U.S. Department of Homeland Security
United States Coast Guard

# Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters

## Notice of Proposed Rulemaking

## *Preliminary Regulatory Analysis and Initial Regulatory Flexibility Analysis*

## USCG-2001-10486
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## Acronyms

| | |
|---|---|
| ANSTF | Aquatic Nuisance Species Task Force |
| BWD | ballast water discharge |
| BWE | ballast water exchange |
| BWM | ballast water management |
| BWT | ballast water treatment |
| CFR | Code of Federal Regulations |
| DWT | Deadweight Ton |
| EEZ | Exclusive Economic Zone |
| ER | empty / refill |
| FR | Federal Register |
| FRFA | Final Regulatory Flexibility Analysis |
| FT | flow-through |
| GAO | United States Government Accountability Office |
| HEC | Herbert Engineering Corp. |
| HFO | heavy fuel oil |
| IMO | International Maritime Organization |
| IRFA | Initial Regulatory Flexibility Analysis |
| LNG | liquefied natural gas |
| MARAD | U.S. Maritime Administration |
| MDO | marine diesel oil |
| MEPC | Marine Environmental Protection Committee |
| MISLE | Marine Information Safety and Law Enforcement System |
| MSIS | Marine Safety Information System |
| MSMS | Marine Safety Management System |
| NAA | No Action Alternative |
| NAICS | North American Industrial Classification System |
| NANPCA | Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 |
| NBIC | National Ballast Water Information Clearinghouse |
| NIS | nonindigenous species |
| NISA | National Invasive Species Act |
| NOBOB | No Ballast On Board |
| NPRM | notice of proposed rulemaking |
| NVMC | National Vessel Movement Center |
| OMB | Office of Management and Budget |
| PEIS | Programmatic Environmental Impact Study |
| PV | present value |
| RORO | Roll-on, Roll-off (Vessel) |
| RA | Regulatory Analysis |
| RFA | Regulatory Flexibility Act |
| SERC | Smithsonian Environmental Research Center |
| TEU | Twenty-foot Equivalent Unit |
| ULCC | ultra large crude carrier |
| VLCC | very large crude carrier |

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# Executive Summary

Under Executive Order 12866, the United States Coast Guard (USCG) is required to conduct an analysis of the costs, benefits, and other impacts for a significant rulemaking. We expect this rulemaking to be economically significant (i.e., the rulemaking would have an annual effect on the economy of $100 million or more). This preliminary Regulatory Analysis (RA) provides supporting documentation for the regulatory evaluation in the preamble of the notice of proposed rulemaking (NPRM) for Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters [USCG-2001-10486]. We did not attempt to replicate precisely the regulatory language of the proposed rule in this RA; the regulatory text, not the text of this RA, would be legally binding.

The unintentional introduction of nonindigenous species (NIS) into the waters of the United States via the discharge of vessels' ballast water continues to pose a serious risk to coastal facilities and global biodiversity. Current U.S. regulations require ballast water management (BWM) to reduce introductions of NIS through ballast water discharge (BWD). Currently, the primary management method for controlling ballast water discharged in U.S. waters is a mid-ocean exchange of ballast water obtained from waters outside the U.S. Exclusive Economic Zone (EEZ). Concern remains that this approach to ballast water management is not sufficiently effective in preventing the introduction of NIS nor can many vessels conduct ballast water exchange because of safety issues and or voyage constraints.

The U.S. is proposing a rule to establish a ballast water discharge standard (BWDS) for the allowable concentrations of living organisms discharged via ballast water into U.S. waters. While it has been adopted by the International Maritime Organization, it has not been ratified by enough countries to bring it into force as an international requirement.  The Coast Guard expects this to eventually be ratified. This rulemaking is consistent with the IMO proposed BWDS under the International Convention for the Control and Management of Ship's Ballast Water and Sediments (also known as BWM Convention) of February 2004..

This RA provides an evaluation of the economic impacts associated with the implementation of standards limiting the quantities of living organisms in vessels' ballast water discharged in U.S. waters. The focus of this assessment is to analyze the costs and benefits of implementing the proposed IMO standard (*Alternative 2*). We considered the following five alternative standards for this rulemaking:

*Alternative 1: No Action*

The No Action Alternative (NAA) would not establish a BWDS but would continue the existing BWM program. As currently framed, the mandatory BWM program, established in 2004, directs vessels to conduct mid-ocean exchange, retain ballast water onboard, or use an environmentally sound management method approved by the USCG.

*Alternatives 2-4: Ballast Water Discharge Concentrations*

Under Alternatives 2-4, maximum discharge concentrations for viable organisms would be established. Each of these alternatives are stated in terms of two different organism size classes and the number of viable organisms per volume discharged for each size class. A third class, microorganisms, is specified in terms of indicator bacteria and the number of colony forming units (cfu) per 100 milliliters (ml). The standard becomes progressively more stringent from Alternative 2 to Alternative 4 (Alternatives 3 and 4 are 10 times and 100 times more stringent than Alternative 2, respectively). Alternative 2 is considered the preferred alternative and analyzed in the depth in this RA. Table ES-1 shows the concentrations of organisms allowed under each alternative.

**Table ES-1 Allowable concentration of organisms in BWD, by size, for Alternatives 2-4**

| | Large Organisms > 50 microns in size | Small Organisms >10 and ≤50 microns in size | Bacteria | | |
|---|---|---|---|---|---|
| | | | Toxigenic *Vibrio cholerae* (O1 and O139) | *E. coli* | Intestinal *Enterococci* |
| Alternative 2 | <10 per $m^3$ | <10 per ml | <1 cfu per 100 ml | <250 cfu per 100 ml | <100 cfu per 100 ml |
| Alternative 3 | <1 per $m^3$ | <1 per ml | <1 cfu per 100 ml | <126 cfu per 100 ml | <33 cfu per 100 ml |
| Alternative 4 | <0.1 per $m^3$ | <0.1 per ml | <1 cfu per 100 ml | <126 cfu per 100 ml | <33 cfu per 100 ml |

*Alternative 5: Essentially Sterilization*

Alternative 5 would require the removal or inactivation of all living membrane-bound organisms (including bacteria and some viruses) larger than 0.1 micron.

## Population Affected

This rule will affect vessels operating in U.S waters[1] equipped with ballast tanks. These vessels are required to install and operate a USCG approved ballast water management system (BWMS) before discharging ballast water into U.S. waters. This would include vessels bound for offshore ports or places. Additionally, whether the vessel traveled 200 nautical miles offshore is not a factor in determining applicability. This means that some vessels that operated exclusively in the coastwise trade (within the EEZ), which were previously exempt from having to perform BWE, would now be required to meet the BWDS.

The primary source of data used in this analysis is the Marine Information for Safety and Law Enforcement (MISLE) system and Ballast Water Reporting Forms submitted to the

[1] Waters of the United States means waters subject to the jurisdiction of the United States as defined in 33 CFR 2.3, including the navigable waters of the United States. For 33 CFR Part 151, subpart C and D, the navigable waters include the territorial sea as extended to 12 nautical miles from the baseline, pursuant to Presidential Proclamation No. 5928 of December 27, 1988.

National Ballast Information Clearinghouse (NBIC). MISLE is the USCG database system for information on vessel characteristics, arrivals, casualties, and inspections. The NBIC database, which is maintained by the Smithsonian and provides information on the amount of ballast water discharged in U.S. ports for the range of vessel types calling on U.S. waters. Since October 2004, all vessels, U.S. and foreign, operating in U.S. waters and bound for U.S. ports or places must submit reports of their BWM practices to the NBIC database. 33 CFR 151.2041.

Approximately 7,575 vessels from the current vessel population, of which 2,616 are U.S. vessels, would be required to meet the BWDS. Full implementation is required by 2016. The installation requirements are phased-in for new and existing vessels over the 2012 through 2016 period. Table ES-2 presents the number of potential vessels operating in U.S. waters that would be covered under the proposed BWDS.

**Table ES-2 Potential vessels affected by BWD Standards**

| Type of Vessel | Classification Criteria [a] | Vessels Operating in U.S. Waters (2007) | | |
|---|---|---|---|---|
| | | U.S. Vessels | Foreign Vessels | Total Number of Vessels |
| **Bulk carriers** | | | | |
| Handy | <50,000 DWT | 22 | 1,050 | 1,072 |
| Panamax | 50,000-80,000 DWT | 11 | 509 | 520 |
| Capesize | >80,000 DWT | 6 | 46 | 52 |
| **Tank Ships** | | | | |
| Handy | <35,000 DWT | 6 | 116 | 122 |
| Handymax-Aframax | 35,000-120,000 DWT | 19 | 709 | 728 |
| Suezmax | 120,000-160,000 DWT | 3 | 100 | 103 |
| VLCC | 160,000-320,000 DWT | 1 | 154 | 155 |
| ULCC | > 320,000 DWT | 0 | 16 | 16 |
| **Container ships** | | | | |
| Feeder | <500 TEU | 27 | 39 | 66 |
| Feedermax | 500-1000 TEU | 10 | 51 | 61 |
| Handy | 1000-2000 TEU | 10 | 126 | 136 |
| Subpanamax | 2000-3000 TEU | 38 | 172 | 210 |
| Panamax | >3000 TEU[b] | 29 | 174 | 203 |
| Postpanamax | >3000 TEU[c] | 21 | 272 | 293 |
| **Other vessels** | | | | |
| Passenger ship | All sizes | 166 | 129 | 295 |
| Gas carrier | All sizes | 6 | 118 | 124 |
| Chemical carrier | All sizes | 23 | 513 | 536 |
| RORO | All sizes | 66 | 321 | 387 |
| Combination vessel | All sizes | 170 | 22 | 192 |
| General cargo | All sizes | 1,166 | 258 | 1,424 |
| Fishing Vessels | All sizes | 731 | 16 | 747 |
| OSVs | All sizes | 85 | 48 | 133 |
| Total | | 2,616 | 4,959 | 7,575 |

a. Vessel classifications source: USGC (2004)
b. Vessel length and beam within Panama Canal limits.
c. Vessel length or beam exceed Panama Canal limits.

This rulemaking is consistent with the IMO proposed BWDS under the International Convention for the Control and Management of Ship's Ballast Water and Sediments (also known as BWM Convention) of February 2004. For the purposes of this RA, we consider the bottom-line costs of this rulemaking to involve U.S. vessels only. Nevertheless, we anticipate that the development of treatment technology will involve the world fleet, not the U.S. fleet alone. Also, for the purpose of this rulemaking we do consider all vessels operating in U.S. waters when developing the average per vessel installation and operating unit costs since the U.S. fleet is relatively small and not representative of all vessel types.

**Costs of Alternative Ballast Water Discharge Standards**

The IMO BWM Convention has spurred development of alternative ballast water management systems (BWMS) that will enable vessels to meet the IMO discharge standard (Alternative 2). Various technologies are being evaluated. Shipboard trials are being conducted for some of these technologies, while other systems are undergoing land-based laboratory testing.

Not all systems are appropriate for all vessel types. Estimated annual operating costs for a BWMS is 2 to 4 times the cost for ballast water management using mid-ocean BWE. The increased operational costs relate, in part, to the use of chemicals or other agents in the BWMS and are also due to the treatment of certain discharges not required under current regulations. Cost estimates contain a degree of uncertainty because these emerging technologies are in their formative stages. The BWMS on ships is a new process for which there is minimal operating practical experience, any discussion of the treatment technologies, effectiveness, costs, and operating issues is provisional.

Approximately 4,758 BWMS installations for the U.S. vessels would be required by 2021 because of projected fleet growth. We expect highest annual costs in the period between 2012 and 2016, as all of the existing fleet of vessels must meet the standards according to the phase-in schedule proposed by the rule (Table ES-3). The primary cost driver of this rulemaking is the installation costs for all existing vessels. After this period, we estimate operating costs to be substantially less.

For the purposes of estimating the total operational cost of BWMS, we multiply the operating costs by the proportion of vessels we have estimated to be treating ballast each year. However, once a vessel begins treatment of ballast water, their operational cost continues to carry-over into the future. Therefore, the total cost of the BWMS during the installation period will increase substantially due to the cumulative nature of operating BWMS.

**Table ES-3 Costs to the U.S. vessels to comply with IMO Convention (Alternative 2) BWD Standard ($Mil)**

| Year | Installation Costs | | Treated Ballast Water ($m^3$) | Annual Operating Costs | | Total Cost | |
|---|---|---|---|---|---|---|---|
| | 3% Discount | 7% Discount | | 3% Discount | 7% Discount | 3% Discount | 7% Discount |
| 2012 | $247.68 | $238.42 | 1,132,153 | $0.19 | $0.18 | $247.87 | $238.61 |
| 2013 | $241.64 | $223.91 | 2,241,913 | $0.37 | $0.34 | $242.00 | $224.25 |
| 2014 | $246.22 | $219.63 | 3,442,354 | $0.54 | $0.48 | $246.77 | $220.11 |
| 2015 | $199.62 | $171.40 | 4,459,499 | $0.68 | $0.59 | $200.30 | $171.99 |
| 2016 | $194.97 | $161.15 | 5,562,279 | $0.83 | $0.68 | $195.80 | $161.84 |
| 2017 | $42.51 | $33.82 | 5,705,753 | $0.82 | $0.66 | $43.33 | $34.47 |
| 2018 | $42.44 | $32.51 | 5,874,496 | $0.82 | $0.63 | $43.26 | $33.14 |
| 2019 | $42.38 | $31.24 | 6,047,200 | $0.82 | $0.61 | $43.20 | $31.85 |
| 2020 | $42.32 | $30.03 | 6,223,966 | $0.82 | $0.58 | $43.14 | $30.62 |
| 2021 | $42.26 | $28.87 | 6,404,897 | $0.82 | $0.56 | $43.09 | $29.44 |
| Total | **$1,342.04** | **$1,171.00** | | **$6.73** | **$5.32** | **$1,348.77** | **$1,176.31** |
| Annualized | **$157.33** | **$166.72** | | **$0.79** | **$0.76** | **$158.12** | **$167.48** |

Note: Totals may not add due to rounding.

We estimate the first-year total (initial) cost of this rulemaking to be $239 million based on a 7 percent discount rate and $248 million based on a 3 percent discount rate. Over the 10-year period of analysis (2012-2021), the total cost of Alternative 2 for the U.S. vessels is approximately $1.18 billion using the 7 percent discount rate and $1.35 billion using the 3 percent discount rate. Our cost assessment includes existing and new vessels.

The costs associated with the higher standards of Alternatives 3 and 4 (one-tenth and one-hundredth of Alternative 2, respectively) are more speculative. Capital and operational costs could certainly increase. We estimate the costs for Alternative 3 would be double those for Alternative 2, and that the costs for Alternative 4 would be quadruple those for Alternative 2.

At this time, the most feasible approach for achieving the Alternative 5 (essentially sterilization) standard is through the elimination of ballast water discharge. For some vessel types, such as large containerships and roll on/roll off vessels, this may be feasible. For other vessel types, such as bulk carriers, it is not possible to eliminate discharge of ballast without significant reduction in cargo carrying capacity - up to 35 percent of the payload.

We compared costs of implementing Alternative 2 (the alternative proposed in the NPRM) for BWDS to shipping revenues and consumer retail prices for goods typically transported by vessels. We have also compared amortized installation costs to long-term charter rates. These costs typically represent less than one percent of long-term charter rates. Costs to the consumer are further diluted because maritime transportation costs generally represent only one to two percent of the retail cost of goods. Although the overall cost of implementing this proposed rule is significant, the cost will not be noticeable by the average consumer because the costs will have minimal impact on the costs of goods and services.

## Economic Costs of Invasions of Non-indigenous Species

NIS introductions contribute to the loss of marine biodiversity and have associated with it significant social, economic, and biological impacts. NIS introductions in U.S. waters are occurring at increasingly rapid rates. Avoided costs associated with future NIS invasions represent one of the benefits of BWM. Economic costs from invasions of NIS range in the billions of dollars annually. Evaluation of these impacts was difficult because of limited knowledge of the patterns and basic processes that influence marine biodiversity. The most extensive review to date on the economic costs of introduced species in the U.S. includes estimates for many types of NIS, and is reflected in Table ES-4.

**Table ES-4 Estimated Annual Costs of Aquatic Introduced Species ($ 2007)**

| Species | Costs |
|---|---|
| Fish | $5.7 billion |
| Zebra and Quagga mussels | $1.06 billion |
| Asiatic clam | $1.06 billion |
| Aquatic weeds | $117 million |
| Green Crab | $47 million |

Note: See Chapter 5 "Economic Cost of Invasions of Non-indigenous Species" for additional details and source information.

Though a particular invasion may have small direct economic impacts, the accumulation of these events may cost in the billions of dollars every year. Only a few invasions to date have led to costs in the billions of dollars per year.

Ballast water discharge is one of the two main vectors by which NIS are introduced into the marine environment associated with shipping - hull-fouling being the other. The proposed BWDS will not address hull fouling. The relative impact of ballast water and hull fouling vectors has not been fully understood (Ruiz 2002).

## Benefits of Ballast Water Discharge Standards

The benefits of BWDS are difficult to quantify because of the complexity of the ecosystem and a lack of understanding about the probabilities of invasions based on prescribed levels of organisms in ballast water. However, evaluation of costs associated with previous invasions (described above) allows a comparison of the cost of discharge standards versus the potential costs avoided. Because the amount of shipping traffic and the number of incidents of invasions per year are both increasing, historical data provide a lower bound for the basis of benefit evaluation.

We assessed the functional benefits prior to comparing monetary benefit measures. The primary functional benefits of Alternative 2 are:

- A reduction in the concentration of all organisms leading to lower numbers of these organisms being introduced per discharge; and

- The elimination of the exemptions in the BWM regulations leading to the discharge of unmanaged ballast water (e.g., safety concerns during exchange, deviation/delay of voyage required to travel to acceptable mid-ocean exchange location).

This overall strategy should reduce the number of new invasions because the likelihood of establishment decreases with reduced numbers of organisms introduced per discharge or inoculation.

We calculate potential benefits of the BWDS by estimating the number of invasions reduced and the range of economic damage avoided. We use information on the invasion rate of invertebrates from shipping reported by Ruiz et al. (2000) to project the number of future shipping invasions per year. We then estimate the number of fish and aquatic plant invasions based on historical relationships of fish and plant invasions to invertebrate invasions. We then adjust the projected invasions to account for the fraction of invasions that are attributable to ballast water and the fraction of invasions that cause severe economic damage. The resulting projection of the number of ballast water invasions that will cause harm is displayed in Table ES-5.

**Table ES-5 Estimated Number of Ballast Water Invasions that Cause Harm**

| Year | Invertebrate | Fish | Aquatic Plant |
|---|---|---|---|
| 2012 | 0.372 | 0.074 | 0.149 |
| 2013 | 0.381 | 0.076 | 0.152 |
| 2014 | 0.390 | 0.078 | 0.156 |
| 2015 | 0.399 | 0.080 | 0.160 |
| 2016 | 0.409 | 0.082 | 0.164 |
| 2017 | 0.419 | 0.084 | 0.168 |
| 2018 | 0.429 | 0.086 | 0.172 |
| 2019 | 0.439 | 0.088 | 0.176 |
| 2020 | 0.450 | 0.090 | 0.180 |
| 2021 | 0.461 | 0.092 | 0.184 |
| Total | 4.149 | 0.830 | 1.659 |

Note: Totals may not add due to rounding.

To estimate the potential economic harm that may be caused by these invasions, we assign a cost per invasion based on the limited available data on the range of costs and damages incurred by past invasions. As no comprehensive estimate is available on the costs from past invasions, we do not try to develop a composite cost estimate for all invasions, but instead select a low and high estimate for fish, aquatic plants, and invertebrates based on representative species. We then calculate a mid-point for the range and calculate costs for future invasions using all three values. The resulting ranges of costs per invasions are summarized in Table ES-6.

**Table ES-6: Range of Annual Costs Associated with Selected NIS Introductions ($ 2007)**

| | Low-Range | | Mid-Range | | High Range | |
|---|---|---|---|---|---|---|
| Fish | $ 15,805,000 | [1] | $ 160,547,000 | | $ 305,289,000 | [2] |
| Invertebrates | $ 19,538,000 | [3] | $ 539,769,000 | | $ 1,060,000,000 | [4] |
| Aquatic Plants | $ 4,507,000 | [5] | $ 214,585,500 | | $ 424,664,000 | [6] |

[1] From Jenkins 2001, economic impact of sea lamprey on Great Lakes, updated from 2001$
[2] From Leigh 1998, commercial and recreational fishing benefits lost due to ruffe invasion of Great Lakes, updated from 1998$
[3] From Connelly et al. 2007, cost of Zebra Mussel control at WTP and electric generation facilities, updated from 2004$
[4] From Piementel et al. 2005, cost of Zebra Mussel or Asian Clam, updated from 2005$
[5] From Rockwell 2003, cost to control Water Hyacinth in Louisiana, updated from 2003$
[6] From Pimentel 2005, cost to control Eurasion watermilfoil, updated from 2005$

We assume that once an invasion is established, it will continue to generate costs and/or damages for each year subsequent to the invasion. Thus, an invasion that occurs in the first year of our analysis (2012) will incur costs/damages in each of the next 10 years (through 2021).

Based on the cumulative impacts of invasions, we have calculated a mid-range estimate of annual costs for all harmful ballast water-introduced invasions over the 10 year period of 2012 to 2021 at $2.016 billion at a 7 percent discount (Table ES-7). These estimates assume no ballast water management.

**Table ES-7 Potential Cost ($Mil)/Damage of BW Invasion over a 10-year Period**

| Range of NIS Costs | Total Cost for (3% disc. rate) | Total Cost for (7% disc. rate) |
|---|---|---|
| Low Range | $ 83 | $ 75 |
| Mid Range | $ 2,232 | $ 2,016 |
| High Range | $ 4,382 | $ 3,957 |

The Draft Programmatic Environmental Impact Statement (USCG 2008) has estimated the reduction in the mean rate of successful introductions of various alternative standards. In comparison with the existing practice of ballast water exchange, Alternative 2 is between 37 percent and 63 percent effective in preventing invasions when fully implemented. We use these estimates of the reduction in the rate of invasions to estimate the economic cost/damage avoided as a result of a BWDS.

As discussed earlier, the implementation of the Alternative 2 BWDS will be phased-in over several years. During the phase-in period of 2012-2016, there is considerable uncertainty as to how effective the measures will be in preventing invasions if only a subset of ships have implemented ballast water management. There is also uncertainty as to the availability and effectiveness of ballast water management technologies in the early stages of implementation. For these reasons we conservatively assume that no invasions will be avoided before the end of this period (2012-2016), which may lead to an underestimate of potential benefits.

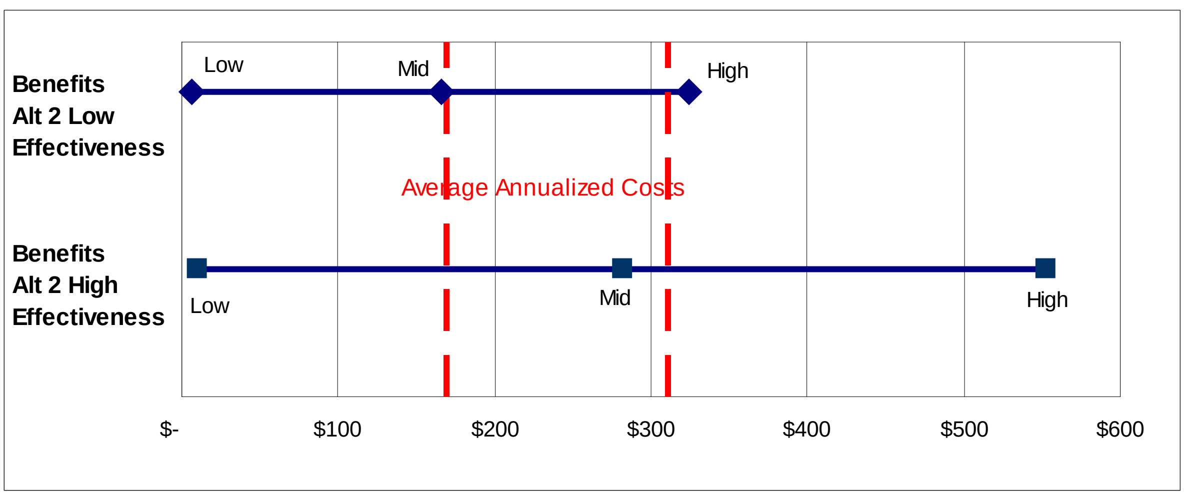
The resulting damages avoided for Alternative 2 range from a minimum of $6 million and the maximum is $553 million with a mid-range estimate of $165-$282 million per year at a 7 percent discount rate[2] (Table ES-8).

**Table ES-8: Potential Annual Benefits (Averted Cost), in Millions, of BW Invasion over a 10-year Period**

| Alternative 2 | Low Range Costs Per Species | | Mid Range Costs Per Species | | High Range Costs Per Species | |
|---|---|---|---|---|---|---|
| Reductions in Mean Rate of Invasion | 3% discount rate | 7% discount rate | 3% discount rate | 7% discount rate | 3% discount rate | 7% discount rate |
| Low Effectiveness - 37% | $ 7 | $ 6 | $ 194 | $ 165 | $ 380 | $ 325 |
| High Effectiveness - 63% | $ 12 | $ 10 | $ 330 | $ 282 | $ 647 | $ 553 |

The annualized cost for U.S. vessels over the 10-year period of 2012-2021 for Alternative 2 is estimated at $167 million at a 7 percent discount rate. Thus, quantified benefits are roughly equal to estimated costs for the mid-point benefits estimate of Alternative 2 Low Effectiveness. The high range annual cost estimate of $307 million is roughly equal to the high range benefits estimate of Alternative 2 Low Effectiveness.

**Figure ES-1: Range of Quantified Benefits and Annual Costs for Alternative 2 (7% Discount Rate, $2007)**

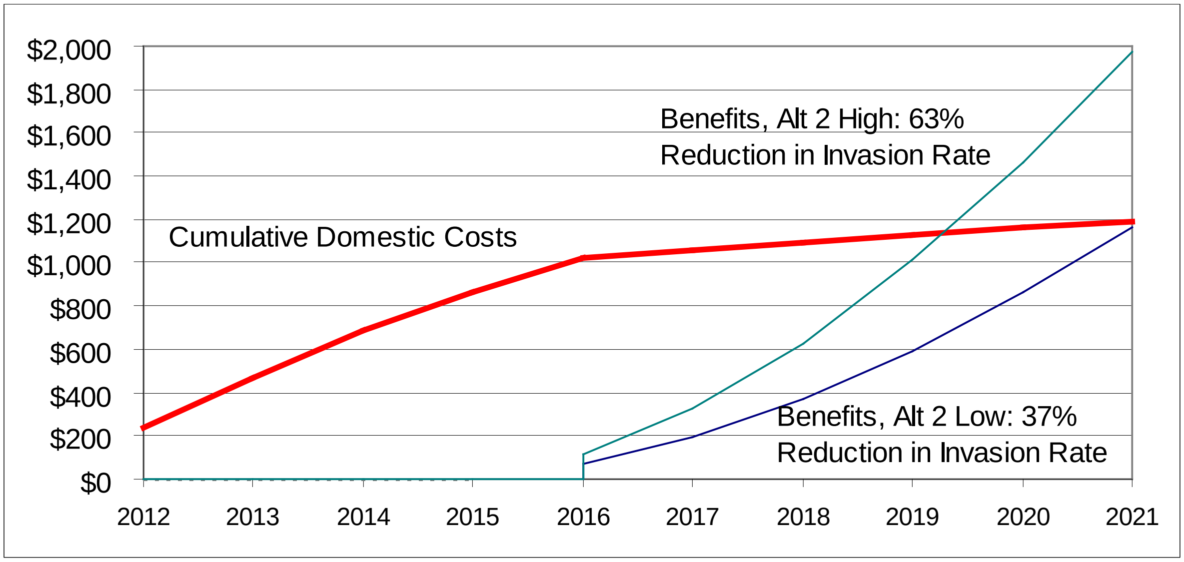



The cumulative economic damages avoided would equal cumulative costs incurred by 2019 for Alternative 2 assuming a higher reduction rate of 63 percent and in 2021 for Alternative 2

[2] The large range in the estimates of benefits from preventing invasive species is due the natural variability in the amount of damage caused by any individual species (i.e., different species can cause a wide range of damages from very little in a small area to large, widespread damages). In addition, the methods, scope, and magnitude used throughout the literature to estimate a dollar value of the damages caused by invasions introduces a considerable amount of uncertainty into the estimates.

assuming a low reduction in invasion rate of 37 percent. Figure ES-2 illustrates the cumulative costs of the BWD in relationship to the damages avoided.

**Figure ES-2: Comparison of Cumulative Costs and Benefits (7% Discount Rate, $2007, Mid-Point Invasion Estimate)**




## Initial Regulatory Flexibility Analysis

In accordance with the Regulatory Flexibility Act (RFA), we have prepared an Initial Regulatory Flexibility Analysis (IRFA) that examines the impacts of the proposed rule on small entities (5 USC 601 et seq.). Based on available data, we determined that more than 50 percent of the businesses affected would be small by the Small Business Administration size standards. We found that these businesses operate almost entirely in coastwise trade and were not involved primarily with larger scale trans-ocean shipping. We determined that some coastwise businesses would incur an impact of more than 1 percent impact on revenue during the installation and phase-in period based. After installation, however, most small businesses would not incur a significant economic impact from the estimated annual recurring operating costs. We have determined that this rule would have a significant economic impact on a substantial number of small entities under section 605(b) of the Regulatory Flexibility Act.

## Reporting and Recordkeeping

The proposed rule would not require additional reporting, recordkeeping, and other paperwork requirements for affected owners or operators. Vessel’s operators or person-in charge will comply with same reporting requirements of 33CFR151.2041.

## OMB A-4 ACCOUNTING STATEMENT

The USCG has determined that this is an "economically significant" rulemaking within the definition of Executive Order (EO) 12866, because estimated annual costs or benefits exceed $100 million in any year. As required by OMB Circular A-4 (available at http://www.whitehouse.gov), the USCG has prepared an accounting statement showing the classification of expenditures associated with the NPRM.

**Agency/Program Office:** USCG
**Rule Title**: Standards for Living Organisms in Ship's Ballast Water Discharged in U.S. Waters
**RIN#:** 1625-AA32
**Date:** June 06, 2008

| Category | Primary Estimate | | Minimum Estimate | | High Estimate | | Source |
|---|---|---|---|---|---|---|---|
| **Benefits** | | | | | | | |
| Annualized monetized benefits ($ Mil) | $165-$282 | 7% | $6 | 7% | $553 | 7% | RA |
| | $194-$330 | 3% | $7 | 3% | $647 | 3% | RA |
| Annualized quantified, but unmonetized, benefits | Unspecified | | Unspecified | | Unspecified | | RA |
| Unquantifiable Benefits | The rulemaking would provide an unquantifiable reduction in the risk of invasions. | | | | | | RA |
| **Costs** | | | | | | | |
| Annualized monetized costs ($ Mil) | $167 | 7% | $167 | 7% | $307 | 7% | RA |
| | $158 | 3% | $158 | 3% | $290 | 3% | RA |
| Annualized quantified, but unmonetized, costs | None | | None | | None | | |
| Qualitative (unquantified) | | | | | | | RA |
| **Transfers** | | | | | | | |
| Annualized monetized transfers: "on budget" | Not calculated | | Not calculated | | Not calculated | | RA |
| From whom to whom? | | | | | | | RA |
| Annualized monetized transfers: "off-budget" | None | | None | | None | | |
| From whom to whom? | None | | None | | None | | |
| **Miscellaneous Analyses/Category** | | | | | | | |
| Effects on State, local, and/or tribal governments | None | | None | | None | | |
| Effects on small businesses | We expect the rulemaking to have a significant economic impact on a substantial number of small entities. | | | | | | RA |
| Effects on wages | None | | None | | None | | |
| Effects on growth | No determination | | No determination | | No determination | | |

Discount rate appears to the right of estimates.
Note 1: We based primary estimates for annualized costs on low cost technology alternatives (see Chapters 3 and 4 for more details and descriptions). The primary cost estimates are the same as the minimum estimate.
Note 2: Primary estimates for annualized benefits are based on the mid-point cost per species estimate for low and high effectiveness (See Chapter 5 for more details). The minimal estimate is from the low range cost per species and low effectiveness. The high estimate is for the high range cost per species and high effectiveness.

# 1 Introduction

## 1.1 Statement of Need

Vessels that release untreated ballast water increase risks to aquatic life and possibly human health and cause other environmental and economic harm without accounting for the consequences of these actions on other parties (sometimes referred to as third parties) who do not directly participate in the business transactions of the business entities. These costs are not borne by the responsible entities and are therefore external to the business decisions of the responsible entity. The goal of environmental legislation and implementing regulations, including the proposed BWDS, is to correct these environmental externalities by requiring vessels to treat their ballast water releases in order to reduce the environmental harm that results from the introduction of some non-indigenous invasive species.

The invasion of NIS in the US waters is a complex negative externality that requires the establishment of a unified ballast water discharge standard. Individual initiatives from some States do not fully address the NIS invasion problem since waterways are interlinked making the withholding of an invasive species a difficult task. Because States regulations are not standardized, the cost and equipment requirements might represent an undo burden on vessels traveling from port – to – port. A Federal regulation that standardizes operational and equipment requirements on all vessels, with the capability of operating ballast tanks, is the most effect alternative to correct this market failure. In a published statement by the American Great Lakes Ports Association, they support the Coast Guards initiative to develop a Federal regulation that would standardize the criteria for the management of ballast water in U.S. waters[3]. In addition, a Federal regulation on ballast water discharge will have the added benefit of a regulation that complies with international treaties.

## 1.2 Overview

As discussed above, the introduction of non-indigenous species (NIS) into the waters of the United States via the discharge of vessels' ballast water continues to pose a serious risk to coastal facilities and global biodiversity. Ruiz et al. (2000a) analyzed the likely sources and pathways for North American marine invasions and concluded that most invasive species are associated with vessels. The authors estimated that of all invasive species introduced into U.S. waters -60 percent, 48 percent, and 64 percent on the Atlantic, Pacific, and Gulf coasts, respectively- could be attributed to some aspect of the shipping industry. Vectors associated with vessels include hull fouling and ballast water discharge (BWD).

The shipping industry uses ballast to optimize the configuration of the vessel so that it operates in a safe and efficient manner. Vessels use ballast to meet orientation (trim, heel, and draft), stability, and strength (bending moments, shear forces, and slamming loads) requirements both in port and at sea. Ballast water taken into the vessel via onboard pumps is the most common form of ballast. Ballast quantities range from a few hundred cubic meters

[3] Source: http://www.greatlakesports.org/aquatic.html

($m^3$) to more than 200,000 $m^3$ for the largest tankers. Analysis of the National Ballast Information Clearinghouse (NBIC) database shows that vessels discharge more than 40 million $m^3$ of ballast water from outside the U.S. into U.S. waters each year.

Current ballast water regulations require vessels that operate outside the U.S. Exclusive Economic Zone (EEZ) to use one of the following ballast water management (BWM) practices:

(a) Conduct mid-ocean ballast water exchange (BWE) at least 200 nautical miles from any shore (some vessels may not be able to conduct BWE depending on vessel design, age, load, sea conditions, and safety concerns);

(b) Retain ballast water onboard; or

(c) Use a United States Coast Guard (USCG) approved alternative method. Because there are currently no approved alternative methods, BWE and retention of ballast water are the only available methods of BWM.

Under the legislative mandate in the non-indigenous Species Act (NISA), the USCG must approve any alternative methods of BWM used in lieu of BWE. 16 U.S.C. 4711(c)(2)(D)(iii). NISA further stipulates that such alternative methods must be at least as effective as BWE in preventing or reducing the introduction of NIS into U.S. waters. 16 U.S.C. 4711(c)(2)(D)(iii). Determining whether an alternative method is as effective as BWE is not an easy task. The effectiveness of BWE is highly variable, largely depending on the specific vessel and voyage. These variables make comparing the effectiveness of an alternative BWM method to BWE extremely difficult. In addition, a majority of vessels are constrained by design or route from practicing BWE effectively. Ballast water exchange that show a proportional reduction in abundance of organisms, so every vessel then has a different allowable concentration of organisms in its discharge, support these results. Thus, vessels with very large starting concentrations of organisms in their ballast tanks might still have large concentrations of organisms after BWE.

For these reasons, BWE is not well suited as the basis for a protective programmatic regimen, even though it has been a useful “interim” management practice. We have concluded that, as an alternative to using BWE as the benchmark, establishing a standard for the concentration of living organisms that can be discharged in ballast water would advance the protective intent of NISA and simplify the process for USCG approval of a ballast water management system (BWMS). Additionally, setting a discharge standard would promote the development of innovative BWM technologies to be used for enforcement of the BWM regulations and assist in evaluating the effectiveness of the BWM program.

This regulatory analysis (RA) and initial regulatory flexibility analysis (IRFA) evaluates the costs, benefits, and other economic impacts associated with implementing a ballast water discharge standard (BWDS). This evaluation includes studies of the feasibility and tradeoffs of compliance alternatives for vessel owners and operators to install and maintain certain types of technology onboard a variety of vessel types and designs.

The remainder of Chapter 1 discusses the alternative discharge standards under consideration and provides an overview of Federal, State, and international regulations and activities.

