BALLAST WATER MANAGEMENT FOR EUROPEAN SEAS – IS THERE A NEED FOR A DECISION SUPPORT SYSTEM?

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Abstract— **The human mediated transfer of aquatic organisms and pathogens via shipping, specifically with ballast water, is a continuing global threat to biodiversity, human health and economic values. In February 2004, as a result of long-term effort of the International Maritime Organization (IMO), the United Nations body which deals with shipping, the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention) was adopted by the international community setting global standards. In the absence of efficient Ballast Water Treatment Systems (BWTS) on existing ships, Ballast Water Exchange (BWE) is currently the only available method approved by IMO. However, BWE has serious limitations that make it biologically inefficient and often impractical under certain conditions. A key question is whether all ships should be requested to conduct BWE (i.e., blanket approach) or whether it is more appropriate that port states determine BWE requirements on a ship-to-ship basis (i.e., selective approach) supported by a decision support system based on risk assessment? In this paper BWE in the framework of the BWM Convention is discussed. The applicability and effectiveness of BWE is studied and suggestions are given for an effective ballast water management approach, including options for a decision support system, in Europe.**

***Key words*— shipping, ballast water, biological invasions, ballast water management, risk assessment, decision support system**

I. Introduction

The large-scale movement and transfer of organisms to regions in which they did not originate is facilitated unintentionally (e.g. shipping) or intentionally (e.g. aquaculture, scientific research) by humans [1], [2]. Several studies conducted in different parts of the world have demonstrated that ships´ ballast water facilitates the transfer of aquatic organisms across natural boundaries [3], [4], [5], [6], [7], [8], [9], [10], [11]. It has also been confirmed that human pathogens are being transferred with ship's ballast water [8], [12].

A summary of European shipping studies revealed that more than 1,000 species are transported with ballast water of ships. Taxa found range from unicellular algae to fish [10, and references therein], [11]. However, organisms are transferred also as biofouling of the underwater parts of ships [9], [13]. Species introduced with ships have resulted in harmful impacts of natural environments, human health and also caused economic losses [14], [15], [16], [17], [18], [19], [20], [21].

The significance of the problem was acknowledged in a 1973 International Maritime Organization (IMO) resolution, while the last decade in particular has born witness to more intense problem-related efforts and the resulting preparation of an international convention on ballast water and sediments. The final text of the *International Convention for the Management and Control of Ballast Water and Sediments* (BWM Convention) was completed and adopted by the IMO in February, 2004, setting global standards on ballast water management requirements.

However, despite the global efforts and international conventions, efficient, financially feasible, environmentally friendly and safe treatment methods to prevent the translocation of harmful aquatic organisms via ballast water of ships are in an early stage of development, but so far lack IMO approval [22]. Conditioned by the absence of adequate prevention systems for harmful introductions and the unfeasible installation of equipment for ballast water treatment on existing ships, Ballast Water Exchange (BWE) is currently the only available method approved by the BWM Convention. Nevertheless, BWE has drawbacks that make it biologically inefficient and often impracticable under certain conditions (e.g. geographical, hydrological, navigational).

As a result, countries that wish to protect their aquatic environments from the introduction of harmful aquatic organisms are confronted with a challenge. Given that a 'blanket approach' (i.e. a mandatory BWE for all ships) may result in biological and trade inefficiencies, lower ship safety and higher costs in the shipping industry, the 'blanket approach' is likely to be deemed unreasonable in a range of different local conditions. An alternative to the blanket approach is a 'selective approach', based on BWM by means of a decision support system (DSS), implying voyage-specific risk assessments. Due to inefficiencies, neither approach, 'blanket" or 'selective', is able to provide complete protection of further introductions of harmful aquatic organisms in ballast water.

Nonetheless it must be emphasized that all BWM approaches cause costs thus laying an additional burden on

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and generating higher costs in the shipping industry. Consequently, a cost-benefit analysis can be undertaken to determine the greatest efficiencies. Undoubtedly, the cost of prevention should be lower than the benefits that it yields.

II. European seas and BW issue

Today global shipping transports over 90 percent of the world's commodities in intercontinental traffic [23]. Within the EU, waterborne traffic accounts for more than 90% in foreign and approximately 40% in domestic trade exchange [24]. Trends anticipate an increasing role for global and local shipping in the future.

The EU seas have numerous ports open for international transport of cargo with many "hub-ports" of intercontinental importance. These hub-ports are connected with a variety of “secondary” EU ports, where goods are distributed or collected by short sea shipping. When coupling these general shipping patterns to the issue of the transfer of harmful aquatic organisms with ballast water, European hub-ports become those most exposed to the translocation risk of non-indigenous species between continents. The ships transporting cargoes inside the EU region are liable to facilitate further translocation of those species that are introduced into the hub ports resulting in “secondary species introductions”.

For instance, the northern region of the Adriatic Sea has the busiest ports indicating a high level of risk for future species introductions [25], [11]. The Slovenian ballast water study has shown that more than 90% of ballast water discharges in the Slovenian Sea originate from Mediterranean ports [2]. As a part of same study ballast water was sampled on 15 ships in the Port of Koper. Analyses confirmed presence of non-indigenous and harmful species in samples of ballast water from Mediterranean source ports [11].

Currently, more than 1000 aquatic alien species are known in EU seas [26], [27], with the Mediterranean Sea being the most invaded. There are more than 660 introduced species in the Mediterranean Sea, and more than 80 in the Adriatic Sea [26]. (See Table 1)

Given these numbers and the patterns of shipping identified, it can be concluded that European ports are very much exposed to the likelihood of continuing aquatic species invasions, including secondary introductions.

Table 1 – Number and share (in percentage) of introduced alien aquatic species in EU seas. [26]

Region	Total	
	number	%
Mediterranean Sea	662	46,8
North Sea	230	16,2
Atlantic coast	177	12,5
Baltic Sea	170	12,0
Black Sea	83	5,9
Azores	25	1,8
Irish waters & NW UK	51	3,6
Arctic waters	18	1,3
Total	**1416**	**100,0**

III. BWE in the framework of the BWM Convention

In the absence of Ballast Water Treatment Systems (BWTS), exchange of ballast water at sea (BWE) is recognised and accepted as reducing the likelihood of species introductions. Most ships are able to carry out ballast BWE by one of the methods available, i.e., by emptying and refilling tanks in sequence (sequential method) or by in-tank pump through of ballast water (flow-through or dilution method). The philosophy behind BWE is that coastal organisms when discharged at sea are unlikely to survive and cause impact, whereas high sea organisms when pumped onboard during the BWE are unlikely to survive and cause impacts when released in coastal regions. Further, it is well-established that organism densities are much lower in high sea areas compared to the coastal situation thereby reducing the risk of species introductions. Nevertheless, ballast water exchange has drawbacks that make it inefficient or even impracticable under certain conditions (e.g., to short voyage, “intended routes” are too close to the shore or in too shallow water depth; the presence of harmful organisms in the area of BWE). In addition, different shipping studies have shown that BWE has several limitations, e.g., higher organism load after BWE [5], [28], and while the BWM Convention requires at least 95% volumetric exchange of water which is not always equivalent to a 95% organism removal as the organisms are not homogeneously distributed in a tank [29].

According to the BWM Convention Regulation B.4-1, a ship shall whenever possible, undertake a BWE at least 200 nautical miles (nm) from the nearest land and in water depths of at least 200 metres. When this is not possible, the BWE shall be conducted at least 50 nm from the nearest land and in waters at least 200 metres in depth. Further, a ship shall not be required to substantially deviate from its intended voyage, or delay the voyage, in order to comply with this particular requirement.

However, these requirements cannot be met in many circumstances (e.g. intra-European shipping, domestic shipping of many countries). Ships in such areas usually sail inside the area of 50 nm distance from nearest land and/or in shallower waters than 200 meters, and therefore, according to the BWM Convention, do not need to conduct BWE. Because of geographical specifics (e.g., Mediterranean, North and Baltic Seas), not only ships in short-sea-shipping, but also ships operated on certain intra-regional shipping routes, fall in this category. For instance, ships sailing between Adriatic ports and Greece, Malta, Morocco, Tunisia or even East Atlantic and some Black Sea ports, do not meet the distance and depth limits on their intended routes. (see Fig. 1).

