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Research article

Risk assessment and management scenarios for ballast water mediated species introductions into the Baltic Sea[1]

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Abstract

This risk assessment study follows the environmental match of donor and recipient regions of ballast water and the voyage duration as risk quantifiers. The ports considered were Gothenburg (Sweden), Copenhagen (Denmark), Kiel (Germany), Klaipeda (Lithuania), Kemi, Tornio and Raahe as one port region (Finland), and Sköldvik/Kilpilahti (Finland). All selected Baltic ports have at least one donor port in the highest risk category, all extreme and high risk donor ports are located in Europe, but mostly outside the Baltic Sea. The most frequently reported high-risk donor ports are Rotterdam (6 times), Bremerhaven (5), Amsterdam (4) and Antwerp (3), and most high-risk donor ports are the major hub ports in Europe. The paper concludes with ballast water management scenarios for intra-Baltic shipping and for vessels engaged on voyages outside the Baltic.

Key words: Risk assessment, HELCOM, shipping, ballast water, management, alien species, Baltic Sea

Introduction

Being a recipient, transit and donor area of aquatic invasive species (hereafter AIS), the Baltic (including the Kattegat) has become an important node in a global network of AIS transfers during recent decades, thereby facilitating and contributing to the process of homogenisation for some of the world's aquatic fauna and flora (Leppäkoski and Olenin 2000). The brackish conditions of the Baltic Sea do not protect it from species introductions. The increasing number of AIS in the Baltic serves as an indicator of global change. The fauna and flora of the Baltic are exposed to other brackish-water biota of the world, owing to the breakdown of large-scale ecological and geographical barriers by ship traffic, which results in the

[1] This paper is a summary of the risk assessment approach developed by the authors for HELCOM (Leppäkoski and Gollasch 2006). The full version of the report is available at http://www.helcom.fi/shipping/ballast/en_GB/ballast/

exchange of species (Leppäkoski and Olenin 2001). The number of AIS is lowest in the northernmost parts of the Baltic and highest in the lagoons in the south as well as in the Kattegat. AIS are common in shallow waters, especially at ports, river mouths and in coastal inlets, transmitted not only with ballast water and sediments but also as a result of hull fouling or via the river and canal systems, in particular from the Ponto-Caspian region (Baltic Sea Alien Species Database 2007). A risk assessment has been undertaken by Panov et al. (2007) of the Northern Corridor (the Volgo-Baltic Waterway) and by Bij de Vaate et al. (2002) for the Central Corridor that connects the Black, Baltic and North Sea catchments.

Many important harbours in the world and especially in NW Europe are located at river mouths. The salinity range of these estuarine habitats is similar to the oligo- and mesohaline conditions of the Baltic Sea (Gollasch and Leppäkoski 1999, Leppäkoski et al. 2002). All highly euryhaline and cold-eurythermal species are potential invaders into the Baltic Sea and there is a pool of species to be kept on a next-to-come list. The ability of these species to live and reproduce in the low salinity waters of the Baltic Sea is a key factor to determine their invasion success (Paavola et al. 2005). The salinity gradient from almost 0 psu in the innermost parts of the large gulfs, through 6-8 psu in the Baltic proper, to 20-24 psu in the Kattegat makes the Baltic Sea susceptible for invasions of freshwater, brackish and marine species.

Vertical gradients strongly influence not only the native biotic communities, but also provide a broad range of temperature and salinity conditions inhabitable by alien species of different biogeographical origins (from cold-stenothermal to eurythermal species). Since both the established and potential AIS originate mostly from warmer areas, changes in the temperature and salinity conditions may influence the invasion pattern and population dynamics of AIS. If the process of global warming continues, the risk that additional warm-water species become established in the Baltic Sea will increase.

Approximately 120 AIS have been recorded in the brackish waters (> 0.5 psu) of the Baltic Sea, most of them being introduced during the last 100 years and with shipping as the most important individual vector (Figures 1, 2). Almost 80 species have established reproducing populations in the Baltic Sea (Baltic Sea Alien Species Database 2007).

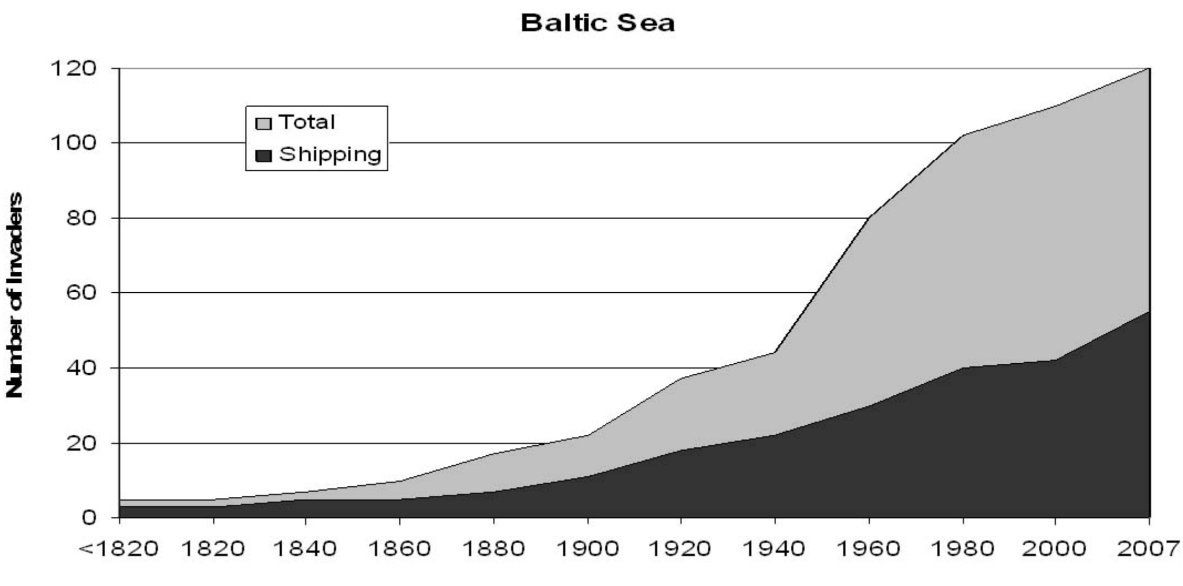

Figure 1. Cumulative number of first records of alien species in the Baltic Sea (105 species, based on Baltic Sea Alien Species Database, 2007) and the share of ship-mediated introductions since the early 1800s

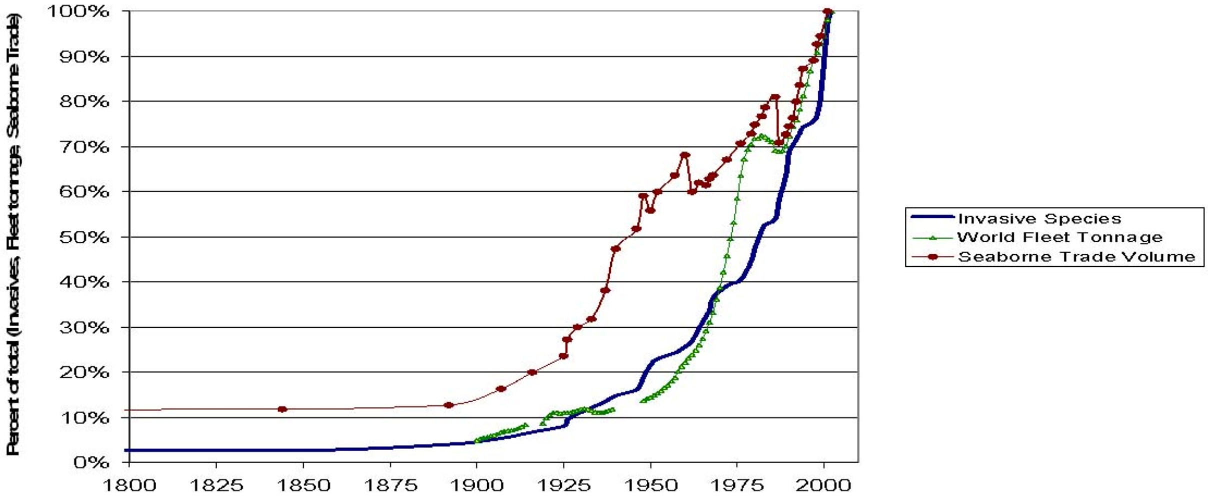

Figure 2. Increase in invasive species as world fleet tonnage and seaborne trade increased over time. Species data are specific to a biological survey for the Black Sea (Alexandrov et al. 2004) (see also Cohen and Carlton 1998); fleet tonnage data from Lloyds Register Statistical Tables for various years; seaborne trade data from various sources (From Corbett and Firestone 2004; Firestone et al. 2004). Courtesy: J. Firestone, Graduate College of Marine Studies, University of Delaware, USA

In the late 1990s there were more than 500 ports in the Baltic Sea with a total annual port throughput close to 700 million tonnes (1997/98) (Rytkönen et al. 2002, Dragsund et al. 2005). In intra-Baltic trade alien species may also be transferred in ballast tanks. However, it is likely that organisms once introduced into one Baltic port may subsequently spread and reach other Baltic regions (secondary introductions) either by natural spread or by other human-mediated means than ballast water (e.g., hull fouling, leisure and fishing vessels). This assumption refers in particular to brackish water species. These species usually show a higher tolerance to variable salinity compared to truly marine and freshwater species. If, for example, a freshwater species becomes introduced in the port of St. Petersburg this species may not be able to reach freshwater habitats adjacent to e.g., the western Baltic coast (e.g., rivers and lakes in Denmark or along the west coast of Sweden) as the higher salinity in the central Baltic would naturally reduce the spreading potential of a freshwater species. Brackish water conditions may also pose a migration barrier for freshwater species. As a result intra-Baltic shipping routes which connect freshwater habitats separated by higher saline brackish waters pose a risk for the introduction of a freshwater species which would be unable to reach other freshwater regions by its own means.

The following acronyms are frequently used in this paper:

AIS: Aquatic Invasive Species
BWE: Ballast Water Exchange
BWM: Ballast Water Management
BWMC: Ballast Water Management Convention (International Convention for the Control and Management of Ships Ballast Water and Sediments of IMO, 2004)
IMO: International Maritime Organization
OSPAR: Oslo Paris Commission
HELCOM: Helsinki Commission

Methods

Previous risk assessment studies of AIS have used frameworks and concepts of general ecological risk assessment. Qualitative risk assessments have been more common (e.g., Gollasch 1996, Gollasch and Leppäkoski 1999, Grigorovich et al. 2003, Hayes and Sliwa 2003) while quantitative predictions have addressed specific groups of target species (e.g., Hayes 1998a, Kolar and Lodge 2002, Nyberg and Wallentinus 2005).

Other NW European ballast water management initiatives (European Union, ICES) are in various stages of development. The OSPAR risk assessment study, developed via the Issue Group on Sustainable Shipping (IGSS), was completed in 2005 as Ballast Water Scoping Study for NW Europe. The focus of this study is for the OSPAR region. This study also includes risk assessment recommendations (Dragsund et al. 2005) and was considered in detail during the preparation of this paper.

Areas/ports and shipping routes that pose a high risk of transferring AIS into the Baltic Sea

The overall analysis of shipping patterns, based on shipping statistics, was used for identification of representative ports/areas to be used for further study. The results cover most of the Baltic Sea.

The risk analysis is based on the assessment of environmental similarity between the Baltic Sea region/ports and the donor/recipient areas, carried out using the matching climate and salinity approach (e.g., Gollasch and Leppäkoski 1999, Paavola et al. 2005) applied to the GloBallast Database (covering some 350 harbours, their salinity conditions and other environmental data) as well as other relevant information (e.g., the Lloyd's Register/Fairplay Port Guide 2003; www.portguide. com).

Quantitative risk assessments might not always be possible, for example, where there is no relevant database available on which to base empirical techniques (Hayes 1998b). Consequently qualitative expressions of risk (e.g., 'low', 'intermediate' and 'high' risk) may have to be used (Simberloff and Alexander 1994; Gollasch and Leppäkoski 1999). A drawback of the qualitative risk measure is the difficulty in expressing levels of uncertainty and in using data for additional calculations, for example cost-benefit analysis (Hayes 1997). However, a reasonable risk assessment is often the best option to get as far-reaching results as possible which can aid management and decision making (Paavola 2005).

Not all harbours or sub-regions within the Baltic are equally exposed to ship-mediated AIS introductions. Factors influencing the level of exposure include propagule pressure, shipping patterns, environmental conditions in the receiving port (e.g., pollution, eutrophication, outflows of cooling water), frequency of inoculations, etc. (Verling et al. 2005). Hotspots of xenodiversity (i.e., structural and functional diversity related to alien species (Leppäkoski and Olenin 2000)) are the coastal lagoons, river mouths and harbour areas in the Baltic and may be important gateways for further species spread to other ports or non-port areas in the Baltic (secondary spread).

Our attempt to identify areas and ports of special interest for management of shipping-related bioinvasions into the Baltic is largely based on discussions at the BSRP/HELCOM/COLAR Workshop (Palanga, Lithuania, in February 2005). This Workshop recommended that at least one port per biogeographical sub-region should be selected for study. Priority should be given to ports (i) with high cargo (and ballast) turnover, (ii) with high number of long distance (overseas) ship arrivals, (iii) which are frequently visited by tankers (and/or bulk carriers) because those ships usually carry high loads of ballast water intended for discharge in the Baltic, (iv) where other vectors of introduction may be present (e.g., inland waterways), and (v) with high number of AIS.

