Ballast Invaders: the Problem and Response

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Abstract

Most world trade is by ship, conducted by more than 33,000 large cargo ships. To maintain stability these ships carry ballast water, drawn from ports and bays. This water contains organisms, sometimes including fish, shellfish, worms, algae and dangerous diseases. 10 billion tonnes of water are moved around the world each year, and each day there are 7,000-10,000 species of organism travelling in ballast water.

When ballast is dumped, organisms are released, and every nine weeks an invasive species establishes somewhere new. The International Maritime Organization (IMO) recognizes that these invaders pose a grave threat to human health, industry, and global biodiversity. By one IMO estimate, marine invaders are costing the world tens of billions of US dollars each year.

Ballast invasions have caused the deaths of more than 10,000 people from cholera in South America, contributed to the collapse of the Baltic Sea fisheries, and pose an imminent threat to the Amazon River ecosystem. The rate if invasion is increasing as world trade grows.

No satisfactory method has yet been found to kill or remove ballast organisms. As an interim measure, the IMO recommends ballast water exchange at sea, a process that reduces but does not stop invasions.

The IMO has developed a Draft International Convention for the Control and Management of Ships' Ballast Water and Sediments, which will require ships to practise ballast exchange. But cargo ships will continue to spread invasive species, especially on their hulls, a problem the IMO has not addressed.

Ships that carry ballast water should pay a tax or levy to pay for the problems they create. The money should pay for research into solutions and compensate those who suffer from ballast invasions.

Introduction

The world is moving towards globalization, a system that encourages the free trade of products between countries. As more and more products move around the world, more and more pests travel with them – for example insects in foods and diseases in livestock. Globalization is creating a world of ever-worsening pest problems.

Animals, plants, or diseases that travel from one country to another – called 'invasive species' or 'alien species' - are ranked by experts, including the executive director of the United Nations Environment Program, as the greatest threat to global biodiversity after habitat destruction. They also pose a grave threat to humans.

Most international trade (more than 80 per cent) is by ship. Lloyds Register of Ships lists more than 91,000 vessels globally. More than 33,000 of these are large ships that travel between countries carrying food, minerals and other goods. It is inevitable that these ships accidentally carry small organisms – such as insects, insect eggs, snails and seeds - hidden among their cargo. Of equal concern are the animals and diseases travelling in the ballast water carried by ships.

Ballast is water pumped into the ballast tanks of a large ship to keep it balanced and stable at sea. Cargo ships are designed to carry very large weights, and a ship without a heavy load cannot travel safely. If cargo has been removed at a port and the ship is leaving without a full load, water from the port is pumped into its tanks at the base of the ship to keep it stable. The water passes through intake hatch covers with holes 1-1.5 centimetres wide, and the water always contains small animals, algae, bacteria and viruses, some of which are still alive when the ballast tanks are emptied somewhere far away.

Big ships carry enormous amounts of water. A typical cargo vessel carries 4,000 tonnes when its tanks are full. By volume, a ship's tanks may hold 200,000 cubic metres of water, equal to 2,000 Olympic-sized swimming pools. The International Maritime Organization estimates that 10 billion tonnes of water are moved around each year. Every day, by IMO estimates, 7,000-10,000 species of organism travel in that water, and every nine weeks, an invasive species establishes somewhere new.

Life forms carried in ballast water include small fish, shellfish, worms, starfish, crustaceans, algae, bacteria and viruses. Both marine and freshwater organisms are included, depending upon where the ship took on ballast water.

Ballast organisms are becoming a major world problem. Some of them kill people, destroy fish and shellfish farms, and dominate marine and freshwater ecosystems. The problem is quickly growing worse because there are more and more ships travelling the seas (world trade nearly doubled between 1970 and 1996), the ships are larger, and they are travelling faster, improving the chances of organisms surviving journeys in ballast tanks.

The problem is also worsening because many countries have reduced pollution in their harbors, so that harbor waters now contain more animal and plant life. Steve Raaymakers of the IMO has declared that "The transfer of invasive marine species in ballast water is perhaps the biggest environmental challenge facing the global shipping industry this century."

