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

36 CFR Part 151 and 46 CFR Part 162
Docket No. USCG-2001-10486
RIN 1625-AA32

Final Rule

Regulatory Analysis and Final Regulatory Flexibility Analysis

November 2010

Prepared by:

United States Coast Guard (USCG)
Office of Standards Evaluation and Development
Standards Evaluation and Analysis Division
USCG Headquarters
Washington, DC

Additional contributions by:

AMSEC, LLC
Virginia Beach, VA

Herbert Engineering Corp. (HEC)
Alameda, CA

Contents

Tables

Figures

Acronyms

BWD	ballast water discharge
BWE	ballast water exchange
BWM	ballast water management
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
FR	Final Rule
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
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
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

This page intentionally left blank

Executive Summary

Under Executive Order 12866, the United States Coast Guard (USCG) is required to assess the costs and benefits of its regulatory actions. This Regulatory Analysis (RA) provides supporting documentation on the costs and benefits for the Final Rule (FR) for Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters [USCG-2001-10486]. This rule is an economically significant regulatory action under Executive Order 12866 and has been reviewed by the Office of Management and Budget (OMB). We did not attempt to exactly replicate the regulatory language of the Final Rule or any other supporting documentation in this report; the regulatory text in the Final Rule, not the text of this report, is 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 prevent 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 this 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 BWDS has been adopted by the International Maritime Organization (IMO), 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.

On August 28, 2009, we published a Notice of Proposed Rulemaking (NPRM) entitled Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters in the Federal Register (74 FR 44632). We received 662 letters in the docket, which contained approximately 2,216 individual comments on the proposed rule. We summarized these comments and corresponding changes in the FR section *V. Discussion of Comments and Changes*.

As a result of public comments, we have revised the NPRM RA to reflect the following changes in the FR:

> (a) Exemption of coastwise[1] vessels operating in more than one COTP Zone and that do not operate outside of the EEZ, and are:

[1] The term used in the Final Rule is "seagoing" vessels. For the purposes of consistency with the NPRM RA, instead of "seagoing" we use the terms "coastwise" and "oceangoing" vessels. Seagoing vessels that do not operate beyond the U.S. EEZ are considered coastwise. Seagoing vessels that operate beyond the U.S. EEZ are considered oceangoing. We used the coastwise and oceangoing terms throughout the NPRM RA. The definition of seagoing vessel is a vessel in commercial service that operates beyond the Boundary Line established by 46 CFR part 7. It does not include a vessel that navigates exclusively on inland waters.

(i) less than or equal to 1600 Gross Register Tons; or

(ii) less than or equal to 3000 Gross Tons (International Tonnage Convention); and

(b) Exemption of inland[2] vessel and vessels that take on and discharge ballast water exclusively in one COTP Zone.

Given the changes in the applicability and exemptions of this rule, we have revised our affected population estimates resulting in changes in the overall cost estimates. The revision on the affected population estimates resulted in changes in the overall cost estimates. The FR costs have decreased due to the reduction in the affected population. The benefits have decreased due to the longer phase-in period. We have also revised the original Initial Regulatory Flexibility Analysis (IRFA) and as a result, our estimates showed that there was a reduction in the number of small entities affected by this rule. Table ES-1 presents a summary of the changes in this FR RA comparing to the NPRM RA:

Table ES-1 Comparison of Regulatory Impacts between the NPRM and FR

	NPRM	FR
Applicability	All vessels discharging ballast water into U.S. waters.	Oceangoing vessels and some coastwise vessels (travelling outside the EEZ and > 1,600 GT).
Compliance Start Date	Beginning 2012	Delayed to beginning 2014
Number of BWMS Installations on Vessels (10-year period of analysis)	4,758	3,046
Costs ($ millions,7% discount rate)	$167 (annualized) $1,176 (10-year)	$92 (annualized) $649 (10-year)
Benefits ($ millions,7% discount rate)	$165-$282 (annualized) $1,161-$1,977 (10-year)	$141-$240 (annualized) $989-$1,684 (10-year)

This RA provides an evaluation of the economic impacts associated with the implementation of a standard limiting the quantities of living organisms in vessels' ballast water discharged in U.S. waters as summarized in Table ES-2.

Table ES-2 Allowable concentration of organisms in BWD, by size, for BWDS

	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*
FR BWDS (IMO Standard)	<10 per m^3	<10 per ml	<1 cfu per 100 ml	<250 cfu per 100 ml	<100 cfu per 100 ml

[2] The term used in the Final Rule is "non-seagoing" vessels. We have used the terms inland in this RA in order to keep consistency with the terms used in the NPRM RA.

For the NPRM, we considered five alternatives:

- Alternative 1: No Action
- Alternative 2: IMO Standard
- Alternative 3: 10 times more strict than the IMO Standard
- Alternative 4: 100 times more strict than the IMO Standard
- Alternative 5: Sterilization

We also considered a Phase 2 Standard that would be 1,000 times stricter than the IMO Standard.

Based on comments received in the NPRM and as discussed in the FR notice, Coast Guard chose to implement the preferred alternative (the IMO Standard) in this Final Rule, with the consideration of more strict standards based upon future practicability. For further discussion of the alternatives considered, please refer to the Regulatory Analysis for the NPRM, the FR preamble and the Final Programmatic Environmental Impact Assessment.

Population Affected

This FR will affect vessels, U.S. and foreign, operating in U.S waters[3] 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. The following vessels are exempt from complying with this rule:

(a) Department of Defense or Coast Guard vessels subject to the requirements of the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) or any vessel of the Armed Forces, as defined in the Federal Water Pollution Control Act that is subject to the "Uniform National Discharge Standards for Vessels of the Armed Forces";
(b) Any warship, naval auxiliary, or other vessel owned or operated by a foreign state, and used, for the time being, only on government non-commercial service.
(c) Crude oil tankers engaged in coastwise trade;
(d) Vessels that operate exclusively within one Captain of the Port (COTP) Zone;
(e) Coastwise (or Seagoing) vessels that operate in more than one COTP Zone, do not operate outside of the EEZ, and are (i) less than or equal to 1600 Gross Register Tons; or (ii) less than or equal to 3000 Gross Tons (International Tonnage Convention);
(f) Inland (Non-seagoing) vessels;
(g) Vessels that take on and discharge ballast water exclusively in one COTP Zone;
(h) Vessels in innocent passage; and
(i) Vessels that use only water from a public water supply, meeting the requirements of the Safe Drinking Water Act as ballast water.

[3] 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.

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 National Ballast Information Clearinghouse (NBIC). MISLE is the USCG database system for information on vessel characteristics, arrivals, casualties, and inspections. The NBIC database 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.

We identified approximately 6,418 vessels as the current vessel population that would be required to meet the BWDS. Of these, 1,459 are U.S.-flagged vessels. We assumed that vessels would be in full compliance with the FR by 2018. The BWMS equipment installation requirements are phased-in for new and existing vessels over the 2014 through 2016 period. Table ES-3 presents the number of potential vessels operating in U.S. waters that are projected to be covered under the BWDS.

Table ES-3 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	11	1,050	1,061
Panamax	50,000-80,000 DWT	6	509	515
Capesize	>80,000 DWT	0	46	46
Tank Ships				
Handy	<35,000 DWT	10	116	126
Handymax-Aframax	35,000-120,000 DWT	17	709	726
Suezmax	120,000-160,000 DWT	7	100	107
VLCC	160,000-320,000 DWT	4	154	158
ULCC	> 320,000 DWT	0	16	16
Container ships				
Feeder	<500 TEU	23	39	62
Feedermax	500-1000 TEU	1	51	52
Handy	1000-2000 TEU	26	126	152
Subpanamax	2000-3000 TEU	52	172	224
Panamax	>3000 TEU[b]	21	174	195
Postpanamax	>3000 TEU[c]	30	272	302
Other vessels				
Passenger ship	All sizes	138	129	267
Gas carrier	All sizes	6	118	124
Chemical carrier	All sizes	23	513	536
RORO	All sizes	66	321	387
Combination vessel	All sizes	131	22	153
General cargo	All sizes	47	258	305
Fishing Vessels	All sizes	83	16	99
OSVs[d]	All sizes	757	48	805
Total		1,459	4,959	6,418

a. Vessel classifications source: USGC (2004)
b. Vessel length and beam within Panama Canal limits.
c. Vessel length or beam exceed Panama Canal limits.
d. OSVs was refined to more precisely categorize the vessel type.

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 management technology will involve the world fleet, not the U.S. fleet alone. In addition, 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 the Ballast Water Discharge Standard

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. The BWMS is an emerging technology in its formative stage. The BWMS on ships is a new process for which there is minimal operating practical experience. Any discussion of the management technologies, effectiveness, costs, and operating issues is provisional. The primary cost driver of this rulemaking is installation costs for all existing vessels. After this period, we estimate operating costs to be substantially less. The operating cost is a function of the number of vessels treating ballast water and the estimated average volume treated each year. We calculated the annual volume treated by using the average annual volume of ballast water discharged by different types of vessels. We expect highest annual costs in the period between 2016 and 2018, as all of the existing fleet must meet the standards according to the phase-in schedule (Table ES-4).

