Ballast Water and Introduced Species:

(adapted – Management options for Narragansett Bay and Rhode Island

INTRODUCTION

This report was developed to meet ballast water management. It summarizes information using the most recent reports on the issue of ballast water and its relation to introduced nonnative species. Information is presented on the ecological and economic impacts of introduced species, global and national management initiatives, and technologies under development to treat ballast water. The report also presents possible management options that could take to address management of ballast water releases and associated introduction of non-native species.

Introduced Species and Ballast Water

Introduced species are a substantial and growing global threat. Canada and the United States have already been seriously impacted by the introduction of species. It is a problem that has accelerated significantly over the last few decades.

Studies conducted in the United States and abroad have show that the single largest transport of non-native species for the marine environment is the exchange or partial exchange of ballast water from ships as they pass through ports throughout the world. Every year, well over 21 billion gallons of ballast water are discharged into N. American waters, containing between 3,000 and 7,000 species. An individual vessel may carry as many as 150,000 metric tons of ballast water, containing sediment and a variety of organisms from varying corners of the globe. A study of 70 vessels surveyed arriving at ports found that 90% of these vessels carried live organisms in their ballast waters. Ship design generally does not allow for complete exchange of ballast; some water and sediments remain that still have the ability to harbor organisms and bacteria of ballast water through a variety of combined technologies. New technologies to treat ballast water are being studied and tested. Several states that have experienced impacts from invasive species have passed their own ballast water management laws after determining that the existing system of voluntary ballast exchange was not effectively protecting their economic and ecological resources.

BALLAST WATER: OPERATIONS

Ballast is drawn into a vessel by intake pumps located in the hull, below the waterline. It is taken on to provide stability and maneuverability in rough seas, and is used when the vessel is at less than maximum cargo load, either during a transit to pick up a product, or after dropping off a portion of the cargo before continuing on to the next port. Therefore, ballast waters can often be a mix of waters from many ports. It is often discharged in order to raise the ship when entering shallower ship channel areas in port.

Modern Ballast Procedures

The water passes through a grate or strainer and reaches the ballast tank. However, these strainers are not meant to remove small organisms and the grates/strainers are often not well maintained, sometimes allowing even sizable aquatic organisms to be introduced to the tanks. For example, a cargo vessel was found to hold over fifty “actively swimming individuals” of a mullet species, each from 30 to 35 cm long, contained within the ballast water.

In order to decrease the risk of introducing foreign species, a small percentage of ships are now, when feasible and safe, voluntarily exchanging ballast at sea, taking in higher salinity ocean waters (more than 300 km offshore) on the idea that inshore species won’t survive the different offshore environment, and offshore species will be less likely to survive inshore. However, this adds time to the voyage and is therefore a cost to the carrier if undertaken. In addition, the captain always has the right to decide if sea conditions are safe enough for such a procedure. Sometimes sediment remain in ballast tanks even after pumping and provide a home to species (or larvae) that can survive the conditions Some toxic life can take a form that can survive within ballast sediments

BALLAST WATER: SPECIES INTRODUCTIONS AND IMPACTS

Non-native species are introduced and as they evolve, organisms develop dispersal mechanisms in order to spread and expand their population. Entry of an aquatic species into a new environment is a normal evolutionary process when it takes place through a natural transport such as wind or ocean currents. However, it is becoming increasingly common, as a result of human activity, to have foreign species introduced far beyond their normal geographic ranges. Such introductions may set up circumstances that allow a species population to grow unchecked by their natural predators.

In the late 1980's, serious economic losses due to invasion by the zebra mussel in the Great Lakes region finally forced this issue into the spotlight, highlighting the ecological and economic devastation that can be wrought by rapid unchecked growth of introduced species in an aquatic ecosystem. This took public officials by surprise; however, it was too late to take any effective measures by the time the invasion was recognized as having occurred.

Ecological Issues

The success of introduced species can depend on several factors including lack of natural predators, abundance of food sources, better tolerance of pollution (or pollution decreases that allow an invader to get a foothold), disease and other stressors, and out-competing a less aggressive species. While, as stated above, only a small percentage of introduced species become established in a new ecosystem, that establishment can have powerful and far-reaching consequences.

Once successfully established, alien species have the potential to cause many problems, ranging from parasitising important native species, to out-competing local populations for food, to outright predation on important native species. Such ecological changes to the ecosystem are often significantly disruptive to the normal functioning of that system.