Chapter 2 presents a description of the affected vessel population, data sources, and estimated fleet growth.

Chapter 3 presents the discussion on the installation and operational costs of the BWMS and uncertainties involved.

Chapter 4 presents estimates of the costs associated with installing and operating a BWMS required to meet the Alternative 2 standards.

Chapter 5 discusses the economic costs of NIS invasions and the benefits of the application of a BWDS.

We analyze some factors contributing to the evaluation of benefits of a BWDS and discuss costs that we may potentially incur or avoid. We also present limitations of the various standards in reducing the invasion of NIS.

Chapter 6 presents a comparison discussion on cost and benefits, BWDS, BWE and a sensitivity analysis in the total cost for U.S. vessels based in the potential in percentages of vessels owners complying with the phase-in schedule.

Chapter 7 contains a Regulatory Flexibility Act (RFA) analysis.

## 1.3 Alternative Ballast Water Discharge Standards

Based on the input provided through the scoping process, as well as the information developed through workshops, international discussions, and public comments, the USCG designated five alternatives for consideration in this RA. The alternatives include: maintaining the current BWE requirement *(Alternative 1 – "No Action")*; three alternatives that would establish different and increasingly stringent levels of maximum concentrations for living organisms in discharged ballast water *(Alternatives 2, 3,* and *4)*; and a one that essentially requires sterilization of ballast water *(Alternative 5). Alternative 2* is the BWDS proposed by the International Maritime Organization (IMO) Ballast Water Convention[4] and is considered the preferred alternative in this RA.

The three concentration-based alternatives—*Alternatives 2, 3,* and *4*—are more stringent than the no action alternative *(Alternative 1)*, but less stringent than sterilization *(Alternative 5). Alternatives 2, 3, and 4* call for limiting discharge to less than a specific number of living organisms of a particular size per unit volume of ballast water and a specified set of indicator microbes not to exceed specified concentrations.

These three alternatives would establish maximum acceptable discharge concentrations for various types of potential NIS such as macrofauna, including fish and invertebrate zooplankton; heterotrophic and autotrophic protists (phytoplankton); and microbes (bacteria and viruses).

**Alternative 1: No Action**

This alternative would not establish a BWDS. Instead, the mandatory BWM program established in accordance with the directives in the NISA would continue for vessels entering U.S. waters. Currently, the mandatory BWM program directs vessels to utilize at least one of the following BWM practices: conduct mid-ocean ballast water exchange, retain ballast water onboard, or use an environmentally sound treatment method approved by the USCG. Some vessels cannot conduct mid-ocean ballast water exchange due to safety and voyage constraints. In addition, the USCG has not yet approved any environmentally sound treatment methods. Thus, *Alternative 1* means that the primary BWM practice for vessels would be to conduct mid-ocean exchange when it is safe to do so and when the voyage permits. The USCG would need to develop an approval program for alternative methods in lieu of a BWDS. Such a program must verify that the alternative methods are as effective as mid-ocean ballast water exchange.

**Alternative 2: Establish The IMO Ballast Water Discharge Standards**

*Alternative 2,* would establish a maximum discharge concentrations for living organisms, and the BWDS would have to be met before the USCG could approve the BWMS. Those vessels

[4] The IMO is an organization of 160 member countries with observers from governmental, industry, environmental, public interest, and labor organizations that is concerned with the safety of shipping and cleaner oceans. To achieve its objectives, the IMO has promoted the adoption of some 30 conventions and protocols, and has adopted well over 700 codes and recommendations concerning maritime safety, the prevention of pollution, and related measures.

that have approved BWMS onboard would discharge a concentration level of living organisms in U.S. waters that meet the standard specified under this alternative.

Under A*lternative 2*, the allowable concentration of living organisms (per volume) in ships' ballast water (by size class) is:

- For organisms larger than 50 microns in minimum dimension: discharge less than 10 living organisms per cubic meter ($m^3$) of ballast water.
- For organisms equal to or smaller than 50 microns and larger than 10 microns: discharge less than 10 living individuals per milliliter (ml) of ballast water.
- For bacteria and viruses, discharge of indicator microbes such that:
  - Toxigenic *Vibrio cholera* (Serotypes O1 and O139) occur at a concentration less than 1 colony forming unit (cfu) per 100 ml.
  - *E. coli* occur at a concentration less than 250 cfu per 100 ml.
  - Intestinal Enterococci occur at a concentration less than 100 cfu per 100 ml.

**Alternative 3: Establish Ballast Water Discharge Standards**

*Alternative 3* would establish a maximum discharge concentrations for living organisms, and the BWDS would have to be met before that the USCG could approve the BWMS. Those vessels that have approved BWMS onboard would discharge a concentration level of living organisms in U.S. waters that meet the standard specified under this alternative.

Under A*lternative 3*, the allowable concentration of living organisms (per volume) in ships' ballast water (by size class) is:

- For organisms larger than 50 microns in minimum dimension: discharge less than one living individual per cubic meter of ballast water.
- For organisms equal to or smaller than 50 microns and larger than 10 microns: discharge less than one living individual per ml of ballast water.
- For bacteria and viruses, discharge of indicator microbes such that:
  - Toxigenic *Vibrio cholera* (Serotypes O1 and O139) occur at a concentration less than 1 cfu per 100 ml.
  - *E. coli* occur at a concentration less than 126 cfu per 100 ml.
  - Intestinal Enterococci occur at a concentration less than 33 cfu per 100 ml.

**Alternative 4: Establish Ballast Water Discharge Standards**

*Alternative 4* would establish a maximum discharge concentrations for living organisms, and the BWDS would have to be met before that the USCG could approve the BWMS. Those vessels that have approved BWMS onboard would discharge a concentration level of living organisms in U.S. waters that meet the standard specified under this alternative.

Under A*lternative 4*, the allowable concentration of living organisms (per volume) in ships' ballast water (by size class) is:

- For organisms larger than 50 microns in minimum dimension: discharge less than 0.1 living individuals per cubic meter of ballast water.
- For organisms equal to or smaller than 50 microns and larger than 10 microns: discharge less than 0.1 living individuals per ml of ballast water.
- For bacteria and viruses, discharge of indicator microbes such that:
    - Toxigenic *Vibrio cholera* (Serotypes O1 and O139) occur at a concentration less than 1 cfu per 100 ml.
    - *E. coli* occur at a concentration less than 126 cfu per 100 ml.
    - Intestinal Enterococci occur at a concentration less than 33 cfu per 100 ml.

**Alternative 5: Ballast Water Sterilization**

This alternative essentially requires sterilization of ballast water. It would require the removal or inactivation of all membrane-bound organisms (including bacteria) and most viruses. Vessels meeting this standard would have approved BWMS onboard that discharge virtually no living organisms in U.S. waters.

## 1.4 Proposed Implementation Schedule

Table 1.1 shows the proposed implementation schedule for meeting the BWDS. This proposed implementation schedule would provide vessel owners and operators sufficient time to install the necessary equipment needed to comply with the discharge standard without causing significant disruptions to vessels operations and maritime commerce.

**Table 1.1 Proposed Implementation Schedule for the Ballast Discharge Standards**

| Vessel's Ballast Water Capacity (cubic meters, $m^3$) | | Vessel's Construction Date | Vessel's Compliance Date |
|---|---|---|---|
| New vessels | Less than 5000 | On or after January 1, 2012 | On Delivery |
| | Equal or greater than 5000 | On or after January 1, 2012 | On Delivery |
| Existing vessels | Less than 1500 | Before January 1, 2012 | First drydocking after January 1, 2016 |
| | 1500-5000 | Before January 1, 2012 | First drydocking after January 1, 2014 |
| | Greater than 5000 | Before January 1, 2012 | First drydocking after January 1, 2016 |

## 1.5 Overview of Ballast Water Management Regulatory Activities

### Federal Regulations

On November 29, 1990, Congress enacted the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) (Pub. L. 101-646), which established the USCG's regulatory jurisdiction over BWM. To fulfill the directives of NANPCA, the USCG published a final rule on April 8, 1993, entitled "Ballast Water Management for Vessels Entering the Great Lakes" in the Federal Register (FR). 58 FR 18330. This rule established mandatory procedures for the Great Lakes as defined in 33 Code of Federal Regulations (CFR) part 151, subpart C.

A subsequent final rule entitled "Ballast Water Management for Vessels Entering the Hudson River", published on December 30, 1994, amended 33 CFR part 151 to extend the BWM requirements into portions of the Hudson River. 59 FR 67632.

On October 26, 1996, Congress enacted the NISA [Pub. L. 104-332], which reauthorized and amended NANPCA. On May 17, 1999, the USCG published an interim rule in the Federal Register on this voluntary program titled "Implementation of the National Invasive Species Act of 1996 (NISA)". 64 FR 26672. The interim rule added a new Subpart D to 33 CFR part 151 titled "Ballast Water Management for Control of Nonindigenous Species in Waters of the United States". We published the final rule in the Federal Register on November 21, 2001. 66 FR 5838.

Through NISA, Congress also directed the Secretary of the Department in which the USCG is operating to submit a report to Congress evaluating the effectiveness of the voluntary BWM program. In the June 3, 2002 report to Congress, the Secretary of the Department of

Transportation[5] concluded that low participation in the voluntary program resulted in insufficient data for an accurate assessment of its effectiveness. This finding triggered the requirement in NISA that the voluntary BWM program become mandatory. A copy of the report to Congress can be found in docket (USCG-2002-13147) at http://www.regulations.gov.

On July 28, 2004, we published a final rule in the Federal Register titled, "Mandatory Ballast Water Management Program for U.S. Waters". 69 FR 44952. This final rule changed the national voluntary BWM program to a mandatory one requiring all vessels equipped with ballast water tanks and bound for ports or places of the United States to conduct a mid-ocean BWE, retain their ballast water onboard, or use an alternative environmentally sound BWM method approved by the USCG.

On June 14, 2004, the USCG published a final rule in the Federal Register titled "Penalties for Non-submission of Ballast Water Management Reports". 69 FR 32864. In this final rule, we established penalties for failure to comply with the reporting requirements located in 33 CFR part 151 and broadened the applicability of the reporting and recordkeeping requirements to a majority of vessels bound for ports or places of the United States.

On August 31, 2005, we published a notice of policy in the Federal Register titled "Ballast Water Management for Vessels Entering the Great Lakes that Declare No Ballast Onboard". 70 FR 51831. Through this policy, we established best management practices for vessels entering the Great Lakes that have residual ballast water and ballast tank sediment.

**State Regulations**

Several coastal and Great Lakes states have enacted legislation that may be more stringent than current federal regulations. Furthermore, the states are considering future activities that go beyond the IMO Convention. If vessels already meet a more stringent standard required by states, then the vessel may reduced the costs of implementing the federal regulations. Because no state regulations currently require a BWDS, the effects of state regulations on costs are not included in this RA.

**California**

California law required the State Lands Commission to adopt new regulations governing ballast water management practices for vessels of 300 gross tons or more arriving at a California port or place from outside of the Pacific Coast Region. The State Lands Commission promulgated regulations requiring vessels to meet a BWDS by January 1, 2009. Title 2, Division 3, Chapter 1, Article 4.7, Performance Standards for the Discharge of Ballast Water For Vessels Operating in California Waters. The State Lands Commission recommended that the implementation date be delayed to 2010.

[5] The USCG moved from the Department of Transportation to the Department of Homeland Security (DHS) on March 1, 2003. Homeland Security Act, P.L 107-296, Section 1.

**Washington**

Washington’s ballast water law applies to self-propelled ships in commerce of 300 gross tons or more and prohibits discharging ballast water into state waters unless a vessel has conducted an exchange of ballast water at least 50 miles offshore,. Some vessels are exempt from this requirement because they retain their ballast water or discharge ballast water or sediments only at the location where they take on ballast water. On August 14, 2007, Washington promulgated emergency rules implementing an interim BWDS for the inactivation or removal of 95 percent of zooplankton organisms and 99 percent of phytoplankton and bacteria organisms.

**Michigan**

The Michigan Department of Environmental Quality established a Ballast Water Control General Permit under the Michigan Natural Resources and Environmental Protection Act in January 2007. The permit is applicable to ocean-going vessels that (1) engage in port operations and do not discharge ballast water or (2) discharge ballast water treated with a method approved by the MDEQ. The MDEQ identified four treatment methods it views as adequate: (1) hypochlorite; (2) chlorine dioxide; (3) ultraviolet (UV) light radiation; and (4) deoxygenation. To date, only permits have been written for ocean-going vessels that do not discharge ballast water in Michigan waters.

**International**

Introductions of potentially harmful organisms via ballast water are an international problem. To address the issue, the IMO adopted voluntary guidelines, “International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships’ Ballast Water and Sediment Discharges” in 1997. In February 2004, the IMO adopted a convention, “International Convention for the Control and Management of Ships’ Ballast Water and Sediments” (BWM Convention), which establishes BWM procedures and includes an international standard for BWD. The USCG coordinated this effort with the EPA, NOAA, the U.S. Department of Defense (DOD), the U.S. Maritime Administration (MARAD), the U.S. Department of Justice (DOJ), and the U.S. Department of State (DOS). The BWM Convention opened for ratification in February 2004, and under its terms does not enter into force until one year after ratification by 30 countries representing not less than 35 percent of the gross tonnage of the world’s merchant shipping. As of June 2008, 13 countries have signed the BWM Convention. The IMO Convention is available via the Internet at: http://www.imo.org/ in the MEPC section.

## 1.6 Regulatory Analysis

We estimate this proposed rule would be economically significant under Executive Order 12866.

This regulatory evaluation presents an analysis of costs and benefits from the NPRM. These cost estimates would likely differ from future costs due to changes in technology, installation, and implementation efficiencies that may take place in industry. We expressed costs in constant 2007 dollars. This analysis covers a 10-year period (2012-2021) covering the phase-in time for the change from ballast management through exchange to management via a performance standard.

# 2 Population Affected

This chapter presents the description of the population affected by this rulemaking, data sources, and the estimation of the fleet growth over the period of this analysis.

As described in the previous chapter, this rule will affect all vessels that operate in the U.S waters,[6] are bound for ports or places in the U.S., and are equipped with ballast tanks. These vessels are required to install and operate a USCG approved BWTS before discharging ballast water into U.S. waters. This would include vessels bound for offshore ports or places. Additionally, whether the vessel traveled 200 nautical miles offshore is not a factor in determining applicability. This means that some vessels that operate exclusively in the coastwise trade (within the EEZ), which were previously exempt from having to perform BWE, would now be required to meet the BWDS.

In accordance with NISA, certain vessels would be exempt from the requirements to install and operate a USCG approved BWMS, such as (NPRM, 2008):

(a) Crude oil tankers engaged in coastwise trade and

(b) Any vessel of the U.S. Armed Forces as defined in the Federal Water Pollution Control Act (33 U.S.C. 1322(a)) that is subject to the Uniformed National Discharge Standards for Vessels of the Armed Forces (33 U.S.C. 1322(n)).

## 2.1 Overview of Data and Sources

The primary source of data used in this analysis is the Marine Information for Safety and Law Enforcement (MISLE) and Ballast Water Reporting Forms (for 2007) submitted to the National Ballast Information Clearinghouse (NBIC). MISLE is the USCG database for information on vessels characteristics, arrivals, casualties, and inspections. This database presents data from 2002 to present and utilizes the SQL Sequel Software interface for the database searches. The Smithsonian Environmental Research Center (SERC) administers the NBIC. We present a description of the used data and their sources below:

**Number of U.S. vessels affected by the rule**

We estimated the U.S. population based on the number of vessels in the MISLE database for the year 2007, which will be affected by this rule. The U.S. population includes only active vessels.

[6] U.S. waters means waters subject to the jurisdiction of the United States as defined in 33 CFR 2.3, including the navigable waters of the United States. For 33 CFR Part 151, subpart C and D, the navigable waters include the territorial sea as extended to 12 nautical miles from the baseline, pursuant to Presidential Proclamation No. 5928 of December 27, 1988.

**Annual arrivals**

We used this data to determine the vessel's origin and the distinct routes the vessel typically transit. We used the routes to differentiate between coastwise and non-coastwise[7] vessels. Both MISLE and the NBIC database provide the last port of call (and country). However, the last port of call is not necessarily the source of ballast water. Vessels that travel between two U.S. ports may discharge ballast that originated outside the EEZ and within 200 miles off shore. The NBIC database provides the source for ballast water. Vessels on U.S. voyages that obtained ballast prior to their first U.S. arrival were entered into the database and included in the estimates of BWM and BWD standards costs.

**Average total ballast capacity**

We used this data to determine the average volumes (in $m^3$) of ballast water that a vessel needs to exchange and the equipment necessary to perform the exchange. We obtained data from Ballast Water Reporting Forms submitted in 2007 to the NBIC. We then compared these average volumes of ballast water for each vessel type (Appendix A) to the data in the BWM RA (USCG, 2004). From these data it was determined that mean ballast water capacity ranges from 1,700 $m^3$ (fishing vessels) to approximately 215,000 $m^3$ (large tankers).

**Vessel service and capacity or size**

We used this data to determine the exchange amount (empty-refill or flow-through) and equipment cost to complete the BWE information in Appendix B. The NBIC database provides the IMO number (a unique vessel identifier) for each vessel. The IMO number was cross-referenced with data from the MISLE (which used the *Lloyd's Register of Shipping 2002*) and database to determine vessel service. We identified distinct types of cargo or passenger services that could feasibly conduct ballast exchange. These services were further delineated by 20-foot equivalent units (TEU) for containerships or deadweight tons (DWT) for all other services, yielding 22 distinct vessel types and sizes of vessels that would be subject to this rulemaking. The type of exchange utilized by the various vessel types was determined from the NBIC data. Although there are trends associated with vessel type, some types and even some specific vessels use both the empty-refill and the flow-through methods.

**Vessel ballast pump capacity**

We used this data to determine the ballast water system maintenance cost as a function of total capital cost for a ballast water system. HEC developed information based on personal communications with members of the marine industry (e.g. equipment manufacturers) and vessel specifications. Ballast water system's pump capacities range from 250 $m^3$/hour for small containerships to 6,500 $m^3$/hour for large liquefied natural gas (LNG) carriers and tankers.

[7] Vessels are deemed to be "coastwise" when they operate exclusively within the U.S. Exclusive Economic Zone (EEZ), which is shipping within 200 miles of U.S. coastal waters. "Non-Coastwise" vessels are those that travel outside the EEZ, with normal operations is to and from foreign ports.

## 2.2 Description of the Maritime Transportation Industry

A diverse group of businesses comprises the ocean transportation industry. Containerships, general cargo vessels, tankers, and dry-bulk carriers dominate the deep-sea cargo carrying fleet. Added to this list are specialized vessels carrying commodities ranging from flammable gases to vehicles to passengers. Vessels pump ballast water, distribute it throughout the vessel, and discharge it from vessels to achieve acceptable conditions of stability, list, trim, and longitudinal strength. Cargo operations may change the required quantity of ballast water.

The U.S. shipping industry is a net importer. In 2004, imports totaled more than 957 million tons while exports were 350 million tons (MARAD 2005). Over the 5-year period from 2000 to 2004, import tonnage increased 18 percent while exports remained flat. This means that the majority of vessels arriving at U.S. ports arrive laden, and thus do not need to discharge large amounts of ballast, crude oil imports for example. Containerships are also much more heavily laden inbound to the U.S. than outbound. One exception to this general trend are shipments of grain in bulk carriers to Asia.

Ocean shipping operations fall into two broad categories: tramp shipping and liner service. Tramp shipping provides convenient, timely, and economical transportation of a broad variety of raw materials and finished goods necessary to a global economy. Tramp vessels contract for particular cargoes on routes that vary from voyage to voyage. These vessels provide excess capacity along established trade routes and low-cost transportation for agricultural goods and many natural (crude oil, timber, ores, mineral products) and manufactured (petroleum, cement, steel, fertilizers) raw materials. In this sector, it is common for all of the cargo on board to belong to a single owner and to be loaded and off-loaded at individual ports. Tankers and dry bulk carriers are vessel types that typically operate on the spot market.[8] In contrast, liner-service vessels operate on set routes and on fixed schedules. They commonly carry a variety of cargoes, the majority of which are finished goods and cargoes belonging to many different cargo owners. In this sector, timely service is critical to a successful operation, and the shipping company typically has a large traffic department responsible for generating the cargo business to fill the company vessels. General cargo and containerships are typical vessel types in this sector.

Vessels in tramp service, moving shipload lots of cargo from one port to another, travel with a minimum of ballast and a maximum of cargo in order to maximize revenue generated by the voyage. After off-loading its cargo, the vessel typically takes on ballast and travels to a different port to load new cargo bound for yet a different port. Thus, these vessels routinely discharge all of their onboard ballast at the port in which they load cargo. Liner-service vessels, by contrast, travel between ports with a combination of cargo and ballast, therefore pumping small volumes of ballast in response to changes in cargo distribution.

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[8] A spot market is one in which commodities, such as grain, gold, crude oil, or computer chips, are bought and sold for cash and delivered immediately. For example, the ownership of crude oil onboard a tanker may change several times during a single voyage.

Prior to BWM requirements, it was unlikely that all ballast water in a particular tank on a liner-service vessel would have originated in a single port, let alone all the ballast water aboard the vessel. Current operations and requirements make the contents of a particular tank much more likely to come from the same source.

## 2.3 Vessel Types and Ownership

We grouped vessels by service and size using a similar procedure as in the BWM RA (USCG 2004). Data developed by the USCG provided the baseline for the vessel types. We identified each vessel in Lloyd's Register of Ships through the seven-digit IMO number and recorded the vessel type reported by Lloyd's Register of Ships for each vessel (Table 2.1). We further divided bulk cargo vessels and tank vessels into subcategories by dead weight tonnage (DWT) according to commonly used industry size ranges (Hunt and Butman 1994). We also placed the largest of these vessels into subgroups according to their ability to navigate the Panama and Suez Canals. We grouped container vessels into six subgroups based on 20-foot equivalent unit (TEU) capacity and their ability to transit the Panama Canal.[9]

[9] Panama Canal operations are such that vessels longer than 294 meters or wider than 32.2 meters are unable to pass through the locks.

**Table 2.1 Vessel Type Definitions**

| Vessel Type (this analysis) | Ship Type (Lloyd's Register) |
|---|---|
| Bulk carriers—<br>Handy<br>Panamax<br>Capesize | Ore/Bulk/Oil Carriers<br>Bulk Carriers<br>Cement Carriers<br>Great Laker<br>Heavy Load Carrier<br>Limestone Carrier<br>Ore Carrier<br>Ore/Oil Carrier<br>Sand Carrier<br>Wood Chip Carrier |
| Tank ships—<br>Handy<br>Handymax-Aframax<br>Suezmax<br>VLCC[a]<br>ULCC[b] | Fruit Juice Tanker<br>Oil Tanker<br>Products Tanker<br>Shuttle Tanker<br>Tanker<br>Vegetable Oil/Wine/Beer Tanker |
| Chemical carriers | Chemical Tanker |
| Gas carriers | Liquefied Gas Carrier<br>Liquid Petroleum Gas (LPG) Tanker<br>Liquid Natural Gas Tanker |
| Feeder<br>Feedermax<br>Handy<br>Subpanamax<br>Panamax<br>Postpanamax | Containerships |
| Passenger ships | Passenger Ferry<br>Passenger Ship |
| General cargo vessel | General Cargo<br>Deck Cargo Ship<br>Refrigerated Cargo<br>Pallets Carrier<br>Other Specialized Cargo<br>Barges and Tank Barges |
| RORO | RORO Cargo Ferry[c]<br>RORO Cargo with Lo/Lo Access[d]<br>RORO Cargo/Vehicle Carrier<br>Passenger RORO Car Ferry |
| Combination vessel | Bulk Carrier + Vehicle Decks<br>Passenger/General Cargo<br>General Cargo with RORO Facility<br>Containership with RORO Facility<br>Mobile Offshore Drilling Units (MODUs)<br>Integrated Tug Barges (ITBs) |
| Fishing Vessels | Fishing Catching Vessels<br>Processing Vessels<br>Charter Fishing Vessels<br>Fishing Support Vessels |
| Offshore Drilling Vessels (OSVs) | |

a. Very Large Crude Carrier
b. Ultra Large Crude Carrier

c. RORO is a vessel with roll-on, roll-off access
d. Lo/Lo is a vessel with lift-on, lift-off access

As shown in Table 2.2, we grouped vessels by size and service into one of 22 vessel types based on data from Lloyd's Register of Ships and MISLE database. We categorized vessels according to these classifications developed in the BWM RA (USCG 2004) to more accurately estimate costs based on pump capacities, which vary by vessel type and size.[10](See Appendix A)

We have not included the following vessels in the affected population that would incur additional costs from the proposed BWDS based on consultation with the ballast water program personnel and USCG expertise:

Vessels less than or equal to 100 ft. Vessels in this size range typically operate in more sheltered environments and do not load and discharge ballast. Their stability characteristics generally accommodate the amount and type of cargo they carry, precluding the need to use ballast water as a stability enhancer.

Some towing vessels (tugs towing behind and general). These vessels do not carry cargo and, thus, do not experience drastic changes in draft that would affect their stability characteristics. Therefore, they do not typically load and discharge ballast water.

River vessels. Rivers are usually very sheltered environments having limited wind and wave spectra. While current conditions play a very large role in sailing and towing characteristics, ballasting is not generally used to improve these. The operations of the river barge trade make installed ballast water systems very rare and loading and discharging ballast water through void tank main deck openings, without installed piping and pumps, would be a costly and extremely time-consuming evolution.

Crew boats. These vessels are light and fast and primarily transport personnel in support of the offshore energy production industry. They operate on dedicated routes from a home base to an oil field and back. While they might occasionally carry cargo, it is not their main purpose. Therefore, these vessels do not typically load and discharge ballast water.

Crude Oil Tankers engaged on coastwise trade. These tankers are exempt from the rule according to 33 CFR 151.2010 (a) (1).

[10] Two tanker categories are renamed to agree with current industry practice. "Handymax" is changed to "Handymax – Aframax," since this group reflects tankers from Handymax to Panamax to Aframax size, and the group previously described as "Panamax" is renamed "Suezmax."

**Table 2.2 Potential vessels affected by BWD Standards**

| Type of Vessel | Classification Criteria [a] | Vessels Operating in U.S. Waters (2007) | | |
|---|---|---|---|---|
| | | U.S. Vessels | Foreign Vessels | Total Number of Vessels |
| **Bulk carriers** | | | | |
| Handy | <50,000 DWT | 22 | 1,050 | 1,072 |
| Panamax | 50,000-80,000 DWT | 11 | 509 | 520 |
| Capesize | >80,000 DWT | 6 | 46 | 52 |
| **Tank Ships** | | | | |
| Handy | <35,000 DWT | 6 | 116 | 122 |
| Handymax-Aframax | 35,000-120,000 DWT | 19 | 709 | 728 |
| Suezmax | 120,000-160,000 DWT | 3 | 100 | 103 |
| VLCC | 160,000-320,000 DWT | 1 | 154 | 155 |
| ULCC | > 320,000 DWT | 0 | 16 | 16 |
| **Container ships** | | | | |
| Feeder | <500 TEU | 27 | 39 | 66 |
| Feedermax | 500-1000 TEU | 10 | 51 | 61 |
| Handy | 1000-2000 TEU | 10 | 126 | 136 |
| Subpanamax | 2000-3000 TEU | 38 | 172 | 210 |
| Panamax | >3000 TEU[b] | 29 | 174 | 203 |
| Postpanamax | >3000 TEU[c] | 21 | 272 | 293 |
| **Other vessels** | | | | |
| Passenger ship | All sizes | 166 | 129 | 295 |
| Gas carrier | All sizes | 6 | 118 | 124 |
| Chemical carrier | All sizes | 23 | 513 | 536 |
| RORO | All sizes | 66 | 321 | 387 |
| Combination vessel | All sizes | 170 | 22 | 192 |
| General cargo | All sizes | 1,166 | 258 | 1,424 |
| Fishing Vessels | All sizes | 731 | 16 | 747 |
| OSVs | All sizes | 85 | 48 | 133 |
| Total | | 2,616 | 4,959 | 7,575 |

a. Vessel classifications source: USGC (2007)
b. Vessel length and beam within Panama Canal limits.
c. Vessel length or beam exceed Panama Canal limits.

This rulemaking is consistent with the IMO proposed BWDS under the International Convention for the Control and Management of Ship's Ballast Water and Sediments (also known as BWM Convention) of February 2004. For the purposes of this RA, we consider the bottom-line costs of this rulemaking for U.S. vessels[11].

In order to estimate the cost associated with BWTS on the U.S. fleet, we needed to develop the range of technologies that may be available and the unit costs of these technologies. We assume that there will be a broad market for the new BWTS that includes both U.S. and foreign vessels, thus improving the range of technologies available and the cost efficiencies of production.

## 2.4 Fleet Growth and Makeup

We estimated the U.S. fleet growth rates for the various vessel types using the following data sources: U.S. Department of Transportation (MARAD), Clarkson Research Service and the U.S. Coast Guard MISLE System Database. Additional details of the U.S. and world fleet growth and removal rate calculations are presented in Appendix A.

We extracted the number of affected vessels from the MISLE database to provide a baseline fleet size for year 2007. In projecting fleet growth, we assumed that there would be no optimization of the fleet for U.S. traffic. That is, we assumed that all vessels involved in international trade will be built to both U.S. and international BWDS requirements.

Table 2.3 shows the assumed growth and removal rates forming the baseline case. We estimated the number of new builds each year by adding the number of vessels removed to the number of vessels needed to achieve the net growth rate.

[11] See appendix A for cost estimates of foreign vessels projected to call in U.S. waters during the 10-year period of analysis.

**Table 2.3 U.S. Fleet Growth and Removal Rates**

| Type of Vessel | Net Growth Rate | Removal Rate[12] |
|---|---|---|
| **Bulk carriers** | | |
| Handy | -1.24% | 2.0% |
| Panamax | -1.24% | 2.0% |
| Capesize | -1.24% | 2.0% |
| **Tank ships** | | |
| Handy | 2.58% | 1.0% |
| Handymax-Aframax | 2.58% | 1.0% |
| Suezmax | 2.58% | 1.0% |
| VLCC | 2.58% | 1.0% |
| ULCC | 2.58% | 1.0% |
| **Container ships** | | |
| Feeder | 1.99% | 2.0% |
| Feedermax | 1.99% | 2.0% |
| Handy | 1.99% | 2.0% |
| Subpanamax | 1.99% | 2.0% |
| Panamax | 1.99% | 2.0% |
| Postpanamax | 1.99% | 2.0% |
| **Other vessels** | | |
| Passenger ship | 3.36% | 2.2% |
| Gas carrier[13] | 2.58% | 2.0% |
| Chemical carrier[14] | 1.99% | 2.2% |
| RORO | 2.59% | 2.2% |
| Combination vessel | 2.65% | 2.0% |
| General cargo[15] | 1.99% | 2.2% |
| Fishing Vessels | 3.54% | 2.2% |
| OSVs | 4.87% | 3.7% |

[12] Removal rates for U.S. fleet is the same as the estimated removal rate for the world fleet, due to the fact that removal rates are related to vessel age and market conditions.
[13] Same as tank ships
[14] Same as container ships
[15] Same as container ships

# 3 Ballast Water Treatment Costs

Onboard ballast water treatment systems (BWTS), which attempt to eliminate or greatly reduce the transmittance of live NIS, are an emerging technology. We have derived some systems from existing shore-side water treatment processes, while others involve innovative techniques and technologies. We have analyzed the technology, costs, and effectiveness of a variety of systems. Much of the present analysis stems from previous work and information in papers submitted to MEPC 53. Many of the manufacturers developing alternative BWMS have provided direct feedback on costs, capabilities, and testing for their systems. Based on analysis of this information, it appears that the technology should be available for installation onboard vessels to meet the proposed *Alternative 2* (BWD-2) standard, the proposed IMO regulation D-2, by the 2012 initial implementation date. Some of the developing technologies may be able to meet stricter standards, such as *Alternative 3* (BWD-3), one-tenth of the IMO proposed levels of NIS, but this will incur additional capital and operating costs and may restrict vessel operations. For some vessel types, services, and operating procedures, the possibility also exists for a vessel to avoid discharge of ballast altogether.

In this RA, we describe alternative BWMS as generic treatment processes, avoiding discussion of specific manufacturers and systems. This approach accommodates situations in which multiple vendors may arise or have arisen for a specific treatment process. The object of this analysis was to survey the marketplace and describe systems currently under development, including the costs and capabilities of those systems. Many of the individual systems are patented or have patents pending. We have evaluated the following six different treatment processes in detail: *Chlorine Generate, Chemical Apply, Filter & Radiate, Deoxygenate, Ozone Generate,* and *Heat Treatment*. See Table 3.1 for a description of these processes, including some of their characteristics and capabilities. We have selected these processes because some vendors are actively developing and testing systems that operate based on the indicated treatment process.

The sources of information regarding the treatment processes are as follows:

1. MEPC 53/2/14 by the USA, dated 15 April 2005;
2. MEPC 53/2/16 by Norway, dated 15 April 2005;
3. MEPC 53/2/6 by Sweden, dated 15 April 2005;
4. USCG supplied system information;
5. Herbert Engineering Corporation (HEC) updated the information for the BWMS technologies and added additional information including updated assessments of capabilities of the system, ability to meet stricter standards, testing carried out and planned, cost estimates for installation and operation, and effect on tank corrosion. This update included research on current BWMS and manufacturers. Some information on current BWMS technology and system capability was more complete and of greater use than others; and
6. Technical information, brochures, technical papers, discussions, and other information provided by manufacturers.

Table 3.1 describes the generic BWMS processes analyzed in this RA. For each, we determined when treatment is applied in the ballast cycle, the time required for the treatment to achieve the desired lethality, and the effect on corrosion in ballast tanks. The effect on corrosion is included because it is a significant concern for vessel owners, and this impact on a BWMS might influence their choice.

**Table 3.1 Ballast Water Treatment Processes**

| Treatment Process | Method of Treatment | When Applied | Time for Lethality(2) | Effect on Corrosion |
|---|---|---|---|---|
| Chlorine Generate | Use electrolytic cell to generate chlorine and bromine that act as biocides. Next, sodium sulfate neutralizes the ballast water prior to discharge. As long as free chlorine exists in the tank, biocide will be active so dosage can be adjusted to keep biocide always active. | At uptake and neutralize at discharge | Hours | High dosage levels promote steel corrosion |
| Chemical Apply | Mix proprietary chemicals with the ballast water in metered dosage rates at intake to kill living organisms. Chemicals degrade over time so ballast will be safe to discharge. | At uptake via eductor | 24 hrs | High dosage levels promote steel corrosion |
| Filter & Radiate | Filtration of the incoming water, usually with self-cleaning 50 micron filters, in parallel with discharge of filtrate to the waters where intake takes place. Ballast water exposed to a form of radiation, such as UV energy or other (AOT to generate hydroxyl radicals), to kill smaller organisms and bacteria. | At uptake for filter & UV and at discharge for UV | At treatment | No effect |
| Deoxygenate | Mix inert gas generated onboard with the ballast water, either by a venturi eductor or by bubbling from pipes in the tanks. This removes oxygen from the water and lowers pH, therefore killing the living organisms. This process requires the atmosphere in the ballast tank be maintained in an inert condition. | At uptake for some systems and in tanks for others | 4 to 6 days | Relatively less corrosive |
| Ozone Generate | Ozone is generated onboard and acts as a biocide. It is applied during the ballast pumping process by eductor either at uptake or discharge. It can be combined with filtration or other methods of treatment. | At uptake for some systems and at discharge for others | Up to 15 hrs | Limited effect as ozone has short life. If treated at discharge, no effect |
| Heat Treatment[16] | Heat ballast water to a predetermined temperature (such as over 42 deg C) for a period of time to kill living organisms. Source of heat is main engine or oil-fired boiler or water heater. | During voyage and in port for vessels with large boilers. | Hours to several days | Heat promotes corrosion |

[16] We did not consider the Heat Treatment process in the analyses of costs due to the uncertainties related to process effectiveness and potential system design and operation (see detailed discussion in Section 3.1)

Regarding the non-responsive manufacturers, their systems cover the following treatment processes:

*Deoxygenate* – 1 manufacturer
*Filtration & UV* – 1 manufacturer,
*Filtration & Chemical Apply* (this is a combination of treatment processes) – 2 manufacturers,
*Hydrodynamic Shear Force* – 1 manufacturer.

We described all of these processes in full or in part by the processes above except *Hydrodynamic Shear Force*. Regarding the combined process of *Filtration* and *Chemical Apply,* the manufacturer that offers only the *Chemical Apply* process found that filtration does not significantly improve the effectiveness of the system. Furthermore, neither manufacturer was far along in testing or development; therefore, the information they could have provided may have been of limited value. For meeting stricter standards, combinations of processes may be required as noted in the section of the RA. Regarding the *Hydrodynamic Shear Force* process, only one manufacturer is promoting that process. Nevertheless, no full-scale testing had been carried out, and the data, if provided, may be of limited value. Obtaining sufficient data from the non-responsive manufacturers prevented us from fully incorporating their treatment options into the analysis. Despite this, we are confident that the data which we did obtain from them is pertinent to this study. Because an adequate level of detail was not available for the non-responsive manufacturers, we deemed it inappropriate to include them in the analysis. Omitting these systems from the analysis should not affect the substance, estimated costs, or conclusions of this RA.