Table ES-4 Costs to the U.S. vessels to comply with IMO Convention BWD Standard ($Mil)

Year	Installation Costs		Treated Ballast Water (m^3)	Annual Operation Costs		Total Cost	
	3% Discount	7% Discount		3% Discount	7% Discount	3% Discount	7% Discount
2014	$51.88	$49.94	280,029	$0.05	$0.05	$51.92	$49.98
2015	$51.71	$47.92	478,831	$0.09	$0.08	$51.80	$48.00
2016	$191.14	$170.50	2,993,916	$0.46	$0.41	$191.61	$170.91
2017	$178.68	$153.43	5,348,917	$0.80	$0.69	$179.49	$154.12
2018	$105.08	$86.86	6,565,633	$0.96	$0.79	$106.04	$87.65
2019	$35.68	$28.39	6,720,480	$0.96	$0.76	$36.64	$29.15
2020	$36.08	$27.63	6,957,572	$0.97	$0.74	$37.05	$28.37
2021	$36.49	$26.90	7,200,434	$0.97	$0.72	$37.46	$27.62
2022	$36.91	$26.19	7,449,212	$0.98	$0.69	$37.88	$26.89
2023	$37.33	$25.51	7,704,056	$0.98	$0.67	$38.31	$26.17
Total	**$760.98**	**$643.25**		**$7.21**	**$5.61**	**$768.20**	**$648.86**
Annualized	**$89.21**	**$91.58**		**$0.85**	**$0.80**	**$90.06**	**$92.38**

Note: Totals may not add due to rounding.

We estimate the first-year total (initial) cost of this rulemaking to be $49.98 million based on a 7 percent discount rate and $51.92 million based on a 3 percent discount rate. Over the 10-year period of analysis (2014-2023), the total cost of the FR BWDS for the U.S. vessels is approximately $648.86 million using the 7 percent discount rate and $768.20 million using the 3 percent discount rate. Our cost assessment includes existing and new vessels.

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-5.

Table ES-5 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 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 a BWDS 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 use the same benefits model for the FR as we did for the NPRM. This model quantifies benefits resulting from the reduction in "initial invasions" from vessels engaged in ocean-going traffic. We have not found complete data or identified appropriate models to quantify the possible benefits associated with reducing the secondary spread of invasions. Therefore, we do not expect the exemption of inland vessels to reduce the estimate of quantified benefits given data and modeling limitations.

We calculate potential benefits of the BWDS by estimating the number of initial invasions reduced and the range of economic damage avoided. We use information on the initial 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.[4] The resulting projection of the number of initial ballast water invasions that will cause harm is displayed in Table ES-6.

Table ES-6 Estimated Number of Initial Ballast Water Invasions that Cause Severe Economic and Financial Harm

Year	Invertebrate	Fish	Aquatic Plant
2014	0.39	0.08	0.16
2015	0.40	0.08	0.16
2016	0.41	0.08	0.16
2017	0.42	0.08	0.17
2018	0.43	0.09	0.17
2019	0.44	0.09	0.18
2020	0.45	0.09	0.18

[4] We recognize that invasive species can cause environmental harm without causing economic harm, but cannot monetize these benefits. Environmental harm from invasive species is discussed more fully in the FPEIS.

2021	0.46	0.09	0.18
2022	0.47	0.09	0.19
2023	0.48	0.10	0.19
Total	4.35	0.87	1.74

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 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-7.

Table ES-7: 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 (2014) will incur costs/damages in each of the next 10 years (through 2023). Also, these estimates of costs include the impact of secondary spread of an invasion to areas other than the site of the initial invasion.

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 (we present results of benefits estimation for a longer period of analysis in Appendix D) of 2014 to 2023 at $1.453 billion at a 7 percent discount (Table ES-8). These estimates assume no ballast water management.

Table ES-8 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	$ 56	$ 54
Mid Range	$ 1,491	$ 1,453
High Range	$ 2,926	$ 2,852

The Final Programmatic Environmental Impact Statement (USCG 2010) 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, the FR BWDS 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 the BWDS.

As discussed earlier, the implementation of the FR BWDS will be phased-in over several years. During the phase-in period of 2014-2018, there is uncertainty as to how effective the measures will be in preventing invasions if only a subset of ships have implemented ballast water management. For the purposes of estimating quantitative benefits, we assume that no invasions will be avoided before the end of this period (2014-2018) because a subset of ships will have implemented ballast water management. This approach may lead to an underestimate of potential benefits.

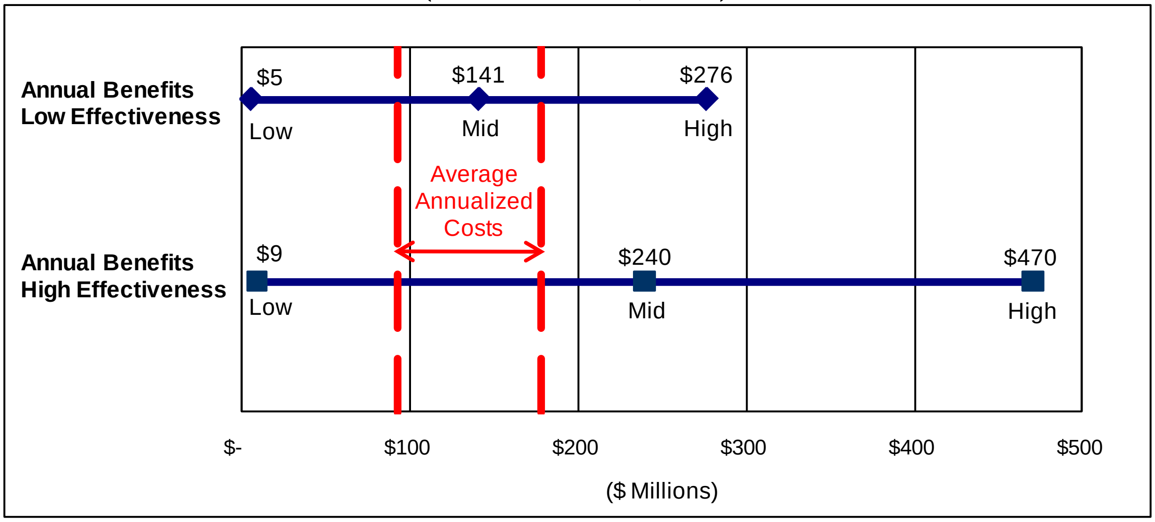
The resulting damages avoided for the FR BWDS range from a minimum of $5 million and the maximum is $470 million with a mid-range estimate of $141-$240 million per year at a 7 percent discount rate[5] (Table ES-9). Over a 10-year period of analysis, we estimate the total discounted present value benefits of the phase-one BWDS to be as high as $3 billion with a mid-range estimate of $0.99 billion to $1.68 billion[6]. Thus, quantified benefits exceed the estimated costs for the mid-point benefits estimate of Low Effectiveness. The high range annual cost estimate of $192 million[7] is less than the high range benefits estimate of Low Effectiveness.

Table ES-9: Potential Annual Benefits (Averted Cost), in Millions, of BW Invasion over a 10-year Period

Reductions in Mean Rate of Invasion	Low Range		Mid Range		High Range	
	3% discount rate	7% discount rate	3% discount rate	7% discount rate	3% discount rate	7% discount rate
Low Effectiveness - 37%	$ 6	$ 5	$ 155	$ 141	$ 304	$ 276
High Effectiveness - 63%	$ 10	$ 9	$ 264	$ 240	$ 518	$ 470

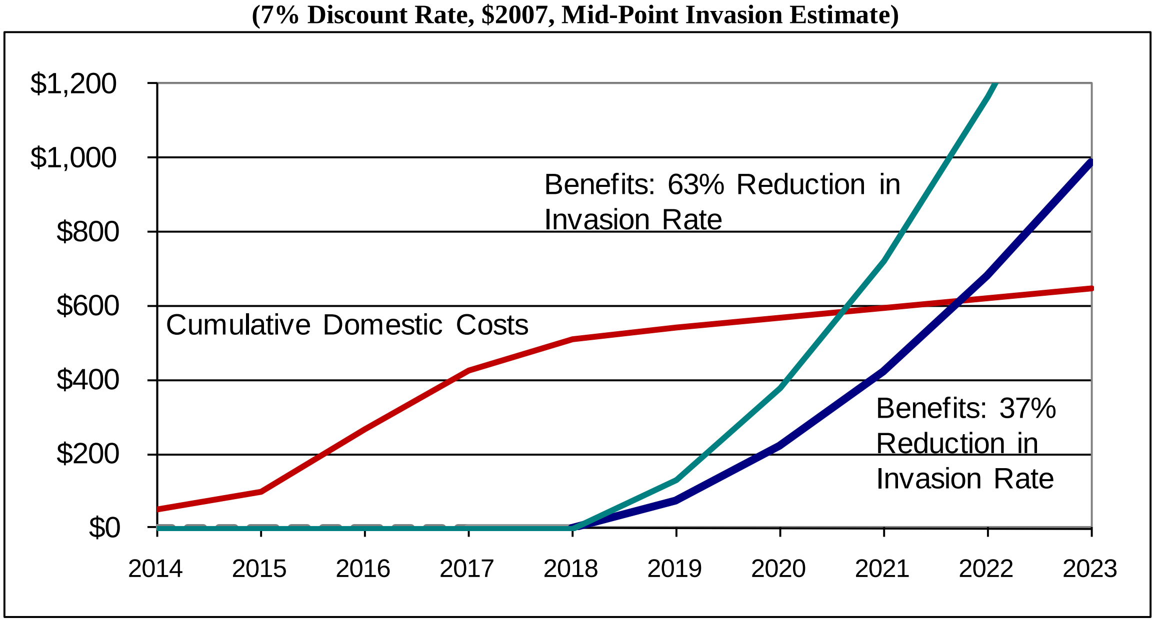
[5] The large range in the estimates of benefits from preventing invasive species is due to the natural variability in the amount of damage caused by any individual species (i.e., different species can cause a wide range of damages from very little in a small area to large, widespread damages).
[6] The mid-range benefit estimate varies based on the assumed effectiveness factors of preventing invasions (37% and 63%). The average of the mid-range benefit estimate for the 10-year period of analysis is $1.34 billion (range: $0.99 billion to $1.68 billion).
[7] See OMB A-4 Account Statement for high cost estimates information.