Shipping traffic which poses high risk for the introduction of invasive alien species into the Baltic Sea

When assessing the risks of species invasions it is not only the volume of ballast water being released in a certain port/port region that matters, but also the frequency of ship visits and, most importantly, the environmental match of donor and recipient region of the ballast water which accounts for the risk ranking one port or port region is exposed to. In general, the number of potential donor ports/port regions the port is connected to increases with the number of ship visits to that port. A large number of potential donor areas with high environmental matching is a higher risk scenario rather than ports with few shipping connections from non-matching donor areas (Tables 1, 2).

Further, frequent ship arrivals result in a higher risk as these ships may release AIS to a favourable matching environmental 'window' over the spectrum of a year that suits the transmitted stage.

Thus species introductions are more likely to occur as ships arriving from the donor region in all seasons may - sooner or later – have taken onboard certain species even if not present in the donor regions throughout the year (propagules, e.g., seasonal larvae availability in the water column). Also, species survival after discharge is more likely in the receiving area when the species arrive in all seasons as it is more likely that favourable conditions for survival will be met.

A detailed risk assessment could not be carried out for all of the 500+ Baltic ports due to a lack of information for many of them. The six ports/port regions selected for closer consideration (see selection criteria above) were Gothenburg (Sweden), Copenhagen (Denmark), Kiel (Germany), Klaipeda (Lithuania), Kemi, Tornio and Raahe as one port region (Finland), and Sköldvik (in Finnish Kilpilahti; Finland) (Figure 3)

Together, these represent:

- busy ports/port regions in the Baltic shipping,
- most Baltic Sea salinities, from almost freshwater (periodically < 0.5 psu) to brackish water < 20 psu),
- different cargo capacities, and different types of cargo handled.

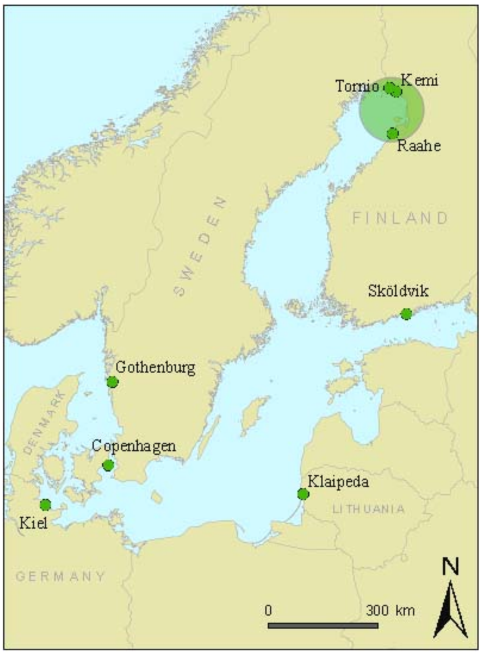

Figure 3. Location of the six ports/port regions selected: Kiel (Germany), Gothenburg (Sweden), Copenhagen (Denmark), Klaipeda (Lithuania), Kemi, Tornio and Raahe as one port region (Finland), and Sköldvik (in Finnish Kilpilahti, Finland)

Table 1. Probability of colonisation of AIS, according to matching salinity in donor and recipient regions (after Carlton 1985)

	DONOR region		
RECIPIENT region	Fresh water	Brackish water	Marine water
Fresh water	high	medium	low
Brackish water	medium	high	high
Marine water	low	high	high

Table 2. Probability of colonisation of AIS, according to matching climate in donor and recipient areas (after Gollasch 1996)

	DONOR region			
RECIPIENT region	Arctic & Antarctic	Cold-temperate	Warm-temperate	Tropics
Arctic & Antarctic	high	medium	Low	low
Cold-temperate	medium	high	Medium	low
Warm-temperate	low	medium	High	medium
Tropics	low	low	Medium	high

Ballast water discharge data are only available for some of the ports selected. However, in this study (and in invasion biology in general) qualitative assessments are generally useful, i.e. where does the ballast water originate (environmental match of donor and recipient region). As these data were lacking for e.g., the Ports of Copenhagen, Klaipeda and Kiel we classified the routes from donor to recipient ports - as it is likely that ballast water arrives in the ports from each port where the shipping routes originate. As a result, a route-specific risk assessment was carried out. To assess the risk each individual vessel may pose, more specific data on the ballast water situation onboard are required. However, the risk for any given route is likely to vary according to the specific behaviour patterns and conditions on each vessel.

Environmental characteristics of the ports selected

Salinity and temperature characteristics of the selected ports/port regions vary (Table 3). The temperature regime was evaluated based upon bioregion mapping (Ekman 1953, Briggs 1974; see Figure 4). The port salinities were extracted from Lloyds Register - Fairplay (2003).

As all Baltic ports are located in the same bioregion they are all exposed to a similar climate regime. Consequently, the individual port salinity (range) is a key differential feature.

Table 3. Salinity and temperature characteristics of the ports/port regions selected. The salinity in Lloyds Register - Fairplay (2003) was given in density and was calculated to parts per thousand following the Aquatext conversion (http://www.aquatext.com) at a water temperature of 8°C

Port /port region	Temperature zone	Salinity regime [psu]
Kiel (DE)	Eastern Atlantic Boreal Region	19.5
Gothenburg (SE)	Eastern Atlantic Boreal Region	13.1-18.2
Copenhagen (DK)	Eastern Atlantic Boreal Region	10
Klaipeda (LT)	Eastern Atlantic Boreal Region	0.5 - < 7
Kemi, Tornio, Raahe (FI)	Eastern Atlantic Boreal Region	0 - 4.2
Sköldvik (FI)	Eastern Atlantic Boreal Region	0 - 6.7

Risk assessment approach for the ports selected

The risk assessment for the ports selected was based upon the comparison of donor and recipient port's environmental match (salinity and sea temperature) and voyage duration. This qualitative approach "ignores" the volume of ballast water discharged (see above). Further, it was assumed that donor ports/port regions outside the Baltic pose a higher risk for species introductions compared to intra-Baltic shipping routes.

Temperature

The donor port temperature zone was assessed following the bioregion mapping according to Ekman (1953) and Briggs (1974) in which the world is divided in four major temperature regions: tropical, warm-temperate, cold-temperate, and Arctic/Antarctic according to the world's oceans (Figure 4). The risk was quoted highest when source and recipient port were located within a matching bioregion (Table 2).

Salinity

In general, the greater the difference in salinities between donor and recipient regions, the less likely it is for a successful species introduction to occur (Table 4). A salinity tolerance margin of 1-3 psu was used to address fluctuating salinities in relevant ports.

Table 4. Salinity characteristics of the ports/port regions selected and the risk quantification scheme used

Port/port region	Salinity regime of port/port region [psu]	Low risk salinity [psu]	Medium risk salinity [psu]	High risk salinity [psu]
Kiel	19.5	< 13 and > 26	14-16 and 23-26	16.5-22.5
Gothenburg	13.1 - 18.2	< 6 and > 25	6.5-9.5 and 21.5-24.5	10-21
Copenhagen	10	< 3 and > 17	3.5-6.5 and 13.5-16.5	7-13
Klaipeda	0.5 - 7[1]	> 14	10.5-13.5	< 10
Kemi, Tornio, Raahe	0 - 4.2	> 11.5	8-11	> 7.5
Sköldvik	0 - 6.7	> 14	10.5-13.5	< 10

[1]Highly unstable conditions depending on winds and intensity of the outflow from the Curonian Lagoon (> 6.5 psu occur 70 days per year, < 0.5 psu 130 days per year; Olenin et al. 1999). The same is true for the ports in the Bothnian Bay (Kemi, Tornio, Raahe) and the eastern Gulf of Finland (Sköldvik), which are influenced by river outflows

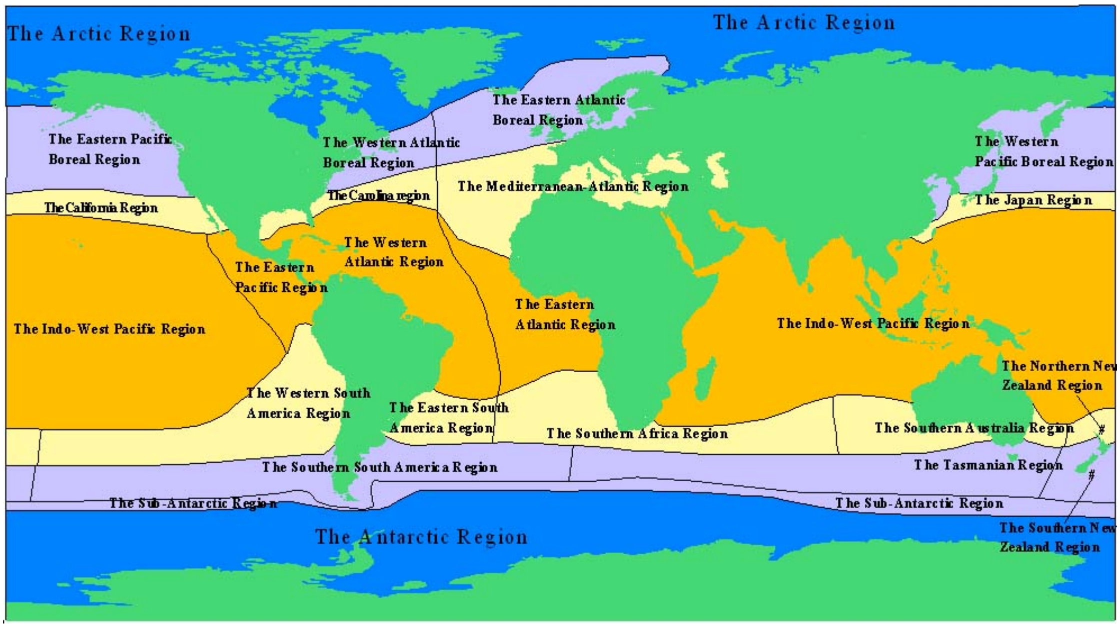

Figure 4. Bioregions according to Ekman (1953) and Briggs (1974)

Voyage duration

Scientific studies of ballast water en-route, with daily sampling frequencies, have shown that numbers of organisms in ballast water decline over time with the greatest decrease during the first three days of the voyage. After ten days few living individuals remained (Gollasch et al. 2000, Olenin et al. 2000). Consequently, the risk quantification (Table 5) was based on the voyage duration from all 278 source ports measured according to the Lloyds Register/Fairplay (2003) distance tables assuming a ship's speed of 16 knots.

Shipping pattern (inside/outside the Baltic)

As outlined above, ports involved in trade routes with potential ballast water source regions outside the Baltic are exposed to a higher risk of a species introduction. Accordingly, all potential donor port/port regions were evaluated and their location inside or outside the Baltic Sea was used as a risk quantifier. In 2004 and 2005, the total number of ports with shipping routes towards the selected Baltic ports/port regions was 278. All donor ports/port regions were also grouped according to bioregion (Table 6).

Table 5. Risk quantification for voyage duration in nautical miles and days according to Lloyds Register/Fairplay (2003) distance tables. To calculate the duration in days a vessel speed of 16 knots was assumed

Voyage duration [nautical miles]	Voyage duration [days]	Risk quantification
0-1000	<3	High
1000-3500	3-10	Medium
>3500	>10	Low

Table 6. Source bioregions (see also Figure 6) of all 278 ports involved in shipping lines connected to the six selected Baltic ports in 2004 and 2005

Donor port Bioregion	Number
Eastern-Atlantic-Boreal Region	224
Mediterranean-Atlantic Region	29
Indo-West-Pacific Region	5
Western-Atlantic-Boreal Region	5
Carolina Region	4
Western-Atlantic Region	4
Eastern-South-America-Region	3
Japan Region	3
Western-South-America-Region	1
Total	278

Results

Present and future shipping patterns in the Baltic Sea

Species invasions are related to the volume of ballast water released, the frequency of ship visits and most importantly, the environmental match of donor and recipient regions of the ballast water. The busiest shipping routes connect the central Baltic through the Kiel Canal and across Denmark to the German Bight and from here via the British Channel around the Iberian Peninsula and into the Mediterranean Sea, and to the Suez Canal.

The busiest Baltic port (Figure 5) is St. Petersburg with more than 14,500 ships visits followed by Gothenburg (> 11,000), Riga (> 8,000) and Copenhagen (> 6,300). All other ports have less than 6,000 ship arrivals. Other important ports are indicated in Fig. 6; all of these 76 ports handle more than 1 million tonnes of cargo per year. The vast majority of the cargo (88%) is handled in the main 76 Baltic ports.

