Risk Assessment of
Ballast Water Mediated Species Introductions –
a Baltic Sea Approach

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The following abbreviations were used in this report:

AIS	Aquatic Invasive Species
AIS*	Automatic Identification System
ALARM	Assessing LArge scale environmental Risks for biodiversity with tested Methods (EU Project)
BITIS	Biological Intergrity of the Baltic Sea Threatened by Invasive Species
BMB	Baltic Marine Biologists
BWC	Ballast Water Convention of IMO (International Convention for the Control and Management of Ships' Ballast Water and Sediments)
BWE	Ballast Water Exchange
CIESM	The Mediterranean Science Commission
DAISIE	Delivering Alien Invasive Species Inventories for Europe (EU Project)
EMBLA	Environmental Ballast Water Management Assessment
GEF	Global Environment Facility
GloBallast	GEF/UNDP/IMO Global Ballast Water Management Programme
HELCOM	Helsinki Commission
HELCOM EC	HELCOM Environment Committee
ICES	International Council for the Exploration of the Sea
IGSS	Issue Group on Sustainable Shipping (reports to OSPAR)
IMO	International Maritime Organization
IOC	International Oceanographic Commission
MEPC	Marine Environment Protection Committee
NEST	A decision support system for management of eutrophication in the Baltic Sea (see MARE Project at http://www.mare.su.se/nest/)
NIS	Nonindigenous Species
NOBANIS	North European and Baltic Network on Invasive Alien Species
NOBOB	No Ballast on Board
OSPAR	Oslo-Paris Commission
SGBWS	Study Group on Ballast Water and Sediments
UNEP	United Nations Environment Programme
WGITMO	Working Group on Introductions and Transfers of Marine Organisms

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Table of Content

Recommendations to HELCOM

The Baltic Sea countries have international obligations to address invasive alien species, principally according to the Convention on Biological Diversity (1992) and, concerning marine areas, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004).

At the meeting of the HELCOM Heads of Delegation, 14-15 June, 2005, Helsinki, Finland, (Paragraph 2.5, LD 6) it was decided to establish a project entitled "Risk Assessment of Ballast Water Mediated Introductions."

This Report, authored by Erkki Leppäkoski (contracted Project Manager; Åbo Akademi University, Turku, Finland) and Stephan Gollasch (GoConsult, Hamburg, Germany), makes ten key Recommendations to improve measures to reduce the introduction of ship-mediated alien species into the Baltic Sea and provide further a suggested ballast water management approach for the Baltic Sea.

1. Recommended actions

Aggressive invaders represent a threat to the biosecurity of most coastal countries of the world. Shipping (ballast water and hull fouling) has been and will continue to be the most important vector for unintentional species introductions into aquatic environments.

Introductions of aquatic invasive species (AIS) are considered as a key influence on various environmental and socio-economic sectors – thereby affecting many stakeholders. Biological invasions are a global phenomenon and thus a feature of ongoing global change – indicating the scale of the problem. The most obvious ecological impacts are directed to coastal biodiversity. AIS may change the native food web and some are known as ecosystem engineers, which result in substantial habitat modifications. It is not only the environment being at risk, also economical and human health issues were reported, e.g. during harmful algal blooms and human consumption of contaminated seafood. Tourism, one of the world's leading industries, is also potentially at risk when hit by harmful algal blooms.

The MARITIME group drafted in a meeting in Copenhagen October 2004 the HELCOM recommendations: "*Measures to address the threat of invasive species transported via the ballast water of ships*". Considering that ballast water exchange (hereafter BWE) is a limited option for ballast water management in the Baltic Sea, the group emphasized the need for regional cooperation when addressing the threat. The Governments of the Contracting Parties to the Helsinki Convention recommended:

- to designate/identify a clear responsibility for coordinating the national response to the issue,

- to request arriving ships to submit ballast water reporting forms using the IMO Guidelines (IMO Resolution A.868(20), adopted on 27 November 1997),
- to require ships flying the country's flag or calling at the country's ports to carry and implement a shipboard ballast water management plan (taking into account the IMO Guidelines),
- to provide adequate reception facilities for sediments in ports and terminals where cleaning and repair of ballast tanks occurs,
- to carry out by 1 January 2007 risk assessments for major ports. The risk assessments should be carried out using the compatible methodology developed under IMO,
- to cooperate in order to establish by 2006 the national and regional information systems for the data obtained from the ballast water reporting as well as during risk assessments, biological surveys and monitoring (including an early warning system),
- to conduct by 1 January 2007 biological surveys and establish a monitoring system for invasive aquatic species in major ports using harmonized methodology developed and updated by the appropriate HELCOM subsidiary bodies and to be based on guidelines prepared under the IMO,
- to link the port surveys and monitoring to an early-warning system, whereby ships can be alerted to outbreaks of harmful species, and
- to cooperate with the North Sea countries when implementing the provision of this Convention.

To address the recommendations from the MARITIME group, the following actions may be considered to significantly reduce the probability of ship-mediated introductions into the Baltic Sea:

1. *Identify pathways* leading to unintentional introductions, e.g. the importance of ballast water vs. other vectors.

2. *Assess*, in particular, *shipping routes that cross biogeographical zones*, which might connect previously separated flora and fauna.

3. *Identify most important source areas* of alien species introductions into the Baltic Sea. Despite academic interest, such information is essential for regional cooperation with the aim to jointly assess control measures and risk assessments. These source areas of species might be specific in different parts of the Baltic Sea and may also change in time due to changes in shipping pattern.

4. *Increase the exchange of information* between scientists and management agencies.

5. *Have in place a basin-wide early warning system* for taking rapid and effective action, including public consultation, should unintentional introductions occur. An early warning system rapidly reporting on new findings of AIS is an important tool when planning to undertake eradication measures of newly introduced AIS. With an early warning instrument, neighbouring countries may be made aware and by doing so concerted

actions may be achieved[1].

6. *Support R&D focused on initiatives to reduce the problems of alien invasives arising from ballast water discharges*, understanding that preventing the introduction of alien invasive species should be the first goal and keeping in mind that mechanical or chemical eradication of *established* AIS is not an option, neither biological control of them (prevention is better than cure). The actions should be focussed on

- development of national and regional ballast water management programmes,
- research on sampling and monitoring regimes,
- information to port authorities and ships' crews on ballast water hazards,
- disseminating international guidelines and recommendations, such as the IMO Ballast Water Management Convention, IMO guidelines on BWE (completed) and BWE zones (in preparation), and
- development of an online decision support system to assist port authorities and ships' crews on appropriate ballast water uptake and discharge zones. This tool may eventually result in an online "*Baltic Sea Ballast Water Management Decision Support System*" providing information on zones in the Baltic Sea where ballast uptake/discharge is permitted/not permitted (depending on origin of the ballast water, taking into account various scenarios of ship routes, etc.). This online system may also include information on ballast water treatment options, risk calculations and occurrence of algal blooms.[2] Consequently, an early warning tool should be included to avoid ballast water uptake in (Baltic) areas where potential harmful species bloom.

7. It is strongly recommended that HELCOM should consider to introduce a *ballast water reporting system* (as also required by the IMO BWC) as soon as possible, i.e. already *before* the BWC has entered into force, to allow data gathering for risk assessment (see lack of data availability as outlined in the report).

8. *Identify high-risk ships or shipping routes through risk assessment* and special measures that can be applied for the management of their ballast water (for example treatment, BWE in designated areas outside the Baltic or treatment at land-based ballast water and sediment reception facilities).

9. *Elaborate a common structured procedure for species-specific assessment* to be used in developing a "black list" of harmful or potentially harmful alien species (= target species) that are especially undesirable to be introduced to the Baltic Sea. The presence/absence of target species will influence the risk level quantification of the shipping routes considered.

[1] Positive eradication examples are known, e.g. the successful removal of *Caulerpa taxifolia* off the Californian coast. It should however be noted that eradication efforts are only successful in case the new species is not established, colonizes a small area only and also benthic organisms may be easier to remove rather than planktonic species. Routine monitoring programmes should consider taking samples in regions of ballast water operations to timely proof the occurrence of new AIS.

[2] A very good example of such system, which may be used as a model, is NEST (on eutrophication in the Baltic) developed by the Stockholm University.

10. *Organize regional introductory training courses* for port administrators, environmental and fisheries administrators as well as NGOs.

2. Suggested ballast water management approach for the Baltic

Each vessel arriving in the Baltic poses a risk to introduce a new AIS. Even ships with no ballast on board (NOBOB) are of risk to introduce new AIS[3]. This indicates the urgent need for efficient ballast water treatment systems. As those 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:

- *Precautionary practices,*
- *Minimizing uptake of harmful aquatic organisms, pathogens and sediments,*
- *When loading ballast, every effort should be made to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms. The uptake of ballast water should be minimized or, where practicable, avoided in areas and situations such as:*
    - *areas identified by the port State… ...port States should inform local agents and/or the ship of areas and situations where the uptake of ballast water should be minimized, such as:*
        - *areas with outbreaks, infestations or known populations of harmful organisms and pathogens;*
        - *areas with current phytoplankton blooms (algal blooms, such as red tides);*
        - *nearby sewage outfalls;*
        - *nearby dredging operations;*
        - *when a tidal stream is known to be the more turbid; and*
        - *areas where tidal flushing is known to be poor.*
    - *in darkness when bottom-dwelling organisms may rise up in the water column;*
    - *in very shallow water; or*
    - *where propellers may stir up sediment.*
- *Removing ballast sediment on a timely basis,*
- *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.*

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3 In inbound traffic to the Great Lakes, NOBOB ships contain an average of 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 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 reduce the numbers or viability of them. 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.

- *Avoiding unnecessary discharge of ballast water,*
- *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.*

3. High risk shipping routes

The risk assessment[4] carried out for the selected ports[5] 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 risk reducing measure, this indicates the need for ballast water treatment.

Ports with the lowest risk levels are all very distant (i.e. oceanic shipping) and many also have temperature regimes different from the Baltic. Here, provided safety permits, a BWE should be carried out as risk reducing measure.

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.

3.1 Ships on oceanic voyages

Ships operated on oceanic voyages are usually enabled to meet the IMO water depth and distance limits for BWE. However, safety aspects may not enable to carry out BWE while being at sea. Further, BWE shows limited efficiency to remove organisms from ballast tanks. However, as an interim solution and until ballast water treatment systems become available, BWE should be carried out wherever possible on those voyages before entering the Baltic Sea.

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

In case a salinity and temperature match occurs in donor and recipient region, e.g. shipping routes connecting a brackish water port in the Chesapeake Bay (east coast

[4] For comparison, various risk assessment approaches were reviewed. A summary is available as Annex 1.
[5] Copenhagen (Denmark), Gothenburg (Sweden), Kiel (Germany), Klaipeda (Lithuania), Sköldvik and the port region Tornio, Kemi, Raahe (Finland).

of North America) with the Baltic proper (both regions are located in similar climate zones), a mid-ocean BWE should be carried out provided that safety permits. It is also recommended to exchange the ballast water in mid-ocean when ships connect two freshwater ports, e.g. Duluth (North American Great Lakes) and St. Petersburg (both ports are located in similar climate zones).

3.1.2 Scenario 2 – Non-matching salinity or temperature in donor and recipient region 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 not be carried out as the risk that a marine organism survives when being released into freshwater conditions is minimal. In case ballast water was taken onboard in a freshwater tropical port and released in Helsinki in winter, the species introduction risk is also minimal. Another case is the release of water from Singapore in the Baltic in the vicinity of thermal discharges (e.g. from power plants) in summer, especially if such species show a broad salinity tolerance. In this case we recommend to carry out BWE as the abiotic conditions of donor and recipient region overlap.

3.2 Inner-European shipping

In northwest (NW)-European shipping the IMO water depth and distance limits for BWE cannot be met. However, the risk to introduce species remains high when donor and recipient regions show similar salinity and temperature conditions. The following scenarios may be considered.

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

When the shipping route connects ports with a match in salinity or temperature, e.g. Rotterdam (= brackish water) with the western Baltic (both ports are located in the 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 being discharged in lower saline brackish waters.

Fresh water ballast originating from outside the Baltic should also be exchanged prior release in freshwater habitats of the Baltic, e.g. on ship voyages from Antwerp to the eastern Baltic, both being freshwater port regions in the identical climate zone.

By doing so the risk to introduce a species is reduced, 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 at best in the beginning of the canals.

3.2.2 Scenario 2 – Non-matching salinity or temperature in donor and recipient region for ships operated on inner-European shipping routes

Ships engaged in voyages without salinity or temperature match, e.g. La Coruna (Spain, marine conditions) to St. Petersburg (= freshwater conditions) may not carry out a BWE as the risk that a marine organism survives when being released into freshwater conditions is minimal.

3.3 Inner Baltic shipping

Inner-Baltic shipping poses the 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 intend 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.

3.4 Designation of a ballast water exchange zone within the Baltic

The IMO currently works out a guideline to identify BWE zones. A draft document will likely be discussed at the next meeting of IMO´s Marine Environment Protection Committee in Spring 2006. Once completed, this guideline should be reviewed for its applicability to address the risk of species movements in inner-Baltic shipping (see above).

3.4.1 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 as a biologically meaningful reasoning cannot be given as 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 shall endeavor to exchange the ballast water prior entry into the Baltic Sea. However, this approach needs careful consideration with affected states as on a voyage from e.g. Antwerp to Helsinki this scenario would result in BWE in the North Sea and in other cases, where ships are on voyages from the Black Sea to NW Europe the Mediterranean Sea may be affected.

3.4.2 Ballast water exchange zone for inner-Baltic shipping

In rare instances a BWE in ships on inner-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).

4. The HELCOM ballast water management approach in the wider European context

As indicated above, various ballast water management approaches are currently developing, e.g. for the OSPAR region, Mediterranean and Caspian Seas. The HELCOM approach recommends to exchange the ballast water of ships arriving from outside the Baltic and also in inner-Baltic shipping (in certain instances – see above). Problems occur to identify appropriate BWE zones as neighbouring seas and jurisdictions may be affected, e.g. when recommending to exchange ballast water of ships in inner-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, but the ultimate goal should be to reduce the amount of ballast water discharges 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 to harmonize the ballast water management approach across all European seas and further to develop guidelines how to identify BWE zones especially for inner-European shipping. It may be considered to launch a "*European Ballast Water Management Decision Support System*".

It should be noted that, assuming the BWC enters into force as planned, BWE is only a risk reducing measure of limited duration, i.e. according to the BWC 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, provided the BWC enters into force as planned, all efforts in this regard will reduce the risks of new AIS introductions. Further, the entry into force of the BWC 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 BWC.

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1 Objectives of the report

The objectives of this report include to present a risk assessment of species introductions to certain Baltic ports, initial recommendations on ballast water management options for the Baltic Sea, and identify available/lacking ballast water related data. The project is in accordance with the overall HELCOM priority in the maritime field: “Based on statistics on ships movements in the Baltic as well as risk assessments to ensure that the increasing maritime traffic and offshore activities are carried out in a safe and environmentally sound manner” and the specific task to “Identify ways to regionally implement the Ballast Water Management Convention, set for adoption in 2004”.

The authors hope that this report may also initiate discussions of ballast water management strategies with and within relevant HELCOM bodies. The following issues are addressed:

1. a brief summary of introduced aquatic species in the Baltic Sea,
2. background information on present and future shipping patterns in the Baltic Sea,
3. history of the ballast water risk assessment measures development,
4. proposed methodologies for risk assessment to be used in the Baltic Sea region:
    a. methods to identify potential source regions that pose a high risk of donating invasive alien species to the Baltic Sea,
    b. procedures for a species-specific risk assessment,
    c. methods to identify areas/ports of special interest, i.e. potential donor locations of future species introductions with ballast water into the Baltic region, where detailed risk assessments should be made, and
    d. methods to identify shipping routes which pose a high risk for the introduction of invasive alien species to the Baltic Sea.
5. the proposed risk assessment methodologies are applied to six selected ports/port regions, i.e. Copenhagen (Denmark), Gothenburg (Sweden), Kiel (Germany), Klaipeda (Lithuania), Sköldvik and the port region Tornio, Kemi and Raahe (Finland),
6. initial measures for reducing or ameliorating the risks identified in risk assessments,
7. suggestions to allow for consistency with other regional guidelines and strategies, and
8. recommended actions to address ballast water issues in a Baltic Sea context.

Problems encountered when preparing this report include (not exhaustive):

- shipping statistics in 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, Felixstowe and Hamburg, rather than the most distant port of this shipping route where the ballast water onboard may originate. An indication of the source region of the vessel and/or last port of call does not provide information on the uptake region of the ballast water onboard. It will therefore remain a challenge to identify source regions of ballast water discharged in the Baltic Sea,
- data on the amount of ballast water released in the Baltic are lacking,

- due to the lack of basin-wide information and data availability on these aspects, particularly the volumes and frequencies of ballast water being discharged, only rough estimates and site-specific examples can be presented. For some Baltic recipient regions the volume of ballast water discharged was assessed by the dimension of the cargo handled, and
- as outlined above the essentially needed shipping pattern details, especially the donor region of the ballast water onboard, were not available. Instead, all ports engaged in trade pattern with the Baltic Sea were listed when developing the risk assessment for species introductions as ballast water discharged in the Baltic may originate from all ports engaged in ships` voyages to the Baltic.

To gather relevant information to overcome these shortcomings, a questionnaire was sent to relevant authorities in all HELCOM countries to ask for information such as annual ship arrivals in all ports, amount of ballast water released and taken onboard.

2 Species introductions, introduction vectors and mitigation measures

2.1 History of species introductions in the Baltic and rising concern of ballast water issues

> *"The Parties of this Convention [for the Control and Management of Ships' Ballast Water and Sediments, IMO 2004], resolved to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of Harmful Aquatic Organisms and Pathogens trough the control and management of ships' Ballast Water and Sediments, as well as to avoid unwanted side-effects from that control and to encourage developments in related knowledge and technology"*

The Baltic Sea[6] is an especially problematic area in regard to bioinvasions. Being a recipient, transit and donor area of nonindigenous[7] species (hereafter NIS), it has become an important node in a global network of NIS transfers during recent decades, thereby facilitating the process of homogenisation of the world's aquatic fauna and flora (Leppäkoski & Olenin 2000).

The unique characters of the Baltic Sea make it a special area not only for the study of bioinvasions but also creates problems with regard to management of ballast water and other ship vectors. The International "*Convention for the Control and Management of Ships' Ballast Water and Sediments*" (hereafter BWC; IMO 2004) is a global tool that does not make any particular reference to semi-enclosed seas and coastal seas with a topography and other environmental conditions that differ considerably from those in the oceans. Therefore protocols for managing the shipping-related invasion vectors in regional seas are essentially needed.

The increasing number of NIS (spread with ballast water, via canals, or intentionally introduced) serves as an indicator of global change also in the Baltic Sea. NIS are common members of the species assemblage in shallow waters, especially at ports, river mouths and in coastal inlets such as coastal lagoons. In the Baltic the number of NIS is lowest in the northernmost parts and highest in the lagoons in the south as well as in the Kattegat. The open sea and deep bottoms were practically free from NIS (with the exception of planktonic larvae of them) until the early1990s when two very successful invaders (the North American spionid polychaete *Marenzelleria* cf. *viridis*[8] and the predatory Ponto-Caspian water flea *Cercopagis pengoi*) started their expansion; both species occupied major parts of the Baltic in less than 10 years.

NIS in the Baltic Sea originate from all continents but South America and Antarctica. The most important donor area, the east coast of North America, has contributed

[6] The Kattegat included all the way in this report.

[7] Synonyms commonly in use: non-native, alien, introduced, invasive, exotic, invader, allochthonous, adventive, translocated, human-mediated, pest; (e.g. Occhipinti-Ambrogi & Galil 2004).

[8] Described as *Marenzelleria neglecta* sp. nov. from the coastal waters of the southern Baltic by Sikorski & Bick (2004).

approximately 30% of all known introductions. The ongoing "Americanisation" is one of the most important processes that contribute to the xenodiversity[9] of all semi-enclosed European seas, including the Baltic (Leppäkoski & Olenin 2000). Other NIS of transoceanic origin than those native to North America are rare in the Baltic, e.g., the New Zealand mud snail *Potamopyrgus antipodarum,* the Chinese mitten crab *Eriocheir sinensis* (not reproducing in the Baltic but adult specimens commonly recorded since the 1930s), and the planktonic Indo-Pacific diatom *Odontella sinensis*.

The brackish conditions of the Baltic Sea do not protect it from species introductions. Today the fauna and flora of the Baltic are exposed to other brackish-water biota of the world, owing to the breakdown of large-scale geographical barriers by ship traffic, which results in an exchange of species (Leppäkoski & Olenin 2001). 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[10]- and mesohaline[11] conditions of the Baltic Sea and thus the ballast water loaded at these sites will be discharged somewhere in the Baltic in harbours with matching salinity conditions (Gollasch & Leppäkoski 1999; Leppäkoski et al. 2002).

In addition to its contact with the Atlantic through the Danish Straits, the Baltic and its drainage area are connected to the Ponto-Caspian brackish seas by rivers and canals, which were opened during the period from 1775 to 1952. Species native or even endemic to Ponto-Caspian basins (Black, Azov and Caspian Seas and the adjacent rivers emptying into these seas) have become established in inland Europe, the Baltic Sea and, most recently, the North American Great Lakes (Ojaveer et al. 2002).

All highly euryhaline[12] and cold-eurythermal[13] species are potential invaders into the Baltic Sea. There is a pool of species to be kept on a next-to-come list (see Table 5.7, page 73). The ability of these species to live and reproduce at the low salinity of the Baltic Sea is a key factor to determine their invasion success (e.g. Pienimäki & Leppäkoski 2004; Paavola et al. 2005). The salinity gradient from almost 0 psu[14] 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.

Also vertical gradients strongly influence not only the native biotic communities, but also provide NIS of different biogeographical origin (from cold stenothermal[15] to eurythermal species) an extended repertoire of hospitable temperature conditions within the broad salinity range. Since both the established and potential NIS originate from warmer areas,

[9] Xenodiversity = diversity caused by non-native species both at species and functional groups/life forms levels (Leppäkoski & Olenin 2000).

[10] Organisms tolerant of only a moderate range of salinities, in this case brackish water with a salinity of 0.5 to 3.0 (or 5.0) psu.

[11] Moderately brackish water with a salinity range of 5-18 psu.

[12] Capable of tolerating a wide range of salt water concentrations.

[13] Adaptable to a wide range of temperatures.

[14] Practical Salinity Unit (almost equal to ‰ or ppt).

[15] Capable of surviving over only a narrow range of temperature.

changes in the temperature and salinity conditions may influence the invasion pattern and population dynamics of NIS. If the process of global warming continues, the risk that additional warm-water species become established in the Baltic Sea will increase.

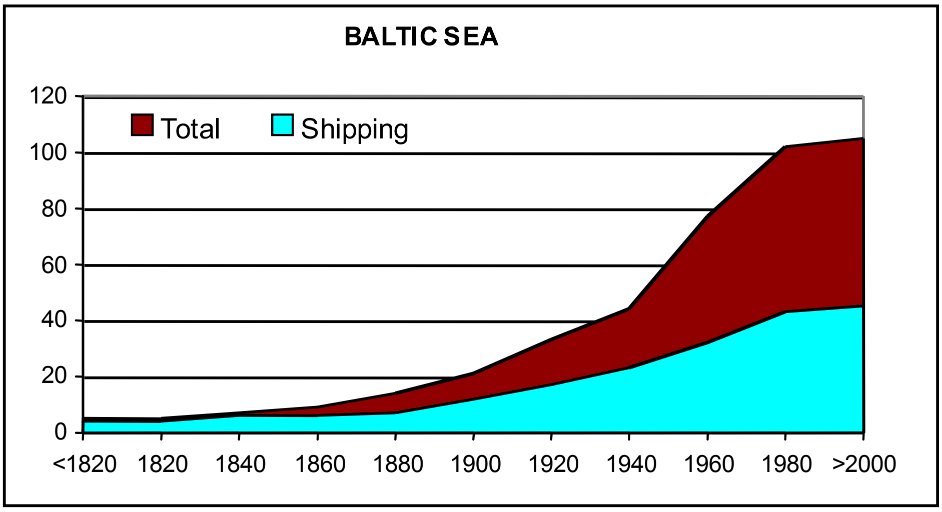


Fig. 2.1. Cumulative number of first records of nonindigenous species (NIS) in the Baltic Sea (105 NIS, based on Baltic Sea Alien Species Database, 2005) and the share of ship-mediated introductions since the early 1800s.

More than 105 NIS 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 main vector (Fig. 2.1). Some 60-70 NIS have established reproducing populations in the Baltic or at least in some parts of it (Baltic Sea Alien Species Database 2005[16]). Generally, and in comparison with most coastal seas worldwide, the alien fauna and flora are well known in the Baltic. For a majority of species, several key questions asked by Vermeij (1996) and Bax et al. (2001) have been answered: (1) confirm that the species is an alien one, (2) identify a donor region, (3) identify the vectors that transported the species, (4) assess the abilities of species in the donor region to take advantage of the routes and means of transport, and (5) identify the regional distribution of the species. On the contrary, there are still a few estimates only available of the actual and potential effects, ecological and socio-economic, of established NIS in the Baltic Sea. Further, the propagule[17] pressure on the recipient areas in the Baltic, i.e. the number of arriving propagules, is largely unknown.

In all, ca. 850 NIS have been reported (up to 2004) in European marine and brackish waters; more than half of them have been established in at least one regional sea (Streftaris et al. 2005). In the NW European seas and adjacent brackish and freshwater habitats more than 350 aquatic NIS are known as established (i.e. self-sustaining populations). Most of these species occur in marine (255 species) and freshwater habitats

[16] Searchable on, e.g., species' names, area of origin, vector of introduction, salinity range, impacts.
[17] Any of various portions of a plant or animal that aid in dispersal of the species and from which a new individual may develop.

(83 species). 31 species are known as typical brackish (Tab. 2.1). The numbers given here should be considered as preliminary as for more than 100 species their population status remains unclear. For 32 species it is unknown whether they are introduced or native (cryptogenic species) (Gollasch 2006).

Table 2.1. Established NIS according to salinity regime and region of occurrence[18] (after Gollasch 2006).

Region	Salinity regime			Total
	freshwater	brackish water	marine	
North Sea	33	10	89	132
Atlantic coast	6	4	91	101
Baltic Sea	41	14	37	92
Irish waters & NW UK	3	2	31	36
Arctic waters		1	7	8
Total	**83**	**31**	**255**	**369**

The origin of several invaders is unknown. Of those species where the origin is known, more than half (115 species) originate from the Pacific Ocean (here including the Indian Ocean). 40 species are native in waters of the western or eastern Atlantic Ocean outside Europe and 51 species originate in European waters outside the geographic scope of this study, e.g. the Mediterranean Sea.