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



The cumulative economic damages avoided would equal cumulative costs incurred in 2020 assuming a higher reduction rate of 63 percent and in 2022 assuming a low reduction by 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)



Regulatory Flexibility Analysis

In accordance with the Regulatory Flexibility Act (RFA), we have prepared a Final Regulatory Flexibility Analysis (FRFA) that examines the impacts of the FR on small entities (5 USC 601 et seq.). Based on available data, we estimated that approximately 29 percent of the businesses affected would be small by the Small Business Administration size standards. 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 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 FR.
Agency/Program Office: USCG
Rule Title: Standards for Living Organisms in Ship’s Ballast Water Discharged in U.S. Waters
RIN#: 1625-AA32
Date: November 2010

Category	Primary Estimate		Minimum Estimate		High Estimate		Source
Benefits							
Annualized monetized benefits ($ Mil)	$141-$240	7%	$5	7%	$470	7%	RA
	$155-$264	3%	$6	3%	$518	3%	RA
Annualized quantified, but unmonetized, benefits	Unspecified		Unspecified		Unspecified		RA
Unquantifiable Benefits	Avoidance of damages due to certain species such as viruses and the secondary spread of invasions Avoidance of environmental damages that cannot be monetized						RA
Costs							
Annualized monetized costs ($ Mil)	$92	7%	$92	7%	$178	7%	RA
	$90	3%	$90	3%	$173	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. High cost estimates are based on high cost technologies.
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 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 Guard's initiative to develop a Federal regulation that would standardize the criteria for the management of ballast water in U.S. waters[8]. 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).

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

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 (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 National Invasive 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.

1.2.a Comparison Between the NPRM RA and the FR RA

The goal of the USCG Final Rule (FR) is to establish a ballast water discharge standard (BWDS) for the allowable concentrations of living organisms discharged via ballast water into U.S. waters. On August 28, 2009, we published a Notice of Proposed Rulemaking (NPRM) entitled Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters in the Federal Register (74 FR 44632). We summarized these comments in the FR section *V. Discussion of Comments and Changes*. The great majority of the comments on the NPRM RA were from the inland, Great Lakes and coastwise industries. The commenters raised many different issues related to the ballast water operations, such as the use of municipal/potable water, technology costs, size limitations and underestimation of the affected population (for not including inland vessels and vessels under 100 feet due to the general applicability of the NPRM). Additionally, commenters expressed concern that the cost estimates for the proposed Phase 2 standard was not included in any of the supporting documentation or analysis. Remaining comments were on cost to foreign vessels, benefits and small entities analysis.

Given the issues raised by commenters on the affected population (mainly from inland, Great Lakes and coastwise industries as stated in the paragraph above), the Coast Guard has revised the applicability of the BWDS rule. The FR requires compliance with IMO BWDS only to the following vessels, intending to discharge ballast water into water of the United States: vessels entering waters of the United States from outside the exclusive economic zone (EEZ); and coastwise vessels that operate in more than one Captain of the Port (COTP) Zone, and are greater than 1600 Gross Register Tons (or 3000 International Gross Tons). The Coast Guard fully intends to expand the BWDS rule to all vessels at some point, as noted in the NPRM, but has determined that additional research and analysis is necessary to support this expansion. Additionally, the Coast Guard has decided to move forward with the NPRM Phase one standard that will not include a standard that is more stringent than the IMO standard.

In order to address the applicability changes in the FR, we have revised the NPRM RA affected population to incorporate the following :

(a) Exemption of coastwise[9] vessels that do not operate outside of the EEZ, and are:

(i) less than or equal to 1600 Gross Register Tons; or

(ii) less than or equal to 3000 Gross Tons (International Tonnage Convention); and

(b) Exemption of inland[10] vessels.

---

[9] The term used in the Final Rule is "seagoing" vessels. For the purposes of this RA, instead of "seagoing" we use the terms "coastwise" and "oceangoing" vessels. Seagoing vessels that do not operate beyond the U.S. EEZ are considered coastwise. Seagoing vessels that operate beyond the U.S. EEZ are considered oceangoing. We used the coastwise and oceangoing terms in this RA in order to keep consistency with the terms used in the NPRM RA. The definition of seagoing vessel is a vessel in commercial service that operates beyond the Boundary Line established by 46 CFR part 7. It does not include a vessel that navigates exclusively on inland waters.

The revision of the affected population estimates and the revised compliance start date resulted in changes in the overall cost estimates. The FR costs have decreased due to the reduction in the affected population. The quantified benefits have decreased due to the longer phase-in period.[11] We have also revised the quantitative findings from the Initial Regulatory Flexibility Analysis (IRFA) and as a result, our estimates showed that there was a reduction in the number of small entities affected by this rule. Table 1.1 presents a summary of the changes in this FR RA compared to the NPRM RA:

Table 1.1 Comparison of Regulatory Impacts between the NPRM and FR

	NPRM	FR
Applicability	All vessels discharging ballast water into U.S. waters.	Oceangoing vessels and some coastwise vessels (travelling outside the EEZ and > 1,600 GT).
Compliance Start Date	Beginning 2012	Delayed to beginning 2014
Number of BWMS Installations on Vessels (10-year period of analysis)	4,758	3,046
Costs ($ millions,7% discount rate)	$167 (annualized) $1,176 (10-year)	$92 (annualized) $649(10-year)
Benefits ($ millions,7% discount rate)	$165-$282 (annualized) $1,161-$1,977 (10-year)	$141-$240 (annualized) $989-$1,684 (10-year)

This RA provides a revised evaluation of the economic impacts associated with FR requirements and is presented as follows:

The remainder of Chapter 1 discusses the alternative discharge standards under consideration and implementation schedule.

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.

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.

---

[10] The term used in the Final Rule is “non-seagoing” vessels. We have used the terms inland in this RA in order to keep consistency with the terms used in the NPRM RA.

[11] We use the same benefits model for the FR as we did for the NPRM. This model quantifies benefits resulting from the reduction in “initial invasions” from vessels engaged in ocean-going traffic. Inland vessels have been increasingly associated with the secondary spread of invasions, but we have not found complete data or identified appropriate models to quantify the possible benefits associated with reducing the secondary spread of invasions. Therefore, we do not expect the exemption of inland vessels to reduce the estimate of quantified benefits given data and modeling limitations. See the Benefits chapter of this report for more discussion on the data and modeling framework used for this rulemaking.

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 the Final Regulatory Flexibility Act (FRFA) analysis.

1.3 Alternative Ballast Water Discharge Standards

As part of the rulemaking process, Coast Guard considered several alternative BWDS. As described in the NPRM RA, these alternatives included:

- 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 as summarized in Table 1.2)*; and
- an alternative that essentially requires sterilization of ballast water *(Alternative 5)*.

Coast Guard also considered a Phase 2 standard that required more stringent levels of maximum concentrations for living organisms in discharged ballast water than Alternative 4. See the NPRM RA for additional detail on the alternatives considered in the NPRM.

Table 1.2 Allowable concentration of organisms in BWD, by size, for Alternatives

	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
Phase 2	<0.01 per m^3	<0.01 per ml	<1 cfu per 100 ml	<126 cfu per 100 ml	<33 cfu per 100 ml

Alternative 2 is the BWDS in the International Maritime Organization (IMO) Ballast Water Convention[12]. Alternative 2 was the preferred alternative in the NPRM RA and is

[12] 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

the standard in the FR. Under the FR BWDS 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.

1.4 Implementation Schedule

Table 1.3 shows the implementation schedule for meeting the BWDS. This implementation schedule provides vessel owners and operators time to install equipment needed to comply with the discharge standard.