Case Studies

In 1991, a cholera epidemic struck Peru, the first in Latin America for more than a century. Several million people were infected and more than 10,000 died. Over the next four years Latin American governments poured more than US $200 billion into emergency repairs to sewage and drinking water systems. Peru lost $1 billion in seafood exports and tourist income. This type of cholera was traced back to ballast water carried from Bangladesh. During the 1990s ships going from Latin America to other countries were found with this cholera in their ballast water.

Despite these events and other disease outbreaks attributed to ballast water, and growing concerns about new diseases, Gloria Casale of the US Health Resources and Services Administration has noted that "the importance of ballast water as a source for the transportation and introduction of disease is largely ignored… Ballast water is a biological time bomb liable to engender significant disease in vulnerable populations anywhere in the world."

In 1982 Leidy's comb jelly (*Mnemiopsis leidyi*), which comes from estuaries in North and South America, was found swimming in small numbers in the Baltic Sea. Within six years it had become the dominant animal there, reaching densities of up to 500 per square metre, and a total biomass of 900 million tons, making up 95 % of the biomass in the sea.

This small jelly-like animal eats other animals including small fish. The Baltic Sea was already polluted and overfished when it arrived in ballast water, and it helped trigger the collapse of most fishing industries in the Baltic. The loss it imposes has been estimated at $500 million per year. It has since spread to the Caspian and Mediterranean Sea, and it poses a serious threat to the biodiversity of the Caspian, where many endemic species occur.

The freshwater zebra mussel (*Dreissena polymorpha*) from central Asia arrived in the Great Lakes of North America in 1985 or 1986. By 1993 it could be found from in Canada to Louisiana in the southern U.S. It forms dense colonies on hard surfaces, clogging pipes, fouling fishing gear, buoys, boats and cooling systems. It smothers clams, and extracts so much plankton from the water that other plankton feeders suffer. Between 1989 and 2000 it cost North America between $750 million and $1 billion. It is also invading European canals.

In the late 1980s the Golden Mussel (*Limnoperna fortunei*), native to Asia, was found in the Rio de la Plata between Uruguay and Argentina. Within 10 years it had spread more than a thousand kilometres upstream, and it now threatens the entire Amazon basin. Like the zebra mussel, it forms dense colonies on surfaces. In 1991 its density at one site in Argentina was 5 per square metre. The next year it was 36,000 per square metre, and by 1998 it was 150,000 per square metre.

In Brazil it reaches densities of more than 27,000 per square metre, mainly on the roots of riverbank trees. It blocks pipes and water systems of cities and factories. The Yacyreta hydroelectric plant bordering Argentina and Paraguay has to be closed down from time to time to remove them. When this mussel invades the Amazon it will change the ecology of that river system forever.

These few examples are enough to illustrate that ballast invaders are causing the deaths of many people, the destruction of major fisheries, and major changes to ecosystems. Many more examples like these could be provided. Steve Raaymakers of the IMO stated recently: *"The global economic impacts of invasive marine species have not been quantified but are likely to be in the order of tens of billions of US dollars a year"*.

Some harbors, bays and seas are now completely dominated by animals and seaweeds from other countries. Organisms travel not only in ballast water, but also by attaching to the hulls of ships (barnacles, for example). Often it is not known how a species arrived. When big ports become infected with invasive species they become relay stations, exporting pests all over the world.

The numbers of invasive species in some bays are now very high. San Francisco Bay has more than 200 and perhaps over 350 invasive species. They include sponges, seasquirts, crayfish, worms, barnacles, sea anemones and more than 30 different fish. Every 12 weeks a new species establishes.

In some parts of the bay almost everything is foreign. An Asian clam (*Potamocorbula amurensis*) now dominates the seafloor, living at densities above 2,000 per square metre. It is so good at filtering out plankton that other plankton-feeders suffer, including shrimps and young fish. One fish in the bay, the thicktail chub, has become extinct.

In other examples, Port Phillip Bay in Australia is estimated to support 300-400 invasive species, mostly from the North Atlantic, and Humboldt Bay in California has 95.