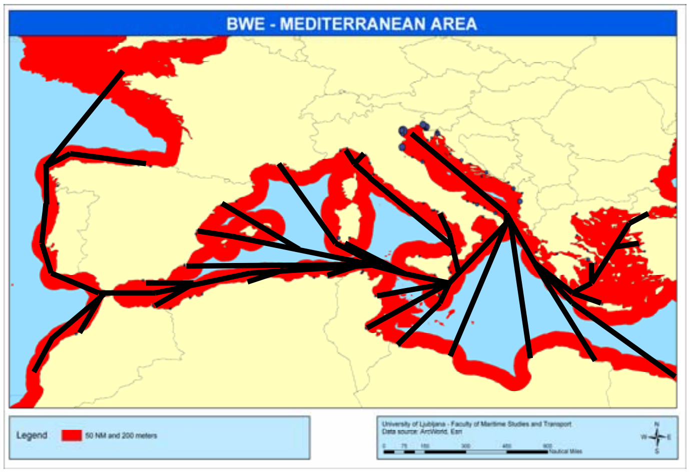

Fig. 1. Main intended routes between Mediterranean and Adriatic Sea ports (black lines) also showing the 50 nm distance to nearest land and 200 metres water depth limits in red.

This is also the case in the North and Baltik Seas. (see Fig. 2)

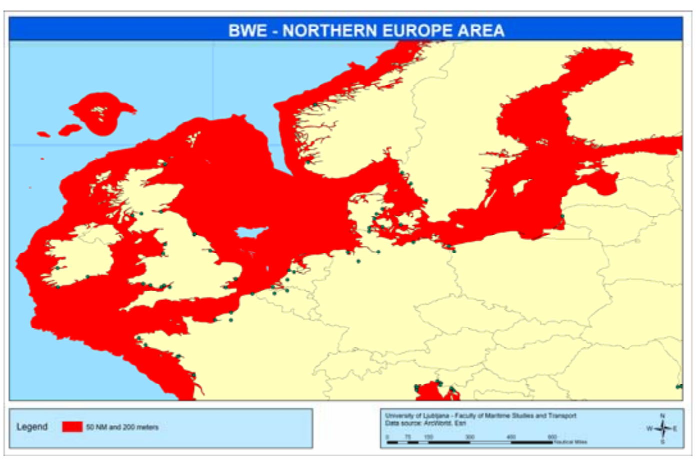

Fig. 2. Areas where the 50 nm distance to nearest land and 200 metres water depth limits in north-western European Seas are not met are marked in red.

IV. "Blanket" or "Selective" Approach

The blanket approach can be readily applied to all ships in all port states. However, at present, and until the implementation of the Ballast Water Performance Standard (Regulation D-2) of the BWM Convention, BWE will be the only available BWM method, and may be implemented under a blanket or selective approach.

BWE has application limitations, which are primarily dependant on shipping patterns of a port (e.g., shipping routes, length of voyages) and local specifics in relation to the required/available conditions according to the BWM Convention (i.e., distance from nearest shore, water depth). In case too many limiting factors for ships discharging ballast waters in a port exist, the blanket approach becomes ineffective and, ships may continue to discharge unmanaged ballast waters in such ports. Consequently the blanket approach in such cases results in "do nothing" until adequate BWTS become available. Further, in a blanket approach all ships are asked to undertake BWE thereby putting an additional burden on those ships with low risk ballast water. However, in the absence of implemented risk assessment techniques the blanket approach to require BWE may be the most reasonable BWM tool today.

According to the BWM Convention (Regulation B.4-2) the designation of Ballast Water Exchange Area(s) (BWEA) and/or (Regulation C.1&2) the requirement of additional BWM measures may minimize or at best prevent discharges of unmanaged ballast water (see Fig. 3). The rationale for the designation of a BWEA is that it indicates an area where ships can safely exchange ballast water as a risk reducing measure while minimising harmful environmental effects. Port states may require ships to slightly deviate from their intended route to meet such BWEA, to slow down when travelling through BWEA to gather extra time to allow for a complete BWE or to exchange just the "critical", i.e. high risk, ballast water [22].