The assumed dominating introduction vector is shipping, with 119 species introduced in hull fouling and 105 in ballast water. The third most important vector is the intentional species introduction for aquaculture and stocking purposes (110 species).

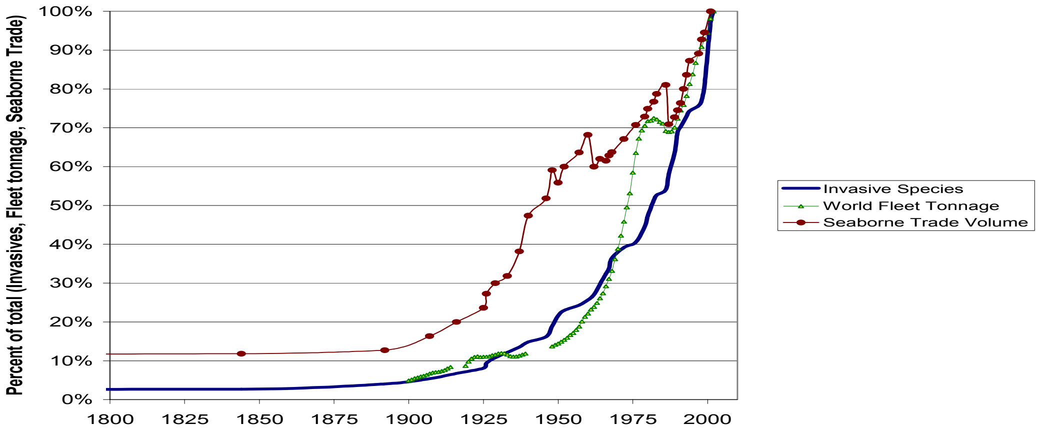
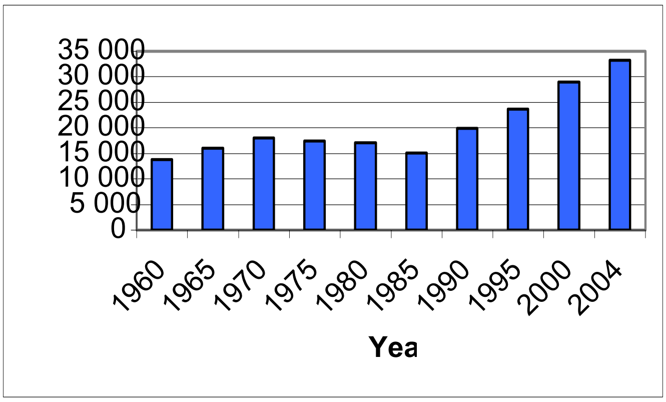


Fig. 2.2. Illustration of increase in invasive species as world fleet tonnage and seaborne trade increased over time. Species data is specific to a biological survey for the Black Sea (Zaitsev et al. 2003) (see also Cohen and Carlton 1998); fleet tonnage data from Lloyds Register Statistical Tables for various years; seaborne trade data from various sources (From Corbett & Firestone 2004; Firestone et al. 2004). Courtesy: J. Firestone, Graduate College of Marine Studies, University of Delaware, USA.

[18] Including freshwaters in close proximity to coastal waters, i.e. inner estuaries, rivers, lakes etc.

A reason for the rising concern of NIS, globally (Fig. 2.2) as well as regionally, is their increasing impact on the environment and economy in certain regions. Well known examples are the zebra mussel *Dreissena polymorpha* introduced to NW Europe and North America, the comb jelly *Mnemiopsis leidyi* introduced into the Black, Azov and Caspian Seas and adjacent water bodies, the Chinese mitten crab *Eriocheir sinensis* which can be found in coastal and inland waters of various NW European countries – including findings in all Baltic countries except Latvia. The number of mitten crab findings is increasing and stretches up to eastern part of the Gulf of Finland.



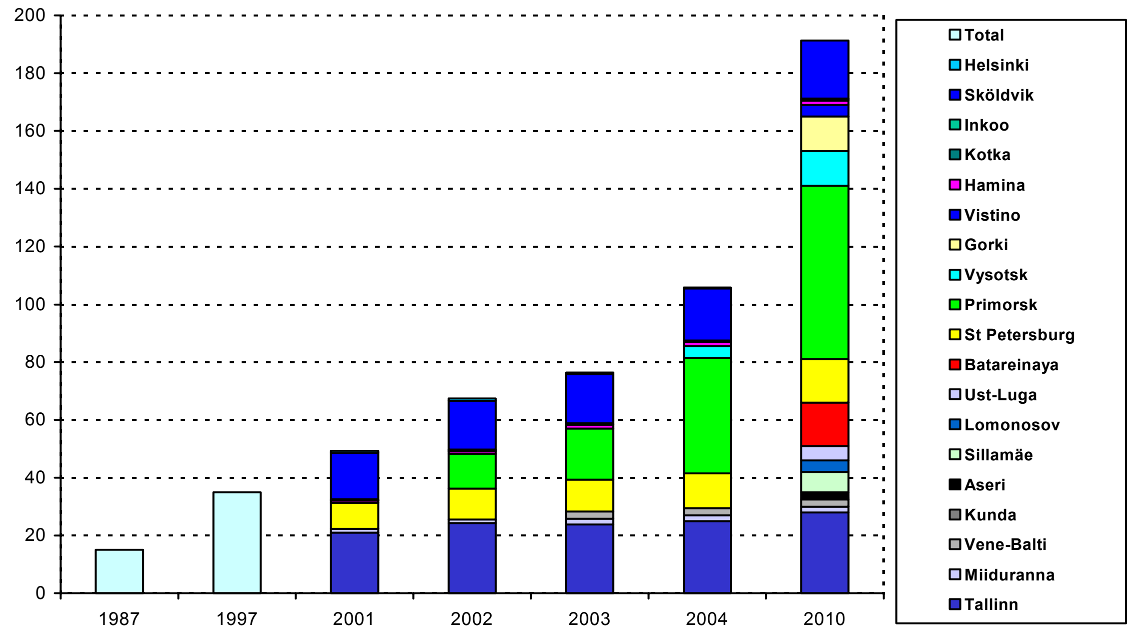


Fig. 2.3. Increase of the number of ships' visits in Finnish ports 1960-2004 and oil transports in the Gulf of Finland 1987-2003 and prognosis for 2004 and 2010 (VTT and Finnish Environment Institute).

2.2 Vectors of species introductions

As shipping is the dominating vector of species introductions and an increase in ship traffic is observed (see Chapter 3 for examples and further discussion), the probability of new species introductions is also increasing. Over the last 30 years, world seaborne trade has increased from ca. 2,500 mio tonnes (1970) to > 5,300 tonnes (2000), i.e. more than doubled (Bax et al. 2003). The merchant fleet of the world comprised almost 30,000 ocean-going vessels (1,000 Gross Tons or greater) in 2004 (Lloyds Register Fairplay); the total registered fleet consists of more than 45,000 vessels. As the fleet grows, the number of ship visits increases, and the faster the ships, the better the survival of organisms during the voyage. As pointed out by Niimi (2004), also ballast water carried by container ships represents an important means for the introduction of AIS – container ships represent 15% of the world fleet but account for 32% of all visits to global ports. Large ports serve as hubs to the 370-1,000 major trade ports world-wide and are frequently visited by regional vessels, which increases the role of container ships as vectors for secondary introductions from port to port.

In the Gulf of Finland alone, a six-fold increase in ship traffic has been estimated for the next decade: This is partly due to the increasing export of oil from new oil terminals in the innermost part of the Gulf (Figs 2.3, 2.4).

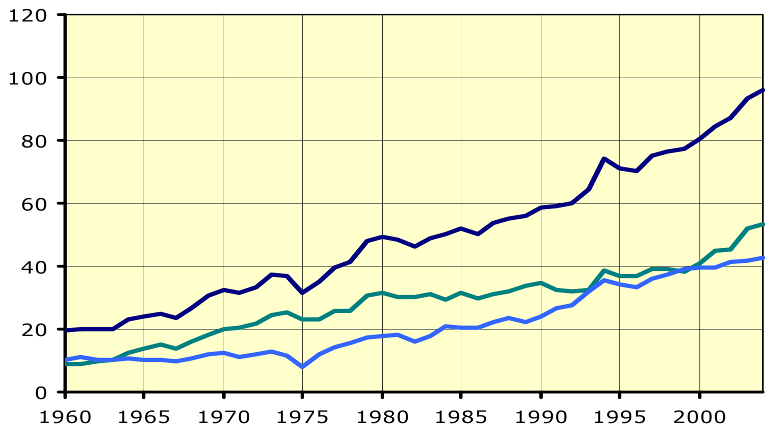


Fig. 2.4. Seaborne transports (mio tonnes) between Finland and foreign countries 1960-2004 (Source: Finnish Maritime Administration; www.fma.fi). Dark blue = total; green = import; light blue = export.

2.3 Management strategies to avoid species introductions

Marine bioinvasions and related environmental and socio-economic issues were introduced to the international agenda especially by the comprehensive review article by Carlton (1985). The first attempts to deal with ballast water related environmental issues date back to the early 1990s when discussions began at the International Maritime Organization (IMO), the United Nations body which deals with shipping. The Marine

Environment Protection Committee (MEPC)[19] within IMO launched a ballast water working group in 1992 and as a result of this work in 1998 the Assembly Resolution A.868 (20): "*Guidelines for the Control and Management of Ship's Ballast Water to Minimise the Transfer of Harmful Aquatic Organisms and Pathogens*" was published. The group continued its work and in February 2004 the IMO BWC was adopted.

As a consequence the IMO based Global Ballast Water Management Programme (GloBallast) was launched as a four-year project. GloBallast came to an end in December 2004 and is considered to have effectively achieved its goals, one of which was to carry out a risk assessment for species movements in ballast water for all six GloBallast demonstration sites (based in Brazil, China, India, Iran, Ukraine and South Africa). Since the completion of GloBallast in 2004, IMO and other funding authorities currently prepare a follow-up initiative, i.e. GloBallast Partnerships. This programme may be launched in 2007 and may put an emphasis on a more regional approach when dealing with ballast water management matters. Another key objective may also be support for the timely implementation on the IMO BWC.

ICES emphasised the need to deal with ballast water already in the end of the 1980s at the 1987 meeting of the ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO). In the end of the 1990s the ICES WGITMO emphasised the need to follow the IMO Assembly resolution A.868(20). In addition to the WGITMO, ICES, IOC and IMO established in 1997 a joint Study Group (SGBWS) focussing on unintentional species introductions with ships. To address the growing concern of other ship vectors than ballast water the Study Group was renamed to Study Group on Ballast and other Ship Vectors (SGBOSV) in 1999. To allow for a longer working term of this group it was renamed again in Working Group on Ballast and Other Ship Vectors (WGBOSV) in 2004 and its work continues with annual meetings.

A regional body particularly relevant in this field is the working group of the BMB on Nonindigenous Estuarine and Marine Organisms, established in 1994. Objectives of the Working Group include:

- to collect and summarise information on introduced species in the Baltic Sea,
- to promote a closer co-operation between biologists dealing with introduced species within the Baltic Sea and between the Baltic Sea and other marine areas, and
- to elaborate recommendations for consideration of HELCOM.

A statement to HELCOM made by the Working Group at its first meeting in Klaipeda in 1995 was appreciated by the HELCOM EC.

Initiated and funded by the German Environmental Protection Agency (Umwelt-bundesamt, Berlin) a ship sampling programme on ballast water, hull fouling and sediments in ballast tanks was carried out 1992-1996 in German ports. This study was the first ballast water sampling study in Europe. It also provided a simplified risk assessment

[19] Of the Baltic Sea countries, Denmark, Finland, Germany, Poland, the Russian Federation, and Sweden have actively contributed to the work of MEPC in the early 2000s when completing the Ballast Water Management Convention.

to analyse the likeliness of species introduction for all NIS found during the investigation. This risk assessment was based upon the comparison of salinity and temperature in the area of origin of the found NIS and NW Europe, with a focus on the North Sea (Gollasch 1996).

During 1997-1998 the Nordic Council of Ministers funded a study entitled "*Initial Risk Assessment of Alien Species in Nordic Coastal Waters*" and the final report was published in 1999. For the Baltic Sea area, Gollasch & Leppäkoski (1999) and their co-workers generated an initial risk assessment overview for Nordic coastal waters. They reviewed existing, and presented new ideas on the components to be included in a risk assessment of NIS (vectors, environmental matching approach, volume of ballast water discharged, port profiles) and conducted qualitative risk assessments for brackish water species and five selected ports along the salinity gradient from St. Petersburg to Bergen. This study was the first of its kind in Europe and addressed the risk of species invasions in various port regions within the Nordic countries.

The project identified:

- Nordic marine areas that might be particularly sensitive to the introduction of NIS,
- NIS that are particularly potent to cause large-scale environmental problems (including impacts on biodiversity) and/or economic effects,
- ecosystems and indigenous species that are particularly sensitive to the impact of NIS,
- economic losses due to the impact of NIS,
- tools for risk assessment for selected harbour areas, including ecological criteria and prerequisites (e.g., salinity and temperature conditions, availability of habitats, turbidity, eutrophication, pollution) for probabilities of harbour areas to act as receivers and/or donors, quantified in relation to survival probabilities of NIS,
- existing vectors in selected, international harbours, including harbour profiles with regard to import/export of ballast water, i.e., an origin/destination profile for imported/exported ballast water. Harbours studied were St. Petersburg (Russia), Turku (Finland), Klaipeda (Lithuania), Stenungsund (Sweden), and Sture (Norway),
- suggestions of measures and strategies to be employed to tackle the problems, and
- the need for further research, and suggestions to monitoring activities.

However, the results from the study can only be applied to the today's situation on a limited scale as e.g. the IMO BWC emerged which addresses certain depth and distance limits for ballast water exchange and other ballast water management requirements. Further, the approach taken was not based on shipping routes, but was more in general nature.

Previous risk assessment studies of aquatic NIS have used frameworks and concepts of general ecological risk assessment (see also Annex 1). Qualitative risk assessments have been more common (e.g. Gollasch 1996, Gollasch & Leppäkoski 1999, Grigorovich et al.

2003, Hayes and Sliwa 2003), but also quantitative predictions have been published e.g. for specific target species (e.g. Hayes 1998b, Kolar & Lodge 2002, Nyberg & Wallentinus 2005).

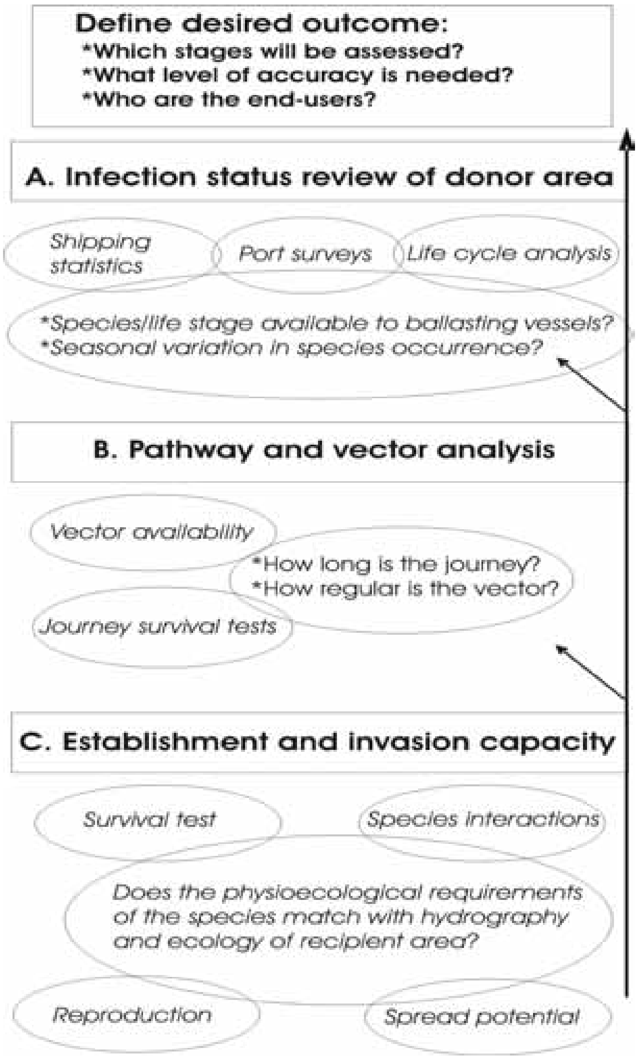


Fig. 2.1. Risk assessment of a ship-mediated aquatic alien species is a stepwise process. The arrows indicate the continuation and updating necessity of risk assessments (Paavola 2005).

Other NW European ballast water management initiatives (European Union, ICES) are in a planned, preparational or developing status. The OSPAR risk assessment study, developed via IGSS, was completed in 2005 as Ballast Water Scoping Study for NW Europe. The focus of this study is the OSPAR region. This study also includes risk assessment recommendations (Dragsund et al. 2005) and was considered in detail when drafting this report.

A Baltic Regional Workshop on Ballast Water Management, funded by IMO and the GloBallast Programme, was held in Tallinn, Estonia in October 2001. The Country Status

Reports compiled in the framework of the workshop showed that all Baltic Region countries have suffered from marine bioinvasions, all are undergoing expansions of their port facilities and are facing significant increases in shipping activities (Raaymakers 2002). During the workshop discussions, all countries agreed that the problem of ballast water and marine bioinvasions must be addressed in the Baltic Sea on a regional basis and that a cooperation between all countries in the region is essential. The reasons given for this position were:

- the Baltic is an enclosed sea and the marine and coastal environments of all Baltic Sea countries are linked,
- shipping is an international industry and ships routinely cross jurisdictional border lines to conduct trade,
- actions by an individual country would therefore be of limited effectiveness, and
- there is a strong history of effective regional cooperation in the Baltic on maritime and marine resource management matters.

Further, the participants at the Baltic Regional Workshop 2001 agreed that a regional cooperation on ballast water control and management should be developed and coordinated through existing regional structures and mechanisms, and should be linked, wherever possible, with existing marine resource management and environmental protection activities. HELCOM and the GEF Baltic Sea Regional Project were identified as the most suitable entities (Raaymakers 2002).

The Nordic Council of Ministers held the Nordic Ballast Water Summit in Oslo in January 2002 at the headquarters of Det Norske Veritas, Hövik (Norway). One of the results from this summit was a call for a "*Regional Strategy and Action Plan for Ballast Water Control and Management*". The outcome of this workshop supported the development of the Det Norske Veritas risk assessment approach, named EMBLA, which is a ballast water risk assessment method. The overall objective of EMBLA is to provide an Internet based decision support system for ballast water exchange on specific voyages. More recently DNV reviewed and updated EMBLA to address new developments at IMO, i.e. compliance with the IMO BWC and the Risk Assessment Guideline G7 which is currently developing. The EMBLA system encompasses the following main modules:

1. **Target Species List,** a list of "unwanted" or potentially negatively impacting species that a country, region or port avoids to become introduced. Target species are either defined by the port/country/region or may be selected by a comparison of the lists of NIS in the donor port and the recipient port. EMBLA recommends that the target species list shall contain at maximum 15 species.
2. **Ballast Water Log** for a specific vessel. This is a vessel specific database documenting the number and type of ballast tanks and the ballast water operation of all tanks over time including volume of ballast water loaded and discharged as well as its geographic origin.
3. **Port Data Base** including environmental data such as temperature and salinity (biogeographic provinces).
4. **Risk Assessment.** EMBLA carries out a ballast water tank specific risk assessment in two stages:

a. environmental match between donor and recipient region of the ballast water. The endpoint of the risk assessment is qualitative, i.e. high, medium and low, and
b. species-specific assessment. The survival probability of target species is calculated in EMBLA according to species survival during each of the ballast water operations (uptake, transfer, discharge, recipient region). Whenever possible different life stages of the target species are taken into account and also the seasonal occurrence of the different target species life stage in the donor port/port region as well as the seasonal changes in environmental conditions in the recipient port/port region. The risk assessment endpoint is quantitative.

As stated in Dragsund et al. (2005), HELCOM 25 in March 2004 recommended the HELCOM Contracting Parties to ratify, as soon as possible, the Ballast Water Management Convention, and each Baltic state should develop a national lead agency for ballast water management. The Maritime group drafted in a meeting in Copenhagen in October 2004 the HELCOM recommendations: "*Measures to address the threat of invasive species transported via the ballast water of ships*". Considering that ballast water exchange is a limited option for ballast water management in the Baltic Sea the group emphasized the need for regional cooperation when addressing the threat. The Governments of the Contracting Parties to the Helsinki Convention recommended:

- to designate/identify a clear responsibility for coordinating the national response to the issue,
- to request arriving ships to submit Ballast Water reporting forms using the IMO Guidelines (IMO Resolution A.868(20), adopted on 27 November 1997),
- to require ships flying the country's flag or calling at the country's ports to carry and implement a shipboard ballast water management plan (taking into account the IMO Guidelines),
- to provide adequate reception facilities for sediments in ports and terminals where cleaning and repair of ballast tanks occurs,
- to carry out by 1 January 2007 risk assessments for major ports. The risk assessments should be carried out using the compatible methodology developed under IMO (the development of the IMO risk assessment guideline is currently ongoing and a draft document will likely be discussed at the next meeting of IMO MEPC in March 2006),
- to cooperate in order to establish by 2006 national and regional information systems for the data obtained from the Ballast Water reporting as well as during risk assessments, biological surveys and monitoring (including an early warning system),
- to conduct by 1 January 2007 biological surveys and establish a monitoring system for invasive aquatic species in major ports using harmonized methodology developed and updated by the appropriate HELCOM subsidiary bodies and to be based on guidelines prepared under the IMO,
- to link the port surveys and monitoring to an early-warning system, whereby ships can be alerted to outbreaks of harmful species, and

- to cooperate with the North Sea countries when implementing the provision of the Ballast Water Management Convention.

The implications in a regional context of the BWC were discussed by Baltic Sea experts at a Workshop in Palanga, Lithuania, in February 2005 (BSRC/HELCOM/COLAR 2005). During this workshop the following subjects were elaborated and discussed further:

- applicability of the risk assessment and port baseline survey methodologies developed under the IMO GloBallast and other relevant projects for the Baltic Sea,
- research capacity, technical potential and financial resources needed for the risk assessment and the port baseline surveys,
- common principles for the monitoring system of invasive species in the Baltic Sea, and
- common information system for the Baltic Sea supporting the implementation of the IMO BWC.

Results and recommendations from all above-mentioned initiatives relevant to risk assessment were considered in great detail during the preparation of this report.

3 Analysis of present and future shipping patterns in the Baltic Sea

> *"For the first time in the history of human endeavor and the history of the ocean, large parcels of plankton-rich water were being transported virtually instantaneously across and between oceans"* (Carlton 1996).

3.1 Today's shipping pattern 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 region of the ballast water (see risk assessment chapters 4 and 5).

Shipping is a gateway to the world's trade business and Europe is part of the major shipping routes in the world. Fig. 3.1 depicts the frequently used shipping lines in north-western Europe. The busiest 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 into the Mediterranean Sea to the Suez Canal. Hot spots in shipping are in the south-western Baltic, central German Bight, British Channel and southern France and Italy.

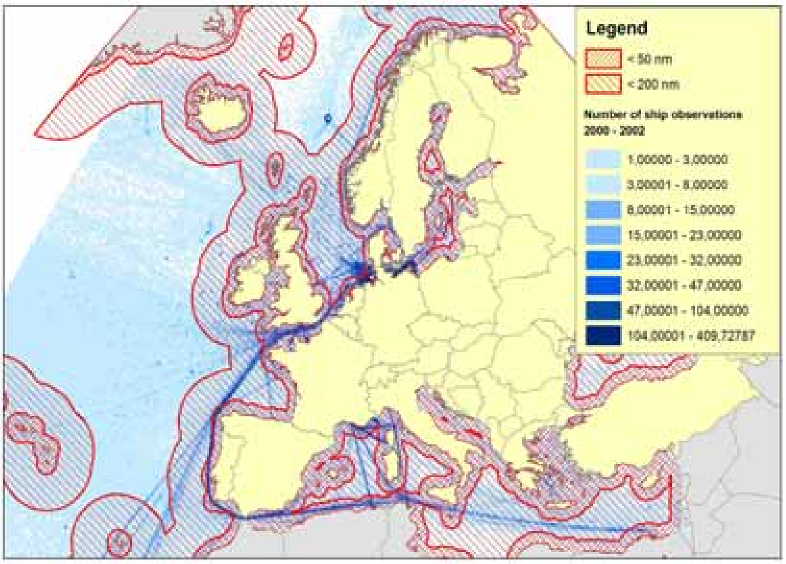


Fig. 3.1. Shipping pattern in number of ship observations in NW Europe 2000-2002 indicating the highly frequented shipping lines in blue. Source: Dragsund et al. 2005.

A close up of Fig. 3.1 is also presented here to show the most frequently used shipping lines in the Baltic (Fig. 3.2). The HELCOM Automatic Identification System (AIS*) provides a very helpful source of information documenting the number and type of vessels in Baltic inbound traffic when passing the five reporting lines (Fig. 3.3).

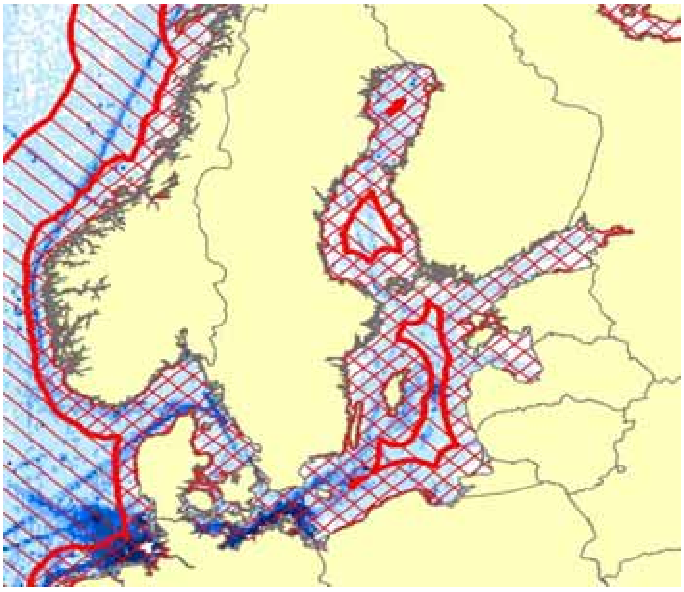


Fig. 3.2. Shipping pattern in number of ship observations in the Baltic 2000-2002 indicating the highly frequented shipping lines in blue. Source: Dragsund et al. 2005.

