Marine Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Same Risk Area: An area-based approach for the management of bio-invasion risks from ships' ballast water

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ARTICLE INFO

Keywords:
Invasive species
Shipping
Ballast water
Area-based approach
Risk assessment
Agent-based modelling

ABSTRACT

Same Risk Area refers to an area-based approach for the risk assessment of aquatic invasive species that considers the extent of natural dispersal. It is a new addition to the Guidelines on Risk Assessment (G7) under the International Convention for the Control and Management of Ships' Ballast Water and Sediments. The method outlined here to define the extent of a Same Risk Area assesses the connectivity of species of concern within a wider area by combining information from simulated hydrodynamic data and agent-based modelling with the biological traits and habitat preferences of the selected target species.

1. Introduction

Invasive species, including pathogens, are viewed as a major threat to aquatic ecosystems worldwide and have been reported to affect local economies and societies [5,37,40]. The shipping industry has been identified as a major vector for the unintentional transport of exogenous species across ecosystems with about a third of all introductions of non-indigenous species due to fouling on the ship hulls and another third due to ballast water exchanges [15,18,19].

Nearly all vessels including bulk cargo carriers, oil tankers, container ships and cruise ships use ballast water as a safety measure to ensure structural integrity and stability of the vessel depending on the weight of cargo that has been loaded and unloaded between successive ports of call. Ballast water is taken up from the coastal waters of a region, along with a variety of other biological material, including plants, animals, viruses, and bacteria, and then may be discharged at another port in an entirely different coastal region. These materials may be non-native to the new region and may cause extensive ecological damage to the aquatic ecosystems there as well as economic impacts on aquatic based industries such as aquaculture [10,37].

To address this issue, the International Maritime Organisation (IMO) in 2004 adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments [25], otherwise known as the Ballast Water Management Convention (BWMC). In 2016, the convention surpassed its mandatory number of 30 ratifying Member States representing more than 35% of the world gross cargo tonnage, thereby entering into force on the 8th September 2017. After this date, over a course of seven years, the vast majority of ships in international trade must meet stringent discharge criteria that *de facto* requires the vessels to disinfect their ballast water before discharge using an on-board Ballast Water Management System (BWMS). These treatment systems, which represent an *a priori* risk reduction measure, must undergo comprehensive testing before they are granted a Type Approval and can be fitted on-board vessels. An original type approval process were found to present flaws (e.g. [9]) and a successful revision of the testing requirements has been completed through a revision of the G8 Guidelines [27].

1.1. Risk assessment for exemption

The convention recognizes that ships trading in certain locations and on voyages between certain ports may be considered as a non-significant risk regarding transport of invasive species via ballast water and therefore the use of a BWMS may not be necessary. Acknowledging this fact, regulation A-4 of the BWMC allows for such ships to be granted an exemption to the ballast water management requirement (i.e. compliance with the discharge criteria which necessitate to have a BWMS installed). To ensure that exemptions are granted with due consideration of the specific occurrence and potential transport of invasive species, the convention requires that a risk assessment is carried out according to its Guidelines on Risk Assessment (G7) [26] and that the risk of transfer of invasive species is found to be acceptable. While the guidelines are not binding, they do outline the standards and best practice that member states should follow in establishing the level of

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https://doi.org/10.1016/j.marpol.2018.05.009
Received 30 December 2017; Received in revised form 6 May 2018; Accepted 6 May 2018

environmental risk from ballast water exchange.

The UN-funded international programme on ballast water, GloBallast has published a series on Monographs in which risk is defined as "the probability that a hazard will lead to loss, or injury/damage to life, property or the environment; it requires knowledge of the extent of exposure to the hazard concerned" [3]. The G7 Guidelines proposes three risk assessment methods, which may be more or less appropriate depending on the ship's route for which the risk assessment is to be carried out. Generally, the *environmental matching* risk assessment focuses on the similarities and dissimilarities of the abiotic factors (e.g. temperature and salinity) between bioregions and therefore might be used appropriately for ships trading between ports very distant from one another and located in very distinct biogeographic regions. The *species biogeographical* risk assessment approach compares the general presence/absence of species between the ports of origin and arrival of the ship, when traversing different biogeographical zones. The *species-specific* risk assessment of the G7 focuses on identifying target species which 'may impair or damage the environment, human health, property or resources and are defined for a specific port, State or biogeographic region' [26], and subsequently applying information on such organism's life history and physiological tolerances to assess the risk of an invasion by these target species.

In particular, the *species biogeographical* risk assessments require comprehensive knowledge of the natural baseline of the biota in each location; currently largely unavailable because monitoring of invasive or non-indigenous species in ports and other locations is not part of the environmental monitoring effort in most countries. GloBallast has published a monograph on Port Biological Baseline Surveys [2] and guidance assessment procedures by the North Sea and Baltic Sea environmental organisations, respectively OSPAR and HELCOM, also promotes port surveys based on spot sampling as a key part of obtaining and comparing incidence data on invasive species [24].