History of Response

The world has been very slow to wake up to the ballast problem. Speculations about ballast water date back some decades, but not until 1975 did biologists first study a ship's tanks after a voyage. A major review of ballast biology was published in 1985 by James Carlton. In 1993, in the journal *Science*, James Carlton and Jonathon Geller warned: "Transport of entire coastal planktonic assemblages across oceanic barriers to similar habitats renders bays, estuaries and inland waters among the most threatened ecosystems in the world".

In the 1980s and 1990s disasters in many countries were blamed on ballast water invaders. There was the cholera epidemic, and many poisonings from toxic dinoflagellates (planktonic algae that infect oysters and other shellfish); each year about 2,000 people are poisoned and many die. There were many new pests attacking shellfish beds and devastating fish and shellfish farms. The evidence suggested a very serious problem that was quickly worsening as world trade grows.

In 1989 the International Maritime Organization formed a ballast water working group. The IMO is a specialized agency of the United Nations responsible for international ship safety and the prevention of marine pollution. In 1990 Australia became the first country to introduce voluntary guidelines requesting ship owners minimize the ballast risk.

Several other countries have since brought in ballast laws. In 1992 the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro called on the IMO to take action over ballast. Member nations of the IMO developed voluntary guidelines for management of ship's water, adopted in 1997 (see www.imo.org). The IMO has also joined with the United Nations Development Programme and other organizations to help less-industrialized countries improve ballast management.

The regulations introduced by the IMO and by some member countries reduce but do not prevent ballast invasions. Ship captains are expected to avoid taking ballast water from high risk locations (near sewage pipes, for example), and to exchange ballast water at sea.

Reballasting

Reballasting - exchange of ballast water out at sea - has become the main method to reduce the risk of ballast invasions. Ballast tanks that were filled in a harbor are refilled at sea with ocean water before a ship reaches its next port. The tanks are emptied and then refilled, or, if this cannot be done safely (mainly on older ships), sea water is pumped through the ballast tanks until three times the volume has passed through.

The assumption behind reballasting is that organisms found in the deep open ocean are not adapted to live close to shore. Furthermore, water in the ocean is often saltier than water in ports and harbors, and the difference in salinity may kill ballast organisms.

Reballasting comes with many problems. It is slow and labor intensive, adding to the cost of shipping. The ship's loading condition must be carefully monitored. It can only be done in calm seas. There is a risk of error. Some older ships cannot reballast safely, and even new ships cannot reballast in rough seas. Military and other government vessels do not have to reballast. Some journeys are too short for reballasting, or ships do not pass through deep enough water (for example between Mexico and the U.S.).

There are also questions about its worth. Early experiments with dyed water suggested that reballasting removed nearly all the original water. But recent tests have found that organisms from ports remain inside, because reballasting never removes everything from ballast tanks. As well as some of the original water there is often mud and sand that was sucked in with the ballast water from turbid shallow ports; many organisms survive in this. A ship may end up carrying tens of tonnes of sediment.

A survey of 343 ships entering Australia found that two thirds carried sediment, and half of these contained dangerous dinoflagellate cysts in the mud. Also, an organic film grows on the sides of ballast tanks, and this biofilm - a tough polymeric matrix – can contain cholera and other diseases. Some experts say that reballasting can even help ballast organisms by providing more oxygen and nutrients. And the original assumptions, that mid-ocean organisms cannot live near coastlines, and vice versa, and that salinity changes are fatal, are often not true.

The IMO and other organizations agree that reballasting does not solve the problem. Reballasting was adopted quickly, before it had been properly tested, because there was nothing better. Everyone agrees that something much better is needed.

Better Solutions

In recent years, many methods of treating ballast water have been tried - toxic chemicals, heat treatment (from the ship's engine), filtration, electro-sanitization, UV, oxygen removal, ultrasound, ozone, and combinations of these. A Ballast Technology Investment Fair was held in Chicago in 2001.