Additional sources were used to assess the number of ships in the Baltic Sea in 2000 (Rytkönen et al. 2002; from UNEP 2005) (Fig. 3.4). Baltic regions with busy shipping are in the south-west (Denmark, Germany, Poland), along the western and southern coast of Sweden and in the waters between Gotland and Latvia. The number of ship arrivals in certain Baltic ports is given in Tab. 3.1. When excluding ferries, the busiest Baltic port 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.

In the late 1990s there were more than 500 ports in the Baltic Sea with a total annual port throughput close to 700 mio tonnes (1997/98) (Rytkönen et al. 2002, Dragsund et al. 2005). The most important ports are indicated in Fig. 3.5; all of these 76 ports handle more than 1 mio tonnes of cargo per year.

Dragsund et al. (2005) provide a cargo turnover calculation for all Baltic ports in 1997/98. According to another source of information (Amerini 2005 and World Bank 2005) a slightly higher value is given (approx. 650 mio tonnes; Tab. 3.2) reflecting the increase in shipping activities. However, in the Dragsund et al. (2005) calculation all cargo transported with ships in the Baltic was given (700 mio tonnes), including cargo in transit, i.e. not being loaded or discharged in Baltic ports. They further estimate that approximetaly 600 mio tonnes of cargo is handled in all Baltic ports – with 100 mio tonnes being in transit. Tab. 3.3 documents the cargo turnover in the main Baltic ports (approximately 575 mio tonnes) indicating the fast majority of the cargo is handled in main Baltic ports, i.e. only 12% of cargo is handled in other than the main ports (see also Tab. 3.4).

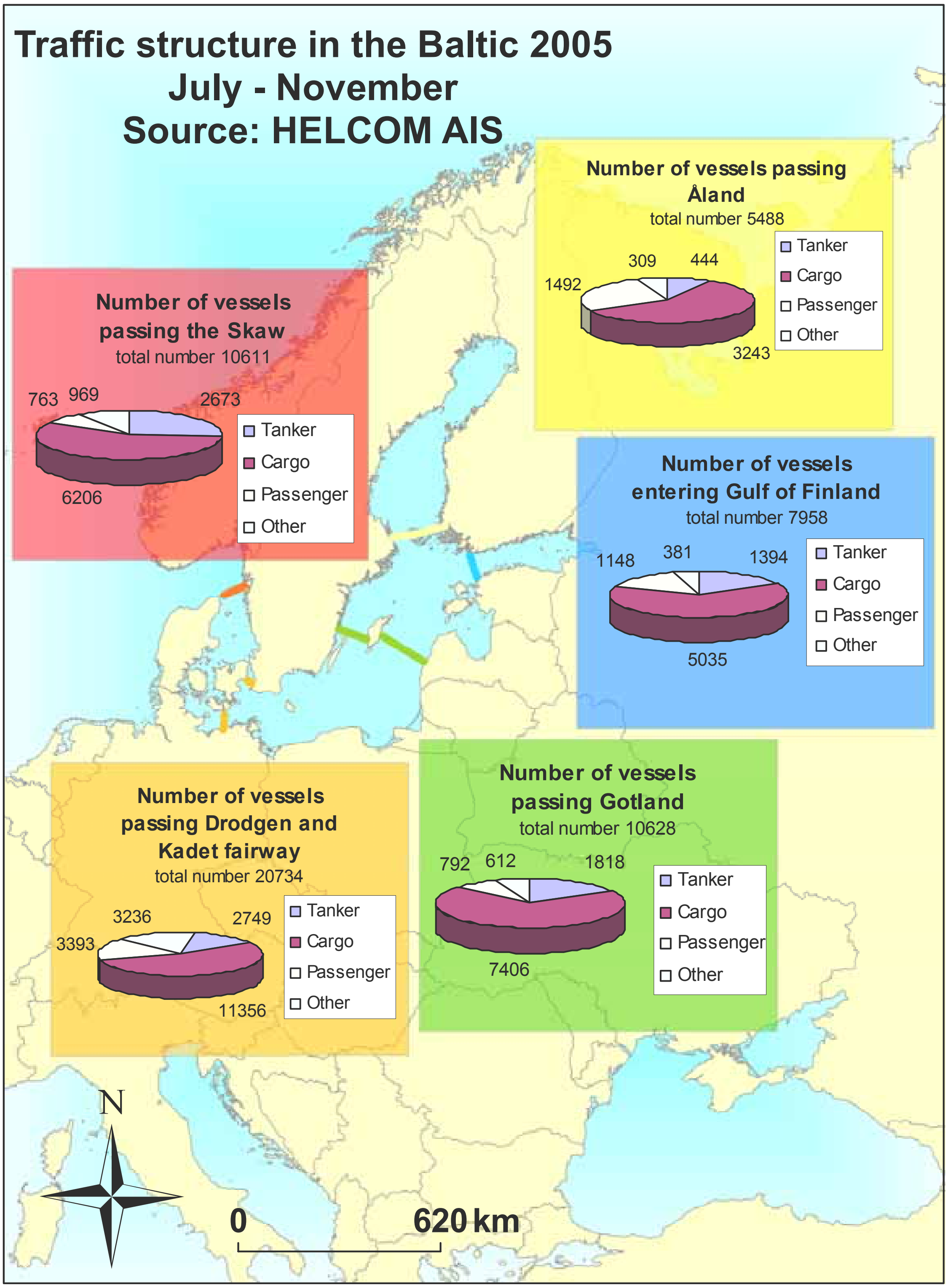


Fig. 3.3. Number and type of inbound vessels passing five reporting lines included in the HELCOM AIS* (Automatic Identification System) in July-November 2005.

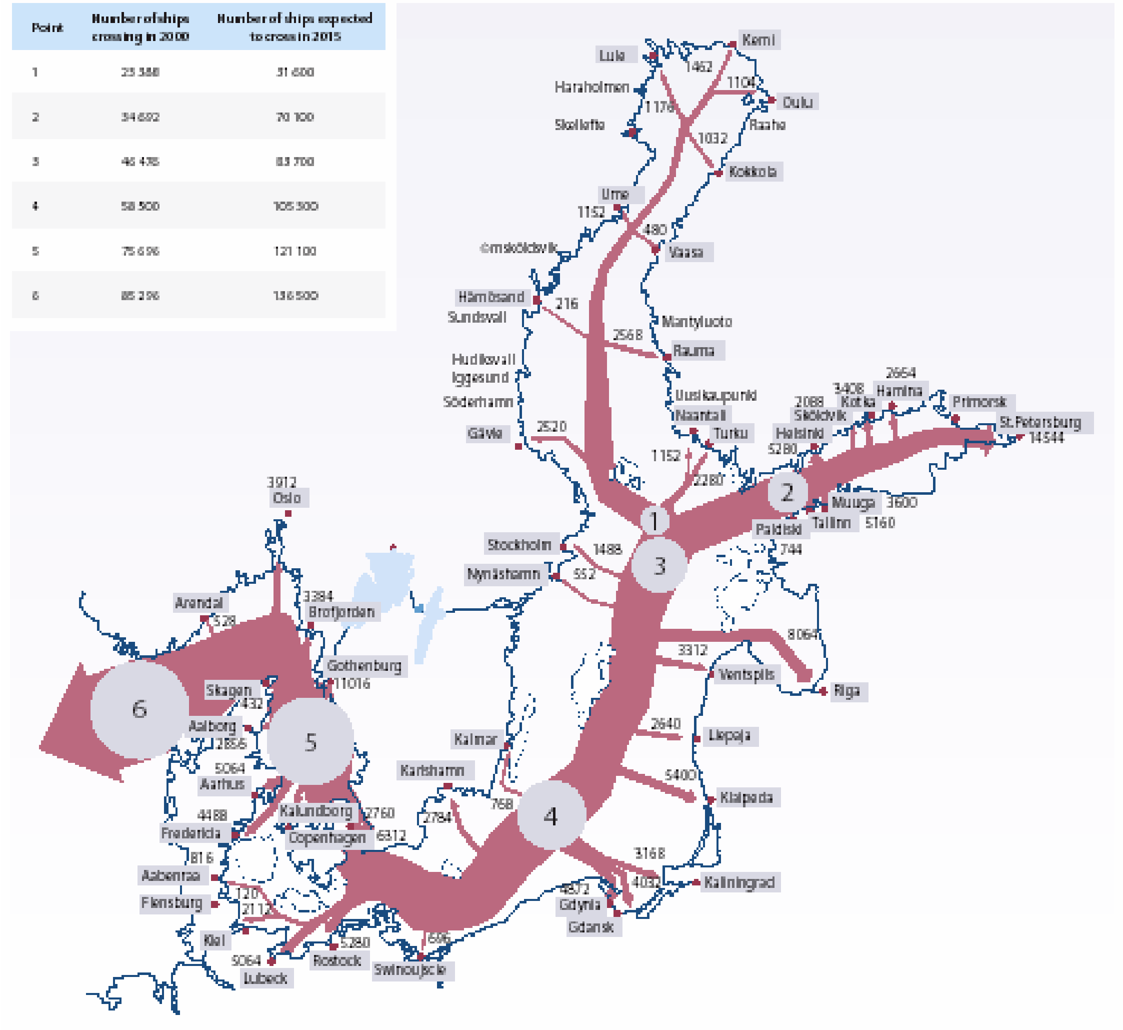


Fig. 3.4. Number of ships (excluding ferry traffic) in the Baltic Sea in 2000 (Rytkönen et al. 2002, from UNEP 2005).

Table 3.1. Number of ships (excluding ferry traffic and ports with less than 2000 visits) in the Baltic Sea 2000 (modified from Rytkönen et al. 2002). The ports in the Bothnian Bay receive less than 2000 ship visits annually and are therefore excluded from the table.

Subarea/port	**Number of ships' visits in 2000**
Bothnian Sea	
Rauma (FI)	2,568
Gävle (SE)	2,520
Archipelago Sea	
Turku (FI)	2,280
Gulf of Finland	
St. Petersburg (RU)	14,544

Table. 3.1. continued

Subarea/port	Number of ships' visits in 2000
Helsinki (FI)	5,280
Tallinn (EE)	5,160
Muuga (EE)	3,600
Kotka (FI)	3,408
Hamina (FI)	2,664
Sköldvik (FI)	2,088
W Baltic proper	
Karlshamn	2,784
E and SE Baltic proper	
Riga (LV)	8,064
Klaipeda (LT)	5,400
Gdynia (PL)	4,872
Gdansk (PL)	4,032
Ventspils (LV)	3,312
Kaliningrad (RU)	3,168
Liepaja (LV)	2,640
S and SW Baltic	
Rostock (DE)	5,280
Lübeck (DE)	5,064
Kiel (DE)	2,112
Danish Straits and Kattegat	
Gothenburg (SE)	11,016
Copenhagen (DK)	6,312
Århus (DK)	5,064
Fredericia (DK)	4,488
Ålborg (DK)	2,856
Kalundborg (DK)	2,760

Table 3.2. Cargo turnover in all Baltic ports. Source: Amerini 2005 and World Bank 2005 for Kaliningrad and St. Petersburg. * = estimated share from countries total: North Sea traffic 10% vs. Baltic traffic 90% (only the estimated Baltic value is given), ** = estimated share: North Sea traffic 80% vs. Baltic traffic 20% (only the estimated Baltic value is given). Both estimates * and ** by the authors.

2003			
Country	Import [mio tonnes]	Export [mio tonnes]	Total [mio tonnes]
DK*	51,2	42,3	93,5
DE**	31,8	19,1	50,9
PL	15,2	35,8	51
LT	4,1	26,1	30,2
LV	3,8	50,9	54,7
EE	4,7	42,4	47,1

Table 3.2. continued.

2003			
Country	Import [mio tonnes]	Export [mio tonnes]	Total [mio tonnes]
FI	57,4	47,1	104,5
SE	88,6	72,9	161,5
Kaliningrad	no data	no data	12,7
St. Petersburg	no data	no data	42,0
Total	**256,8**	**336,6**	**648,1**
Total EU-25	2144,5	1248,8	3393,3

Cargo import/export data are given in Tab. 3.3. It is interesting to note that Germany handles more cargo from/to outside EU-25 countries than in inner EU-25 shipping. All other countries have a higher share of inner EU-25 shipping rather than outside EU-25 countries. Further, domestic shipping plays a minor role, except for Denmark where more than 17% of the total cargo handled was transported between Danish ports.

Table 3.3. Cargo turnover in main Baltic ports. For reasons of comparison the total cargo turnover for all EU-25 countries is given. Source: Amerini 2005 and World Bank 2005 for Kaliningrad and St. Petersburg. * = estimated share from countries total: North Sea traffic 10% vs. Baltic traffic 90% (only the estimated Baltic value is given), ** = estimated share: North Sea traffic 80% vs. Baltic traffic 20% (only the estimated Baltic value is given). Both estimates * and ** by the authors.

2003				
Country	Total [mio tonnes]	Domestic shipping [%]	Inner EU-25 [%]	Out EU-25 [%]
DK*	71,8	17,4	52,6	30,0
DE**	49,5	2,0	45,1	52,9
PL	50,7	no data		
LT	22,9	0,0	71,9	28,1
LV	53,8	no data		
EE	45,3	1,0	84,9	14,1
FI	92,2	5,9	70,4	23,7
SE	133,6	8,7	69,0	22,3
Kaliningrad	12,7	no data		
St. Petersburg	42,0	no data		
Total	**574,5**			

Tab. 3.4 documents the increase in cargo handling for selected Baltic ports. Whereas the cargo handled increased in the period 2000-2003 in all countries, certain ports experience a slight decrease. Consequently a change in shipping pattern occurs for certain ports over time.

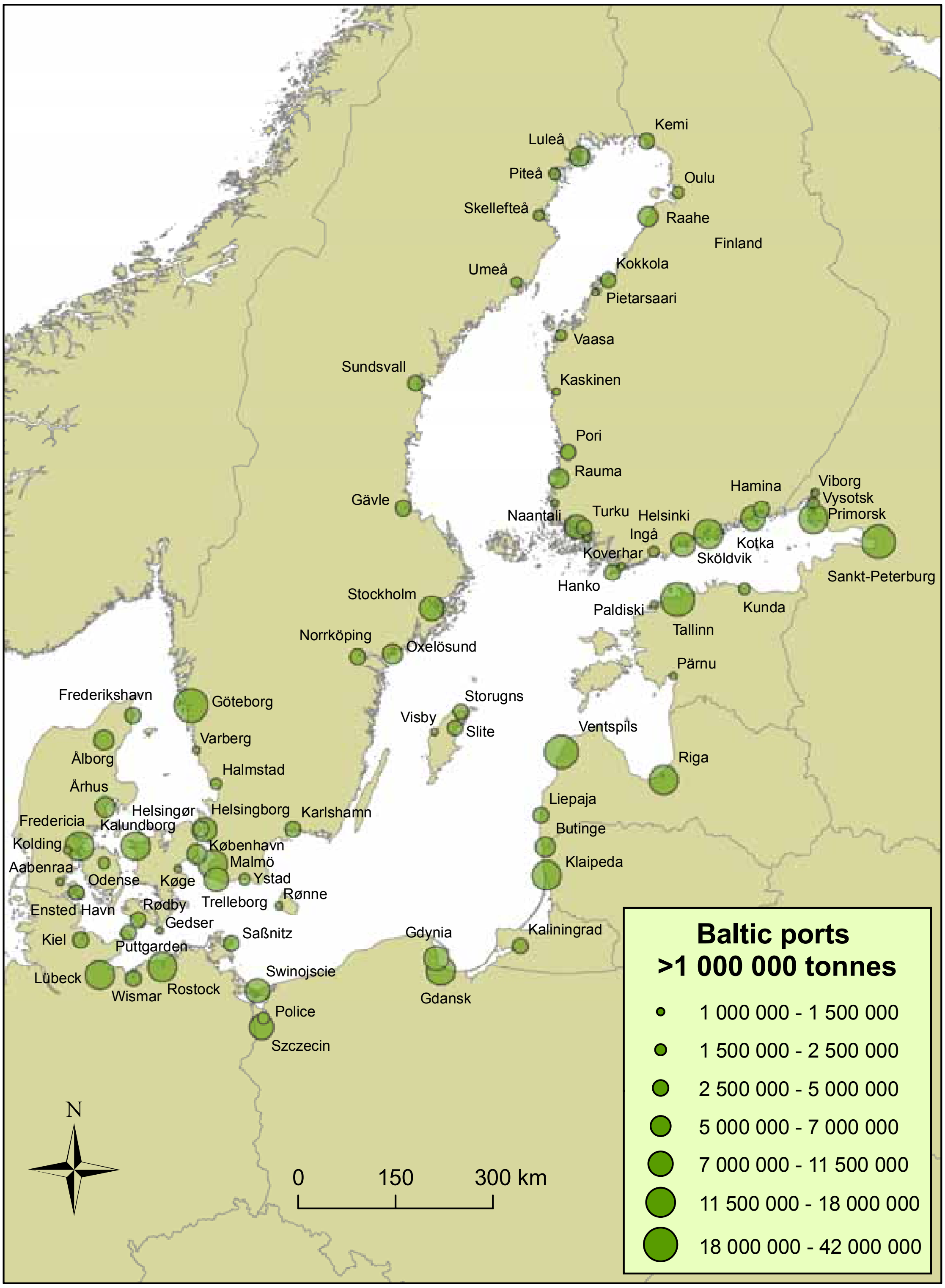


Fig. 3.5. Baltic Sea ports handling > 1 mio tonnes of cargo per year (derived from data in Hänninen 2004).

Table 3.4. Cargo turnover in selected Baltic ports. Source: World Bank 2005 and relevant Ministries of Transport.

Port	Cargo turnover per year [mio tonnes]			
	2000	**2001**	**2002**	**2003**
Tallinn	29,3	32,3	37,8	37,6
Other Estonian ports	10,5	9	9	9,6
Total Estonia	**39,8**	**41,3**	**46,8**	**47,2**
Ventspils	34,8	37,9	28,7	27,3
Riga	13,4	14,9	18,1	21,7
Liebaja	3	3,3	4,3	4,9
Other Latvian ports	0,6	0,8	1,1	0,9
Total Latvia	**51,8**	**56,9**	**52,2**	**54,8**
Klaipeda	19,4	17,2	19,7	21,2
Butinge Oil Terminal	3,5	5,1	6,2	10,7
Total Lithuania	**22,9**	**22,3**	**25,9**	**31,9**
St. Petersburg	32,4	36,9	42,7	42
Kaliningrad	4,3	5,8	9,5	12,7
Grand total	**151,2**	**163,2**	**177,1**	**188,6**

The increase in cargo being transported is shown in Fig. 3.6. Here, as an example, the amount of oil being transported across the Baltic is on a continuous increase since 2000. Between 2000 and 2004 the amount of oil transported was almost doubled (67.7 mio tonnes in 2000; 128.3 mio tonnes in 2004) and another significant increase was estimated for 2005 (158.7 mio tonnes). This business is also expected to increase even further (see also Tab. 3.6).

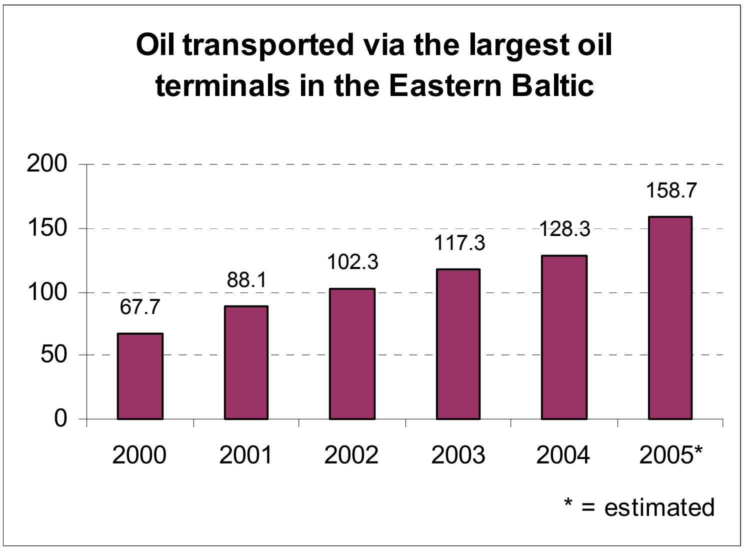


Fig. 3.6. Amount of oil transported (in mio tonnes) via 11 largest oil terminals in East Baltic (Gdansk, Klaipeda, Ventspils, Muuga, Primorsk, Porvoo, Naantali, Riiga, Butinge, St Petersburg and Kaliningrad) grew over 230% since 2000. Source: HELCOM.

Fig. 3.7 shows the relation of the number of ports per country and the number of all NIS. The trend-line indicates that the more ports are located in a region the higher is the number of NIS; thereby highlighting ships as major species introduction vector.

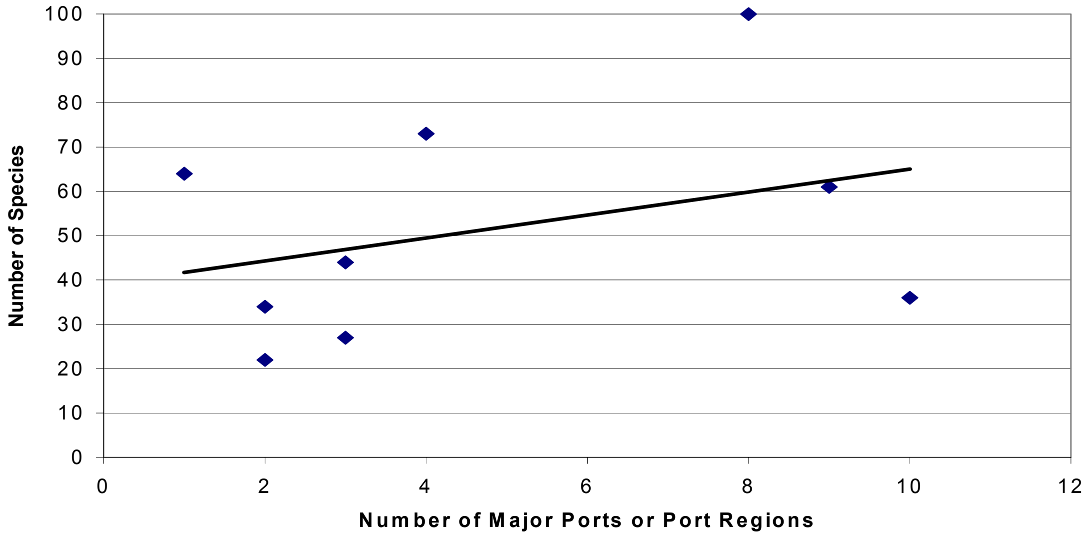


Fig. 3.7. Number of all NIS (including freshwater, brackish and marine species as well as unestablished species) according to number of major ports and/or port regions of countries along the Baltic Sea (after Gollasch unpubl.).

The shipping profiles for selected ports (Fig. 3.8) differ considerably with regard to import/export ratio and type of cargo handled. These examples clearly demonstrate that conversion factors to estimate the volume of loaded/discharged ballast water are difficult to apply. However, this was the only approach to take with the very limited amount of data being available to the authors. 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.

3.2 Short sea shipping

As seen from the statistics presented in this chapter, the share of short sea shipping[20] can reach up to 92% (Finland). Consequently, ships operated on those shipping lines cannot carry out BWE in open sea to meet the IMO water depth and distance to nearest land limits. Further, the duration of short-distance voyages might not be long enough to exchange or treat the ballast water onboard.

[20] Short Sea Shipping (SSS) is defined here as the transport of goods between ports in the EU-15 and Norway, on the one hand, and ports situated in geographical Europe, on the Mediterranean and Black Seas on the other, i.e. ports in EU countries (Belgium, Denmark, Germany; Estonia; Greece; Spain; France, Ireland, Italy; Cyprus, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Slovenia; Finland; Sweden and the United Kingdom), EEA countries (Iceland and Norway), Baltic Sea countries (Russia), and Mediterranean countries (Albania, Algeria, Bosnia-Herzegovina, Croatia, Egypt, Israel, Lebanon, Libya, Montenegro, Morocco, Syria, Tunisia and Turkey) and Black Sea countries (Bulgaria, Georgia, Moldova, Romania, Russia, Turkey and Ukraine).

In 2003, 1.9 billion tonnes of cargo were handled in EU-15 countries in short sea shipping (SSS) predominantly in the Mediterranean and North Sea regions (Tab. 3.5, Fig. 3.9). The types of cargo in SSS are given in Fig. 3.10. The prevailing type of cargo is liquid bulk followed by dry bulk (Xenellis 2005). The total cargo handled by EU-15 countries was almost 3,2 billion tonnes (Amerini 2005) – meaning that SSS is slightly dominating long-distance shipping routes. However, this figure is regionally very different. In Finland SSS accounted for 92% and in Denmark for 83% of all shipping activities. SSS in the Baltic from/to EU-15 countries' ports was dominated by shipping routes with Germany, Sweden, the Netherlands and Finland (Xenellis 2005).

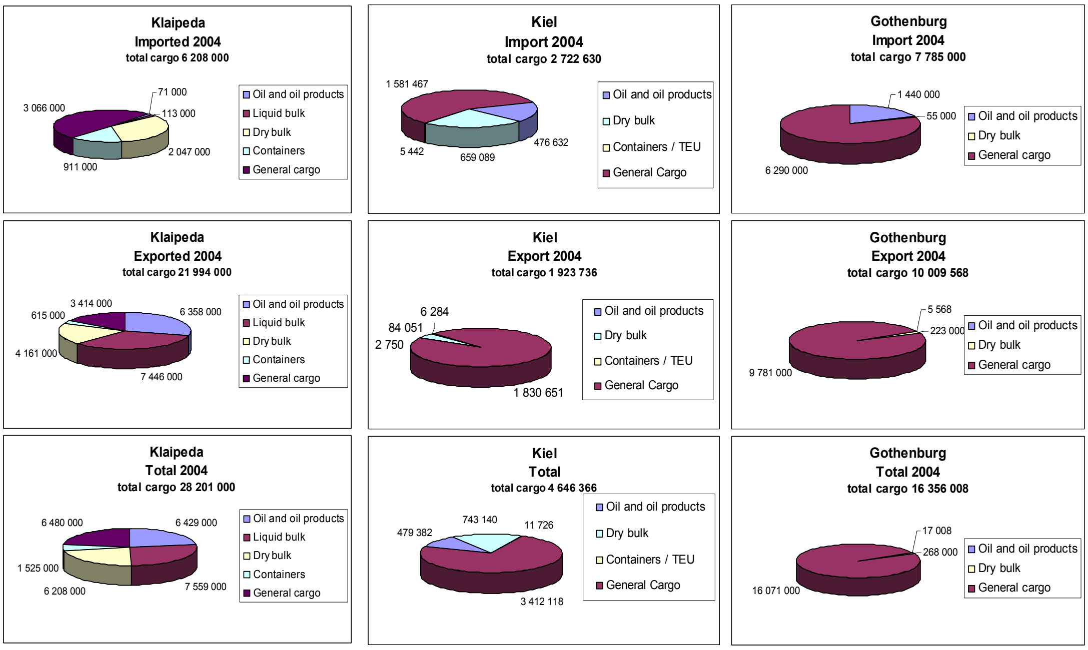


Fig. 3.8. Export and import and total cargo handled in the Ports of Klaipeda (Lithuania), Kiel (Germany), and Gothenburg (Sweden) in 2004.