Introductions of exotic species have radically altered the structure and biodiversity of ecosystems around the globe. Europe, Australia, New Zealand, Russia (Black Sea), and the U.S. have all experienced major shifts/losses of local aquatic species, human health risk and economic loss of shellfish due to outbreaks of toxic algal blooms or even human pathogenic organisms. It has been estimated that at least 400 aquatic non-native species had become established by 1990.

Introduced species can cause unexpected and unpredictable ripple effects within the food web of an ecosystem. The latter happened in the Black Sea, where a comb jelly species from the U.S preyed on fish larvae as well as their prey food, essentially wiping out the anchovy fishery there.

Human Health Issues

The spread of human pathogens to new areas is considered to be a substantial human health risk. Tests measured levels of bacteria such as *Vibrio cholerae* (which cause human cholera) in the ballast tanks of vessels entering some ports from foreign carriers, and found very high numbers. Their data indicated that viable cell populations of *V. cholerae* can be delivered by ships coming from foreign ports.

Paralytic shellfish poisoning (PSP) results from the consumption of shellfish products contaminated with neurotoxins produced by certain species of phytoplankton (floating microscopic

Several countries around the Pacific Ocean have experienced phenomenal population explosions of a number of toxic species thought to have been transported

ballast sediments. Such "red tides" (a term linked to colouration of the water by the microscopic toxic plants) make the shellfish in the area unsafe to eat for humans, and can also kill fish.

Economic Impacts

In addition to ecological impacts, there are clear economic impacts from introduced species. The OTA report estimates that the cost of prevention and control of these species approaches $137 billion per year . Invasive species can replace an economically important species or cause costly removal/clean-up to water-linked industries (e.g., zebra mussels, which rapidly clog pipes of cooling intakes of power plants as well as drinking water reservoir pipes). Recent figures from the Great Lakes show that tens of millions of dollars are spent each year on zebra mussel control. Great Lakes area nuclear power plants alone spend an additional $825,000 each annually for zebra mussel control.

Introduced fish species (sea lamprey, ruffe and round goby) harm native fish populations and threaten a national sport and commercial fishing industry that is valued at almost $4.5 billion annually and supports 81,000 jobs

Negative economic impacts include lost revenues from lost or damaged fisheries, clearing and removal costs for clogged piping (cooling water intakes, etc.), costs for replacement and repair of docks, etc. from introduced marine wood-borers, and damage from shore erosion due to burrowing behavior

The cost of studies of invading species and possible methods to attempt to control them are in the tens of millions at this time.

International and National Management Efforts

Due to the fact that ballast water crosses international and national boundaries, the international community, the U.S. government and some state governments have taken some steps to address the introduction of species via ballast discharge.

International Efforts

By the late 1980s, both Australia and Canada had experienced severe bio-invasions by introduced species (Japanese dinoflagellates in Australia; zebra mussels in Canada). Both countries began investigating regulatory means to address these problems and initiated ballast water studies. In 1989, Canada started requesting that vessels entering the St. Lawrence Seaway and the Great Lakes complete a full ballast exchange in ocean waters prior to entrance. Australia developed voluntary exchange guidelines in 1990. In 1991, these nations and others petitioned the United Nations' International Maritime Organization (IMO) to create international guidelines for ballast water. The IMO subsequently
issued voluntary **"International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges."** These voluntary measures include:

- Minimizing the uptake of organisms during ballasting by avoiding port areas where harmful organisms are known to occur, in shallow waters and darkness, and when bottom-dwelling organisms might rise in the water column;
- Cleaning ballast tanks and removing sediments that accumulate in ballast tanks on a regular basis;
- Avoiding unnecessary ballast discharges; and
- Initiating ballast water management measures including exchanging ballast while at sea, replacing it with "clean" ballast water; non-release or minimal release of ballast water; and discharge to onshore reception and treatment facilities.

Because it was voluntary many ships did not do it so they wanted to make an act that would require all 130 members of IMO follow the ballast exchange guidelines. This may not occur for several years and is dependent on broad support by the member nations.
The United States, in IMO discussions, has strongly supported the concept of legally binding international regulations on ballast.
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The Act also included a requirement that the. Coast Guard develop guidelines that would
eventually become regulations regarding mid-ocean ballast exchange and other control measures for international shipping. The initial guidelines requested that all vessels entering the Great Lakes from outside the 300 km zone exchange their ballast water in the open ocean and provide documentation that this had been done. In May 1993, these guidelines became mandatory.. This represents one of a few regulatory approaches to ballast water management worldwide.
"Mid-ocean exchange is widely recognized as only a stop-gap measure to minimize the introduction of nuisance species. There is a great need to develop more effective and efficient approaches to ballast management on ships."