Companies often come to the IMO with exaggerated and untested claims about their new treatments, none of which has yet proved better than reballasting. Any company that solves the problem will reap enormous profits if their technology is adopted worldwide. The global market has been estimated at almost $10 billion dollars over twelve years. Despite this, investment in research is very low - about $10 million - to solve a problem costing tens of billions. Investors have been discouraged by a lack of international standards of performance.

Steve Raaymakers of the IMO has called for an investment budget of up to $1 billion. He has called for more research into shore-based treatment systems, which, he says, "have tended to be brushed over in international discussions". There are ports in Alaska and Scotland using such systems, he says, "providing clear proof that the engineering and economics are feasible and viable to pump, store and treat on land the huge volumes of ballast water associated with the world's largest oil tankers."

There are two problems to solve. First, a treatment must be found that works, is safe for ships, environmentally safe (non-polluting), and not too slow or expensive. Second, there must be international standards outlining an acceptable level of treatment. It is not expected that any treatment will kill everything inside ballast tanks. Many small (and dangerous) organisms such as dinoflagellates produce tiny protected cysts or other dormant stages that are very difficult to kill by heat or poison, and which are too small to be easily removed by filters. This means that any treatment will be a compromise between practicality and effectiveness.

Ballast Convention

Since the early 1990s the IMO Marine Environment Protection Committee (MPEC) has been developing an international treaty for treatment of ballast water. There is an urgent need to get all countries to introduce uniform laws governing ballast water treatment. At present, some countries have laws and others do not, and differing regulations cause difficulty for shipping companies.

At the 49th meeting of MPEC in July this year, agreement was reached on a *Draft International Convention for the Control and Management of Ships' Ballast Water and Sediments*. This will go to the International Conference on *Ballast Water Management for Ships* in February 2004, for review and adoption. MEPC Chairman Andreas Chrysostomou has declared that "a decision to move forward with the Convention now would be hailed in history as one of the most significant global environmental achievements in the early part of the 21st century".

The convention embraces reballasting despite its limitations. The ballast problem is so urgent that nations cannot wait for anything better. New methods will be tested when they are developed, and endorsed by the convention if they prove effective. In the meantime, many ships will be modified so that reballasting is quicker, safer and works better.

Here are some extracts from the convention illustrating its strengths and weaknesses.
[The square brackets indicate distances for which no agreement has yet been reached.]

"Each ship shall have on board and implement a Ballast Water Management Plan approved by the Administration. Such a plan shall be based on Ballast Water Management Guidelines developed by the Organization. The Ballast Water Management Plan shall be specific to each ship and shall at least:

... whenever possible, conduct such Ballast Water exchange at least [200] nautical miles from the nearest land and in water at least [200] metres in depth, taking into account the Guidelines developed by the Organization;"

The following guidelines will reduce the risk of ships filling their tanks with dangerous ballast water:
"A Party shall endeavour to notify mariners of areas under their jurisdiction where ships should not uptake Ballast Water due to known conditions. The Party shall include in such notices the precise co-ordinates of the area or areas, and, where possible, the location of any alternative area or areas for the uptake of Ballast Water.

Warnings may be issued for areas:

- *known to contain outbreaks, infestations, or populations of Harmful Aquatic Organisms and Pathogens (e.g. toxic algal blooms) which are likely to be of relevance to Ballast Water uptake or discharge;*
- *nearby sewage outfalls; and*
- *where tidal flushing is poor or times during which a tidal stream is known to be more turbid."*

The following guideline deals with the disposal of sediments:
"Each Party undertakes to ensure as soon as practicable that ports and terminals where cleaning or repair of ballast tanks occurs, have adequate reception facilities for the reception of Sediments."

The convention specifies that 95 % exchange of ballast water is acceptable. Ships are not required to exchange ballast water *"if the master reasonably decides that such exchange would threaten the safety or stability of the ship, its crew, or its passengers because of adverse weather, vessel architectural design, equipment failure, or any other extraordinary condition"*.

Nor does the convention apply to **"***any warship, naval auxiliary or other ship owned or operated by a Party and used, for the time being, only on government non-commercial service."*

Limitations of the Convention

The convention will lessen but not solve the problem of marine invasive species, for the following reasons:

- It endorses a treatment - reballasting - that everyone admits has limited value. Even when better technology emerges, many years will pass before this technology is fitted to all cargo ships. Any new technology is not expected to eliminate ballast invasion.