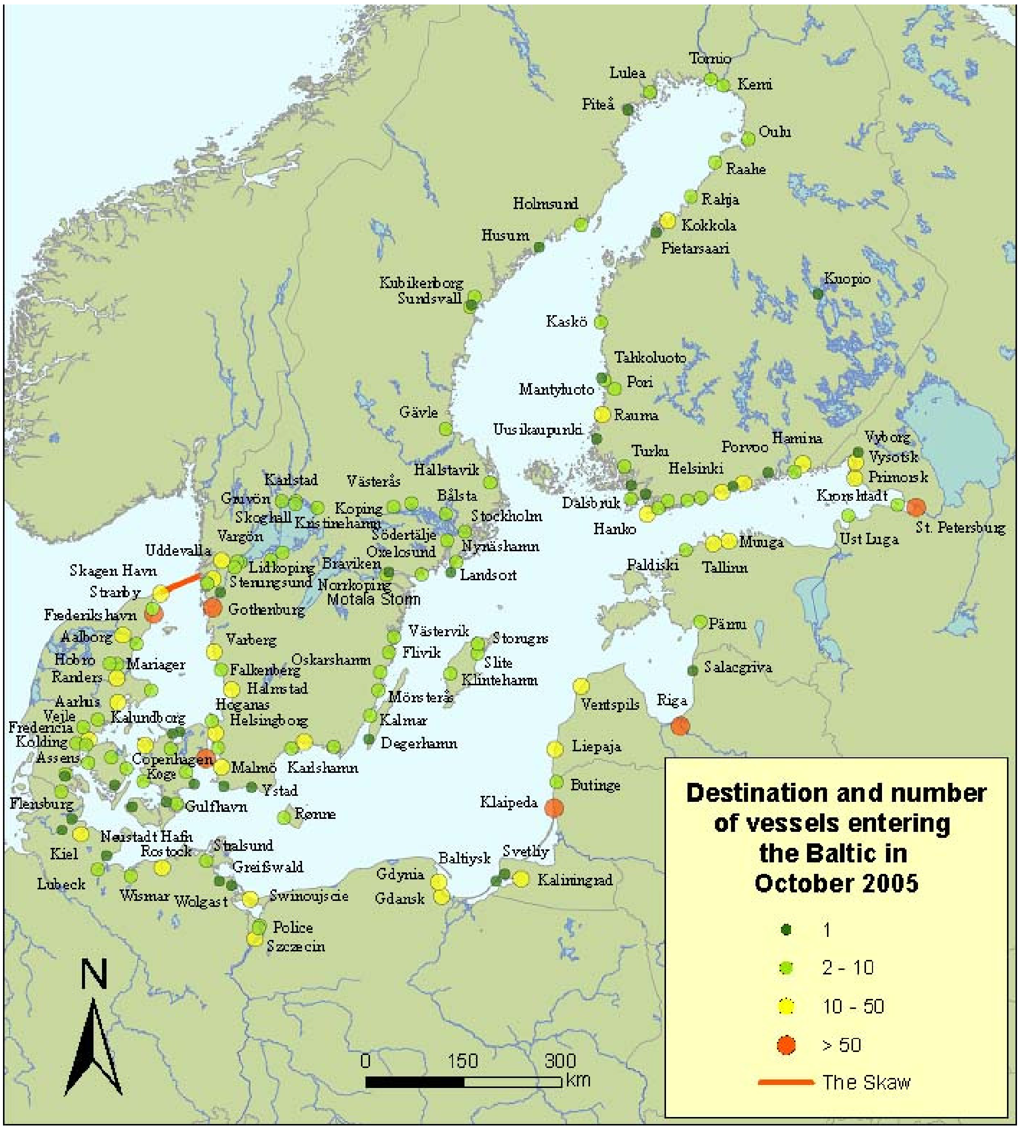

Figure 5. Ships entering the Baltic Sea in October 2005 (i.e. number and destinations of vessels passing the Skaw/Skagen). Derived from HELCOM Automatic Identification System for monitoring maritime traffic in the Baltic Sea area which was officially launched on 1 July 2005

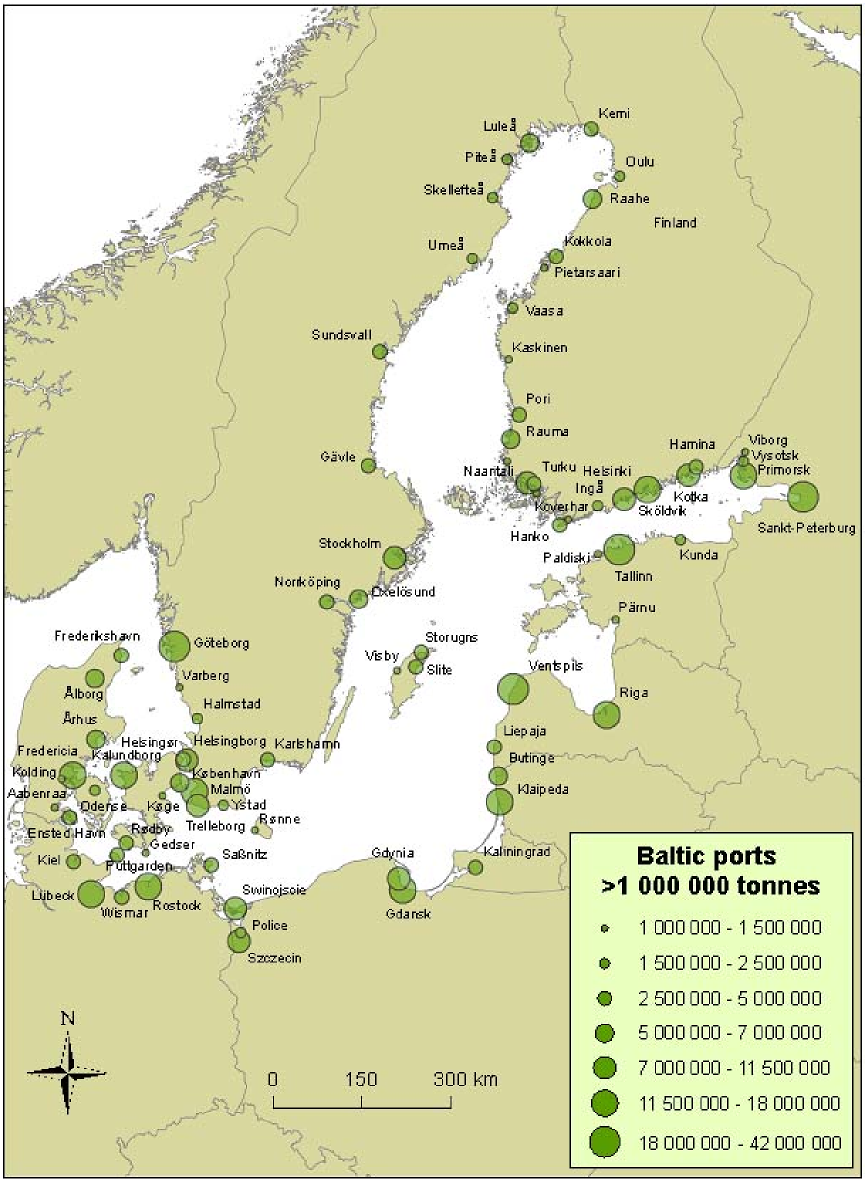

Figure 6. Baltic Sea ports handling > 1 million tonnes of cargo per year (derived from data in Hänninen 2004)

Prediction of future shipping patterns in the Baltic

The number of ship operations (voyages, excluding ferry traffic) in the Baltic is estimated at 150,000 per year. In Sweden only, the number of cargo ship arrivals in 2004 was estimated at 33,400 and that of ferries at > 84,600 (Karin Hoffren, Swedish Maritime Administration; pers. comm.). In Finland, 39,200 ship visits were registered in 2003; 94% of these ships operated as foreign traffic – but mainly on short sea voyages to ports in other Baltic Sea countries. The share of cargo carriers was 57% (22,400 visits). It is assumed that the shipping activities in the Baltic will increase as almost in all regions worldwide. The maritime traffic is expected to double from 1995 to 2017 (COWI 1998; Table 7) with the largest increase being in container traffic.

The increase in oil export from Russia is uncertain, but was estimated to grow by 40% in the same period. From 1995 to 2000 oil export increased from 55 million tonnes to 80 million tonnes (Dragsund et al. 2005). In 2004, 106 million tonnes of oil was transported by sea through the Gulf of Finland, and the annual oil transport is expected to reach 190 million tonnes by the end of the decade (Hänninen and Rytkönen 2004). This increase is generally attributed to the new Russian oil terminals of Primorsk and Vysotsk at the eastern end of the Gulf of Finland.

Table 7. Expected growth (in %) of trade in the Baltic Sea from 1995 to 2017 (COWI 1998; from UNEP 2005)

Commodity	Trade volume (million tonnes)		Expected growth (%)
	1995	2017	
Break bulk	29	82	186
Dry bulk	61	113	84
General cargo	22	64	186
Liquid bulk	1	2	84
Oil	81	112	39
TOTAL	194	372	92

Volume and origin of ballast water discharged

The total quantity of ballast water discharged from ships in international traffic into the Baltic Sea and adjacent lakes (e.g., in Sweden and Finland) cannot be estimated. Due to the lack of basin-wide information and data available on these aspects, only rough estimates and site-specific examples can be presented. Therefore the need for a regional ballast water reporting system is highlighted. However, tentative estimates can be based on shipping statistics, using conversion factors, but this may result in very uncertain calculations. On average, the maximum ballast water capacity of a vessel may be up to 30% of the ships cargo carrying capacity. To address this in greater detail the cargo situation of vessels must be known – the above-mentioned 30% refers to vessels not carrying cargo. These data are currently only available in exceptional cases (e.g., the Port of Sköldvik, Finland).

It will remain a challenge to identify the source regions of ballast water discharged into the Baltic Sea. In order to identify high-risk donor areas, shipping statistics need to be analysed to document all potential donor areas of AIS. However, most shipping statistics for Europe lack data on the source region of the vessels. The source regions indicated (if any) are mainly based on ships' cargo. In some cases the last port of call is given, but this may well be another European port, such as the major hub ports in Europe, e.g., Rotterdam, Antwerp and Hamburg. Also, an indication of the source region of the vessel and/or last port of call does not necessarily provide information on the uptake region of the ballast water onboard.

The amount of discharged ballast water gives an indication of how exposed certain regions are to species introductions. However, this figure is not equivalent to the risk these regions are exposed to. The risk of AIS invasions becomes clearer when comparing the salinity and temperature of donor and recipient regions of ballast water. Even if the amount of ballast water discharged is comparably small, when salinity and temperature of the donor and recipient regions match, the risk is relatively high. Due to the lack of ballast water data for the ports selected we focus the risk assessment for AIS introduction on the environmental match of donor and recipient ports/port regions (qualitative match).

Risk assessment for the selected ports

The four risk quantifiers (salinity, temperature, voyage duration and location of the potential donor port inside/outside the Baltic Sea) result (Figure 7) in a maximum risk level of 12, i.e. for each of the four risk quantifiers used low risk = 1, medium risk = 2, and high risk = 3. The value 12 was quoted as extremely high risk, 11 = high risk, 9-10 = medium and values < 8 as low risk.

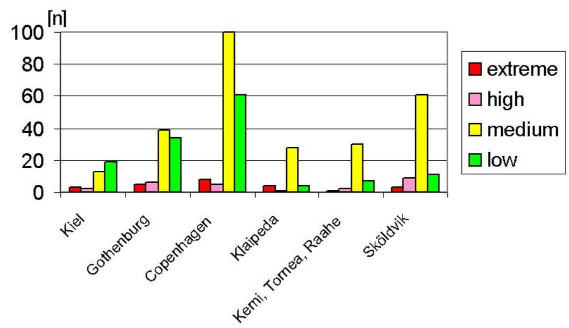

Figure 7. Number of source ports for the selected Baltic ports classified according to risk level

Table 8 documents the risk assessment results of all selected ports according to the risk level based on data assessment as provided in the Annexes 1-6. As the basis for the risk assessment was qualitative, due to (among other reasons) the lack of data on the amount of ballast water discharged, the table should be looked at in qualitative terms – and it becomes clear that:

- all selected Baltic ports have at least one donor port in the highest risk category,
- all extreme and high-risk donor ports are located in Europe, but outside the Baltic Sea – with the exception of only two high-risk donor ports (Hamina and Hanko for Gothenburg as recipient port) which are located within the Baltic Sea,
- the most frequently reported high-risk donor ports are Rotterdam (6 times), Bremerhaven (5), Amsterdam (4) and Antwerp (3), and
- most high-risk donor ports are the major hub ports in Europe.

In all selected ports the number of medium and low-risk donor ports is highest, but it is of concern that all selected ports are connected to at least one extremely high-risk donor port. Comparing the risk level of source ports for each port selected, the share of extreme high-risk donor ports ranges from 2.5% (Kemi, Tornio and Raahe) up to 10.8% (Klaipeda) indicating that Klaipeda has the highest percentage of extreme high-risk port connections, followed by Kiel (8.1%; Table 9).