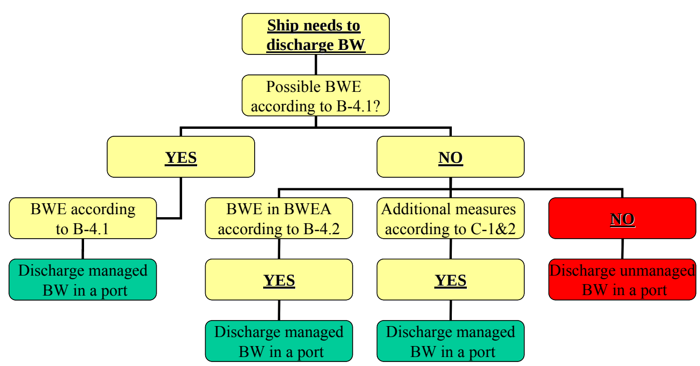

Fig. 3. BWE options according to the BWM Convention. [30]

Risk assessment under the BWM Convention has two different approaches, i.e., "environmental matching" and "species specific" assessments. Risk estimation on the assessment of environmental matching between the areas of ballast water origin and discharge considers salinity and temperature as surrogates for the species capability of survival in the new environment. The risk identification in the species specific approach is focused on the assessment of the potential invasiveness of each species and anticipations of the harm that it could cause in the new environment.

The implementation of the BWM Convention under a blanket approach is simpler, however, there are many issues arising from a variety of situations/conditions in EU seas which limit the possibility of its implementation, at the same favouring the selective approach. These limiting situations/conditions include that shipping routes lack sufficiently large stretches in deeper waters more than 200 nm from nearest land.

In contrast the selective approach aims to select high risk ballast water and to request BWM requirements only for those ships. This is more demanding for port state implementation which may limit its application. Hence, the suitability should be studied and a BWM requirement decision should at best be taken on a case by case, i.e. on a route specific port by port basis.

V. DSS as a BWM tool

A Decision Support System (DSS) can be defined as a supporting tool enhancing the decision-making process [31]. DSSs today are widely supporting decision-making processes in business, social, medicine, policy, games, information technologies, transport [32], and they are major building blocks in environmental management and science today [33]. Decision-makers are frequently faced to take timely decisions on very complex issues, requiring a large data input. DSS help decision makers to reduce uncertainties [34] and they will ease and speed-up the decision process.

Under the selective approach, a decision on the minimum BWM measure required should be taken according to the level of risk assessed. Such a process requires more extensive data gathering for port states, as well as more data documentation and reporting requirements for ships. It may also require higher skills and knowledge for port state personnel. However, this can be aided by an appropriate DSS. In contrast, a DSS can provide more consistency and transparency in the decision making process, thus providing a level of Quality Control across ships and ports. The need for a DSS for BWM primarily arose with the implementation of a selective BWM approach, which requires a supporting tool when deciding on the BWM needs in the light to reduce any additional burden to ships as practicable.

VI. Discussion

The human mediated transfer of harmful organisms via shipping leads to biodiversity change, alteration of ecosystems, negative impacts on human health and in many regions economic loss. This has raised considerable attention especially in the last decade. Despite the global efforts and international conventions, efficient, financially feasible, environmentally friendly and safe BWM methods to prevent the translocation of harmful organisms via ballast water of ships have not yet been developed.

Conditioned by the inexistence of an efficient prevention system for harmful introductions and the unfeasible installation of BWTS on existing ships, BWE is the only available method approved by the IMO. Nevertheless, BWE has drawbacks that make it inefficient or even impracticable under certain conditions. As a result, the countries that wish to protect their seas from the introduction of harmful organisms are confronted with a challenge to balance requirements between (a) the efficiency of BWM measures and the safety and higher costs in the shipping industry as the result of these and (b) the risk of future species introductions.