## 3.1 Descriptions of the BWTS and Assessment of Meeting the IMO Standard[17]

We believe most of the BWTS analyzed to have a 50 percent or greater chance of meeting the BWD-2 discharge standard within the next few years. We used multiples sources to determine the probability of an alternative BWTS meeting the BWD-2 proposed discharge standard. All analyzed treatment processes have, at some point, been tested—many on full-size prototypes on vessels. All of the systems have had biological testing of effectiveness to varying degrees, and all of the processes have a proven ability to kill living marine organisms. We consider all of these processes to be systems that can be made effective for some flow rates and levels of treatment based upon industry information, publicly available test results, and Herbert Engineering Corporation (HEC) industry experience with marine equipment. Many of the systems need further optimization to determine the size of the components, the power requirements (such as for UV), or the lethal dosage and the flow rate that can be sustained for a given equipment size.

Killing small aquatic life with chemical biocides based on chlorine or bromine is a proven technology used extensively in shore-side water treatment. We can adjust the degree of lethality by changing the dosage rate. However, the main concern with these systems is making the water suitable for discharge in order to minimize harm to the receiving waters. This can be accomplished by retaining the ballast onboard for a few days and allowing the treatment chemical to degrade (*Chemical Apply Treatment*, as claimed by manufacturer) or by adding a neutralizing substance (*Chlorine Generate*). These systems reach effectiveness in hours. The processes that kill the organisms consume the chemical biocide. The dosage rate is set at a level that will leave a small residual in the tank, which can be effective in killing any remaining organisms. Further dosing can be accomplished if the residual is consumed. Setting the correct dosage rate is an important consideration in the effectiveness of these types of systems.

Treatment processes that deoxygenate the ballast water have a similar level of effectiveness. We base this rating on recent published reports on the effectiveness of testing a full-size unit

[17] New information about additional Ballast Water Treatment Systems was available after the completion of this RA. We have not incorporated these new findings in our analysis due to the complexities of the calculations used in estimating costs per treatment type, which would require an extensive re-estimation of all costs associated with this RA. The new treatment systems available are Hydroyclone – Electrochlorination and Menadione or Vitamin K.

The Hydroyclone – Electrochlorination system utilizes two methods to optimize the reduction of living organism in ballast water. The system's initial operation (Hydoyclone) is intended to filter the in-coming ballast water by forcing the water into a high velocity rotational centrifugal motion resulting in the separation between particles (organisms) and water. Then the Electrochlorination process is introduced to either the particles and or the water to maximize the neutralization of any living organisms.

Menadione or Vitamin K (proprietary name Seakleen), is a natural product that is used as a disinfectant for the neutralization of living organisms in ballast water. Method of use is as a chemical compound (powder or liquid) that is poured into the ballast tank.

on a bulk carrier.[18] The deoxygenation process occurs either at uptake by mixing inert gas with the water by an eductor or by bubbling the gas into the ballast tanks by a dispersed array of bubbler pipes. The hypoxic inert gas will drive the oxygen out of the water. The presence of carbon dioxide in the inert gas stream will also significantly lower the pH of the water. The combination of low oxygen levels and low pH is toxic to most marine organisms. However, the process takes several days to complete and the ballast water needs an inert atmosphere for the entire period. Thus, the ballast tanks need to connect to a central inert gas system with a closed venting system similar to cargo tanks on tankers. This requires modification of the tanks in addition to the installation of a system to apply the inert gas to the ballast water. According to the research findings, when the ballast water is discharged, the hypoxic and low pH ballast water quickly returns to normal levels upon mixing with the receiving waters. According to research, the time required to achieve the desired kill rates is about 3 to 6 days, which may pose a problem for vessels on short routes. Additionally, some organisms, such as spores, are more resistant to this treatment method, particularly if the oxygen levels and pH levels are not as low as intended.

Treatment processes based upon *Filtration and Radiation* are considered capable of meeting the BWD-2 standard, but testing done to date shows it may not be as effective as some of the other processes.

For many of these systems, the filtration design can remove organisms above 50 microns in size, and filtration takes place at uptake with the filtrate returned to the source waters. One vendor proposes a portable system for ballast discharge. For this design, the filtrate needs to be disposed of ashore or retained onboard for disposal in the deep ocean. Some of the problems linked to filtration systems are that excessive sediment can overload them and some organisms can slip through filters because of their shape. Smaller organisms require a secondary treatment, such as ultra violet (UV) radiation or processes that use photocatalytic effects to create hydroxyl radicals. Both UV and hydroxyl radicals damage cells so that life is no longer sustainable. These technologies are well established; for example, UV is widely used in water purification. However, UV and other electromagnetic radiation-based treatments are sensitive to the transmittance capacity of the water and can be less effective in cloudy water and when insufficient wattage is applied. These systems require no residence time in the tank for the treatment to be effective.

A fifth treatment process is the generation of ozone onboard. The systems proposed for this treatment are less well established compared to the other treatment processes considered. Application of the correct dosage depends on the condition of the incoming water and, therefore, these systems require complex controls and an ozone generator. Additionally, because ozone is a hazardous gas, the process becomes more complicated. Residuals, such as bromine-based compounds, may persist in the discharged water. Ballast residence time is not a concern with these types of systems because some of the procedures work at discharge only and others require only hours of residence time in the tank.

[18] These systems require an inert gas generator and may require installation of a closed vent piping system for the ballast tanks, plus additional piping if the gas is distributed by a bubbler system.

While the use of heat as a means to sterilize water is well documented and utilized extensively onshore, there is uncertainty about whether sufficient heat is available onboard to meet the required temperature and maintain it for the requisite period of time. These uncertainties include:

(1) The degree to which additional heat generators are needed to achieve the required heat;
(2) Whether sufficient residence time is available at the required temperature;
(3) The very large differences in allowable ballast flow rate depending on the temperature of the incoming water;
(4) The significant impact of ambient conditions; and
(5) Whether heat is only available at sea when the main engine is under full power.

The *Heat Treatment* system may require operation while underway if there is insufficient heat available in port[19] to achieve the required temperatures to kill the necessary number of organisms during ballast water loading. This system may not be practical except in circumstances in which recirculation of ballast water between the heating elements and the individual tanks is feasible and desirable. We did not consider *Heat Treatment* in the analyses of costs and performance described below because of the uncertainties identified above. Of particular concern is the large range in capital and operating costs, depending on the heat sources onboard the vessel and whether additional heat sources are necessary to achieve a fully functional heat treatment system on a variety of vessels. This process did not appear to offer lower costs or more effectiveness than competing treatment processes; therefore, we will not discuss this option further.

We evaluated the following treatment processes and found that they have well-defined systems under development with the potential to meet the BWD-2 standard: *Chlorine Generate, Chemical Apply, Filter & Radiate, Deoxygenate* and *Ozone Generation.* These processes are included in the analysis of their suitability for the various categories of vessels and the costs to acquire, install, and operate them. We also evaluated the potential for the various treatment processes to meet stricter standards than BWD-2 and their impact on costs for meeting such standards.

[19] The source of heat will normally be the main propulsion system. This system may not be active in port or not operating at a level sufficient to provide heat to the ballast water treatment system.

## 3.2 Applicability of BWTS to Vessel Types

In Table 3.2, we evaluated twenty-two different categories of vessels for this project.

**Table 3.2 Suitability of BWTS to Vessel Type**

| Vessel Category | Vessel Size Range | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxygenate | Ozone Generate |
|---|---|---|---|---|---|---|
| **Bulk carriers** | | | | | | |
| Handy | < 50,000 DWT | Yes | Yes | Yes | Yes | Yes |
| Panamax | 50,000–80,000 DWT | Yes | Yes | Yes | Yes | Yes |
| Capesize | > 80,000 DWT | Except large | Yes | Except large | Yes | Yes |
| **Tank ships** | | | | | | |
| Handy | < 35,000 DWT | Yes | Yes | Some systems | Yes | Some systems |
| Handymax-Aframax | 35,000–120,000 DWT | Yes | Yes | Some systems | Yes | Some systems |
| Suezmax | 120,000–160,000 DWT | Yes | Yes | Some systems | Some systems | Some systems |
| VLCC | 160,000–320,000 DWT | No, too large | Yes | No, too large | Some systems | Some systems |
| ULCC | > 320,000 DWT | No, too large | Yes | No, too large | Some systems | Some systems |
| **Containerships** | | | | | | |
| Feeder | < 500 TEU | Yes | Yes | Yes | Yes | Yes |
| Feedermax | 500–1000 TEU | Yes | Yes | Yes | Yes | Yes |
| Handy | 1000–2000 TEU | Yes | Yes | Yes | Yes | Yes |
| Subpanamax | 2000–3000 TEU | Yes | Yes | Yes | Yes | Yes |
| Panamax | > 3000 TEU | Yes | Yes | Yes | Yes | Yes |
| Postpanamax | > 3000 TEU | Yes | Yes | Yes | Yes | Yes |
| **Other vessels** | | | | | | |
| Passenger ship | All sizes | Yes | Yes | Yes | Yes | Yes |
| Gas carrier | All sizes | Except large | Yes | Except large | Some systems | Some systems |
| Chemical carrier | All sizes | Except large | Yes | Except large | Some systems | Some systems |
| RORO | All sizes | Yes | Yes | Yes | Yes | Yes |
| Combination vessel | All sizes | Yes | Yes | Yes | Yes | Yes |
| General cargo | All sizes | Yes | Yes | Yes | Yes | Yes |
| Fishing Vessels | All sizes | Yes | Yes | Yes | Yes | Yes |
| OSVs | All sizes | Yes | Yes | Yes | Yes | Yes |

Note: For tankers, chemical carriers, and gas carriers, some systems are not suitable, either because they are not designed to be installed in a hazardous atmosphere such as a tanker pump room or because they are not produced at the high capacity required for large tankers.

## 3.3 Acquisition and Installation Costs

Manufacturers have supplied estimates of the acquisition and installation costs for the alternative BWTS. Acquisition costs include the following: costs for designing the system, license fees, regulatory approvals, cost to purchase equipment, and costs for developing a specification suitable for installation of the unit on the desired vessel. We also included in the cost estimate the necessary changes to existing piping, equipment, arrangement, and structure. For new vessel construction, the information would be provided to the shipyard design staff so that they could properly incorporate the alternative BWTS into the ballast system and machinery space. Installation costs include transporting the system to the installation location, providing service technicians, surveying by regulatory agencies, carrying out required modifications to the vessel, installing the system onboard, and testing. Some of the less intrusive systems can be installed with the vessel in service, but many systems require the vessel to be out of service for several days to make the necessary modifications. The *Chlorine Generate, Chemical Apply, Ozone Generate* at discharge (if container mounted) and *Filter and Radiate* are easy to install on smaller vessels. The *Deoxygenate* systems would require a modification to the ballast tank venting system and the vessel to be out of service for several days or weeks. None of the proposed systems requires the vessel to be drydocked.

Costs associated with out-of-service time are not included in the installation cost estimates because we assumed the work would be completed either with the vessel on its normal schedule or during a regularly scheduled maintenance and repair out-of-service period. Installation costs would vary depending on the geographic location of the modification.

In general, the cost of incorporating an alternative BWTS into a new vessel would be lower than an existing vessel because the required space and interface connections for the ballast and electric power systems can be designed in the most efficient manner without having to modify the vessel. However, the new construction designs and building cycle takes several years. Problems may arise if industry is not provided adequate implementation time to incorporate the systems into the initial design of some new vessels; therefore, a retrofit would be the only living option.

Because this type of specialized equipment cannot be independently priced, the cost analysis relies largely on manufacturer provided data. Manufacturers, evaluated for reasonableness, supplied costs for equipment and installation, and adjustments made where appropriate. We estimated installation costs if unavailable from the manufacturers. Table 3.3 shows the costs to acquire and install systems in the U.S. (high) and China (low) based on four nominal capacities of systems.

**Table 3.3 Installed Costs ($000) per Vessel for Typical BWTS**

| System Size (m3/hr) | Costs for each process | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxy-genate | Ozone Generate |
|---|---|---|---|---|---|---|
| 250 | Acquire | 250 | 200 | 175-250 | 100-400 | 200-250 |
| | Install, High | 100 | 100 | 100-110 | 100-150 | 100-125 |
| | Install, Low | 50 | 50 | 50-60 | 65-100 | 50-65 |
| 750 | Acquire | 350 | 225 | 390-450 | 300-400 | 375-400 |
| | Install, High | 150 | 150 | 150-175 | 150-250 | 150-200 |
| | Install, Low | 75 | 75 | 75-100 | 100-150 | 75-125 |
| 2,000 | Acquire | 500 | 275 | 650-700 | 400-625 | 650-750 |
| | Install, High | 200 | 200 | 325 | 220-450 | 250-400 |
| | Install, Low | 100 | 100 | 200 | 120-250 | 125-250 |
| 5,000 | Acquire | NA | 400 | NA | 512-900 | 1,150-1,825 |
| | Install, High | NA | 250 | NA | 255-750 | 375-700 |
| | Install, Low | NA | 125 | NA | 150-425 | 200-400 |

Source: Herbert Engineering Corporation. Note: We indicate a range of costs for a process when several manufacturers for that process were part of this analysis. We provide a single cost where a single manufacturer supplied data for that system. NA means the system is not available in that size.

We applied the above costs to the 22 categories of vessels evaluated in this analysis. Because this work occurs at a wide variety of ports, we considered it suitable to use an average installed cost (average cost of acquisition and installation). For example, we calculate the cost of a 1,300 $m^3$/hr chorine generate system by interpolating the costs of the 750 and 2,000 $m^3$/hr systems as follows[20]:

Average Cost of 750 $m^3$/hr system = 350 + (150+75)/2 = 463

Average Cost of 2,000 $m^3$/hr system = 500 + (200+100)/2 = 650

Per $m^3$/hr change to system cost = $\frac{650-463}{2000-750} = 0.15$

Total Cost of 1,300 $m^3$/hr system = 463 + (1300-750) x 0.15 = 545

Tables 3.4 provides the average ballast pumping capacities for each category of vessel and state the costs for the systems of the indicated capacities (using the data in Table 3.3) for the U.S fleet. Installed costs vary, depending on the technology utilized and the cost of the equipment to implement that process. However, variations in cost are also related to a process's development stage.

[20] This sample calculation is meant to estimate the combined costs for installations in both U.S. and foreign vessels. To reflect the costs to the US fleet only, we adjust the equations by removing the lowest installation cost if there is a range of costs dependent on where the system is installed as provided in Table 3.3. The rationale for the adjustment of the equation above is the assumption that higher costs are incurred in the US while the lower costs will be realized overseas.

**Table 3.4 Estimated Average Installed Cost ($000) for the U.S. Fleet by Vessel Category and BWTS**

| Vessel Category | Est. Ballast Pumping Capacity (m3/hr) | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxygenate | Ozone Generate |
|---|---|---|---|---|---|---|
| **Bulk carriers** | | | | | | |
| Handy | 1,300 | 764 | 419 | 801 | 837 | 842 |
| Panamax | 1,800 | 668 | 459 | 961 | 1007 | 1062 |
| Capesize | 3,000 | 867 | 533 | 641 | 1267 | 1,608 |
| **Tank ships** | | | | | | |
| Handy | 1,100 | 556 | 403 | 737 | 769 | 754 |
| Handymax/ Aframax | 2,500 | 725 | 504 | 750 | 1061 | 1,292 |
| Suezmax | 3,125 | 894 | 541 | 641 | 1167 | 1,563 |
| VLCC | 5,000 | NA | 650 | NA | 1650 | 2,525 |
| ULCC | 5,500 | NA | 615 | NA | 1488 | 2,375 |
| **Containerships** | | | | | | |
| Feeder | 250 | 350 | 300 | 360 | 550 | 375 |
| Feedermax | 400 | 395 | 323 | 440 | 580 | 443 |
| Handy | 400 | 395 | 323 | 440 | 580 | 443 |
| Subpanamax | 500 | 425 | 338 | 462 | 563 | 488 |
| Panamax | 500 | 425 | 338 | 462 | 563 | 488 |
| Postpanamax | 750 | 500 | 375 | 625 | 650 | 600 |
| **Other vessels** | | | | | | |
| Passenger ship | 250 | 350 | 300 | 360 | 550 | 375 |
| Gas carrier | 4,800 | NA | 638 | NA | 1612 | 2,433 |
| Chemical carrier | 600 | 455 | 353 | 546 | 620 | 533 |
| RORO | 400 | 395 | 323 | 440 | 580 | 443 |
| Combination vessel | 400 | 395 | 323 | 440 | 580 | 443 |
| General cargo | 400 | 395 | 323 | 440 | 580 | 443 |
| Fishing Vessels[21] | 250 | 350 | 300 | 360 | 550 | 375 |
| OSVs[22] | 325 | 319 | 258 | 346 | 508 | 347 |

Source: Herbert Engineering Corporation. Note: The costs are derived from HEC information in Table 3.3. Data in the table reflect the costs of both installation and operation for the US fleet only.

[21] Information obtained through consultation with the U.S. Coast Guard Commercial Fishing Vessels Division.
[22] Information obtained through consultation with the U.S. Coast Guard Offshore Vessels Division.

## 3.4 Operation Costs

The operational costs of a BWMS have several components. They are as follows:

1. Energy, usually electrical, to power the system.
2. Consumables utilized in operating the system. For some treatments, chemicals are consumed in the process. Others utilize lamps or filters that must be replaced periodically. The manufacturers for each process identified these.
3. Crew labor to operate the system.
4. Periodic maintenance and servicing of the system.
5. Replacing components as they wear out or become defective.
6. Other logistics, including training and technical information.

The manufacturers supplied us with estimates for the energy needs. Based on these estimates, we developed a nominal cost per cubic meter of pumped ballast. Manufacturers also advised us on the normal consumables expended in the operation of the system. For example, using this information, we estimated the costs associated with chemical biocides on a cubic meter processed basis. Some consumables (such as UV lamps) are required after a certain quantity of hours of operation. We converted these costs into per cubic meter costs utilizing the pumping rate of the system. The cost of required crew labor was not a significant cost to manufacturers because most systems featured automatic controls in varying forms. We added all the direct operational costs together into an order of magnitude cost per cubic meter treated. We evaluated the costs for four nominal system sizes. Table 3.5 includes the estimated direct operational costs per cubic meter treated, covering costs for energy, consumables, and labor.

Although not a direct cost of operation, the costs for service technicians, maintenance, repair, and replacement of components can be the largest cost component of a BWTS. The BWTS generally contain many expensive components, as evidenced by the high acquisition costs, and many of these components require servicing and periodic maintenance. Additionally, many components will require replacement over a vessel’s lifetime. As an estimating guide based on HEC input, we assumed that half the initial cost of a system was associated with mechanical and electrical components that need maintenance, repair, and replacement over time. The other half focuses on design fees, license fees, structural elements, etc. Based upon marine industry maintenance and repair experience, we have taken the annualized maintenance and replacement costs at 10 percent of the purchase cost for machinery per year.

To determine the maintenance costs per year for each treatment systems, HEC averaged the different vessel category’s acquisition costs in Tables 3.4, divided it by two to account for machinery and electrical equipment costs, and multiplied that figure by 10 percent to yield a net annualized maintenance cost of 5 percent of the initial cost per year. We then divided the estimated annual costs for the four nominal system sizes by the estimated annual ballast flow for each system equal to about 100 times the system flow rate to get the estimated annual maintenance cost per cubic meter of treated ballast.[23] As can be seen, the maintenance and replacement costs are larger than the direct operating costs. As expected from economies of scale, the maintenance and replacement costs per cubic meter treated get smaller as the system size increases because large systems cost less to buy and maintain per cubic meter treated.

**Table 3.5 Operation Costs per Cubic Meter Treated by Treatment Process ($/m$^3$)**

| System Size (m3/hr) | Cost Component | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxygenate | Ozone Generate |
|---|---|---|---|---|---|---|
| 250 | Direct Operation | $0.02 | $0.08 | $0.05 | $0.05 | $0.05 |
| | Maintenance & Replacement | $0.42 | $0.33 | $0.36 | $0.17 | $0.38 |
| | **Total** | **$0.44** | **$0.41** | **$0.41** | **$0.22** | **$0.43** |
| 750 | Direct Operation | $0.02 | $0.08 | $0.05 | $0.05 | $0.05 |
| | Maintenance & Replacement | $0.23 | $0.15 | $0.28 | $0.20 | $0.26 |
| | **Total** | **$0.25** | **$0.23** | **$0.33** | **$0.25** | **$0.31** |
| 2,000 | Direct Operation | $0.02 | $0.08 | $0.05 | $0.05 | $0.05 |
| | Maintenance & Replacement | $0.13 | $0.07 | $0.17 | $0.13 | $0.18 |
| | **Total** | **$0.15** | **$0.15** | **$0.22** | **$0.18** | **$0.23** |
| 5,000 | Direct Operation | NA | $0.08 | NA | $0.05 | $0.05 |
| | Maintenance & Replacement | NA | $0.03 | NA | $0.08 | $0.12 |
| | **Total** | **NA** | **$0.11** | **NA** | **$0.13** | **$0.17** |

Source: Herbert Engineering Corporation. Note: NA means the system is not available in that size.

Table 3.6 shows the total estimated operating costs per year for each category of vessels analyzed in this RA. We obtained these values by interpolating the data for total operational costs based on nominal systems sizes as given in Table 3.5, assuming the average pumping capacity for each vessel category as given in Tables 3.4.

[23] This estimate is based upon a review of typical numbers of voyages and amounts discharged across all vessel types as in the BWE section.

**Table 3.6 Estimated Average Operational Cost per Cubic Meter of Ballast Treated by Vessel Category and Treatment Process ($/m$^3$)[24]**

| Vessel Category | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxygenate | Ozone Generate |
|---|---|---|---|---|---|
| **Bulk carriers** | | | | | |
| Handy | $0.21 | $0.19 | $0.28 | $0.22 | $0.27 |
| Panamax | $0.17 | $0.16 | $0.24 | $0.19 | $0.24 |
| Capesize | $0.13 | $0.14 | $0.18 | $0.16 | $0.21 |
| **Tank ships** | | | | | |
| Handy | $0.22 | $0.21 | $0.30 | $0.23 | $0.29 |
| Handymax/Aframax | $0.11 | $0.12 | $0.17 | $0.15 | $0.20 |
| Suezmax | $0.13 | $0.14 | $0.17 | $0.16 | $0.21 |
| VLCC | NA | $0.11 | NA | $0.13 | $0.17 |
| ULCC | NA | $0.11 | NA | $0.13 | $0.17 |
| **Containership** | | | | | |
| Feeder | $0.44 | $0.41 | $0.41 | $0.22 | $0.43 |
| Feedermax | $0.38 | $0.36 | $0.39 | $0.23 | $0.39 |
| Handy | $0.38 | $0.36 | $0.39 | $0.23 | $0.39 |
| Subpanamax | $0.35 | $0.32 | $0.37 | $0.24 | $0.37 |
| Panamax | $0.35 | $0.32 | $0.37 | $0.24 | $0.37 |
| Postpanamax | $0.25 | $0.23 | $0.33 | $0.25 | $0.31 |
| **Other vessels** | | | | | |
| Passenger ship | $0.44 | $0.41 | $0.41 | $0.22 | $0.43 |
| Gas carrier | NA | $0.21 | NA | $0.13 | $0.17 |
| Chemical carrier | $0.31 | $0.29 | $0.36 | $0.24 | $0.35 |
| RORO | $0.38 | $0.36 | $0.39 | $0.23 | $0.39 |
| Combination vessel | $0.38 | $0.36 | $0.39 | $0.23 | $0.39 |
| General cargo | $0.38 | $0.36 | $0.39 | $0.23 | $0.39 |
| Fishing Vessels | $0.44 | $0.41 | $0.41 | $0.22 | $0.43 |
| OSVs | $0.43 | $0.38 | $0.40 | $0.22 | $0.42 |

Source: Herbert Engineering Corporation. Note: NA means the system is not available in that size.

## 3.5 Meeting Stricter Standards

We are evaluating stricter standards that reduce permitted discharge levels of NIS to one-tenth or even one-hundredth of what is permitted by BWD-2. These are termed BWD-3 (one-tenth of IMO) and BWD-4 (one-hundredth of IMO). Possible means for achieving an effectively zero discharge standard are discussed separately.

In our assessment, if a possible system meets the BWD-2 standard, then it may be modified to meet a stricter standard such as BWD-3. However, verifying whether a system meets BWD-4 limits is problematic because BWD-4 institutes a high kill rate. Current testing methodology is not capable of ascertaining whether BWD-4 goals are achievable. Furthermore, testing such strict standards onboard a vessel will be even more difficult. Considering the vast diversity of organisms in the sea with multiple orders of magnitude difference in size, the problem of how to measure the achieved discharge rates of NIS as analyzed in the various alternative standards is a serious concern of all involved parties. The

[24] We assumed operational costs are the same for the U.S. and the foreign fleets.

IMO is evaluating draft guidelines for testing and approval that may be applicable to future regulations. In BWD-2, only 10 organisms per cubic meter, 50 micron, in size or larger, can be discharged. If a single test proves insufficient, onboard personnel must test several additional cubic meters of water to confirm that the shipboard system meets the standard. However, if a standard of one-tenth of the BWD-2 limits were implemented (BWD-3), testing of several tens of cubic meters or more is needed in order to ensure the validity of the data. For the BWD-4 standard that permits only 1 live organism per 10 cubic meters, the quantity of water for testing reaches into the hundreds of cubic meters. Therefore, finding the few living organisms that may have survived is a difficult and impractical task utilizing existing technology. Most manufacturers agreed this was of concern when we discussed the possibility of their system undergoing improvements to meet a stricter standard. They claimed it would be possible to improve their system to meet a stricter standard, but that there was no practical way of demonstrating it.

A standard can only be effective if there is a practical and repeatable means for testing and confirming the standard's goal. If a system meets a standard in the laboratory or in a type approval test in a shop, this does not necessarily prove that the system will operate at this level under real world circumstances. We based this conclusion on the difficulties encountered when testing BWTS in full-scale on vessels. The latest guideline (G8) from IMO, per MEPC 53, requires full-scale shipboard testing as part of the type approval process. For individual vessel installations, only functional testing would be required.

Several approaches to meeting a stricter standard, such as BWD-3, appear promising. One involves making the system more lethal by increasing dosage rates, increasing UV radiation power, and increasing residence time in tanks. Another approach requires processing the water twice, by either installing equipment in series or treating the water a second time ("second pass") after it has been placed in the ballast tank and before discharge. A third approach combines treatment and exchange.

In consultation with the vendors, we conducted an initial investigation of each of the treatment processes subjected to analysis in this RA to determine how to meet a stricter standard, such as BWD-3 (1/10 IMO). Table 3.7 presents the results of this investigation.

**Table 3.7 Cost Impacts of Achieving a Stricter BWD-3 Discharge Standard**

| Treatment Process | Way to make more effective | How to reach BWD-3 | Effect on Capital Cost | Effect on Operating Cost |
|---|---|---|---|---|
| Chlorine Generate | Higher dosage rates | Increase dosage rate, monitor and redose if TRO becomes low. Requires more de-oxidant because of higher dose | 150% | 175% |
| Chemical Apply | Higher dosage rate | Dosage to about 7 ppm | 125% | 200% |
| Filter & Radiate | Duplication, more intensity, lower flow | Process two times. May cause delay in vessel operation by slow ballast rates | 175% (less if ballast can be retreated at later time in voyage) | 250% |
| Deoxygenate | Longer residence time in tanks | Larger venturi (or more bubbler pipes) for a more comprehensive treatment. More days may cause vessel delays; adding to operating cost | 125% | 250% |
| Ozone Generate | Higher dosage rate or double treatment | Increase dosage rate and slower flow. May cause delay in vessel operation by slow ballast rates | 175% | 250% |

Source: Herbert Engineering Corporation. Note: The indicated percentages for the Effects on Capital and Operating Costs are the increased costs to meet BWD-3 compared to meeting BWD-2.

For several of the processes, the operating costs increased by a factor of 2.5 (250 percent) because it is anticipated that some delays will occur due to the fact that more intense treatment slows the ballast pumping rates. This cost factor includes costs associated with possible delays. Because manufacturers have not developed designs for meeting stricter standards, these cost increases provide a rough order of magnitude. For purposes of estimating the order of magnitude on a fleet-wide basis, we propose using a capital cost factor of 175 percent and an operating cost factor of 200 percent for comparing the costs of systems designed to meet BWD-3 with the cost of systems designed to meet BWD-2.

Utilizing Table 3.7, it appears that the chemical biocide systems is promising because the higher kill rates may be achieved by a single processing of the ballast water, albeit with a higher dosage rate. This approach has the smallest increase on capital costs. The *Chemical Apply* system has double the operating cost because it utilizes more chemicals to increase the dosage rate. In the *Chlorine Generate* system, some operating costs are not directly related to the dosage rate, so the operating cost will not increase as much.

A vessel may achieve a more effective rate of filtration by filtering the water twice. During the first filtration, there may be some clogging or poor sealing of the filter, or some organisms may slip through; but they would likely be captured in the second round when the water would be cleaner. Similarly, for the UV or other secondary treatment applied after the filtration, a second treatment would significantly increase the kill rate because the water should be clearer and have fewer living organisms. Double processing may require installing duplicate systems, which may increase the capital cost by 175 percent (not all costs would be duplicated, just some of the equipment costs).

The effectiveness of the *Deoxygenate* systems cannot be improved by a more intense treatment because once the oxygen is taken out and the pH lowered, the system is at its maximum efficiency. To meet a stricter standard, more powerful equipment may be provided to ensure that the most complete processing is employed; that is, to ensure that the required levels of deoxygenation and pH are achieved every time and fully maintained over the required period of time. This is the logic behind assigning a factor of 125 percent to this system. The effectiveness of this system can be improved by retaining the water in the deoxygenated environment for a longer period of time. For vessels on shorter voyages, this will create additional costs if a vessel has to wait or hold unwanted ballast because it cannot meet the required residence time, approximately 6 to 10 days.

Chemical biocides may be the most efficient means of achieving higher kill rates.  Several manufacturers mentioned that the effectiveness of some of the other systems may improve by adding a chemical biocide treatment. For example, if manufacturers added this treatment to a filtration and UV system, the expected impact on cost would be similar to that given above. Such an approach would eliminate the need to double-process the water and would simplify the handling of ballast for the vessel operator. This change, however, makes the installed system more complex and may create concerns about handling chemicals and possibly neutralizing them before discharge. Based on testing done by several manufacturers for chemical biocide systems, there appears to be no benefit in combining biocides with filtering because the biocide can kill all organisms.

For some of the processes, longer exposure to treatment and additional processing will improve the kill rate and may achieve a higher level of sterilization. However, lowering the flow rate will increase the time for ballasting and may cause the vessel to remain in port longer, thus delaying vessel operations.

Conducting further research would provide a clearer picture of the benefits of combining treatment and exchange. However, conceptually it appears to achieve a reduced level of organisms in the treated water. This technique would work as follows:  any ballast water taken on in coastal or port waters would be treated so that the water in the ballast tanks had reduced organisms compared to untreated water. The treated coastal ballast water would be replaced via BWE during the voyage, either by the ER or FT method, with mid-ocean water. It is possible that water taken on in mid ocean would have far fewer organisms than coastal or port waters. Treating the mid-ocean water upon intake could further improve overall effectiveness. This dual process approach has the potential of meeting a stricter standard with existing technology designed for the BWD-2 standard. There would be no impact on capital cost, but operating cost would roughly double because the contents of a ballast tank require treatment at least twice because of exchange. However, this approach would, not alleviate safety concerns associated with BWE.

Evaluating technologies capable of meeting *Alternative 4* (BWD-4) standards remains an uncertain endeavor. In general, the approaches and issues applicable to BWD-3 apply to BWD-4.

Direct costs of the chemicals in chemical biocide systems are a function of dosage rate. Equipment costs are a function of system capacity, which in turn depends on maximum anticipated dosage rate. For higher dosage rates, equipment size increases, including larger storage tanks, dosage pumps, and pipes. Increases in equipment size and costs are not linear increases in flow rate because of some economies of scale. Other technologies might require repeated processing or series application of the method, all of which would increase costs. Longer retention times introduce the risk of voyage delays that can incur additional costs of tens of thousands of dollars per day based upon lost opportunity or demurrage fees.

Approaches that occur at uptake, such as filtration or hydroclonic separation, may be appropriate for some NIS size ranges. These approaches would also be appropriate as a method to achieve near-zero discharge of NIS *(Alternative 5)*. Filtration could be an effective approach (CSLC 2005), but recent trials (Wright and Mackey 2006) indicate that filtration is not necessarily completely effective. Early testing of hydroclonic separation, which eliminates particles (sediment or biota), shows some promise.

Eliminating BWD achieves maximum reduction in introduction of NIS. Effectively zero discharge *(Alternative 5)* might be achieved by a combination of operational practices that virtually eliminate discharge and the use of treatment systems capable of BWD-4 or similar standards to be used in the case of emergency. These emergency uses could be regulated and would not require high capacity systems. For a further discussion of effectively zero discharge, see Section 3.6.

## 3.6 Discussion

### Cost Uncertainty

Several issues regarding the certainty of the estimations made for this RA merit discussion. Although significant progress has been made in the development of the treatment systems able to meet the BWDS, these technologies are in continual development and refinement. Systems should start to be commercially available by the end of 2009 (Lloyds, 2008). Therefore, we base all costs on manufacturer estimates for the prices they hope to receive for their equipment. The rigors of the competitive marketplace have not honed prices. Additionally, the ease of installation onboard vessels depends on the vessel arrangement and its piping and machinery systems. Vessels within the same basic category can have significant differences that would affect the ease of installation. The costs for individual ships could vary widely from what is estimated for that category of vessel. Therefore, it is possible that estimated installation costs could vary with location or due to competition in the market place. Similar variance is possible for operating costs.

**Approval Technology Testing**

The technologies discussed in this RA will be subjected to the USCG BWTS approval process before being available in the marketplace. The USCG is establishing an approval program, including requirements for designing, installing, operating, and testing BWMS to ensure these systems meet required safety and performance standards. Currently, manufacturers are submitting BWMS designed to meet the BWDS. All indications are that there will soon be technologies available on the market to allow vessels to meet this standard (see NPRM for detailed information on BWDS receiving approval). Nevertheless, testing is still an ongoing process as technologies are adapted to the different vessel design, operations and environmental conditions.

**Time Frame for Implementation**

Another area of uncertainty is the possibility that there may be a shortage of equipment to implement BWTS on a large scale around the world in a short time frame. Because this is a new product, the specific components needed for this equipment are most likely not being manufactured today on the scale needed. Certainty about the requirements, testing, and approvals is needed before companies will invest in the facilities for large-scale production. There may be a time lag of several years from the time there is significant certainty to justify investment until equipment is produced and delivered on a wide scale. Additionally, the time lag between technical development of the regulatory requirements and enforcement of the regulation should be taken into consideration. Once the regulatory regime is articulated and actual production and installation have begun, we consider it relatively easy to install a treatment system. The equipment for installation is often similar to commercially available equipment and production can be increased to meet demand. However, any specialized components may not be immediately available. The normal vessel repair industry can do the installation if it does not require special training or tools.

**Safety Issues**

The purpose of BWTS is to kill living organisms. The processes utilize chemicals, radiation, and equipment that create conditions that may be hazardous to human health. There is an existing regulatory environment onboard vessels and in industry regarding safety precautions and handling techniques for hazardous chemicals. We assume that any necessary modifications or special handling procedures will be resolved by individual vessels during the choice and installation of equipment. Manufacturers who use chemicals in the system have proposed transporting and restocking chemicals onboard using only their trained service agents, not the vessel's crew. Manufacturers would also like to set up procedures for disposal of unused chemicals in the event that the system on a vessel needs to be disabled or dismantled. Most of the BWTS are sealed processes, in which case the vessel's crew would not handle or apply the chemicals by hand. Sealed pipes transfer chemicals from the storage tanks to the processing equipment. To prevent discharge of large amounts of hazardous chemicals during a vessel casualty, requirements are needed to ensure that the quantities onboard should be limited and that they should be stored in sturdy containers in a protected location.

Systems that employ radiation, such as UV-based systems, require safeguards in place to ensure against human exposure to the UV and that users are aware of any special precautions needed for disposing of the UV lamps. Vessel operators should already be aware of these precautions as UV equipment is currently used onboard vessels for potable water sterilization. Chlorine generation systems have already been used onboard vessels on a small scale for eliminating fouling in vessel seawater cooling systems. With regard to the *Deoxygenate* process, in which the ballast tanks need to be inerted, tanks must be well-vented prior to personnel entering them. Tankers currently have experience with inerted cargo tanks, but most dry cargo vessel crews have no such experience. If there are cracks in the ballast tank bulkhead, inert gas may flow into adjacent spaces, including cargo holds or void spaces, posing a hazard to anyone entering those spaces. Good tank entry practice is to test the atmosphere in any enclosed space, such as a tank, for oxygen prior to entry. These procedures need to be rigorously applied onboard a vessel that employs a process utilizing inert gas. Overall, we believe the safety issues with regard to the operation of BWTS onboard vessels can be managed.

**Environmental Concerns**

BWTS that employ chemicals or generate chemicals onboard need to be designed in a manner that ensures that no active biocides are discharged overboard. For many of the systems, the biocide has a short life and would degrade by the time the vessels discharges ballast. Other manufacturers have determined that the discharged ballast water would have residual biocide and they have incorporated features into their systems to neutralize the residual chemicals. This typically involves adding a neutralizing agent, which makes it safe to discharge ballast overboard. Manufacturers that employ the *Deoxygenate* process have tested the effect of the hypoxic and low pH water on the receiving waters and have determined that it dissipates within a few meters of discharge. There are pending guidelines from IMO about the testing requirements for systems that employ active substances, and these requirements cover verification of the effects on the environment of discharging ballast water treated in the proposed manner.

**Effect on Corrosion in Tanks**

The proposed BWTS processes have varying effects on the corrosion of steel in ballast tanks. Several systems have no effect, such as the ones that filter and irradiate the water. The systems that deoxygenate the water actually reduce corrosion in tanks because there is less oxidation of the steel at reduced oxygen levels (Tamburri and Ruiz, 2005). Furthermore, manufacturers indicate that because these processes do not fully remove all oxygen, anaerobic conditions do not exist in the tanks; therefore, growth of anaerobic bacteria would not be promoted. Possible establishment of anaerobic conditions would be of concern because anaerobic bacteria are able to accelerate corrosion.

BWTS that apply chemicals such as chlorines and ozone generally create oxidants that can promote corrosion. If a tank is well-coated with a hard epoxy, there should be limited deleterious effects at the concentrations of chemicals required for ballast treatment. However, if tank coatings have deteriorated, then we expect accelerated corrosion. In addition, if we increase dosage rates to meet stricter standards, corrosion will increase. The heat treatment process also promotes corrosion in ballast tanks. This is an effect well known to the marine industry because ballast tanks adjacent to heated oil tanks suffer from accelerated coating breakdown and steel corrosion. Quality of coatings is an important consideration in adopting this system.

It is difficult to quantify the impact of these processes on corrosion before implementation of the systems or collection of actual corrosion data. We do not anticipate that corrosion will be a significant cost driver except, perhaps, in the case of the heat treatment system, and, therefore, the effect of corrosion is not included in the cost analysis.

**Zero Discharge as a Means of Meeting Alternative 5 Ballast Water Discharge Standard**

The most effective way to stop the spread of NIS through BWD, and thus meet the *Alternative 5* standard, is by eliminating the discharge of ballast water containing live organisms into U.S. waters. This solution is difficult to apply to all vessels because of the wide variety of vessels, cargoes, and the need of some vessels to discharge ballast in U.S. waters for safety reasons. Nevertheless, the primary strategy for eliminating the discharge of live organisms is to discharge no ballast and, if the vessel has to discharge ballast, to take measures to ensure sterilization of the ballast. We have outlined some possible approaches in the following discussion.

**Sterilized Ballast**

There are several approaches to sterilizing ballast water for discharge in ports; however, none is without significant cost and many require some change in vessel operations or investment in facilities and means of transport. Approaches to achieve sterile ballast include:

- *Sterilize the water onboard*. To accomplish sterilization of ballast water onboard requires a highly effective and intrusive BWT system, probably including filtration, high levels of biocides, and long retention times. Unlike most facilities that sterilize municipal potable water, which start with relatively clean water, these systems must account for the large amount of organisms contained in the uptake water, requiring very high kill rates.
- *Use fresh water for ballast*: Clean fresh water taken from shore is one approach to ensure sterilization of ballast water. The principal difficulties in using fresh water for vessels that normally load and discharge ballast are its cost and availability.
- *Shore-based Treatment*: Seawater ballast could be treated in a shore-based facility rather than onboard the vessel. A vessel could take on treated ballast or ballast taken on elsewhere could be discharged to a facility for treatment and disposal. Investment in widespread facilities for ballast treatment would cost millions of dollars, even at a regional level (URS/Dames & Moore 2000), and would most likely be paid for by fees to process the ballast. Considering the high cost of implementation, shoreside sterilization also appears to be a niche solution.

**No Discharge of Ballast**

Besides the sterilization of ballast water, the other alternative to obtain zero discharge of live organisms is for vessels to avoid discharging ballast in ports or coastal waters. As discussed in this RA, many vessels have already adopted this policy for many of their U.S. ports calls, particularly the ports with the most stringent regulation of ballast discharge.

One approach is to change vessel designs to make vessels more multi-purpose so they can carry a larger variety of cargoes. This would improve the possibility for backhaul cargoes. A zero discharge solution would encourage a new round of innovative solutions, but would no doubt also significantly increase overall costs.

In evaluating the possibility of eliminating discharge of ballast, we divide vessels into two primary groups:

1. Vessels that carry ballast and cargo: Vessels that normally carry a mix of ballast and cargo are the ones for which this approach is most practical. These vessels would normally not discharge or take on much ballast in any port and might achieve zero discharge.

Vessels that normally carry a mix of cargo and ballast are:
- Containerships
- RORO ships
- General cargo ships
- Combination ships
- Passenger ships

2. Vessels that carry ballast or cargo: Some vessel types carry full loads of cargo from port to port and sail from discharge ports back to the loading port in a ballast condition. These vessels generally carry bulk cargoes, either dry or liquid. Such vessels would suffer the most from a no discharge of ballast operating mode. The weight of ballast onboard when entering the loading port would reduce by the same weight the amount of cargo that can be loaded, since these vessels normally take on full loads of cargo. This lost revenue represents the cost of implementing a zero-discharge standard.

The vessels that carry either ballast or cargo are:
- Tankers
- Bulk carriers
- LNG ships
- Chemical carriers

For these vessels, the quantity of ballast onboard for a normal sea passage is roughly 35 percent of the full load cargo weight. In good weather, it may be possible for these vessels to deballast as they approach the loading port to a state where the ballast weighs only 10 to 20 percent of the full load of cargo weight. In addition, vessels such as oil tankers and LNG carriers generally arrive at U.S. ports fully laden with cargo. Such vessels will normally not discharge ballast, but will take on ballast for the return leg, and thus could meet the zero-discharge standards for U.S. arrivals.

# 4 Application of Ballast Water Treatment Cost Models

In this chapter, the system costs developed in the previous chapter is applied to the affected population. The analysis covers a 10-year period from 2012 to 2021, when the requirements for BWM first stipulate meeting BWD performance.

We have estimated the number of vessels that will have to install or retrofit ballast water systems each year for each vessel type based on the proposed phase-in schedule (presented on Table 1.1). We apply these data together with the one-time capital and installation costs to develop overall implementation costs for U.S. vessels.[25] Capital installation costs are based on the type of systems presented in Table 3.4.

This rulemaking is consistent with a multi-lateral agreement at the IMO. For the purposes of this RA, we consider the bottom-line costs of this rulemaking to involve U.S. vessels. Nevertheless, we anticipate that the development of treatment technology will involve the world fleet, not the U.S. fleet alone.

In order to estimate the cost associated with BWTS on the U.S. fleet, we needed to develop the range of technologies that may be available and the unit costs of these technologies. We assume that there will be a broad market for the new BWTS that includes both U.S. and foreign vessels, thus improving the range of technologies available and the cost efficiencies of production.

## 4.1 Calculation Approach for Costs of Ballast Water Discharge Standards

In this section, we describe the costs to install and operate BWTS. We have developed low and high estimates for installed costs for systems that would be applicable to the various vessel types.

The BWMS industry is in its formative stage, and we expect scale-based efficiencies to evolve. As noted in the previous chapter, the costs should decrease over time, but the extent is unknown and, therefore, only considered in the uncertainty analysis presented at the end of this chapter.

Under the current rulemaking, implementation of BWTS would be required starting in 2012 for new vessels and phased in over the next 5 years for existing vessels. We use the growth assumption (including removal rates) as outlined in Chapter 2 to determine the size of the fleet and the number of new vessels each year. Projecting growth trends out 10 years is an uncertain process. The entire fleet will be required to meet the discharge standards by 2016. In our cost model, for the period beyond 2016, we account only for the new vessels built in 2016 or later.

[25] See appendix A for cost estimates of foreign flag vessels projected to call in U.S. waters during the 10-year period of analysis.

Tables 4.1 presents the installation costs for the U.S. fleet. The installation costs were calculated based on the average costs for each available ballast water treatment system (Table 3.4). The low costs presented on the tables below are related to the cheapest treatment available and the high costs are related to the most expensive treatment available.

**Table 4.1 Installed Ballast Water Treatment System Costs ($000) for the U.S. Vessels**

| Vessel Type | Installed Costs in 2007 | |
|---|---|---|
| | Low | High |
| **Bulk carriers** | | |
| Handy | 419 | 842 |
| Panamax | 459 | 1,062 |
| Capesize | 533 | 1,608 |
| **Tank ships** | | |
| Handy | 403 | 769 |
| Handyman-Aframax | 504 | 1,292 |
| Suezmax | 541 | 1,563 |
| VLCC | 650 | 2,525 |
| ULCC | 615 | 2,375 |
| **Container ships** | | |
| Feeder | 300 | 550 |
| Feedermax | 323 | 580 |
| Handy | 323 | 580 |
| Subpanamax | 338 | 563 |
| Panamax | 338 | 563 |
| Postpanamax | 375 | 650 |
| **Other vessels** | | |
| Passenger ships | 300 | 550 |
| Gas carriers | 638 | 2,433 |
| Chemical carriers | 353 | 620 |
| RORO | 323 | 580 |
| Combination vessels | 323 | 580 |
| General Cargo | 323 | 580 |
| Fishing Vessels | 300 | 550 |
| OSVs | 258 | 508 |

Source: Herbert Engineering Corporation (reference Table 3.4)

The capital costs of installing the BWTS are significantly greater than existing BWE costs (Appendix B). In practice, many vessels do not discharge in U.S. waters and many could adjust their operations to avoid discharge. For example, many container vessels already set up their ballast before arriving in the EEZ based upon advance information about the next departure load condition. We anticipate that this will become the practice for many of these vessels independent of the imposed standard. In theory, these vessels could avoid the capital costs entirely. However, vessel owners will not consider the U.S. approach in isolation. For example, tankers that discharge no ballast in the U.S. may discharge ballast in other ports and so would install a BWTS if required to do so by any of the loading ports along their expected trading routes. In general, the likely approach would be to acquire the least expensive and easiest system to install and manage the ballast so that all the ballast onboard could be discharged at any time if needed.

In year 2014, vessels built before 2012 with ballast capacities between 1,500 and 5,000 cubic meters will be required to meet the discharge standards under the rulemaking phase-in structure (Table 1.1). While industry practice is to delay additional costs as long as possible, a certain proportion of the fleet will undergo these installations during routine shipyard visits for other regularly scheduled maintenance. We have assumed that 30 percent will install BWTS each year in the first two years (2012 and 2013) and 40 percent in the last year of the compliance requirement (2014).

In 2016, the remainder of the fleet built before 2012 and certain new vessels will be required to meet the BWDS. In this case, we have assumed that 20 percent of the population will install the system each year (from 2012 to 2016). Given these assumptions and the projected fleet growth as defined in Chapter 2 (Table 2.3), the number of vessels undergoing BWTS installations is as shown in Table 4.2. In order to account for the impact of these assumptions we have performed a sensitivity analysis on the effect of compliance percentage per year and the total cost of the rulemaking for U.S. vessels (section 6.2).

**Table 4.2 Number of U.S. Vessels undergoing BWTS Installation by Year and Type**

| Vessel type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017* | 2018* | 2019* | 2020* | 2021* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk carriers** | | | | | | | | | | | |
| Handy | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 24 |
| Panamax | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 12 |
| Capesize | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.5 |
| **Tank ships** | | | | | | | | | | | |
| Handy | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 9.5 |
| Handy-Aframax | 5.1 | 5.1 | 5.2 | 5.2 | 5.2 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 30.3 |
| Suezmax | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 4.5 |
| VLCC | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 1.75 |
| **Containerships** | | | | | | | | | | | |
| Feeder | 8.1 | 8.1 | 8.8 | 6.3 | 6.3 | 1.3 | 1.3 | 1.3 | 1.4 | 1.4 | 44.3 |
| Feedermax | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 16.5 |
| Handy | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 16.5 |
| Subpanamax | 11.0 | 11.0 | 11.5 | 9.6 | 9.7 | 1.8 | 1.8 | 1.9 | 1.9 | 2.0 | 62.2 |
| Panamax | 8.4 | 8.5 | 8.9 | 7.2 | 7.3 | 1.4 | 1.4 | 1.4 | 1.5 | 1.5 | 47.5 |
| Postpanamax | 5.8 | 5.8 | 5.8 | 5.9 | 5.9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 34.4 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 54.4 | 54.8 | 58.1 | 46.7 | 47.1 | 12.4 | 12.8 | 13.3 | 13.7 | 14.2 | 327.5 |
| Gas carriers | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 10 |
| Chemical carriers | 6.6 | 6.7 | 6.7 | 6.7 | 6.8 | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 | 40.5 |
| RORO | 21.1 | 21.2 | 23.1 | 16.0 | 16.1 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 | 118.5 |
| Combination vessels | 49.4 | 49.6 | 49.8 | 50.1 | 50.3 | 10.0 | 10.3 | 10.5 | 10.8 | 11.1 | 301.9 |
| General Cargo | 344.8 | 345.8 | 365.3 | 292.7 | 293.8 | 58.3 | 59.5 | 60.7 | 61.9 | 63.1 | 1,945.9 |
| Fishing | 240.3 | 242.0 | 254.2 | 214.2 | 216.1 | 57.4 | 59.4 | 61.5 | 63.7 | 66.0 | 1,474.8 |
| OSV | 33.5 | 34.0 | 35.9 | 30.5 | 31.0 | 11.2 | 11.7 | 12.3 | 12.9 | 13.5 | 226.5 |
| Total | **807** | **811** | **852** | **709** | **714** | **163** | **168** | **173** | **178** | **183** | **4,758** |

Note: Totals may not add due to rounding.
* We estimated the number of new vessels that will undergo installation after the phase-in period. We applied fleet growth rates (Table 2.3) to estimate the number of new vessels in the U.S. fleet per year. Some types of vessels have values representing a fraction of a vessel coming into service yearly. The fraction means that the rate of installation would be less than one per year.

## 4.2 Installation Costs of Ballast Water Treatments Systems

The assumptions and calculations described above form the basis for the baseline cost of the *Alternative 2* discharge standard (BWDS-2). Table 4.3 shows the breakdown by year, vessel type, and the overall share for each vessel type.

**Table 4.3 Costs for U.S. Installed BWDS-2 ($Mil)**[26]

| Vessel Type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk Carriers** | | | | | | | | | | | |
| Handy Bulk | 1.97 | 1.96 | 1.96 | 1.96 | 1.96 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 10.11 |
| Panamax Bulk | 1.08 | 1.08 | 1.08 | 1.08 | 1.07 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 5.54 |
| Capesize | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 3.5 |
| **Tank Ships** | | | | | | | | | | | |
| Handy | 0.65 | 0.65 | 0.66 | 0.66 | 0.66 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 3.85 |
| Handymax-Aframax | 2.58 | 2.59 | 2.60 | 2.61 | 2.62 | 0.43 | 0.44 | 0.45 | 0.47 | 0.48 | 15.27 |
| Suezmax | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.07 | 0.07 | 0.08 | 0.08 | 0.08 | 2.58 |
| VLCC | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 1.05 |
| **Containerships** | | | | | | | | | | | |
| Feeder | 2.42 | 2.43 | 2.63 | 1.88 | 1.89 | 0.39 | 0.39 | 0.40 | 0.41 | 0.42 | 13.26 |
| Feedermax | 0.89 | 0.89 | 0.90 | 0.90 | 0.90 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 | 5.28 |
| Handy | 0.89 | 0.89 | 0.90 | 0.90 | 0.90 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 | 5.28 |
| Subpanamax | 3.71 | 3.72 | 3.89 | 3.26 | 3.27 | 0.61 | 0.62 | 0.64 | 0.65 | 0.66 | 21.03 |
| Panamax | 2.85 | 2.86 | 3.01 | 2.45 | 2.46 | 0.47 | 0.48 | 0.49 | 0.50 | 0.51 | 16.08 |
| Postpanamax | 2.17 | 2.18 | 2.19 | 2.19 | 2.20 | 0.38 | 0.38 | 0.39 | 0.40 | 0.41 | 12.89 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 16.33 | 16.43 | 17.42 | 14.02 | 14.14 | 3.73 | 3.85 | 3.98 | 4.12 | 4.25 | 98.27 |
| Gas carriers | 1.07 | 1.07 | 1.08 | 1.08 | 1.09 | 0.19 | 0.20 | 0.20 | 0.20 | 0.21 | 6.39 |
| Chemical carriers | 2.34 | 2.36 | 2.37 | 2.38 | 2.39 | 0.47 | 0.48 | 0.49 | 0.50 | 0.52 | 14.3 |
| RORO | 6.82 | 6.85 | 7.47 | 5.17 | 5.20 | 1.29 | 1.32 | 1.35 | 1.39 | 1.42 | 38.28 |
| Combination vessels | 15.94 | 16.02 | 16.09 | 16.17 | 16.25 | 3.23 | 3.32 | 3.40 | 3.49 | 3.59 | 97.5 |
| General Cargo | 111.36 | 111.70 | 118.01 | 94.53 | 94.89 | 18.84 | 19.22 | 19.60 | 19.99 | 20.39 | 628.53 |
| Fishing | 72.09 | 72.60 | 76.27 | 64.25 | 64.82 | 17.22 | 17.83 | 18.46 | 19.11 | 19.79 | 442.44 |
| OSVs | 8.65 | 8.76 | 9.25 | 7.87 | 8.00 | 2.88 | 3.02 | 3.17 | 3.33 | 3.49 | 58.42 |
| **Total** | 255.11 | 256.35 | 269.06 | 224.67 | 226.03 | 50.75 | 52.20 | 53.68 | 55.22 | 56.80 | **1,499.87** |
| **Total PV 3%** | 247.68 | 241.64 | 246.22 | 199.62 | 194.97 | 42.51 | 42.44 | 42.38 | 42.32 | 42.26 | **1,342.04** |
| **Total PV 7%** | 238.42 | 223.91 | 219.63 | 171.40 | 161.15 | 33.82 | 32.51 | 31.24 | 30.03 | 28.87 | **1,170.98** |

Note: Totals may not add due to rounding

[26]Our Analysis acknowledges that there are U.S. flag handy and Gas Carrier vessels operating in U.S. waters. Therefore, because these vessels are not exempt under 33 CFR 151.2010, they are required to install a BWTS on their vessels even if they have not reported any ballast water discharge as indicated on Table 4.4.

## 4.3 Operating Costs of Ballast Water Treatment System

BWTS operational costs are in addition to the capital costs for installation. In order to obtain a cost of operation for U.S, we first calculated the amount of ballast discharge per vessel type (Table 4.4).

**Table 4.4 Estimated Ballast Water Discharge for U.S. Vessels in 2007**

| Vessel Type | # of Arrival | Total Ballast Water Discharged | Average Ballast Water Discharged per Vessel Type Arrival |
|---|---|---|---|
| **Bulk carriers** | | | |
| Handy | 1,135 | 10,572,584 | 9,314 |
| Panamax | 214 | 8,362,151 | 39,066 |
| Capesize | 578 | 12,719,493 | 21,993 |
| **Tank ships** | | | |
| Handy | - | - | - |
| Handymax-Aframax | 34 | 2,931,103 | 85,543 |
| Suezmax | 2 | 655,633 | 298,892 |
| VLCC | 1 | 70,706 | 85,245 |
| **Container ships** | | | |
| Feeder[a] | - | - | - |
| Feedermax | 52 | 18,868 | 362 |
| Handy | 280 | 1,246,886 | 4,456 |
| Subpanamax | 110 | 1,030,473 | 9,372 |
| Panamax | 290 | 547,131 | 1,887 |
| Postpanamax | 410 | 4,254,689 | 10,377 |
| **Other vessels** | | | |
| Passenger ships | 1 | 13 | 11 |
| Gas carriers | - | - | - |
| Chemical carriers | 160 | 224,040 | 1,398 |
| RORO | 357 | 21,508 | 60 |
| Combination vessels | 29,718 | 15,673,816 | 527 |
| General Cargo | 12,046 | 204,819 | 17 |
| Fishing Vessel | 120 | 2,237 | 19 |
| OSV | 114 | 1,415 | 12 |

Note: Totals may not add due to rounding
a. Information for Feeder vessel is assumed to the same as for Feedermax.

The average amount of ballast water discharged per vessel type is calculated by using data collected by NBIC for year 2007. The amounts of discharge from vessels, represented in the above table, are of those vessels that reported actual discharge of ballast in year 2007. This data was then cross-referenced to population data gathered from USCG MISLE database in order to match vessel activity with their corresponding category by vessel type.

Once the ballast water discharge by vessel type was determined, we multiplied these estimates by the number of vessels undergoing installation in Table 4.2 Then multiply this product by the cost presented in Table 3.6 using the lowest cost per cubic meter of water for each particular vessel type. The calculated value is then used to formulate an annual operating cost for BWT (Table 4.5) per vessel type.

Table 4.5 displays the operating costs for all affected vessels in the population. The total operating costs covering the period of analysis is $8.1 million with a discounted cost of $6.7 and $5.3 million at 3 and 7 percent discount rates, respectively.

**Table 4.5 Annual Operating Costs for BWT U.S. ($Mil)**

| Vessel Type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk Carriers** | | | | | | | | | | | |
| Handy Bulk | 0.008 | 0.017 | 0.025 | 0.033 | 0.041 | 0.042 | 0.042 | 0.042 | 0.043 | 0.043 | 0.336 |
| Panamax Bulk | 0.015 | 0.029 | 0.044 | 0.059 | 0.073 | 0.074 | 0.074 | 0.075 | 0.075 | 0.076 | 0.593 |
| Capesize | 0.004 | 0.008 | 0.012 | 0.016 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.159 |
| **Tank Ships** | | | | | | | | | | | |
| Handy | 0.002 | 0.004 | 0.006 | 0.008 | 0.010 | 0.010 | 0.011 | 0.011 | 0.011 | 0.012 | 0.085 |
| Handymax-Aframax | 0.053 | 0.105 | 0.158 | 0.211 | 0.265 | 0.274 | 0.283 | 0.292 | 0.301 | 0.311 | 2.252 |
| Suezmax | 0.034 | 0.068 | 0.102 | 0.136 | 0.170 | 0.176 | 0.182 | 0.188 | 0.194 | 0.200 | 1.450 |
| VLCC | 0.003 | 0.003 | 0.011 | 0.003 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.024 |
| **Containerships** | | | | | | | | | | | |
| Feeder | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 |
| Feedermax | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.015 |
| Handy | 0.004 | 0.009 | 0.013 | 0.018 | 0.022 | 0.023 | 0.024 | 0.025 | 0.025 | 0.026 | 0.190 |
| Subpanamax | 0.033 | 0.066 | 0.100 | 0.129 | 0.158 | 0.164 | 0.169 | 0.175 | 0.181 | 0.187 | 1.362 |
| Panamax | 0.005 | 0.010 | 0.016 | 0.020 | 0.024 | 0.025 | 0.026 | 0.027 | 0.028 | 0.029 | 0.210 |
| Postpanamax | 0.014 | 0.028 | 0.042 | 0.056 | 0.070 | 0.072 | 0.074 | 0.077 | 0.079 | 0.082 | 0.593 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.011 |
| Gas carriers | 0.003 | 0.006 | 0.009 | 0.012 | 0.015 | 0.015 | 0.016 | 0.016 | 0.017 | 0.017 | 0.125 |
| Chemical carriers | 0.003 | 0.005 | 0.008 | 0.011 | 0.014 | 0.014 | 0.015 | 0.015 | 0.016 | 0.016 | 0.117 |
| RORO | 0.000 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.019 |
| Combination vessels | 0.009 | 0.019 | 0.028 | 0.038 | 0.047 | 0.049 | 0.051 | 0.053 | 0.055 | 0.057 | 0.408 |
| General Cargo | 0.002 | 0.004 | 0.006 | 0.008 | 0.010 | 0.010 | 0.011 | 0.011 | 0.012 | 0.012 | 0.087 |
| Total | 0.195 | 0.388 | 0.591 | 0.770 | 0.958 | 0.984 | 1.014 | 1.044 | 1.075 | 1.107 | **8.127** |
| Total PV 3% | 0.190 | 0.365 | 0.541 | 0.684 | 0.826 | 0.824 | 0.824 | 0.824 | 0.824 | 0.824 | 6.728 |
| Total PV 7% | 0.183 | 0.339 | 0.483 | 0.587 | 0.683 | 0.656 | 0.631 | 0.608 | 0.585 | 0.563 | 5.317 |

Note: Totals may not add due to rounding.

## 4.4 Total Costs of Ballast Water Treatment Systems

For the purposes of estimating the total cost of BWTS, we multiply the operating costs by the proportion of vessels we have estimated to be treating ballast each year. However, once a vessel begins treatment of ballast water, their operational cost continues to be carried-over into the following periods. Therefore, total cost of the BWMS during the installation period will increase substantially due to the commutative nature of operating BWT. This section illustrates the total costs (installation and operational) for U.S. vessels over the period of analysis (2012 – 2021).

We estimate the first-year total (initial) cost of this rulemaking to be $239 million based on a 7 percent discount rate and $248 million based on a 3 percent discount rate (Table 4.6). Over the 10-year period of analysis (2012-2021), the total cost of Alternative 2 for the U.S. vessels is approximately $1.18 billion using the 7 percent discount rate and $1.35 billion using the 3 percent discount rate. The annualized cost over the 10-year period is $167.48 million at 7 percent and $158.12 at 3 percent. At the high end of costs, assuming all vessels install the highest cost treatment equipment, the annual costs over the 10-year period are $307 million at 7 percent and $290 million at 3 percent. Our cost assessment includes existing and new vessels. In Appendix C Table C.7 we show the foreign cost to illustrate the potential impact to vessel owners and operators that will be operating in U.S. waters.

In addition, owners and operators performing BWE will no longer be required to perform BWE. See Appendix B for more detail on BWE costs. We have not considered the potential cost savings due to the termination of the BWE operations in the BWDS total costs estimation presented in table 4.6 because BWE costs are extremely small when compared to the BWDS estimated costs, representing less than 0.1 percent of the total cost of this proposed rule.

**Table 4.6 Total Cost of the Rulemaking to US Vessels ($ Mil)**

| Year | Installation Costs | | Treated Ballast Water ($m^3$) | Annual Operating Costs | | Total Cost | |
|---|---|---|---|---|---|---|---|
| | 3% Discount | 7% Discount | | 3% Discount | 7% Discount | 3% Discount | 7% Discount |
| 2012 | $247.68 | $238.42 | 1,132,153 | $0.19 | $0.18 | $247.87 | $238.61 |
| 2013 | $241.64 | $223.91 | 2,241,913 | $0.37 | $0.34 | $242.00 | $224.25 |
| 2014 | $246.22 | $219.63 | 3,442,354 | $0.54 | $0.48 | $246.77 | $220.11 |
| 2015 | $199.62 | $171.40 | 4,459,499 | $0.68 | $0.59 | $200.30 | $171.99 |
| 2016 | $194.97 | $161.15 | 5,562,279 | $0.83 | $0.68 | $195.80 | $161.84 |
| 2017 | $42.51 | $33.82 | 5,705,753 | $0.82 | $0.66 | $43.33 | $34.47 |
| 2018 | $42.44 | $32.51 | 5,874,496 | $0.82 | $0.63 | $43.26 | $33.14 |
| 2019 | $42.38 | $31.24 | 6,047,200 | $0.82 | $0.61 | $43.20 | $31.85 |
| 2020 | $42.32 | $30.03 | 6,223,966 | $0.82 | $0.58 | $43.14 | $30.62 |
| 2021 | $42.26 | $28.87 | 6,404,897 | $0.82 | $0.56 | $43.09 | $29.44 |
| Total | **$1,342.04** | **$1,171.00** | | **$6.73** | **$5.32** | **$1,348.77** | **$1,176.31** |
| Annualized | **$157.33** | **$166.72** | | **$0.79** | **$0.76** | **$158.12** | **$167.48** |

Note: Totals may not add due to rounding.

## 4.5 Cost of Ballast Water Management Systems in Terms of Vessel Value and Daily Charter Rates

Shipowners face three cost elements: capital, operating, and voyage. Capital costs are fixed costs, whereas operating and voyage costs are variable. Because the fixed costs are always present, shipowners will offer their vessels for charter if at least the variable costs are covered. These costs represent the lower bound of charter rates. Installation of BWTS for new buildings represents part of the capital cost. We can compare the cost impact to the vessel value at various ages and their amortized cost to the increase in the charter rate necessary to recover this investment. Operational costs associated with BWTS would form part of the lower bound charter rate. However, as shown below for bulk carriers, these operational costs are small in comparison to charter rates.

Long-term (i.e., 12-month) charter rates reflect supply and demand. Table 4.8. shows a twenty-year average (1980-2000) of the daily time charter rates for several vessel types. However, current rates are significantly higher for most vessel types.

**Table 4.8 Average Daily Time Charter Rates, 1980-2000 (Kite-Powell 2001)**

| Vessel Type | $/day |
|---|---|
| **Bulk Carriers** | |
| Handy | 8,000 |
| Panamax | 9,500 |
| Capesize | 14,000 |
| **Tank Ships** | |
| Product | 12,000 |
| Aframax | 13,000 |
| Suezmax | 16,500 |
| VLCC | 22,500 |
| **Containerships** | |
| 400 TEU (Feeder) | 5,000 |
| 100 TEU (Feedermax) | 9,000 |
| 1500 TEU (Handy) | 13,500 |
| 2000 TEU (Subpanamax) | 18,000 |

Source: Hebert Engineering Corp., and AMSEC, LLC

Bulk carriers represent 14 percent of the overall installation costs for BWD-2. Estimated installation costs in 2021 for Handy size bulk carriers range from $419,000 to $842,000 per vessel (see Tables 3.4). Estimated values of bulk carriers at the top of the Handy size range (~50,000 DWT) vary, depending on trade demands. At the end of 2005, the estimated value of this size bulk carrier ranged from $29 million for a new vessel to $10 million for a 20-year-old vessel (Compass 2006).

The Baltic Exchange, formerly known as the Baltic Freight Index (BFI), tracks bulk carrier potential revenues through the Baltic Dry Index (BDI). From 1996 to 2003, this index varied in the range from approximately 1000 to approximately 1500 (Findata 2006). In the next two years, this index soared to over 5500 on two occasions, with a minimum below 2000, exhibiting a recent trend toward increasing volatility (Findata 2006). At the end of 2005, the BDI was about 2400. Recent projections based upon increased demand by China and other Asian countries suggest that the BDI, and thus charter rates, will tend to increase over the long term (Fearnley 2006).

The assumption that current rates represent an estimate of future returns allows for the approximation of an upper bound of the amortized cost of BWT systems relative to potential revenues.

At the end of 2005, the average 12-month time charter rate for the top of the Handy size range was $17,000 per day (Compass 2006). According to HEC, amortizing the BWMS installation costs of $419,000 to $842,000 over an assumed 15-year service life, the additional cost of BWT is approximately 0.4 to 0.8 percent of the daily charter rate. Even if the charter rates were to temporarily return to the 20-year average of $8,000 per day, the amortized cost would rise to only about 1.7 percent of the daily charter rate. HEC has estimated operating costs in 2006 to be less than 0.05 percent of the daily charter rate.

For a Capesize bulk carrier, the 10-year-old vessel estimated value is $38 million and the current average 12-month time charter is $34,500 per day (Compass 2006). Upper bound installation costs are about 3.8 percent of the value of a 10-year-old vessel. Amortizing the cost over 15 years indicates a daily cost of approximately 0.8 percent of the daily charter rate.

Tanker long-term charter rates also reflect supply and demand. Over the past four years, charter rates for Aframax tankers have steadily increased from $17,000 per day at the end of 2002 to $37,500 per day at the end of 2005 (Compass 2006). Demand for oil continues to increase as population and energy use per capita increase, thus requiring an increase in oil shipment. Tanker orders declined in 2005 compared with the previous two years (Marsoft 2006). The existing fleet of single hull tankers has largely been replaced and new construction is tapering off.

Assuming that the average 12-month time charter is $35,000 per day for an Aframax tanker, amortizing the installation cost over 15 years indicates a cost of approximately 0.6 percent of the daily charter rate. Assuming a 20-year average of $13,000 per day, the cost of the BWMS, installation increases to about 1.6 percent of the daily charter rate. Other vessel types exhibit comparable trends.

Industry experts were consulted by HEC to assess other factors affecting costs and economies of scale are possible for BWTS. The consensus was that prices provided by manufacturers represent current costs with current technologies and construction facilities. Offshore manufacturing (e.g., in China, Korea) and larger manufacturing facilities will drive down future costs.

Charter rates and the overall cost of shipping goods are market driven. The operating costs represent the lower bound of charter rates. Ship owners will pull vessels off the market when rates fall much below this level. Therefore, in the short term, modest capital costs, such as the installation of BWTS will have little or no effect on charter rates. Over the longer run, the cost of shipping goods will reflect the costs of BWTS because ship owners must ultimately recapture their investment in order to remain commercially viable.

# 5 Benefits from Reducing Invasions of Non-indigenous Species

Bioinvasions of aquatic ecosystems can result in adverse economic impacts on industries that are dependent on those ecosystems. The purpose of this section is to discuss the costs associated with bioinvasions of aquatic ecosystems, and specifically to discuss the overall economic harm attributable to bioinvasions resulting from the introduction of NIS through ballast water. Subsequent sections discuss the costs (economic harm) associated with the primary economic activities impacted by aquatic bioinvasions: (1) water-dependent infrastructure, (2) subsistence, (3) tourism and recreation, (4) water-related subsistence activities, (5) commercial fishing, and (6) recreational (sport) fishing. Quantification of some of the economic impacts, as well as a reliable assessment of public health risks (and costs) related to bioinvasions of aquatic ecosystems remain problematic.

In the second part of this chapter, we attempt to quantify and monetize avoided costs associated with future NIS invasions that represent the benefits of BWM. These avoided costs provide the same benefits whether the reduction in invasions is achieved through BWM via exchange (USCG 2004) or the use of a BWDS. Economic costs from invasions of NIS are in the billions of dollars annually.

## 5.1 Resources at Risk

### Loss of biodiversity

Invasions of U.S. waters by NIS are occurring at increasingly rapid rates (Carlton et al. 1995, Ruiz et al. 2000a). The U.S. Commission on Ocean Policy notes that invasive species are considered one of the greatest threats to coastal environments and can contribute substantially to altering the abundance, diversity, and distribution of many native species (USCOP 2004). While introduction of a NIS does not necessarily lead to invasion, the sudden availability of a new habitat and absence of natural predators can lead to runaway growth that pushes out other species. Unlike oil and other forms of pollution, where the deleterious effects can degrade over time, invasive species can persist, reproduce, and spread. The discharge of ballast water is considered a primary pathway for the introduction of NIS (USCOP 2004). The social and economic implications of accelerating the loss of biodiversity bear directly on several ecological interrelationships, including the following (NRC, 1995):

- the ocean's capacity to sustain economically significant fisheries,
- the quality of bays and estuaries as nurseries for important stocks,
- the loss of species with significant potential for biomedical products,
- the recreational value of ocean margins, and
- the aesthetic value of marine environments that remain close to their aboriginal state.

### Water-dependent infrastructure

Water-dependent infrastructure includes water intake pipes, storm sewer drains, docks, piers, canals, dams, navigation locks, and facilities such as electric power plants, drinking water treatment plants, water storage facilities, and water distribution systems (USCG 2006). Water-dependent infrastructure must deal with the impacts of unexpected interruptions caused by disruption or contamination (USEPA 2001).

Invasive invertebrates, such as the zebra mussel and the Asian clam, have adversely affected water-dependent infrastructure by fouling intake pipes and screens, causing equipment malfunction and overheating, and jamming valves and other mechanisms. Affected systems include electric power generation stations, drinking water treatment plants, industrial facilities, and navigation lock and dam structures. Additionally, invasive aquatic plants have caused problems on rivers and canals. Costs associated with the zebra mussel approach $1 billion annually and were about the same in the 1980s for the Asian clam (Pimentel et al. 2005).

**Subsistence living primarily involving Native American, Alaskan, and Hawaiian tribes**

Subsistence living in the U.S. involves Native American, Alaskan, and Hawaiian tribes, as well as the inhabitants of the U.S. territories that include Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam, and the Commonwealth of Northern Mariana Islands. The Indigenous Environmental Network (see http://www.ienearth.org/) notes that indigenous peoples depend on the fish, aquatic plants, and wildlife to a greater extent and in different ways than the general population. Many indigenous peoples are reliant on a subsistence-based lifestyle. Consumption and use of aquatic resources not only meets basic nutritional and economic needs, but also provides resources for cultural, traditional, and religious purposes (Maybee 2001). Fish stocks and water quality are linked to the health of an ecosystem and to the activities that occur in the watershed. NIS can impact both fish species and water quality, causing disruptions to local food webs. These disruptions can impact subsistence fishing and, in turn, the livelihoods of people who rely on it.

**Impacts to Commercial Fishing, Recreational Fishing, and Water-Dependent Tourism**

Invasions of NIS are capable of disrupting commercial and recreational fisheries and adversely affecting local and regional economies. NIS can degrade water-dependent tourism and recreational activities associated with fishing, boating, swimming, and scuba diving.