1.2. Challenges for short sea shipping

Since the guidelines do not offer a mechanism to extend knowledge on invasive species from one port basin to the next, let alone other ports in the proximity, establishing the data set necessary for a risk assessment requires a considerable number of surveys to be conducted in any sizeable port, and makes it cumbersome both for exemption issuing authorities and the shipping industry to implement. In particular, the short sea shipping sector as defined by European Commission [11], may face considerable challenges employing the exemption regime. The short sea shipping sector carries cargo and passengers in local areas and is key to efforts to decrease rates of carbon dioxide emissions by moving heavy cargo traffic off roads [12]. These vessels may regularly call at several ports in an area, or may occasionally use alternative berths in the same port, or even call ports not included in their original schedule, often separated by only short distances. The costs of sourcing the data needed to underpin a risk assessment for each individual ship and route to allow such common local trading patterns would be prohibitive, effectively excluding the option of exemptions for the short sea shipping sector.

1.3. An area-based approach

The G7 guidelines as originally released did not propose to account for natural dispersal of organisms (i.e. that not mediated by shipping). Mobile aquatic species, pelagic life stages of marine organisms (meroplankton) and holoplankton may disperse naturally across international borders, irrespective of other vectors of transfer such as ship's ballast water. Ships that take short sea voyages within such an area of natural dispersion may be unlikely to greatly alter the consequences from the natural transfer of potentially harmful and invasive species.

To address these issues, an area-based approach taking natural dispersal into account was proposed as early as 2014 [45]. The so-called Same Risk Area (SRA) approach matured over the successive submissions of member states to the IMO [28–34]. The IMO eventually concluded that a SRA should be defined as: "an agreed geographical area based on a completion of a risk assessment carried out in line with these Guidelines [33]. The terminology decided by IMO differs slightly from proposals previously published and therefore only the most recent as mentioned above should be applied. The concepts behind the SRA approach are illustrated in Fig. 1 where there are a number of ports across different States or countries, with their waters connected hydrodynamically in all directions.

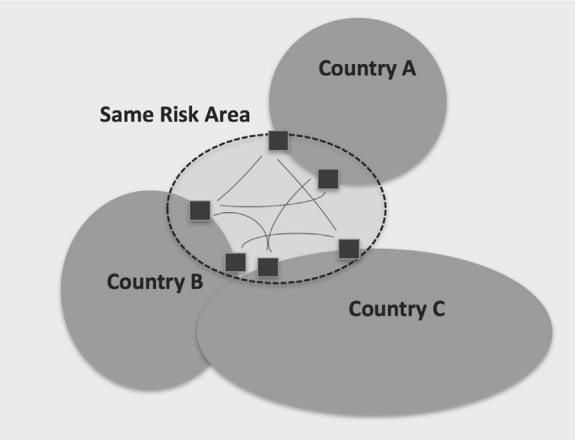

Fig. 1. An area-based approach delineating a conceptual Same Risk Area (SRA) between ports and locations in a defined area.

The primary advantage of an area-based approach is that it can be used by administrations as a decision-support tool to grant area-based exemptions to ships trading in short sea shipping. This allows a key underlying dataset and model to be shared between administrations and the ship-owners to use one coherent environmental assessment as the common basis for the exemption of individual vessels. A secondary benefit is that ship-owners and others may conduct initial simple modelling of a potential area to check the feasibility of undertaking a full modelling and exemption process.

In the present paper, the definition proposed by the IMO is used and approaches to define target species characteristics and model their dispersion is provided with the objective of generating information to carry out a risk assessment using an area-based approach. The detailed risk assessment itself is not the focus of the present contribution and should be completed according to the G7 Guidelines as an expert-driven process.

2. Proposed methodology supporting the prediction of data for an area-based approach to risk assessment

2.1. Overview of the proposed approach

One of the key tasks when applying an area-based risk assessment in an effort to define an SRA, is the evaluation of the natural dispersal of species in an area governed by unique hydrographic characteristics. The authors consider that the area-based risk assessment proposed for such studies should be based on a species-specific risk assessment under the G7 guidelines in that it should start with a decision on which identified target species should be used to carry out the modelling exercises. The modelling assessment necessitates that a proper and calibrated hydrodynamic model is setup and used as a basis upon which individual-based biological models (also known as Agent Based Models – ABM) are coupled/combined [7,46,50]. This combination of modelling approaches is also referred to as biophysical modelling (e.g. [44]), particle tracking (e.g. [38]) or Lagrangian modelling (e.g. [50]).

The data required is not limited to but may include: