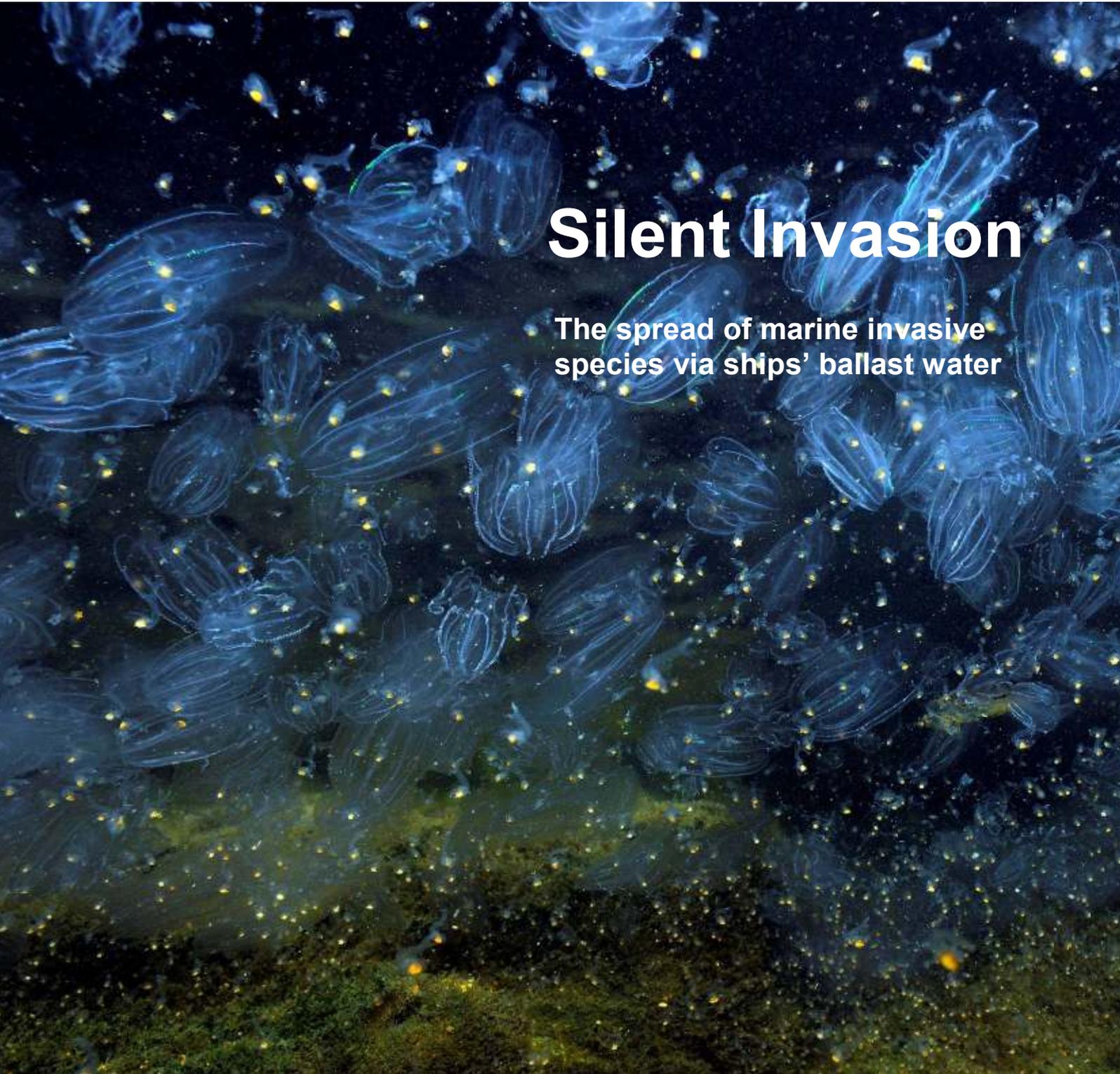




for a living planet

Silent Invasion

The spread of marine invasive species via ships' ballast water



Silent Invasion – *The spread of marine invasive species via ships' ballast water*

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Cover photograph: © Erling SVENSEN / WWF-Canon: Swarm of *Mnemiopsis leydi*, the North American comb jelly that caused collapse of fisheries in the Black Sea and is now invading the Caspian Sea, North Sea and the Baltic Sea. Photograph taken in Egersund, SW Norway, 2008

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Introduction

Every day, every hour, an estimated 7,000 marine and coastal species travel unnoticed across the world's oceans, silently stowed away in ships' ballast water tanks. When released in a new environment, these unwanted travellers can become invasive, out-competing and changing native flora and fauna and resulting in irreversible ecological change and economic loss.

The 2004 International Maritime Organization's (IMO) *Convention on the Control and Management of Ships' Ballast Water and Sediments* (Ballast Water Convention) is widely accepted by governments and the global shipping industry as the only international instrument that can prevent trading ships from continuing to spread harmful invasive species via transfers of unmanaged ballast water.

However, the convention has not yet entered into force, and five years after its adoption, invasions of new places by new species continue to be recorded. If 12 additional member States ratify or otherwise accede to the Ballast Water Convention during the remaining months of 2009, and if these States represent 19.6% or more of the world's registered merchant tonnage (additional to the 15.4% already represented), the Convention will enter into force in January 2011. Only then is it a powerful legal instrument to stem the ongoing and future invasions due to ballast water.

Most ship owners and fleet managers want to avoid transferring potentially harmful species from port to port, but without jeopardising ship and crew safety and/or incurring delays, extended voyages or unfair expenses that reduce competitiveness and efficiencies. Responsible ship owners have therefore welcomed the Convention.

The shipping industry also has a role to play in stopping the spread of invasive species, in ensuring that ballast water is treated through use of approved technology on board all vessels.

This briefing provides information on the rising numbers of these unwanted travellers (including two regional seas examples), gives an idea as to the cost of invasive species to society and that of fitting treatment systems onboard vessels, outlines available policy and technical solutions to the problem of invasive species, explains how the main obstacles to why States have hesitated to ratify have been overcome, and ends by urging all stakeholders to ensure these solutions are applied.

It is hoped that the information provided will be useful for policymakers to facilitate the preparations for flag States to ratify the Ballast Water Convention, and for shipping company executives to invest in appropriate ballast water treatment technology onboard all vessels.

Invasive species – how do they get around?

Shipping plays a major role in world trade, carrying approximately 90% of all internationally traded goods. Ballast water is essential to the stability and structural integrity of a cargo ship when it is partly or completely empty of cargo. All conventional types of trading ship use ballast tanks to prevent heavy rolling and capsizing, but also to achieve adequate propulsion, steerage, forward visibility and maximum fuel efficiency. Over 10 billion tonnes of ballast water are estimated to be moved around the world in ballast tanks each year.

But as ships fill up their ballast tanks, they take in water surrounding the ship – and with it come the organisms living in that water. These unwanted stowaways – marine and freshwater fish larvae and small fish, crustaceans, algae, invertebrates, and even viruses and bacteria – are then let out into a new environment when the ship reaches the next port and discharges its ballast to load cargo.

How can new species be a problem?

Most of these silent travellers do not survive the journey or in the new area, but occasionally some do and, if aggressive and fast reproducing, may become invasive – out-competing local flora or fauna. In new surroundings, an introduced species may not have the same natural brakes, such as pathogens, grazers, predators or parasites, on its population number as in its native environment.

The introduction of new species can therefore often expand unhindered and have large and detrimental consequences on the new host ecosystem, affecting the productivity of fisheries and aquaculture, as well as the economy and livelihoods of communities dependent upon the invaded area's biodiversity.

At temporary oil spills and other chemical pollution events, natural biological processes will decompose the alien substances so that the impacted environment in time might regain pre-spill status. At an aquatic bioinvasion, on the other hand, the natural biological processes work to the benefit of the invasive species, making it essentially unstoppable, unless it is fortuitously detected at its earliest stage, and occurs in a confined location amenable to a practical, affordable eradication campaign.

The cost of invasive species

Since the Ballast Water Convention was adopted in 2004, almost all of the world's seas and waterways have continued to be invaded by unwanted species. Global economic losses from the damage caused by harmful invasive aquatic species were estimated to have exceeded USD7 billion per year in 2004/05, making the total bill between the 2004 adoption of the Convention and end of 2009 at least USD50 billion in present-day value, or equivalent to the 2008 gross domestic product of the country of Bulgaria.

This sum reflects damage and repair costs to fisheries, aquaculture, water supply systems, industrial infrastructure and harbours. It does *not* include all of the indirect economic losses caused by changes to marine biodiversity and habitats, including impacts to and even near-extinctions of endemic species.

Even relatively minor changes of habitats are likely to cause additional stress to the ecosystem in ways which are hard to calculate, both from environmental and economic point of view – and will lower the local environment’s resilience to other stress factors, such as pollution, climate change and overfishing.

Detecting initial incursions of these silent, potentially invasive species requires considerable monitoring efforts, and even the eradication of a small population from the confines of a small harbour or estuary requires an intensive, long term and costly effort (typically several millions of dollars).

Only a handful of successful cases of eradicating an invasive species have been reported so far, as that of the black striped mussel from an Australian marina, which included using chemicals to kill all life in the marina and two adjacent marinas also affected, to a total cost of 2.2 million Australian dollars.

Why is the problem growing?

Merchant ships have increased dramatically in their number, average size and speed since the 1950s, with the sector currently estimated to grow at 8% per year until 2020 in response to widening world trade. Routes have expanded and diversified, leading to much greater quantities of ballast water being moved more frequently, and more quickly, to and from an increasing number of new destinations.

Opportunities for spread and population increases of non-native species can also be expected to increase due to factors such as regional warming associated with global climate change, and increasing port and coastal water eutrophication in many areas.

Ports that service international trade and receive regular discharges of ballast water are regarded as high risk nodes and potential ‘regional hubs’ for the introduction and spread of potentially invasive aquatic species. Another factor considered to increase the risk of an introduction from a ballast water ‘donor’ port to a distant ballast water ‘recipient’ port is the level of environmental similarity between the two ports – particularly overlap in their water temperature and salinity ranges.

What species can become invasive?

Not all species transported in a ballast tank will become invasive, and not all survive the journey. But it is difficult to predict which, where and when an introduced species will start to spread by itself into new habitats (an invasive species) and damage the local ecosystem and its resources (a harmful invasive species). Even invasive species that originally do not seem harmful may become so if conditions in their environment

change, such as temperature, nutrients, the introduction of another alien species, that give the new species an ecological advantage.

A 2008 study ranked 13 introduced species of molluscs, crustaceans, seaweeds and a toxic plankton species found in the ecologically sensitive, species poor and brackish Baltic Sea, as having a *very high* threat level based on ecological impact, geographic extent, invasive potential and management control difficulty, and ranked another 17 species new to the Baltic as having a *high* level of threat¹.

What makes a new species invasive?

A harmful invasive species usually displays at least one of the following characteristics in its new range:

- displaces local native species by competing directly for food, space or light;
- substantially disrupts the local food web, sea floor or river habitat (i.e. keystone, engineering or blooming species such as comb jellies or a substrate-smothering mussel);
- enjoys prolific reproduction, recruitment, growth and survival due to its 'escape' from the natural predators, grazers, parasites or pathogens that control it in its native range;
- causes nuisance fouling to boats, ships, fishing gear, aquaculture equipment, industrial cooling water systems, jetty piles, etc; and
- has noxious or pathogenic effects that cause fish mortalities, disrupt aquaculture operations and/or directly threaten public health (e.g. toxic 'red-tide' microalgae, waterborne diseases).

The rising tide of silent invaders

The 2008 analysis of marine invasions found that marine invasive species have been reported for at least 84% of the world's 232 marine ecoregions. The study also identified international shipping as being the major introduction pathway for these species.

Studies of introduction records for particular ports, bays, countries or regions have yielded estimates of aquatic species invasion rates, including some alarmingly high rates for invasion-prone ports and estuaries. For example, introduction rates as high as two to three new species every year have been reported for Port Phillip Bay (Melbourne, Australia) and up to one species every nine weeks for San Francisco Bay (California, USA).

¹ Molnar et al. 2008. *Assessing the global threat of invasive species to marine biodiversity*. *Frontiers in Ecology and the Environment*. Vol. 6, No. 9, pp. 485-492.

Molnar et al compiled information from over 350 data sources into a regularly updated database including at least 329 marine invasive species. Each species was assigned a score for the following categories: ecological impact, geographic extent, invasive potential, and management difficulty, with score 3 = high invasive potential; and 4 = very high invasive potential.

An idea as to the potential range of invasions that can be linked to continued unmanaged ballast discharges since the IMO Assembly adopted the Ballast Water Convention can be gained from post-2004 records in aquatic invasive species databases, and annual country summaries such as those of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO reports, ICES 2005-2008). A table giving an overview of invasions detected after 2004, and two regional seas examples are annexed to this briefing.

Since the adoption of the Ballast Water Convention, invasions have continued to be reported with at least 24 newly established or greatly expanded ranges of invasive species recorded in areas across the world (see Annex 1). These include some of the worst invaders recorded, such as:

- the **North American comb jellyfish** that helped to virtually wipe out anchovy and sprat stocks in the Black Sea in the late 1980s and that has now spread to and continues to expand in the Caspian Sea as well as in the North Sea and the Baltic Sea².
- the **Red mysid shrimp**, a native to fresh and brackish waters around the Black and Caspian Seas, now in the Baltic Sea, the Rhine River (Germany) and discovered in the North Sea spreading from the Netherlands in 1997 to Belgium, France, England, and Ireland. Within two years of its 2006 arrival in US Lakes Michigan and Ontario from Europe, it spread to the St Lawrence River as well as all of the lakes except Superior. Significant impacts on the ecosystem are feared due to its wide diet that includes zooplankton and algae.
- the **Chinese mitten crab**, now found in estuaries and rivers bordering the North Sea, Baltic Sea and the North American Atlantic and Pacific coasts, causing greatly altered habitats and erosion of river banks due to its extensive burrowing habits, as well as clogging of industrial water systems. The economic impacts in Germany alone are estimated to total €80 million.

Ballast tanks can also transport large numbers of bacteria and viruses, with hundreds of trillions of micro-organisms capable of accumulating in a single tank, of which a minority can pose potential public health risks such as cholera and intestinal pathogens such as *Giardia duodenalis*.

What is the solution?

Management practices and technological treatment systems that prevent invasions are a far more practical and cost-effective approach to the problem of invasive species

² The presence of the North American comb jelly (*Mnemiopsis leidyi*) in the northern part of the Baltic Sea is currently under investigation, as there is a possibility that the detected comb jelly here may in fact be another potentially invasive species originally from the Arctic. Until this has been established scientifically, this report considers the alien comb jelly in the Baltic Sea as *M. leidyi* as has been reported by HELCOM.

transported in ballast tanks than clean-ups once a species has been discovered and may already be established in a new area.

Unilateral actions of individual States will lead to inequitable distribution of both costs and environmental impacts, to the detriment of efficient and environmentally sustainable global trade. A collaborative effort to develop a suitable instrument for managing ballast water on an international basis was undertaken under the guidance of the International Maritime Organization (IMO), with the key aim of circumventing the need for concerned port States to take further unilateral actions on ballast water control.

These international efforts led to the adoption by the 168 member States of the IMO of the *Convention on the Control and Management of Ships' Ballast Water and Sediments* (the Ballast Water Convention), to put an end to the problem with invasive species transported in ballast water. The IMO Member States recognise it forms the only instrument at hand provides the means to minimize the ballast-mediated spread of invasive species in a coherent, safe and efficient fashion by enabling:

- consistency and planning confidence to regulators, ship owners and equipment manufacturers
- development of a set of design and operation guidelines for Administrations, port State control, ship operators, classification societies and treatment system developers and vendors

However, the Convention will not enter into force until it has been ratified by at least 30 States that represent at least 35% of the world's registered merchant shipping tonnage. By 30 June 2009, 18 States representing 15.4% of the world's shipping tonnage had ratified the Convention³.

Of the world's 40 largest flag States, together holding 92.5% of global registered merchant shipping tonnage, only five (Liberia, Norway, Antigua & Barbuda, France and Spain) had ratified the Ballast Water Convention as of 30 June 2009. And of the top ten flag States, only one, Liberia, had ratified, with Panama (the world's largest flag State with 22.6% of registered merchant shipping tonnage), Bahamas, Greece, Singapore, Hong Kong, Marshall Islands, Malta, Cyprus and China yet to ratify.

What the shipping industry wants

Until the Ballast Water Convention comes into force, ship owners and fleet managers cannot progress ballast water management in a consistent, business-predictable and safe manner, and without fear of their ships having to operate different procedures,

³ Upon ratification, the Convention will supersede the current *Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens* (as adopted in 1997 by IMO Resolution A.868 (20)). These are voluntary and focus on ballast water exchange and reporting.

equipments and performance standards when trading between different countries, or even different ports within a single country.

Furthermore, the lack of a globally ratified Ballast Water Convention restrains the incentive for research and development of approved treatment systems.

This is a major concern to the industry, which has been trying to alert important trading nations to the fact that, compared to a mixture of various unilaterally imposed codes and requirements by individual nations, States and regional groups of States, a single set of consistent international guidelines for ballast water management will not only provide more effective control but also minimise logistical and economic costs to international shipping and global trade.

By and large, most ship owners and fleet managers want to avoid transferring potentially harmful species from port to port, but without jeopardising ship and crew safety and/or incurring delays, extended voyages or unfair expenses that reduce competitiveness and efficiencies. Ship owners have welcomed the Convention because it:

- provides the only mechanism for achieving internationally consistent procedures and methods
- accelerates investment, research and development into ballast water treatment systems
- provides for other management methods and future alternatives, including:
 - discharge to shore- or barge-based treatment facilities (potentially practical for some liner and long period charter bulk liquid routes)
 - future innovative hull designs, such as ‘continuous ballast flow-thru’ and ‘ballast-free’ solutions

Ballast water treatment systems – how do they work?

More than 80 manufacturing firms, water treatment companies and maritime businesses have undertaken research and development, testing and trialling work of ballast water treatment technologies since 2000.

A number of forward-thinking shipping and ship-building companies have also supported this effort, including ship operators headquartered in Australia, Brazil, Canada, Germany, Japan, Korea, New Zealand, Norway, Sweden, UK and US who have assisted in shipboard trials and in some cases laboratory testing.

Twenty ballast water treatment systems have been passing through the Convention’s approval process since 2006, eighteen of which have sought approval owing to their use of chemicals. Twelve treatment systems may have achieved their final approval by the IMO Marine Environment Protection Committee (MEPC) in 2009, with six

having obtained type approvals by national administrations and are thus ready for the market⁴.

The modular treatment systems now coming on to the market are sufficiently compact to fit in or around most engine rooms and the majority involve pre-treatment and end-treatment as follows:

- 1) During ballasting, the inflow is passed through filter/s to remove larger organisms, sediments and other suspended solids.
- 2) The filtered water is then subjected to the main treatment which kills or inactivates the small organisms that had escaped filtration.
- 3) At the end of the voyage the ballast water is subjected to a repeat treatment prior to its discharge, so as to destroy any organisms that may have regrown in the tanks during the voyage.

Ballast water treatment systems

Treatment systems available to date can be placed into one of three categories:

- Systems that do not require or produce biocidal chemicals. Systems in this category include filtration plus UV, oxygen stripping and pH reduction, and magnetic filtration.
- Systems that use advanced oxidation, electrolysis or oxidative chemical dosing modules to produce short-lived radicals (OH[•], O₃, ClO[•]) that decay without producing long-lived toxic end-products.
- Systems that generate chloride ions – typically by electro-chlorination – that can produce long-lived end-products at potentially toxic concentrations, therefore requiring adequate decay time or sulphite treatment, particularly if the organic content is high.

The cost of treatment systems

The operational costs of a ballast water treatment system will vary according to ship type and size, as well as the type of system that is selected. Preliminary cost estimates have ranged from 2 USD cents per tonne of treated water to possibly as much as 40 USD cents per tonne depending on system type, but this broad range can be expected to narrow to the 4-20 USD cent range and possibly less as more systems come on to the market. Capital cost estimates for installation onboard range between USD150,000 and USD500,000; extending to USD1 million for systems installed on very large carriers.

However the total installation cost for a particular ship will also vary according to the number and arrangement of its ballast tanks and the difficulty of the retrofit. For the owners of large bulk carriers that have many topside tanks that gravity drain directly

⁴ For an up-to-date list of approved treatment systems and how the approval process works, please consult www.imo.org under Marine Environment/Ballast Water Management/BWM Technologies

to sea, the installation cost for systems that can achieve the performance standard without a 'follow-up' treatment at the time of discharge, can be expected to be financially attractive.

The estimated cost of equipping a new ship as it is being built with treatment technology may be up to 40% cheaper than retrofitting that ship with the same technology later in its life cycle. This should be a powerful incentive for ship owners to ensure new ships are fitted with technology to treat ballast water ahead of the obligations imposed by the Ballast Water Convention once in force.

The cost of NOT treating ballast water

Using the estimated figure for direct global economic loss to society for damage caused by invasive species of USD7 billion per year and the figure of 10 billion tonnes of ballast water used every year by international shipping (see page 2), we can calculate a cost per tonne of untreated ballast water at 70 USD cents. Thus, the cost to society of not ensuring ballast water treatment is at least 350% higher than that of fitting adequate treatment onboard vessels, using the higher estimate for cost of treatment.

A wide roll-out of treatment technology facilitated by the entry into force of the Convention could lower costs to only 4 US cents per tonne of treated water – less than 6% of the annual costs of damage done.

Add to this the fact that the Convention puts the cost of fitting treatment technology on board onto the ship owner, not on society, according to the Polluter Pays Principle.

Why have States not ratified?

Many of the IMO member States have recognised the need to ratify the Convention as soon as practically possible, so as to facilitate its timely entry into force. However many of these States have been confronted by issues that made them reluctant to ratify the Convention during the years following its 2004 adoption. An early entry into force has been perceived as having the potential to cause many disruptions, inefficiencies and technically ineffective yet potentially costly solutions to both the shipping industry and administrations of the ratifying parties.

The complexity of the Convention and its overly optimistic schedule regarding the availability of approved ballast treatment systems (in time for the first installations to have occurred from 1 January 2009), were not fully appreciated at the time of its adoption.

The main issues holding back many States from ratifying the Convention have been: lack of agreed guidelines; insufficient cooperation between States that share shallow or enclosed seas; the need for assistance to developing and emerging States to develop legislation and management procedures; the need adequate testing and approval mechanisms for treatment systems, and a lack of for economically viable and effective technical solutions.

The main issues are resolved

Substantial progress has been made in the last two years on resolving the obstacles and issues that were making many countries hesitate to ratify the Convention, despite the announced intentions by many of them to do so.

The main obstacles that had drawn concerns from member States and how the level of progress on these issues has ensured these are no longer justified reasons for postponing the ratification of the Ballast Water Convention are explored below:

- *Completion of the Convention's Guidelines:* All of the significant guidelines needed to operationalize the Ballast Water Management Convention were fully drafted by 2007 and completed in 2008. Further guidance on how port State control should respond to any ballast water 'emergency' has also been circulated in 2008. Even if some of the more technical aspects of the guidelines receive further fine tuning, there has been more than sufficient information for countries to complete any outstanding regulatory impact assessment by the earliest date the Convention could come into force.
- *Collaborative preparations and arrangements by States that share shallow and/or enclosed seas:* Countries bordering the Arabian Gulf region, the Baltic Sea and other shallow sea areas off northwest Europe have completed their reviews and road maps towards ratifying the Convention (facilitated by ROPME, Helcom and OSPAR) and are already in the process of implementing interim, risk-based ballast water measures in anticipation of the Convention's entry into force. The detailed work achieved by these countries is fully accessible and provides excellent models to other regional seas groups, many of which are now working on these preparations as part of the GloBallast Partnerships⁵ programme.
- *Support for regional seas groups that include emerging and developing countries:* emerging and developing countries in the Mediterranean/Adriatic, Black Sea, Caribbean, western African, south-east Pacific and south-west Pacific regions have been taking advantage of the training and capacity-building support provided by the Globallast Partnerships programme since 2008 (and in many cases the individual support provided by IMO during 2005-2007). By using the detailed road maps and arrangements developed by the more advanced regional sea groups as models, much time and duplication of effort can be avoided. At least some of the country groups, such as the Adriatic and Caribbean, appear capable of achieving at least interim agreements and working arrangements before the end of 2010.
- *Treatment technology testing regimes and approvals procedures:* The initial procedural issues and bottlenecks that constrained the testing and approval of ballast water treatment systems during 2005-2007 have now been ironed out, and

⁵ The GEF/UNDP/IMO Global Ballast Water Management Programme (GloBallast) is assisting developing countries to reduce the transfer of harmful aquatic organisms and pathogens in ships' ballast water, implement the IMO Ballast Water Guidelines and prepare for the IMO Ballast Water Convention. <http://globallast.imo.org>

the MEPC and flag State administrations have continued to work on smoothing out and accelerating the approvals process during 2008 and 2009. This can be testified by the record number of system approvals reviewed at MEPC 59 in July 2009, and the high probability that at least six systems, as developed by six different manufacturers, will have gained their G8 type approval status before the end of 2009. Final testing of at least three ballast water systems will also be well underway under the US STEP program before the end of 2009.

- *Ensuring there is a sufficient range and supply of treatment system units available on the market for installing on new ships:* IMO Assembly Resolution 1008.(5) was passed in November 2007 so as to exempt new ships constructed during 2009 with a moderate ballast capacity to fit treatment onboard. Should the Convention enter into force in January 2011, the need to exempt ships whose construction starts prior to the entry into force date can be readily accommodated by the two options that are available for amending its schedule. This exemption is not a precedent, and can follow the same principles that were applied to the ships whose construction started after 1 January 2009.

Conclusion

A rapid entry into force of the IMO Ballast Water Convention is essential to prevent further spread of invasive species and their potentially devastating impacts on ecology and economy in areas where they do not belong.

The cost to society of continuing to not implement global ballast water management procedures will continue to rise as international shipping grows.

The Ballast Water Convention provides the set of internationally consistent practices, standards and guidelines needed for effective control of ballast water management, as well as minimises the logistical and economic costs to international shipping and global trade of complying with various national ballast water regulations.

Of the world's top 10 flag States, only one, Liberia, had ratified by 30 June 2009. Should Panama (the world's largest flag State with 22.6% of registered merchant shipping tonnage) ratify the Convention, the tonnage condition for its entry into force would be fulfilled (35%), with another 11 flag States' signatures (regardless of the size of their registry) sufficient to fulfil the required number of signatories (30).

Given the advances in ballast water management and treatment technologies that have been made in recent years, including the range of treatment systems now coming onto the market as a result of the treatment technology approval procedures being operated by the IMO and an increasing number of flag States, it is not unreasonable to argue that the Convention should be ratified by all IMO member States, so it can enter into force by January 2011.

Responsible flag States must also ensure effective implementation of the Convention to ensure all ships under their flags are fitted with the appropriate technology in order to stem new invasions.

The interval between now and 1 January 2011 will provide sufficient time not only to ensure that enough treatment systems produced by a variety of manufacturers and vendors will reach the market, but also for any ratifying country that is prepared to make a genuine effort to complete its legislative preparations, risk-based collaborative arrangements and an institutional framework for operating the Convention, including countries that share a regional sea or waterway in Europe, the Middle East or the Americas.

In addition, indicative costs of installing treatment technology to avoid transferring invasive species across the globe in ballast water onboard new vessels provide an economic argument for ship owners to do so already now, rather than to wait to retrofit all vessels once the Ballast Water Management Convention enters into force.

Time for action

WWF urges all IMO member States and especially States operating a shipping register to ratify and implement the IMO Ballast Water Convention immediately, with large flag States having a particular responsibility to do so.

WWF also asks responsible ship owners and operators to:

1. Fit all vessels with appropriate technology to remove harmful invasive organisms from ballast tanks, in preparation for the Ballast Water Convention's entry into force
2. Choose to register their vessels under flags that have ratified and implemented the Ballast Water Convention and other international marine conventions

Annex 1

Examples of post-2004 species introduction and spread

Part 1: Examples of species with strong to moderate links to ballast water	
<p>North American comb jelly <i>Mnemiopsis leidyi</i></p>	<p>Increasing capture records and abundance have been reported in the North Sea (Netherlands), Germany and Sweden from 2004-2005. It may have first appeared in the southern North Sea as early as the late 1990s, but mis-identified as a native species. In 2006 it was recorded for the first time in the northwest Europe (Kiel Bight (Baltic Sea), Norway and Swedish west coast waters), becoming more abundant during 2007 and appearing in other parts of the Baltic Sea. It has continued to spread eastward in the Baltic⁶.</p>
<p>Australian spotted jellyfish <i>Phyllorhiza punctata</i></p>	<p>Appeared for the first time in US Texan waters in 2006, and has extended its range north-eastward to western Florida. It continues to threaten large commercial shrimp and crab fisheries in the Gulf of Mexico. It is vectored by ballast water and its introduced range now includes the eastern Mediterranean, Hawaii, Brazil, Puerto Rico, much of the Caribbean and parts of the Gulf of Mexico (GISP database).</p>
<p>West Atlantic brackish clam <i>Rangia cuneata</i></p>	<p>First reported in Belgian waters in August 2005 (as a few small individuals in Antwerp harbour), and then found in vast numbers at this port in 2006. This is a new invader to European brackish waters, and the Belgian records represent the first well established population of <i>R. cuneata</i> beyond its native range (Gulf of Mexico). It is considered to be vectored by ballast water, but was introduced to the Atlantic coast of North America via oyster aquaculture.</p>
<p>Conrad's false mussel <i>Mytilopsis leucophaeata</i></p>	<p>First noted in Finnish Baltic waters in 2004 and now expanding its range, with the largest numbers centered on cooling water outfalls of power plants in 2006. Its original native range is cloudy (possibly Gulf of Mexico, eastern N America or even West Africa), with its hopping spread linked to ballast water (Laine et al 2006).</p>
<p>Zebra mussel <i>Dreissena polymorpha</i></p>	<p>This nuisance fouling mussel native to the drainage basins of the Black, Caspian and Aral Seas has continued to expand its invasive range in North America and Western Europe since 2004, and was first recorded in North Wales in 2006.</p>
<p>Asian green mussel <i>Perna viridis</i></p>	<p>This nuisance fouler appeared in the Caribbean in 1989, has continued to expand its range within the Caribbean and northward along the US Atlantic coast, reaching South Carolina for the first time in 2006.</p>
<p>North Asian amphipod <i>Corophium insidiosum</i></p>	<p>Recorded for the first time in Irish waters in 2006 (Reid et al. 2009).</p>

⁶ See footnote 2 on page 5

<p>Gammarid amphipod <i>Gammarus tigrinus</i></p>	<p>A West Atlantic invasive that has recently appeared in Finnish waters, expanding its range between 2005 and 2006, and found for the first time and in high abundance at Helsinki (Gulf of Finland) during summer-autumn 2007. Now firmly established in the northern Baltic, outcompeting and replacing native herbivorous <i>Gammarus</i> spp. Future impacts may include increased algae, already abundant due to eutrophication.</p>
<p>Gammarid amphipod <i>Hyale spinidactyla</i></p>	<p>Found at the Spanish Atlantic coast for first time in 2006 (ICES 2007).</p>
<p>Fish-hook water flea <i>Cercopagis pengoi</i></p>	<p>Native to the Ponto-Caspian region, and has spread by ballast water to the waterways of East Europe, Baltic Sea, the Great Lakes and the US Finger Lakes. Clogging nets and fishing gear, this voracious predator competes with native planktivorous invertebrates and vertebrates, with potential to reduce the abundance of zooplanktivorous fish and their larvae.</p>
<p>Asian skeleton shrimp <i>Caprella mutica</i></p>	<p>Expanded its distribution and abundance in both Canada and western Europe during 2005-2006, including first records in Ireland in 2003 and Scotland, plus increased densities in southern North Sea harbours such as Zeebrugge. Its first record in Canada (Baie des Chaleurs) in 2003 and has since appeared in the Canadian Magdalen Islands in 2005. It has been colonising mussel culture facilities but its impact on Canadian mariculture harvest sizes remains unclear.</p>
<p>Indian Ocean skeleton shrimp <i>Caprella scaura</i></p>	<p>Recorded for the first time on the Iberian peninsula (Girona, Spain) in July 2005, most probably vectored by ballast water. Originally described from Mauritius, it has a large introduced range including the Western Atlantic and, more recently, parts of the Mediterranean (e.g. McCain 1968, Serejo 1998, Martínez & Adarraga 2008).</p>
<p>Tanaid shrimp <i>Hexapleomera robusta</i></p>	<p>Recorded for the first time on the Spanish Atlantic coast at Guipuzcoa in 2006 (ICES 2007).</p>
<p>Red mysid shrimp <i>Hemimysis anomala</i></p>	<p>Native to fresh and brackish waters around the Black and Caspian Seas, and the 6th aquatic Ponto-Caspian species to reach Ireland (Minchin & Holmes 2008). It has been found in the Baltic, the Rhine River (Germany), Netherlands, Belgium, France, and then England in 2004, and Ireland in April 2008 (Minchin & Holmes 2008). Within two years of its 2006 arrival in the US Great Lakes (Michigan and Ontario from Europe), this shrimp spread to the St Lawrence River as well as all of the lakes except Superior (Kestrup & Ricciardi 2008). Significant impacts are feared due to its wide diet that includes zooplankton and algae. Swarms in some European reservoirs have accelerated silica cycling, diatom blooms and silica deposition (www.glerl.noaa.gov).</p>
<p>Asian shrimp <i>Palaemon macrodactylus</i></p>	<p>A hardy shrimp with a wide temperature tolerance, invaded north-west America from its East Asian home range via ballast water. It also established in UK rivers and estuaries (1990s) then spread (first record for Belgian coastal waters was 2004 (Zeebrugge) then 2005 for Netherlands and Germany (e.g. Gonzalez et al. 2007).</p>

<p>Chinese mitten crab <i>Eriocheir sinensis</i></p>	<p>Found for the first time in the Venice lagoon in May 2005, then subsequently recorded in southern Wales and southern Ireland in 2006, implying its continued ‘clockwise’ spread around the British Isles. Now found in estuaries and rivers bordering the North Sea, Baltic Sea and Atlantic coasts, to as far as 700 km upstream (River Elbe, Germany). First appeared in North America in the 1980s and then spread (e.g. San Francisco Bay in 1992, Detroit River, Great Lakes). Found for the first time on the US Atlantic Coast in 2006. Its native range is temperate rivers and estuaries from western Korea to China, bordering the Yellow Sea. Ballast water is a key vector.</p>
<p>Asian shore crab <i>Hemigrapsus sanguineus</i></p>	<p>Reported for the first time in Belgium coastal waters in 2005 (Knokke Heist) then again in 2006 (Nieuwpoort), the year when it was also found in northern France, with ballast water the suspected vector. Native to East Asia, its introduced range includes parts of Europe (France, Netherlands, Croatia) and Atlantic North America from Maine to North Carolina. Ballast water is one its vectors due to its month long larval life. It has a broad diet and is feared to reduce native species populations by disrupting food webs and direct competition with native crabs (Benson 2008).</p>
<p>West Atlantic blue crab <i>Callinectes sapidus</i></p>	<p>Recorded in 2005 on the Spanish Atlantic seaboard, plus many captures off the Belgian coast (ICES 2007). Resident populations believed established at southern North Sea ports (Netherlands, Belgium, France), with adults moving into coastal waters to reproduce. Ballast water is suspected as a key vector since this species often appears in or close to a busy port where ballast discharges frequently occur. Invading Japan plus Adriatic, Mediterranean and Aegean Seas, with records for Greece, western Turkey and recently the Dardanelles (Tuncer & Bilgin 2008).</p>

<p>Part 2: Microbes</p>	
<p>Toxic dinoflagellate <i>Alexandrium minutum</i></p>	<p>This planktonic ‘red-tide’ microalgae originates and is widespread in the coastal waters of all Europe (Northeast Atlantic, North Sea, Baltic Sea, Mediterranean and Black Sea), and now present in the South China Sea, south-eastern Australia, New Zealand and more recently New York (in Guiry 2006)⁷.</p>
<p>Bacteria and viruses</p>	<p>Work since 2004 by Dobbs <i>et al</i> has confirmed presence of large numbers of bacteria and viruses in ships’ ballast tanks, of which a minority can pose potential public health risks such as <i>Vibrio cholerae</i> (cholera) and intestinal pathogens such as <i>Cryptosporidium parvum</i> and <i>Giardia duodenalis</i>.</p>

Part 3: Examples with moderate to weak links to the ballast water vector	
Black pygmy mussel <i>Xenostrobus securis</i>	First recorded on the Spanish Atlantic seaboard in 2005 (Garcil et al. 2007). Very high concentrations are colonising estuarine waters, and settling on numerous colonies of economically-important blue mussels.
Veined whelk <i>Rapana venosa</i>	Has continued spreading in American and Mediterranean regions plus Argentina and Uruguay coastal waters, was recorded in the North Sea (Netherlands and UK waters) for the first time in 2005 and has since spread further. It is predicted to become a severe competitor for native whelks and may also impact blue mussel and oyster mariculture. Ballast water is a possible vector (e.g. Harding & Mann 2005; USGS-NAS, undated).
Asian pencil crab <i>Hemigrapsus penicillatus</i>	First discovered in France in 1994 then spread to artificial shore substrates in north France and Belgium by 2003, this crab has increased its range and abundance, being found on the Spanish Atlantic seaboard in 2006 and trawled for the first time from natural seabed habitats off Oostende in 2006. Infestation densities up to 20 crabs/m ² can cause significant impact to native shore-line and near shore communities by predation and competitive feeding. Its native range is from north Japan to China and its vectors include both ballast water and hull-fouling.
Lionfish <i>Pterois volitans</i>	This ornamental but poisonous and predatory Indo-Pacific reef fish was probably initially introduced to tropical coastal waters of the Western Atlantic via aquarium release, but subsequent spread of its eggs or larvae by ballast water is considered possible (e.g. Whitfield 2002). Since 2004 it has continued to expand its range and abundance in the Caribbean and Northwest Atlantic at an alarming rate, as far north as Massachusetts (Waquoit Bay) in 2006. Now found on the coastal reefs of mainland Central America and South America (including Colombia and Costa Rica in 2009), its potential impacts to native reef fish and ability to spread rapidly are the focus of several ongoing research efforts.
Round goby <i>Neogobius melanostomus</i>	This fish from the Ponto-Caspian basin ⁸ was recorded for the first times in Finnish waters and in the North Sea (Netherlands) in 2005 (e.g. van Beek 2006). It has been spreading within both the Baltic Sea and the Great Lakes regions, and ships' ballast water is one of its vectors (e.g. in van Beek 2006).

⁸ This biogeographic region extends from the Dniepr River to the Ural (30° to 55°E) and from the Black Sea and the Caucasus to the taiga belt (45° to 55°N)

Annex 2

Two regional case studies

1. *The Baltic Sea*

The Baltic Sea is a young and relatively simple ecosystem, and therefore particularly vulnerable to invasion and ecological change, as new species can relatively easily find unoccupied ecological niches. The present eutrophic (nutrient overloaded) conditions and rapid expansion in shipping have heightened the risk of new invasions that may increase present stresses on the ecosystem.

Shipping activity to, from and within the Baltic Sea has steadily increased over the past 20 years, reflecting increasing international trade, co-operation and economic prosperity. The Baltic Sea today has some of the busiest shipping lanes in the world. At any one time some 2,000 sizeable ships are at sea within the Baltic, including large oil tankers, container ships, cruise ships and RO-RO ferries.

The increase in shipping has caused more non-native species to find their way into the Baltic Sea than before. Over 120 non-native aquatic species have been recorded in the Baltic Sea to date, 80 of which have established viable, self-reproducing populations in at least some parts of the region

Most of the introductions have arrived from freshwater or brackish-water environments in the Ponto-Caspian and from North America. The majority are considered the result of ballast-mediated introductions (and in the case of small vessels that use canals, possibly also their bilge water).

In the southern Baltic Sea, non-native species have repeatedly altered local ecosystems, with the more hardy invaders becoming dominant in polluted areas. Non-natives with high pollution tolerance have outnumbered or replaced native species, and in turn have also become replaced by more recent, hardier newcomers.

Of the eighty species that have firmly established in the Baltic, the impacts of four have been highlighted by the Helsinki Commission (HELCOM) as examples of the invasive species problem, and three of these have been listed in a recent study⁹ as having a high to very high invasive potential:

The Ponto-Caspian water flea (*Cercopagis pengoi*). Fishing operations in the eastern Baltic were disrupted in the 1990s following the arrival of the predatory water flea, causing serious economic losses by clogging the gills of fish and fishing nets and by competing with herring larvae for zooplankton prey. By 1998 it had spread as far as Stockholm and Gotland, and was exceptionally numerous in the Bothnian Bay in the warm summer of 2002. ***Very high invasive potential.***

The North American polychaete worm (*Marenzelleria viridis*) lives in seafloor sediments. First recorded in the southern Baltic Sea in 1985, it then spread northward to the Bothnian Bay. Initially restricted to shallow coastal areas, it began colonising the deeper waters of the Bothnian and Åland Seas in 2000–2002 and is now well established in the Bothnian Bay

⁹ See footnote 1 on page 4 for explanation of score.

where it can out-compete the few species that form the native benthic community. ***High invasive potential.***

The dinoflagellate (*Prorocentrum minimum*) is potentially toxic and arrived in the Baltic Sea in ships' ballast water or by currents. It is now well established in the southern Baltic Sea and, in summer 2002, formed blooms in the Archipelago Sea along the Finnish coast, and has also been found in the Gulf of Finland. So far there are no records of toxic *P. minimum* blooms in the Baltic Sea. ***Very high invasive potential.***

The North American comb jelly (*Mnemiopsis leidyi*) is fast-growing and consumes large quantities of zooplankton and juvenile fish. First found in the southern Baltic Sea in 2006, it moved into the northern parts of the Baltic basin in 2007 and increasing abundances in the Åland Sea and Gulf of Finland until winter 2008¹⁰. It tolerates very low salinities (to 3 psu) and temperatures (to 4°C), has survived two winters by moving into deep warmer waters, and has no natural enemies in the Baltic Sea. It is now feared to threaten food webs and local fish stocks. (Not included in ranking study)

2. Northeast America

Substantial shipping lanes are located along the eastern seaboard of North America¹¹, with 4,000 ships plying the St Lawrence Seaway, where ships enter the Great Lakes from the North Atlantic, every year. Ballast water and hull fouling have been responsible for almost half of all aquatic species introductions in the St. Lawrence River over the last century. For the Great Lakes, a new introduction in has been discovered on average about once every six months over the past 30 years.

The southern end of the North American eastern seaboard has not escaped bioinvasions, although not on the scale experienced in the Laurentian and Great Lakes.

Here follow some examples of recent invasions in the Northeast American waters.

The Eurasian spiny water flea (*Bythotrephes longimanus*), native to north Europe and Asia, lives in freshwater and was introduced to the Great Lakes via the ballast water of ocean going ships, and has since spread into other inland lakes. It competes directly with native juvenile fish and predatory zooplankton, can foul fishing lines and downrigger cables, and alters native zooplankton community structure.

The Chinese mitten crab (*Eriocheir sinensis*) has been increasingly found in the eastern waters of Canada and US over the past four years. Maritime traffic to the St. Lawrence has been relatively steady, but an average of 42% of the arriving ships come from the same European countries that experienced the recent booms in the numbers of this species (by a factor of ten or more for some countries). The wave of introductions to North America's eastern seaboard has therefore been related to the increased numbers of larvae being transported in ballast water from European ports. While the crab will not establish in the Great Lakes due to the need for saline waters to breed, there are fears that significant populations will establish in the St Lawrence Seaway. Its burrowing habit causes river banks to collapse, entailing problems to built structures as well as alters habitats and

¹⁰ See footnote 2 page 5

¹¹ From the Gulf of Mexico, Florida and the northern Caribbean waters in the south, to the north-east US, Canada and the Newfoundland and St Lawrence waters in the north.

The Asian green mussel (*Perna viridis*) was discovered in Trinidad in 1991 and subsequently spread to ports in Venezuela, Jamaica, and Florida in 1999, reaching South Carolina in 2006. In December 2008, two small specimens were found adjacent to Panama City. It is a fast growing nuisance fouler of industrial cooling systems, aquaculture facilities, navigational buoys, ships and smaller vessels, and can out-compete many benthic species to alter local communities and food webs, may disrupt oyster and pearl mariculture operations. ***High invasive potential.***



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