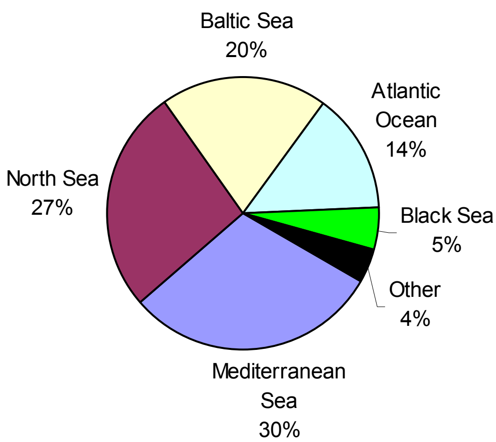


Fig. 3.9. Short Sea Shipping in EU-15 countries by sea region in% of tonnes cargo in 2003.

Table 3.5. Short Sea Shipping by reporting country and by sea region in 1000 tonnes for 2003. Source: Xenellis 2005. The Baltic Sea countries highlighted.

Country	Atlantic Ocean	Baltic Sea	Black Sea	Mediterranean Sea	North Sea	Other
BE	13279	19314	687	20252	40604	617
DK	3240	34606	7	673	26707	418
DE	10621	74818	479	10053	61722	2627
EL	1205	5731	10081	58076	3302	1357
ES	33946	16751	11092	83259	24840	7778
FR	43859	17786	14859	55133	47617	26355
IE	16995	1401	98	656	13924	178
IT	7809	17503	33981	216792	12586	13331
NL	28261	56696	2583	41360	85274	11913
PT	10081	2289	1733	9622	8405	133
FI	3726	48557	61	2037	29914	287
SE	3501	62619	40	2002	47214	2876
UK	111385	28863	873	22393	176377	1981
Total	**287908**	**386934**	**76574**	**522308**	**578486**	**69851**

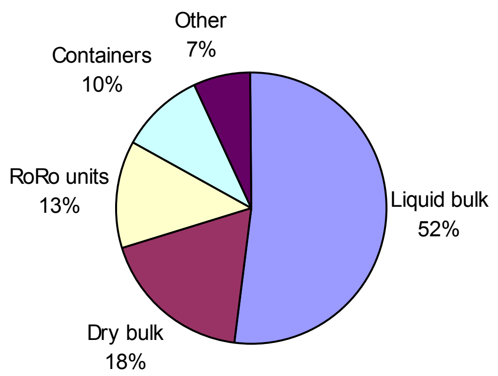


Fig.3.10. The type of cargo in Short Sea Shipping in EU-15 countries in% of tonnes cargo in 2003.

3.3 Prognosis 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 in foreign traffic – but mainly on short sea voyages (see above). 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 Country Status Reports compiled in the framework of the Baltic Regional Workshop indicate that all Baltic Region countries expect significant increases in shipping activity (Raaymakers 2002). Some examples of increased shipping volumes are given in Figs. 3.11 and 3.12. The maritime traffic is expected to double from 1995 to 2017 (COWI 1998; Tab. 3.6) with the largest increase 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 mio tonnes to 80 mio tonnes (Dragsund et al. 2005). In 2004, 106 mio tonnes of oil was transported by sea through the Gulf of Finland, and the annual oil transport is expected to reach 190 mio tonnes by the end of the decade (Hänninen & 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 3.6. Expected growth (in %) of trade in the Baltic Sea from 1995 to 2017 (COWI 1998; from UNEP 2005).

Commodity	**Trade volume (mio 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**

3.4 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 in e.g. Sweden and Finland cannot be estimated. Due to the lack of basin-wide information and data available on these aspects, particularly the volumes and frequencies of ballast water being discharged, only rough estimates and site-specific examples can be presented. Therefore the need for a regional ballast water reporting system is highlighted.

While most authors and administrations agree that ballast water discharges are the most important shipping-related pathway for NIS transfers, ships also transport viable organisms in ballast tank sediments, as in-tank fouling, on the hull, in sea chests and sea water piping systems, and on anchors as well as anchor chains.

The task to estimate the annual volumes of ballast water transferred in or out the Baltic Sea or even different sub-areas of it is too ambitious – practically no precise data are available. However, very tentative estimates can be based on shipping statistics, using conversion factors (cargo imported/exported x factor = roughly the volume of ballast water released). However, this may result in a very uncertain calculation. In average, up to 30% of the ships cargo carrying capacity may be the amount of the maximum ballast water capacity of a vessel. To address this in greater detail the cargo situation of vessels must be known – the above mentioned 30% refers to empty vessels. Those data are currently only available in exceptional cases (e.g. the Port of Sköldvik, Finland).

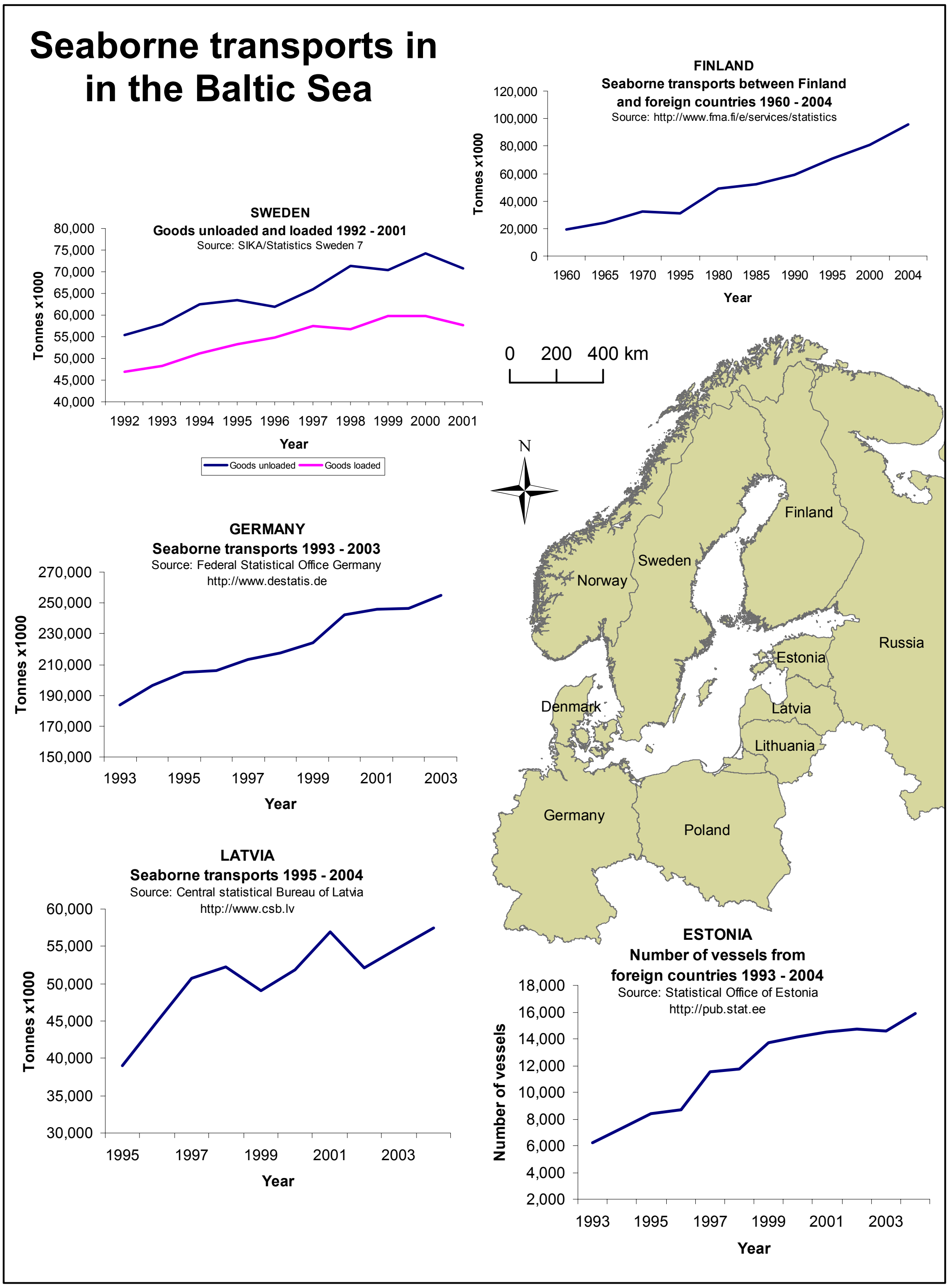


Fig. 3.11. Increase of shipping in some Baltic Sea countries. N.B. different parameters and time scales. Sources inserted in the figures.

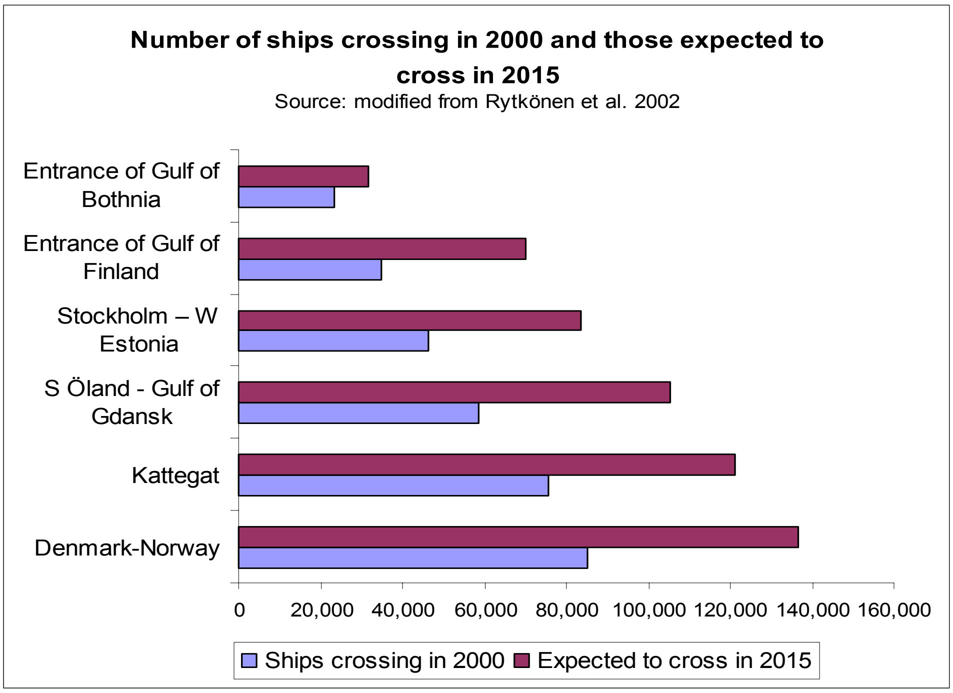


Fig. 3.12. Shipping activities according to Baltic regions in 2000 (blue) and the expected increase until 2015 (red).

A promising information source visited was Hänninen (2004) in which detailed data on the number of port visits and the volume of cargo handled in 2001 and/or 2002 are presented. However, these data could not be used for the ballast water volume calculations due to (a) inclusion of ferries which will deliver a biased result as ferries carry very little ballast, (b) domestic and international ship arrivals were not separated, and (c) the numbers of ship visits in Russian ports were excluded.

Collecting loading/unloading of ballast water data must be done on a ship-by-ship basis. One exception may be crude oil carriers. The oil exporting ports in Russia, Estonia, Latvia and Lithuania receive empty ships, i.e. with up to 30% of their cargo capacity being ballast water onboard. For containers and general cargo carriers such an assessment cannot be delivered as those ships arrive always partly loaded with each voyage representing a unique "ballast-water-onboard" situation.

The following paragraphs describe the ballast water situation in Sweden and Finland. It should be noted that although some ballast water discharge information is available for a port or country, we lack data on the origin of the ballast water released (e.g. on the last ports visited before entering the Baltic).

In the late 1990s, the amount of ballast water discharged from ships in international traffic into Swedish coastal and inland waters was estimated at about 23 mio tonnes per year. Non-tankers made up about two thirds (15.6 mio tonnes) of this quantity. Tankers accounted for a discharge of about 7.6 mio tonnes. It was indicated that 79% of the international calls by tankers and 53% of those by non-tankers discharge ballast water. Tankers discharge on average 2,272 tonnes and non-tankers 1,634 tonnes of ballast water each time they call for a Swedish port (Magnusson 1998; Gollasch & Leppäkoski 1999 and references therein).

In 2000 more than 14,000 oil tankers passed through the straits between Denmark and Sweden discharging roughly estimated 30 mio tonnes of ballast water in Baltic ports (Dragsund et al. 2005).

Vessels calling at the Butinge oil terminal (Lithuania) are all in ballast and this terminal receives large volumes of ballast water. There is no any official estimate of volumes released at Butinge, but as the cargo turnover (oil) was 6.4 mio tonnes in 2004, the amount of ballast water can be estimated at ca. 2 mio tonnes. This is of particular importance as Butinge is the only off-shore oil terminal in the Baltic. For the sake of comparison, Olenin et al. (1999) estimated that 2-4 mio tonnes of ballast water are discharged in the Port of Klaipeda annually. Today's volumes are supposed to be higher (Olenin pers. comm.).

Due to increasing volumes of cargo transported and future developments of new ports in the eastern Gulf of Finland (specially the Primorsk Oil Terminal, Russia, that started operation in December 2001) and further expansion of ports such as St. Petersburg and Muuga/Tallinn, a four-fold increase in oil transports in the Gulf of Finland was expected from 1994 to 2005, up to > 90 mio tonnes per year. This increase of sea traffic also means increased volumes of ballast water to be discharged in the Gulf of Finland. Assuming incoming oil tankers are empty and applying the above mentioned conversion factor an export of 90 mio tonnes of oil may result in 30 mio tonnes of ballast water being discharged. Therefore, the Gulf can be added to the list of "hot spots" receiving large amounts of ballast water, also acting as a potential donor area for transfer of NIS to other parts of the Baltic and/or to seas outside the Baltic area. In fact, if preventive actions are not implemented, accidental oil spills and "biological pollution" by NIS could be the most important environmental issues for the Gulf of Finland in the near future (Leppäkoski 2002).

The only detailed country report available is for Sweden (Magnusson 1998) in which the estimations were based on the information received from questionnaires (254 ships of different types) and shipping statistics from 1996. The estimations indicate that about 23 mio tonnes ballast water was discharged per year from dry cargo ships and tankers (n = 22,200) in international traffic calling Swedish ports.

For the Gulf of Finland, statistics (specially on liquid cargo transports) for 2002-2004 for all major harbours are summarized and available in Hänninen & Rytkönen (2004) and via Internet references in Hänninen (2004). Based on this data, only a rough estimate of likely amounts of ballast water discharged in different sub-areas of the Baltic could be calculated by adopting conversion factors if detailed information of the cargo status of the ships was available (see above).

Estimating the volume of ballast water discharged in the Baltic Sea was defined as one of the key issues in the Work Plan. However this appeared to be a "mission impossible" for several reasons. As mentioned repeatedly in this report, comparable shipping statistics for countries/individual ports were not available. There are too many uncertainties in the national reports to allow for an overall reliable assessment of ballast volumes:

(i) different parameters used in reports (e.g. number of ship arrivals, amount of cargo handled),
(ii) the share domestic/international/overseas traffic not specified,
(iii) passenger ships (and even ferries) included/excluded,
(iv) Norway included/excluded (being a HELCOM Contracting Party but not having any seaports within the geographic Baltic Sea area), and
(v) the very few data available are mostly based upon shipping details more than 5 years old (see Swedish example below). Shipping patterns change over time rapidly and therefore "older" data may result in a biased calculation.

To provide an estimate on ballast water discharges in the Baltic Sea the following approach was chosen. However, for the reasons as outlined above, the following calculations must be taken as a very preliminary attempt – the authors hope that the real figures do not differ by an order of magnitude!

Assuming that

- the Swedish data for 1996 are representative for all the Baltic Sea ports with regard to the number of ships' visits and types of vessels,
- the (obvious) differences between ships in international and domestic traffic can be omitted,
- the relative increase of RoRo ships and other NOBOB ships can be omitted,
- the numbers of port calls given in Tab. 3.7 are reliable, and
- the average increase since 1998 at 25% (16-35%) of shipping volume derived from graphs in Fig. 3.11 is realistic,

we calculated accordingly as follows:

22,200 ships (number of ships in the Swedish report) were estimated to discharge 23 mio tonnes of ballast water. Thus, the estimated number of all ships calling Baltic Sea ports is 65,000 (= 52,100 ships in 1998 (according to Tab. 3.7) + 25% increase until 2003-2004) and can be expected to discharge 68 mio tonnes of ballast water. An additional source of uncertainty is the export increase of Russian crude oil from the terminals in the eastern Baltic area (150 mio tonnes of crude oil exported in 2005; see Fig. 3.6). To reflect the increase in Russian crude oil export, we assume that 30% of the tanker cargo capacity may be filled with ballast water which is discharged when taking onboard crude oil. Consequently, in total **118 mio tonnes of ballast water may be discharged in the Baltic annually**. It should be noted that when assessing the risk of NIS introductions, the ballast water quantity is of minor importance. Even small amounts of ballast water discharges pose a high risk when originating from source ports/port regions of matching environmental conditions with the receiving port.

It will remain a challenge to identify the source regions of ballast water discharged in the Baltic Sea. In order to identify high risk donor areas, shipping statistics need to be analysed to document all potential donor areas of NIS. However, most shipping statistics in 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 provide information on the uptake region of the ballast water onboard.

Table 3.7. Number of ship visits in the Baltic Sea ports in 1998 (modifies from Rytkönen et al. 2002).

Country[1]	**Bulk/ comb**	**Tankers**	**Gas**	**General cargo**	**Container**	**RoRo**	**Total[2]**
Sweden	446	3,002	241	8,382	648	1,831	14,550
Finland	362	1,128	53	3,904	374	2,086	7,907
Russia	240	411	1	2,291	179	143	3,265
Estonia	104	531	1	1,711	60	142	2,549
Latvia	357	490	53	1,969	67	237	3,173
Lithuania	168	118	0	929	17	146	1,378
Poland	478	707	55	2,544	168	230	4,182
Germany	197	388	10	2,601	20	955	4,171
Denmark	653	2,100	85	6,642	480	967	10,927
Total	**3,005**	**8,875**	**499**	**30,973**	**2,013**	**6,737**	**52,102**

1) Norway excluded; there are no Norwegian ports in the geographic Baltic Sea area

2) Passenger ships, reefers ((N=810) and other ships (N=130) excluded

The amount of discharged ballast water gives an indication how exposed certain regions are to ballast water discharges. However, this figure is not equivalent to the risk these regions are exposed to. The risk of NIS invasions becomes clearer when comparing the salinity and temperature of donor and recipient region of ballast water (Chapter 4). Even if the amount of ballast water discharged is comparably small, when salinity and temperature of the donor and recipient region match the risk is relatively high. Due to the lack of data on ballast water discharge and uptake in the Baltic (quantitative data) we focus the risk assessment for NIS introduction on the environmental match of donor and recipient ports/port regions (qualitative match).

4 Potential donor and recipient regions of ballast water

4.1 Life in ballast tanks

Today, ballast water is suggested as one key vector for introducing NIS. Sampling programmes of ballast water, carried out in Europe, revealed that nearly 1,000 taxa were found in arriving ships. The organism variety ranged from unicellular algae to fish. Ballast tank sediment has been recently recognised as a means of dispersal for algae and animals and especially their resting stages, all of which could be released when the sediment is removed untreated or may become resuspended at ballasting/deballasting or in case ballast water exchange is carried out.

Any species transported in ballast tanks must survive the ballasting and deballasting processes in addition to the harsh conditions prevailing inside the ballast tanks[21]. Consequently, the species assemblage to reach the port where ballast water is discharged results from a stepwise process:

- uptake of the organisms dependent on water depths, time of day, season, algal blooms, i.e. availability of organisms to be taken onboard, propagule pressure,
- survival when passing the pumps during the ballasting and deballasting process, and
- survival in tanks during the voyage.

The conditions prevailing in the ballast tanks can be described as follows:

(a) three main habitats are available in the ballast water tanks, free water mass, soft-bottom sediments, and hard substrates, i.e. the walls of the tank;
(b) the ballast water tank configuration influences the physical and chemical habitat diversity of living space and conditions in the tanks; and
(c) darkness, water often polluted (by e.g. oil), ships´ vibration, water temperature and oxygen conditions varying during the voyage.

4.1.1 Ballast water

During the 14 European ship sampling studies considered here, a total of 1,508 samples (1,219 ballast water, 289 tank sediment) were collected on 550 ships. The total number of taxa identified during all completed shipping studies varied between 3 and 502 per study and the number of taxa identified overall was 990 (http://www.ku.lt/nemo/EuroAquaInvaders.htm). The most frequently collected taxa were diatoms, harpacticoid copepods, rotifers, calanoid copepods, larvae of Gastropoda, Bivalvia and Polychaeta. The largest specimens found inside a ballast tank were sea lampreys (*Petromyzon marinus*) of 15 cm length.

[21] For a review, see Gollasch et al. 2002.

4.1.2 Tank sediment

The amount of sediment in the ballast tanks can reach several hundred tonnes. The maximum thickness of sediment known to be transported in ballast tanks reached more than 50 cm. The origin of sediment-bound organisms remains largely unknown, because tank sediments comprise a mixture of deposits accumulated over several years, loaded from a large number of different port areas. In addition, the fate of sediment-dwelling organisms is poorly understood, since a portion of the individuals is resuspended during ballasting operations and some may be pumped out at deballasting.

Life in tank sediments has been studied in a few cases only. Obviously there is no published information available from the Baltic Sea area on the contents of macroscopic organisms in ballast tank sediments. In the early 1990s a shipping study was undertaken in Germany to assess species importations in ballast water, hull fouling and tank sediments into German ports. Here, macroscopic bottom-dwelling animals in tanks were studied. Sediment from the bottom of ballast tanks was sampled from 71 vessels and more than 100 taxa were collected (Gollasch 1996).

During the only ballast tank study of meiofauna[22] known from NW Europe (Radziejewska et al. 2004) a rich and viable meiofauna (up to hundreds per litre) was found even in the residual sediment left after cleaning the tanks of a bulk carrier sampled in Szczecin, Poland. The interior hard substrates, i.e. the ballast water tank walls and internal structures, such as platforms and support frames, act as a habitat for rich microbial assemblages. The biofilms formed on tank surfaces are rich in viruses, bacteria (pathogens among them) and dinoflagellate cysts that may be released with ballast water (Drake et al. 2005).

4.1.3 Ballast tank habitats and risk assessment

As a result, it is strongly recommended to include all three ballast tank "habitats", i.e. water, surface fouling and sediments, into future risk assessments. However, this study has clearly shown the difficulties to gather ballast water data and it is assumed that data on in-tank fouling and tank sediments are even more difficult to gather. Consequently, with our today's knowledge, a risk assessment can only be undertaken – with all its limitations as outlined in this report – for NIS transported in ballast water.

4.2 Identification of shipping routes that pose a high risk of transferring invasive alien species into the Baltic Sea

This chapter intends to provide information necessary for quantifying and understanding the role of shipping vectors for the introduction of alien species in ballast water into and within the Baltic Sea. The aim is to estimate shipping contacts to and from the Baltic Sea area and to determine the likelihood that a species will be

[22] In this study a 0.03 mm mesh size sieve was used.

introduced with ballast water from a donor or source region. As a result high-risk donor areas will be identified.

The analysis is based on available shipping statistics (see Chapter 3), wherever possible including information about port(s) of call previous to entry into the Baltic Sea where ballast water uptake may have occurred, the destination ports of vessels leaving the Baltic Sea (to determine the probability of transfer of Baltic species, native as well as introduced, to other areas – the Baltic Sea as donor), the type of vessel and estimates of amounts of ballast water transported.

Risk assessment of further (secondary) spread from the Baltic to adjacent freshwater systems serves as an example of how this approach can be adopted in a regional context (Pienimäki & Leppäkoski 2004). In their study, the availability of adequate vectors was surveyed through shipping statistics for the Saimaa Canal which connects the Finnish Lake District with the Baltic Sea. Ships arrive in the district mainly from ports located in the northern Baltic Sea, but also from the southern Baltic and North Sea coasts (Fig. 4.1). Finally the potential of 29 NIS present in NE European waters to become introduced and established in Finnish inland lakes was assessed. The physiological and ecological demands of these species were compared with the abiotic and biotic conditions prevailing in the lakes. The establishment of six species turned out to be most probable, with the Gulf of Finland as the main donor area.

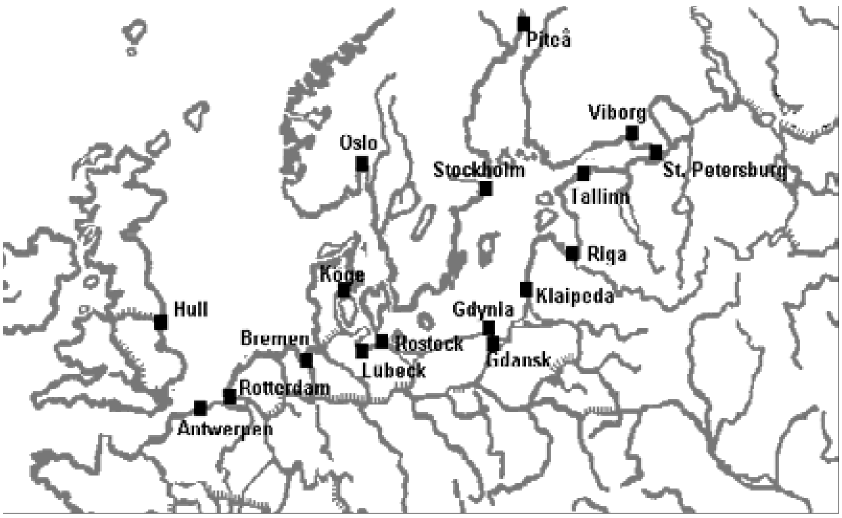


Fig. 4.1. Major NW-European harbours operated by cargo ships from/to the Finnish Lake District (connected with the Baltic via a canal at Viborg) in 1996-2006 (Pienimäki 2002).