Table 8. Risk level of the selected Baltic ports/port regions according to number of source ports. Ports posing an extreme or high risk were listed in alphabetical order. For details see Annexes 1-6

Port /port region	Number of source ports according to risk level			
	Extreme (risk value 12)	High (risk value 11)	Medium (risk level 9-10)	Low (risk level <8)
Kiel (DE)	3 Cuxhaven (DE) Mo i Rana (NO) Rotterdam (NL)	2 Bremerhaven (DE) Wilhelmshaven (DE)	13	19
Gothenburg (SE)	5 Amsterdam (NL) Bremerhaven (DE) Immingham (GB) Rotterdam (NL) Tilbury (GB)	6 Cork (IE) Dublin (IE) Frederikstd (NO) Hamina (FI) Hanko (FI) Newcastle (GB)	39	34
Copenhagen (DK)	8 Amsterdam (NL) Bremerhaven (DE) Brunsbüttel (DE) Cuxhaven (DE) Delfzijl (NL) Emden (DE) Moss (NO) Rotterdam (NL)	5 Glasgow (GB) Hull (GB) Inverness (GB) Thamesport (GB) Tilbury (GB)	100	61
Klaipeda (LT)	4 Bremerhaven (DE) Hamburg (DE) Oostend (BE) Rotterdam (NL)	1 Antwerp (BE)	28	4
Kemi, Tornio, Raahe (FI)	1 Antwerp (BE)	2 Amsterdam (NL) Rotterdam (NL)	30	7
Sköldvik (FI)	3 Bützfleth (DE) Hamburg (DE) Stade (DE)	9 Amsterdam (NL) Antwerp (BE) Blexen (DE) Bremen (DE) Bremerhaven (DE) Cuxhaven (DE) Ghent (BE) Rotterdam (NL) Terneuzen (NL)	61	11

Table 9. Absolute and relative risk level of the selected Baltic ports/port regions according to number of source ports

Risk level	Port/port region											
	Kiel		Gothenburg		Copenhagen		Klaipeda		Kemi, Tornio, Raahe		Sköldvik	
	n	%	n	%	n	%	n	%	n	%	n	%
Extreme	3	8,1	5	6,0	8	4,6	4	10,8	1	2,5	3	3,6
High	2	5,4	6	7,1	5	2,9	1	2,7	2	5	9	10,7
Medium	13	35,1	39	46,4	100	57,0	28	75,7	30	75	61	72,6
Low	19	51,4	34	40,5	61	35,0	4	10,8	7	17,5	11	13,1
Total	37	100	84	100	174	100	37	100	40	100	84	100

Discussion

The shipping profiles for selected ports differ considerably with regard to import/export ratio and type of cargo handled; conversion factors to estimate the volume of loaded/discharged ballast water are difficult to apply. However, this was the only available approach with the very limited amount of data available. To deliver a more realistic figure of loaded/discharged ballast water all such efforts should be based on more detailed estimates on a port-by-port and ship-by-ship basis.

It has to be taken into account that all general rules or models have exceptions and cannot be applied for all habitats. Matching temperatures in the area of origin and the new habitat does not explain the potential of a species to tolerate or adapt to temperatures uncommon in its native range. A well-known example is the ship-boring mollusc *Teredo navalis* (shipworm; see Nehring 2000 for a review). It is believed to be of tropical origin and introduced with wooden sailing vessels. Nowadays the species causes damages to wooden installations in warm-temperate and even in cold-temperate climates. The first documented record in Europe was a mass occurrence of the species resulting in heavy damages to tide protection installations, quays and wharves along the coasts of The Netherlands, Germany and Denmark in the 1730s. The species was often found in the western Baltic Sea due to secondary introductions by ships or saltwater inflows from the North Sea. Until the early 1990s, no self-reproducing population was observed in the Baltic Sea. Most recently larvae of the shipworm were found along the eastern German Baltic coast, indicating a self-reproducing population.

Similarly, the unexpected increase of mussels, believed to be zebra mussels, since 2003 off the Finnish nuclear power plants in Lovisa, eastern Gulf of Finland, and Olkiluoto, Bothnian Sea, was shown to be due to the recently invaded dark false mussels (*Mytilopsis leucophaeata*), a species previously not recorded in the northern Baltic Sea (Laine et al. 2006, Laine and Urho 2007). This species is native to the Gulf of Mexico area; being a warm-water species it obviously benefits from the raised water temperature off the cooling water outlet of the power plant.

Both species were surprisingly able to adapt to cold climates and to lower salinities of brackish waters. None of the established risk assessment models of today would have quoted these species on the list of target, "hotspot" species for the introduction into cold-temperate and brackish waters due to non-matching climate and salinity regimes of donor and recipient region.

1. *Suggested ballast water management approach for the Baltic*

Several ballast water management options have been discussed and evaluated (see Matheickal et al. 2004 for a review of ongoing technical efforts). In the absence of approved ballast water treatment systems, the following options may be considered:

- <u>*land-based port reception facilities for untreated ballast water*</u>. This option may only be useful in certain ports with certain types of cargo, e.g., smaller ports handling predominantly crude oil or other fluid cargo may be candidates for reception facilities as pipework is already installed and instead of cargo, ballast water may also be discharged to land-based facilities using this pipework. However, it should be noted that ballast water transported in oil cargo compartments may be contaminated by unpumpable oil, which cannot be discharged, and therefore this option needs to be critically reviewed,

- *oceanic ballast water exchange (BWE)* for vessels that pass through waters that are at least 200 nm (or 50 nm) from nearest land and at the same time are at least 200 m in depth (see IMO requirements for BWE, IMO 2004). It should be noted that this is only recommended when time is sufficient to complete the ballast water exchange. Partly exchanged ballast water may "refresh" the water in the tank resulting in species survival and is therefore not acceptable,
- *identification of ballast water exchange zones*, i.e. zones where it is believed that the exchange of unmanaged/untreated ballast water causes at best no harm although these areas may not meet the depth and distance requirements (see above). BWE in designated areas may reduce but not eliminate the risk of species introductions, but is a better approach than discharging untreated ballast water in a port. The invasion risk may be reduced when, for example offshore-directed currents dominate. However, it is supposed that no BWE zone of sufficient size to allow for complete BWE can be identified in the Baltic as the waters are mostly too shallow to assume a risk-reducing effect. Also outside the Baltic Sea (but within Europe) BWE seems to be a difficult option, and BWE zones maybe impossible to identify noting the following requirements:
    - to avoid voyage deviation,
    - to ensure efficient "dilution", and
    - to avoid the risk of secondary species introductions.

A risk assessment based management approach is essentially needed to identify high-risk vessels and/or high-risk donor ports or port regions as it is assumed that not all vessels on all voyages can manage or treat their ballast water. This assessment should not be limited to vessels with travel schedules outside the Baltic Sea as within-Baltic traffic may also promote the secondary spread of organisms within the Baltic.

The first ports in the Baltic region have started to implement ballast water related requirements. Vessels calling at the Butinge oil terminal (Lithuania) are all in ballast resulting in a large amount of water being discharged. The Butinge port authorities have imposed a ballast water requirement for all vessels that arrive with ballast water which originates from outside the North or Baltic Seas. These vessels have to exchange their ballast water prior to reaching the North Sea before arrival to the Butinge oil terminal (Sergej Olenin, Klaipeda University, pers. comm.).

Each vessel arriving in the Baltic poses a risk to introduce new AIS. Even ships with no ballast on board (NOBOB) represent a risk of introducing new AIS. As shown in the Great Lakes, NOBOB ships contain an average 60 tonnes of unpumpable residual water and sediment in ballast tanks. This unpumpable ballast contains up to tens of millions of viable resting stages of invertebrates per tonne of sediment (Gray et al. 2005). Experimental studies performed by the same authors showed that exposure to high-saline water does not effectively eliminate sediment-bound resting stages but only reduces numbers or viability. This unpumpable ballast may not be discharged when a ship arrives in a Baltic port. However, once one tank with residual ballast water and sediment was filled in one Baltic port the sediment and organisms may be recirculated into the water column and may be released when this ship calls for the next (Baltic) port and has to discharge this tank here. This illustrates the urgent need for efficient ballast water treatment systems. As such systems are not yet readily available, BWE is the only option to reduce the risk of AIS introductions with ballast water release. In addition all measures should be undertaken to avoid species uptake in the ballast water donor region. The recommendations of the IMO Guideline 868(20) should whenever possible be followed. These measures include:

1. The uptake of ballast water should be minimized or, where practicable, avoided in areas and situations such as:

- areas with outbreaks, infestations or known populations of harmful organisms and pathogens;
- areas with current phytoplankton blooms;
- nearby sewage outfalls;
- nearby dredging operations;
- in darkness when bottom-dwelling organisms may rise up in the water column;
- in very shallow water; or
- where propellers may stir up sediment.

2. Removing ballast sediment on a timely basis.
3. Where practicable, routine cleaning of the ballast tank to remove sediments should be carried out in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's ballast water management plan.
4. Avoiding unnecessary discharge of ballast water.
5. If it is necessary to take on and discharge ballast water in the same port to facilitate safe cargo operations, care should be taken to avoid unnecessary discharge of ballast water that has been taken up in another port.

2. High-risk shipping routes

The risk assessment carried out for the selected ports revealed that high-risk shipping routes are those connecting ballast water donor and recipient regions in the same bioregion or within identical climate zone(s). The major difficulty in Europe is that BWE cannot be carried out on those shipping routes as all high-risk ports are in regional seas not meeting the IMO depth and/or distance limits for BWE during the ships voyage. As BWE cannot be carried out here as a risk reducing measure, this indicates the need for ballast water treatment.

Due to the varying salinity conditions throughout the Baltic and its adjacent waters, a route-specific approach to address ballast water management is recommended. However, all shipping routes may be grouped in three categories as outlined below. The measures recommended below assume that ballast water treatment systems are unavailable and also that ballast water reception facilities are lacking. As a result the "only" risk reducing measure is BWE.

2.1. Ships on oceanic voyages

Ships operated on oceanic voyages are usually able to meet the IMO water depth and distance limits for BWE. However, safety aspects may not enable BWE while at sea. Further, BWE shows limited efficiency in the removal of organisms from ballast tanks (Olenin et al. 2000, McCollin et al. 2001, 2007). However, as an interim solution and until ballast water treatment systems become available, BWE should be carried out wherever possible on such voyages before entering the Baltic Sea.

2.1.1 Scenario 1 – Matching salinity or temperature in donor and recipient regions for ships operated on oceanic voyages

Where salinity or temperature match occurs in donor and recipient regions (e.g., shipping routes connecting a brackish water port in Chesapeake Bay (east coast of North America) with the Baltic proper), a mid-ocean BWE should be carried out, ,if safety considerations permit. It is also recommended that ballast water is exchanged in mid-ocean when ships connect two freshwater ports, such as Duluth (North American Great Lakes) and St. Petersburg (both ports are located in similar climate zones).

2.1.2 Scenario 2 – Non-matching salinity or temperature in donor and recipient regions for ships operated on oceanic voyages

On shipping routes without salinity match (e.g., Singapore (fully marine conditions) to Helsinki (low-brackish conditions)) BWE may be considered optional as the risk that a marine organism would survive when released into freshwater conditions is minimal. If ballast water was taken onboard in a freshwater tropical port and released in Helsinki in winter, the species introduction risk is also minimal. However, this does not include, for example, the release of water from Singapore to the Baltic in the vicinity of thermal discharges (e.g., from power plants) in summer, especially if species show a broad salinity tolerance. In this case we recommend carrying out BWE as the abiotic conditions of donor and recipient regions overlap.

2.2. Intra-European shipping

In northwest Europe the IMO water depth and distance limits for BWE cannot be met.

However, the risk of introduction species remains high when donor and recipient regions show similar salinity and temperature conditions. The following scenarios may be considered:

2.2.1 Scenario 1 – Matching salinity or temperature in donor and recipient regions for ships operated on NW-European shipping routes

When a shipping route connects ports with a match in salinity or temperature, for example, Rotterdam with the western Baltic (both ports are brackish and located in identical climate zones), a BWE should be carried out in fully marine water conditions although the IMO depth and distance limits cannot be met. It is believed that organisms in the high saline water taken onboard during BWE will not likely survive when discharged in lower salinity brackish waters.

Fresh water ballast originating from outside the Baltic should also be exchanged prior to release in freshwater habitats of the Baltic, for example, on ship voyages from Antwerp to the eastern Gulf of Finland, both being freshwater port regions in the same climate zone. Such action will reduce the risk of introducing a species, although the risk reduction is not as efficient as in ships operated on oceanic voyages due to the lower water depth in the BWE zone.

In addition ships operated in the Ponto-Caspian – Baltic inland waterway (matching salinity) should carry out a BWE en-route, ideally at the beginning of the canals.

2.2.2 Scenario 2 – Non-matching salinity or temperature in donor and recipient regions for ships operated on intra-European shipping routes

Ships engaged in voyages without salinity or temperature match, for example, La Coruna (Spain, marine conditions) to St. Petersburg (freshwater conditions) may consider BWE optional as the risk that a marine organism would survive when released into freshwater conditions is assumed to be minimal.

2.3. Intra-Baltic shipping

Intra-Baltic shipping poses a risk for secondary spread of previously introduced species. As in NW-European shipping, ships operated within the Baltic are not able to meet the IMO water depth and distance limits for BWE. However, on certain shipping routes a BWE may be required in case a salinity match occurs between ports separated by more saline waters between them. As an example, ships carrying ballast water from St. Petersburg (freshwater) and intending to discharge this ballast water in freshwater ports at river mouths in the southern Baltic Sea should exchange the water within the Baltic at the highest salinity. One reasoning for this scenario is that introduced freshwater organisms occurring in the inner Gulf of Finland would not be able to reach freshwater habitats adjacent to the southern or western Baltic as the increasing salinity between these areas prevents their natural spread.