The domestic commercial fish and shellfish industry, which obtains its catch from many fresh and saltwater sources, including the Columbia River, the Great Lakes, the Atlantic and Pacific Oceans, and the Gulf of Mexico, contributes $45 billion to the U.S. economy annually (ERS 2004). This contribution reflects not only direct economic effects—the value of the fish and shellfish harvested—but also indirect effects, which include processing fish and shellfish for market, servicing the commercial fishing fleet, and repairing and maintaining commercial fishing gear.

An example of costs to the local economy associated with NIS concerns Ohio’s $600 million Lake Erie sport fishery, which lost 50 to 65 percent of its value between 1985 and 1995. Possible reasons include an above-capacity walleye population in early 1982, a rapidly growing white perch population from 1985 to 1993, and the zebra mussel (Hushhak 1997).

**Impacts to Public Health**

While the introduction of bacteria and viruses through ballast water is a growing concern, potential public health impacts remain virtually unexplored by scientists (Ruiz et al. 2000b). Concentrations of bacteria and viruses in ballast water have been found at very high levels—up to six to eight times higher than those for other taxonomic groups in ballast water—suggesting that invasions may be relatively common (Carlton and Geller 1993; Drake et al. 2001; Drake et al. 2002; Ruiz et al. 2000b). For example, human pathogen microorganisms are common in coastal waters and have been found in the ballast water of vessels (Ruiz et al. 2000b).

During the 1997 and 1998 shipping seasons, samples were taken from the ballast tanks of 28 transoceanic vessels (Knight et al. 1999; Reynolds et al. 1999; Zo et al. 1999). The sampling revealed the presence of a host of microorganisms, many of which are human pathogens, including fecal coliform, fecal streptococci, clostridium, salmonella, *E. coli*, *Vibrio cholerae*, cryptosporidium, giardia, and enteroviruses. The presence of these organisms demonstrated the survival of human pathogens during transoceanic transport of ballast water. It has been shown that certain microbial organisms can survive and become successfully established following BWD, thereby becoming vectors for human exposure.

The global increase in HAB via BWD poses an increased risk to human health. Some algal species contain powerful toxins, which can adversely affect fish, birds, and humans through the consumption of contaminated fish and shellfish. Paralytic shellfish poisoning, diarrheic shellfish poisoning, amnesic shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera fish poisoning are associated with natural toxins produced by HAB-forming diatoms and dinoflagellates.

## 5.2 Economic Impacts of Past NIS

Reporting on the costs in NIS invasions is almost an industry in itself. Despite the difficulty of obtaining economic estimates of the costs of aquatic introductions (Randall and Gollamudi 2001), such figures are widely published. The importance of these estimates is that they establish the scale of the costs in comparison with the costs of meeting a BWDS. Ultimately, the quantified and monetized benefits of more stringent standards lie in the reduction of the costs of invasions such as those described herein.

The U.S. EPA (Lovell and Stone 2005) has published a literature review on NIS and has noted the weaknesses of the currently available estimates: "Current empirical estimates are not comprehensive enough to determine the national or regional economic impacts of aquatic invasives. Additionally, the realm of impact categories differs across the scale of analysis and methods of estimation. By and large, there are few estimates of the non-market impacts using known methods." (Lovell et al 2006).

In the absence of a comprehensive estimate of the economic impacts due to invasive aquatic species, we review the literature on the existing estimates and develop a range of costs/impacts on a per species basis to characterize potential economic impacts of preventing future NIS invasions. The following discussion summarizes some of the available estimates of costs and damages related to past invasions, with more detailed information presented in Appendix D.

A landmark assessment of the losses from selected NIS (Table 5.1) was made in 1993 by the U.S. Congress Office of Technology Assessment (OTA 1993).

**Table 5.1 Estimated Cumulative Losses to the United States from Selected, Harmful, Nonindigenous Species, 1906-1991 (OTA 1993)**

| Category | Species analyzed (number) | Cumulative loss estimates (millions of dollars, 1991) | Species not analyzed[a] (number) |
|---|---|---|---|
| Plants | 15 | 603 | - |
| Terrestrial vertebrates | 6 | 225 | >39 |
| Insects | 43 | 92,658 | >330 |
| Fish | 3 | 467 | >30 |
| Aquatic invertebrates | 3 | 1,207 | >35 |
| Plant pathogens | 5 | 867 | >44 |
| Other | 4 | 917 | - |
| Total | 79 | 96,944 | >478 |

Source: U.S. Congress Office of Technology Assessment (OTA 1993), "Harmful Non-Indigenous Species in the United States."

In the above table, the cumulative losses due to selected fish and aquatic invertebrates total nearly $1.7 billion. Other costs are not easily assigned to marine sources; however, the marine contribution is significant. In particular, the costs associated with non-native aquatic plants are notable. O'Neill (2000) has estimated the damages costs of the Zebra Mussel (*Dreissena spp*.) introduction in the U.S and obtained amounts between $750 million and $1 billion for the period 1989–2000.

In the most extensive review to date on the economic costs of introduced species in the U.S., Pimentel et al. (2005) covers estimates for many types of NIS. As part of an overall estimate that includes both direct and indirect cost of $120 billion annually, they include $7.8 billion associated with damages and costs of controlling aquatic invaders. Aquatic contributions are broken down as follows.

**Table 5.2 Estimated Annual Costs of Aquatic Introduced Species (based on Pimentel et al. 2005) ($ 2007)**

| Species | Costs[27] |
|---|---:|
| Fish | $5.7 billion |
| Zebra and quagga mussels | $1.06 billion |
| Asiatic clam | $1.06 billion |
| Aquatic weeds | $117 million |
| Green Crab | $47 million |

The potential negative economic impact caused by aquatic invasive fish species has not been studied to the extant such that direct and indirect costs resulting from invasions can be quantified, nor is there very much data to support prevailing assumptions about the costs of invasions. In one study, an estimate of $5.7 billion is given for annual fish related costs (Pimentel 2005). This study defines cost in terms of losses to commercial and sports fishing in the Great Lakes and other U.S. inland waters. Two invasive species in particular are nearly always cited on this subject – the Ruffe *(Gymnocephalus cernuus)* and the Sea lamprey *(Petromyzon marinus)*. The Ruffe came from Europe via ballast water in the 1980's and the Sea lamprey migrated naturally. Both species prey on other fish and compete for habitat. In two studies on these species, losses were quantified in terms of future angler days lost due to decreases in fishing population (Leigh 1998 and Lupi et al 2003). While these two studies (which do not quantify costs in terms of actual expenditures) by themselves cannot be used to support the above figure of $5.7 billion, they underline one of the primary economic concerns to environmentalists regarding aquatic invasions, which is that they have the potential to cause significant harm to native fish populations and aquatic ecosystems.

The economic costs associated with mollusk infestation to U.S. waters has been estimates at as high as $1 billion per year in direct cost for Zebra Mussels *(Dreissena polymorpha)* (O'Neill 1997), and $1 billion per year for Asian Clams *(Corbicula fluminea)* (Pimentel et al. 2005). The origin of Zebra Mussel is the Caspian Sea. Scientist believe that the introduction of Zebra Mussels occurred through ballast water discharged into the Great Lakes during the early part of the 1980's. Their high rate of reproduction has enabled Zebra Mussels' colonies to spread quickly throughout U.S. waters.

The Asiatic Clam like the Zebra Mussel is believed to have entered U.S. costal waters through ballast water discharge. The first reported infestation of Asiatic Clams was discovered in San Francisco Bay during the early 1980's. Like the Zebra Mussels, the Asiatic Clam colonization around the openings of drainage pipes and siphoning pipes have caused damages to industrial facilities.

Aquatic weeds, in particular the Hydrilla weed *(Hydrilla verticillata)* which is "native to warmer areas of Asia, was first discovered in the U.S. in 1960….in Florida" (Langeland K.A. 1996). Most damages caused by this weed are the blocking of irrigation, drainage canals, and the entanglement of propeller blades.

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[27] All economic costs/damages in benefits analysis have been updated to 2007 dollars (using the Consumer Price Index).

Shipworms *(Teredo navalis)* are not worms, but an elongated clam that feeds on and lives inside wooden structure. The destruction of wooden structures by Shipworm begins during the larval stage (Chesapeake Bay Program 2008) which makes detection of the infestation impossible until the damage has all ready done. Damage is usually done to wooden boats and piers that are untreated.

The first European Green Crab (Carcinus maenas) was reported in North America in 1817 along the Atlantic Coast. (Prince William Sound Regional Citizen's Advisory Council 2004). The crab was then introduced to the west coast during the 1980's through ballast water. Damage from the Green Crabs is seen in the disappearance of native species, due in part to the aggressive nature of these crabs.

## 5.3 Benefits of Ballast Water Discharge Standards

This section describes the benefits likely to occur from the establishment of a BWDS. The standard's main goal is the prevention of future NIS invasions. Prevention of future NIS invasions will also prevent the negative impacts of such invasions, including loss of biodiversity, damage to water-dependent infrastructure, and impacts on commercial fishing, recreational fishing, water-dependent tourism, public health, and subsistence populations. We use estimates of costs associated with past NIS invasions to estimate benefits of preventing future invasions. The estimates of costs resulting from past invasions are derived from a selection of studies that vary in which types of costs are covered by the study and often vary on the time period and the geographic region covered by the study. Most often these studies include costs to control invasive species, with damages to infrastructure and impacts on fishing and tourism occasionally included. We are unable to quantify potential benefits associated with ecological damages such as loss of biodiversity, impacts to public health and impacts on subsistence populations.

Further, the majority of the studies analyzed are not specific on the entities directly affected by the NIS damages, making the identification of the portion of benefits that are transfer payments difficult. We discuss this issue in greater detail in Section 5.9.

We start the discussion of potential benefits a BWDS by presenting information on the functional benefits of the standard. We then project the number of expected future invasions and the portion of invasions prevented by the standard. We present an analysis of the range of potential cost per species and the estimated total damages of future species, as well as the potential benefits of the standard. Finally, we discuss potential transfers and uncertainties inherent in our estimates.

## 5.4 Functional Benefits of the Ballast Water Standards

Although it is difficult to determine monetary measures of the benefits of controlling NIS, we can assess the functional benefits. The primary functional benefits of the second alternative standard (BWD-2) are:

- A reduction in the concentration of organisms greater than 50 microns in size, leading to lower numbers of these organisms being introduced per discharge.

- A reduction in the concentration of organisms in the 10–50 micron size range for ballast water that was initially rich in organisms.

- A general reduction in concentrations from BWM values due to the practical requirements of meeting an upper bound standard.

- A consistent upper bound on number of organisms (of all sizes) introduced for a given discharge size.

- The potential to reduce the survivability of organisms that have been present in sediments in NOBOB vessels that subsequently take on ballast. This applies to systems that maintain a toxic environment in the ballast tank during the voyage.
- Elimination of the exemptions in the BWM regulations leading to discharge of unmanaged ballast water (e.g., safety concerns during exchange, delay of voyage required to travel to acceptable mid-ocean exchange location). The elimination of these exemptions is significant, because they often lead to discharge of large amounts of untreated ballast water. Large inoculations (i.e., large number of organisms in a discharge) are linked positively to the risk of invasions (Minton et al. 2005, Ruiz et al. 2000a, and others). In 2005, 7.7 million cubic meters of ballast was discharged from vessels from outside the EEZ that did not travel further than 200 miles from shore and thus were unable to perform mid-ocean exchange. This represents about 19 percent of the ballast discharged from vessels whose ballast originated outside the EEZ.

This overall strategy should reduce the number of new invasions because the likelihood of establishment increases with the number of organisms introduced per discharge or inoculation (Ruiz et al. 2000a, Minton et al. 2005).

The more stringent discharge standards (BWD-3 and BWD-4 at 1/10 and 1/100 concentration levels, respectively) further strengthen these benefits. Inoculation sizes will decrease in proportion to the reduction in concentrations. This reduces the chance of invasion, but the effects are extremely uncertain. There is evidence that probability of invasion reduces asymptotically with reduction in concentration (Tamburri 2005).

Zero discharge standards, if achievable, would effectively eliminate the introduction of invasive species into ballast water.

## 5.5 Annual Number of Invasions Due to Ballast Water Discharge

### Rate of Future Invertebrate Invasions

To assist in assessing the benefit of BWDS, we first estimate the number of invasions introduced by BWD from shipping. The approach is based on the invasion rate of invertebrates from shipping reported by Ruiz et al. (2000) to estimate an approximated number of invasions per year. The authors compiled data on past marine invasions of invertebrates and algae in North America from 1790 to 2000. The authors found 298 invertebrate and algae NIS in the coastal waters of North America, with an additional 76 instances in which a species has spread to more than one coast (designated as repeat invaders). The authors note that these estimates likely understate the number of actual invertebrate and algae invasions: "Our data provide only minimum estimates for established invasions of marine invertebrates and algae. We have excluded consideration of boundary residents and cryptogenic[28] species from our estimates, and the latter group may include hundreds of NIS that have gone unrecognized as such. Furthermore, many sites and taxa within North America have received little scrutiny" (Ruiz et al. 2000).

Ruiz et al characterized the mechanism for introduction of invasions and found that 62 percent of the invasions over the most recent 30-year period studied (1970 – 2000) were due to shipping. An additional 15 percent of invasions had shipping as one of the potential mechanisms, often with fishing as the other potential mechanism.

The authors also calculated the rate of invasions due solely to shipping based on historical invasion data (i.e., the number of invasions by time period back to 1790). The authors derive a "best fit mathematical model" to characterize the historical trend in invasions. The best fit model is an exponential function which is represented by the equation: $y = 1.127 \cdot e^{(0.024x)}$ , where x is time in 30-year intervals since 1790.[29]

We assume that this historical trend in invasions will continue in the future. We use this equation to project the number of invasions per year due to shipping for our evaluation period of 2012 to 2021 (see Table 5.4). Since this equation does not include the 15 percent of invasions in which shipping was one of several potential mechanisms, this approach is likely to underestimate the actual number of invasions that are the result of shipping activities.

**Rate of Future Fish and Aquatic Plant Invasions**

The Ruiz et al analysis includes only invasions of invertebrate and algae species: "Although our analysis is restricted to invertebrates and algae, it is noteworthy that at least 100 species of non-indigenous fish and 200 species of non-indigenous vascular plants are know to be established within this coastal area" (Ruiz et al 2000). To account for the additional number of fish and plant invasions that are expected to occur, we use the results of the Ruiz et al 2000 model to estimate the number of fish and plant invasions per year, based on historical data on the relationship of invasions for different specie groups. Table 5.3 summarizes the results of previous studies that characterized invasions for specific bodies of water.

[28] Cryptogenic – not clearly native or introduced

[29] The model shape (the exponential function) means that as time progresses, the rate of invasions increases greater than a simple linear relationship. In this equation, the values of 1.127 and 0.024 are constants that define the shape of the trend line (similar to the slope in a linear equation). The variable of x is a measure of time, specifically time in 30-year intervals since 1790.

**Table 5.3 Distribution of NIS by Plants, Invertebrates and Fish for Three Regions (Cohen and Carlton, 1995)**

| | Miller et al. 1993 Great Lakes | Mills et al. 1995 Hudson River | Cohen and Carlton 1995 San Francisco Estuary |
|---|---|---|---|
| Plants | 60% | 63% | 23% |
| Invertebrates | 20% | 18% | 61% |
| Fish | 18% | 19% | 13% |

Source: Cohen and Carlton, 1995, page 283.

In two of the studies, the percent of invasive fish species was roughly equal to the number of invertebrates and the number of plant species was roughly 3 times the number of invertebrates. The third study employed a more strict criteria for inclusion of plant species and found that the number of plant species was 40 percent of the number of invertebrates and fish species were roughly 20 percent of the number of invertebrates. We use these two sets of relationships to project the annual number of invasive fish and plant species as displayed in Table 5.4. For the purposes of estimating economic impacts of invasions, we use the number of fish and aquatic plant invasions that result from Relationship 2 (i.e., aquatic plants are 40 percent of invertebrates and fish are 20 percent).

**Table 5.4 Forecasted Number of Shipping Invasions Per Year**

| Year | Invertebrate Invasions [a] | Relationship 1 [b] | | Relationship 2 [c] | |
|---|---|---|---|---|---|
| | | Fish | Aquatic Plant | Fish | Aquatic Plant |
| 2012 | 7.74 | 7.74 | 23.22 | 1.55 | 3.10 |
| 2013 | 7.93 | 7.93 | 23.78 | 1.59 | 3.17 |
| 2014 | 8.12 | 8.12 | 24.36 | 1.62 | 3.25 |
| 2015 | 8.32 | 8.32 | 24.95 | 1.66 | 3.33 |
| 2016 | 8.52 | 8.52 | 25.56 | 1.70 | 3.41 |
| 2017 | 8.73 | 8.73 | 26.18 | 1.75 | 3.49 |
| 2018 | 8.94 | 8.94 | 26.82 | 1.79 | 3.58 |
| 2019 | 9.16 | 9.16 | 27.47 | 1.83 | 3.66 |
| 2020 | 9.38 | 9.38 | 28.13 | 1.88 | 3.75 |
| 2021 | 9.61 | 9.61 | 28.82 | 1.92 | 3.84 |

a. Derived from Ruiz et al. 2000 equation
b. Derived from Great Lake & Hudson River data; fish equal to invertebrates, aquatic plants equals 3 times invertebrates
c. Derived from San Francisco Estuary data; fish equal to 20 percent of invertebrates, aquatic plants equal to 40 percent of invertebrates

## Fraction of Shipping Invasions Due to Ballast Water

Ballast water discharge is one of the two main vectors associated with shipping—hull fouling being the other. These proposed discharge standards will not address hull fouling, so the fraction of invasions associated with hull fouling needs to be removed from our estimates of future invasions.

There are competing factors with regard to the influence of hull fouling versus BWD. On the one hand, reductions in the impact of hull fouling are expected as fuel costs continue to increase in overall importance and more attention is paid to maintaining non-fouled bottoms. Further, the trend to larger ships results in more volume for a given hull surface area, thus increasing the relative importance of ballast discharge as a vector.

Reduced toxicity of bottom paint, improved water quality, creation of new harbor facilities, vessel activities (e.g., vessels that remain in place for long periods), biological triggers, and other factors (Minchin 2002) suggest that hull fouling may become a more significant vector. One contributing factor to this scenario is that NIS have a higher survivability rate on hulls than in ballast tanks.

Past analyses of ballast water and hull fouling indicate that the rate of shipping invasions due to ballast water could be as high as 63 percent (Mills, et al. 1993) and as low as 10 percent. The relative impact of ballast water and hull fouling vectors has not been fully understood (Ruiz 2002).

In a recent analysis of historical invertebrate invasions, Fofonoff, et al. (2003) classified nonnative species (invertebrates, algae and fish) associated with shipping to assess the likelihood of invasion by the subvectors based on traits such as life history, etc.  Table 5.5 summarized the results of the Fofonoff et al. (2003) analysis:

**Table 5.5 Number of Nonnative Coastal Marine Species by Shipping Vector (Fofonoff, et al. 2003)**

| Shipping Vector | Number of Species | Percent of Species |
|---|---|---|
| Ballast Water | 20 | 20% |
| Ballast/Hull Fouling | 34 | 34% |
| Hull Fouling | 36 | 36% |
| Ballast Water/Dry Ballast | 1 | 1% |
| Hull Fouling/Dry Ballast | 1 | 1% |
| Hull Fouling/Dry Ballast/Ballast Water | 1 | 1% |
| Dry Ballast | 1 | 1% |
| Ballast Water/Cargo or Packing material | 3 | 3% |
| Dry Ballast/Cargo or Packing material | 1 | 1% |
| Cargo or Packing material | 1 | 1% |
| Total | 99 | 100% |
| Only Ballast Water | | 20% |
| Ballast Water + Ballast/Hull Fouling | | 60% |
| Ballast Water + Proportion of Ballast Water/Hull Fouling | | 32% |

Source: Fofonoff et al. "In Ships or On Ships? Mechanisms of Transfer and Invasion for Nonnative Species to the Coast of North America," Invasive Species: Vectors and Management Strategies, Island Press, Washington DC, 2003, page 170.

Based on this analysis, 20 percent of invasions are solely attributed to ballast water, while another 34 percent of invasions could be attributable to either ballast water or hull fouling. If we assume none of the “Either Ballast Water or Hull Fouling” invasions was due to ballast water, then 20 percent of shipping invasions are due to ballast water. Similarly, if we assume that all of the “Either Ballast Water or Hull Fouling” are due to ballast water, the resulting fraction of ballast water invasions is 54 percent. If we assume that the “Either Ballast Water or Hull Fouling” invasions are distributed proportionally, then ballast water accounts for 32 percent of invasions. Table 5.6 presents the potential number of invasions per year from 2012 to 2021 assuming 22 percent, 32 percent, and 48 percent of shipping invasions are attributable to ballast water. For the purposes of our main analysis, we assume that 32 percent of shipping invasions are attributable to ballast water.

**Table 5.6 Estimated Number of Ballast Water Invasions**

| Year | Number of Shipping Invasions | | | Number of Ballast Water Invasions (32% of Shipping Invasions) | | |
|---|---|---|---|---|---|---|
| | Invertebrate | Fish | Aquatic Plant | Invertebrate | Fish | Aquatic Plant |
| 2012 | 7.74 | 1.55 | 3.10 | 2.48 | 0.50 | 0.99 |
| 2013 | 7.93 | 1.59 | 3.17 | 2.54 | 0.51 | 1.01 |
| 2014 | 8.12 | 1.62 | 3.25 | 2.60 | 0.52 | 1.04 |
| 2015 | 8.32 | 1.66 | 3.33 | 2.66 | 0.53 | 1.06 |
| 2016 | 8.52 | 1.70 | 3.41 | 2.73 | 0.55 | 1.09 |
| 2017 | 8.73 | 1.75 | 3.49 | 2.79 | 0.56 | 1.12 |
| 2018 | 8.94 | 1.79 | 3.58 | 2.86 | 0.57 | 1.14 |
| 2019 | 9.16 | 1.83 | 3.66 | 2.93 | 0.59 | 1.17 |
| 2020 | 9.38 | 1.88 | 3.75 | 3.00 | 0.60 | 1.20 |
| 2021 | 9.61 | 1.92 | 3.84 | 3.07 | 0.61 | 1.23 |
| Total | 86.43 | 17.29 | 34.57 | 27.66 | 5.53 | 11.06 |

Note: Totals may not add due to rounding.

Fofonoff et al. 2003 also evaluated temporal changes in the shipping vectors and found that ballast water invasions appear to be growing at a faster rate over the past 30 years in comparison to hull fouling invasions, although there is considerable uncertainty due to the relatively large number of invasions that could not be definitively classified.

## Fraction of Invasions That Cause Harm

Further, not all invasions will cause harm. According to Windle 1997: "On average, 15 percent of foreign species trigger severe economic or financial damage and about 40 percent cause some harm." For the purposes of this analysis, we assume that 15 percent of the invasions will cause economic damage, a figure that is also in line with the findings of the OTA 1993 assessment. We note that we may be underestimating the number of harmful species by not including all or some fraction of the 40 percent of species that may cause some harm. As seen in Table 5.7, during the period of 2012-2021, 4.1 invertebrate invasions, 0.8 fish invasions, and 1.7 aquatic plant invasions due to ballast water are expected to cause severe economic or financial damage.

**Table 5.7 Estimated Number of Ballast Water Invasions That Cause Harm**

| Year | Invertebrate | Fish | Aquatic Plant |
|---|---|---|---|
| 2012 | 0.372 | 0.074 | 0.149 |
| 2013 | 0.381 | 0.076 | 0.152 |
| 2014 | 0.390 | 0.078 | 0.156 |
| 2015 | 0.399 | 0.080 | 0.160 |
| 2016 | 0.409 | 0.082 | 0.164 |
| 2017 | 0.419 | 0.084 | 0.168 |
| 2018 | 0.429 | 0.086 | 0.172 |
| 2019 | 0.439 | 0.088 | 0.176 |
| 2020 | 0.450 | 0.090 | 0.180 |
| 2021 | 0.461 | 0.092 | 0.184 |
| Total | 4.149 | 0.830 | 1.659 |

Note: Totals may not add due to rounding.

## 5.6 Costs of Ballast Water Invasions

As discussed earlier, no comprehensive estimate is available on the costs from past invasions. Most studies focus on one species and often only consider certain types of costs or costs in certain regions, resulting in a wide variability of estimates. For this reason, we do not try to develop a composite cost estimate for all invasions, but instead select a low and high estimate for fish, aquatic plants and invertebrates based on representative species. We then calculate a mid-point for the range and calculate costs for future invasions using all three values.

Appendix E contains a summary of available cost estimates for invasions and a discussion documenting the choice of the low and high range cost estimates per species. Table 5.8 displays the range of values used in subsequent calculations.

**Table 5.8 Range of Annual Costs Associated with Selected NIS Introductions ($ 2007)**

| | Low-Range | | Mid-Range | | High Range | |
|---|---|---|---|---|---|---|
| Fish | $ 15,805,000 | [1] | $ 160,547,000 | | $ 305,289,000 | [2] |
| Invertebrates | $ 19,538,000 | [3] | $ 539,769,000 | | $ 1,060,000,000 | [4] |
| Aquatic Plants | $ 4,507,000 | [5] | $ 214,585,500 | | $ 424,664,000 | [6] |

[1] From Jenkins 2001, economic impact of sea lamprey on Great Lakes, updated from 2001$
[2] From Leigh 1998, commercial and recreational fishing benefits lost due to ruffe invasion of Great Lakes, updated from 1998$
[3] From Connelly et al. 2007, cost of Zebra Mussel control at WTP and electric generation facilities, updated from 2004$
[4] From Piementel et al. 2005, cost of Zebra Mussel or Asian Clam, updated from 2005$
[5] From Rockwell 2003, cost to control Water Hyacinth in Louisiana, updated from 2003$
[6] From Pimentel 2005, cost to control Eurasian watermilfoil, updated from 2005$

We assume that once an invasion is established, it will continue to generate costs and/or damages for each year subsequent to the invasion. Thus, an invasion that occurs in the first year of our analysis (2012) will incur costs/damages in each of the next 10 years (through 2021).

Based on the cumulative impacts of invasions, we have calculated a mid-range estimate of annual costs for all harmful BW-introduced invasions over the 10 year period of 2012 to 2021 at $2.016 billion (7 percent) assuming that ballast water invasions represent 32 percent of shipping invasions. The annual cost of ballast water invasion for the period of 2012 to 2021 varies from approximately $75 million to $3.957 billion based on the range of estimated costs per invasions as shown on Table 5.9 at 7 percent discount rate. This estimate assumes no ballast water management.

**Table 5.9 Potential Cost ($ Mil)/Damage of BW Invasion over a 10-year Period**

| Range of NIS Costs | Total Cost for (3% disc. rate) | Total Cost for (7% disc. rate) |
|---|---|---|
| Low Range | $ 83 | $ 75 |
| Mid Range | $ 2,232 | $ 2,016 |
| High Range | $ 4,382 | $ 3,957 |

## 5.7 Benefits (Averted Costs) of Ballast Water Discharge Standards

This section describes the main benefits likely to occur from the establishment of BWDS. The standards main goal is the prevention of future NIS invasions. The value of the benefits for each alternative considered varies based on a particular alternative's effectiveness in preventing future invasions. The Draft Programmatic Environmental Impact Statement (DPEIS)[30] has estimated the reduction in the mean rate of successful introductions of various alternative standards. As described in detail in Appendix A of the DPEIS, a mathematical model was developed based on the premise that a decrease in the number of living organisms initially introduced through ballast water discharges into a waterway reduces the probability that a population becomes successfully established. The researchers first develop a model of the simplest case in which a single species is discharged during a ballast water discharge event (referred to as a single species model). The researchers then used this simple model to develop a more complex model representing a situation where multiple species are discharged from a vessel (referred to as the multi-species model). The multiple species model is the appropriate model to use for the calculation of benefits as it is the more ecologically realistic scenario.[31]

The goal of the multi-species model is to estimate the probability that a single ballast water discharge containing multiple invasive species in different concentrations will result in at

[30] USCG. 2008. Draft Programmatic Environmental Impact Statement for Standards for Living Organisms in Ship's Ballast Water Discharged in U.S. Waters. DOT Document Number: USCG-2001-10486. Page 4-13.

[31] DPEIS, page 4-15.

least one successful introduction of an invasive species. The BWDS in Alternatives 2 through 5 are intended to decrease the probability of NIS establishment by reducing the number of individual organisms that are introduced via BWD. The alternatives differ in the degree to which they would prevent introduction of individual organisms in different size classes and hence, the degree to which they increase extinction probability of NIS. The multi-species model is used to estimate the probability of a successful invasive species introduction for Alternatives 2 through 4. The probability of introductions for each Alternative is compared against the baseline probability of introduction to calculate the reduction in the probability of introduction attributable to that Alternative.[32]

The DPEIS developed two different baselines based on different assumptions about current ballast water management practices. One baseline assumes that no ballast water management is being practiced and the other assumes that ballast water exchange takes place. To estimate benefits, we use the ballast water exchange baseline as most ocean-going vessels are currently required to conduct ballast water exchange. However, some of the vessels engaged in coastal traffic do not conduct ballast water exchange. For these vessels, the no ballast water management assumption may be the more appropriate baseline. For the purposes of this analysis of benefits, we are unable to separate out the invasion risk associated with different classes of vessels and therefore use the conservative assumption that all vessels are conducting ballast water exchange.

Table 5.10 presents the reduction in the mean rate of invasions that would result from Alternatives 2 through 4. In comparison with the existing practice of ballast water exchange, Alternative 2 is between 37 percent to 63 percent effective in preventing invasions when fully implemented.[33] Please refer to the DPEIS for further information on the derivation of these estimates.

[32] Alternative 5 is basically sterilization which results in a 100% reduction in invasions.

[33] The range in effectiveness is the result of different assumptions as to the threshold below which a population is considered extinct for the purposes of invasive species. For example, a Ne=1 in Table 5.10 assumes that all organisms of a particular species have to be eradicated for species to be unable to colonize the new environment (i.e., the new waterway). For many species, however, a certain population size is necessary for successful colonization. Thus, the analysis in the DPEIS also uses a threshold of 100, meaning that 100 organisms of a species would need to survive for the invasion to be successful (Ne=100). Please refer to Appendix A of the DPEIS for further explanation.

**Table 5.10 Reductions in the Mean Rate of Successful INS Introductions (Multiple Species Model)**

| **Extinction Threshold Assumption [1]** | $N_e = 1$ | | $N_e = 100$ | |
|---|---|---|---|---|
| **Baseline Assumption** | No BW Management | BW Exchange | No BW Management | BW Exchange |
| Alternative 2 | 52% | 37% | 78% | 63% |
| Alternative 3 | 73% | 64% | 94% | 90% |
| Alternative 4 | 88% | 85% | 100% | 100% |

Source: DPEIS, Page 4-13, Table 4-2.

[1] The extinction threshold refers to the number of organisms below which a population is considered extinct.
[2] Alternative 5 is essentially sterilization and would result in 100% reduction in invasions.

Applying these reductions in our projected number of harmful ballast water invasions results in the invasions avoided displayed in Table 5.11a. Based on this data, Alternative 2 is estimated to prevent between 2.5 and 4.2 harmful ballast water invasions over a 10-year period, an average of .25 to .42 invasions avoided per year.

**Table 5.11a Harmful Ballast Water Invasions Avoided by Alternative 2**

| Year | Number of Harmful Ballast Water Invasions Avoided – Alt 2 Low Effectiveness | | | Number of Harmful Ballast Water Invasions Avoided – Alt 2 High Effectiveness | | |
|---|---|---|---|---|---|---|
| | Invertebrate | Fish | Aquatic Plant | Invertebrate | Fish | Aquatic Plant |
| 2012 | 0.137 | 0.027 | 0.055 | 0.234 | 0.047 | 0.094 |
| 2013 | 0.141 | 0.028 | 0.056 | 0.240 | 0.048 | 0.096 |
| 2014 | 0.144 | 0.029 | 0.058 | 0.246 | 0.049 | 0.098 |
| 2015 | 0.148 | 0.030 | 0.059 | 0.252 | 0.050 | 0.101 |
| 2016 | 0.151 | 0.030 | 0.061 | 0.258 | 0.052 | 0.103 |
| 2017 | 0.155 | 0.031 | 0.062 | 0.264 | 0.053 | 0.106 |
| 2018 | 0.159 | 0.032 | 0.063 | 0.270 | 0.054 | 0.108 |
| 2019 | 0.163 | 0.033 | 0.065 | 0.277 | 0.055 | 0.111 |
| 2020 | 0.167 | 0.033 | 0.067 | 0.284 | 0.057 | 0.113 |
| 2021 | 0.171 | 0.034 | 0.068 | 0.290 | 0.058 | 0.116 |
| Total | 1.53 | 0.31 | 0.61 | 2.61 | 0.52 | 1.05 |

Note: Totals may not add due to rounding.

As discussed in Chapter 4, the implementation of the Alternative 2 Ballast Water Discharge Standard will be phased-in over several years. During the phase-in period of 2012-2015, there is considerable uncertainty as to how effective the measures will be in preventing invasions if only a subset of ships have implemented ballast water treatment. There is also uncertainty as to the availability and effectiveness of ballast water treatment technologies. For these reasons, we conservatively assume that no invasions will be avoided during the phase-in period of 2012-2015, which may lead to an underestimate of potential benefits. The resulting schedule of invasions avoided for the Alternative 2 Ballast Water Treatment Standard is displayed in Table 5.11b.

**Table 5.11b Harmful Ballast Water Invasions Avoided by Alternative 2 – Phased-In Schedule**

| Year | Number of Harmful Ballast Water Invasions Avoided – Alt 2 Low Effectiveness | | | Number of Harmful Ballast Water Invasions Avoided – Alt 2 High Effectiveness | | |
|---|---|---|---|---|---|---|
| | Invertebrate | Fish | Aquatic Plant | Invertebrate | Fish | Aquatic Plant |
| 2012 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2013 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2015 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2016 | 0.151 | 0.030 | 0.061 | 0.258 | 0.052 | 0.103 |
| 2017 | 0.155 | 0.031 | 0.062 | 0.264 | 0.053 | 0.106 |
| 2018 | 0.159 | 0.032 | 0.063 | 0.270 | 0.054 | 0.108 |
| 2019 | 0.163 | 0.033 | 0.065 | 0.277 | 0.055 | 0.111 |
| 2020 | 0.167 | 0.033 | 0.067 | 0.284 | 0.057 | 0.113 |
| 2021 | 0.171 | 0.034 | 0.068 | 0.290 | 0.058 | 0.116 |
| Total | 0.96 | 0.19 | 0.39 | 1.64 | 0.33 | 0.66 |

Note: Totals may not add due to rounding.

The total potential benefit from the different proposed standards alternatives are presented in Table 5.12, assuming no benefits during the phase-in period of 2012-2015. For Alternative 2, the minimum estimated annual cost avoided is $6 million and the maximum is $553 million with a mid-range estimate of $165-$282 million per year at a 7 percent discount rate. Appendix D displays benefits by year.

**Table 5.12 Potential Annual Benefits (Averted Cost) of BW Invasion over a 10-year Period ($ Mil)**

**Alternative 2**

| | Low Range Costs Per Species | | Mid Range Costs Per Species | | High Range Costs Per Species | |
|---|---|---|---|---|---|---|
| **Reductions in Mean Rate of Invasion** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** |
| Low Effectiveness - 37% | $ 7 | $ 6 | $ 194 | $ 165 | $ 380 | $ 325 |
| High Effectiveness - 63% | $ 12 | $ 10 | $ 330 | $ 282 | $ 647 | $ 553 |

**Alternative 3**

| | Low Range Costs Per Species | | Mid Range Costs Per Species | | High Range Costs Per Species | |
|---|---|---|---|---|---|---|
| **Reductions in Mean Rate of Invasion** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** |
| Low Effectiveness - 64% | $ 12 | $ 11 | $ 335 | $ 286 | $ 658 | $ 561 |
| High Effectiveness - 90% | $ 18 | $ 15 | $ 471 | $ 402 | $ 925 | $ 789 |

**Alternative 4**

| | Low Range Costs Per Species | | Mid Range Costs Per Species | | High Range Costs Per Species | |
|---|---|---|---|---|---|---|
| **Reductions in Mean Rate of Invasion** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** | **3% discount rate** | **7% discount rate** |
| Low Effectiveness - 85% | $ 17 | $ 14 | $ 445 | $ 380 | $ 873 | $ 746 |
| High Effectiveness - 100% | $ 19 | $ 17 | $ 523 | $ 447 | $ 1,027 | $ 877 |

## 5.8 Potential Benefits Transfer

The estimates of costs avoided by preventing NIS invasions encompass many categories of losses, some of which may represent a potential transfer of benefits. Some of the categories of losses that are included in the avoided costs include:

- Costs to control non-indigenous species
- Damage to infrastructure and resulting losses
- Loss of both commercial and recreational fishery resources
- Loss of recreation and tourism opportunities

Losses of natural or capital resources are generally not considered transfers. Thus, control costs, damage to infrastructure, and loss of fishery resources are not likely to be transfers, although lost business resulting from damaged infrastructure may be a transfer. Loss of recreation and tourism opportunities may be a transfer if the recreational user substituted another form of recreation or participated in the same activity at a different location. Under the presumption that the original recreational experience was the first choice of the user, the alternative recreational opportunities would not have the same value as the primary choice of activity with the difference representing a net economic loss.