Table 1.3 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, 2014	On Delivery
Existing vessels	Less than 1500	Before January 1, 2014	First scheduled drydocking after January 1, 2016
	1500-5000	Before January 1, 2014	First scheduled drydocking after January 1, 2014
	Greater than 5000	Before January 1, 2014	First scheduled drydocking after January 1, 2016

1.5 Regulatory Analysis

This rule is economically significant under Executive Order 12866.

This report presents an analysis of costs and benefits from this rule. 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

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.

constant 2007 dollars, which is the same as the NPRM RA. This analysis covers a 10-year period (2014-2023) 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 the FR, data sources, and the estimation of the fleet growth over the period of this analysis.

As described in the previous chapter, this FR will affect vessels, U.S. and foreign, that operate in the U.S waters,[13] 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 BWMS before discharging ballast water into U.S. waters. The FR includes the following vessel exemptions (please see the FR, sections 151.2015 and 151.2020, for more information on exemptions):

(1) Department of Defense or Coast Guard vessels subject to the requirements of section 1103 of the Nonindigenous Aquatic Nuisance Prevention and Control Act as amended by the National Invasive Species Act, or any vessel of the Armed Forces, as defined in the Federal Water Pollution Control Act (33 U.S.C. 1322(a)) that is subject to the "Uniform National Discharge Standards for Vessels of the Armed Forces" (33 U.S.C. 1322(n));

(2) Warship, naval auxiliary, or other vessel owned or operated by a foreign state, and used, for the time being, only on government non-commercial service. However, each such foreign state shall ensure that such vessels act in a manner consistent, so far as is reasonable and practicable, with this subpart;

(3) Crude oil tankers engaged in coastwise trade;

(4) Vessels that operate exclusively within one Captain of the Port (COTP) Zone.

(5) Seagoing self-propelled vessels that operate in more than one COTP Zone, do not operate outside of the EEZ, and are (i) less than or equal to 1600 Gross Register Tons; or (ii) less than or equal to 3000 Gross Tons (International Tonnage Convention);

(6) Inland (Non-seagoing) vessels;

(7) Vessels that take on and discharge ballast water exclusively in one COTP Zone;

(8) Vessels in innocent passage; and

(9) Vessels that use only water from a public water supply, meeting the requirements of the Safe Drinking Water Act as ballast water.

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 system (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

[13] 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.

Research Center (SERC) administers the NBIC. We present a description of the data used and their sources in the following discussion.

Number of U.S. vessels affected by the rule

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

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 (oceangoing)[14] 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 nautical 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

[14] Vessels are deemed to be "coastwise" when they operate exclusively within the U.S. Exclusive Economic Zone (EEZ), which is shipping within 200 nautical 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.

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. Herbert Engineering Corporation (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.

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. 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.[15] 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,

[15] 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.

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.

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.[16]

[16] 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— Handy Panamax Capesize	Ore/Bulk/Oil Carriers Bulk Carriers Cement Carriers Great Laker Heavy Load Carrier Limestone Carrier Ore/Oil Carrier Sand Carrier Wood Chip Carrier
Tank ships— Handy Handymax-Aframax Suezmax VLCC[a] ULCC[b]	Fruit Juice Tanker Oil Tanker Products Tanker Shuttle Tanker Tanker Vegetable Oil/Wine/Beer Tanker
Chemical carriers	Chemical Tanker
Gas carriers	Liquefied Gas Carrier Liquid Petroleum Gas (LPG) Tanker Liquid Natural Gas Tanker
Feeder Feedermax Handy Subpanamax Panamax Postpanamax	Containerships
Passenger ships	Passenger Ferry Passenger Ship
General cargo vessel	General Cargo Deck Cargo Ship Refrigerated Cargo Pallets Carrier Other Specialized Cargo
RORO	RORO Cargo Ferry[c] RORO Cargo with Lo/Lo Access[d] RORO Cargo/Vehicle Carrier Passenger RORO Car Ferry
Combination vessel	Bulk Carrier + Vehicle Decks Passenger/General Cargo General Cargo with RORO Facility Containership with RORO Facility Mobile Offshore Drilling Units (MODUs) Integrated Tug Barges (ITBs)
Fishing Vessels	Fishing Catching Vessels Processing Vessels Charter Fishing Vessels 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.[17](See Appendix A)

We have not included the following vessels in the affected population due to the FR exemptions:

(1) Coastwise (Non-Seagoing) vessels that are less than or equal to 1600 Gross Register Tons; or less than or equal to 3000 Gross Tons (International Tonnage Convention);

(2) Inland and Great Lakes (Lakers) vessels; and

(3) Crude Oil Tankers engaged in coastwise trade.

[17] 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	11	1,050	1,061
Panamax	50,000-80,000 DWT	6	509	515
Capesize	>80,000 DWT	0	46	46
Tank Ships				
Handy[b]	<35,000 DWT	10	116	126
Handymax-Aframax	35,000-120,000 DWT	17	709	726
Suezmax	120,000-160,000 DWT	7	100	107
VLCC	160,000-320,000 DWT	4	154	158
ULCC	> 320,000 DWT	0	16	16
Container ships				
Feeder	<500 TEU	23	39	62
Feedermax	500-1000 TEU	1	51	52
Handy	1000-2000 TEU	26	126	152
Subpanamax	2000-3000 TEU	52	172	224
Panamax	>3000 TEU[b]	21	174	195
Postpanamax	>3000 TEU[c]	30	272	302
Other vessels				
Passenger ship	All sizes	138	129	267
Gas carrier	All sizes	6	118	124
Chemical carrier	All sizes	23	513	536
RORO	All sizes	66	321	387
Combination vessel	All sizes	131	22	153
General cargo	All sizes	47	258	305
Fishing Vessels	All sizes	83	16	99
OSVs[d]	All sizes	757	48	805
Total		1,459	4,959	6,418

a. Vessel classifications source: USGC (2007)
b. Vessel length and beam within Panama Canal limits.
c. Vessel length or beam exceed Panama Canal limits.
d. OSVs was refined to more precisely categorize the vessel type.

This rulemaking is consistent with the IMO 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[18].

In order to estimate the cost associated with BWMTS 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 BWMS 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.

[18] See appendix D 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[19]
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[20]	2.58%	2.0%
Chemical carrier[21]	1.99%	2.2%
RORO	2.59%	2.2%
Combination vessel	2.65%	2.0%
General cargo[22]	1.99%	2.2%
Fishing Vessels	3.54%	2.2%
OSVs	4.87%	3.7%

[19] 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.
[20] Same as tank ships
[21] Same as container ships
[22] Same as container ships

3 Ballast Water Management Costs

Onboard ballast water management systems (BWMS), which are intended to eliminate or greatly reduce the transmittance of live NIS, are an emerging technology. Manufacturers 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 *Alternative 2* (BWD-2) standard, the IMO regulation D-2, by the 2014 initial implementation date.

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 (management) 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 United States, 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 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[23]	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

[23] 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)

3.1 Descriptions of the BWMS and Assessment of Meeting the IMO Standard[24]

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 on a bulk carrier.[25] The deoxygenation process occurs either at uptake by mixing inert gas with the water by an eductor or by bubbling the gas into the

---

[24] New information about additional Ballast Water Management Systems was available after the completion of the NPRM RA. We have not incorporated these new findings in our analysis due to the complexities of the calculations used in estimating costs per system type, which would require an extensive re-estimation of all costs associated with this RA. The new 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.

[25] 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.

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 for this treatment are less 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.

While the use of heat as a mean 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[26] 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 IMO 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.

[26] 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 BWMS to Vessel Types

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

Table 3.2 Suitability of BWMS 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 BWMS. 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 BWMS 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. Based on information from system developers and manufactures, these systems do not require the vessel to be drydocked for installation.

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 drydocking schedule or during other regularly scheduled maintenance or 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 BWMS 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 feasible option.

Because this type of specialized equipment is difficult to independently price, the cost analysis relies largely on manufacturer provided data. Manufacturers supplied costs for equipment and installation. We estimated installation costs if unavailable from the manufacturers. Table 3.3 shows the high and low ranges of costs to acquire and install systems based on four nominal capacities of systems.

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

System Size (m3/hr)	Costs for each process	Chlorine Generate	Chemical Apply	Filter & Radiate	Deoxygenate	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).

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.

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

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	250	350	300	360	550	375
OSVs	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.

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 BWMS. The BWMS 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 management system, 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. 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 Management 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.

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

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 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 systems able to meet the BWDS, these technologies are in continual development and refinement.

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 refined prices due to production efficiencies and competitive pressures. 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 BWMS 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 FR 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

There may be a shortage of equipment to implement BWMS 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 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 BWMS 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 BWMS 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 BWMS onboard vessels can be managed.

Environmental Concerns

BWMS 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 vessel 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 by these systems.

Effect on Corrosion in Tanks

BWMS 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.

BWMS 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 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:

- *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 Ballast Water Management Systems Cost

In this chapter, the system costs developed in the previous chapter are applied to the affected population. The analysis covers a 10-year period from 2014 to 2023, 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 phase-in schedule (presented on Table 1.3. We apply these data together with the one-time capital and installation costs to develop overall implementation costs for U.S. vessels. Capital installation costs are based on the type of systems presented in Table 3.1.