2.4. Designation of a ballast water exchange zone within the Baltic

2.4.1 Ballast water exchange zone for shipping from outside the Baltic

It is assumed that a BWE zone in the Baltic for ballast water originating from outside the Baltic cannot be identified. This is because the Baltic is too shallow and all potential BWE zones are located in (very) close proximity to the coast. Instead, ships intending to discharge ballast water from outside the Baltic should endeavour to exchange the ballast water before entering the Baltic Sea. However, this approach needs careful consideration as neighbouring states to the BWE may become affected, for example, a voyage between Antwerp and Helsinki would involve an exchange in the North Sea and a voyage from the Black Sea to NW Europe may affect Mediterranean States.

2.4.2 Ballast water exchange zone for intra-Baltic shipping

In rare instances a BWE of ships on intra-Baltic voyages may be required, e.g., transport of freshwater ballast across more saline waters, which will be discharged in freshwater recipient regions (see above).

Recommendations

As indicated above, various ballast water management approaches are currently being developed, including for the OSPAR region, Mediterranean and Caspian Seas. The HELCOM approach recommends exchanging ballast water of ships arriving from outside the Baltic and also in intra-Baltic shipping (in certain instances – see above). Problems occur when trying to identify appropriate BWE zones as neighbouring seas and jurisdictions may be affected, for example, recommending ballast water exchange of ships in intra-European traffic prior entry into the Baltic which may result in a water exchange in the North Sea. From the Baltic perspective this is considered as a risk reducing measure. However, at the same time it exposes the North Sea to additional ballast water discharges. The ultimate goal should be to reduce the amount of ballast water discharges (frequency and volume) to the essential minimum. This conflict of interest may only be solved by the development of a European-wide ballast water management approach. It is therefore recommended to launch a working group of experts involving various stakeholders across all European seas. The target of this initiative should include the standardization of ballast water management approaches across all European seas and the further development of guidelines for the identification of BWE zones, especially for intra-European shipping. It may be considered valuable to launch a "European Ballast Water Management Decision Support System".

It should be noted that, assuming the IMO Ballast Water Management Convention (BWMC) enters into force as planned, BWE is only a risk reducing measure of limited duration, for example, according to the BWMC the first ships need to meet the higher discharge standards (organism concentration limit) by January 1st 2009. All risk reducing measures including BWE, are seen as an essential tool to protect European seas from new AIS introductions. As a result, although BWE may have a limited duration all efforts in this regard will reduce the risks of new AIS introductions. However, the entry into force of the BWMC may be delayed due to lack of signatory countries with sufficient world fleet tonnage. It is also believed that the implementation of mandatory BWE requirements may prompt the ratification of the BWMC.

There is no doubt that ballast water discharges are an important and locally may be the prime species introduction vector. Reducing the number of organisms discharged also reduces the risk of new species introductions considerably. Regulating this vector is an important step in saving our waters from biological invasions. However, species introduction with ships will continue as another introduction vector is largely unregulated – the hull fouling of vessels.

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Annex 1

Detailed risk assessment results for the Port of Copenhagen (Denmark)

Risk assessment according to source ports of ships arriving in Copenhagen (Denmark). For information source(s) see text and www.tv.cphport.dk. Temperature zones according to Briggs (1974) and Ekman (1953), CL = Carolina Region, EAB = Eastern Atlantic Boreal Region, ESA = Eastern South America, IWP = Indo-West Pacific Region, MA = Mediterranean Atlantic Region, WA = Western Atlantic Region, WAB = Western Atlantic Boreal Region. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Copenhagen	Denmark	10	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Aabenraa	Denmark	18,2	EAB	no	1	yes	3	0,5	196	3	yes	1	8
Aalborg	Denmark	18,2	EAB	no	1	yes	3	0,4	143	3	yes	1	8
Aarhus	Denmark	20,0	EAB	no	1	yes	3	0,3	113	3	yes	1	8
Algerciras	Spain	30,9	MA	no	1	no	2	5,2	1916	2	no	3	8
Amsterdam	Netherlands	0-11,8	EAB	yes	3	yes	3	1,6	572	3	no	3	12
Amuay Bay	Venezuela	30,9	WA	no	1	no	1	12,9	4707	1	no	3	6
Antwerp	Belgium	0	EAB	no	1	yes	3	1,9	704	3	no	3	10
Barcadera	Aruba	30,9	WA	no	1	no	1	12,8	4664	1	no	3	6
Augusta	Italy	34,8	MA	no	1	no	2	8,1	2949	2	no	3	8
Asnaesvaerkets Havn	Denmark	5,4-25,9	EAB	yes	3	yes	3	0,3	115	3	yes	1	10
Bergen	Norway	30,9	EAB	no	1	yes	3	1,2	457	3	no	3	10
Bilbao	Spain	30,9	MA	no	1	no	2	3,6	1322	2	no	3	8
Bremen	Germany	0	EAB	no	1	yes	3	1,4	515	3	no	3	10
Bremerhaven	Germany	9,3-13,1	EAB	yes	3	yes	3	1,3	480	3	no	3	12
Bristol	UK	18,2	EAB	no	2	yes	3	3,1	1128	2	no	3	10
Brofjorden	Sweden	>30	EAB	no	1	yes	3	0,5	174	3	yes	1	8
Bruges	Belgium	30,9	EAB	no	1	yes	3	1,8	657	3	no	3	10
Brunsbüttel	Germany	0-9,3	EAB	no	3	yes	3	0,6	216	3	no	3	12
Cherbourg	France	30,9	MA	no	1	no	2	2,3	829	3	no	3	9
Cuxhaven	Germany	10-25	EAB	yes	3	yes	3	0,6	232	3	no	3	12
Delfzijl/ Eemshaven	Netherlands	9,3-22,1	EAB	yes	3	yes	3	1,4	495	3	no	3	12
Nantes-St Nazaire	France	2,9-30,9	MA	yes	3	no	2	3,2	1184	2	no	3	10
Dover	UK	30,9	EAB	no	1	yes	3	1,9	683	3	no	3	10
Drammen	Norway	30,9	EAB	no	1	yes	3	0,7	262	3	no	3	10
Dundee	UK	22,1	EAB	no	1	yes	3	1,7	604	3	no	3	10
Egersund	Norway	24,6	EAB	no	1	yes	3	0,9	321	3	no	3	10
Elsinore	Denmark	18,2	EAB	no	1	yes	3	0,1	22	3	yes	1	8
Emden	Germany	10,6-24,6	EAB	yes	3	yes	3	1,4	498	3	no	3	12
Esbjerg	Denmark	29,8	EAB	no	1	yes	3	1	381	3	no	3	10
Fawley	UK	18,2-30,9	EAB	no	1	yes	3	2,2	799	3	no	3	10
Fredericia	Denmark	18,2	EAB	no	1	yes	3	0,4	143	3	yes	1	8
Gdansk	Poland	7	EAB	no	3	yes	3	0,7	274	3	yes	1	10
Gdynia	Poland	6,7	EAB	no	3	yes	3	0,7	270	3	yes	1	10
Ghent	Belgium	0	EAB	no	1	yes	3	1,9	684	3	no	3	10
Gibraltar	Gibraltar	30,9	MA	no	1	no	2	5,2	1916	2	no	3	8
Glasgow	UK	0-4,2	EAB	no	2	yes	3	2,7	977	3	no	3	11

Annex1 (continued)

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Gothenburg	Sweden	13,1-18,2	EAB	no	3	yes	3	0,4	137	3	yes	1	10
Grangemouth	UK	23,4	EAB	no	1	yes	3	1,7	638	3	no	3	10
Grimsby	UK	22,1	EAB	no	1	yes	3	1,6	597	3	no	3	10
Gulfhavn	Denmark	8-28,5	EAB	yes	3	yes	3	0,4	143	3	yes	1	10
Halden	Norway	18,2	EAB	no	1	yes	3	0,6	235	3	no	3	10
Halmstad	Sweden	15	EAB	no	2	yes	3	0,2	70	3	yes	1	9
Hamburg	Germany	0	EAB	no	1	yes	3	0,7	252	3	no	3	10
Hamina	Finland	2,9	EAB	no	2	yes	3	1,7	616	3	yes	1	9
Hanko	Finland	5,4	EAB	no	2	yes	3	1,3	492	3	yes	1	9
Härnosand	Sweden	0	EAB	no	1	yes	3	1,7	612	3	yes	1	8
Harwich	UK	30,9	EAB	no	1	yes	3	1,7	632	3	no	3	10
Helsingborg	Sweden	5,4-24,6	EAB	yes	3	yes	3	0,1	22	3	yes	1	10
Helsinki	Finland	0-6,7	EAB	no	2	yes	3	1,5	555	3	yes	1	9
Holmestrand	Norway	30,9	EAB	no	1	yes	3	0,7	240	3	no	3	10
Horsens	Denmark	24,6	EAB	no	1	yes	3	0,4	143	3	yes	1	8
Houston	USA	0	CL	no	1	no	1	14,5	5317	1	no	3	6
Hull	UK	15,7-18,2	EAB	no	2	yes	3	1,7	608	3	no	3	11
Ijmuiden	Netherlands	30,9	EAB	no	1	yes	3	1,5	557	3	no	3	10
Immingham	UK	20,8	EAB	no	1	yes	3	1,6	601	3	no	3	10
Invergordon	UK	20,8-30,9	EAB	no	1	yes	3	1,7	633	3	no	3	10
Inverness	UK	4,2	EAB	no	2	yes	3	1,8	642	3	no	3	11
Izmir / Dikli	Turkey	37,3	MA	no	1	no	2	9,7	3553	1	no	3	7
Kaliningrad	Russia	0	EAB	no	1	yes	3	0,8	307	3	yes	1	8
Kalmar	Sweden	7	EAB	no	3	yes	3	0,5	198	3	yes	1	10
Kalundborg	Denmark	30,9	EAB	no	1	yes	3	0,3	115	3	yes	1	8
Karlshamn	Sweden	8	EAB	no	3	yes	3	0,4	146	3	yes	1	10
Karlstad	Sweden	0	EAB	no	1	yes	3	0,7	258	3	yes	1	8
Kiel	Germany	19,5	EAB	no	1	yes	3	0,4	162	3	yes	1	8
Klaipeda	Lithuania	<8	EAB	no	3	yes	3	0,9	323	3	yes	1	10
Koge	Sweden	8	EAB	no	3	yes	3	0,1	30	3	yes	1	10
Kokkola	Finland	2,9	EAB	no	2	yes	3	2	741	3	yes	1	9
Kolding	Denmark	18,2	EAB	no	1	yes	3	0,4	150	3	yes	1	8
Korsör	Denmark	15,7	EAB	no	2	yes	3	0,4	135	3	yes	1	9
Kotka	Finland	2,9	EAB	no	2	yes	3	1,7	610	3	yes	1	9
Kristiansand	Norway	30,9	EAB	no	1	yes	3	0,7	246	3	no	3	10
La Coruna	Spain	33,5	MA	no	1	no	2	3,6	1322	2	no	3	8
Laajasalo	Finland	0-6,7	EAB	no	2	yes	3	1,5	555	3	yes	1	9
Landskrona	Sweden	9,3-14,4	EAB	yes	3	yes	3	0,1	16	3	yes	1	10
Larvik	Norway	30,9	EAB	no	1	yes	3	0,6	223	3	no	3	10
le Havre	France	30,9	MA	no	1	no	2	2,2	798	3	no	3	9
Leith	UK	18,2	EAB	no	1	yes	3	1,7	620	3	no	3	10
Leixoes	Portugal	32,2	MA	no	1	no	2	4	1481	2	no	3	8
Lerwick	UK	30,9	EAB	no	1	yes	3	1,5	562	3	no	3	10
Liepaya	Latvia	<8	EAB	no	3	yes	3	0,9	325	3	yes	1	10
Lübeck	Germany	<10	EAB	no	3	yes	3	0,4	150	3	yes	1	10
Lulea	Sweden	0	EAB	no	1	yes	3	2,2	799	3	yes	1	8
Lysekil	Sweden	33,5	EAB	no	1	yes	3	0,5	174	3	yes	1	8
Malaga	Spain	30,9	MA	no	1	no	2	5,4	1975	2	no	3	8
Malmö	Sweden	11,8	EAB	no	3	yes	3	0,1	20	3	yes	1	10
Milford Haven	UK	32,2	EAB	no	1	yes	3	3	1079	2	no	3	9
Mina Al Ahmadi	Kuwait	30,9	IWP	no	1	no	1	19,2	7039	1	no	3	6
Moss	Norway	5,4-30,9	EAB	yes	3	yes	3	0,7	239	3	no	3	12
Naantali	Finland	6,7	EAB	no	3	yes	3	1,4	496	3	yes	1	10

Annex1 (continued)