It is difficult to comprehensively ascertain the portion of the calculated benefits in each category in order to break out potential transfers. Many of the estimates of costs per species simply do not provide sufficient detail to divide costs into the categories. In addition, the distribution of costs by category differ from invasive specie to specie. A few studies have provided specie-specific information of costs or damages by category. For example, O'Neill 1997 surveyed infrastructure owners on their expenditures on zebra-mussel related activities. Only about 1.1 percent of the zebra mussel expenditures were related to recreation or tourism. The majority of the expenditures were related to water treatment plants and electric power generation facilities. Pimentel 2005 estimated that about 16 percent of economic impacts (damages and control costs) from mussels in the New York State Canal and Hudson River system were related to tourism or recreation. On the other hand, Pimentel 2005 estimates that 50 percent of the impacts from invasive fish species in this region are related to tourism or recreational activities such as sport fishing. Based on this limited information, some portion of the estimated benefits from preventing future invasions may represent transfers, but the amount will vary widely depending on the nature of the specie and extent of the invasions.

## 5.9 Sources of Uncertainties and Alternative Use of Risk-Based Decision-Making in Addressing Benefits

The environmental repercussions of undertaking a specific policy are frequently unknown. The framework of environmental policy is typified by uncertainty concerning the effect and irreversibility of some effects. The explicit difference between risk and uncertainty is that risk refers to situations where the nature of the probability distribution of future events is known, while uncertainty refers to situations where the probabilities are unknown (Hosking & du Preez, 2004). The problem of uncertainty in cost-benefit analysis may be addressed, to some extent, through sensitivity analysis as changes are made to particularly important variables. Nevertheless, sensitivity analysis should not be the only tool used to evaluate decisions when uncertainties affect the mainstream issues in the analysis.

The damage and benefit analyses are based on assumptions regarding a number of inputs, which introduces uncertainty into the resulting estimates. Table 5.13 summarizes some of the assumptions underlying the analyses and assesses the likely impact of the assumptions on the estimates of damages and benefits.

**Table 5.13 Uncertainties and Possible Effects on Estimation of Benefits**

| Uncertainty | Effect on Benefits Estimate | | |
|---|---|---|---|
| | Under-Estimate | Over-Estimate | Unknown Impact |
| Rate of future invertebrate invasions (uses Ruiz el al 2000 model to project) | | | X |
| Exclusion of invasions that have shipping as one of the potential vectors | X | | |
| Relationship of the number of fish and aquatic plant invasions to the number of invertebrate invasions | X | | |
| Fraction of shipping invasions due to ballast water | | | X |
| Fraction of invasions that cause harm | X | | |
| Costs per invasion | Quantified in the primary analysis (addresses range of potential underestimate or overestimate) | | |
| Mean rate of invasions/invasions reduced | Quantified in the primary analysis (addresses range of potential underestimate or overestimate) | | |
| Invasions avoided during phase-in period | X | | |
| Potential transfers | | X | |
| Risk-based approach to evaluate NIS invasions from ballast water | X | | |
| Potential impacts on biodiversity, public health, and subsistence populations are not quantified in the analysis | X | | |

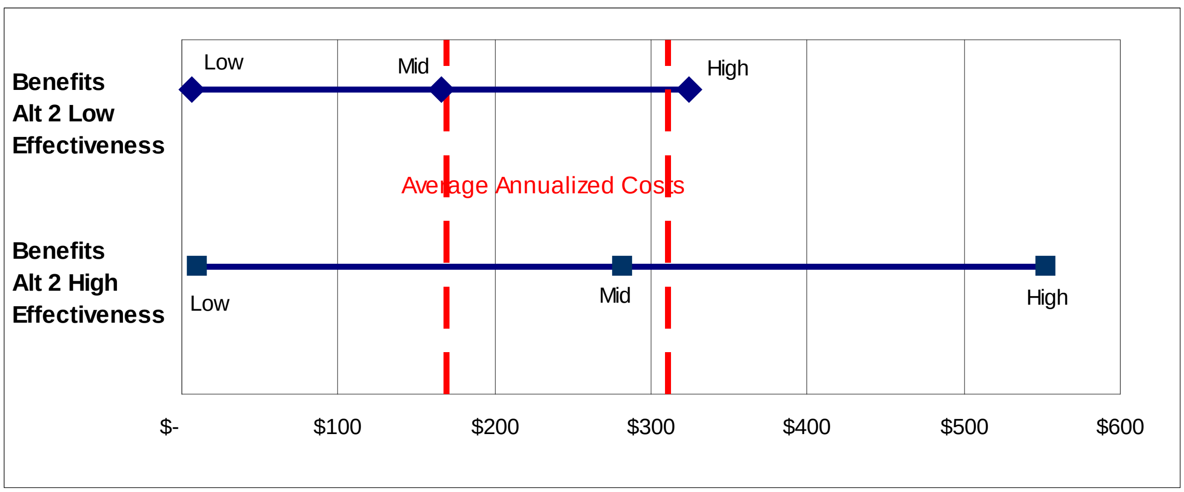
# 6 Comparison of Costs and Benefits

## 6.1 Comparison of Costs and Benefits of Ballast Water Discharge Standards

### Comparison of Potential Benefits with Costs

The annualized cost for domestic vessels over the 10-year period of 2012-2021 for Alternative 2 is estimated at $167 million[34] at a 7 percent discount rate. The estimate of quantified benefits for Alternative 2 ranges from $6 million to $553 million per year (see Figure 6.1), with a mid-point of $165-$282 million per year at a 7 percent discount rate. Thus, quantified benefits are roughly equal to estimated costs for mid-point benefits estimate of Alternative 2 Low Effectiveness. The high range annual cost estimate of $307 million is roughly equal to the high range benefits estimate of Alternative 2 Low Effectiveness. Additional benefits to the areas of ecological damages such as loss of biodiversity, impacts to public health and impacts on subsistence populations are expected to accrue due to BWDS proposed in the rulemaking, but cannot be quantified at this time. Benefits may also accrue due to reduced invasions in foreign ports. However, we do not include either benefits in foreign waters or costs to foreign vessels in our primary analysis as these will mainly be attributable to foreign vessels complying with treaty obligations of their flag administration (government) under IMO.

**Figure 6.1 Range of Quantified Benefits and Annual Costs for Alternative 2 (7% Discount Rate, $2007)**




Installation costs to meet BWD-3 and BWD-4 standards are estimated to be higher, on the order of two and three times BWD-2 costs, respectively. Effectiveness in controlling NIS invasions will also be higher as displayed in Table 5.10. The range of potential benefits for Alternatives 3 and 4 (Table 5.12) are in general less than two to three times higher than Alternative 2, possibly indicating that the cost to benefit comparisons would be less favorable

[34] Total discounted cost of $1.191 billion amortized over 10 years using the Capital Recovery Factor equation at 7% discount rate because of the large capital installation costs required by the rulemaking.

for these Alternatives. However, the range of uncertainty in both the cost and effectiveness assessments for these standards makes it difficult to conclusively draw comparisons.

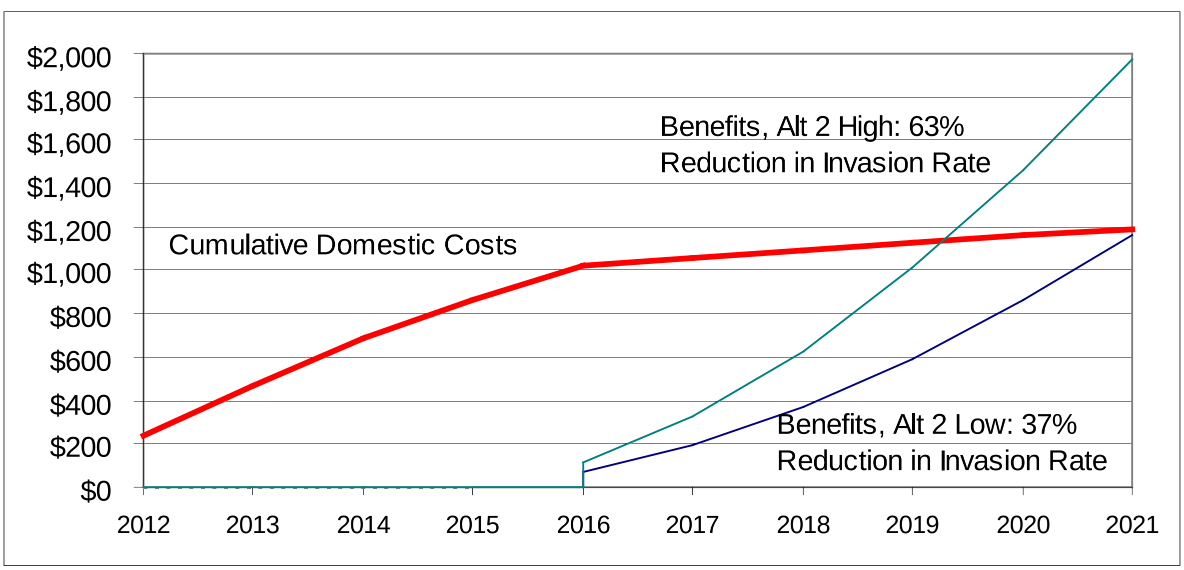
Other phase-in schedules under consideration are in agreement with the IMO schedule after 2016; thus, costs after 2016 will be similar for similar BWD standards. The alternative under consideration by the Coast Guard incorporates the higher BWD-4 standard after 2016 and thus costs will be higher.

### Invasions Prevented to Reach Breakeven

We can roughly assess the threshold at which the benefits of BWD outweigh the costs in terms of how many invasions must be prevented. Based on the analysis presented in Chapter 5, Alternative 2 prevents between 0.15 to 0.26 harmful NIS invasions per year, assuming no invasions are avoided during the phase-in period. Zebra mussels are at least the second instance of a NIS that attacked water-based infrastructure with costs in the billions of dollars—the Asiatic clam preceded it. If an invasion generating the costs associated with the Zebra mussel invasion of the 1990s or the Asiatic clam invasion of the 1980s is preventable, then BWD standards are clearly cost-effective.

Based on our projected invasions avoided, the breakeven point (discounted cumulative benefits equal or outweigh discounted cumulative costs) would be reached by 2019 for the Alternative 2 assuming a 63 percent reduction in the invasion rate and 2021 for Alternative 2 assuming a low reduction in invasion rate of 37 percent. Figure 6.2 illustrates the cumulative costs of the BWD in relationship to the damages avoided.

**Figure 6.2 Comparison of Cumulative Costs and Benefits (7% Discount Rate, $2007, Mid-Point Benefit per Invasion Estimate)**



## 6.2 Potential Total Cost Variation due to Changes in Compliance with the Phase-In Schedule

Under the proposed rulemaking, all vessels will be required to convert to BWT by the end of 2016. Some vessels will be required to convert by the end of 2014. The vessels that have the early conversion deadline are those with a ballast water capacity of greater than 1,500 and less than 5,000 cubic meters. These will be referred to below as type 2 vessels. The remaining vessels will be referred to as type 1 vessels. We have calculated three different conversion rate scenarios in order to determine the present value (PV) of the future costs of the rule. The first scenario in table 6.1 is the one used in the cost chapter (chapter 4) of this RA. It assumes that type 1 vessels will begin converting in the year 2012 at a rate of 20 percent of the fleet per year, through 2016. For type 2 vessels under this scenario, the rate is 30 percent in 2012 and 2013, and 40 percent in 2014. The PV for this scenario is $1.349 billion using a 3 percent discount rate.

**Table 6.1 Current Phase-In Schedule (Scenario I)**

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|
| Type 1 Vessels | 20% | 20% | 20% | 20% | 20% | 100% |
| Type 2 Vessels | 30% | 30% | 40% | | | 100% |
| PV 3% ($Mil) | $1,349 | | | | | |
| PV 7% ($Mil) | $1,176 | | | | | |

The second scenario in table 6.2 assumes that each firm will wait as long as possible to convert, with 100 percent of type 1 vessels converting in 2016 and 100 percent of type 2 vessels converting in 2014. The PV for this scenario is $1.297 billion using a 3 percent discount rate.

**Table 6.2 Phase-In Schedule (Scenario II)**

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|
| Type 1 Vessels | 0% | 0% | 0% | 0% | 100% | 100% |
| Type 2 Vessels | 0% | 0% | 100% | | | 100% |
| PV 3% ($Mil) | $1,297 | | | | | |
| PV 7% ($Mil) | $1,074 | | | | | |

The third scenario is for a gradual increase in the rate of conversion. Under this scenario, the PV is $1.336 billion using a 3 percent discount rate.

**Table 6.3 Phase-In Schedule (Scenario III)**

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|
| Type 1 Vessels | 10% | 15% | 20% | 25% | 30% | 100% |
| Type 2 Vessels | 20% | 30% | 50% | | | 100% |
| PV 3% ($Mil) | $1,336 | | | | | |
| PV 7% ($Mil) | $1,150 | | | | | |

The difference between the PV (at 3 percent) of the rulemaking total costs varies from $1.349 billion to $1.297 billion, depending whether the vessels owners decide to comply earlier or later in the process. The difference between the timing of compliance results in a difference of approximately 4 percent of the total annual cost of this rulemaking.

## 6.3 Comparison between Ballast Water Exchange (BWE) and proposed Ballast Water Discharge Standard (BWDS)

Alternative 1, No Action, option continues existing ballast water exchange requirements for vessels equipped with ballast water tanks that enter the U.S. after operating beyond the EEZ. In this scenario, existing BWM regulations would continue and management achieved through BWE using the methods of empty/refill or flow-through. The BWM RA (USCG 2004) estimated annual cost for BWE to be $15.8 million (USCG 2004). However, the amount of ballast water exchange reported in the NBIC data collected recently is much smaller than that assumed in the BWM RA. Thus, we have re-estimated that cost of ballast water exchange as described in Appendix B at $5 million per year. As of 2016, vessels that were conducting ballast water exchange would no longer incur these costs as they comply with the ballast water discharge standard.

The annualized cost for Alternative 2 is estimated at $167 million at 7 percent discount. It should be noted that the BWM requirements apply to a subset of vessels that fall under the BWDS. Specifically, vessels engaged in coast-wise traffic that do no leave the EEZ are not subject to the BWM requirements. Hence, when making direct comparisons of the costs of BWM and the BWDS, we should keep in mind that more vessels are treating ballast water, resulting in greater reductions in the risk of invasions. For example, Alternative 2 is expected to result in a 37-63 percent reduction in the mean rate of successful invasions with potential avoided costs of $165-$282 million.

# 7 Initial Regulatory Flexibility Act Analysis

## 7.1 Summary of Findings

The U.S. Coast Guard (USCG) has performed this initial regulatory flexibility analysis of the impacts on small businesses and other entities from the 2008 NPRM for Standards for Living Organisms in Ship's Ballast Water Discharged in U.S. Waters. We have performed this assessment using the cost information discussed in chapter 4. We have determined that the rule will result in a significant economic impact on a substantial number of small entities under section 605(b) of the Regulatory Flexibility Act.

Based on the information from this analysis, we found:

- There are an estimated 850 U.S. businesses that would be affected by the rulemaking, these businesses operate 2,616 vessels affected by the rule;
- It is estimated that of these 850 firms, 57 percent are considered small;
- These firms will be required to purchase and install a ballast water management system for each affected vessel they own, costing between $258,000 and $419,000 per vessel, depending on the vessel type;
- We have assumed that firms will finance the purchase of this equipment and therefore we have used the annual payment to service the loan as the annual cost for installation;
- Annual recurring operational costs of the rule result in less than 1% impact on revenue for 100 percent of the firms;
- For a 10-year finance scenario, we estimated 72 percent of small firms would incur an annual cost impact greater than 1 percent of annual revenue.
- For a 20-year finance scenario, we estimated 59 percent of small firms would incur an annual cost impact greater than 1 percent of annual revenue.

## 7.2 Preliminary Initial Regulatory Flexibility Analysis

The Regulatory Flexibility Act of 1980 (Public Law 96-354) (RFA) establishes "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation. To achieve this principle, agencies are required to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration."

Under the RFA, we are required to consider if this rule will have a significant economic impact on a substantial number of small entities. Agencies must perform a review to determine whether a rule will have such an impact. If the agency determines that it will, the agency must prepare a regulatory flexibility analysis as described in the RFA.
Under Section 603(b) of the RFA, the regulatory flexibility analysis must provide and or address:

- A description of the reasons why action by the agency is being considered;
- A succinct statement of the objectives of, and legal basis for, the proposed rule;
- A description of and, where feasible, an estimate of the number of small entities to which the proposed rule will apply;
- A description of the projected reporting, recordkeeping and other compliance requirements of the proposed rule, including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
- An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the proposed rule; and,
- A description of any significant alternatives to the proposed rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the proposed rule on small entities.

The RFA covers a wide-range of small entities. The term “small entities” comprises small businesses, not-for-profit organizations that are independently owned and operated and are not dominant in their fields, and governmental jurisdictions with populations of less than 50,000. We determined that the rule affects a variety of large and small businesses, not-for-profit organizations, and governments (see the “Description of the Potential Number of Small Entities” section below). Based on the requirements above, we have prepared the following regulatory flexibility analysis assessing the impact on small entities from the rule.

## 7.3 Description of the Reasons for Agency Action

The unintentional introduction of non-indigenous species (NIS) into the waters of the United States via the discharge of ships’ ballast water continues to contribute to the loss of marine biodiversity and to lead to significant social, economic, and biological impacts. Current U.S. regulations require ballast water management (BWM) to reduce introductions of NIS through ballast water discharge (BWD). Currently, the primary management method for controlling ballast water discharged in U.S. waters is a mid-ocean exchange of ballast water obtained from waters outside the U.S. Exclusive Economic Zone (EEZ). Concern remains that this approach to ballast water management is not sufficiently effective in preventing the introduction of NIS nor can many vessels conduct ballast water exchange because of safety issues and or voyage constraints. The U.S. is proposing a rule to establish a ballast water discharge standard for the allowable concentrations of living organisms discharged via ballast water into U.S. waters.

## 7.4 Statement of Legal Basis and Objectives for the Rule

The statutory authority for the Coast Guard to prescribe, change, revise, or amend the affected domestic regulation 33 CFR part 151 is provided under 16 U.S.C. 4711; as delegated to the Coast Guard in the Department of Homeland Security Delegation No. 0170.1.

The objective for the rule is to reduce the probability of unintentional introduction of NIS into the waters of the United States via the discharge of ships' ballast water. Reducing the probability will reduce the harmful biological and economic effects of NIS with the goal of reducing the number of NIS invasions and resulting biological impacts and economic losses.

## 7.5 Description of Record Keeping and Other Compliance Requirements

The rulemaking would not require additional reporting, recordkeeping, and other paperwork requirements for affected owners or operators. Vessel's operators or person-in charge will comply with same reporting requirements of 33 CFR § 151.2041.

## 7.6 Overlapping, Duplicative, or Conflicting Federal Rules

Potential ballast water discharge standards would not duplicate, overlap, or conflict with any other federal requirement.

## 7.7 Costs of Compliance

To estimate the compliance cost to small entities, we considered the cost for acquiring, installing, and operating a ballast water management system by vessel type. The cost for acquiring and installing the system is summarized in Table 7.1 below. This assumes vessel owners will opt for the least expensive system available.[35] There are many types of vessels that will be impacted by the rule, but we have found that the small businesses impacted by this rule operate only a few certain types, these being the smaller vessels in the population. Our analysis has determined that 92 percent of small-business vessels are either general cargo (mainly barges) or offshore supply vessels. Small firms will likely benefit from economies of scale as big firms equip their fleets, driving down installation costs. Therefore, there is a high probability that these figures are upper-bound estimates and that the actual installation costs will be significantly lowered once the rule goes into effect. Furthermore, these vessels are coastwise vessels and relatively small. They will perform considerably less ballast water treatment than will larger, ocean-going vessels. The annual operating cost for these firms will be very low, as operational costs are based on quantity of water treated, and these vessels will be treating small quantities.

[35] Chemical Apply is the lowest cost treatment in this study (see Chapter 3 for information on the treatment effectiveness).

**Table 7.1 Fleet, Installation Cost, Finance Cost ($000)** [a]

| Vessel Type | Total Number in U.S. Fleet | Installation Cost Per Vessel | Annual Cost to Finance | |
|---|---|---|---|---|
| | | | 10 Year | 20 Year |
| Bulk Carriers - Handy | 22 | 419 | $59.7 | $39.6 |
| Offshore Supply Vessel | 85 | 258 | $36.7 | $24.4 |
| General Cargo | 1,166 | 323 | $46.0 | $30.5 |
| RORO | 66 | 323 | $46.0 | $30.5 |
| Passenger Ship | 166 | 300 | $42.7 | $28.3 |

a. Based on 10 and 20 year loan at 7 percent rate of interest

## 7.8 Description of the Potential Number of Small Entities

Based on current data provided by the Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database, we estimate that there are approximately 850 U.S. entities operating 2,616 vessels affected by this rule.

We used available operator name and address information to research public and proprietary databases for entity type (subsidiary or parent company), primary line of business, employee size, revenue, and other information.[36] We matched this information to the Small Business Administration's (SBA) "Table of Small Business Size Standards" to determine if an entity is small in its primary line of business as classified in the North American Industry Classification System (NAICS).[37]

We researched and compiled the employee size and revenue data for a random sample of 150 operators.[38] We were able to find employee size and revenue data for 136 operators in the sample (about 91 percent of the sample). We determined that of these 136 operators, 71 would be classified as small entities based on the SBA size standards. Assuming that the companies with no information are small entities, we will have a total of 85 small companies in our sample, representing approximately 57 percent of our sample.

We found small entities affected by this rule to have multiple business lines. Some have a primary business line or NAICS code that is not unique to the maritime industry. Table 7.2

[36] We used information and data from Manta (http://Manta.com) and ReferenceUSA (http://www.referenceusa.com).

[37] The SBA lists small business size standards for industries described in the North American Industry Classification System (NAICS). See http://www.smallbusinessnotes.com/fedgovernment/sba/13cfr121/201-4849.html (as of April 7,2008).

[38] We selected a statistical sample so we would not need to research and collect employee size and revenue information for the entire affected operator population. We determined the sample size at a 95% confidence level with a 5% confidence interval. We selected the operators in the sample through a random number generator process available in most statistical or spreadsheet software.

lists the standard, range, and frequency of NAICS codes for small entities found in the sample.

**Table 7.2 Sample NAICS Categories for Small Entities**

| NAICS Code | Description | % of Small Entities | SBA Standard | |
|---|---|---|---|---|
| | | | Revenue ($ Mil) | Employees |
| 236210 | Industrial Building Construction | 6% | $33.5 | - |
| 238110 | Poured Concrete Foundation and Structure Contractors | 1% | $14 | - |
| 238910 | Site Preparation Contractors | 1% | $14 | - |
| 311712 | Fresh and Frozen Seafood Processing | 1% | - | 500 |
| 331316 | Aluminum Extruded Product Manufacturing | 1% | - | 750 |
| 336611 | Ship Building and Repairing | 3% | - | 1000 |
| 336612 | Boat Building | 3% | - | 500 |
| 423810 | Construction and Mining (except Oil Well) Machinery and Equipment Merchant Wholesalers | 1% | - | 100 |
| 423830 | Industrial Machinery and Equipment Merchant Wholesalers | 1% | - | 100 |
| 423860 | Transportation Equipment and Supplies (except Motor Vehicle) Merchant Wholesalers | 1% | - | 100 |
| 424130 | Industrial and Personal Service Paper Merchant Wholesalers | 1% | - | 100 |
| 441222 | Boat Dealers | 3% | $7.0 | - |
| 483111 | Deep Sea Freight Transportation | 7% | - | 500 |
| 483112 | Deep Sea Passenger Transportation | 1% | - | 500 |
| 483113 | Coastal and Great Lakes Freight Transportation | 10% | - | 500 |
| 483114 | Coastal and Great Lakes Passenger Transportation | 1% | - | 500 |
| 483211 | Inland Water Freight Transportation | 24% | - | 500 |
| 484121 | General Freight Trucking, Long-Distance, Truckload | 1% | $25.5 | - |
| 487110 | Scenic and Sightseeing Transportation, Land | 3% | $7.0 | - |
| 487210 | Scenic and Sightseeing Transportation, Water | 11% | $7.0 | - |
| 488320 | Marine Cargo Handling | 1% | $25.5 | - |
| 488330 | Navigational Services to Shipping | 7% | $7.0 | - |
| 488510 | Freight Transportation Arrangement (Except non-vessel owning common carriers and household good forward $23.5) | 6% | $7.0 | - |
| 541618 | Other Management Consulting Services | 1% | $7.0 | - |
| Total: | | 100% | | |

Note: Not all totals will sum due to independent rounding.

## 7.9 Cost and Affordability Impact Analysis

The compliance cost incurred by operators depends on the number of affected vessels the operator owns and the annual ballast water discharge per vessel. We estimated the revenue impact for two finance periods, 10 and 20 years with a 7 percent annual interest. We considered that less favorable financing terms, such as shorter loan durations or higher rates of interest, to the small entities is possible. In those cases, the annual cost will be higher. Since the main cost driver of this rule is the BWT installation, we calculate the percent revenue impact by dividing the annual cost for the 10-year and 20-year finance (presented in Table 7.1) by average annual revenue. The costs are the payment to service the equipment loan, plus operational costs for the year.

For the 10-year finance scenario, we estimate that 72 percent of small firms would incur an annual cost impact greater than 1 percent of annual revenue. Table 7.3.a presents the range of cost impacts on annual revenue for potential small entities.

**Table 7.3.a Installation Impact on Small Entities (10-year Finance)**

| Impact Range | Small Entities Found | Percent | Small Entities Found & Unknown |
|---|---|---|---|
| ≤ 1% | 20 | 28% | 24 |
| > 1 to ≤ 3% | 16 | 23% | 20 |
| > 3 to ≤ 5% | 8 | 11% | 9 |
| > 5 to ≤ 10% | 8 | 11% | 10 |
| > 10 to ≤ 20% | 12 | 17% | 14 |
| > 20% | 7 | 10% | 8 |
| Total | 71 | 100% | 85 |

Note: Totals may not add due to rounding.

We also considered a 20-year finance scenario for companies to purchase and install the BWTS (see Table 7.3.b). For this scenario, we estimated 59 percent of small firms would incur an annual cost impact greater than 1 percent of annual revenue.

**Table 7.3b Installation Impact on Small Entities (20-year Finance)**

| Impact Range | Small Entities Found | Percent | Small Entities Found & Unknown |
|---|---|---|---|
| ≤ 1% | 29 | 41% | 35 |
| > 1 to ≤ 3% | 12 | 17% | 14 |
| > 3 to ≤ 5% | 8 | 11% | 10 |
| > 5 to ≤ 10% | 11 | 15% | 13 |
| > 10 to ≤ 20% | 8 | 11% | 10 |
| > 20% | 3 | 4% | 4 |
| Total | 71 | 100% | 85 |

## 7.10 Alternatives Considered

We considered five regulatory alternatives, including a no action alternative, to achieve ballast water discharge standards. Each alternative, besides the no action, considered varying levels of stringency with regards to the concentration of NIS in ballast water. The least stringent alternative is the one being analyzed here. This is the least expensive alternative after no action. These alternatives are discussed in more detail in the other sections of the RA.

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# Appendix A Fleet Makeup

**Table A-1a Ballast Water Capacities ($m^3$) for U.S. Vessels**

| U.S. Vessel Category | MISLE/NBIC 2007 | | Ballast Water Volume Breakdown | | |
|---|---|---|---|---|---|
| | Sample Size | Average Capacity | <1,500 | 1,500 -5,000 | >5,000 |
| **Bulk Carriers** | | | | | |
| Handy | 7 | 14,329 | | | 100.00% |
| Panamax | 7 | 36,258 | | | 100.00% |
| Capesize | 5 | 59,065 | | | 100.00% |
| **Tank ships** | | | | | |
| Handy | 21 | 17,038 | 4.76% | | 95.24% |
| Handymax - Aframax | 2 | 9,379 | 50.00% | | 50.00% |
| Suezmax | 2 | 61,558 | | | 100.00% |
| VLCC | 1 | 214,863 | | | 100.00% |
| ULCC | N/A | N/A | | | 100.00% |
| **Container ships** | | | | | |
| Feeder | 5 | 6,927 | 60.00% | 20.00% | 20.00% |
| Feedermax | 1 | 4,195 | 100.00% | | |
| Handy | 2 | 17,891 | | | 100.00% |
| Subpanamax | 28 | 9,469 | 10.71% | 10.71% | 78.57% |
| Panamax | 16 | 11,729 | 6.25% | 12.50% | 81.25% |
| Postpanamax | 12 | 21,359 | | | 100.00% |
| **Other vessels** | | | | | |
| Passenger ships | 7 | 6,416 | 42.86% | 14.29% | 42.86% |
| Gas carriers | 2 | 30,841 | | | 100.00% |
| Chemical carriers | 11 | 17,266 | | | 100.00% |
| RORO | 22 | 5,896 | 18.18% | 22.73% | 59.09% |
| Combination vessels | 28 | 15,764 | | | 100.00% |
| General Cargo | 29 | 5,571 | 37.83% | 13.49% | 48.68% |
| Fishing Vessels | 26 | 1,666 | 80.77% | 11.54% | 7.69% |
| OSVs | 16 | 7,605 | 31.25% | 12.50% | 56.25% |

**Table A-1b Ballast Water Capacities (m3) for Foreign Vessels**

| Foreign Vessel Category | MISLE/NBIC 2007 | | Ballast Water Volume Breakdown | | |
|---|---|---|---|---|---|
| | Sample Size | Average Capacity | <1,500 | 1,500 -5,000 | >5,000 |
| **Bulk Carriers** | | | | | |
| Handy | 549 | 13,753 | 2.37% | 9.47% | 88.16% |
| Panamax | 215 | 27,849 | | 0.93% | 99.07% |
| Capesize | 7 | 46,153 | | | 100.00% |
| **Tank ships** | | | | | |
| Handy | 43 | 14,952 | 11.63% | 37.21% | 51.16% |
| Handymax - Aframax | 398 | 28,411 | 0.50% | | 99.50% |
| Suezmax | 67 | 55,560 | | | 100.00% |
| VLCC | 95 | 98,983 | | | 100.00% |
| ULCC | 10 | 82,045 | | | 100.00% |
| **Container ships** | | | | | |
| Feeder | 21 | 4,928 | 28.57% | 52.38% | 19.05% |
| Feedermax | 24 | 5,093 | 4.17% | 79.17% | 16.67% |
| Handy | 61 | 5,543 | 13.11% | 24.59% | 62.30% |
| Subpanamax | 85 | 11,631 | | | 100.00% |
| Panamax | 76 | 12,691 | | | 100.00% |
| Postpanamax | 180 | 18,502 | 0.00% | | 100.00% |
| **Other vessels** | | | | | |
| Passenger ships | 78 | 3,176 | 15.38% | 75.64% | 8.97% |
| Gas carriers | 78 | 15,469 | 3.85% | 30.77% | 65.38% |
| Chemical carriers | 324 | 14,378 | 0.31% | 9.88% | 89.81% |
| RORO | 121 | 7,951 | 9.92% | 15.70% | 74.38% |
| Combination vessels | 14 | 5,128 | 57.14% | 21.43% | 21.43% |
| General Cargo | 190 | 7,226 | 29.47% | 31.05% | 39.47% |
| Fishing Vessels | N/A | N/A | 80.77% | 11.54% | 7.69% |
| OSVs | 11 | 3,209 | 54.55% | 36.36% | 9.09% |

## World Fleet Growth and Makeup

Based on information provided by HEC, a BWDS would be phased in over the period from 2012 to 2016 under the proposed U.S. and international regulations. During this period, the population of vessels will potentially change— some vessels would be removed and others will be constructed. We obtained estimates of growth and removal rates for the various vessel types from a number of sources. Primary sources are the Transportation Research Board (TRB) and the Maritime Administration (MARAD). We also consulted private sector information sources: Clarkson Register, RS Platou for generalized fleet forecasts; PIERS, Mercator Transportation Management, Herbert Engineering Corp, and MDS Transmodal for container traffic forecasts; and the American Bureau of Shipping and ConocoPhillips for LNG forecasts. Appendix A contains additional details on Fleet Makeup.

We extracted the number of affected vessels from the MISLE database to provide a baseline fleet size for year 2007. In projecting fleet growth, we assumed that there would be no optimization of the fleet for U.S. traffic. That is, we assumed that all vessels involved in international trade will be built to both U.S. and international BWDS requirements.

In addition to growth in number of vessels, the size composition of the fleet is changing, especially in the LNG and container fleets. The relationship between ballast water capacity and vessel size (deadweight) is approximately linear (see Figures A-5, A-6 and A-7). Although the increased cargo may be carried on a fleet that is growing more slowly in numbers than in tonnage or TEU capacity, the assumption is made that the amount of ballast water discharged will grow with tonnage or TEU capacity.

Table A.2 shows the assumed growth and removal rates forming the baseline case. We estimated the number of new builds each year by adding the number of vessels removed to the number of vessels needed to achieve the net growth rate.

**Table A.2 World Fleet Growth and Removal Rates**

| Type of Vessel | Net Growth Rate | Removal Rate |
|---|---|---|
| **Bulk carriers** | | |
| Handy | -0.5% | 2.0% |
| Panamax | -0.5% | 2.0% |
| Capesize | -0.5% | 2.0% |
| **Tank ships** | | |
| Handy | 2.0% | 1.0% |
| Handymax-Aframax | 2.0% | 1.0% |
| Suezmax | 2.0% | 1.0% |
| VLCC | 2.0% | 1.0% |
| ULCC | 2.0% | 1.0% |
| **Container ships** | | |
| Feeder | 4.4% | 2.0% |
| Feedermax | 4.4% | 2.0% |
| Handy | 4.4% | 2.0% |

| | | |
|---|---|---|
| Subpanamax | 4.4% | 2.0% |
| Panamax | 4.4% | 2.0% |
| Postpanamax | 4.4% | 2.0% |
| **Other vessels** | | |
| Passenger ship | 2.8% | 2.2% |
| Gas carrier | 6.0% | 2.0% |
| Chemical carrier | 2.8% | 2.2% |
| RORO | 2.8% | 2.2% |
| Combination vessel | 0.0% | 2.0% |
| General cargo | 2.8% | 2.2% |
| Fishing Vessels | 2.8% | 2.2% |
| OSVs | 3.6% | 3.7% |

# Data Source for Fleet Growth Calculations

## U.S. Fleet Growth Rates

We estimated the U.S. fleet growth rates using different data sources: U.S Department of Transportation (MARAD), Clarkson Research Service and U.S.C.G. MISLE System database.

**Table A.3 Number of Active U. S. Vessels and Percentage Change (2002-2007)**

| Type of Vessel | Year | | | | | | Increase % | Average Change % |
|---|---|---|---|---|---|---|---|---|
| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | | |
| Bulk Carriers[39] | 65 | 64 | 64 | 61 | 60 | 61 | -6.15 | -1.24 |
| Tanks[40] | 7,229 | 7,381 | 7,419 | 7,661 | 7,901 | 8,209 | 13.56 | 2.58 |
| Containers[41] | 41,391 | 43,806 | 42,766 | 43,300 | 44,186 | 45,596 | 10.16 | 1.99 |
| Passenger Ships | 19,413 | 20,402 | 20,889 | 21,431 | 22,027 | 22,898 | 17.95 | 3.36 |
| RoRo[42] | 57 | 63 | 63 | 73 | 69 | 66 | 12.12 | 2.59 |
| Combination Vessels[43] | 9,901 | 10,423 | 10,392 | 10,633 | 10,913 | 11,275 | 13.88 | 2.65 |
| Fishing Vessels[44] | 61,989 | 66,059 | 66,300 | 67,930 | 72,154 | 73,661 | 18.83 | 3.54 |
| Offshore Supply Vessel | 1,465 | 1,530 | 1,522 | 1,583 | 1,624 | 1,849 | 26.21 | 4.87 |

[39] Based on Clarkson Research Service (Source: U.S. Department of Transportation, Maritime Administration, Water Transportation Statistical Snapshot, May 2008)
[40] Based on MISLE database, includes tank barges and tank ships.
[41] Based on MISLE database, includes freight barges and freight ships.
[42] Based original data from Clarkson Research Service available at U.S. Department of Transportation, Maritime Administration, Water Transportation Statistical Snapshot (May 2008)
[43] Based on MISLE database, includes mobile offshore drilling units, oil recovery vessels and towing vessels.
[44] Based on MISLE database, includes commercial fishing vessels and fish processing vessels.

## World Fleet Growth and Removal Rates

We estimated the world growth and removal rates using the following data sources:

### Transportation Research Board

The Transportation Research Board has published forecasts for U.S. International Marine Trade[45], as summarized in the following tables.