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 BWMS 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 BWMS 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 BWMS. 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.

Under the current rulemaking, implementation of BWMS would be required starting in 2014 for new vessels and phased in 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. Vessels affected in this FR will be required to meet the discharge standards by 2018 (based on the phase-in and drydocking schedules). In our cost model, for the period beyond 2018, we account only for the new vessels.

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 system. The low costs presented on the tables below are related to the cheapest system available and the high costs are related to the most expensive system available.

Table 4.1 Installed Ballast Water 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)

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 BWMS 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.

Vessels built before 2014 with ballast capacities between 1,500 and 5,000 cubic meters will be required to meet the discharge standards on first scheduled drydocking after January 1, 2014 (Table 1.2). Oceangoing vessels are required to drydock twice every 5 years[27]; therefore, we assume that vessel owners will phase-in the installation over a period of 2.5 years after the compliance date. We assume that 40 percent will install BWMS each year in the first two years (2014 and 2015) and 20 percent in the last year of the compliance FR requirement (2016).

In 2016, the remainder of the fleet built before 2014 and certain new vessels will be required to meet the BWDS. In this case, we have assumed that 40 percent of the population will install the system each year in the first two years (2016 and 2017) and 20 percent in the last year of the compliance requirement (2018). Given these assumptions and the projected fleet growth as defined in Chapter 2 (Table 2.3), the number of vessels undergoing BWMS 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 6.1).

[27] Drydocking requirements are specified in the following CFRs: 46 CFR 71.50-3 (passenger vessels); 46 CFR 176.600 (small passenger vessels); 46 CFR 126.140(a) (offshore supply vessels); 46 CFR 31.10-21(tank vessels), and 46 CFR 91.40-3 (freight vessels)

Table 4.2 Projected number of U.S. Vessels undergoing BWMS Installation by Year and Type*

Vessel type	2014	2015	2016	2017	2018	2019	2020*	2021*	2022*	2023*	Total
Bulk carriers											
Handy	0.1	0.1	3.8	3.8	1.9	0.1	0.1	0.1	0.1	0.1	9.9
Panamax	0.0	0.0	2.1	2.1	1.0	0.0	0.0	0.0	0.0	0.0	5.4
Capesize	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tank ships											
Handy	0.4	0.4	4.9	4.9	2.7	0.5	0.5	0.5	0.5	0.5	15.7
Handy-Aframax	0.7	0.7	8.3	8.3	4.5	0.8	0.8	0.8	0.9	0.9	26.7
Suezmax	0.3	0.3	3.4	3.4	1.9	0.3	0.3	0.3	0.4	0.4	11.0
VLCC	0.2	0.2	1.9	1.9	1.1	0.2	0.2	0.2	0.2	0.2	6.3
Containerships											
Feeder	2.9	2.9	9.4	8.5	4.8	1.1	1.2	1.2	1.2	1.2	34.5
Feedermax	0.0	0.0	0.5	0.5	0.3	0.0	0.1	0.1	0.1	0.1	1.5
Handy	1.2	1.2	11.7	11.7	6.5	1.3	1.3	1.3	1.4	1.4	39.0
Subpanamax	4.6	4.6	22.3	21.2	11.9	2.6	2.6	2.7	2.7	2.8	78.0
Panamax	2.0	2.0	8.9	8.4	4.7	1.0	1.1	1.1	1.1	1.1	31.5
Postpanamax	1.3	1.4	13.5	13.5	7.5	1.5	1.5	1.5	1.6	1.6	45.0
Other vessels											
Passenger ships	17.8	18.2	65.1	61.2	36.1	11.0	11.4	11.8	12.2	12.6	257.5
Gas carriers	0.3	0.3	2.7	2.7	1.5	0.3	0.3	0.3	0.3	0.3	9.2
Chemical carriers	1.2	1.2	10.8	10.8	6.1	1.4	1.4	1.5	1.5	1.5	37.3
RORO	9.9	10.0	28.0	25.0	14.6	4.2	4.3	4.4	4.5	4.6	109.5
Combination vessels	7.1	7.3	62.3	62.5	35.3	8.1	8.3	8.6	8.8	9.0	217.5
General Cargo	4.7	4.8	19.8	18.6	10.5	2.4	2.5	2.5	2.6	2.6	71.1
Fishing	10.0	10.2	40.3	38.4	22.7	7.0	7.2	7.5	7.8	8.0	159.2
OSV	126.4	130.6	395.5	380.1	244.7	109.5	114.8	120.4	126.2	132.4	1,880.4
Total	**191**	**196**	**715**	**688**	**420**	**153**	**160**	**167**	**174**	**181**	**3,046.4**

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 Management Systems

The assumptions and calculations described above form the basis for the baseline cost (based on the low installation costs presented on Table 4.1) of the FR discharge standard. 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)

Vessel Type	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Bulk Carriers											
Handy Bulk	0.03	0.03	1.58	1.58	0.80	0.03	0.03	0.03	0.03	0.03	4.17
Panamax Bulk	0.02	0.02	0.94	0.94	0.48	0.02	0.02	0.02	0.02	0.02	2.49
Capesize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tank Ships											
Handy	0.17	0.17	1.96	1.96	1.08	0.19	0.20	0.20	0.21	0.21	6.34
Handymax-Aframax	0.36	0.37	4.16	4.17	2.29	0.41	0.42	0.43	0.44	0.45	13.48
Suezmax	0.16	0.16	1.84	1.84	1.01	0.18	0.18	0.19	0.19	0.20	5.96
VLCC	0.11	0.11	1.26	1.27	0.69	0.12	0.13	0.13	0.13	0.14	4.09
Containerships											
Feeder	0.87	0.87	2.83	2.56	1.45	0.34	0.35	0.36	0.36	0.37	10.35
Feedermax	0.01	0.01	0.15	0.15	0.08	0.02	0.02	0.02	0.02	0.02	0.48
Handy	0.38	0.38	3.78	3.79	2.10	0.42	0.42	0.43	0.44	0.45	12.60
Subpanamax	1.55	1.56	7.53	7.17	4.02	0.87	0.89	0.91	0.92	0.94	26.36
Panamax	0.68	0.68	3.02	2.84	1.60	0.35	0.36	0.37	0.37	0.38	10.65
Postpanamax	0.51	0.52	5.06	5.07	2.82	0.56	0.57	0.58	0.59	0.60	16.87
Other vessels											
Passenger ships	5.35	5.45	19.54	18.37	10.84	3.31	3.42	3.54	3.66	3.78	77.25
Gas carriers	0.18	0.19	1.73	1.74	0.97	0.20	0.21	0.21	0.21	0.22	5.86
Chemical carriers	0.43	0.44	3.80	3.81	2.15	0.49	0.50	0.51	0.53	0.54	13.18
RORO	3.19	3.22	9.04	8.08	4.71	1.35	1.39	1.42	1.46	1.50	35.37
Combination vessels	2.30	2.36	20.14	20.20	11.41	2.62	2.69	2.76	2.84	2.91	70.25
General Cargo	1.53	1.55	6.39	6.00	3.39	0.79	0.81	0.82	0.84	0.85	22.97
Fishing	3.01	3.07	12.09	11.53	6.81	2.10	2.17	2.25	2.33	2.41	47.75
OSVs	32.60	33.69	102.04	98.06	63.12	28.24	29.61	31.06	32.57	34.16	485.16
Total	**53.43**	**54.86**	**208.87**	**201.11**	**121.82**	**42.60**	**44.37**	**46.22**	**48.16**	**50.17**	**871.62**
Total PV 3%	**51.88**	**51.71**	**191.14**	**178.68**	**105.08**	**35.68**	**36.08**	**36.49**	**36.91**	**37.33**	**760.98**
Total PV 7%	**49.94**	**47.92**	**170.50**	**153.43**	**86.86**	**28.39**	**27.63**	**26.90**	**26.19**	**25.51**	**643.25**

Note: Totals may not add due to rounding
* The estimated cost on Table 4.3 was obtained using data from Table 4.2 (project number of vessels undergoing BWTS installation), and multiplying it with the Lower range cost of Table 4.1 (installed BW system cost). We divide the results by 1,000 and present those results in Table 4.3.

4.3 Operating Costs of Ballast Water Management System

BWMS 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 Arrival
Bulk carriers			
Handy	1,135	10,572,584	9,315
Panamax	214	8,362,151	39,075
Capesize	578	12,719,493	22,006
Tank ships			
Handy	-	-	-
Handymax-Aframax	34	2,931,103	86,209
Suezmax	2	655,633	327,817
VLCC	1	70,706	70,706
Container ships			
Feeder[a]	-	-	-
Feedermax	52	18,868	363
Handy	280	1,246,886	4,453
Subpanamax	110	1,030,473	9,368
Panamax	290	547,131	1,887
Postpanamax	410	4,254,689	10,377
Other vessels			
Passenger ships	1	13	13
Gas carriers	-	-	-
Chemical carriers	160	224,040	1,400
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 a cumulative annual operating cost for BWM (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 $7.2 million and $5.6 million at 3 and 7 percent discount rates, respectively.