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Naestved	Denmark	5,4	EAB	no	2	yes	3	0,5	170	3	yes	1	9
New York	USA		WAB	no	2	no	2	10	3675	1	no	3	8
Newcastle upon Tyne	UK	24,6	EAB	no	1	yes	3	1,6	592	3	no	3	10
Norrköping	Sweden	<5	EAB	no	2	yes	3	1	375	3	yes	1	9
Nyborg	Denmark	9,3	EAB	yes	3	yes	3	0,4	138	3	yes	1	10
Nynäshamn	Sweden	7	EAB	no	3	yes	3	1	354	3	yes	1	10
Odessa	Ukraine	14,4	MA	no	2	no	2	11,1	4054	1	no	3	8
Odense	Denmark	11,8-22,1	EAB	no	3	yes	3	0,4	137	3	yes	1	10
Örnsköldsvik	Sweden	4,2	EAB	no	2	yes	3	1,8	650	3	yes	1	9
Ortviken	Sweden	0-5,4	EAB	no	2	yes	3	1,6	603	3	yes	1	9
Oskarshamn	Sweden	7	EAB	no	3	yes	3	0,8	302	3	yes	1	10
Oslo	Norway	30,9	EAB	no	1	yes	3	0,7	272	3	no	3	10
Oulu	Finland	0	EAB	no	1	yes	3	2,3	833	3	yes	1	8
Oxelösund	Sweden	7	EAB	no	3	yes	3	0,9	341	3	yes	1	10
Pasajes	Spain	30,9	MA	no	1	no	2	3,7	1340	2	no	3	8
Pembroke	UK	32,2	EAB	no	1	yes	3	3	1082	2	no	3	9
Pensacola	USA	30,9	CL	no	1	no	1	13,7	5009	1	no	3	6
Pietarsaari	Finland	1,6	EAB	no	1	yes	3	2	724	3	yes	1	8
Pori	Finland	4,2	EAB	no	2	yes	3	1,6	572	3	yes	1	9
Porvoo	Finland	0-6,7	EAB	no	2	yes	3	1,6	582	3	yes	1	9
Puerto La Cruz	Venezuela	30,9	WA	no	1	no	1	12,7	4643	1	no	3	6
Punta Cardon	Venezuela	32,2	WA	no	1	no	1	12,9	4713	1	no	3	6
Quebec	Canada	0	WAB	no	1	no	2	9,1	3328	2	no	3	8
Ras Lanuf	Libya	33,5	MA	no	1	no	2	8,9	3252	2	no	3	8
Rauma	Finland	2,9-4,2	EAB	no	2	yes	3	1,5	553	3	yes	1	9
Reykjavik	Iceland	33,5	EAB	no	1	yes	3	3,4	1259	2	no	3	9
Riga	Latvia	1,6	EAB	no	1	yes	3	1,3	478	3	yes	1	8
Rönne	Denmark	5,4	EAB	no	2	yes	3	0,3	103	3	yes	1	9
Ronneby	Sweden	0	EAB	no	1	yes	3	0,4	151	3	yes	1	8
Rostock	Germany	6,7-10,6	EAB	yes	3	yes	3	0,3	108	3	yes	1	10
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	1,7	608	3	no	3	12
Rouen	France	0	MA	no	1	no	2	2,4	868	3	no	3	9
Ruwais	United Arab Emirates	30,9 - >40,0	IWP	no	1	no	1	18,6	6798	1	no	3	6
Sandefjord	Norway	30,9	EAB	no	1	yes	3	0,6	225	3	no	3	10
Sandnes	Norway	30,9	EAB	no	1	yes	3	1	359	3	no	3	10
Santos	Brazil	8-24,6	ESA	yes	3	no	1	16,4	5981	1	no	3	8
Seville	Spain	0	MA	no	1	no	2	5,2	1895	2	no	3	8
Shuaiba	Kuwait	30,9	IWP	no	1	no	1	19,2	7029	1	no	3	6
Sikka	India	30,9	IWP	no	1	no	1	18,4	6736	1	no	3	6
Skagen	Denmark	30,9	EAB	no	1	yes	3	0,4	152	3	no	3	10
Skelleftea	Sweden	0	EAB	no	1	yes	3	2,1	757	3	yes	1	8
Skoghall	Sweden	0	EAB	no	1	yes	3	0,7	258	3	yes	1	8
Slite	Sweden	5,4	EAB	no	2	yes	3	0,9	316	3	yes	1	9
Söderhamn	Sweden	5,4	EAB	no	2	yes	3	1,5	565	3	yes	1	9
Södertälje	Sweden	6,7	EAB	no	3	yes	3	1	372	3	yes	1	10
Sölvesborg	Sweden	8	EAB	no	3	yes	3	0,4	136	3	yes	1	10
Southampton	UK	18,2-30,9	EAB	no	1	yes	3	2,2	803	3	no	3	10
St. Petersburg	Russia	0	EAB	no	1	yes	3	1,9	699	3	yes	1	8
Stade	Germany	0	EAB	no	1	yes	3	0,6	235	3	no	3	10
Stavanger	Norway	30,9	EAB	no	1	yes	3	1	382	3	no	3	10
Stenungsund	Sweden	20-28	EAB	no	1	yes	3	0,4	162	3	yes	1	8
Stigsnaesvaerkets Havn	Denmark	8-28,5	EAB	yes	3	yes	3	0,4	143	3	yes	1	10

Annex1 (continued)

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Stockholm	Sweden	5,4	EAB	no	2	yes	3	1,2	427	3	yes	1	9
Stralsund	Germany	9,3-13,1	EAB	yes	3	yes	3	0,2	88	3	yes	1	10
Stockholm	Sweden	5,4	EAB	no	2	yes	3	1,2	427	3	yes	1	9
Stralsund	Germany	9,3-13,1	EAB	yes	3	yes	3	0,2	88	3	yes	1	10
Strömstad	Sweden	>25	EAB	no	1	yes	3	0,6	224	3	yes	1	8
Sundsvall	Sweden	0-5,4	EAB	no	2	yes	3	1,6	603	3	yes	1	9
Svendborg	Denmark	19,5	EAB	no	1	yes	3	0,4	156	3	yes	1	8
Swinoujscie	Poland	1,6	EAB	no	1	yes	3	0,4	130	3	yes	1	8
Szczecin	Poland	0	EAB	no	1	yes	3	0,4	163	3	yes	1	8
Tallinn	Estonia	2,9	EAB	no	2	yes	3	1,5	533	3	yes	1	9
Tampico	Mexico	6,7	CL	no	3	no	1	14,8	5407	1	no	3	8
Terneuzen	Netherlands	0	EAB	no	1	yes	3	1,8	666	3	no	3	10
Thamesport	UK	>14,4	EAB	no	2	yes	3	1,8	674	3	no	3	11
Tilbury	UK	14,4	EAB	no	2	yes	3	1,9	684	3	no	3	11
Tonsberg	Norway	30,9	EAB	no	1	yes	3	0,6	230	3	no	3	10
Travemünde	Germany	8	EAB	no	3	yes	3	0,4	139	3	yes	1	10
Trelleborg	Sweden	8	EAB	no	3	yes	3	0,1	50	3	yes	1	10
Trondheim	Norway	30,9	EAB	no	1	yes	3	2,1	753	3	no	3	10
Tuborg	Denmark	5,4	EAB	no	2	yes	3	0,1	5	3	yes	1	9
Tunis	Tunisia	34,8	MA	no	1	no	2	7,4	2706	2	no	3	8
Turku	Finland	4,2	EAB	no	2	yes	3	1,4	497	3	yes	1	9
Uddevalla	Sweden	18,2	EAB	no	1	yes	3	0,5	180	3	yes	1	8
Valencia	Spain	30,9	MA	no	1	no	2	6,3	2299	2	no	3	8
Varberg	Sweden	18,2	EAB	no	1	yes	3	0,3	92	3	yes	1	8
Västerås	Sweden	0	EAB	no	1	yes	3	1,2	432	3	yes	1	8
Västervik	Sweden	0-5,4	EAB	no	1	yes	3	0,8	295	3	yes	1	8
Ventspils	Latvia	1,6	EAB	no	1	yes	3	1,0	359	3	yes	1	8
Vlaardingen	Netherlands	24,6	EAB	no	1	yes	3	1,6	602	3	no	3	10
Vlissingen	Netherlands	27,2	EAB	no	1	yes	3	1,8	654	3	no	3	10
Vordingborg	Denmark	9,3	EAB	yes	3	yes	3	0,5	171	3	yes	1	10
Vyborg	Russia	5,4	EAB	no	2	yes	3	1,8	666	3	yes	1	9
Wallhamn	Sweden	>20	EAB	no	1	yes	3	0,4	162	3	yes	1	8
Warnemünde	Germany	6,7-10,6	EAB	yes	3	yes	3	0,3	108	3	yes	1	10
Wismar	Germany	2,9-11,8	EAB	yes	3	yes	3	0,4	139	3	yes	1	10
Zeebrügge	Belgium	30,9	EAB	no	1	yes	3	1,8	651	3	no	3	10

Annex 2

Detailed risk assessment results for the Port of Gothenburg (Sweden)

Risk assessment according to source ports of ships arriving in Gothenburg (Sweden). For information source(s) see text. Temperature zones according to Briggs (1974) and Ekman (1953), CL = Carolina Region, EAB = Eastern Atlantic Boreal Region, ESA = Eastern South America, IWP = Indo-West Pacific Region, J = Japan Region, MA = Mediterranean Atlantic Region, WAB = Western Atlantic Boreal Region, WSA = Western South America. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Gothenburg	Sweden	13,1-18,2	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Amsterdam	Netherlands	0-11,8	EAB	yes	3	yes	3	1,3	465	3	no	3	12
Antwerp	Belgium	0	EAB	no	1	yes	3	1,6	597	3	no	3	10
Aarhus	Denmark	20,0	EAB	yes	3	yes	3	0,4	151	3	yes	1	10
Barcelona	Spain	30,9	MA	no	1	no	2	6,3	2320	2	no	3	8
Bilbao	Spain	30,9	MA	no	1	no	2	3,3	1215	2	no	3	8
Bremerhaven	Germany	9,3-13,1	EAB	yes	3	yes	3	1	373	3	no	3	12
Brindisi	Italy	30,9	MA	no	1	no	2	8,4	3087	2	no	3	8
Brofjorden	Sweden	>30	EAB	no	1	yes	3	0,2	55	3	yes	1	8
Buenos Aires	Argentina	30,9	ESA	no	1	no	2	18,6	6785	1	no	3	7
Busan	Korea	30,9	J	no	1	no	2	30,5	11169	1	no	3	7
Copenhagen	Denmark	10	EAB	no	3	yes	3	0,4	137	3	yes	1	10
Cork	Ireland	18,2	EAB	yes	3	yes	3	2,8	1016	2	no	3	11
Dublin	Ireland	22,1	EAB	no	2	yes	3	2,5	913	3	no	3	11
Fredrikshavn	Denmark	24,6	EAB	no	2	yes	3	0,1	50	3	yes	1	9
Fredrikstad	Norway	0-8,0	EAB	no	2	yes	3	0,3	122	3	no	3	11
Gävle	Sweden	4	EAB	no	1	yes	3	1,8	663	3	yes	1	8
Gdansk	Poland	7	EAB	no	2	yes	3	1,1	406	3	yes	1	9
Gdynia	Poland	6,7	EAB	no	2	yes	3	1,1	402	3	yes	1	9
Ghent	Belgium	0	EAB	no	1	yes	3	1,6	577	3	no	3	10
Halmstad	Sweden	15	EAB	yes	3	yes	3	0,2	90	3	yes	1	10
Hamburg	Germany	0	EAB	no	1	yes	3	0,9	326	3	no	3	10
Hamina	Finland	2,9	EAB	no	2	yes	3	2	747	3	no	3	11
Hanko	Finland	5,4	EAB	no	2	yes	3	1,7	620	3	no	3	11
Helsingborg	Sweden	5,4-24,6	EAB	yes	3	yes	3	0,3	117	3	yes	1	10
Helsingör	Denmark	18,2	EAB	yes	3	yes	3	0,3	117	3	yes	1	10
Helsinki	Finland	0-6,7	EAB	no	2	yes	3	1,9	687	3	yes	1	9
Hong Kong	China	20,8-27,2	J	yes	3	no	2	27,6	10097	1	no	3	9
Imminghamn	UK	20,8	EAB	yes	3	yes	3	1,4	494	3	no	3	12
Kalmar	Sweden	7	EAB	no	2	yes	3	0,9	334	3	yes	1	9
Karlshamn	Sweden	8	EAB	no	2	yes	3	0,8	280	3	yes	1	9
Karlstad	Sweden	0	EAB	no	1	yes	3	0,3	121	3	yes	1	8
Kemi	Finland	0,2	EAB	no	1	yes	3	2,6	966	3	yes	1	8
Kiel	Germany	19,5	EAB	yes	3	yes	3	0,6	236	3	yes	1	10
Klaipeda	Lithuania	<8	EAB	no	2	yes	3	1,2	453	3	yes	1	9
Kokkola	Finland	2,9	EAB	no	1	yes	3	2,4	872	3	yes	1	8
Kotka	Finland	2,9	EAB	no	1	yes	3	2	741	3	yes	1	8
Kristiansand	Norway	30,9	EAB	no	1	yes	3	0,4	136	3	no	3	10
La Coruna	Spain	33,5	MA	no	1	no	2	3,3	1215	2	no	3	8

Annex2 (continued)