**Table A.4 TRB Summary of Major Forecasts of Waterborne Cargo**

| Sector | Units | Traffic | | Compound Annual Growth Rate (%) | Percent Change | Source |
|---|---|---|---|---|---|---|
| | | 2000 | 2020 | | | |
| International | Million tons | 1,143.4 | 1,674.5 | 1.9 | 46 | Global Insight |
| Container | TEUs (thousands_ | 120,350 | 48,401 | 4.4 | 138 | Global Insight |
| Petroleum | Million tons | 669.7 | 1,056.3 | 2.3 | 58 | EIA |
| Dry bulk | Million tons | 355.9 | 444.0 | 1.1 | 25 | Global Insight |
| Total inland river | Million tons | 66137 | 836.0 | 1.3 | 26 | USACE |

### MARAD Statistics

Vessel statistics compiled by MARAD are shown below

**Table A.5 U.S. Waterborne Imports, Arrivals by Type**

| Vessel Calls | Year | | | | | | Increase % | Growth Rate %/year |
|---|---|---|---|---|---|---|---|---|
| Vessel Type | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | | |
| Tanker | 17,279 | 18,535 | 18,387 | 17,320 | 18,503 | 19,316 | 12% | 2.3% |
| • Product | 10,875 | 11,868 | 11,780 | 10,949 | 10,998 | 11,572 | 6% | 1.3% |
| • Crude | 6,404 | 6,667 | 6,607 | 6,317 | 7,505 | 7,744 | 21% | 3.9% |
| Container | 16,625 | 17,410 | 17,076 | 17,138 | 17,287 | 18,279 | 10% | 1.9% |
| Dry Bulk | 11,946 | 12,013 | 11,628 | 11,112 | 10,271 | 11,631 | -3% | 0.5% |
| RORO | 5,.73 | 5,542 | 5,712 | 5,632 | 5,191 | 5,317 | 5% | 0.9% |
| Vehicle | 3,072 | 3,646 | 3,646 | 3,605 | 3,113 | 3,065 | 0% | 0.0% |
| Gas Carrier | 683 | 708 | 739 | 739 | 926 | 916 | 34% | 6.0% |
| Combination | 767 | 856 | 770 | 761 | 666 | 459 | -40% | 9.8% |
| General Cargo | 4,354 | 4,318 | 4,076 | 3,894 | 3m915 | 3m967 | -9% | -1.8% |
| All Types | 56,727 | 59,382 | 58,388 | 56,596 | 56,759 | 59,885 | 6% | 1.1% |

[45] The marine transportation system and the federal role: measuring performance, targeting improvement / Committee for a Study of the Federal Role in the Marine Transportation System. Transportation Research Board Special Report, 279

**Table A.6 U.S. Waterborne Trade**

| Year (1000 Metric Tons) | | | | | | Increase | Growth Rate |
|---|---|---|---|---|---|---|---|
| **Direction** | **2000** | **2001** | **2002** | **2003** | **2004** | | |
| Imports | 809,928 | 829,959 | 813,571 | 881,414 | 957,210 | 18% | 4.3% |
| Exports | 347,906 | 331,423 | 323,640 | 324,760 | 349,628 | 0% | 0.1% |

Source: U.S. Maritime Administration, Waterborne Databank

**Figure A-1 Imports (Metric Tons) on Containerships, 1998-2003**

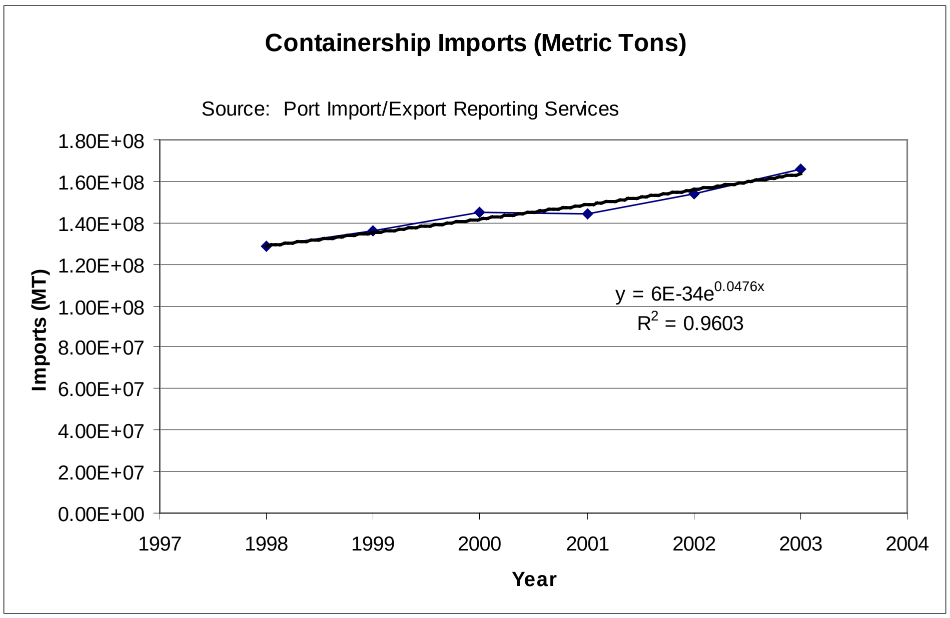
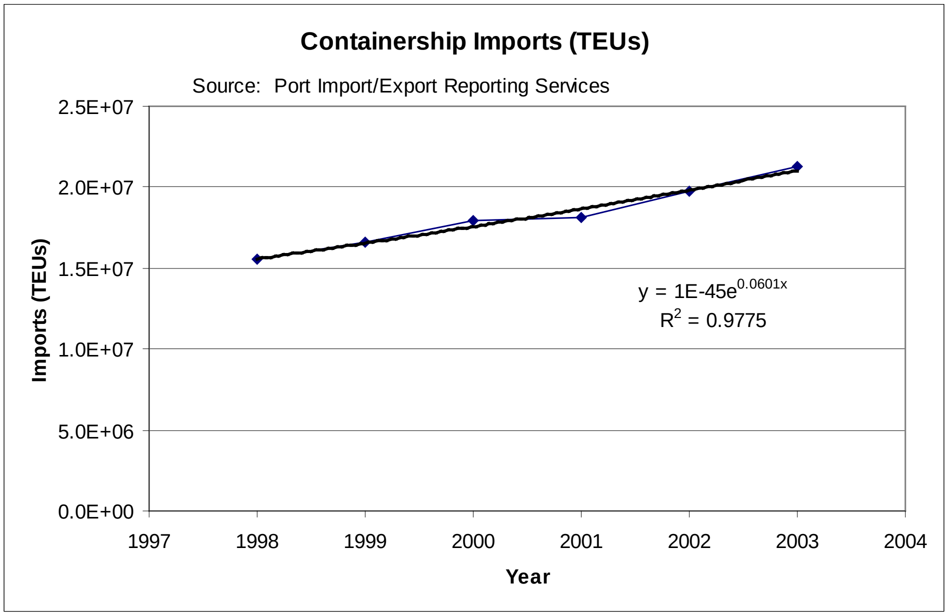


**Figure A-2 Imports (TEUs) on Containerships, 1998-2003**




## The Platou Report

R.S. Platou Economic Research provides and presents analyses of all major shipping markets, as well as markets representing the external conditions for worldwide shipping.

**Table A.7 World Fleet Development (The Platou Report) (Mil DWT)**

| Year | Tankers | Bulk Carriers | Comb. Carriers | Others | Total |
|---|---|---|---|---|---|
| 1995 | 270.9 | 22.9 | 25.9 | 134.8 | 661.5 |
| 1996 | 270.5 | 241.3 | 20.7 | 140.9 | 673.4 |
| 1997 | 275.2 | 250.0 | 17.3 | 149.1 | 691.5 |
| 1998 | 279.5 | 260.7 | 16.9 | 155.3 | 712.4 |
| 1999 | 285.2 | 260.4 | 16.1 | 160.9 | 722.6 |
| 2000 | 289.5 | 264.8 | 15.2 | 166.7 | 736.2 |
| 2001 | 296.4 | 274.0 | 14.6 | 169.3 | 754.3 |
| 2002 | 290.0 | 287.4 | 13.8 | 174.7 | 765.9 |
| 2003 | 294.2 | 295.0 | 12.6 | 181.2 | 783.0 |
| 2004 | 305.2 | 303.3 | 12.2 | 189.6 | 810.3 |
| 2005 | 322.1 | 320.8 | 11.7 | 200.5 | 855.0 |
| Increase % | 19% | 40% | -55% | 49% | 29% |
| Growth Rate %/year | 1.7% | 3.4% | -7.6% | 4.1% | 2.6% |

Source: The Platou Report (www.platou.com)

**Table A.8 World Fleet Development with Derived Removal Rates (The Platou Report) (Mil DWT)**

| Year | Tankers | Removed | R Rate | Bulk Carriers | Removed | R Rate | Other | Removed | R Rate |
|---|---|---|---|---|---|---|---|---|---|
| 1995 | 270.9 | 10.9 | | 229.9 | 2.6 | | 160.7 | 2.2 | |
| 1996 | 270.5 | 6.8 | 0.025 | 241.3 | 8.5 | 0.037 | 161.6 | 2.6 | 0.016 |
| 1997 | 275.2 | 3.7 | 0.014 | 250.0 | 7.9 | 0.033 | 166.3 | 4.8 | 0.030 |
| 1998 | 279.5 | 7 | 0.025 | 260.7 | 11.8 | 0.047 | 172.2 | 4.3 | 0.026 |
| 1999 | 285.2 | 16.4 | 0.059 | 260.4 | .1 | 0.035 | 177.0 | 4.8 | 0.028 |
| 2000 | 289.5 | 14.1 | 0.049 | 264.8 | 4.4 | 0.017 | 181.9 | 3.6 | 0.020 |
| 2001 | 296.4 | 19.7 | 0.068 | 274.0 | 7.2 | 0.027 | 183.9 | 4.8 | 0.026 |
| 2002 | 290.0 | 19.3 | 0.065 | 287.4 | 6 | 0.022 | 188.5 | 5.1 | 0.028 |
| 2003 | 294.2 | 18.9 | 0.065 | 295.0 | 3.5 | 0.012 | 193.8 | 3.5 | 0.019 |
| 2004 | 305.2 | 10.3 | 0.035 | 303.3 | 0.8 | 0.003 | 201.8 | 1.5 | 0.008 |
| 2005 | 322.1 | | | 320.8 | | | 212.1 | | |
| Increase % | 19% | | 0.045 | 40% | | 0.026 | 32% | | 0.022 |
| Growth Rate %/year | 1.7% | | | 3.4% | | | 2.8% | | |

## LNG Fleet Growth Projections

### Bloomberg Report:  LNG Fleet Needs to Expand 66 percent

The global fleet of tankers carrying liquefied natural gas needs to expand by 66 percent by 2010 to meet current and future demand from exporters including Qatar, Australia and Nigeria, according to LNG Shipping Solutions, as reported by Bloomberg.

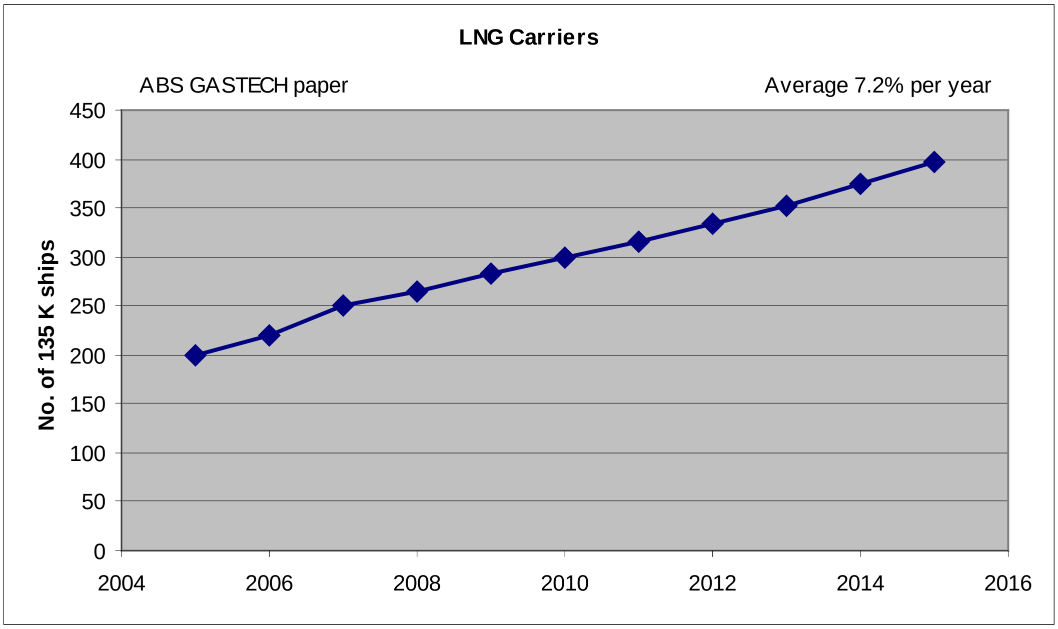
About 205 carriers need to be ordered, adding to the 182 vessels in service and 127 units already contracted to be built, to meet demand for existing and future LNG projects. In addition, as many as 105 vessels need to be ordered to meet demand for future projects and 100 vessels for current contracts.

Source:  http://www.marinelink.com/MembersNew/ViewStoryNR.asp?StoryID=200525 accessed Oct 13, 2005.

**ABS**

Numerous LNG vessels are under order in anticipation of rising demand for LNG shipments. We estimated an additional 220 vessels.

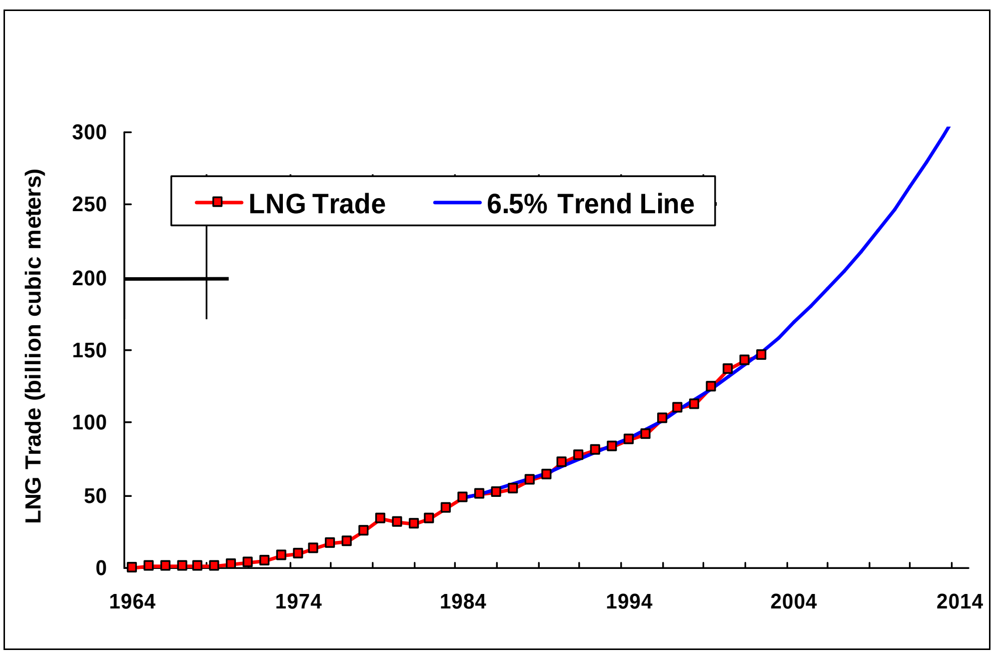
**Figure A-3 LNG Fleet Growth (from ABS GASTECH paper) Based Upon 138K $m^3$ Capacity**




## Conoco Phillips Marine, USA

Figure A-4 below shows the trend of LNG shipping (Noble, P. 2004).

**Figure A-4 LNG Growth Projected**



**Ballast Water Capacity as a Vessel Cargo Capacity for Various Vessel Types**

A key assumption in the assumed growth rates is that modeling growth in cargo carrying capacity (DWT, TEU or volume) correlates to growth in ballast water capacity and thus, discharge potential. The following figures demonstrate that this assumption is well-founded.

**FigureA-5 Bulk Carrier BW Capacity vs. Deadweight**

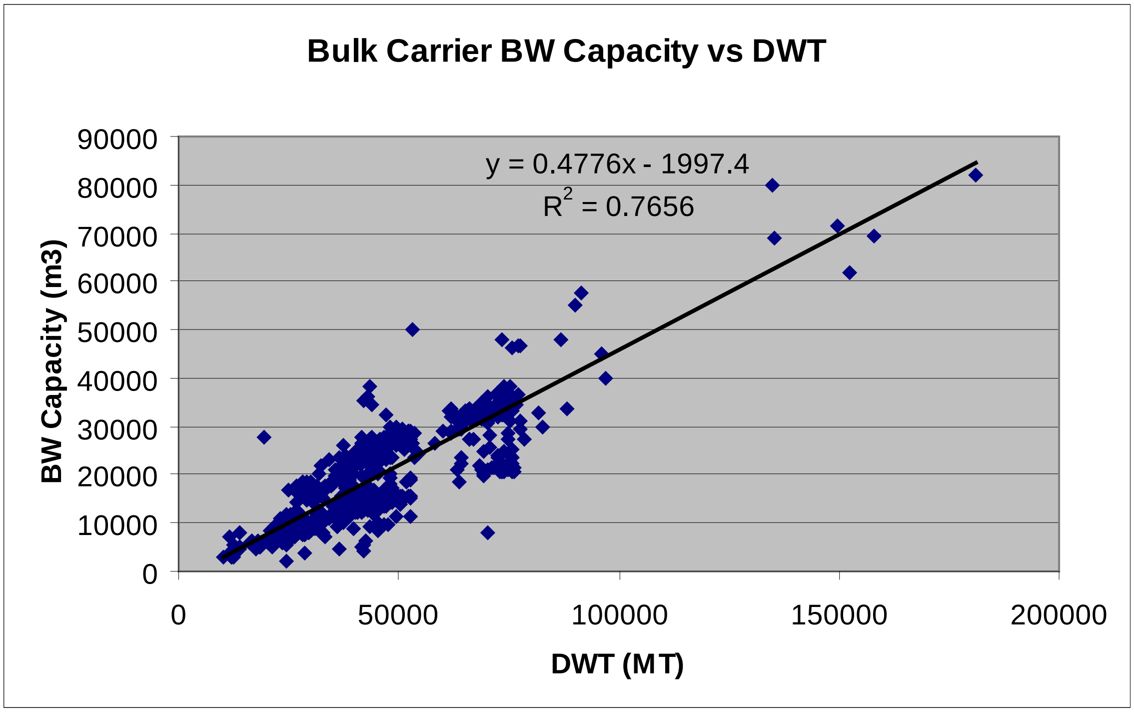


**Figure A-6 Containership BW Capacity vs. TEU**

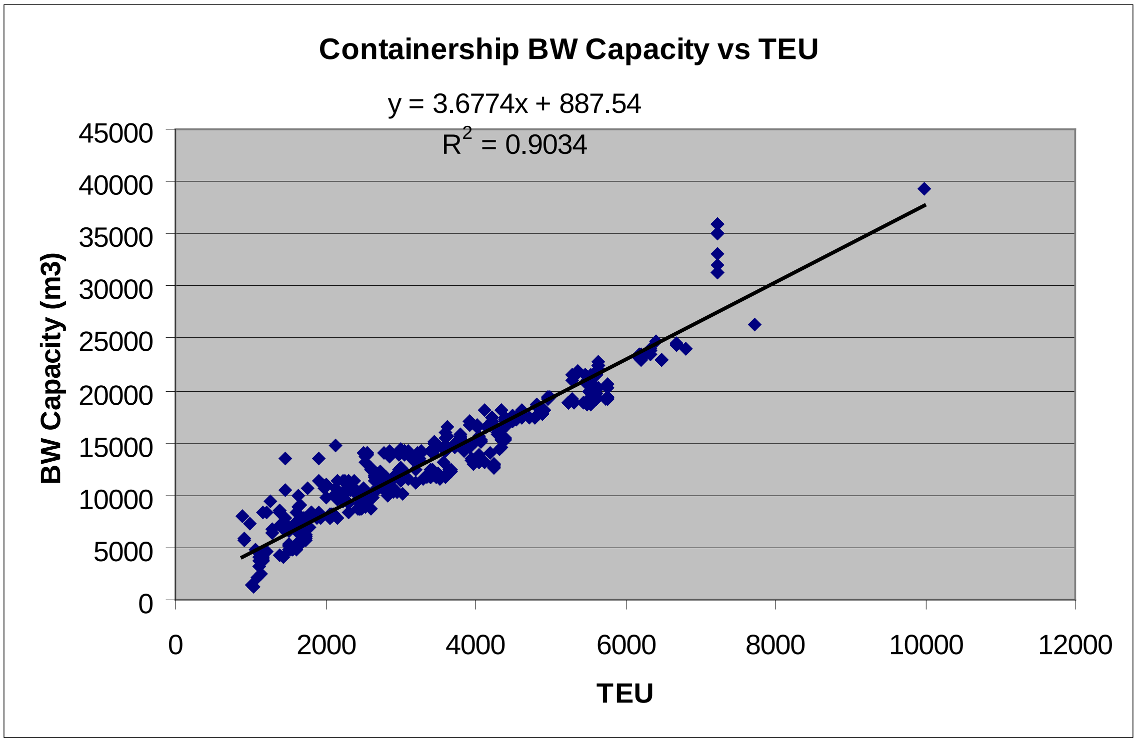
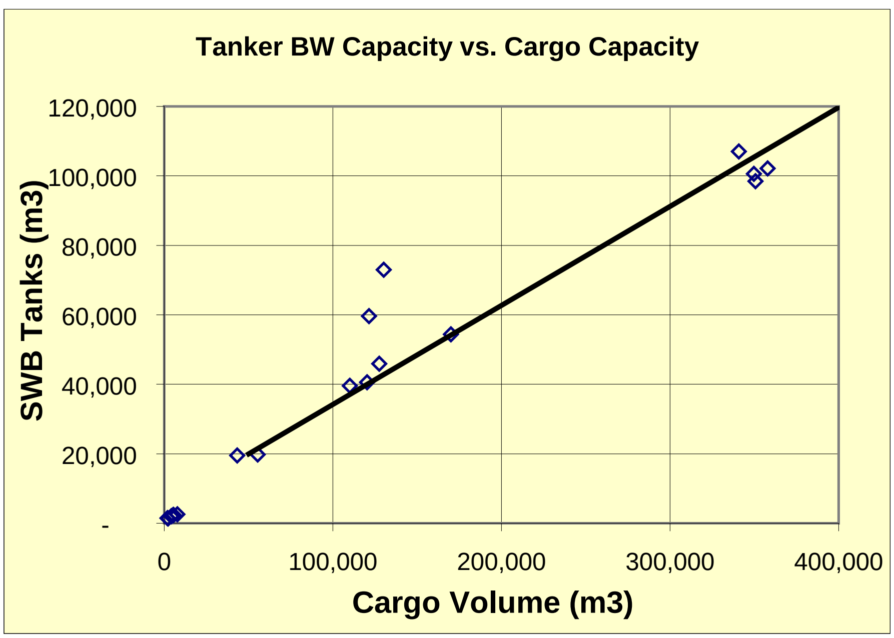



**Figure A-7 Tanker BW Capacity vs. Cargo Capacity (from HEC data)**



# Appendix B Ballast Water Exchange (BWE) Cost[46]

This appendix presents the calculation of the ballast water exchange (BWE) cost, baseline cost, based on the 2007 vessel information provided by the National Ballast Information Clearinghouse (NBIC) database. The baseline cost is equivalent to the Alternative 1 (No Action) described in this RA. We then compared the BWE costs the proposed BWDS, alternative 2 (see Chapter 6 for discussion).

The direct costs of the current ballast water management practices (BWE) onboard vessels include the cost incurred by pumping additional ballast water and the cost of additional crew labor required to carry out the mid-ocean exchanges. Herbert Engineering Corp (HEC) estimated the pumping costs based on the cost of generating the electricity to run the ballast pump and the additional maintenance costs for the ballast pump and piping resulting from pumping more ballast. HEC assumed that no new equipment is required to comply with the rule. In determining the amount of ballast water involved in the exchange, three volumes of ballast tank capacity represents a complete flow-through (FT) exchange, while two volumes of the ballast tank capacity represents an empty/refill (ER) exchange.

To determine pumping costs, HEC estimated the cost for pumping one cubic meter of ballast water. HEC used fluid mechanic equations to calculate the kilowatts (kW) of power required to pump one cubic meter of water against a typical ballast system pressure head of 25 m. Taking into account the efficiencies of the pumps, motors, and generators, HEC calculated that it takes 0.11 kW of generated power to pump one cubic meter per hour ($m^3/h$) of ballast is pumped. Because most vessels have diesel generators, HEC based the cost estimate on generating power in this manner. Considering the fuel rates of typical diesel generators and a fuel cost of $620 per ton for marine diesel oil (MDO), and $300 per ton for heavy fuel oil (HFO), plus lube oil costs, the calculated cost per $m^3/h$ based on MDO fuel is $0.13 and based on HFO fuel is $0.07. As a rough order estimate, HEC assumed that half the vessels use MDO for generators and half use HFO; consequently, HEC estimated the average cost for powering the pumps to be $0.10 per $m^3/hr$ pumped.

Another component in the calculation of cost of BWE is the additional maintenance cost incurred by the use of the ballast pumps and piping systems to carry out BWE. A reasonable estimate based on industry experience is that the average annual maintenance costs are approximately 10 percent of the ballast pump's capital cost.[47] In order to adequately account for the extra maintenance burden, a uniform annual maintenance cost of 10 percent of the capital cost of one ballast pump is added for each vessel conducting exchanges. HEC divide this cost by the estimated annual quantity of ballast pumped per year. HEC estimate the annual quantity of ballast pumped without BWE with the assumption that the pumps operate at rated capacity for 100 to 125 hours per year,[48] increased by a factor of 2.5 on average by BWE (average factor of 2 for empty/refill and 3 for flow-through). HEC also assume this

[46] Methodology and sources provided by Herbert Engineering Corporation, information updated to 2007.
[47] This number was also used in the BWM RA (USCG 2004). Here it is refined to account only for those costs that truly depend upon the increased ballast pumped required by BWE.
[48] This estimate is based upon a review of typical numbers of voyages and amounts discharged across all vessel types.

maintenance cost covers replacement parts for pumps such as impellers, as well as maintenance of piping system components, such as pipes and valves. Approximately half of this maintenance cost is considered to be affected by increased flow through the system and half based on time of exposure to salt water by the system, which is unaffected by BWE. The maintenance cost affected by flow through the system is increased by 250 percent to account for BWE, and the total is divided by the estimated annual flow in the system to obtain the additional maintenance cost per cubic meter of ballast pumped for BWE. See Table B-1 for details on the maintenance cost calculations.

**Table B-1 Additional Maintenance Costs per $m^3$ of Ballast Pumped for BWE**

| System Size ($m^3$/hr) | Annual Maint Cost (no BWE) | Variable Maint Cost (1/2 affected by flow) | Ballast Pumped/Yr-No BWE | Additional Ballast by BWE (250%) | BWE Additional Maint./ Yr | BWE Add Maint / $m^3$ pumped |
|---|---|---|---|---|---|---|
| 250 | $1,500 | $750 | 25,000 | 62,500 | $1,875 | $0.030 |
| 750 | $2,500 | $1,250 | 75,000 | 187,500 | $3,125 | $0.017 |
| 2000 | $5,000 | $2,500 | 200,000 | 500,000 | $6,250 | $0.013 |
| 5000 | $10,000 | $5,000 | 500,000 | 1,250,000 | $12,500 | $0.010 |

Because carrying out BWE doubles or triples the amount of time needed to empty and refill or flow-through ballast tanks and could require many hours of operation at sea, it is reasonable to add additional crew labor costs to this number.[49] This factor recognizes that the crew could be doing other work during this time. The charges would be primarily for officers to oversee the ballasting and possibly for unlicensed crew if the vessel has manually-operated valves. The labor charges vary from very low cost[50] to over $50[51] per hour for U.S. or European officers.[52] Table B-2 shows an estimated average labor cost for BWE and includes the cost for BWE labor per $m^3$ of water. HEC assumed that no additional personnel would be added to the vessel to conduct BWE. For smaller vessels, it is assumed that less time is required for ballasting and less supervision is required compared to a large tanker or bulk carrier, where ballasting is a major operation.

**Table B-2 Additional Crew Costs per $m^3$ of Ballast Water Pumped for BWE**

| System Size ($m^3$/hr) | Voyage /Year | Add Labor Cost/Voy BWE | Add Labor Cost/Yr BWE | Additional Ballast by BWE (250%) | BWE Labor Cost/$m^3$ |
|---|---|---|---|---|---|
| 250 | 15 | $90 | $1,350 | 62,500 | $0.022 |
| 750 | 15 | $120 | $1,800 | 187,500 | $0.010 |
| 2000 | 10 | $150 | $1,500 | 500,000 | $0.003 |
| 5000 | 6 | $180 | $1,080 | 1,250,000 | $0.001 |

[49] Based upon recent industry experience, it is assumed that vessels can maintain course and speed while performing BWE.
[50] Costs are loaded.
[51] U.S. wage rate source comes from BLS data for year 2007 using NAIC 483100 and SOC Code # 53-5021. This is the mean wage rate, times the load rate of 40%, gave us approximately $50 load wage rate for U.S.
[52] For small incremental increases in labor use on a ship, it is appropriate in assessing real costs to use direct labor charges.

Table B.3 summarizes the components of the cost for BWE described above and provides a total cost per cubic meter pumped for BWE.

**Table B-3 Total Cost per $m^3$ for Ballast Pumped for BWE**

| System Size ($m^3$/hr) | Elect Power Cost | Maintenance Cost | Labor Cost | Total Cost |
|---|---|---|---|---|
| 250 | $0.010 | $0.030 | $0.022 | $0.062 |
| 750 | $0.010 | $0.017 | $0.010 | $0.037 |
| 2000 | $0.010 | $0.013 | $0.003 | $0.026 |
| 5000 | $0.010 | $0.010 | $0.001 | $0.021 |

Note: All costs are per $m^3$ of ballast pumped

Based on the above estimated cost per cubic meter of ballast pumped, HEC estimated the annual cost of BWE. While this estimate carries uncertainty, it provides a reasonable estimate of the magnitude of costs industry can expect to incur because of BWE.

## Ballast Water Exchange Practices

The costs of BWE influence shipping operations. The NBIC data indicate how much ballast is managed through exchange; whether ER, FT, or alternative methods are used. Alternative methods as reported in the NBIC data can include treatment, mid-ocean filling, or undetermined methods. However, they represent only a small portion (<0.5 percent) of managed ballast water.

Vessels that carry goods into the U.S. typically discharge little ballast. Imports and foreign goods dominate U.S. maritime trade. In particular, large VLCC and ULCC tankers, which have the largest ballast capacities, discharge virtually no ballast in U.S. waters; this is not surprising, since the U.S. imports primarily crude oil.

Containerships vary significantly in the likelihood that they will discharge ballast, with the smallest size being the most likely to discharge. Nationally, large containerships discharge at a rate of about two-thirds of their port arrivals. HEC expect this rate to decrease over time. Generally, we expect all operators to minimize the costs of BWE. Ballast discharge data for regions such as the Great Lakes and California, where mandatory BWM programs have been in effect for a number of years, demonstrate this trend.

In an assessment of the role of no ballast onboard (NOBOB) vessels in the introduction of NIS into the Great Lakes (Johengen, et al. 2005), it was concluded that over 90 percent of the vessels entering the Great Lakes have NOBOB.[53] HEC also used data from California,

[53] The cited reference confirmed earlier analyses that NOBOBs dominate Great Lakes saltwater vessel entries despite significant discrepancies in the details reported by Colautti et al (2003) and the U.S. USCG. In most cases the disagreement involved a Colautti et al. designation of NOBOB vs. a USCG designation of ballast on board . St. Lawrence Seaway data for the 2000 season indicate that 89 percent of the vessels entered as NOBOBs. The cited reference included further analysis of the Seaway data that revealed that only ~7 percent of the vessels entering that year would have legally been subject to the deep-water ballast exchange and salinity

where BWM has been mandatory since 2000, to corroborate the behavior observed in the NBIC data. This data shows that implementation of the mandatory BWM program for vessels[54] arriving at California ports (CSLC 2005) reduces the amount of ballast water discharged. Additionally, note that for containerships the no-discharge ratio has increased from about two-thirds to over 80 percent. Panamax and Post-Panamax vessels dominate containership traffic in California.

HEC's experience in developing BWE exchange plans for industry and their personal communications with vessel operators supported these behavior patterns.

These data support the findings of this RA that the actual amount of ballast discharged, and thus requiring management, is significantly lower than the assumptions used in the upper bound evaluation made in the previous BWM RA (USCG 2004).

The NBIC data also provide information on how the ballast water is managed. Table B-4 presents the ratio of ballast water managed using ER and FT, as well as using alternative methods (discussed above). ER is the dominant process for most vessel types. Bulk carriers and passenger ships extensively use FT.

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verification requirements in effect at that time, the remainder having entered the system as NOBOBs, but ballasted at freshwater ports between Quebec City and Montreal, and were thus counted as in a ballasted condition by the Seaway. Such vessels would have been counted as being in a ballasted condition, but compliant with entry regulations, by the U.S. USCG. These numbers lead the authors to conclude that the best estimate is that over 90 percent of the vessels entering the Great Lakes do so as NOBOBs.

[54] Vessel types are as categorized by California.

### Annual Ballast Water Exchange Costs

The BWE exchange costs were calculated based on the percentage ballast water managed through ER or FT[55] and by the current discharged amount of non-coastwise vessels operating in the U.S. waters in 2007. In order to calculate the amount of managed ballast water, HEC assumed that all ballast water will be exchanged on every voyage to a U.S. port from outside the U.S. EEZ. Most operators will likely exchange only the tanks they need before entering port depending on the cargo operations they intend to perform once in the United States. They also assigned a uniform annual maintenance cost to every vessel that made at least one transit outside the EEZ; for many vessels that only make one port call in the United States from outside the EEZ, this would overstate the annual cost to this vessel. HEC believe, however, that even though they could be overestimating the annual cost of the final rule, their costs certainly represents the magnitude of the expenditure they would expect to see. The estimated a total annual cost for BWE to be $5 million for year 2007.

**Table B-4 BWE Costs for 2007**

| Vessel Type | %ER | %FT | 2007 Cost/m$^3$ | Total Discharge | BWE Costs |
|---|---|---|---|---|---|
| **Bulk Carriers** | | | | | |
| Handy | 0.35 | 0.37 | $0.036 | 19,205,314 | $17,657 |
| Panamax | 0.23 | 0.65 | $0.028 | 13,643,470 | $13,019 |
| Capesize | 0.50 | 0.26 | $0.025 | 13,058,853 | $8,135 |
| **Tank ships** | | | | | |
| Handy | 0.12 | 0.17 | $0.037 | 700,461 | $20,035 |
| Handymax - Aframax | 0.21 | 0.17 | $0.022 | 165,111,289 | $3,367,364 |
| Suezmax | 0.07 | 0.00 | $0.025 | 101,459,503 | $344,409 |
| VLCC | 0.45 | 0.00 | $0.022 | 1,939,980 | $37,906 |
| ULCC | 1.00 | 0.00 | $0.021 | 9,900 | $418 |
| **Container ships** | | | | | |
| Feeder | 0.03 | 0.09 | $0.067 | 20,068 | $45 |
| Feedermax | 1.00 | 0.00 | $0.059 | 20,068 | $239 |
| Handy | 0.45 | 0.10 | $0.056 | 1,275,040 | $8,635 |
| Subpanamax | 0.72 | 0.05 | $0.050 | 1,216,466 | $9,800 |
| Panamax | 0.70 | 0.02 | $0.050 | 654,601 | $4,817 |
| Postpanamax | 0.74 | 0.00 | $0.037 | 4,468,678 | $25,197 |
| **Other vessels** | | | | | |
| Passenger ships | 0.06 | 0.00 | $0.064 | 809,286 | $6,289 |
| Gas carriers | 0.23 | 0.05 | $0.022 | 189,918 | $2,552 |
| Chemical carriers | 0.37 | 0.18 | $0.045 | 7,946,202 | $455,901 |
| RORO | 0.39 | 0.02 | $0.056 | 365,683 | $17,475 |
| Combination vessels | 0.99 | 0.00 | $0.056 | 15,673,816 | $657,801 |
| General Cargo | 0.47 | 0.23 | $0.056 | 257,428 | $6,310.96 |
| Total | | | | 348,026,022 | $5,004,003 |

[55] Percentages provided by Herbert Engineering Corporation

# Appendix C Ballast Water Treatment Costs for the Foreign Vessels

This appendix presents the information on the ballast water treatment costs for the foreign vessels that operate in U.S. waters. The data sources for the information below are described on chapters 2 and 3 of the main document.