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

Vessel Type	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Bulk Carriers											
Handy Bulk	0.000	0.000	0.007	0.014	0.017	0.017	0.017	0.017	0.017	0.018	0.125
Panamax Bulk	0.000	0.001	0.013	0.026	0.033	0.033	0.033	0.033	0.034	0.034	0.240
Capesize	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Tank Ships											
Handy	0.001	0.001	0.007	0.013	0.016	0.017	0.017	0.018	0.019	0.019	0.128
Handymax-Aframax	0.007	0.015	0.099	0.184	0.231	0.239	0.248	0.256	0.265	0.274	1.820
Suezmax	0.012	0.025	0.167	0.309	0.388	0.402	0.416	0.430	0.445	0.461	3.055
VLCC	0.005	0.002	0.018	0.018	0.010	0.002	0.002	0.002	0.002	0.002	0.063
Containerships											
Feeder	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.005
Feedermax	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Handy	0.002	0.004	0.023	0.041	0.052	0.054	0.056	0.058	0.060	0.063	0.412
Subpanamax	0.014	0.028	0.094	0.158	0.194	0.201	0.209	0.217	0.226	0.234	1.575
Panamax	0.001	0.002	0.008	0.013	0.016	0.016	0.017	0.018	0.018	0.019	0.129
Postpanamax	0.003	0.006	0.039	0.071	0.089	0.092	0.096	0.100	0.104	0.107	0.708
Other vessels											
Passenger ships	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.008
Gas carriers	0.000	0.001	0.006	0.010	0.013	0.014	0.014	0.015	0.015	0.016	0.105
Chemical carriers	0.000	0.001	0.005	0.010	0.012	0.013	0.013	0.014	0.015	0.015	0.098
RORO	0.000	0.000	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.016
Combination vessels	0.001	0.003	0.015	0.026	0.033	0.035	0.036	0.038	0.040	0.041	0.268
General Cargo	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
Fishing	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.008
OSV	0.001	0.001	0.003	0.005	0.006	0.007	0.007	0.008	0.008	0.009	0.054
Total	**0.050**	**0.090**	**0.508**	**0.904**	**1.114**	**1.146**	**1.187**	**1.230**	**1.273**	**1.318**	**8.820**
Total PV 3%	**0.048**	**0.085**	**0.465**	**0.803**	**0.961**	**0.960**	**0.965**	**0.971**	**0.976**	**0.980**	**7.215**
Total PV 7%	**0.046**	**0.079**	**0.414**	**0.690**	**0.794**	**0.763**	**0.739**	**0.716**	**0.693**	**0.670**	**5.605**

Note: Totals may not add due to rounding.

4.4 Total Costs of Ballast Water Management Systems

For the purposes of estimating the total cost of BWMS, we multiply the operating costs by the estimated volume of treated ballast water each year. We calculated the annual volume of ballast water treated by using the average annual volume of ballast water discharged by the different types of vessels. Once a vessel begins exchange of ballast water through ballast management technology, their operational cost continues to be carried-over into the following periods. Therefore, total cost will increase substantially due to the commutative nature of operating BWM. This section illustrates the total costs (installation and operational) for U.S. vessels over the period of analysis (2014 – 2023). Appendix D (table D-8) presents the total cost for U.S. and foreign vessels.

We estimate the first-year total (initial) cost of this rulemaking to be $49.98 million based on a 7 percent discount rate and $51.92 million based on a 3 percent discount rate (Table 4.6). Over the 10-year period of analysis (2014-2023), the total cost of Alternative 2 for the U.S. vessels is approximately $649 million using the 7 percent discount rate and $768 million using the 3 percent discount rate. Our cost assessment includes existing and new vessels. The annualized cost over the 10-year period is $92 million at 7 percent and $90 million at 3 percent[28]. Our cost assessment includes existing and new vessels. In Appendix D (table D-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.

In Appendix C, we also present a discussion on the cost of BWMS in terms of vessel value and daily charter rates. We presented this discussion in the NPRM RA (Section 4.5). We found information to suggest that capital costs, such as the installation of BWMS, will have little or no effect on charter rates. We also found additional information suggesting the same finding in terms of the magnitude of global trade and the effects of costs being passed to consumers.[29]

[28] At the high end of costs, assuming vessel owners will install the highest cost system (Table 4.1), the annual costs over the 10-year period are $178 million at 7 percent and $173 million at 3 percent.

[29] King, Dennis. 2011. MEPC 62 special: The world can afford sustainable shipping. Sustainable Shipping, July 8 2011 (http://www.maritime-enviro.org/news/King_Sustainable_Shipping_070811.pdf). King suggests that if the cost of ballast water regulations was passed along to global businesses and consumers, the price increase of imported goods will be minimal and statistically indistinguishable from no change.

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
2014	$51.88	$49.94	280,029	$0.05	$0.05	$51.92	$49.98
2015	$51.71	$47.92	478,831	$0.09	$0.08	$51.80	$48.00
2016	$191.14	$170.50	2,993,916	$0.46	$0.41	$191.61	$170.91
2017	$178.68	$153.43	5,348,917	$0.80	$0.69	$179.49	$154.12
2018	$105.08	$86.86	6,565,633	$0.96	$0.79	$106.04	$87.65
2019	$35.68	$28.39	6,720,480	$0.96	$0.76	$36.64	$29.15
2020	$36.08	$27.63	6,957,572	$0.97	$0.74	$37.05	$28.37
2021	$36.49	$26.90	7,200,434	$0.97	$0.72	$37.46	$27.62
2022	$36.91	$26.19	7,449,212	$0.98	$0.69	$37.88	$26.89
2023	$37.33	$25.51	7,704,056	$0.98	$0.67	$38.31	$26.17
Total	**$760.98**	**$643.25**		**$7.21**	**$5.61**	**$768.20**	**$648.86**
Annualized	**$89.21**	**$91.58**		**$0.85**	**$0.80**	**$90.06**	**$92.38**

Note: Totals may not add due to rounding.

4.5 Discussion on More Stringent Standards

While the IMO BWDS is practicable to achieve in the near term and will considerably advance environmental protection over the current exchange-based regime, we also recognize that it is not the ultimate endpoint for protection of U.S. waters. The purpose of NISA, as already noted, is to ensure, to the maximum extent practicable, that NIS are not introduced and spread into U.S. waters. In the NPRM published on August 28, 2009, we proposed a phase two standard that is potentially 1,000 times more stringent than the standard analyzed in this FR RA. Due to the lack of information on the phase two standard and issues raised by the public comments, the Coast Guard has decided to move forward with phase one standard while we assess the following issues:

- practicability of implementing a phase-two standard,
- obtain additional data on technology available to meet the phase-two standard for various vessel types, and
- develop a subsequent rule with the economic and environmental analysis necessary to support the phase-two standard, since the Coast Guard fully intends to issue a rule that will establish a more stringent phase-two discharge standard.

In the NPRM, we have solicited information from the public on the phase two standard with respect to the following issues:

1. Acquisition, installation, operation/maintenance and replacement costs of technological systems that are able to meet more stringent standards,

2. Technology scalability to meet multiple stringency standards,
3. Additional costs for vessels compliant with the phase-one standard to go to the phase-two standard,
4. Technology alternatives and costs for smaller coastwise vessel types,
5. Additional avoided environmental and social damages and economic benefits of ballast water discharge standards at more stringent standards, and
6. Potential for the rule to ensure to the maximum extent practicable that aquatic nuisance species are not discharged into waters of the United States from vessels, as required by NISA.

We have not received any information from the public that would contribute to the development of the economic analysis for the phase two standard. Some commenters pointed out that this technology is still not available and therefore, they could not provide data on potential technology costs. We have received some data on costs for phase one only (Appendix E). Other commenters noted that the lack of the ability to test for compliance with stricter standards poses difficulties in determining whether an existing technology has the capacity to meet a higher standard.

In addition to requesting information from the public, the Coast Guard has been conducting further research on BWMSs. Since the NPRM publication, the Coast Guard has conducted additional research on available BWMs technologies. The research has focused on systems' cost and capacity of achieving more strict standards. Selected vendors of different BWMs technologies were interviewed in order to obtain information on the current systems status, costs and scalability potential for meeting standards that are more stringent.

We have researched and contacted vendors of the following types of BWMS technologies:
(1) Filtration + Chlorine,
(2) Filtration+ Radiation (UV), and
(3) Cavitation + Sterilization + Filtration.

