presence of high concentrations of suspended particles, which provide a specific medium for the growth of microorganisms colonizing ballast tanks. Jung et al. (2020) also draw attention to the need for regular training of the crew of ships that are equipped with ballast water treatment systems. Mere introduction of new regulations will not be sufficient if the crew is not fully prepared for the proper use of BWTs and, consequently, will not be able to carry out their proper operation and maintenance.

Another reason for the introduction of non-native species, in addition to the inefficiency of ballast water treatment systems, is the poor knowledge of BWM principles among seafarers (Rahman 2017, Wan et al. 2018, Gerhard et al. 2019, Golasch & David 2019). In our survey as much as 15% of seafarers declared no knowledge of BWM principles. For 85%, new regulations raised concerns. Equally important is the economic situation of shipowners obliged to decide which ballast water treatment systems will be most suitable for use in their ships (Tan 2015, Olenin et al. 2016, Wan et al. 2018, Gerhard et al. 2019). Many of the respondents noted that the most frequently installed BWT systems are of poor quality and prone to failure. These failures are not only due to the way the ballast water systems are constructed but also by dependence on the human factor. The results of the received questionnaires indicate that in many cases the principles of controlling and managing ships' ballast water and sediments are disregarded, which the respondents justified by the lack of readiness to implement such regulations. In addition, although the relevant bodies are required to manage the environmental programme under the BWM Convention, many seafarers complain about the lack of harmonisation of current national legislative restrictions (Verna & Harris 2016, Cohen et al. 2017, Gerhard & Gunscha 2018, Liu et al. 2019, Rak et al. 2019). Albert et al. (2013) indicate that the regulations established by the International Maritime Organisation (IMO) have not led to the unification of ballast water management standards and have even resulted in the establishment of completely different guidelines for individual countries. Similar suggestions were made by Gerhard et al. (2018) on the basis of legal regulations in the USA and Australia. Drillet et al. (2016) notes, in turn, that despite careful testing of the ballast water treatment systems (BWTS), it is not possible to ensure their effective operation at any given time for every type of water in the tanks. These problems are compounded by the fact that some seafarers prefer not to comply with the complex BWT rules by declaring that they are not familiar with the legislation in force today. Only respondents in the highest positions admitted that they pay special attention to all the work required of them concerning control and Management of Ships' ballast water and sediment.

5. Conclusions

The introduction of new legal standards such as the International Convention on the Control and Management of Ballast Water and Sediments represents a great opportunity for the protection of aquatic environments from non-native organisms. Adherence to these regulations may preserve the biodiversity of many ecosystems. Unfortunately, saving aquatic habitats is only possible if BWT systems meet minimum efficiency standards. Additionally, it is critical to ensure more precise training of crews who are to manage ballast water treatment systems.

Based on the obtained results of our survey, the vast majority of surveyed seafarers (85% of all respondents) knew the requirements of the International Convention for the Control and Management of Ships' Ballast Water and Sediments. However, this does not mean that they understand this legislative direction. Unfortunately, based on the survey data, a large proportion of the ships' crews (33%) were not convinced about the merits of improving the provisions on ballast water treatment. According to our respondents, it results in the introduction of overly complex and faulty BWM systems in the equipment of ships. Their concerns relate to the inadequate training of seafarers responsible for these systems and also burdensome additional inspections and other new obligations. On the other hand, seafarers in charge of the ballast water treatment systems see BWM regulations as a chance for improving the protection of the aquatic environment and progressively improving the process of ballast water exchange. Unfortunately, if seafarers are still not adequately informed and trained in terms of the requirements of BWT systems and the development of an effective system for the elimination of organisms carried in the ballast water, then despite the introduction of new regulations, the transport of non-native organisms in the ballast water of ships may still have a significant negative impact on the ecological status of aquatic ecosystems.

We would like to thank all seafarers who have devoted their time to us and completed the questionnaires.

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