- The convention also fails to consider the problem of organisms travelling on ship hulls. Biologists have assumed that ballast water is the main pathway for marine invaders, but this may not be correct.

- Ship owners until recently protected their hulls from invasive species (which slow down ships by increasing drag) by coating them in paints containing highly toxic tri-butyl-tin (TBT). But TBT is very toxic when it is scraped off ships into harbors, and the IMO has adopted the International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), which will end use of TBT.

- There is already evidence of more organisms now travelling on hulls. Hull travel was probably always substantial, as anti-fouling paints are often poorly applied and maintained, especially on smaller vessels. A study in Hawaii concluded that 212 out of 343 marine exotic species had probably come from hulls. Hull invaders are difficult to stop because they travel on fishing boats and yachts as well as cargo ships, and the IMO is not addressing this problem.

- Marine species also travel in seachests – the water intakes in ships; these sometimes contain shellfish, crabs and worms. A recent New Zealand study found 'compelling evidence' that sea chests are an important pathway for marine invasions.

The Future – A Levy?

Ballast invaders are a form of biological pollution. To address pollution, many economists now advocate a polluter pays policy. For example, the U.S. government imposes a levy on all oil shipments. This money pays to clean-up after oil spills. The levy is a fair tax because it pays for problems created by those who are taxed. The same kind of levy should be imposed on cargo ships to pay for the costs of ballast invaders.

The state of California already imposes such a tax. Its *Ballast Water Management and Control Program* charges $200 for each ship that enters its ports. The $1.6 million it collects each year pays for inspections to ensure that ship captains meet state ballast rules, and some of it funds the California Exotic Species Control Fund, for research, monitoring, and education.

Without such a tax, we are left with an unfair situation, as described by lawyer Peter Jenkins, one who advocates taxes to recover the costs of biological invasions:

"In essence, taxpayers are subsidizing economic globalization by paying to clean up the biological messes it leaves behind. And when government agencies cannot afford to clean them up, our forests, waters, and other resources suffer long-term damage."

Shipowners would pass on the cost of a ballast levy to their customers, which might lead to higher prices for imported goods. These new prices would better reflect the real costs of these products, because they would factor in the harm done by aquatic invasive species.

As noted earlier, IMO technical adviser Steve Raaymakers says ballast invaders probably cost the world tens of billions of dollars each year. This cost should be borne in the first instance by the industry that causes it, which would pass on the cost ultimately to consumers, who would end up paying more realistic prices for imported products.

A ballast levy or tax could be used in many different ways:

1) For research into better methods of treating ballast water. Only $10 million is spent each year when the IMO says

$1 billion is required. More effort should be directed into shore-based treatment methods, as proposed by Raaymakers.

2) To assist developing nations to upgrade their port inspection policies and to train biologists to conduct port surveys and test ballast water. This investment would help wealthier nations because many ballast invaders are exported from developing to developed nations.
3) Better biological information gathering. There should be regular surveys of harbors all over the world to detect new pests, and global databases to share this information, and to share information about their ecological impacts and methods of control.
4) Research into biological control and other methods of controlling ballast invaders.
5) Funding of rapid response teams to eradicate new invaders when they first establish.
6) Research on hull invaders to determine the scale of the problem and the best solutions.
7) Lastly and very importantly, compensation payments for those who suffer from ballast invasions. There should be compensation for loss of health, harm to aquatic resources and aquaculture farms, and funding to repair and protect aquatic ecosystems.

International shipping is an ideal industry for imposition of a levy. When the ballast water convention comes into force there will be close monitoring of ballast water movements by port officials. In many countries there already is.

A tax could be imposed by port officials when they inspect a ship's ballast water management plans. There are only about 33,000 ships moving ballast globally, and these are owned by a far smaller number of shipping companies. A levy could be incorporated into the *Draft International Convention for the Control and Management of Ships' Ballast Water and Sediments* before it is ratified in February next year.

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