## Installation Costs of Ballast Water Treatments Systems

In order to calculate the installation costs for the foreign vessel, HEC assumed that these vessels will have a wide range of options of BWTS vendors and therefore, the installation costs will be potentially lower than the costs incurred by the U.S. vessels. Tables C-1 provides the average ballast pumping capacities for each category of vessel and the costs for the systems of the indicated capacities for the foreign fleet. Installed costs vary, depending on the technology utilized and the cost of the equipment to implement that process. However, variations in cost are also related to a process's development stage

**Table C-1 Estimated Average Installed Cost ($000) for the Foreign Fleet by Vessel Category and BWTS**

| Vessel Category | Est. Ballast Pumping Capacity (m3/hr) | Chlorine Generate | Chemical Apply | Filter & Radiate | Deoxygenate | Ozone Generate |
|---|---|---|---|---|---|---|
| **Bulk carriers** | | | | | | |
| Handy | 1,300 | 544 | 333 | 634 | 453 | 593 |
| Panamax | 1,800 | 572 | 363 | 788 | 501 | 723 |
| Capesize | 3,000 | 400 | 425 | 567 | 567 | 967 |
| **Tank ships** | | | | | | |
| Handy | 1,100 | 474 | 321 | 573 | 434 | 541 |
| Handymax/ Aframax | 2,500 | 500 | 400 | 708 | 544 | 871 |
| Suezmax | 3,125 | 375 | 431 | 531 | 573 | 991 |
| VLCC | 5,000 | NA | 525 | NA | 662 | 1,350 |
| ULCC | 5,500 | NA | 525 | NA | 662 | 1350 |
| **Containerships** | | | | | | |
| Feeder | 250 | 300 | 250 | 225 | 165 | 252 |
| Feedermax | 400 | 338 | 265 | 297 | 236 | 311 |
| Handy | 400 | 338 | 265 | 297 | 236 | 311 |
| Subpanamax | 500 | 363 | 275 | 345 | 283 | 351 |
| Panamax | 500 | 363 | 275 | 345 | 283 | 351 |
| Postpanamax | 750 | 425 | 300 | 465 | 400 | 450 |
| **Other vessels** | | | | | | |
| Passenger ship | 250 | 300 | 250 | 225 | 165 | 252 |
| Gas carrier | 4,800 | NA | 515 | NA | 653 | 1,312 |
| Chemical carrier | 600 | 388 | 285 | 393 | 330 | 391 |
| RORO | 400 | 338 | 265 | 297 | 236 | 311 |
| Combination vessel | 400 | 338 | 265 | 297 | 236 | 311 |
| General cargo | 400 | 338 | 265 | 297 | 236 | 311 |
| Fishing Vessels[56] | 250 | 300 | 250 | 225 | 165 | 252 |
| OSVs[57] | 325 | 340 | 258 | 325 | 200 | 282 |

Source: Herbert Engineering Corporation. Note: The costs are for the processes considered the most cost-effective for the category of vessel, considering both installed cost and operating cost.

Table C-2 presents the installation costs for the foreign vessels by vessel type. The installation costs were calculated based on the average costs for each available ballast water

[56] Information obtained through consultation with the U.S. Coast Guard Commercial Fishing Vessels Division.
[57] Information obtained through consultation with the U.S. Coast Guard Offshore Vessels Division.

treatment system presented on Table C-1. The low costs presented on the table below are related to the cheapest treatment available and the high costs are related to the most expensive treatment available.

**Table C-2 Installed Ballast Water Treatment System Costs ($000) for the Foreign Vessels**

| Vessel Type | Installed Costs in 2007 | |
|---|---|---|
| | Low | High |
| **Bulk carriers** | | |
| Handy | 333 | 634 |
| Panamax | 363 | 788 |
| Capesize | 400 | 967 |
| **Tank ships** | | |
| Handy | 321 | 573 |
| Handyman-Aframax | 400 | 871 |
| Suezmax | 375 | 991 |
| VLCC | 525 | 1,350 |
| ULCC | 525 | 1,350 |
| **Container ships** | | |
| Feeder | 165 | 300 |
| Feedermax | 236 | 338 |
| Handy | 236 | 338 |
| Subpanamax | 275 | 363 |
| Panamax | 275 | 363 |
| Postpanamax | 300 | 465 |
| **Other vessels** | | |
| Passenger ships | 165 | 300 |
| Gas carriers | 515 | 1,312 |
| Chemical carriers | 285 | 393 |
| RORO | 236 | 338 |
| Combination vessels | 236 | 338 |
| General Cargo | 236 | 338 |
| Fishing Vessels | 165 | 300 |
| OSVs | 200 | 340 |

Source: Herbert Engineering Corporation

The foreign fleet will be subjected to the same phase-in schedule as the U.S. fleet (Table 1.1). In the year 2014, vessels built before 2012 with ballast capacities between 1,500 and 5,000 cubic meters will be required to meet the discharge standards under the rulemaking phase-in structure. While industry practice is to delay additional costs as long as possible, a certain proportion of the fleet will undergo these installations during routine shipyard visits for other regularly scheduled maintenance. For the vessels that will comply with this rulemaking by 2014, we have assumed that 30 percent will install BWTS each year, in the first two years (2012 and 2013) and 40 percent in the last year of the compliance requirement (2014). In 2016, the remainder of the fleet built before 2012 and certain new buildings will be required to meet the BWDS. In this case, we have assumed that 20 percent of the population will install the system each year (from 2012 to 2016). Given these assumptions and the projected fleet growth as defined in Chapter 2 (Table 2.3), the number of foreign vessels undergoing BWTS installations is as shown in Table C-3.

**Table C-3 Number of Foreign Vessels Undergoing BWTS Installation by Year and Type**

| Vessel type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk carriers** | | | | | | | | | | | |
| Handy | 248 | 248 | 259 | 217 | 217 | 15 | 15 | 15 | 15 | 15 | 1,264 |
| Panamax | 116 | 116 | 116 | 114 | 114 | 7 | 7 | 7 | 7 | 7 | 611 |
| Capesize | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 1 | 1 | 55 |
| **Tank ships** | | | | | | | | | | | |
| Handy | 35 | 35 | 40 | 20 | 20 | 4 | 4 | 4 | 4 | 5 | 171 |
| Handy-Aframax | 182 | 183 | 183 | 184 | 184 | 25 | 26 | 26 | 27 | 28 | 1,048 |
| Suezmax | 26 | 26 | 26 | 26 | 26 | 4 | 4 | 4 | 4 | 4 | 150 |
| VLCC | 40 | 40 | 40 | 40 | 40 | 6 | 6 | 6 | 6 | 6 | 230 |
| ULCC | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 25 |
| **Containerships** | | | | | | | | | | | |
| Feeder | 15 | 16 | 18 | 8 | 8 | 4 | 4 | 4 | 4 | 4 | 85 |
| Feedermax | 22 | 22 | 27 | 7 | 7 | 5 | 5 | 5 | 5 | 6 | 111 |
| Handy | 46 | 46 | 50 | 35 | 36 | 12 | 12 | 13 | 14 | 14 | 278 |
| Subpanamax | 57 | 57 | 58 | 59 | 59 | 16 | 17 | 18 | 18 | 19 | 378 |
| Panamax | 58 | 58 | 59 | 59 | 60 | 16 | 17 | 18 | 19 | 19 | 383 |
| Postpanamax | 90 | 91 | 92 | 93 | 94 | 26 | 27 | 28 | 29 | 30 | 600 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 50 | 50 | 62 | 15 | 16 | 8 | 9 | 9 | 9 | 9 | 237 |
| Gas carriers | 39 | 40 | 44 | 27 | 27 | 8 | 8 | 8 | 8 | 8 | 217 |
| Chemical carriers | 197 | 200 | 210 | 187 | 190 | 69 | 73 | 78 | 83 | 88 | 1,375 |
| RORO | 102 | 102 | 109 | 85 | 85 | 21 | 21 | 22 | 22 | 23 | 592 |
| Combination vessels | 6 | 6 | 6 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 26 |
| General Cargo | 86 | 87 | 97 | 59 | 59 | 17 | 17 | 17 | 18 | 18 | 475 |
| Fishing | 5 | 5 | 5 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 28 |
| OSV | 19 | 19 | 21 | 12 | 13 | 5 | 5 | 5 | 5 | 6 | 110 |
| Total | 1,453 | 1,461 | 1,539 | 1,270 | 1,279 | 269 | 279 | 290 | 301 | 312 | 3,060 |

Note: Totals may not add due to rounding

Table C-4 shows the breakdown by year, vessel type, and the overall share for each vessel type.

**Table C-4 Installation Costs for the BWTS for Foreign Vessels ($Mil)**

| Vessel Type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk Carriers** | | | | | | | | | | | |
| Handy Bulk | 82.74 | 82.72 | 86.20 | 72.14 | 72.11 | 5.01 | 4.99 | 4.96 | 4.94 | 4.91 | 420.72 |
| Panamax Bulk | 42.05 | 42.04 | 42.21 | 41.47 | 41.45 | 2.65 | 2.64 | 2.62 | 2.61 | 2.60 | 222.34 |
| Capesize | 4.17 | 4.17 | 4.17 | 4.17 | 4.16 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 22.14 |
| **Tank Ships** | | | | | | | | | | | |
| Handy | 11.13 | 11.16 | 12.74 | 6.54 | 6.56 | 1.34 | 1.36 | 1.39 | 1.42 | 1.45 | 55.09 |
| Handymax-Aframax | 72.94 | 73.13 | 73.31 | 73.51 | 73.70 | 10.17 | 10.37 | 10.58 | 10.79 | 11.01 | 419.51 |
| Suezmax | 9.65 | 9.67 | 9.69 | 9.72 | 9.75 | 1.34 | 1.37 | 1.40 | 1.43 | 1.46 | 55.48 |
| VLCC | 20.79 | 20.85 | 20.90 | 20.96 | 21.01 | 2.90 | 2.96 | 3.02 | 3.08 | 3.14 | 119.61 |
| ULCC | 2.16 | 2.17 | 2.17 | 2.18 | 2.18 | 0.30 | 0.31 | 0.31 | 0.32 | 0.33 | 12.43 |
| **Containerships** | | | | | | | | | | | |
| Feeder | 2.56 | 2.58 | 3.03 | 1.34 | 1.36 | 0.61 | 0.63 | 0.66 | 0.69 | 0.72 | 14.18 |
| Feedermax | 5.19 | 5.23 | 6.49 | 1.68 | 1.73 | 1.13 | 1.18 | 1.24 | 1.29 | 1.35 | 26.51 |
| Handy | 10.77 | 10.86 | 11.90 | 8.28 | 8.40 | 2.80 | 2.93 | 3.06 | 3.19 | 3.33 | 65.52 |
| Subpanamax | 15.64 | 15.80 | 15.97 | 16.14 | 16.32 | 4.46 | 4.66 | 4.86 | 5.08 | 5.30 | 104.23 |
| Panamax | 15.82 | 15.98 | 16.15 | 16.33 | 16.51 | 4.51 | 4.71 | 4.92 | 5.13 | 5.36 | 105.42 |
| Postpanamax | 26.99 | 27.26 | 27.54 | 27.84 | 28.15 | 7.69 | 8.03 | 8.39 | 8.76 | 9.14 | 179.79 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 8.28 | 8.31 | 10.29 | 2.54 | 2.58 | 1.36 | 1.40 | 1.44 | 1.48 | 1.52 | 39.2 |
| Gas carriers | 20.34 | 20.44 | 22.79 | 13.86 | 13.96 | 3.90 | 4.00 | 4.12 | 4.23 | 4.35 | 111.99 |
| Chemical carriers | 56.19 | 57.08 | 59.96 | 53.16 | 54.22 | 19.76 | 20.95 | 22.20 | 23.54 | 24.95 | 392.01 |
| RORO | 23.98 | 24.10 | 25.66 | 20.03 | 20.16 | 4.86 | 4.99 | 5.13 | 5.28 | 5.42 | 139.61 |
| Combination vessels | 1.35 | 1.35 | 1.47 | 0.98 | 0.98 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 6.63 |
| General Cargo | 20.40 | 20.50 | 22.88 | 13.84 | 13.94 | 3.90 | 4.01 | 4.13 | 4.24 | 4.36 | 112.2 |
| Fishing | 0.82 | 0.83 | 0.87 | 0.72 | 0.73 | 0.17 | 0.17 | 0.18 | 0.18 | 0.19 | 4.86 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OSVs | 3.78 | 3.80 | 4.29 | 2.50 | 2.53 | 0.96 | 1.00 | 1.03 | 1.07 | 1.11 | 22.07 |
| Total | 457.75 | 460.01 | 480.69 | 409.91 | 412.50 | 80.20 | 83.04 | 86.00 | 89.10 | 92.35 | 2651.55 |
| Total PV 3% | 444.42 | 433.61 | 439.90 | 364.20 | 355.83 | 67.17 | 67.52 | 67.89 | 68.29 | 68.71 | 2377.54 |
| Total PV 7% | 427.80 | 401.79 | 392.39 | 312.72 | 294.11 | 53.44 | 51.71 | 50.05 | 48.46 | 46.94 | 2079.41 |

## Operating Costs of Ballast Water Treatment System

BWTS operational costs are in addition to the capital costs for installation. In order to obtain a cost of operation for the foreign vessel, we first had to calculate the amount of ballast discharge per vessel type (Table C-5).

**Table C-5 Estimated ballast water discharge in 2007**

| Vessel Type | # of Arrival | Total Ballast Water Discharged | Average Ballast Water Discharged per Vessel |
|---|---|---|---|
| **Bulk carriers** | | | |
| Handy | 1,137 | 8,632,730 | 7,593 |
| Panamax | 300 | 5,281,319 | 17,604 |
| Capesize | 42 | 339,360 | 8,080 |
| **Tank ships** | | | |
| Handy | 120 | 700,461 | 5,837 |
| Handymax-Aframax | 7,303 | 162,180,186 | 22,207 |
| Suezmax | 4,040 | 100,803,870 | 24,951 |
| VLCC | 285 | 1,869,274 | 6,559 |
| ULCC | 11 | 9,900 | 900 |
| **Container ships** | | | |
| Feeder[58] | N/A | N/A | N/A |
| Feedermax | 6 | 1,200 | 200 |
| Handy | 22 | 28,154 | 1,280 |
| Subpanamax | 68 | 185,992 | 2,735 |
| Panamax | 56 | 107,470 | 1,919 |
| Postpanamax | 92 | 213,989 | 2,326 |
| **Other vessels** | | | |
| Passenger ships | 1,003 | 809,272.3 | 807 |
| Gas carriers | 23 | 189,917.56 | 8,257 |
| Chemical carriers | 1,211 | 7,722,161.79 | 6,377 |
| RORO | 533 | 344,174.99 | 646 |
| Combination vessels | N/A | N/A | N/A |
| General Cargo | 55 | 52,609.2 | 957 |
| Fishing Vessel | N/A | N/A | N/A |
| OSV | 6 | 24,022 | 4,004 |

Note: Totals may not add due to rounding.

The average amount of ballast water discharged per vessel type is calculated by using data collected by NBIC for year 2007. The amounts of discharge from vessels, represented in the above table, are of those vessels that reported actual discharge of ballast in year 2007. This data

[58] Information for Feeder vessel is assumed to the same as for Feedermax

was then cross-referenced to population data gathered from USCG MISLE database in order to match vessel activity with there corresponding category by vessel type.

Once the average yearly amount of ballast discharge was determined, we multiplied these estimates by the number of vessels undergoing installation in Table C.3. Then multiply this product by the cost presented in Table  using the lowest cost per cubic meter of water for each particular vessel type.  The calculated value is then used to formulate an annual operating cost for BWT (Table C-5) per vessel type.

Table C-6 displays the operating costs for all affected vessels in the population.  The total operating costs covering the period of analysis is approximately $85.5 million with discounted costs of approximately $71 and $56 million at 3 and 7 percent discount rates, respectively.

**Table C-6 Annual Operating Costs for BWT ($Mil)**

| Vessel Type | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Vessel Type Sub-Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bulk Carriers** | | | | | | | | | | | |
| Handy Bulk | 0.36 | 0.72 | 1.09 | 1.40 | 1.72 | 1.74 | 1.76 | 1.78 | 1.80 | 1.82 | 14.19 |
| Panamax Bulk | 0.33 | 0.65 | 0.98 | 1.30 | 1.62 | 1.64 | 1.66 | 1.68 | 1.71 | 1.73 | 13.3 |
| Capesize | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.48 |
| **Tank Ships** | | | | | | | | | | | |
| Handy | 0.04 | 0.09 | 0.13 | 0.16 | 0.18 | 0.19 | 0.19 | 0.20 | 0.20 | 0.21 | 1.59 |
| Handymax-Aframax | 0.49 | 0.97 | 1.46 | 1.95 | 2.44 | 2.51 | 2.58 | 2.65 | 2.72 | 2.79 | 20.56 |
| Suezmax | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.46 | 0.48 | 0.49 | 0.50 | 0.52 | 3.8 |
| VLCC | 0.03 | 0.06 | 0.09 | 0.11 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 1.21 |
| ULCC | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0004 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.002 |
| **Containerships** | | | | | | | | | | | |
| Feeder | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Feedermax | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.08 |
| Handy | 0.02 | 0.04 | 0.07 | 0.08 | 0.10 | 0.10 | 0.11 | 0.12 | 0.12 | 0.13 | 0.89 |
| Subpanamax | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.27 | 0.28 | 0.30 | 0.31 | 0.33 | 2.24 |
| Panamax | 0.04 | 0.07 | 0.11 | 0.14 | 0.18 | 0.19 | 0.20 | 0.21 | 0.22 | 0.24 | 1.6 |
| Postpanamax | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 | 0.26 | 0.27 | 0.29 | 0.30 | 0.32 | 2.19 |
| **Other vessels** | | | | | | | | | | | |
| Passenger ships | 0.02 | 0.03 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 | 0.59 |
| Gas carriers | 0.07 | 0.14 | 0.21 | 0.26 | 0.31 | 0.32 | 0.33 | 0.35 | 0.36 | 0.38 | 2.73 |
| Chemical carriers | 0.36 | 0.73 | 1.12 | 1.47 | 1.82 | 1.95 | 2.08 | 2.23 | 2.38 | 2.54 | 16.68 |
| RORO | 0.02 | 0.05 | 0.07 | 0.09 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 | 0.14 | 0.98 |
| Combination vessels | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| General | 0.03 | 0.06 | 0.09 | 0.11 | 0.13 | 0.14 | 0.15 | 0.15 | 0.16 | 0.16 | 1.18 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cargo | | | | | | | | | | | |
| Total | 2.03 | 4.07 | 6.18 | 8.07 | 9.97 | 10.31 | 10.66 | 11.02 | 11.40 | 11.79 | 85.5 |
| Total PV 3% | 1.97 | 3.84 | 5.66 | 7.17 | 8.60 | 8.63 | 8.67 | 8.70 | 8.74 | 8.77 | 70.75 |
| Total PV 7% | 1.90 | 3.56 | 5.04 | 6.16 | 7.11 | 6.87 | 6.64 | 6.41 | 6.20 | 5.99 | 55.88 |

Note: Total may not add due to rounding.

## Total Costs of Ballast Water Treatment Systems for Foreign Vessels

In Table C-7, we estimate the total cost over the period of analysis for the foreign vessels. The total estimated cost was $2.4 billion with a 3 percent discount rate and $2.1billion with a 7 percent discount rate.

**Table C-7 Total Cost of the Rulemaking to Foreign Vessels ($Mil)**

| Year | Installation Costs | | Treated Ballast Discharged ($m^3$) | Annual Operating Costs | | Total Cost | |
|---|---|---|---|---|---|---|---|
| | 3% Discount | 7% Discount | | 3% Discount | 7% Discount | 3% Discount | 7% Discount |
| 2012 | $444 | $428 | 11,553,390 | $1.97 | $1.90 | $446 | $430 |
| 2013 | $434 | $402 | 23,142,938 | $3.84 | $3.56 | $437 | $405 |
| 2014 | $440 | $392 | 35,009,044 | $5.66 | $5.04 | $446 | $397 |
| 2015 | $364 | $313 | 45,978,943 | $7.17 | $6.16 | $371 | $319 |
| 2016 | $356 | $294 | 56,994,305 | $8.60 | $7.11 | $364 | $301 |
| 2017 | $67 | $53 | 58,664,985 | $8.63 | $6.87 | $76 | $60 |
| 2018 | $68 | $52 | 60,388,596 | $8.67 | $6.64 | $76 | $58 |
| 2019 | $68 | $50 | 62,164,181 | $8.70 | $6.41 | $77 | $56 |
| 2020 | $68 | $48 | 63,994,138 | $8.74 | $6.20 | $77 | $55 |
| 2021 | $69 | $47 | 65,880,987 | $8.77 | $5.99 | $77 | $53 |
| Total | $2,378 | $2,079 | | $70.75 | $55.88 | $2,448 | $2,135 |
| Annualized | $279 | $296 | | $8.29 | $7.96 | $287 | $304 |

# Appendix D Benefits (Economic Costs Avoided) By Year

**Table D-1 Benefits by Year – 7%**

| | 7% Discount Rate | | | | | |
|---|---|---|---|---|---|---|
| | Low Effectiveness - 37% | | | High Effectiveness - 63% | | |
| Year | Low | Mid | High | Low | Mid | High |
| 2012 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2013 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2014 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2015 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2016 | $2 | $66 | $130 | $4 | $113 | $222 |
| 2017 | $5 | $125 | $246 | $8 | $214 | $419 |
| 2018 | $7 | $178 | $349 | $11 | $303 | $595 |
| 2019 | $8 | $225 | $441 | $14 | $382 | $750 |
| 2020 | $10 | $266 | $521 | $17 | $452 | $887 |
| 2021 | $11 | $301 | $592 | $19 | $513 | $1,008 |
| Total | $43 | $1,161 | $2,279 | $74 | $1,977 | $3,881 |
| Annualized | $6 | $165 | $325 | $10 | $282 | $553 |

**Table D-2 Benefits by Year – 3%**

| | 3% Discount Rate | | | | | |
|---|---|---|---|---|---|---|
| | Low Effectiveness - 37% | | | High Effectiveness - 63% | | |
| Year | Low | Mid | High | Low | Mid | High |
| 2012 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2013 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2014 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2015 | $0 | $0 | $0 | $0 | $0 | $0 |
| 2016 | $3 | $83 | $164 | $5 | $142 | $279 |
| 2017 | $6 | $164 | $321 | $10 | $279 | $547 |
| 2018 | $9 | $241 | $474 | $15 | $411 | $807 |
| 2019 | $12 | $316 | $621 | $20 | $539 | $1,057 |
| 2020 | $14 | $389 | $763 | $25 | $662 | $1,299 |
| 2021 | $17 | $458 | $900 | $29 | $781 | $1,532 |
| Total | $62 | $1,652 | $3,243 | $105 | $2,813 | $5,521 |
| Annualized | $7 | $194 | $380 | $12 | $330 | $647 |

# Appendix E Derivation of Estimates of Costs and Damages Due to Aquatic NIS

Non-indigenous aquatic invasive species can cause considerable economic damages such as costs to control the invasion, damage to infrastructure and other assets, loss of fishery resources, and loss of recreation and tourism opportunities. We have reviewed the literature on economic damages resulting from existing NIS invasions to predict damages from future invasions. Since each invasive specie is unique, the type and level of cost varies widely from specie to specie (i.e., variability). Further, the cost estimates of damage for an individual specie can also vary as different studies focus on particular aspects of costs or costs within a specific geographic range (i.e., uncertainty). Because of variability in the amount of damage across species and the uncertainty in estimating damages for an individual species, we have not attempted to derive a comprehensive estimate of costs per non-invasive species. Instead, we establish a range of values to use – a low end of the range and upper end estimate with a calculated mid-range by species groups – invertebrates (mollusks), fish, and aquatic plants.

Table E-1 summarizes estimates of costs due to NIS invasions as derived from the existing literature. The following discussion provides an explanation for the derivation of the low and upper end estimates by species group.

**Invertebrates**

- At the upper end, Piementel, et al. 2005 estimates costs resulting from Zebra Mussels of $1 billion per year. The estimate would be $1,093,000,000 annually updated to 2008 price level. This value is meant to be a comprehensive estimate covering all damages and control costs in all geographic areas. In addition, Pimentel, et al 2005 reports an estimate for the Asian Clam at $1 billion per year in damages and costs, based on the reported cost in the 1993 OTA report. The estimate would be $1,093,000,000 annually updated to 2008 price level. Based on the damage estimates for these two species of mollusks (Zebra Mussel and Asian Clam), we establish the upper end of the range at $1.093 billion per year in potential costs and damages for invertebrates.

- At the lower end, two survey-based studies collected information on the amount that facilities (mainly electric generation and water treatment facilities) have spent on zebra mussel control and/or prevention. A 2007 study (Connelly, et al) provided in estimate of $17.8 million per year spent by electric generation and water treatment facilities over the time period of 1989 to 2004 ($20.121 million updated to 2008). O'Neill 1997 provided an estimate of $17.751 million per year for infrastructure owners and operators ($24.87 million updated to 2008). Both of these studies, while based on survey responses, only account for a subset of impacted parties and only one category of costs, but can be used to establish the lower end of the range of potential costs from invertebrates.

- The calculated mid-range between the upper end ($1.093 billion) and lower end ($20.121 million) is $555.0605 million.

**Fish**

- At the upper end, Leigh 1998 estimates that the annual commercial and recreational fishing benefits lost due to the ruffe invasion in the Great Lakes range from $24 million and $119 million to $240 million (1998 prices), $31.4 million, $155.9 million and $314.4 million updated (based on varying assumptions about the loss of yellow perch and walleye populations). We use the upper estimate of $314.4 million per year to represent potential damages for invasive fish species.

- At the lower end, Jenkins 2001 reports an estimate of the economic impact of sea lamprey at $13.5 million, updated to $16.3 million.

- The calculated mid-range between the upper end ($314.4 million) and lower end ($16.3 million) is $165.3675 million.

**Aquatic Plants**

- At the upper end, Pimentel 2005 estimates that the costs to control Eurasion milfoil is $400 million per year ($437.2 million updated) based on an average cost per hectacre.

- At the lower end, Rockwell 2003 reported estimates of costs to control Water Hyacinth in Louisiana of $4.0 million per year, updated to $4.642 million.

- The calculated mid-range between the upper end ($437.3 million and lower end ($4.642 million) is $220.921 million.

**Summary**

**Table E-1 Annual Range of Costs Associated with Selected NIS Introductions ($ 2008)**

| | Low-Range | | Mid-Range | | High Range | | |
|---|---|---|---|---|---|---|---|
| Fish | $ 16,335,000 | [1] | $ 165,367,500 | | $ 314,400,000 | [2] | |
| Invertebrates | $ 20,121,000 | [3] | $ 555,060,500 | | $ 1,090,000,000 | [4] | |
| Aquatic Plants | $ 4,642,000 | [5] | $ 220,921,000 | | $ 437,200,000 | [6] | |
| | | | | | | | |
| | | | | | | | |

[1] From Jenkins 2001, economic impact of sea lamprey on Great Lakes, updated from 2001$
[2] From Leigh 1998, commercial and recreational fishing benefits lost due to ruffe invasion of Great Lakes, updated from 1998$
[3] From Connelly et al. 2007, cost of Zebra Mussel control at WTP and electric generation facilities, updated from 2004$
[4] From Piementel et al. 2005, cost of Zebra Mussel or Asian Clam, updated from 2005$
[5] From Rockwell 2003, cost to control Water Hyacinth in Louisiana, updated from 2003$
[6] From Pimentel 2005, cost to control Eurasion watermilfoil, updated from 2005$

**Table E-2 Summary of Cost Estimates for Invertebrates from Literature**

**Zebra Mussel**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
|---|---|---|---|---|
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | US Army COE Environmental Laboratory, "http://el.erdc.usace.army.mil/zebra/zmis/zmishelp/economic_impacts_of_zebra_mussel_infestation.htm"<br><br>Zebra Mussel Information Review, January-February 1994, congressional researchers estimate costs of $3 billion over 7 years for power industry alone, $5 billion by end of decade. | All damages and control costs | $ 1,000,000,000 | 2005 |
| Pimentel, "Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and the Great Lake Basin: An Economic and Environmental Assessment," Environmental Management. 35:5 (2005) 692-701 | Derived from larger estimate of $1 billion total. | Damages to tourism, electric industry, fishing, boating, other recreation for limited geographic area | $ 12,500,000 | 2005 |
| Ben Grumbles, AA Office of Water, USEPA, Testimony Before WATER RESOURCES AND ENVIRONMENT SUBCOMMITTEE OF THE HOUSE TRANSPORTATION AND INFRASTRUCTURE COMMITTEE, March 7, 2007 | O'Neill, C. R. 2000. National Aquatic Nuisances Species Clearinghouse, New York Sea Grant Extension, Brockport NY, Personal Communication, 22 Dec. 2000. As reported in Carlton, Introducted Species in US Coastal Water for the Pew Oceans Commission | Losses to natural resources and damage to infrastructure in Great Lakes of $750 million to $1 billion from 1989 to 2000 | $ 75,000,000 | 2007 |
| | | | $ 100,000,000 | 2007 |
| | EPA estimates, quotes from Dr. David Lodge of Notre Dame in a variety of media | Costs for control and treatment of zebra mussels at industrial and municipal facilities fo $100 to $200 million per year in Great Lakes | $ 100,000,000 | 2007 |
| | | | $ 200,000,000 | 2007 |
| US General Accounting Office, INVASIVE SPECIES: Clearer Focus and Greater Commitment Needed to Effectively Manage the Problem, October 2002, GAO-03-01. | GAO estimates | Annual costs to the American power industry | $ 60,000,000 | |
| | US Fish & Wildlife Service estimate as reported in Cataldo, R. "Musseling in on the Ninth District Economy," Fedgazette, 13(1) 15-17. | Impacts on industry, recreation and fisheries of $3.1 billion over next ten years | $ 310,000,000 | 1991 |

| | | | | |
|---|---|---|---|---|
| US Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States September 1993, OTA-F-565. | Contractor report by Mark J. Cochran, Non-indigenous species in the United States-economic consequences, 1992. | Economic impact over next 10 years of $3.1 billion ($1991) | $ 310,000,000 | 1991 |
| Connelly, et al. Economic Impacts of Zebra Mussels on Drinking Water Treatment and Electric Power Generation Facilities, Environ Manage 40 (2007) 105–112 | Survey of a subset of electric generation and drinking water treatment facilities within zebra mussel range in 2004 | $267 million (BCa 95% CI = $161 million–$467 million) in total economic costs for electric generation and water treatment facilities through late 2004, since 1989. | $ 17,800,000 | 2004 |
| O'Neill, Economic Impact of Zebra Mussels - Results of the 1995 National Zebra Mussel Information Clearinghouse Study, Great Lakes Research Review 3:1(April 1997). | Survey to infrastructure owners and operators | $17751000 annually in 1995 for respondents only (no scaling for non-response or universe of facilities), average $11,500,000 annually for 1989-1995 | $ 17,751,000 | 1995 |
| Hushak, L.J. and Y. Deng, 1997. Costs of Alternative Zebra Mussel Control Strategies: The Case of Great Lakes Surface Water Users, Ohio Sea Grant College Program, Ohio State University | Estimate of zebra mussel research expenditures | $8.8 million annually for 1992, 1992 and 1994 | $ 8,000,000 | 1994 |

**Asian Clam**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
|---|---|---|---|---|
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | OTA | All damages and control costs | $ 1,000,000,000 | 2005 |
| US Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States September 1993, OTA-F-565. | B.G. Isom, Historical Review of Asiatic Clam Invasions and Biofouling of Waters and Industries in the Americas | All damages and control costs | $ 1,000,000,000 | 1991 |

**Shipworm**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
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| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | Cohen, A.N., Carlton, J.T., 1995. Nonindigenous Aqautic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta. United States Fish and Wildlife Service, Washington, DC. | Damages | $ 205,000,000 | 2005 |

**Green Crab**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
|---|---|---|---|---|
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | Lafferty, K.D., Kuris, A.M., 1996. Biological control of marine pests. Ecology 77 (7), 1989–2000. | Economic impacts | $ 44,000,000 | 2005 |
| Lafferty, K.D., Kuris, A.M., 1996. Biological control of marine pests. Ecology 77 (7), 1989–2000. | Original analysis | Economic value of existing fishery harvest at risk from introduction of green crab on west coast | $ 46,700,000 | 1991 |

**Fish**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
|---|---|---|---|---|
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | Unpublished data by author | Economic losses due to 138 alien invasive species that have negatively affected native fishes and other aquatic biota | $ 5,400,000,000 | 2005 |
| Leigh, "Benefits and Costs of the Ruffe Control Program for the Great Lakes Fishery," Journal of Great Lakes Research, 24:2 (1998) 351-360. | Estimation of annual commercial and recreational fishing benefits lost due to ruffe invasion using a value per angler/day approach | Recreational, commercial and sport fishing (assumes 10%, 35% and 60% reduction in the population of yellow perch and 1%, 12.5% and 25% reduction in the population of wall-eye) | $ 24,000,000 | 1998 |
| | | | $ 119,000,000 | 1998 |
| | | | $ 240,000,000 | 1998 |
| US Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States September 1993, OTA-F-565. | Great Lake Commission estimates | Economic losses due to ruffe | $ 90,000,000 | 1991 |

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| US Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States September 1993, OTA-F-565. | Schnittker, J., ‘ ‘Federal Policy on Non- Indigenous Species: An Overview of the U.S. Department of Agriculture, ” contractor report prepared for the Office of Technology Assessment, December 1991. | Value of lost fishing opportunities and indirect impacts if sea lamprey is not controlled in the Great Lakes | $ 500,000,000 | 1991 |
| Jenkins, P. 2001. “Economic Impacts of Aquatic Nuisance Species in the Great Lakes.” Report prepared by Philip Jenkins and Associates, Ltd., for Environment Canada, Burlington, Ontario. | As reported in Lovell et al 2006 | Economic impact of sea lamprey in Great Lakes (US and Canada) | $ 13,500,000 | 2001 |

**Aquatic Plants**

| Reference: | Source: | What is included in estimate? | Annual Cost | Price Level |
|---|---|---|---|---|
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | OTA | Amount invested annually in alien species aquatic week control (assume for 5 species: hydrilla, European loosestrife, erasion water milfoil, melaluca, salt cedar) | $ 110,000,000 | 2005 |
| Pimentel et al., "Update on the environmental and economic costs associated with alien-invasive species in the United States". Ecological Economics. 52 (2005) 273-288 | Center et al, 1997 | Spending by Florida for hydrilla control | $ 14,500,000 | 2005 |
| Pimentel, "Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and Great Lakes Basin: An Economic and Environmental Assessment." Environmental Management. 35:5 (2005) 692-701 | Calculated based on reported cost per ha to control | Cost to control Eurasion Watermilfoil nationally | $ 400,000,000 | 2005 |
| Pimentel, "Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and Great Lakes Basin: An Economic and Environmental Assessment." Environmental Management. 35:5 (2005) 692-702 | Data from USGS | Cost to control purple loosestrife nationally | $ 229,000,000 | 2005 |

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| Pimentel, "Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and Great Lakes Basin: An Economic and Environmental Assessment." Environmental Management. 35:5 (2005) 692-703 | Calculated based on reported costs to control in Lake Champlain Basin | Cost to control water chestnut nationally | $ 200,000,000 | 2005 |
| US Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States September 1993, OTA-F-565. | Courtenay, W. R., Jr., ‘ ‘Pathways and Consequences of the Introduction of Non-Indigenous Fishes in the United States, ” contractor report prepared for the Office of Technology Assessment, August 1991. | Amount invested annually in alien species aquatic weed control (assume for 5 species: hydrilla, European loosestrife, erasion water milfoil, melaluca, salt cedar) | $ 110,000,000 | 1991 |
| Bell , F.W., and M.A. Bonn. 2004. “Economic Sectors at Risk from Invasive Aquatic Weeds at Lake Istokpoga, Florida.” The Bureau of Invasive Plant Management, Florida De-partment of Environmental Protection, Tallahassee, Florida. Available at http://www.aquatics.org/pubs/economics.htm | Original analysis | Economic value at risk from invasive aquatic weeds (primarily hydrilla) in a FL lake includes recreation, agriculture support, flood control and property values | $ 40,103,000 | 2004 |
| Drissoll, P & et al, The Effect of Aquatic Plants on Residential Shoreline Property Values at Gunterville Reservoir, Tennessee Valley Authority and U.S. Army Corps of Engineers, 1994 | Original analysis using a hedonic model to related property values to aquatic weed conditions (primarily hydrilla) | Complete control of aquatic plants increased property values by 17% for developed lots and 35% for undeveloped properties | N/A | N/A |
| Rockwell 2003, "Summary of a Survey of the Literature on the Economic Impact of Aquatic Weeds", August 2003. | USAID, Economic Damage Caused by Aquatic Weeds, 1971 | Spending by Louisianna to control water hyacinth | $ 4,000,000 | 2003 |
| Rockwell 2003, "Summary of a Survey of the Literature on the Economic Impact of Aquatic Weeds", August 2003. | USAID, Economic Damage Caused by Aquatic Weeds, 1971 | Annual losses in Louisianna due to water hyacinth in agriculture, drainage, fish and wildlife, navigation, and public health | $ 35,000,000 | 2003 |
| Rockwell 2003, "Summary of a Survey of the Literature on the Economic Impact of Aquatic Weeds", August 2003. | Schmitz et al 1991 | Spending by Florida for hydrilla control | $ 7,000,000 | 1989 |
| Carlton, "Introduced Species in US Coastal Waters", 2001 | Various | Federal and state spending on cordgrass control over 2 fiscal years | $ 1,888,000 | 2001 |

Note: Blue Shaded Estimates Used to Derive Upper End, Yellow Shaded Estimates Used to Derive Lower End