Only the vendor of one system (Filtration + Chlorine) said that they could currently meet standards that are more stringent then the IMO, such as the California standard[30]. The other

---

[30] **California Interim Performance Standards for Ballast Water Discharges (Section 2293).**

Subject to the Implementation Schedule in Section 2294, before discharging ballast water in waters subject to the jurisdiction of California, the master, owner, operator, or person in charge of a vessel to which this section applies shall conduct ballast water treatment so that ballast water discharged will contain:

(a) No detectable living organisms that are greater than 50 micrometers in minimum dimension;
(b) Less than 0.01 living organisms per milliliter that are less than 50 micrometers in minimum dimension and more than 10 micrometers in minimum dimension;
(c) For living organisms that are less than 10 micrometers in minimum dimension:
  (1) less than 1,000 bacteria per 100 milliliter;
  (2) less than 10,000 viruses per 100 milliliter;
  (3) concentrations of microbes that are less than:
    (A) 126 colony forming units per 100 milliliters of *Escherichia coli*;
    (B) 33 colony forming units per 100 milliliters of Intestinal enterococci; and
(C) 1 colony forming unit per 100 milliliters or 1 colony forming unit per gram of wet weight of zoological samples of Toxicogenic *Vibrio cholerae* (serotypes O1 and O139)

vendors were not certain if their systems could meet the more stringent standards because the current testing protocols are based on the IMO standard. Speculations on potential changes to a system to meet a higher standard included: installing UV bulbs in series (instead of parallel), increasing biocide concentration, and using finer filter meshes.

In relation to the increase in acquisition, installation and operation costs for systems to meet a higher standard, vendors did not provide any information. According to one vendor, system development is still in the conceptual stage, thus predicting costs is not feasible without more certain information on the characteristics of the technology, the costs of R&D to develop the technology (which would need to be factored into the ultimate cost of the system) and the manufacturing costs.

We have also been following Lloyd's Register publications on ballast water technologies. According to the Lloyd's Register (2007 and 2008) estimates that the costs for BWMSs will range between \$135K to \$2.3 million for capacities of 200 m^3 /hr to 2,000 m^3/hr respectively for systems meeting IMO standards. The Coast Guard cost estimates for BWMS are within the range described in the Lloyd's report. The current Lloyd's Register (February 2010) has the mean cost of BWMS ranging from \$281K to \$863K for capacities of 200 m^3 /hr to 2,000 m^3/hr respectively for systems meeting IMO standards, which is still within range of Coast Guard's estimates. The 2010 Lloyd's Register report shows technologies that have undergone preliminary pilot trails. According to the report, data from these trials has shown the systems to be generally effective with reference to the IMO standard. At present, there is no available information on any manufactures that are developing and designing a system that will meet standards more stringent than the IMO standard. These finding are in concurrence with other organizations and the Coast Guard's conclusions about management systems that go beyond the IMO standard.

In our research, we have also found that some vessels owners have requested the States (such as New York) postpone the implementation of phase two standard (1,000 times the IMO standard) due to the lack of technology available. According to the industry memo sent to the New York State Department of Environmental Conservation (DEC), there is currently no ballast water treatment technology, and there is no realistic expectation that such technology will be available in the near future[31].

For these reasons, at this time we cannot estimate the costs of meeting stricter ballast water discharge standards based on the level of uncertainty of system configuration, performance and cost.

After the publication of the NPRM, the EPA requested its Science Advisory Board (SAB) provide review and advice regarding whether existing shipboard treatment technologies can reach specified concentrations of organisms in vessel ballast water, how these technologies might be improved in the future, and how to overcome limitations in existing data (EPA SAB

---

[31] http://www.infomarine.gr/attachments/article/857/New%20York%20Extension%20Request.doc or http://www.gard.no/webdocs/GardAlert25062010.doc

2011)[32]. The Panel used industry information as the source material for its assessment of ballast water treatment performance and, as requested by the EPA, used proposed ballast water discharge standards as the performance benchmarks.

Based on its evaluation of the available data, the SAB concluded that the performance standards for discharge quality proposed by IMO and the USCG are currently measurable, based on data from land-based and shipboard testing. However, current methods (and associated detection limits) prevent testing of BWMS to any standard more stringent than BWDS-2 Phase I (i.e., IMO D-2) and make it impracticable for verifying a standard 100 or 1000 times more stringent. New or improved methods will be required to increase detection limits sufficiently to statistically evaluate a standard 10x more stringent than BWDS-2 Phase I; such methods may be available in the near future. The SAB concluded that establishment of a ballast water discharge limit at the proposed BWDS-2 Phase I discharge standard will result in a substantial reduction in the concentration of living organisms in the vast majority of ballast water discharges, compared to discharges of ballast water managed by mid-ocean exchange or discharges of unexchanged ballast water. The numeric limitations in today's rule represent the most stringent standards that ballast water management systems currently safely, effectively, credibly, and reliably meet (US EPA SAB, 2011).

[32] US EPA Science Advisory Board (SBA). 2011. Efficacy of Ballast Water Treatment Systems: a Report by the EPA Science Advisory Board. Washington, D.C.

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 economic costs associated with bioinvasions of aquatic ecosystems, and specifically to discuss the overall economic harm[33] 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.

We use the same benefits model for the FR as we did for the NPRM. This model quantifies benefits resulting from the reduction in "initial invasions" from vessels engaged in ocean-going traffic. We have not found complete data or identified appropriate models to quantify the possible benefits associated with reducing the secondary spread of invasions. Therefore, we do not expect the exemption of inland vessels to reduce the estimate of quantified benefits given data and modeling limitations.

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):

[33] This section focuses on quantifying and monetizing the economic harm caused by aquatic NIS. The Programmatic Environmental Impact Statement provides a discussion of the environmental harm caused by NIS.

- 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 (Hushak 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 national 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 H.

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[34]
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 extent 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 estimated 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. Scientists 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, including recent spread into the waters of western States.

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

The Asiatic Clam like the Zebra Mussel is believed to have entered U.S. coastal 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.

Shipworms *(Teredo navalis)* are not worms, but elongated clams that feed on and live inside wooden structures. 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 is already 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 start the discussion of potential benefits of 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 and potential transfers.

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 IMO standard (Alternative 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).

More stringent discharge standards 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 initial 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). We focus our primary analysis on the number of initial invasions, with a discussion of the impact of reducing “repeat invaders” in a later section of this document.

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[35] 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).[36]

Ruiz et al characterized the mechanism for introduction of initial 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 initial 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.[37]

We assume that this historical trend in initial 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 2014 to 2023 (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

---

[35] Cryptogenic – not clearly native or introduced

[36] According to the NAS 2011 report, studies on invasions in North America waters have involved mining occurrence records from the literature and diverse research programs, rather than an organized field-based monitoring program designed explicitly to detect invasions. Therefore, today’s knowledge of invasions represent an underestimate of the total number of NIS species that have colonized.

[37] 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.

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 known 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.

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 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 Initial Shipping Invasions Per Year

Year	Invertebrate Invasions [a]	Relationship 1 [b]		Relationship 2 [c]	
		Fish	Aquatic Plant	Fish	Aquatic Plant
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

2022	9.84	9.84	29.52	1.97	3.94
2023	10.08	10.08	30.23	2.02	4.03

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. The discharge standard in this rule will not address risks associated with hull fouling, so the fraction of invasions associated with hull fouling needs to be removed from our estimates of future invasions. Appendix F presents a summary from the FEIS on the science and benefits of preventing invasions, including discussion on hull fouling.

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		54%
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 and using species as a proxy for invasions, 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 2014 to 2023 assuming 32 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 Initial Invasions

Year	Number of Shipping Invasions			Number of Ballast Water Invasions (32% of Shipping Invasions)		
	Invertebrate	Fish	Aquatic Plant	Invertebrate	Fish	Aquatic Plant
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
2022	9.84	1.97	3.94	3.15	0.63	1.26
2023	10.08	2.02	4.03	3.22	0.64	1.29
Total	90.68	18.14	36.27	29.02	5.80	11.61

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 Economic Harm

Further, not all invasions will cause economic 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 economic harm. We are also not including the impacts of invasions that cause environmental damage that does not result in economic harm. As seen in Table 5.7, during the period of 2014-2023, 4.35 invertebrate invasions, 0.87 fish invasions, and 1.74 aquatic plant invasions due to ballast water are expected to cause severe economic or financial damage.

Table 5.7 Estimated Number of Ballast Water Initial Invasions That Cause Severe Economic or Financial Harm

Year	Invertebrate	Fish	Aquatic Plant
2014	0.39	0.08	0.16
2015	0.40	0.08	0.16
2016	0.41	0.08	0.16
2017	0.42	0.08	0.17
2018	0.43	0.09	0.17
2019	0.44	0.09	0.18
2020	0.45	0.09	0.18
2021	0.46	0.09	0.18
2022	0.47	0.09	0.19
2023	0.48	0.10	0.19
Total	4.35	0.87	1.74

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 H 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 (2014) will incur costs/damages in each of the next 10 years (through 2023). Also, these estimates of costs include the impact of secondary spread of an invasion to areas other than the site of the initial invasion.

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 2014 to 2023 at $1.453 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 2014 to 2023 varies from approximately $54 million to $2.852 billion based on the range of estimated costs per invasions as shown on Table 5.9 at 7 percent discount rate.