For these reasons, the 'blanket approach' of requiring all ships to undertake BWM is less favourable. The 'selective BWM approach' enables, by means of a DSS, the adjustment of the intensity of measures based upon a voyage-specific risk assessment, thus reducing safety risks and costs to the shipping industry while simultaneously allowing for the gains in protection of the environment.

Noting all shortcomings of BWE it is hoped that IMO approved BWTS become available shortly to better protect our seas from aquatic invasive species introductions.

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References

[1] Gollasch, S., Removal of Barriers to the Effective Implementation of Ballast Water Control and Management Measures in Developing Countries, for GEF/IMO/UNDP, 1998, p. 197.

[2] Minchin, D., Aquaculture and transport in a changing environment: Overlap and links in the spread of alien biota, Marine Pollution Bulletin 55, 2004, pp. 302-313.

[3] Carlton, J.T., Transoceanic and interoceanic dispersal of coastal organisms: the biology of ballast water, Ocenaogr. Mar. Biol. Ann. Rev. 23, 1985, pp. 313-371.

[4] Williams, R.J., Griffiths, F.B., Van der Wal, E.J. & Kelly, J., Cargo vessel ballast water as a vector for the transport of nonindigenous marine species, Estuar. Coast. Shelf Sci. 26, 1988, pp. 409– 420.

[5] Macdonald, E.M. & Davidson, R.D., The occurrence of harmful algae in ballast water discharges in Scottish ports and the effects of mid-water exchange in regional seas. In: Reguera B, Blanco J, Fernandez ML & Wyatt T (eds) Harmful Algae. Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, 1998, pp. 220-223.

[6] Gollasch, S., Lenz, J., Dammer, M. & Andres, H.G., Survival of tropical ballast water organisms during a cruise from the Indian Ocean to the North Sea. Journal of Plankton Research 22, 2000, pp. 923–937.

[7] Olenin, S., Gollasch, S., Jonusas, S. & Rimkute, I., En-route investigation of plankton in ballast water on ship's voyage from the Baltic Sea to the open Atlantic coast of Europe, Int. Rev. Hydrobiol. 85, 2000, pp. 577–596.

[8] Ruiz, G.M., Rawlings, T.K., Dobbs, F.C., Drake, L.A., , T., Huq, A. & Colwell, R.R., Global spread of microorganisms by ships - Ballast water discharged from vessels harbours a cocktail of potential pathogens, Nature, 408 (49-50 NOV 2), 2000.

[9] Gollasch, S., The importance of ship hull fouling as a vector of species introductions into the North Sea. Biofouling 18, 2002, pp. 105-121.

[10] Gollasch, S., Macdonald, E., Belson, S., Botnen, H., Christensen, J., Hamer, J., Houvenaghel, G., Jelmert, A., Lucas, I., Masson, D., McCollin, T., Olenin, S., Persson, A., Wallentinus, I., Wetsteyn, B. & Wittling, T., Life in Ballast Tanks, pp.217-231, In: Leppäkoski, E., Gollasch, S. & Olenin, S. (eds.): Invasive Aquatic Species of Europe: Distribution, Impacts and Management. KLUWER Academic Publishers, Dordrecht, The Netherlands, 2002, p. 583.

[11] David, M. Gollasch, S., Cabrini, M., Perkovič, M., Bošnjak, D. & Virgilio, D., Results from the First Ballast Water Sampling Study in the Mediterranean Sea - the Port of Koper Study, Marine Pollution Bulletin 54, 2007, 53-65.

[12] Casale, G. A., Ballast water – a public health issue? GloBallast Programme, IMO London, Ballast Water News, Issue 8, 2002.

[13] Coutts, A.D.M., Kirrily, M.M., Chad, L.H., Ships' sea-chests: an overlooked transfer mechanism for non-indigenous marine species. Marine Pollution Bulletin 46 (11), 2003, pp. 1510–1513.

[14] Boalch, G. T. & Harbour, D. S., Unusual diatom off the coast of south west England and its effect on fishing. Nature (Lond.) 269, 1977, pp. 687-688.