BALLAST WATER TREATMENT TECHNOLOGIES

Recent research has targeted technologies that treat ballast water to remove or destroy the living organisms being carried. Based on research to date, it appears that a
single treatment method would not provide an effective solution; research results point to the use of combinations of technologies The information below regarding the methods available or under study is derived in part from Tzankova, 2001, and Mackey,
2001.

Ballast Water Exchange

The primary standard for ballast water treatment has been the exchange of ballast water. This
involves pumping out existing ballast and taking on "fresh" ballast. It takes place in an open ocean environment so that discharged species taken on in bays and estuaries (where ports are located) would find it more difficult to survive. This also helps prevent the spread of non-native species into other bays and estuaries. While it does minimize the uptake of ballast-borne organisms, even pumping out and replacing ballast water does not remove all water or sediments from the tanks thus leaving a viable pathway for the introduction of species. Ballast water exchange is considered a partial solution and some existing ballast water controls imposed by states specifically recognize this fact Additionally, exchange of ballast water is constrained by sea conditions, vessel routing and scheduling. Federal law provides a safety exemption if a vessel's captain judges that completing a ballast

exchange at sea would jeopardize the safety of his crew and ship. While ships and crews need to operate safely, this also means that there will be many instances when ballast cannot be exchanged.

Filtration/Physical Separation

Modern filtration technologies allow separation of organisms above a certain size. This is effective in filtering larger organisms but does not remove smaller microorganisms, bacteria and dinoflagellate cysts from ballast water. When done at the time that ballasting is taken on, the material filtered can be re-deposited in the waters where it originates; this solves the problem of where to dispose such matter. However, secondary treatment will be required to inactivate the bacteria, cysts and viruses.

A different method for separating larger particles is the use of cyclonic separators that use centrifugal force to separate organisms from ballast water.

Chemical Biocides

Chemical biocides can work in instances where other options are limited (e.g., no ballast on board vessels with low volumes of ballast). While biocides can be effective, there are issues of cost, need for high doses, and potentially toxic residuals with ballast water discharge. Chlorine is a well-proven disinfectant that has been shown to be effective against most viruses and bacteria as well as dinoflagellate cysts but its reaction to use in seawater is not well known. Also, it is a corrosive chemical and would produce a toxic discharge when the ballast was released.

Ultraviolet Light

Ultraviolet light or UV has proven to be extremely effective and environmentally benign way to destroy microorganisms and bacteria by destroying their DNA. The use of UV in combination with physical separation has been a focus of treatment technology research in recent years. In fact, two of the Princess Cruise Line ships are currently fitted with such combined systems in a pilot demonstration project.

Heat Treatment

It was thought that the heat generated by ship engines could be used in some form to treat ballast water. Experiments with that technology have shown some possibilities but many constraints. One advantage that heat treatment has is that it could be applied in transit and makes use of waste heat. However, the temperatures reached via this technology are not effective against most human pathogens. Also, the increased heat may increase system corrosion and may even promote the growth of heat-loving algae.

Ultrasound

This approach has shown potential to be a very effective secondary treatment technology. It can produce extreme pressure and temperature change to destroy microorganisms and bacteria. However, this is still a new technology and there are potential challenges with large-scale operations related to consistent application, energy requirements and equipment durability. Until further testing and research is completed, its use as a viable secondary treatment is unable to be assessed.

Ozone

Ozone, also used as a disinfectant, is a known technology that has been applied to water treatment on smaller scales. Challenges in using ozone include the fact that it reacts with bromides in seawater, can cause corrosion problems and is not effective against dinoflagellate cysts.

Deoxygenation using nitrogen gas

Researchers in California, with funding and support from government and industry, have tested a technology that not only reduces rust and corrosion caused by sea water in ballast tanks but also kills a significant percentage of organisms being carried in that water. Nitrogen gas is bubbled into the ballast water, eliminating oxygen content. Without adequate oxygen, most organisms cannot survive for more than a few days. Tests conducted at the Monterey Aquarium Research Institute showed kill percentages of as much as 80 percent for organisms in the water. An added plus: the process can save shipping companies as much as $100,000 a year in reduced maintenance costs. While not a perfect solution, this technology shows promise and provides a strong economic incentive for industry to comply.