4.3 Identification of areas/ports of special interest

The overall analysis of shipping patterns, based on shipping statistics in combination with the known distribution of the target species selected, was used for identification of representative ports/areas to be used for further study. The results

may be extrapolated to cover the whole Baltic Sea (as far as scientifically reasonable).

The analysis is based on the assessment of environmental similarity between the Baltic Sea region/ports and the donor/recipient areas. The environmental similarity analysis is carried out applying the matching climate and salinity approach (e.g. Gollasch & Leppäkoski 1999; Paavola et al. 2005) using 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; www.portguide. com).

Quantitative risk assessments might not always be possible to conduct (no relevant databases on which to base empirical techniques upon are available) (Hayes 1998a). Consequently qualitative expressions of risk (e.g. 'low', 'intermediate' and 'high' risk) may have to be used (Simberloff & Alexander 1994; Gollasch & Leppäkoski 1999). A drawback of the qualitative risk measure is the difficulty to express uncertainty and to use data for additional calculations, e.g. cost-benefit analysis (Hayes 1997). However, a *reasonable* risk assessment is often the best option to get as far-reaching results as possible (Paavola 2005).

Neither all sub-regions of the Baltic nor all harbours within a region are equally exposed to ship-mediated NIS introductions. This is due to the actual propagule pressure, shipping patterns, environmental conditions in the receiving port (i.e. pollution, eutrophication, outflows of cooling water), frequency of inoculations, etc. (see Fig. 4.2 for an example).The most invaded (bio-polluted) coastal lagoons, river mouths and harbour areas in the Baltic are known as centres of xenodiversity - these hotspot sites may be important gateways for further species spread to other ports or non-port areas in the Baltic (secondary spread).

Figs. 4.3 and 4.4 show recent (October 2005) destinations for ships entering/leaving the Baltic Sea. The ports within the Baltic and worldwide which are potentially exposed to imported/exported ballast water are indicated. Within one month only, a remarkable number of ships entered the Swedish inland lakes thus increasing the risk of the most euryhaline or freshwater species to become introduced by ships directly from remote donor areas or via the Baltic Sea.

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). The Workshop recommended that at least one port per biogeographical sub-region should be selected. The 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] as those ships usually carry high loads of ballast water intended for discharge in the Baltic, (iv) where other vectors of introduction, e.g. inland waterways, may be present, and (v) with high number of NIS.

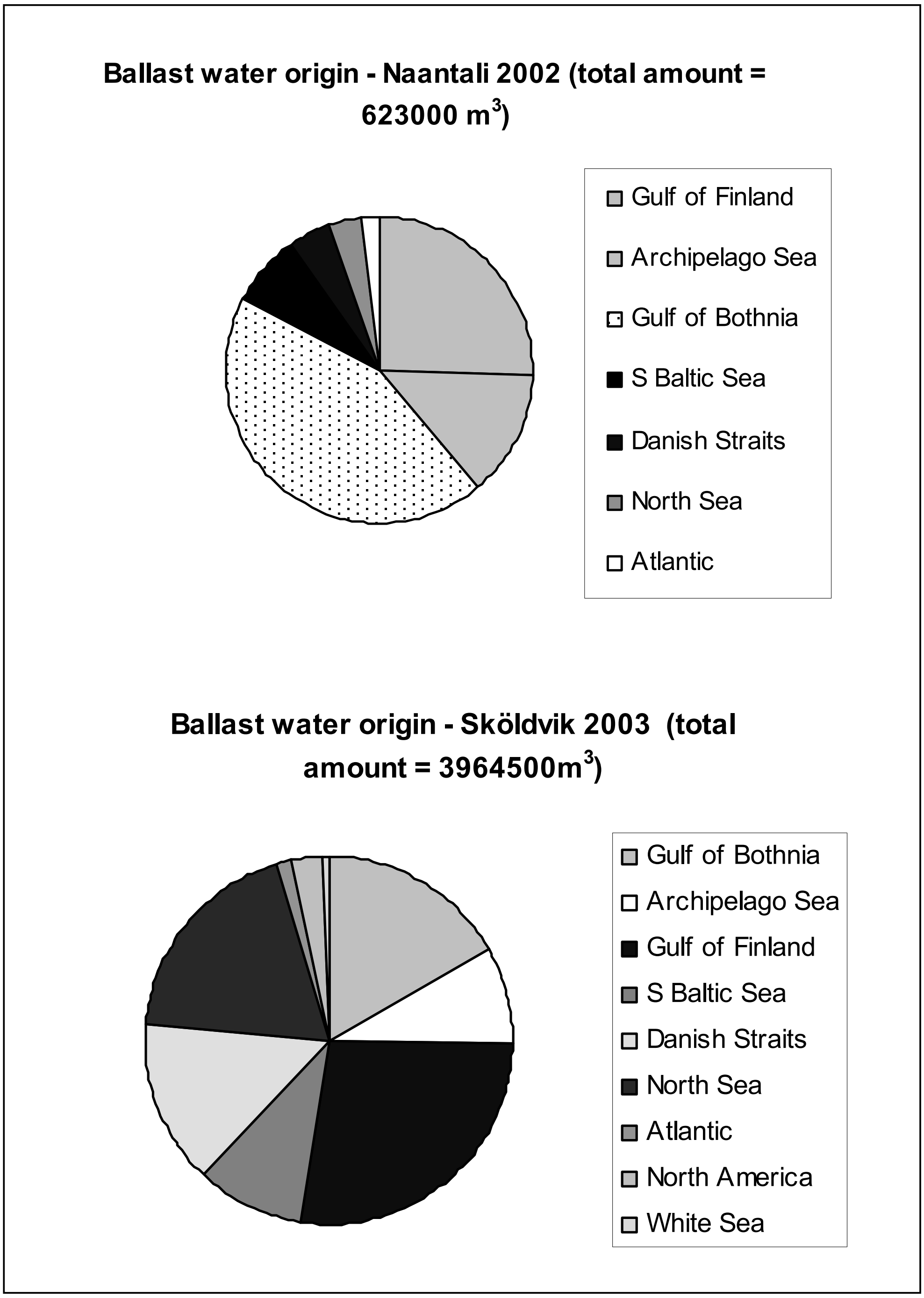


Fig. 4.2. Different shipping profiles influence the origin of ballast water transferred to two oil-handling ports situated close to each other. At the Naantali refinery (SW Finland), the share of speciality products (bitumens, solvents, small engine gasoline, racing gasoline) accounts for ca. 20 %, while the Porvoo refinery (E Gulf of Finland, the Port of Sköldvik) focuses on the production of high quality, low-emission traffic fuels (source: Paavola et al., in prep.)

Fig. 4.3. Ships entering the Baltic Sea in October 2005 (i.e. number and destinations of vessels passing the Skaw/Skagen). Derived from HELCOM AIS*.

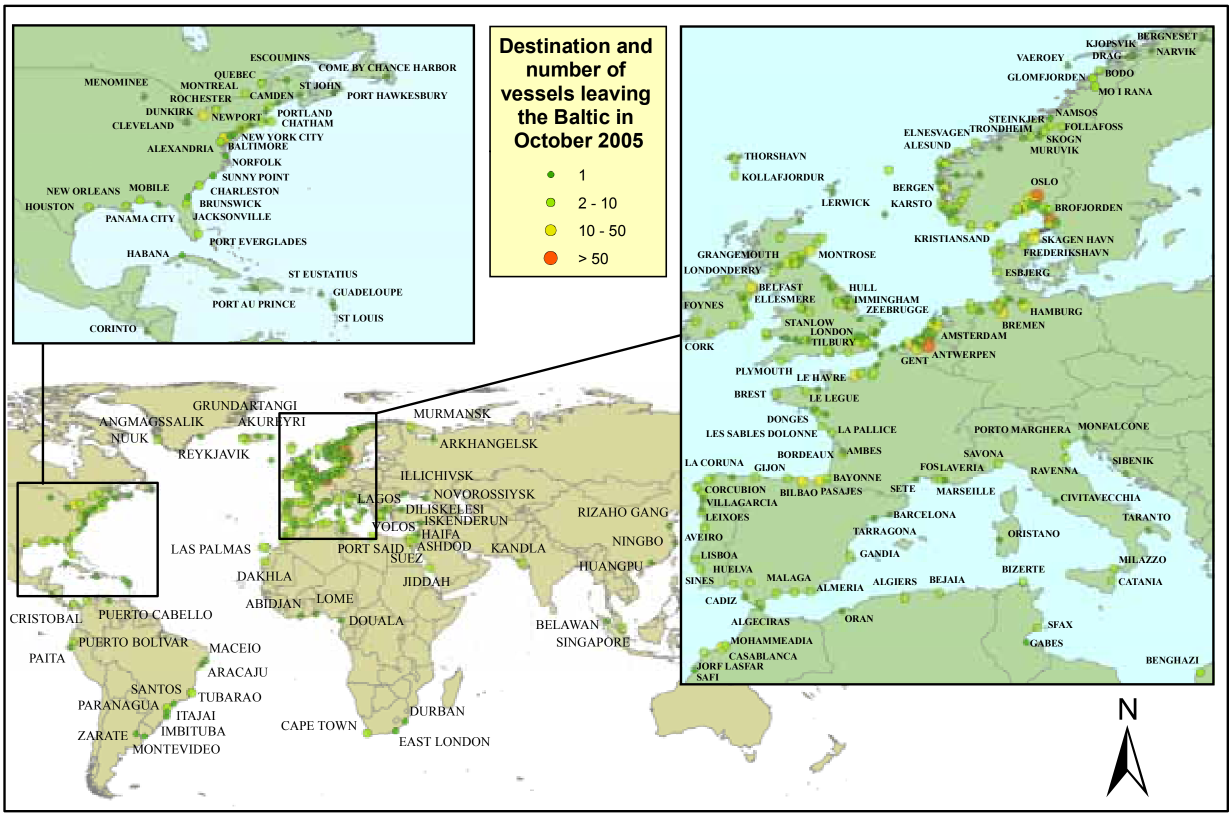


Fig. 4.4. Ships leaving the Baltic Sea in October 2005 (i.e. number and destinations of vessels passing the Skaw/Skagen). Derived from HELCOM AIS*.

Examples from Finland given in this report are based on two sources: (1) A detailed study on shipping to/from the Finnish Lake District was performed in 2003 (Pienimäki & Leppäkoski 2004; Fig. 4.1); (2) Two recently launched information systems appeared to be extremely valuable for mapping and assessment of shipping patterns (but not the amount of ballast water carried) in the Baltic Sea in the early 2000s. These tools are the HELCOM AIS* Display System, available since July 2005, and the Finnish PortNet system. All ships of > 300 gross tonnage engaged on international voyages are required to be fitted with AIS*. Ships provide information to AIS* on ship's identity, type, position, course, speed and other safety-related data. The present PortNet system (www.portnet.fi) is running since 2000. Presently the user can extract information on port arrivals and departures, destination port and previous port(s), among other data (see Fig. 4.5 for an example). All > 40,000 ship visits per year in foreign trade in Finnish harbors are registered. Therefore, several of the examples on cargo flow and ballast water carried presented in this report are based on readily available data derived from PortNet.

We pay most attention on the port of Sköldvik (FIN Kilpilahti, east of Helsinki), serving an oil refinery and petrochemical industries and being the most important Finnish import port (liquid bulk only; > 10 mio tons in 2004, of this 5.8 mio tons crude oil) and being the third most important Finnish export port (5.5 mio tons). The most frequent shipping contacts and, consequently, the ballast water loadings/discharges, are with ships involved in Baltic Sea and North Sea shipping (Fig. 4.6).

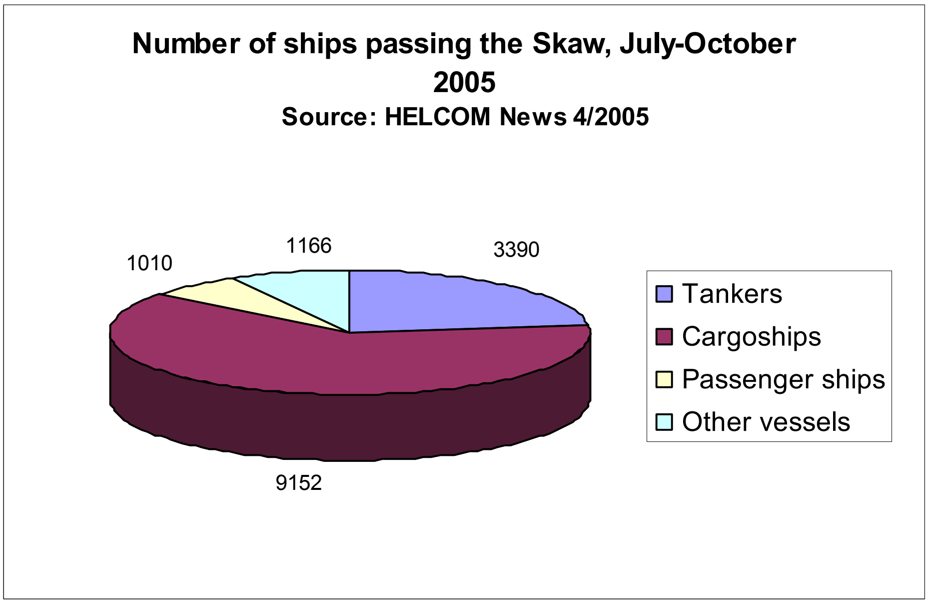


Fig. 4.5. Number of ships passing the Skaw (Skagen) in July-October 2005 (based on HELCOM AIS*; from HELCOM News 4/2005).

Fortunately NIS are well studied in almost all Baltic Sea countries. As a result hot spots, i.e. Baltic regions with a high number of NIS, can be identified. The number of NIS found in the riparian countries is regionally very different (Fig. 4.7). The highest number of NIS was found in western and southern Sweden, Germany and Poland. The lowest number of NIS is known from Russian waters and Latvia. It should however be noted that not all the Baltic coastline is regularly monitored for the occurrence of NIS, consequently the figures may deliver a biased impression, but are based on all known datasets.

4.4 Identification of shipping traffic which poses high risk for the introduction of invasive alien species into the Baltic Sea (high risk donor ports)

The goals of this chapter are to discuss and facilitate identification of high-risk shipping routes, and propose special measures, which could be applied for the management of ballast water:

- **exchange of ballast water in designated areas outside the Baltic,**
- **exchange of ballast water in designated areas in the Baltic, and**
- **treatment on board, or at land-based ballast water and sediment reception facilities.**

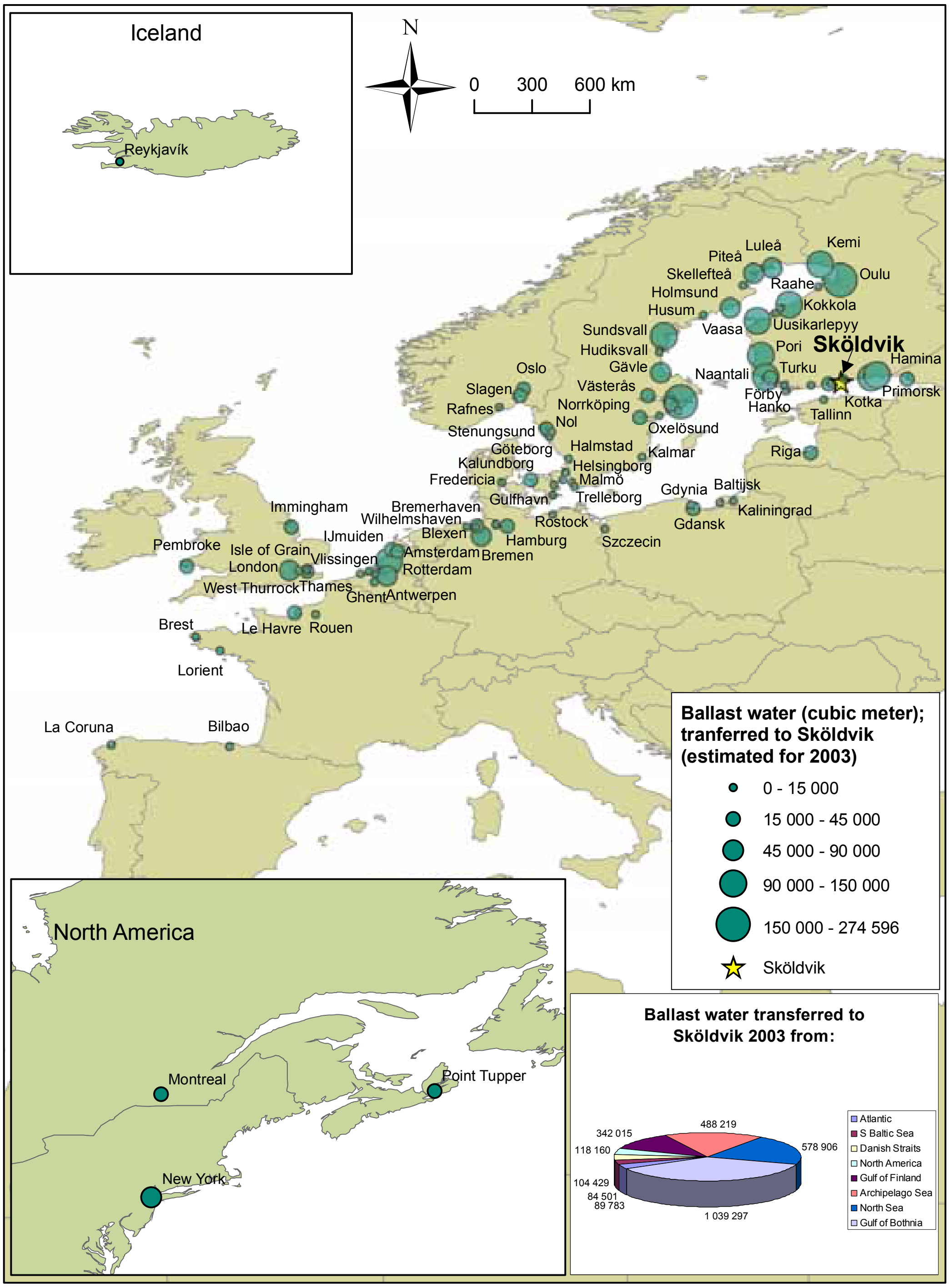


Fig. 4.6. Source ports of ballast water discharged in the Port of Sköldvik (Kilpilahti), estimated for 2003. Data based on questionnaires to ships (n=544). Courtesy: Marjo Paavola (neé Pienimäki), Åbo Akademi University.

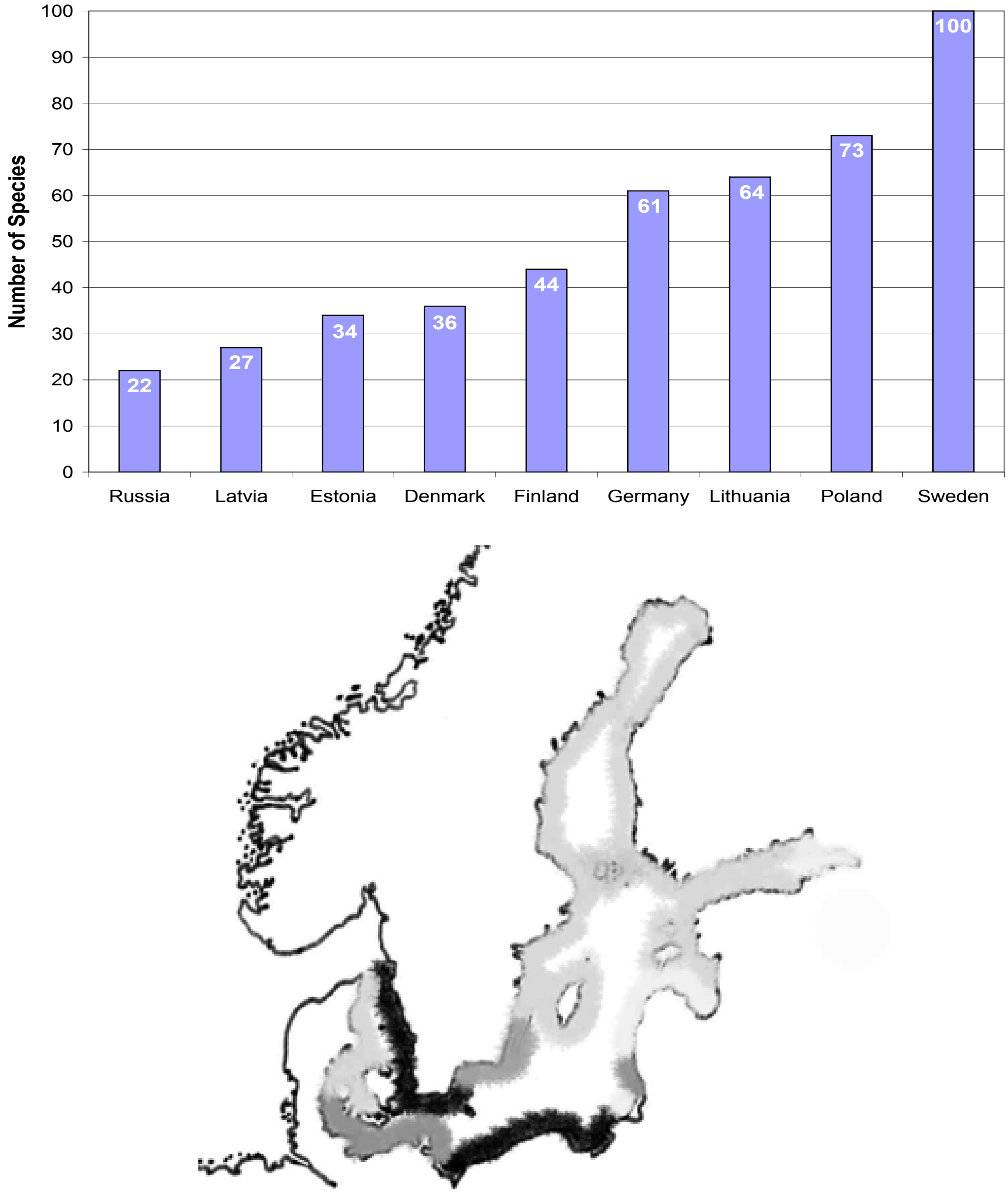


Fig. 4.7. Number of all nonindigenous species (including species found occasionally only, i.e. un-established) reported from coastal regions and adjacent freshwater habitats of Baltic countries (after Gollasch unpubl.). The darker the coastline is the higher is the number of NIS found.

When assessing the risks of species invasions it is not only the volume of ballast water being released in a certain port/port region what 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 greater the number of ship visits in a port is, the greater is the number of potential donor ports/port regions the port is connected to. A large number of potential donor areas (i.e. environmental match) is a higher risk scenario rather than ports with only a few shipping connections.

Further, frequent ship arrivals result in a higher risk as ship arrivals are likely more evenly distributed over the year/seasons. 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 waters year-round (propagules, e.g. larvae availability in the water column). Also, species survival after discharge is more likely in the receiving area as the species arrive in all seasons and it is therefore obvious that favourable conditions for survival will be met.

Table 4.1 Total voyage duration from selected overseas and Baltic Sea source ports.

Departure from	Arrival to	Distance [nautical miles]	Duration [days at vessel speed of 16 knots]	Duration [hours at vessel speed of 16 knots]	Time needed to exchange ballast water assuming a pump capacity of 500 t/h		Sufficient time to exchange ballast water during voyage		Treatment capacity required to treat water en-route [t per hour]	
					Volume of ballast water carried [t]		Volume of ballast water carried [t]		Volume of ballast water carried [t]	
					10,000	50,000	10,000	50,000	10,000	50,000
Odessa	Gothen-burg	3,947	10.8	259.2	20	100	yes	yes	39	193
Rotterdam	Gothen-burg	501	1.4	33.6	20	100	yes	no	298	1,488
San Francisco	Gothen-burg	8,268	22.6	542.4	20	100	yes	yes	18	92
Boston	Klaipeda	3,824	10.5	252.0	20	100	yes	yes	39	198
Rio de Janeiro	Klaipeda	6,111	16.7	400.8	20	100	yes	yes	25	125
Yokohama	Klaipeda	11,989	32.8	787.2	20	100	yes	yes	13	64
Antwerp	St. Peters-burg	1,395	3.8	91.2	20	100	yes	no	110	550
Gdynia	St. Peters-burg	561	1.5	36.0	20	100	yes	no	277	1,388
Nynäs-hamn	St. Peters-burg	402	1.1	26.4	20	100	yes	no	385	1,923
Felixstowe	Copen-hagen	630	1.7	40.8	20	100	yes	no	244	1,220
Antwerp	Copen-hagen	704	1.9	45.6	20	100	yes	no	219	1,096
Haifa	Copen-hagen	3,912	10.7	256.8	20	100	yes	yes	38	195
Helsinki	Kiel	631	1.7	40.8	20	100	yes	no	245	1,225
Barcelona	Kiel	2,147	5.9	141.6	20	100	yes	yes	71	353

This analysis was carried out by taking the most important risk factors into consideration (area of origin in relation to the environmental conditions of the receiving port, duration of the voyage, results obtained under tasks above).

Tab. 4.1 provides examples of typical shipping routes inside and from outside the Baltic. As an example the voyage from Odessa to Gothenburg takes approx. 260 hours. Assuming that the time for a ballast water exchange when carrying 10,000 tonnes of ballast water takes 20 hours (and 100 hours when carrying 50,000 tonnes of water) there is sufficient time during the voyage to exchange the water (ignoring the water depth and distance to nearest land requirements of IMO). Also, the voyage duration is long enough to treat the water at reasonable treatment rates (a treatment capacity of approx. 40 tonnes/h is needed for 10,000 tonnes of ballast water when the treatment is undertaken during the entire voyage). However, it can be questioned whether any treatment systems and technologies developed now and in the future will be effective enough to process > 1,000 tonnes per hour of ballast water on shorter (< 2 days) voyages, as e.g. from Rotterdam to Gothenburg when 50,000 tonnes of water need to be treated (Tab. 4.1). It should however be noted that not necessarily all ballast water carried onboard needs to be treated as possibly not all ballast water is intended to be discharged.