[15] Hallegraeff G.M. & Bloch C.J,. Transport of toxic dinoflagellate cysts via ship's ballast water. Marine Pollution Bulletin 22, 1991, pp. 27-30.

[16] Leppäkoski, E. J., Introduced species - Resource or threat in brackish-water seas? Examples from the Baltic and the Black Sea, Marine Pollution Bulletin, 23, 1991, 219-223.

[17] Zibrowius, H., Ongoing Modification of the Mediterranean Marine Fauna and Flora by the Establishment of Exotic Species, Bull. Mus. Hist. Nat. Marseille, 51, 1991, pp. 83-107.

[18] Ivanov, V.P., Kamakin, A.M., Ushivtzev, V.B., Shiganova, T., Zhukova, O., Aladin, N., Wilson, S.I., Harbison, R.G., Dumont, H., Invasion of the Caspian Sea by the comb jellyfish *Mnemiopsis leidyi* (Ctenophora), Biological Invasions 2, 2000, pp. 255–258.

[19] Boudouresque, C.F. & Verlaque, M., Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes, Marine Pollution Bulletin 44, 2001, pp. 32-38.

[20] Wolff, W.J., Non-indigenous marine and estuarine species in The Netherlands. Zoologische Mededelingen, 79-1, 2005, pp. 1-116.

[21] Gollasch, S. & Nehring, S., National checklist for aquatic alien species in Germany, Aquatic Invasions 1(4), 2006, pp. 245-269.

[22] Gollasch, S., David, M., Voigt, M., Dragsund, E., Hewitt, C.,L., Fukuyo, Y., Critical review of the IMO International Convention on the Management of Ships' Ballast Water and Sediments, Marine Pollution Bulletin Harmful Algae, to be published, Available online 9 February 2007.

[23] IMO. http://www.imo.org

[24] EU Commission, Green paper, Towards a future Maritime Policy for the Union: A European vision for the oceans and seas, Commission of the European Communities, Brussels, COM (2006) 275 final, 2006, p. 49.

[25] Perkovič, M., Suban, V., David, M., Ballast water discharges in the Slovenian sea, In: Fabjan, Daša (ed.). 8th International Conference on Traffic Science - ICTS 2004, Conference proceedings, 2004, p. 12.

[26] Gollasch, S. & David, M., More than 1000 aquatic invaders in European Seas, 4th International Conference on Aquatic Invasive Species (ICAIS), Wellington, New Zealand, 2005, unpublished.

[27] Database on introduced species in Europe. Delivering Alien Invasive Species Inventories for Europe (DAISIE), in development. Contract Number: SSPI-CT-2003-511202

[28] McCollin, T., Macdonald, E.M., Dunn, J., Hall, C. & Ware, S., Investigations into ballast water exchange in European regional seas, In: International Conference on Marine Bioinvasions, New Orleans, April 9-11 2001, 2001, pp. 94-95.

[29] Murphy, K.R., Ritz D., Hewitt, C.L., Heterogeneous zooplankton distribution in a ship's ballast tanks, Journal of Plankton Research 24 (7), 2002, pp. 729-734.

[30] David, M., Implementation of the IMO BWM Convention, Ballast Water Exchange Area in the Adriatic – IMO BWM Convention / Regulation B-4-2, 2nd meeting of the Trilateral Ballast Water Management

Sub Commission, Portorož, Slovenia, 16-17 December 2004, unpublished.

[31] Bhatt, G.D., Zaveri, J., The enabling role of Decision Support Systems in organizational learning, Decision Support Systems 32 (3), 2002, pp. 297–309.

[32] Marquez, A.C., Blanchar, C., A Decision Support System for evaluating operations investments in high-technology business. Decision Support Systems 41, 2006, pp. 472– 487.

[33] Denzer, R., Generic integration of environmental decision support systems – state-of-the-art. Environmental Modelling & Software 20, 2005, pp. 1217–1223.

[34] Graham, I., Jones, P.L., Expert Systems: Knowledge, Uncertainty, and Decision, Chapman and Hall, New York, 1988.