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
La Spezia	Italy	30,9	MA	no	1	no	2	7,3	2674	2	no	3	8
Landskrona	Sweden	9,3-14,4	EAB	yes	3	yes	3	0,4	129	3	yes	1	10
le Havre	France	30,9	MA	no	1	no	2	1,9	691	3	no	3	9
Lisbon	Portugal	30,9	MA	no	1	no	2	4,2	1530	2	no	3	8
Lübeck	Germany	<10	EAB	no	3	yes	3	0,8	280	3	yes	1	10
Lysekil	Sweden	33,5	EAB	no	1	yes	3	0,2	55	3	yes	1	8
Malmö	Sweden	11,8	EAB	yes	3	yes	3	0,4	145	3	yes	1	10
Naantali	Finland	6,7	EAB	no	2	yes	3	1,7	632	3	yes	1	9
Naples	Italy	30,9	MA	no	1	no	2	7,6	2784	2	no	3	8
New Orleans	USA	0	CL	no	1	no	2	13,7	5012	1	no	3	7
New York	USA		WAB	yes	3	no	2	9,8	3568	1	no	3	9
Newcastle	UK	24,6	EAB	no	2	yes	3	1,3	485	3	no	3	11
Norrköping	Sweden	<5	EAB	no	1	yes	3	1,4	511	3	yes	1	8
Nynäshamn	Sweden	7	EAB	no	2	yes	3	1,3	490	3	yes	1	9
Oskarshamn	Sweden	7	EAB	no	2	yes	3	1,2	433	3	yes	1	9
Oslo	Norway	30,9	EAB	no	1	yes	3	0,4	163	3	no	3	10
Oxelösund	Sweden	7	EAB	no	2	yes	3	1,3	477	3	yes	1	9
Pori	Finland	4,2	EAB	no	1	yes	3	1,9	703	3	yes	1	8
Reykjavik	Iceland	33,5	EAB	no	1	yes	3	3,2	1152	2	no	3	9
Riga	Latvia	1,6	EAB	no	1	yes	3	1,7	609	3	yes	1	8
Rio de Janeiro	Brazil	24,6	ESA	no	2	no	2	15,6	5687	1	no	3	8
Rostock	Germany	6,7-10,6	EAB	no	2	yes	3	0,7	240	3	yes	1	9
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	1,4	501	3	no	3	12
Singapore	Singapore	30,9	IWP	no	1	no	1	23,8	8695	1	no	3	6
Södertälje	Sweden	6,7	EAB	no	2	yes	3	1,4	508	3	yes	1	9
St. Petersburg	Russia	0	EAB	no	1	yes	3	2,3	830	3	yes	1	8
Stenungsund	Sweden	20-28	EAB	no	2	yes	3	0,1	53	3	yes	1	9
Stockholm	Sweden	5,4	EAB	no	1	yes	3	1,5	560	3	yes	1	8
Strömstad	Sweden	>25	EAB	no	2	yes	3	0,3	111	3	yes	1	9
Sundsvall	Sweden	0-5,4	EAB	no	1	yes	3	2	736	3	yes	1	8
Swinoujscie	Poland	1,6	EAB	no	1	yes	3	0,7	262	3	yes	1	8
Tallinn	Estonia	2,9	EAB	no	1	yes	3	1,8	665	3	yes	1	8
Tampico	Mexico	6,7	CL	no	2	no	2	14,5	5300	1	no	3	8
Tilbury	UK	14,4	EAB	yes	3	yes	3	1,6	577	3	no	3	12
Tokyo	Japan	30,9	J	no	1	no	2	31,6	11571	1	no	3	7
Travemünde	Germany	8	EAB	no	2	yes	3	0,7	269	3	yes	1	9
Trelleborg	Sweden	8	EAB	no	2	yes	3	0,5	180	3	yes	1	9
Turku	Finland	4,2	EAB	no	1	yes	3	1,7	633	3	yes	1	8
Uddevalla	Sweden	18,2	EAB	yes	3	yes	3	0,2	71	3	yes	1	10
Umeå	Sweden	0	EAB	no	1	yes	3	2,2	813	3	yes	1	8
Valparaiso	Chile	30,9	WSA	no	1	no	2	21	7681	1	no	3	7
Varberg	Sweden	18,2	EAB	yes	3	yes	3	0,1	51	3	yes	1	10
Västerås	Sweden	0	EAB	no	1	yes	3	1,5	565	3	yes	1	8
Västervik	Sweden	0-5,4	EAB	no	1	yes	3	1,2	426	3	yes	1	8
Wallhamn	Sweden	>20	EAB	yes	3	yes	3	0,1	53	3	yes	1	10
Zeebrügge	Belgium	30,9	EAB	no	1	yes	3	1,5	544	3	no	3	10

Annex 3

Detailed risk assessment results for the Port of Kiel (Germany)

Risk assessment according to source ports of ships arriving in Kiel (Germany). For information source(s) see text. Temperature zones according to Briggs (1974) and Ekman (1953), EAB = Eastern Atlantic Boreal Region, MA = Mediterranean Atlantic Region. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk.

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Kiel	Germany	19,5	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Aarhus	Denmark	20,0	EAB	yes	3	yes	3	0,4	133	3	yes	1	10
Algiers	Algeria	30,9	MA	no	1	no	2	5,6	2044	2	no	3	8
Amsterdam	Netherlands	0-11,8	EAB	no	1	yes	3	0,8	288	3	no	3	10
Antwerp	Belgium	0	EAB	no	1	yes	3	1,2	423	3	no	3	10
Benghazi	Libya	32,2	MA	no	1	no	2	8,1	2965	2	no	3	8
Brake	Germany	1,6	EAB	no	1	yes	3	0,4	149	3	no	3	10
Bremerhaven	Germany	9,3-13,1	EAB	no	2	yes	3	0,4	135	3	no	3	11
Brunsbüttel	Germany	0-9,3	EAB	no	1	yes	3	0,1	54	3	no	3	10
Casablanca	Morocco	30,9	MA	no	1	no	2	4,5	1657	2	no	3	8
Copenhagen	Denmark	10	EAB	no	1	yes	3	0,4	162	3	yes	1	8
Cuxhaven	Germany		EAB	yes	3	yes	3	0,2	70	3	no	3	12
Dunkirk	France	30,9	EAB	no	1	yes	3	1,1	412	3	no	3	10
Frederiksvaerk	Denmark	30,9	EAB	no	1	yes	3	0,4	161	3	yes	1	8
Fredrikshavn	Denmark	24,6	EAB	no	2	yes	3	5,0	201	3	yes	1	9
Gdansk	Poland	7	EAB	no	1	yes	3	0,9	344	3	yes	1	8
Gothenburg	Sweden	13,1-18,2	EAB	yes	3	yes	3	0,6	236	3	yes	1	10
Hamburg	Germany	0	EAB	no	1	yes	3	0,2	90	3	no	3	10
Kaliningrad	Russia	0	EAB	no	1	yes	3	1,0	365	3	yes	1	8
Karlshamn	Sweden	8	EAB	no	1	yes	3	0,6	227	3	yes	1	8
Klaipeda	Lithuania	<8	EAB	no	1	yes	3	1,1	397	3	yes	1	8
Lübeck	Germany	<10	EAB	no	1	yes	3	0,3	97	3	yes	1	8
Mo I Rana	Norway	11,8-30,9	EAB	yes	3	yes	3	2,6	944	3	no	3	12
Oslo	Norway	30,9	EAB	no	1	yes	3	1,0	355	3	no	3	10
Riga	Latvia	1,6	EAB	no	1	yes	3	1,5	550	3	yes	1	8
Rostock	Germany	6,7-10,6	EAB	no	1	yes	3	0,2	84	3	yes	1	8
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	0,9	323	3	no	3	12
Slite	Sweden	5,4	EAB	no	1	yes	3	1,1	400	3	yes	1	8
Sölvesborg	Sweden	8	EAB	no	1	yes	3	0,6	217	3	yes	1	8
St. Petersburg	Russia	0	EAB	no	1	yes	3	2,1	778	3	yes	1	8
Stade	Germany	0	EAB	no	1	yes	3	0,2	73	3	no	3	10
Stenungsund	Sweden	20-28	EAB	yes	3	yes	3	0,7	255	3	yes	1	10
Svendborg	Denmark	19,5	EAB	yes	3	yes	3	0,2	63	3	yes	1	10
Szczecin	Poland	0	EAB	no	1	yes	3	0,6	221	3	yes	1	8
Tallinn	Estonia	2,9	EAB	no	1	yes	3	1,7	610	3	yes	1	8
Travemünde	Germany	8	EAB	no	1	yes	3	0,2	86	3	yes	1	8
Tunis	Tunisia	34,8	MA	no	1	no	2	6,6	2426	2	no	3	8
Wilhemshaven	Germany	27,2-30,9	EAB	no	2	yes	3	0,4	132	3	no	3	11

Annex 4

Detailed risk assessment results for the Port of Klaipeda (Lithuania)

Risk assessment according to source ports of ships arriving in Klaipeda (Lithuania). For information source(s) see text and www.portofklaipeda.lt. Temperature zones according to Briggs (1974) and Ekman (1953), EAB = Eastern Atlantic Boreal Region. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Klaipeda	Lithuania	0,5-7	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Aabenraa	Denmark	18,2	EAB	no	1	yes	3	1,2	426	3	yes	1	8
Aarhus	Denmark	20,0	EAB	no	1	yes	3	1,2	429	3	yes	1	8
Antwerp	Belgium	0	EAB	yes	3	yes	3	2,8	1021	2	no	3	11
Bremerhaven	Germany	9,3-13,1	EAB	no	3	yes	3	2,2	797	3	no	3	12
Bruges	Belgium	30,9	EAB	no	1	yes	3	2,7	974	3	no	3	10
Copenhagen	Denmark	10	EAB	no	3	yes	3	0,9	323	3	yes	1	10
Domsjo	Sweden	4,2	EAB	yes	3	yes	3	1,3	468	3	yes	1	10
Felixstowe	UK	30,9	EAB	no	1	yes	3	2,6	947	3	no	3	10
Fredericia	Denmark	18,2	EAB	no	1	yes	3	1,3	468	3	yes	1	8
Gdansk	Poland	7	EAB	yes	3	yes	3	0,3	117	3	yes	1	10
Gdynia	Poland	6,7	EAB	yes	3	yes	3	0,3	113	3	yes	1	10
Gothenburg	Sweden	13,1-18,2	EAB	no	2	yes	3	1,2	453	3	yes	1	9
Hallstavik	Sweden	5,4	EAB	yes	3	yes	3	0,8	299	3	yes	1	10
Hamburg	Germany	0	EAB	yes	3	yes	3	1,3	487	3	no	3	12
Helsinki	Finland	0-6,7	EAB	yes	3	yes	3	0,9	337	3	yes	1	10
Hull	UK	15,7-18,2	EAB	no	1	yes	3	2,5	925	3	no	3	10
Husum - Ornskoldsvik	Sweden	4,2	EAB	yes	3	yes	3	1,3	468	3	yes	1	10
Iggesund	Sweden	4	EAB	yes	3	yes	3	1	380	3	yes	1	10
Inkoo	Finland	5,4	EAB	yes	3	yes	3	0,9	316	3	yes	1	10
Ipswich	UK	24,6	EAB	no	1	yes	3	2,6	957	3	no	3	10
Kaliningrad	Russia	0	EAB	yes	3	yes	3	0,3	110	3	yes	1	10
Karlshamn	Sweden	8	EAB	yes	3	yes	3	0,6	223	3	yes	1	10
Karskar	Sweden	0	EAB	yes	3	yes	3	1	350	3	yes	1	10
Kiel	Germany	19,5	EAB	no	1	yes	3	1,1	397	3	yes	1	8
Kotka	Finland	2,9	EAB	yes	3	yes	3	1,1	394	3	yes	1	10
Norrköping	Sweden	<5	EAB	yes	3	yes	3	0,8	297	3	yes	1	10
Oostende	Belgium	2,9	EAB	yes	3	yes	3	2,6	963	3	no	3	12
Riga	Latvia	1,6	EAB	yes	3	yes	3	0,6	236	3	yes	1	10
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	2,5	925	3	no	3	12
Sassnitz/ Mukran	Germany	<10	EAB	yes	3	yes	3	0,7	271	3	yes	1	10
Skutskar	Sweden	0	EAB	yes	3	yes	3	1	350	3	yes	1	10
St. Petersburg	Russia	0	EAB	yes	3	yes	3	1,3	478	3	yes	1	10
Stockholm	Sweden	5,4	EAB	yes	3	yes	3	0,7	265	3	yes	1	10
Sundsvall	Sweden	0-5,4	EAB	yes	3	yes	3	1,2	421	3	yes	1	10
Szczecin	Poland	0	EAB	yes	3	yes	3	0,8	294	3	yes	1	10
Tallinn	Estonia	2,9	EAB	yes	3	yes	3	0,9	316	3	yes	1	10
Teesport	UK	30,9	EAB	no	1	yes	3	2,5	909	3	no	3	10

Annex 5

Detailed risk assessment results for the Port of Sköldvik/Kilpilahti (Finland)