Species are more likely to become established in environments, which are similar to those of their origin. Therefore, if the port of loading and port of discharge are ecologically comparable the risk of a species introduction is relatively high (Tab. 4.3 and 4.4).

Table 4.3. Probability of colonisation of NIS, according to matching salinity in donor and recipient region (after Carlton 1985).

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

Table 4.4. Probability of colonisation of NIS, according to matching climate in donor and recipient area (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

It has to be taken into account that all general rules or models have their exceptions and cannot be applied for all habitats. Matching temperatures in the area of origin and the new habitat do not explain the potential of species to tolerate or adapt to temperatures uncommon to its native range. A well-known example is the ship-boring mussel *Teredo navalis* (shipworm). It is believed to be of tropical origin and introduced with wooden sailing vessels. Nowadays the species occurs and causes damages to wooden man-made 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 from 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 plant in Lovisa, eastern Gulf of Finland, was shown to be due to the recently invaded dark false mussels *(Mytilopsis leucophaeata),* a species previously not reported from the brackish Baltic Sea (Laine et al. 2006). This mussel species is native to the Gulf of Mexico area; being a warm water species it obviously benefits from the elevated 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, hot spot species for the introduction into cold-temperate and brackish waters due to non-matching climate and salinity regimes of donor and recipeint region.

5 Risk assessment results

This chapter documents the chosen risk assessment approach (see also Annex 1) and also provides results from the risk assessment for the ports selected.

5.1 Ballast water management and risk assessment

Several ballast water management options have been discussed and evaluated (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:

- land-based port reception facilities for untreated ballast water. 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). 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). Ballast water exchange in designated areas may reduce but not eliminate the risk of species introductions, but is a better approach rather than to discharge untreated ballast water in a port. The invasion risk may be reduced when e.g. offshore-directed currents dominate. However, it is supposed that no ballast water exchange zone of sufficient dimension to allow for complete ballast water exchange 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 difficult to be carried out, and BWE zones maybe even impossible to be identified noting the following requirements:
    - to avoid voyage deviation,
    - to ensure efficient "dilution", and
    - to avoid the risk for secondary species introductions.

Consequently, WGBOSV (2005) highlighted the need for efficient:

- ballast water treatment systems, and
- risk assessment approaches to apply relevant requirements for high-risk vessels only.

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, i.e., within-the-Baltic) spread of organisms. The difficulty with risk assessment is that this approach is in its infancy in Europe. Key information, such as characteristics of NIS is only available for selected Baltic ports hindering an effective application of risk assessment. However, this option is the most promising approach, especially as efficient ballast water treatment systems are not currently available.

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 in ballast water which originates from outside the North or Baltic Seas. These vessels have to exchange their ballast water prior they reach the North Sea before arrival to the Butinge oil terminal (Olenin pers. comm.).

5.2 Proposals for risk assessment methodologies to be used in the Baltic Sea region

This and the following chapters aim at contributing to the development of a basin-wide system for assessing the probability of transfers of new NIS into the Baltic, and secondary spread of established NIS within the sea.

Being one of the main outputs from the project the work was based on summarized data on recent shipping statistics including cargo flows, knowledge of existing and expected NIS, and data on matching salinity/temperature conditions of donor and recipient and the ballast water origin. Concerns were expressed at the early stage of the project as it was unknown whether or not the data required to carry out the assessment are available.

Due to the lack of data, a detailed risk assessment could not be carried out for all Baltic ports, especially noting that more than 500 ports are in operation in the Baltic Sea region. The six ports/port regions selected for closer consideration (see selection criteria above) were Copenhagen (Denmark), Gothenburg (Sweden), Kiel (Germany), Klaipeda (Lithuania), Kemi, Tornio and Raahe as one port region (Finland), and Sköldvik (in Finnish Kilpilahti; Finland) (Fig. 5.1) and represent:

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

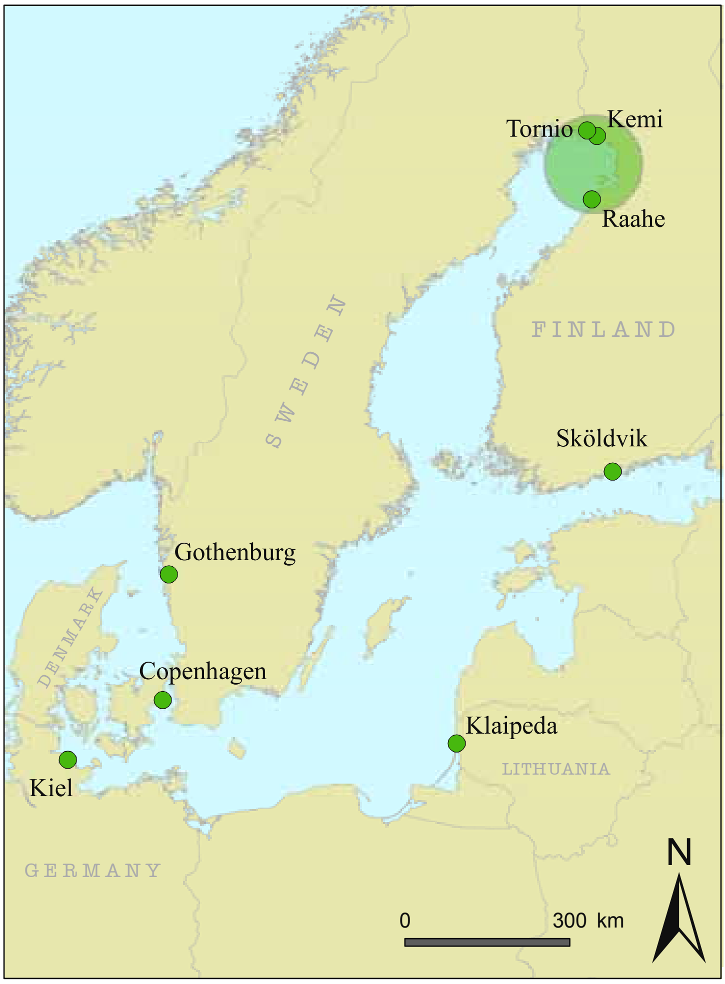


Fig. 5.1. Location of the six ports/port regions selected (from west to east): Kiel (Germany), Gothenburg (Sweden), Copenhagen (Denmark), Klaipeda (Lithuania), Kemi, Tornio and Raahe as one port region (Finland), and Sköldvik (in Finnish Kilpilahti, Finland).

It was planned to gather information on the ballast water quantities discharged and the source regions of the water for all selected ports. However, and as outlined in Chapter 4, this objective could not be met for all six ports due to the lack of relevant data. Detailed ballast water information is available for Sköldvik Port only (for 2003) and some basic information was gathered for Swedish ports. Not to base the risk assessment on the Finnish and Swedish ports alone, an alternative approach was developed.

For some of the ports selected ballast water discharge data are available - for others those data are lacking. However, in this study and in invasion biology in general, quantity does not matter much. The quality is more important, 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 took the shipping routes as risk assessment basis - 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.

It should be noted that quantities of released ballast water are also of interest when planning to install land-based ballast water reception facilities to allow for appropriate capacities of such facilities. However, there is currently no interest to make such facilities available in Baltic ports.

5.3 Risk assessment approach for the ports selected

Despite the best efforts, such as Internet search, contacting various national and international authorities and sending out a questionnaire to country focal points, ballast water discharge quantities could not be revealed in detail for all ports selected. As a result a quantitative risk assessment of ballast water mediated species introductions could not be carried out. As mentioned above, the authors feel that the volumes of ballast water discharged or taken on board in general are of minor importance in risk assessment as it is not the quantity indicating the risk, but rather the quality, i.e. the environmental match of donor and recipient region of the ballast water. To clarify this statement we give an example. We compare the following scenarios:

(a) 10 mio tonnes of ballast water originating from a tropical seawater port are discharged in one Baltic port annually,

(b) 0.5 mio tonnes of ballast water which originates from a cold-temperate brackish area along the east coast of North America are discharged in one Baltic port annually, and

(c) 0.5 mio tonnes of ballast water which originates from a cold-temperate brackish area along the European Atlantic seabord are discharged in one Baltic port annually.

In this scenario, options (b) and (c) pose a higher risk for a species introduction due to environmental match of donor and recipient compared to option (a) where, although the amount of ballast water is much higher, the source and recipient regions of the ballast water are substantially different in their abiotic water conditions. A ranking of options (b) and (c) reveals that option (c) poses a higher risk as the voyage duration from the EU-Atlantic coast to a Baltic port is much shorter than from North America resulting in an increased survival of species in the ballast tank. En-route scientific studies have shown that organisms die in ballast tanks over time, i.e. the longer a voyage duration lasts the less likely is organism survival (e.g. Gollasch et al. 2000, Olenin et al. 2000).

As a consequence the risk assessment for the ports selected was based upon the comparison of donor and recipient port's environmental match (salinity and 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 inner-Baltic shipping routes. In inner Baltic trade species may also be transferred in ballast tanks. However, it is likely that organisms once introduced into one Baltic port may spread and reach other

Baltic regions (secondary introductions) by their natural means of 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 salinity compared to truly marine and freshwater species. Marine conditions do not exist in the Baltic, but freshwater habitats need special attention here. In case a freshwater species becomes introduced in e.g. 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. Even brackish water conditions may pose a migration barrier for freshwater species. As a result inner-Baltic shipping routes which connect freshwater habitats being separated by higher saline brackish waters pose a risk to introduce a species which would be unable to reach other freshwater regions by its own means.

5.3.1 Environmental characteristics of the ports/port regions selected

Table 5.1 shows the salinity and temperature characteristics of the ports/port regions selected. The temperature regime was evaluated based upon bioregion mapping (Ekman 1953, Briggs 1974; see Fig. 5.2). The port salinities were extracted from Lloyds Register - Fairplay (2003).

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

Table 5.1. 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 (www.aquatext.com) at the water temperature of 8°C.

Port /port region	Temperature zone	Salinity regime [ppt]
Kiel	Eastern Atlantic Boreal Region	19.5
Gothenburg	Eastern Atlantic Boreal Region	13.1 - 18.2
Copenhagen	Eastern Atlantic Boreal Region	10
Klaipeda	Eastern Atlantic Boreal Region	0.5 - < 7
Kemi, Tornio, Raahe	Eastern Atlantic Boreal Region	0 - 4.2
Sköldvik	Eastern Atlantic Boreal Region	0 - 6.7

5.3.2 Risk evaluation parameters

As outlined above, the key risk evaluation parameters are temperature, salinity, voyage duration and shipping pattern, both inside and outside the Baltic. All parameters were calculated based on the identical sources as used to describe the ports selected (see above).

The risk of ballast water mediated species invasions was assessed in three categories: low, medium and high. The following section describes how the risk was assessed and quantified.

5.3.2.1 Temperature

The donor port temperature zone was assessed following the bioregion mapping according to Ekman (1953) and Briggs (1974). Here the world is divided in four major temperature regions: tropical, warm-temperate, cold-temperate, and Arctic/Antarctic according to the world's oceans (Fig. 5.2).

The risk was quoted highest when source and recipient port were located in the identical bioregion. When donor and source ports were located in different regions the risk was assumed as low – and lowest when these regions were not adjacent to each other. In summary, the greater the distance between the regions the lower is the risk.

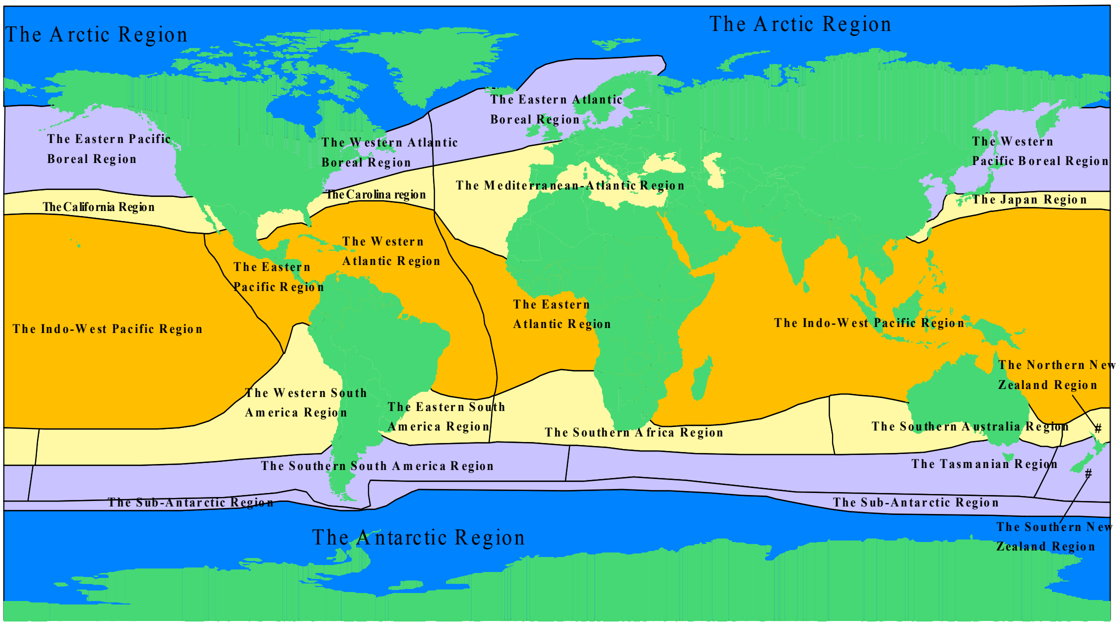


Fig. 5.2. Bioregions according to Ekman (1953) and Briggs (1974).

5.3.2.2 Salinity

The port/port region salinity for all potential ballast water source ports from where shipping routes are connected to the Baltic ports selected was extracted from Lloyds Register - Fairplay (2003). Here the salinity was given in density which was calculated to parts per thousand following the Aquatext conversion (www.aquatext.com) at a water temperature of 8 °C.

Figs 5.3 and 5.4 show results from the matching salinity approach adopted in this study. We classified the ballast water donor harbours into different salinity categories. Self-evidently all Baltic Sea ports were identified as high-risk donor sites, as were several brackish North Sea ports situated along rivers or at river mouths.

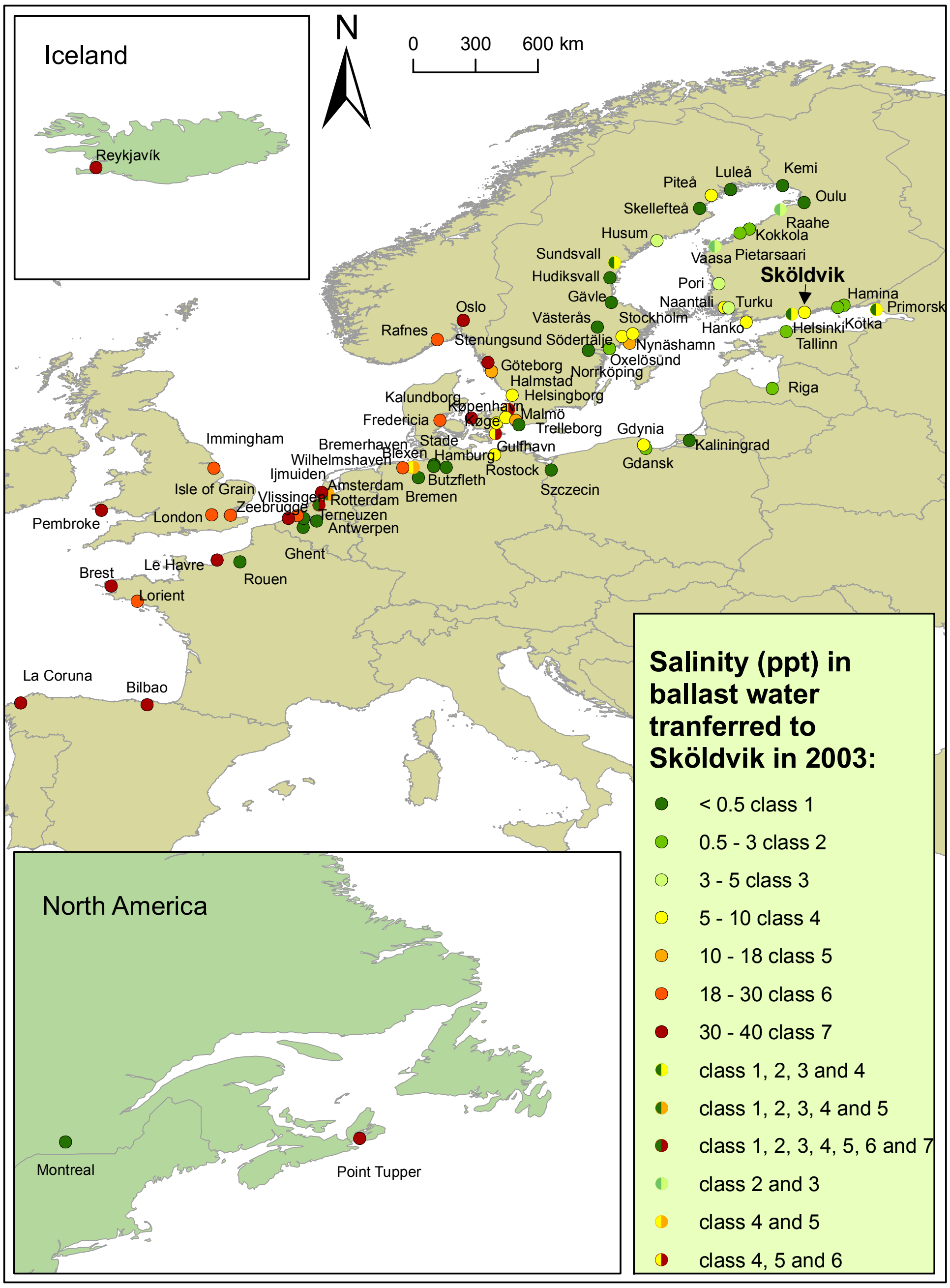


Fig. 5.3. Origin of ballast water unloaded in Sköldvik, E Gulf of Finland, in 2003. Based on PortNet data for ships loading oil products in this port. Salinity in Sköldvik is ca. 4 psu, therefore donor ports marked in green and yellow (< 0.5 to 10 psu) can be regarded as high-risk sites due to their matching salinity.

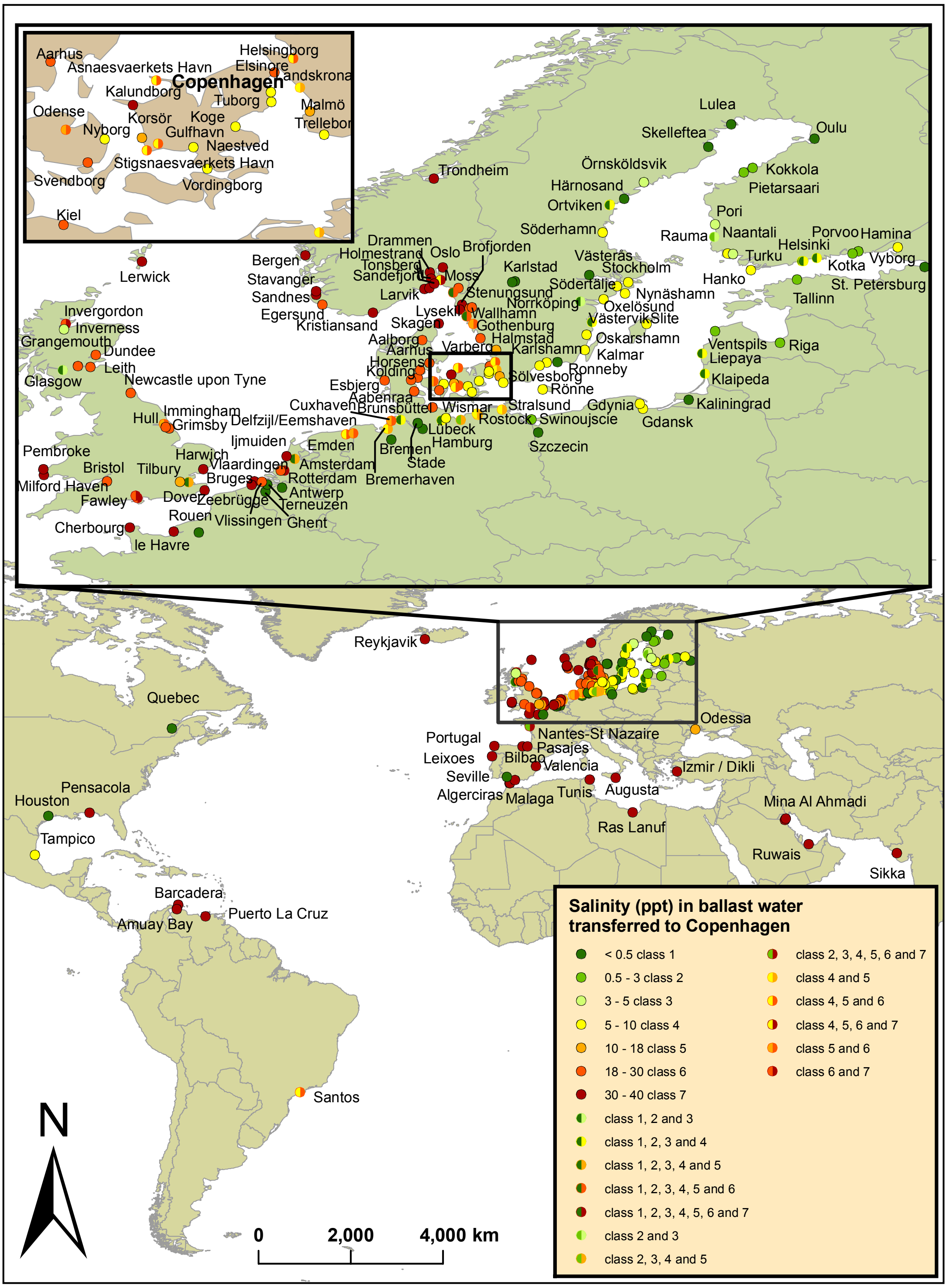


Fig. 5.4. Origin of ballast water unloaded in Copenhagen in 2003. Based on PortNet data for ships loading oil products in this port. Salinity in Copenhagen is ca. 10 psu, therefore donor ports marked in light green, yellow and orange (7 to 13 psu) can be regarded as high-risk sites due to their matching salinity.

Due to the different salinities of the selected ports the following risk quantification applied (Tab. 5.2). The philosophy behind the risk quantification is that, in general, the more different the salinities of donor and recipient region are, the less likely is a successful species introduction. In addition a salinity tolerance margin of 1-2 ppt was used to address fluctuating salinities in relevant ports.

Table 5.2. Salinity characteristics of the ports/port regions selected and the risk quantification scheme used.

Port/port region	Salinity regime of port/port region [ppt]	Low risk salinity [ppt]	Medium risk salinity [ppt]	High risk salinity [ppt]
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 ppt occur 70 days per year, < 0.5 ppt 130 days per year; Olenin et al. 1999).

5.3.2.3 Voyage duration

Scientific studies of ballast water en-route, with daily sampling frequencies, showed that organisms in ballast water die out over time. The most significant decrease in organism densities occurs during the first 3 days of the voyage and after 10 days most individuals were found dead (Gollasch et al. 2000, Olenin et al. 2000). Consequently, the following risk quantification was used (Tab. 5.3).

The voyage duration from all 278 source ports was measured according to the Lloyds Register/Fairplay (2003) distance tables assuming a ships speed of 16 knots.

Table 5.3. Risk quantification for the 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

5.3.2.4 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 risk quantifier. Over the years 2004 to 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 the bioregions used above (Tab. 5.4).

Table 5.4. Source bioregions (see also Fig. 5.2) of all 278 ports being involved in shipping lines connected to the selected Baltic ports in 2004 and 2005.

Donor port bioregions	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**

5.4 Results of the 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 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 below 8 as low risk.

Results from the risk assessment approach as outlined above are given in this chapter according to the ports/port regions selected. As expected the risk of species introductions varies between the selected Baltic ports (Fig. 5.5).

Table 5.5 documents the risk assessment results of all selected ports according to the risk level based on the data assessment as provided in the Annexes 2-7. 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, i.e. 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.

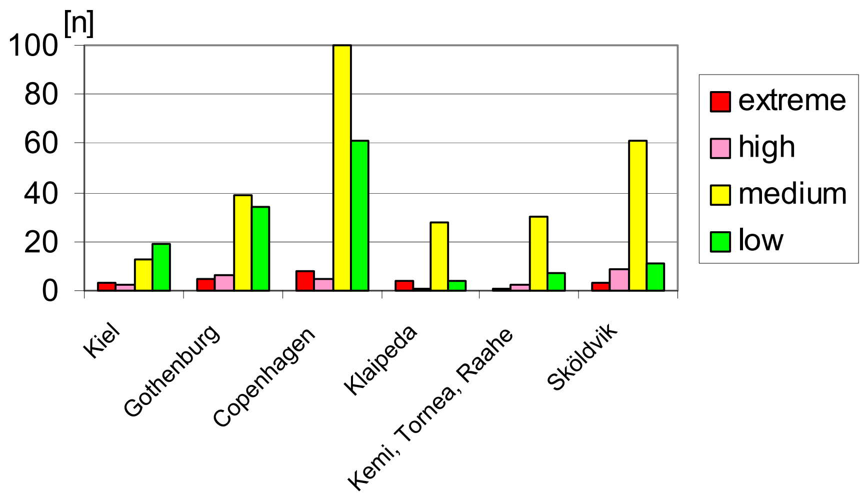


Fig. 5.5. Number of source ports for the selected Baltic ports according to risk level.

It is interesting to note that in all selected ports the number of medium and low risk donor ports is highest. As in ballast water mediated species introductions it is not the quantity which matters, but the quality – and 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 to be followed by Kiel (8.1%) (Tab. 5.6).

5.5 Needs and proposals for monitoring of invasive species and port baseline surveys

In this chapter the authors underline the need of detailed knowledge on native and non-indigenous biota in ports or port regions, which is essential when conducting species-specific risk assessment.

According to the risk assessment guideline currently in preparation by IMO (see Annex 1) specific port sampling programmes targeting NIS may need to be implemented. Further, data from existing monitoring programmes may also be used to prepare a risk assessment evaluation in the Baltic taking into account current monitoring programs within HELCOM and the EU and the development of relevant Guidelines at the IMO.

Table 5.5. 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 2-7.

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	**3** Cuxhaven (DE) Mo I Rana (NO) Rotterdam (NL)	**2** Bremerhaven (DE) Wilhelmshaven (DE)	**13**	**19**
Gothenburg	**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	**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	**4** Bremerhaven (DE) Hamburg (DE) Oostend (BE) Rotterdam (NL)	**1** Antwerp (BE)	**28**	**4**
Kemi, Tornio, Raahe	**1** Antwerp (BE)	**2** Amsterdam (NL) Rotterdam (NL)	**30**	**7**
Sköldvik	**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**

Many routine monitoring programmes lack sampling stations in ports. However, for some ports information on non-native taxa is available and this information can be used when preparing the species-specific risk assessment approach. However, several countries worldwide have already developed port sampling protocols. This refers in particular to Australia, New Zealand, USA, the demonstration sites of the GloBallast Programme, and the Mediterranean Sea. With the PORTAL project, CIESM[23] has launched the first Mediterranean-wide port survey programme aiming at the collection of baseline data on alien species of targeted phyla (macrophytes, bryozoans, serpulids, hydroids, ascidians, molluscs and barnacles) inhabiting port and port-proximate manmade hard substrates. Other organisms that might be disseminated by shipping from Mediterranean ports that pose a significant risk to human health (*Vibrio cholerae*, dinoflagellate cysts) are also included. Scientists have been enlisted to sample 9 shipping ports, from Barcelona to Izmir, and two recreational marinas. The data obtained from these surveys could also be part of an early warning system on the occurrence of harmful aquatic species.

Table 5.6. Absolute and relative risk level of the selected Baltic ports/port regions according to number of source ports.

	Port/port region											
	Kiel		Gothenburg		Copenhagen		Klaipeda		Kemi, Tornio, Raahe		Sköldvik	
Risk level	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	28	75,7	30	75	61	72,6
Low	19	51,4	34	40,5	61	35	4	10,8	7	17,5	11	13,1
Total	**37**	**100**	**84**	**100**	**174**	**100**	**37**	**100**	**40**	**100**	**84**	**100**

Port sampling data in the Baltic are only available in scattered coverage and previously undertaken studies did neither standardise the sampling technique nor the habitats to be sampled. For these reasons a species-specific risk assessment could not be carried out for the Baltic ports selected. However, to better explain the benefits from a species-specific risk assessment – also indicating the need to gather such data, the following chapters describe how target species may be selected and how the occurrence of target species in donor ports/port regions may influence the risk assessment.

5.6 Development of proposals for a common structured procedure for species-specific risk assessments

The aims of this chapter are to (i) clarify the background data needed for a proper species-specific risk assessment of potential new NIS to enter the Baltic, and (ii) give examples of species, which may (if introduced with shipping) cause harm to nature or interfere with human interests.

Screening criteria for defining harmfulness of NIS encompass issues such as ecological impact, impact on human health and socio-economical values (e.g. Leppäkoski 2002); Pienimäki & Leppäkoski 2004). These data may be used to develop a "black list" of

[23] CIESM = The Mediterranean Science Commission

harmful or potentially harmful alien species, which are especially undesirable to be introduced to the Baltic Sea.

Consequently, questions to be answered in assessing the risks posed by potential NIS are:

- Vector and pathway analysis: Can the species enter the Baltic Sea as a ballast water-mediated NIS?
- Ecological and ecophysiological assessment: Can the species establish self-reproducing populations?
- Ecological and invasion capacity assessment: Can the species spread further from its first bridge head(s)?
- Hazard analysis: Can the species cause negative economic or ecological impacts?
- Benefit assessment: Can the species add new beneficial functions to the ecosystem, or serve as a new exploitable resource (e.g., food item for commercial fish, selective fishing of the introduced species)?

Species-specific risk assessment of NIS is under development in different regions of the world (reviewed by e.g. Hayes 1997, Gollasch 2002, Paavola et al. 2005, and developed further by Claudi & Ravishankar 2006, among others). In the Baltic area, the key newcomers which likely become established are those that tolerate low salinities, low temperatures, eutrophic conditions and periodically low oxygen conditions in soft bottom habitats.

As in the North Sea region, where many of the busiest ports are located in estuaries with low salinities or freshwater conditions, the Baltic shows a large range of salinity conditions (from > 0 to > 20 psu) and is therefore a suitable habitat for many NIS of different biogeographical and ecological origin. Usually organisms show a limited tolerance to varying salinities, i.e. freshwater NIS will not likely be spread by natural means from the easternmost Baltic towards other freshwater regions in the western Baltic as higher saline waters in the central Baltic pose a migration barrier. These organisms may, however, be transported from one location to another in the ballast water of ships, thereby highlighting the need not to exclude all within-Baltic shipping from ballast water management requirements.

It is assumed that on a voyage from e.g. St. Petersburg to Hamburg time would permit a water exchange in the Baltic proper – reducing the risk of species transfer as the freshwater organisms originating from St. Petersburg will not likely survive in the brackish waters of the Baltic proper and species contained in the brackish water taken onboard here during exchange will not likely survive in the freshwater port of Hamburg after discharge. However, this general rule has its limitations (see Chapter 4.4) and therefore a species based risk assessment is recommended, possibly in combination with a route-based approach.

5.7 Target species list (the "Black List" approach)

A target species is an organism that is potentially able to become introduced and is known to cause large-scale environmental problems due to impacts to native biodiversity and/or economic effects. A list of target species may be used as a first step to evaluate the potential "danger" of NIS introductions into the Baltic Sea.

The prediction of further NIS invasions is rather difficult. However, the introduction of certain species in other regions may indicate the likeliness to become also introduced in the Baltic Sea. As a first attempt during the 1997-1999 risk assessment study in Nordic countries a black list of species was compiled (Gollasch & Leppäkoski 1999).

5.7.1 Which species will become a successful invader?

As discussed elsewhere in this report, several recent developments have greatly influenced the transfer of ballast-mediated organisms:

- shorter port residency time (less opportunity for organisms to settle on a ship; as a result the proportion of ballast-mediated NIS suppressed that of plants and animals attached to ship hulls),
- faster ships (a shorter voyage duration implies better survival of organisms in ballast tanks and better post-release condition. Further, faster ships result in more frequent ship arrivals),
- use of separate tanks instead of cargo tanks for ballast water,
- improved water quality in donor areas (more species to be taken onboard and less polluted ballast water) and recipient areas (improved survival of specimens when released with ballast water),
- bigger vessels (discharging an increasing amount of ballast water).

Various factors make a successful invader. The main characteristics of most aquatic high-risk invasive organisms are listed as follows (compiled from Gollasch & Leppäkoski (1999) and references therein):

- high abundance in native habitat,
- ability to survive the introducing process (e.g., resistant resting stages),
- high tolerance to abiotic factors, especially temperature and salinity, during the voyage as well as in the receiving area,
- high mobility (e.g. planktonic larva),
- wide range of habitat selection,
- ecological niche (microhabitat and/or functional role) available in receiving environment,
- capacity to adapt to a new trophic niche,
- absence of competitors, predators, parasites and diseases in the recipient region,
- high potential to replace/compete with native species,
- vegetative or hermaphroditic reproduction,
- non-specificity in food preferences,

- high rate of reproduction,
- fast vegetative growth rate,
- growth earlier in season than native species,
- short and simple life-cycle,
- high genetic variation, and
- known as invader in other areas.

In Table 5.7 some examples of target species are given which may become new NIS in the Baltic Sea. Several of them are of marine origin and can thus be expected to establish in the Kattegat but not inside the Danish Straits or further east in the Baltic region. The actual world-wide number of potential NIS to enter the Baltic in the future is much higher. For instance, Grigorovich et al. (2003) adopted a qualitative risk-screening framework for predictive risk assessment of ballast-mediated introduction of NIS into the North American Great Lakes. Their list of species predicted to invade the Lakes consists of 56 species of which 20 are potential ship-mediated invaders which also occur in the Baltic Sea.

All listed species below are known to have been introduced to and become established in waters outside of their native range in temperate climates. Therefore, these species may also become introduced into the Baltic Sea with shipping.

In a recent study (Paavola et al. 2005) the role of salinity was studied more closely for the brackish Baltic, Black and Caspian Seas. In these seas, already established NIS are well adapted to salinity zones of lowest native species richness, not only in these recipient seas but already in their native areas. The salinity tolerance of NIS is an adequate tool for assessing the potential spread of a species in a brackish water sea (Paavola et al. 2005). Species-specific data are scarce, and thus risk assessments at species level, including environmental matching (in the Baltic especially in regard to salinity and temperature), are possible but laborious to conduct.

5.7.2 Target species – two case studies

Risk assessment, specific of target species, considers information about relevant individual species and the environmental conditions in the receiving port. As stated in WGBOSV 2005, species-specific risk assessments are most useful for a small suite of species and rapidly lose their effectiveness in identifying risk scenarios with increasing numbers of target species.

Here we provide two examples of how the occurrence of a target species in a donor port/port region may influence a route-specific risk assessment. The species selected for closer consideration are the comb jelly *Mnemiopsis leidyi* and the predatory snail *Rapana venosa*.

Table 5.7. Selected target species which may potentially survive in parts of the Baltic Sea (Gollasch & Leppäkoski 1999; modified and updated). This list compiles aquatic species (most of them unwanted) introduced to areas outside their native range but with no or occasional findings in Baltic Sea. L = limnetic (freshwater) species, B = brackish water species; M = marine species.

Group/species	Habitat	Current area of distribution world-wide	No findings in NW Europe
Algae			
Toxic dinoflagellates or other groups causing harmful algal blooms, e.g. fish killing *Pfiesteria piscicida*	B	World-wide NE America	 x
Seed plants			
Zostera japonica (dwarf eelgrass)	M	E Asia, Pacific N America	X
Animals			
Mnemiopsis leidyi (comb jelly, ctenophore)	B-M	NE America, Black, Caspian & Mediterranean Seas	X
Maeotias marginata (jellyfish)	B	NW France, Black Sea, San Francisco Bay, recently found in NW Estonian and Lithuanian waters	
Blackfordia virginica (hydrozoan)	B	NE America, Black Sea, NW France	
Bougainvillia megas (hydrozoan)	B-M	N Atlantic	
Asterias amurensis (sea star)	M	Asia, Australia	X
Ficopomatus enigmaticus (polychaete)	B-M	Indo-Pacific, Black Sea, along the North Sea coasts of Belgium, the Netherlands, UK, Germany, established in Copenhagen harbour	
Callinectes sapidus (blue crab)	B-M	NE America, Mediterranean Sea, North Sea, Bay of Biscay, Black Sea	
Hemigrapsus penicillatus (Asian crab)	B	Asia, France, Spain (Atlantic coast), Belgium, the Netherlands	
Hemigrapsus sanguineus (Asian crab)	B	Japan, NE America, NW France, the Netherlands	
Balanus eburneus (barnacle)	M	NE America, North Sea, Black Sea, Caspian Sea, India, West Africa, NW France	
Rapana venosa (gastropod)	M	Japan, Black Sea, NW France	
Anadara inaequivalvis (bivalve)	B-M	Indo-Pacific, Black Sea, Adriatic Sea	x
Dreissena bugensis (bivalve)	L-B	Ponto-Caspian, Great Lakes, recently reported from the eastern Gulf of Finland (Russia)	

5.7.2.1 The North-American comb jelly *Mnemiopsis leidyi*

The ctenophore *Mnemiopsis leidyi*, native to the American east coast, was first recorded in the Black Sea in 1982 and was probably imported with ballast water (GESAMP 1997).

Thereafter the species was also found in the Sea of Marmara, the northeastern Mediterranean and the Caspian Sea (Fig. 5.6). Today the comb jelly is well established and influences the whole pelagic food web in the Black and Caspian Seas.

The diet of *M. leidyi* consists mainly of mesozooplankton[24], in particular copepods, the staple food of small pelagic fishes such as anchovy (Black Sea) and kilka (Caspian Sea, 3 species), and includes fish eggs and larvae. Recent mass occurrences of the comb jelly followed the weakening of the populations of small pelagic fish through overexploitation, thus indicating that overfishing was the primary reason for the decline of these fish stocks allowing *M. leidyi* to compete successfully with the reduced fish populations and explode into blooms of unprecedented intensity (Bilio & Niermann, 2004).

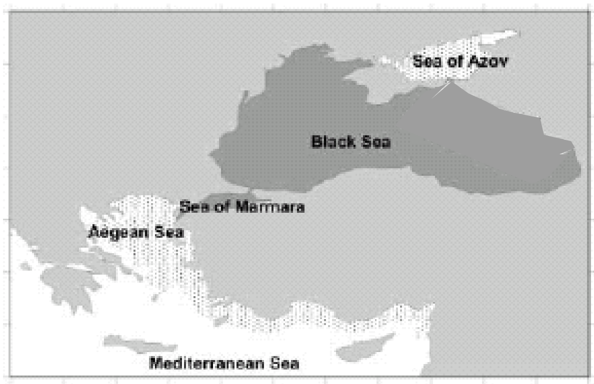


Fig. 5.6. Occurrence of *Mnemiopsis leidyi* in the northeastern Mediterranean and the Black Sea in 1999 (dark shading: all-year presence, light shading: summer occurrence). Source: Shiganova et al. 2001.

The high temperature and salinity tolerance of *Mnemiopsis* in the Caspian Sea (Tab. 5.8) suggests the possibility of its survival in the western and central Baltic Sea. According to Aladin (pers. comm.), the Caspian Sea population of *Mnemiopsis* may even be tolerant of a wider range of abiotic factors than the population of the Black Sea.

As already stated by Gollasch & Leppäkoski (1999), *Mnemiopsis* may become introduced into the Baltic Sea either by ballast-water transport from its native East American region or the Ponto-Caspian area. The salinity and temperature tolerance of this species would permit colonization of the western and central Baltic Sea. As a result, ports in the Baltic Sea which receive ships and ballast water from areas where *Mnemiopsis* occurs, are exposed to a higher risk than ballast water receiving ports which lack such shipping connections. Among the ports considered in this report in greater detail, Copenhagen, Gothenburg and Sköldvik receive ships from the American east coast, the origin of *Mnemiopsis*. In addition, ships calling at the port of Copenhagen are also operated on shipping lines into the Black Sea where the comb jelly has already been introduced. Consequently, these three ports have a high risk of receiving *Mnemiopsis* and according

[24] Planktonic animals in the size range 0.2-20 mm.

to the salinity and temperature tolerance the species may become established here. A risk-reducing measure may be to exchange the ballast water in sea areas where *Mnemiopsis* is absent and cannot establish itself. It should be noted that the ship-traffic pattern may change in the future. In case additional shipping routes are established which connect other Baltic ports with source regions of *Mnemiopsis*, the risk of its introduction may increase. This also indicates that species-specific risk assessments need to be revised regularly to address modifications in shipping connections and also to check the possible presence of target species in donor ports/port regions.

Table 5.8. Salinity and temperature ranges of *Mnemiopsis* in the Caspian Sea according to Aladin, Volovik, Kamakin, Ushivtsev & Shiganova (pers. comm.).

Factor range	**Salinity [ppt]**	**Temperature [°C]**
Tolerance	4-26	4-29
Optimum range	6-18	7-26
Lower/upper limit	3-4 / 26-36	2-4 / 29-34

In order to obviate a threat to Baltic populations of pelagic fish feeding on zooplankton (sprat, Baltic herring) through heavy competition with *Mnemiopsis*, overfishing should be avoided at any cost thus maintaining the competitive strength of the fish against the invader (see Bilio 2004).

5.7.2.2 *Rapana venosa* – a large-sized Japanese snail

The Asian gastropod *Rapana venosa*, native to the Sea of Japan, Yellow Sea, Bohai Sea, and the East China Sea to Taiwan, was introduced to the Black Sea with subsequent range expansion to the Adriatic and Aegean Seas, the Chesapeake Bay (east coast of the USA), and the Rio de la Plata between Uruguay and Argentina. Reproductive populations are or seem to be present in all these regions. In addition, there are a limited number of reports of the species from the Brittany coastline of France, Washington State (USA), and the North Sea (one empty shell only) and New Zealand (Mann et al. 2004 and references therein). More recently, in summer 2005, the species was also found in the Dutch part of the North Sea (near Scheveningen) and in one location between Oostende, Belgium and Harwich, United Kingdom (Vink & Post 2005, Kerckhof et al. 2006). Introduction vectors may be larval transport in ballast water, adult gastropods in the hull fouling of ships (in sheltered hull regions such as sea chests), egg case transport on ship hulls or with fishing gear, aquaculture species and their packing material.

The ecological impacts, i.e. *Rapana* predation on bivalves, have been severe. Locally the *R. venosa* predation is considered as the prime reason for the decline in blue mussels (*Mytilus* spp.), oysters (*Ostrea* spp.) and scallops (*Pecten* spp.). Further, the rapa whelk itself is commercially exploited by fisheries. The gastropod meat is sold in Asia and the shells to tourists.

The prime habitats are estuarine regions with warm summer temperatures. Freezing conditions are overcome by migration into deeper waters. The species is also tolerant to water pollution and to oxygen deficiency. The species colonizes waters with a wide salinity range from mid-estuarine (approximately 12 psu) through oceanic values. The temperature tolerance stretches from 4 to 27 °C, with an upper limit between 27 and 34. If the temperature remains above 20 °C for extended periods, then egg case deposition, hatching and larval development may occur (Mann et al. 2004 and references therein).

The wide salinity and temperature tolerance of this invader indicates the suitability of especially the western and central Baltic as appropriate habitat, but the required temperature for egg-laying and larval development (> 20 °C) may not occur in the Baltic each year over the minimum needed time period. However, in certain areas such requirements may be met in warm summers. In additional areas with warm water effluents from power plants may support the species reproduction as well as warmer summers resulting from global temperature change.

As a result ports in the western and central Baltic with shipping connections to areas were *Rapana* occurs are at highest risk to become invaded by the species. As for *Mnemiopsis* (see above) Copenhagen, Gothenburg and Sköldvik receive ships from the North American east coast, where *Rapana* is known to occur. In addition the port of Copenhagen is involved in shipping routes to the Black Sea where the species was previously introduced.

In the same way as to reduce the risk of a *Mnemiopsis* introductions, ballast water exchange may be undertaken prior those vessels reach the Baltic. However, *Rapana* may also become introduced in the hull fouling of ships indicating that water exchange will not eliminate the risk of this invader to become introduced completely. Once this invader establishes in the North Sea, most – if not all – Baltic ports have shipping route connections to at least one potential source port of *Rapana* indicating the high invasion risk of this species – and also the need for ballast water management in inner-European shipping.

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Annex 1 Consistency with other regional risk assessment guidelines and strategies

This annex is focussed on experience of other national and international risk assessments as well as the IMO Ballast Water Management Convention and relevant guidelines.

1 Risk Assessment Recommendations in IMO Assembly Resolution 868(20)

The following paragraphs were extracted from the *IMO Guidelines in Assembly Resolution 868(20)* and are included here for reasons of comparison. It should be noted that new risk assessment guidelines are in preparation by MEPC and are referred to further below.

The objectives of these Guidelines are to assist Governments and appropriate authorities, ship masters, operators and owners, and port authorities, as well as other interested parties, in minimizing the risk of introducing harmful aquatic organisms and pathogens from ships' ballast water and associated sediments. The selection of appropriate methods will depend upon several factors, including the type of organisms being targeted, the level of risk involved, its environmental acceptability, the economic and ecological costs involved and the safety of ships.

The following is provided for the guidance of port State authorities in the implementation of their ballast water management programme, and to assess risks in relation to ballast water containing harmful aquatic organisms.

- **Conditions between uptake and discharge ports**
  Significantly different conditions may exist between port(s) of origin and the port in which ballast water is discharged (e.g., freshwater ballast released into highly saline ports). There is a lower probability of species establishment under such transport events.
- **Ballast water age**
  The time during which ballast water is kept in ballast tanks may be a factor determining the number of surviving organisms, because of the absence of light, decreasing nutrients and oxygen, changes of salinity and other factors. Water older than 100 days could be considered to contain a substantially lower number of organisms compared to the day of uptake. Ballast water and sediments may contain dinoflagellate cysts and other resting stages capable of surviving for a much longer time.
- **Presence of target organisms**
  Under certain circumstances it may be possible to determine if one or more target species are present in the water of a specific port and have been ballasted in a ship. In these circumstances, the receiving port State authority may invoke management measures accordingly. Even if such target species are not present, the ship may still be carrying many untargeted species which, if released in new

waters, could be potentially harmful. Port States are encouraged to carry out biological baseline surveys in their ports and to disseminate the results of their investigations.

Consistent with the precautionary approach to environmental protection, these Guidelines can apply to all ships unless specifically exempted (according to *Regulation A-4*) by a port State authority within its jurisdiction. Port State authorities should inform the IMO on how the Guidelines are being applied.

Compliance monitoring should be undertaken by port State authorities by, for example, taking and analysing ballast water and sediment samples to test for the continued survival of harmful aquatic organisms and pathogens.

2 Risk Assessment Requirements in IMO Ballast Water Management Convention

The BWC provides requirements relevant to risk assessment. In particular, *Regulation A-4* of this Convention allows Parties to exempt vessels from compliance to ballast water management procedures prior to discharge for up to 5 years if an acceptably low risk can be discerned.

Currently MEPC develops a guideline relevant to risk assessment, i.e. *Guidelines for Risk Assessment to Grant Exemptions under Regulation A-4.* The following paragraphs were extracted and slightly modified from the risk assessment guideline, being presently in an advanced preparational stage. Changes to the paragraphs below may occur until the final version of this guideline is agreed upon at IMO.

The port State granting exemptions shall give special attention to *Regulation A-4.3* which states that any exemptions granted under this regulation shall not impair or damage the environment, human health, property or resources of adjacent or other States.

Once the level of risk has been assessed, the result can be compared to the level of risk a Party is willing to accept in order to determine whether an exemption can be granted.

An assessment should be deemed high risk if it identifies at least one species that is likely to:

- cause harm and being present in the donor port or region,
- be transferred to the recipient port, and
- survive in the recipient port.

It is recommended that a third party peer review of the risk assessment method and data used and the assumptions made, be undertaken in order to ensure the most appropriate data and risk assessment methods have been used. The peer review should be undertaken by an independent third party with biological and risk assessment expertise.

There are several main procedural options for granting exemptions in accordance with *Regulation A-4*. The options include:

- the Party undertakes a risk assessment for trade routes and ships to determine whether an exemption can be granted for a specific voyage or voyages,
- the Party undertakes a risk assessment for a voyage or voyages on request of an exemption from a ship owner or operator, and
- a ship owner or operator may undertake a risk assessment for a voyage or voyages using the Party's risk assessment model and subsequently applies to a Party for an exemption for a specific voyage or voyages.

Ships on a voyage(s) or route(s) that satisfy the requirements of *Regulation A-4.1* and that pass(es) the terms of acceptance in the risk model may be granted an exemption. The result of the risk assessment should be stated as:

- the voyage(s) or route(s) represent(s) an acceptable risk. The application for an exemption may be granted,
- the voyage(s) or route(s) may represent an unacceptable risk. Further consideration is required, and
- the voyage(s) or route(s) represent(s) an unacceptable risk. The exemption from the ballast water management requirements of the Convention should not be granted.

It is recommended that an intermediate review be undertaken within [12][25] months but in any circumstances no later than [36] months after permission is granted. A recipient port State may require several reviews to be taken during the period the exemption is granted for, but more frequent than annual reviews generally should not be required.

No renewal of an exemption following the initial 60 months may be granted without a thorough review of the risk assessment and consultation with affected States.

An exemption granted under *Regulation A-4* of the Convention may need to be withdrawn in the event of an emergency situation. Emergency situations are outbreaks, infestations, or populations of harmful aquatic organisms and pathogens (e.g., harmful algal blooms) which are likely to be taken up in ballast water (*Regulation C-2* of the Convention).

3 Risk assessment methods

There are two risk assessment methods outlined in this guideline for assessing the risks in relation to granting an exemption in accordance with *Regulation A-4* of the Convention:

- environmental matching risk assessment (i.e. salinity and temperature), and
- species-specific risk assessment.

[25] Square brackets indicate that its content is of controversial discussion.

3.1 Environmental matching risk assessment

The data necessary to enable an assessment of risk using environmental matching between the donor port(s) or location(s) and the recipient port or location includes, but is not limited to:

- origin of the ballast water to be discharged in recipient port,
- biogeographical region of donor port(s) or location(s). Biogeographical regions applied should be clearly defined and based on appropriate criteria, and
- environmental parameters in donor port, bioregion and recipient port. This should include seasonal or monthly variations of salinity and temperature, taking into account:
    - depth stratification,
    - distance to fresh/marine water bodies,
    - tidal and anthropogenic influence on salinity regime,
    - seasonal freshwater influx, and
    - salinity classification: fresh, marine or between fresh and marine for the entire year.

3.2 Species-specific risk assessment

The data necessary to enable an assessment of risk using the species-specific risk assessment includes, but is not limited to:

- biogeographical region of donor and recipient ports or locations. The biogeographical regions applied should be clearly defined using appropriate criteria,
- the presence of all non-indigenous species (including cryptogenic species) in the donor port(s), location(s) or biogeographical regions,
- the presence of all non-indigenous species (including cryptogenic species) in the recipient port(s), location(s) or biogeographical regions,
- the difference between non-indigenous species (including cryptogenic species) or target species in the donor and recipient ports, locations or biogeographical regions,
- native species in the donor port(s) or location(s) not present in the recipient ports, locations or biogeographical regions that may impair or damage the environment, human health, property or resources, including, e.g.:
    - occurrence of harmful phytoplankton blooms in the donor area, and
    - occurrence of harmful organisms, pathogens or outbreaks and epidemics in the donor port.
- the presence of target species in the donor and recipient port(s), location(s) or biogeographical regions if target species are used.

Target species should be identified and agreed in consultation with affected States. Target species that may impair or damage the environment, human health, property or resources may be selected and defined for a specific port, State or geographical region. The elements to consider when identifying target species include, but should not be limited to:

- evidence of prior introduction,
- demonstrated impacts on environment, human health, property or resources,
- strength and type of ecological interactions e.g. ecological engineers,
- economic significance on property or resources,
- current distribution,
- relationship with vectors, and
- available control mechanisms.

It should be noted that there are limitations involved with using a target species approach. Although some data and information can be obtained to support decision making, identifying species that may impair or damage the environment, human health, property or resources is largely subjective and there will be a degree of uncertainty associated with the approach. For example, it is possible that species identified as harmful in some environments may not be harmful in others and vice versa.