Risk assessment according to source ports of ships arriving in Sköldvik/Kilpilahti (Finland). For information source(s) see text. Temperature zones according to Briggs (1974) and Ekman (1953), EAB = Eastern Atlantic Boreal Region, MA = Mediterranean Atlantic Region, WAB = Western Atlantic Boreal Region. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Sköldvik	Finland	0-6,7	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
Amsterdam	Netherlands	0-11,8	EAB	yes	3	yes	3	3,1	1143	2	no	3	11
Antwerp	Belgium	0	EAB	yes	3	yes	3	3,5	1275	2	no	3	11
Bilbao	Spain	30,9	MA	no	1	no	2	5,2	1893	2	no	3	8
Blexen	Germany	5,4-14,4	EAB	yes	3	yes	3	2,9	1053	2	no	3	11
Bremen	Germany	0	EAB	yes	3	yes	3	3,0	1086	2	no	3	11
Bremerhaven	Germany	9,3-13,1	EAB	no	3	yes	3	2,9	1051	2	no	3	11
Brest	France	30,9	MA	no	1	no	2	4,4	1599	2	no	3	8
Bützfleth	Germany	0	EAB	yes	3	yes	3	2,0	725	3	no	3	12
Copenhagen	Denmark	10	EAB	no	3	yes	3	1,6	576	3	yes	1	10
Cuxhaven	Germany		EAB	no	2	yes	3	2,0	722	3	no	3	11
Fredericia	Denmark	18,2	EAB	no	1	yes	3	2,0	718	3	yes	1	8
Gävle	Sweden	4	EAB	yes	3	yes	3	0,8	304	3	yes	1	10
Gdansk	Poland	7	EAB	yes	3	yes	3	1,2	443	3	yes	1	10
Gdynia	Poland	6,7	EAB	yes	3	yes	3	1,2	439	3	yes	1	10
Ghent	Belgium	0	EAB	yes	3	yes	3	3,4	1255	2	no	3	11
Gothenburg	Sweden	13,1-18,2	EAB	no	2	yes	3	1,9	708	3	yes	1	9
Gulfhavn	Denmark	8-28,5	EAB	no	3	yes	3	1,8	661	3	yes	1	10
Halmstad	Sweden	15	EAB	no	2	yes	3	1,7	638	3	yes	1	9
Hamburg	Germany	0	EAB	yes	3	yes	3	2,0	742	3	no	3	12
Hamina	Finland	2,9	EAB	yes	3	yes	3	0,3	105	3	yes	1	10
Hanko	Finland	5,4	EAB	yes	3	yes	3	0,3	103	3	yes	1	10
Helsingborg	Sweden	5,4-24,6	EAB	yes	3	yes	3	1,6	595	3	yes	1	10
Helsinki	Finland	0-6,7	EAB	yes	3	yes	3	0,1	49	3	yes	1	10
Hudiksvall	Sweden	4	EAB	yes	3	yes	3	0,9	336	3	yes	1	10
Iggesund	Sweden	4	EAB	yes	3	yes	3	0,9	336	3	yes	1	10
Ijmuiden	Netherlands	30,9	EAB	no	1	yes	3	3,1	1128	2	no	3	9
Immingham	UK	20,8	EAB	no	1	yes	3	3,2	1172	2	no	3	9
Isle of Grain	UK	22,1	EAB	no	1	yes	3	3,4	1245	2	no	3	9
Kaliningrad	Russia	0	EAB	yes	3	yes	3	1,2	445	3	yes	1	10
Kalmar	Sweden	7	EAB	yes	3	yes	3	1,2	439	3	yes	1	10
Kalundborg	Denmark	30,9	EAB	no	1	yes	3	1,9	684	3	yes	1	8
Kemi	Finland	0,2	EAB	yes	3	yes	3	1,6	603	3	yes	1	10
Kiel	Germany	19,5	EAB	no	1	yes	3	1,8	652	3	yes	1	8
Koge	Sweden	8	EAB	no	3	yes	3	1,6	571	3	yes	1	10
Kokkola	Finland	2,9	EAB	yes	3	yes	3	1,4	519	3	yes	1	10
Kotka	Finland	2,9	EAB	yes	3	yes	3	0,2	76	3	yes	1	10
La Coruna	Spain	33,5	MA	no	1	no	2	5,2	1893	2	no	3	8
Laajasalo	Finland	0-6,7	EAB	yes	3	yes	3	0,1	49	3	yes	1	10

Annex5 (continued)

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk calcu-lation
le Havre	France	30,9	MA	no	1	no	2	3,7	1369	2	no	3	8
London	UK	24,6	EAB	no	1	yes	3	3,5	1276	2	no	3	9
Lorient	France	22,1	MA	no	1	no	2	4,6	1669	2	no	3	8
Lulea	Sweden	0	EAB	yes	3	yes	3	1,6	578	3	yes	1	10
Malmö	Sweden	11,8	EAB	no	2	yes	3	1,6	576	3	yes	1	9
Montreal	Canada	0	WAB	yes	3	no	2	11,0	4038	1	no	3	9
Naantali	Finland	6,7	EAB	yes	3	yes	3	0,6	205	3	yes	1	10
New York	USA		WAB	no	1	no	2	11,6	4246	1	no	3	7
Norrköping	Sweden	<5	EAB	yes	3	yes	3	0,9	321	3	yes	1	10
Nynäshamn	Sweden	7	EAB	yes	3	yes	3	0,8	278	3	yes	1	10
Oslo	Norway	30,9	EAB	no	1	yes	3	2,3	840	3	no	3	10
Oulu	Finland	0	EAB	yes	3	yes	3	1,6	603	3	yes	1	10
Oxelösund	Sweden	7	EAB	yes	3	yes	3	0,8	287	3	yes	1	10
Pembroke	UK	32,2	EAB	no	1	yes	3	4,5	1653	2	no	3	9
Pietarsaari	Finland	1,6	EAB	yes	3	yes	3	1,4	502	3	yes	1	10
Pitae	Sweden	6,7	EAB	yes	3	yes	3	1,5	556	3	yes	1	10
Point Tupper	Canada	30,9	WAB	no	1	no	2	9,4	3433	2	no	3	8
Pori	Finland	4,2	EAB	yes	3	yes	3	0,7	239	3	yes	1	10
Porvoo	Finland	0-6,7	EAB	yes	3	yes	3	0,1	22	3	yes	1	10
Primorsk	Russia	0-5,4	EAB	yes	3	yes	3	0,5	175	3	yes	1	10
Raahe	Finland	1,6-4,2	EAB	yes	3	yes	3	1,6	589	3	yes	1	10
Rafnes	Norway	24,6	EAB	no	1	yes	3	2,2	798	3	no	3	10
Reykjavik	Iceland	33,5	EAB	no	1	yes	3	5,0	1830	2	no	3	9
Riga	Latvia	1,6	EAB	yes	3	yes	3	0,9	337	3	yes	1	10
Rostock	Germany	6,7-10,6	EAB	yes	3	yes	3	1,6	601	3	yes	1	10
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	3,2	1179	2	no	3	11
Rouen	France	0	MA	yes	3	no	2	3,9	1439	2	no	3	10
Skelleftea	Sweden	0	EAB	yes	3	yes	3	1,5	536	3	yes	1	10
Slagen	Norway	>20	EAB	no	1	yes	3	2,2	802	3	no	3	10
Södertälje	Sweden	6,7	EAB	yes	3	yes	3	0,8	296	3	yes	1	10
Stade	Germany	0	EAB	yes	3	yes	3	2,0	725	3	no	3	12
Stenungsund	Sweden	20-28	EAB	no	1	yes	3	2,0	732	3	yes	1	8
Stockholm	Sweden	5,4	EAB	yes	3	yes	3	0,7	258	3	yes	1	10
Sundsvall	Sweden	0-5,4	EAB	yes	3	yes	3	1,0	377	3	yes	1	10
Szczecin	Poland	0	EAB	yes	3	yes	3	1,6	579	3	yes	1	10
Tallinn	Estonia	2,9	EAB	yes	3	yes	3	0,2	66	3	yes	1	10
Terneuzen	Netherlands	0	EAB	yes	3	yes	3	3,4	1237	2	no	3	11
Thamesport	UK	>14,4	EAB	no	2	yes	3	3,4	1245	2	no	3	10
Trelleborg	Sweden	8	EAB	no	3	yes	3	1,5	534	3	yes	1	10
Turku	Finland	4,2	EAB	yes	3	yes	3	0,6	206	3	yes	1	10
Vaasa	Finland	1,6-4,2	EAB	yes	3	yes	3	1,2	456	3	yes	1	10
Västerås	Sweden	0	EAB	yes	3	yes	3	0,9	340	3	yes	1	10
Vlissingen	Netherlands	27,2	EAB	no	1	yes	3	3,3	1225	2	no	3	9
Wilhemshaven	Germany	27,2-30,9	EAB	no	1	yes	3	2,8	1041	2	no	3	9
Zeebrügge	Belgium	30,9	EAB	no	1	yes	3	3,3	1222	2	no	3	9

Annex 6

Detailed risk assessment results for the port region Tornio, Kemi, and Raahe (Finland)

Risk assessment according to source ports of ships arriving in Tornio, Kemi, and Raahe (Finland). For information source(s) see text and www.portnet.fi. Temperature zones according to Briggs (1974) and Ekman (1953), EAB = Eastern Atlantic Boreal Region, MA = Mediterranean Atlantic Region, WAB = Western Atlantic Boreal Region. The voyage duration in days was calculated at a ships speed of 16 knots. Colour shading indicates the risk level with green = low risk, yellow = medium risk and red = high risk, except in column "port/port region" where red = extreme risk and purple = high risk

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone
Kemi, Tornea, Raahe	Finland	0-4,2	EAB

Port/port region	Country	Salinity (psu) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Intra-Baltic shipping	Risk level	Total risk
Aalborg	Denmark	18,2	EAB	no	1	yes	3	2,7	979	3	yes	1	8
Aarhus	Denmark	20,0	EAB	no	1	yes	3	2,6	942	3	yes	1	8
Aberdeen	UK	30,9	EAB	no	1	yes	3	3,8	1401	2	no	3	9
Amsterdam	Netherlands	0-11,8	EAB	yes	3	yes	3	3,8	1403	2	no	3	11
Antwerp	Belgium	0	EAB	yes	3	yes	3	4,2	1535	3	no	3	12
Bilbao	Spain	30,9	MA	no	1	no	2	5,9	2153	2	no	3	8
Bordeaux	France	0-32,2	MA	yes	3	no	2	5,8	2125	2	no	3	10
Delfzijl/ Eemshaven	Netherlands	9,3-22,1	EAB	no	2	yes	3	3,6	1326	2	no	3	10
Halmstad	Sweden	15	EAB	no	1	yes	3	2,5	897	3	yes	1	8
Helsinki	Finland	0-6,7	EAB	yes	3	yes	3	1,6	582	3	yes	1	10
Honfleur	France	0	MA	yes	3	no	2	4,5	1634	2	no	3	10
Immingham	UK	20,8	EAB	no	1	yes	3	3,9	1432	2	no	3	9
Ipswich	UK	24,6	EAB	no	1	yes	3	4	1471	2	no	3	9
Karlsborg	Sweden	<4,2	EAB	yes	3	yes	3	0,2	64	3	yes	1	10
Koge	Sweden	8	EAB	no	2	yes	3	2,3	828	3	yes	1	9
Kokkola	Finland	2,9	EAB	yes	3	yes	3	0,3	121	3	yes	1	10
Köping	Sweden	0	EAB	yes	3	yes	3				yes	1	7
Kotka	Finland	2,9	EAB	yes	3	yes	3	1,7	638	3	yes	1	10
Kubikenborg	Sweden	0-5,4	EAB	yes	3	yes	3	0,8	290	3	yes	1	10
Kunda (Tallinn)	Estonia	2,9	EAB	yes	3	yes	3	1,5	565	3	yes	1	10
Lübeck	Germany	<10	EAB	no	2	yes	3	2,5	899	3	yes	1	9
Lulea	Sweden	0	EAB	yes	3	yes	3	0,2	74	3	yes	1	10
Naantali	Finland	6,7	EAB	no	3	yes	3	1,4	494	3	yes	1	10
Oulu	Finland	0	EAB	yes	3	yes	3	0,2	62	3	yes	1	10
Philadelphia	USA	0	WAB	yes	3	no	1	12,7	4651	1	no	3	8
Pori	Finland	4,2	EAB	yes	3	yes	3	0,8	292	3	yes	1	10
Porvoo	Finland	0-6,7	EAB	yes	3	yes	3	1,7	609	3	yes	1	10
Rauma	Finland	2,9-4,2	EAB	yes	3	yes	3	0,9	322	3	yes	1	10
Riga	Latvia	1,6	EAB	yes	3	yes	3	1,7	638	3	yes	1	10
Rönnskär/ Skelleftea	Sweden	0	EAB	yes	3	yes	3	0,3	115	3	yes	1	10
Rotterdam	Netherlands	0,2-30,9	EAB	yes	3	yes	3	3,9	1439	2	no	3	11
Scheveningen (Hoek van Holland)	Netherlands	18,2	EAB	no	1	yes	3	3,9	1422	2	no	3	9
Slite	Sweden	5,4	EAB	no	3	yes	3	1,5	548	3	yes	1	10
Stockholm	Sweden	5,4	EAB	no	3	yes	3	1,2	450	3	yes	1	10
Sundsvall	Sweden	0-5,4	EAB	yes	3	yes	3	0,8	290	3	yes	1	10
Turku	Finland	4,2	EAB	yes	3	yes	3	1,4	495	3	yes	1	10
Västerås	Sweden	0	EAB	yes	3	yes	3	1,6	577	3	yes	1	10
Ventspils	Latvia	1,6	EAB	yes	3	yes	3	1,5	548	3	yes	1	10
Vlissingen	Netherlands	27,2	EAB	no	1	yes	3	4,1	1485	2	no	3	9