Life history information from target species and physiological tolerances (e.g. temperature and salinity) of each life stage should be identified to determine the likelihood of the species completing its life cycle in the recipient port.

The likelihood of target species surviving each of the ballast water operational stages should be assessed, including:

- uptake – probability of viable stages entering the vessel’s ballast water tanks during ballast water uptake operations,
- transfer – probability of survival during the voyage, and
- discharge – probability of viable stages entering the recipient port through ballast water discharge on arrival and probability of survival in the recipient port.

The total likelihood of survival of viable stages of target species in the recipient port should be a function of survival during each of the ballast water operational stages. To the extent possible the different life stages of the target species should be assessed considering seasonal variations of life stage occurrence in donor port areas with seasonal conditions in the recipient port.

4 International Council for the Exploration of the Sea

At the last meeting of WGBOSV in March 2005 all risk assessment approaches relevant to biological invasions known were briefly reviewed with the aim to prepare a guidance document for consideration at IMO MEPC. The information WGBOSV provided was also reviewed in detail by ICES. The following paragraphs represent the ICES comments on risk assessment relevant to ballast water management.

According to this analysis, several types of risk assessment have been conducted on ballast water with varying scales of assessment and objectives. As a result, discussions within ICES focused mostly on the recently implemented IMO Ballast Water Management Convention, under which some provisions require a risk-based ballast water management approach. ICES considers that the risk assessment to support an exemption must be able to determine the likelihood of an unmanaged ballast water discharge causing at least one new species into the receiving port.

Two types of risk assessment are likely to achieve the stated goal:

- environmental matching risk assessments which compare environmental conditions in the donor and receiving port to determine if they are sufficiently different that any species found in the source port are unlikely to survive in the receiving port; and
- species-specific risk assessments which consider information about individual species and the environmental conditions in the receiving port.

In addition, under the IMO Ballast Water Management Convention, an exemption can be granted for up to five years for a ship that operates within a specified transit between two or more ports. While it was noted that states should inform neighbouring states when an exemption is granted, ICES concluded that the only biologically defensible means to support an exemption over such a time period would be to limit its application to transits between ports located within a single bioprovince (ecozone). ICES also concluded that there is a need to review risk-based exemptions on a regular basis because of the current rate of invasions in many regions of the world (e.g. a newly introduced species was recorded every seven months in the North Sea and adjacent water bodies since the 1950s).

Some progress was made by ICES on the development of criteria for the determination and/or ranking of risks, mainly with respect to the two risk assessment approaches mentioned above. Some limitations or caveats were provided with regards to the use of environmental matching and species-specific risk assessment methods in support of *Regulation A-4* of the IMO Ballast Water Management Convention. More specifically, it was concluded that *Regulation A-4* exemptions should only be based on environmental matching risk assessments between freshwater (< 0.5 psu) and fully marine environments (> 30 psu), and on species-specific risk assessments for voyages within the same biological province.

Under these limitations, environmental matching risk assessments should include spatio-temporal comparisons of salinity, as well as an assessment of native, cryptogenic or non-indigenous species that can tolerate wide ranges of salinity (euryhaline, diadromous species). As for species-specific assessments within a biological province, they should target non-indigenous and cryptogenic species in all the port for which the exemption is sought as well as native species only present in the source ports, including those that may have socio-economic impacts.

Based on these conclusions, a system that documents biological separation between coastal regions is needed to support ballast water risk assessment and related management. ICES recognizes the fact that several classification systems exist and no single system is sufficient for all species in all habitats (benthic, pelagic or neritic).

There are differing views and philosophies relating to the benefits of applying risk assessment and risk management principles to ballast water management versus taking a 'blanket', all-encompassing approach. The key issues addressed by the participants at the round table discussion were:

- what is the role of risk assessment in the new IMO Ballast Water Management Convention?
- under what circumstances and what bio-geographic scale does risk assessment become biologically meaningful?

A number of papers were at the 2005 meeting of WGBOSV of direct relevance to this Term of Reference. Following the presentations a template was designed to ease the comparison and evaluation of relevant risk assessment approaches (Tab. 1).

In general, two different assessment philosophies have been developed: risk assessment versus hazard assessment. A hazard assessment will allow management (or control) based on a ranking exercise, but not on a vessel-by-vessel basis. A risk assessment allows a single vessel or ballast tank to be evaluated and subject to management (or control). This table only covers management of vessels - other risk assessment methods are being used to identify ballast exchange areas, target species, etc.

Table 1 compares key risk assessment features of 12 research initiatives. The projects considered were carried out or are ongoing in Australia, North America, Europe and during the GloBallast Programme (Brazil, China, India, Iran, South Africa, and Ukraine). Key objectives of the studies considered here included:

- risk identification for species invasions,
- estimates of the cost of toxic dinoflagellate introductions,
- identifying low risk routes, vessels and tanks,
- enhancing awareness and recommending ballast water management strategies,
- creating baseline knowledge on the risks associated with NIS and shipping, and
- recommending ballast water management plans.

The management unit of the risk assessments were either target species, routes, vessels or ports. The assessment unit covered regions, target species, port or routes on either a qualitative or (semi-)quantitative approach.

The overall principles for assessing the risk were either environmental match (studying up to 37 variables), species based tolerance or models covering four steps in the bio-invasion process: donor port infection, vessel infection, journey survival and survival in the recipient port. The temporal resolution ranges from monthly to annual data.

Table 1. Comparison of selected risk assessment initiatives relevant to vessel management. DSS = Decision Support System. Source: WGBOSV 2005.

Risk assessment initiative	Manage-ment unit	Assess-ment unit	Assessment based on	Approach	Environ-mental variables	Endpoint	Temporal resolution	Purpose	Date
Germany (Gollasch 1996)	Target species (varies)	Region	Environmental matching between localities	Qualitative	2	Hazard assessment	Annual	Risk identification for species invasions in German coastal waters	1992 - 1996
Australia (AQIS 1994)	Target species (2)	Target species (2)	Species based tolerance, volume of ballast discharged and bloom dynamics	Quantitative	1	Estimate economic impact of toxic dinoflagellates on aquaculture, tourism, etc	Annual	Estimate cost of toxic dinoflagellate introductions in Australian waters	1994
Australian DSS (Hayes and Hewitt 1998, 2000)	Routes	Target species (8+)	Models four steps in the bio-invasion process: donor port infection, vessel infection, journey survival and survival in the recipient port	Quantitative	1	Target species life cycle completion in recipient port	Month	Identify low risk routes, vessels and tanks	1997 - ongoing
NORDIC countries (Gollasch & Leppäkoski 1999)	Target species (varies)	Port	Environmental match between donor and source localities	Qualitative	5	Hazard assessment	Annual	Risk identification for species invasions in NORDIC countries	1998-1999
Global EMBLA (Det Norske Veritas)	Target species	Target species (various)	Models four steps in the bio-invasion process: donor port infection, vessel infection, journey survival and survival in the recipient port	Quantitative	2	Target species life cycle completion in recipient port	Month	Identify low risk routes, vessels and tanks	1998 - ongoing
Global (GloBallast)	Routes	Port	Environmental matching between localities, weighted by target species presence in the donor location and inoculation factors	Semi-quantitative	37	Identify and rank high and low risk ports	Annual	Enhance awareness and recommends ballast water management strategies	2000 - 2004

Tab. 1. continued.

Risk assessment initiative	Manage-ment unit	Assess-ment unit	Assessment based on	Approach	Environ-mental variables	Endpoint	Temporal resolution	Purpose	Date
Slovenia	Vessels	Vessel + Target species	Four step assessment of the bio-invasion process: donor port infection, journey survival, survival in recipient port and potential to cause harm in recipient port	Quantitative ~ qualitative	2	Identify and rank high and low risk ports as well as high risk target species	Annual	Vessel-to-vessel assessment from low to high risk ballast water before discharge for ballast water management purpose (DSS)	2001 - ongoing
Canada 1 (MacIsaac et al. 2002)	Vessels	Target taxa	species based tolerance, and taxa concentrations in no ballast on board vessels (NOBOB)	Quantitative	2+	Journey survival of target species		Estimate risk associated with NOBOB vessels entering the Great Lakes	2002
Finland (BITIS)	Port	Port	Environmental match between donor and source localities	Qualitative	2	Hazard assessment	Seasonal	Create baseline knowledge on the risks associated with NIS and shipping	2003 - 2005
EMBLA (Croatia)	Routes	Routes	Locality based region and species tolerances	qualitative	1	Hazard assessment	Seasonal	Recommend ballast water management plan for Croatia	2004 - 2005
Netherlands	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	Review and develop a ballast water risk assessment framework	2004 - ongoing
Canada 2 (Raaymakers et al. in prep.)	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	unknown, in prep.	Review and develop a ballast water risk assessment framework	2005 - ongoing

4.1 Conclusions of ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors

A summary report expressing the groups findings relevant to risk assessment was drafted for submission to the next meeting of IMO Marine Environment Protection Committee (MEPC) in Summer 2005. The following general conclusions were drawn. A synthesis of the following section was prepared as a submission to IMO MEPC:

WGBOSV notes that the IMO Risk Assessment Guidelines are to support the International Convention on the Management of Ships' Ballast Water and Sediments. Specifically, *Regulation A-4* that allows Parties to exempt vessels from compliance with ballast water management prior to discharge if an acceptably low risk can be discerned. WGBOSV discussed the application of risk assessment principles in relation to *Regulation A-4* application. It was agreed that the risk assessment to support an exemption must be able to determine the likelihood of an unmanaged ballast water discharge causing at least one new species introduction into the receiving port. An additional requirement includes identifying whether the species is known or suspected to impair or cause harm to the environment, human health, property or resources to aid in determining whether the species is "harmful".

Under the IMO Ballast Water Management Convention an exemption can be granted for up to 5 years for a ship that operates within a specified transit between two or more ports. It was agreed that the only biologically defensible means to determine an evaluation of risk over this period would be to undertake a species specific exemption within a single bioprovince (defined below). We noted that states have to inform neighbour states when an exemption is granted. Concerns were expressed regarding whether or not neighbouring states will have the power to veto the exemption under the proposed convention.

Several types of risk assessment have been conducted on ballast water with varying scales of assessment and objectives. Following significant discussion, it was agreed that the goal to achieve *Regulation A-4* would be "to determine the likelihood of unmanaged ballast water discharge causing at least one new species introduction (defined either as discharge, establishment, or spread) into the receiving port". It was agreed that two types of risk assessment are likely to achieve the stated goal.

4.1.1 Environmental matching risk assessments compare environmental conditions in the donor and receiving port to determine if they are *sufficiently* different that any species found in the source port are unlikely to survive in the receiving port.

- in order for environmental matching to "determine the likelihood of at least one new species introduction (defined either as discharge, establishment, or spread) into the receiving port", the environmental conditions of the source region must represent the physiological tolerances of the species found in that region,
- environmental matching risk assessment (between freshwater and marine environments) should include seasonal comparisons of salinity, taking into account:
    - depth stratification,
    - distance to fresh/marine water bodies,
    - tidal and anthropogenic influence on salinity regime, and
    - seasonal freshwater influx.
- environmental matching risk assessments (between freshwater and marine environments) should include an assessment of native, cryptogenic or non-indigenous species, taking into account:

- species that require freshwater and marine environments to complete their life-cycle, including species migrating between waters of different salinity regimes, i.e. anadromous (e.g. sea lamprey) and catadromous (e.g. Chinese mitten crab) species, and
- species that are capable of surviving in both freshwater and marine environments.

- species-specific risk assessment is applicable for situations within biological regions, but port-to-port environmental matching is important when used between biological regions where there is a different species distribution,
- it was also discussed whether or not environmental matching will work with species that have resting stages,
- low-resolution information on receptor ports and broad data on tolerances for possible invaders complicate the task of risk assessment, and
- ship transit information is available from e.g. Lloyds of London, but this does not indicate where the ballast water originates because there are no records of ballasting and discharge.

4.1.2 Species-specific risk assessments consider information about individual species and the environmental conditions in the receiving port.

- species-specific risk assessments are most useful for a small suite of species and rapidly lose the ability to discern 'low-risk' scenarios with increasing numbers of species,
- given that many species may cause harm when introduced to new locations and the uncertainties associated with the large numbers of native species that are present in a source region, we recommend that species-specific risk assessments should only be conducted where the source and receiving ports share a majority of native species. This will enable the focus of a species-specific risk assessment to be restricted to those species that are non-native in the source and receiving ports, and any unshared species that may be harmful,
- species-specific risk assessment (within a biological province) should identify:
    - the presence of all non-indigenous species (including cryptogenic species) in the ports or locations for which the exemption is sought,
    - the difference between non-indigenous species (including cryptogenic species) in the donor and receiving ports or locations,
    - those non-indigenous species (including cryptogenic species) that may impair or damage the environment, human health, property or resources, and
    - those rare instances of native species in the source port not present in the receiving ports that impair or damage the environment, human health, property or resources.
- species-specific risk assessments should be conducted on:
    - nonindigenous species (including cryptogenic species) that are present in the donor port or locations but absent from the receiving port or location,
    - a list of actual or potentially harmful non-indigenous species (including cryptogenic species) agreed between the affected parties, or

    - a list of harmful native species agreed between the affected parties.
- species-specific risk assessments may estimate various events in the process of biological invasions. The two events recommended below are least sensitive to uncertainty - either of these should be used:
    - discharge of living organisms in the receiving ports or locations, and
    - completion of the species' life cycle in the receiving ports or locations.
- species-specific risk assessments may consider multiple species. Exemptions should only be granted for assessments that consider ALL risk-assessed species as low risk, and
- for many species the Australian risk assessment approach delivers helpful data but as has been demonstrated by the target species *Crassostrea gigas* (Pacific oyster) the risk assessment results do not always correspond with observations. The model indicates that *C. gigas* would be able to grow north of Brisbane, but observations indicate it does not grow in this area. On the other hand the model results show unfavourable conditions for growth in Tasmania, however, *C. gigas* grows well there. As a result extreme values of tolerance need to be considered.

A system is needed that documents biological separation between coastal regions. These regions are defined as *biological provinces* (bioprovinces[26]). We recognize that several classification systems exist and no single system is sufficient for all species (i.e. most are applicable to benthic species but not pelagic or neritic). Determination and agreement of an acceptable system for the purpose of ballast water risk based exemptions requires significant scientific discussion and should be fit for purpose.

4.1.3 Risk assessment application

When using environmental matching, a limited suite of these parameters are likely to be the prime drivers of invasion success, adding further variables can have little effect and can create "noise" around the signal. Examining the signal:noise ratio one can seek to identity the most important versus less important variables required for the risk assessment. However, adding too many variables may make the signal become less obvious resulting in a lack of risk resolution.

Some environmental overlap exists between all bioprovinces based on two relevant environmental parameters (temperature and salinity). This suggests that environmental matching between a source province and a receiving port will represent high risk in virtually all instances.

[26] Bioprovince = an area within which the animal and plant species show a high degree of similarity. Examples of the biological provinces of the world are provided in Annex 5. Additional expertise is required in order to finalize the provinces and boundaries between them. We note that all boundaries between biological provinces overlap. Ekman and Briggs used predominantly physical processes to define bioprovinces, but this should be updated to include latest work. Also consider demographic process, allee effects, low carrying capacity. How are geographic regions be defined? If one takes propagules and move them to a new location if there are allee effects the movement will erode the boundary between regions. As a result the marine border idea needs to be specified. Seasonal issues and impacts should also be included (e.g. harmful Algal Blooms may be seasonally a problem but not throughout the year). Biogeographic boundaries are integrating these complex processes. Is there gene flow across boundaries? Does it contribute to establishment of genetic material from elsewhere.

One exception is noted: comparison of freshwater [< 0.5 psu] and fully marine [> 30 psu] environments. This exception will require a more detailed risk assessment outlined below.

Therefore, in reviewing the use of both types of risk assessment, WGBOSV recommends that:

- neither environmental matching nor species-specific risk assessed exemptions under *Regulation A-4* are scientifically justified for voyages that start and end between contiguous or non-contiguous biological provinces with the exception below, and
- *Regulation A-4* exemptions should only be based on:
  - environmental matching risk assessments between freshwater [< 0.5 psu] and fully marine [> 30 psu] environments, and
  - species-specific risk assessments for voyages that start and end within the same biological province.

Parties considering exemptions should consult any State that the Parties determine may be adversely affected by the species included, or explicitly excluded, in the risk assessment.

4.1.4 Other considerations

Risk based exemptions should be reviewed every 12 months and no later than 24 months because of the current rate of invasions in many regions of the world (e.g. a newly introduced species was recorded every 7 months in the North Sea and adjacent water bodies since 1950s).

Provision for rapid [< 14 days] suspension, cessation or immediate review of the exemption should be made for circumstances such as:

- outbreaks or infestations of harmful aquatic organisms (including algal blooms) or pathogens in the donor port,
- detection of new non-indigenous species (including cryptogenic species) in the donor port,
- new evidence of harmful behaviour by any species in the donor port, and
- significant and enduring change in environmental conditions in the donor and/or receiving ports or locations (e.g. diversion of fresh or saline water flow, new warm effluent discharge of e.g. power plants).

Biogeographic considerations associated with natural dispersal, oceanographic connectivity between locations, the distribution of known introduced marine pests and operational limitations of ships operating on "regional routes" must be considered when developing risk assessment approaches further.

5 OSPAR (IGSS) Scoping Study (Dragsund et al. 2005)

Vessels visiting European ports will need to undertake ballast water exchange until treatment systems are available and installed onboard. Treatment facilities on board will be required from 2014/2016 onwards for existing vessels or from 2009/2012 onwards for new-built vessels. According to Royal Haskoning (2004) two possible approaches are identified with respect to ballast water management:

Option 1 *The blanket approach*:

- all ballast water should be managed (exchange or treatment) prior to discharge without exemptions. This approach will likely be implemented in the North American Great Lakes from 2008,
- due to safety reasons or other accepted circumstances, some ships may not be able to carry out a ballast water exchange. These cases need to be documented by the ship, and
- ballast water exchange is accepted until IMO approved treatment systems are available.

Option 2 *The selective approach* allows for exemptions based on the results of risk assessments. This approach encloses three options for granting exemptions, when the results of risk assessment considers to be of a low risk to allow discharge without performing ballast water exchange or treatment:

- exemptions on a regional basis (i.e. vessels intending to discharge ballast water only from ports within the identical bioprovince) are not required to manage ballast water,
- trade/ship-type specific exemptions (i.e. vessels operated on regular routes between the same ports or port areas), and
- voyage specific exemptions.

The selective approach requires a standardised risk assessment method (e.g. monitoring of NIS) and a warning system to report outbreaks of unwanted species, such as harmful algal blooms. However, a selective target species approach will leave the ballast water recipient region unprotected of invasions of non-target species.

In case risk assessment is decided to be useful in North West Europe to reduce the risk of ballast water mediated species invasions risk mitigation strategies need to be developed for high-risk shipping routes which is currently lacking.

Dragsund et al. (2005) support the conclusions drawn by Royal Haskoning (2004) that: "*although the blanket approach will give the best protection against unwanted introductions, it does not seem feasible since this imposes all the ship owners with the costs involved with ballast water management, irrespective of the risk of discharge of unmanaged ballast water*." This leaves the selective approach as the preferred option.

6 BSRP/HELCOM/COLAR Workshop on "Ballast water introductions of alien species into the Baltic Sea"

The workshop was held 21-25 February 2005, Palanga, Lithuania with the objectives to:

- assess the applicability of risk assessment and port baseline survey methodologies developed under the IMO GloBallast and other relevant projects for the Baltic Sea,
- evaluate the research capacity, technical potential and financial resources needed for the risk assessment and the port baseline surveys,
- elaborate common principles for the monitoring system of invasive species in the Baltic Sea, and
- develop a common information system for the Baltic Sea supporting the implementation of the IMO Ballast Water Management Convention.

6.1 HELCOM action to address ballast water issue

The Workshop discussed the draft HELCOM Recommendation "*Measures to address the threat of invasive species transported via the ballast water of ships*" (October 2004) elaborated in accordance with the IMO's BWC.

The Workshop also agreed that because of the geographical characteristics of the Baltic Sea (a mean depth of 55 metres; all areas deeper than 200 m are within less than 50 nautical miles to the nearest land) the requirements of the BMWC (*Regulation B-4*, paragraphs 1.1. and 1.2.) for conducting ballast water exchange cannot be met in the Baltic Sea. An evaluation of the suitability of designating areas in the Baltic where a ship may conduct ballast water exchange, in accordance with *Regulation B-4*, paragraph 2, must be made by the port states. Ballast water exchange within the Baltic may prevent the spread of freshwater invasive alien species from one freshwater Baltic port to another. However, the ballast water exchange should not be considered as the only effective measure for managing ballast water within the Baltic. Development of risk assessment methodology and other tools (biological surveys, monitoring, early-warning systems, appropriate treatment of ballast water) is extremely important for prevention of ballast water mediated introductions of invasive alien species.

The Workshop agreed that the internal Baltic ship traffic is not of primary interest for the risk assessments because alien species once settled in some part of the Baltic, are able to spread through natural means, if the environmental conditions (salinity, temperature, etc.) are acceptable, as well as through ballast water and other human-mediated vectors. Possibilities are very limited for effectively preventing secondary introductions through ballast water within the region and thus limit the advantages of using risk assessment procedures. However, there could be certain cases where the internal shipping risks should be analyzed, for example when extraordinary measures are required to prevent the spread of a particularly harmful species (such as a pathogen or toxic algae).

6.2 Common principles of the monitoring system of invasive species in the Baltic Sea

The Workshop took note of the information on the HELCOM data and assessment strategy and the ongoing review of the HELCOM COMBINE monitoring programme. The Workshop also noted that the input to the review process should be given via national contacts to MONAS and MON-PRO.

The Workshop indicated that it is important to report to HELCOM on findings of alien species at national monitoring stations which presently are not included into the HELCOM COMBINE system (e.g. county's monitoring, national fishery institutes' surveys, etc.).

For management of ballast water it is important to include other groups that are currently not monitored (e.g. pathogenic microflora, meiobenthos, resting stages, marine fungi, etc.). Special attention should be paid to the groups which are listed in the BWC [Ballast Water Performance Standard (*Regulation D-2*)]. A common methodology should be developed for the monitoring of those groups.

6.3 Proposals for a common information system for the Baltic Sea

The Workshop agreed that there is a need for a common information system for the Baltic Sea States supporting the implementation of the IMO Ballast Water Management Convention. The system should support risk assessment activities and decision-making in Baltic Sea ports. It should also serve as a data source for other regions that may be potential recipients of Baltic Sea species. The system should also provide a basis for exchanging information and feed into an early-warning system.

The common information system should include:

- an early-warning system on new introductions and spread of invasive alien species and warning for outbreaks of harmful organisms which may affect the suitability of ballast water uptake (BWC *Regulation C-2*),
- information for Baltic Sea countries and recipient countries outside the Baltic Sea region about the status of alien species etc.,
- information on water quality and abiotic conditions in Baltic harbours, and
- a list of targeted or most unwanted species.

Whenever possible, such a common information system should benefit from the recent European initiatives, such as the FW6 IP ALARM and FW6 STREP DAISIE as well from the information system already existing in the Baltic Sea region, such as the Baltic Sea Alien Species Database[27], NOBANIS[28], AquaInvader[29] etc.

[27] Baltic Sea Alien Species Database www.ku.lt/nemo/mainnemo.htm

[28] NOBANIS North European and Baltic Network on Invasive Alien Species www.artportalen.se/nobanis

[29] Database of Aquatic Invasive Species of Europe (AquaInvader) www.zin.ru/rbic/projects/aquainvader/

Problems:

- data on biota in ballast water uptake areas are scattered
- standardized port/port region sampling programmes are needed

6.4 Ballast water exchange and protected sea areas

In any case, ballast water operations should be kept to the essential minimum or even be prohibited in protected water bodies. According to IMO's initiative to protect particular sensitive sea areas (PSSA) from adverse effects of shipping most European seas are already identified as PSSA's. So far, measures not permitted in PSSA's as recommended by IMO do not include provisions on ballast water operations. However, PSSA's clearly identify the uniqueness of certain sea areas. As ballast water mediated introduction pose a high risk to the receiving environment relevant provisions for PSSA's may be considered.

As a result, all attempts should be undertaken to avoid the identification of ballast water exchange zones in or near sensitive aquatic areas. As IMO is currently working on the Guideline on Designation of Areas for Ballast Water Exchange (G14) it may be considered express the abovementioned concerns to ensure that sensitive and protected aquatic areas are not negatively affected by ballast water exchange.

In case exchange zones are identified, which is unlikely for the Baltic and other regional seas, constant monitoring programmes should be implemented. The reasoning for monitoring may include to document the occurrence of harmful aquatic organisms in such areas which may be introduced by ballast water exchange. In case harmful aquatic organisms are found to be introduced here, the designated area may be closed to avoid promoting the spread of such newly occurring species to other regions by carrying out ballast water exchange.

Annex 2 Detailed risk assessment results for the Port of Copenhagen (Denmark)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Copenhagen	Denmark	10	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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
Naestved	Denmark	5,4	EAB	no	2	yes	3	0,5	170	3	yes	1	9

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-Baltic shipping	Risk level	Total risk calcu-lation
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
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

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-Baltic shipping	Risk level	Total risk calcu-lation
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 3 Detailed risk assessment results for the Port of Gothenburg (Sweden)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Gothenburg	Sweden	13,1-18,2	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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	Lithunia	<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

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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 4 Detailed risk assessment results for the Port of Kiel (Germany)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Kiel	Germany	19,5	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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	Lybia	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	Marocco	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	Lithunia	<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 5 Detailed risk assessment results for the Port of Klaipeda (Lithuania)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Klaipeda	Lithuania	0,5-7	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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 6 Detailed risk assessment results for the Port of Sköldvik/Kilpilahti (Finland)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Sköldvik	Finland	0-6,7	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-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 7 Detailed risk assessment results for the port region Tornio, Kemi, and Raahe (Finland)

Tab. 1. Risk assessment carried out according to source ports of arriving ship 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 (ppt) at 8 °C	Temp. zone
Kemi, Tornea, Raahe	Finland	0-4,2	EAB

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-Baltic shipping	Risk level	Total risk calcu-lation
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

Tab. 1 continued.

Port/port region	Country	Salinity (ppt) at 8 °C	Temp. zone	Salinity match	Salinity risk level	Temp. match	Temp. risk level	Voyage duration [days]	Voyage duration [nm]	Voyage risk level	Inner-Baltic shipping	Risk level	Total risk calcu-lation
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