Table 5.9a Summary of 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	$ 56	$ 54
Mid Range	$ 1,491	$ 1,453
High Range	$ 2,926	$ 2,852

Table 5.9b Potential Cost ($ Mil)/Damage of BW Invasion over a 10-year Period – 7 Percent Discount Rate

	7% Discount Rate		
Year	**Low**	**Mid**	**High**
2014	$10	$256	$503
2015	$18	$485	$952
2016	$26	$688	$1,351
2017	$32	$868	$1,704
2018	$38	$1,027	$2,015
2019	$43	$1,165	$2,288
2020	$48	$1,287	$2,525
2021	$52	$1,391	$2,731
2022	$55	$1,481	$2,907
2023	$58	$1,557	$3,056
Total	$380	$10,205	$20,031
Annualized	$54	$1,453	$2,852

Table 5.9c Potential Cost ($ Mil)/Damage of BW Invasion over a 10-year Period – 3 Percent Discount Rate

Year	3% Discount Rate		
	Low	Mid	High
2014	$10	$256	$503
2015	$19	$504	$989
2016	$28	$743	$1,458
2017	$36	$973	$1,910
2018	$45	$1,196	$2,347
2019	$53	$1,410	$2,768
2020	$60	$1,617	$3,174
2021	$68	$1,816	$3,565
2022	$75	$2,009	$3,943
2023	$82	$2,194	$4,306
Total	$474	$12,718	$24,962
Annualized	$56	$1,491	$2,926

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 Final Programmatic Environmental Impact Statement (FPEIS)[38] 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[39]. 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

[38] Source: USCG. 2010. Final 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..

[39]As identified in the NAS 2011 report, there are major data gaps ("a profound lack of data and information") and therefore no available information on multiple discharges (at the time of this rule publication). As recommended by NAS, models need to be developed to assess these risks and to link to new information as they become available. USCG will consider models that may be available during a practicability review performed under NISA. This may provide additional information to address the risk associated with multiple ballast discharges.

model is the appropriate model to use for the calculation of benefits as it is the more ecologically realistic scenario.[40]

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 least one successful introduction of an invasive species. The BWDS is intended to decrease the probability of NIS establishment by reducing the number of individual organisms that are introduced via BWD. The multi-species model is used to estimate the probability of a successful invasive species introduction. The probability of introductions is compared against the baseline probability of introduction to calculate the reduction in the probability of introduction.

The FPEIS 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, not all ocean-going vessels can conduct exchange for all voyages, thus some fraction of voyages may occur under the no ballast water management baseline. For the purposes of this analysis of benefits, we are unable to separate out the invasion risk associated with conditions under which exchange is not conductedand therefore use the conservative assumption that all ocean-going vessels are conducting ballast water exchange for all voyages.

Table 5.10 presents the reduction in the mean rate of invasions that would result from the BWDS. In comparison with the existing practice of ballast water exchange, the BWDS is between 37 percent to 63 percent effective in preventing invasions when fully implemented. [41] Please refer to the FPEIS for further information on the derivation of these estimates.

---

[40] Source: FPEIS.

[41] 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 FPEIS 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 FPEIS for further explanation.

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

Extinction Threshold Assumption [1]	BW Exchange
$N_e = 1$	37%
$N_e = 100$	63%

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

[1] The extinction threshold refers to the number of organisms below which a population is considered extinct.

As discussed in Chapter 4, the implementation of the FR BWDS will be phased-in over several years. For the purposes of estimating quantitative benefits, we assume that no invasions will be avoided before the end of this period (2014-2018), because only a subset of ships will have implemented ballast water management. This approach may lead to an underestimate of potential benefits.[42] The resulting schedule of invasions avoided for the Ballast Water Discharge Standard is displayed in Table 5.11.

Table 5.11 Harmful Ballast Water Initial Invasions Avoided – Phased-In Schedule

Year	Number of Harmful Ballast Water Invasions Avoided –Low Effectiveness			Number of Harmful Ballast Water Invasions Avoided –High Effectiveness		
	Invertebrate	Fish	Aquatic Plant	Invertebrate	Fish	Aquatic Plant
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	0.000	0.000	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000	0.000	0.000
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
2022	0.175	0.035	0.070	0.298	0.060	0.119
2023	0.179	0.036	0.072	0.305	0.061	0.122
Total	0.85	0.17	0.34	1.45	0.29	0.58

Note: Totals may not add due to rounding.

Benefits are presented in Table 5.12 and assume no benefits during the phase-in period of 2014-2018. Tables G-1 and G-2 in Appendix G present the estimate of benefits by year.

The minimum avoided costs is $5 million and the maximum is $470 million with a mid-range estimate of $141-$240 million per year at a 7 percent discount rate.

[42] We estimate benefits using an alternative assumption that the fraction of invasions avoided will be proportional to the fraction of the vessels installing management systems in Appendix F.

Table 5.12 Potential Annual Benefits (Avoided Costs) of Ballast Water Initial Invasions over a 10-year Period ($ Mil)*

	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%	$ 6	$ 5	$ 155	$ 141	$ 304	$ 276
High Effectiveness - 63%	$ 10	$ 9	$ 264	$ 240	$ 518	$ 470

* We estimated the costs in Table 5.12 using values in Table 5.8 and Table 5.11. Tables G-1 and G-2 in Appendix G present the estimate of benefits by year.

Over a 10-year period of analysis, we estimate the total discounted present value benefits of the phase-one BWDS to be as high as $3 billion with a mid-range estimate of $0.99 billion to $1.68 billion[43] (see Appendix G for details on 10 and 20-year estimates).

The estimates of benefits resulting from the ballast water discharge standard are based on preventing initial invasions only. The range of costs per invasion presented in Table 5.6 includes the impact of secondary spread of invasions, but only in the context of preventing an initial invasion (i.e., if an initial invasion is prevented, the secondary spread of that invasion is also prevented). We have not found complete data or identified appropriate models to quantify the possible benefits associated with reducing the secondary spread of invasions. Therefore, we do not expect the exemption of inland vessels to reduce the estimate of quantified benefits given data and modeling limitations.

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

[43] The mid-range benefit estimate varies based on the assumed effectiveness factors of preventing invasions (37% and 63%). The average of the mid-range benefit estimate for the 10-year period of analysis is $1.34 billion (range: $0.99 billion to $1.68 billion).

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 benefit analysis is 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.

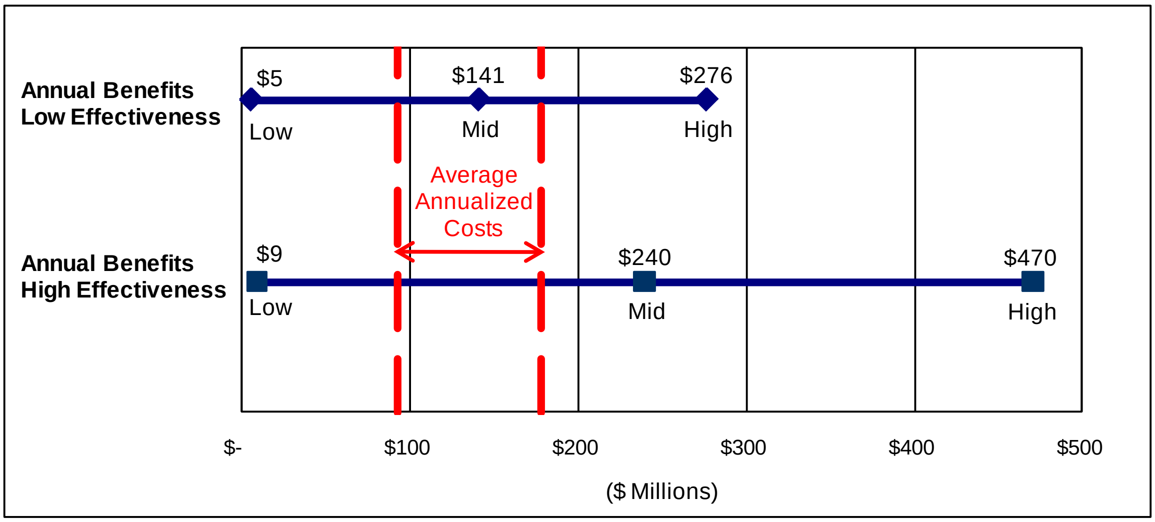
Table 5.13 Uncertainties and Possible Effects on Estimation of Benefits

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		
Impact of reducing secondary spread of invasions through coastwise and inland traffic	X		
Potential impacts on biodiversity, public health, and subsistence populations are not quantified in the analysis	X		

6 Comparison of Costs and Benefits

The annualized cost for domestic vessels over the 10-year period of 2014-2023 for the phase one standard is estimated at $92 million[44] at a 7 percent discount rate. The estimate of quantified benefits for the phase one standard ranges from $5 million to $470 million per year (see Figure 6.1), with a mid-point of $141-$240 million per year at a 7 percent discount rate. Thus, quantified benefits exceed the estimated costs for mid-point benefits estimate of Low Effectiveness. The high range annual cost estimate of $178 million is considerably less than the high range benefits estimate of 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 as a result of the BWDS, but cannot be quantified at this time.

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

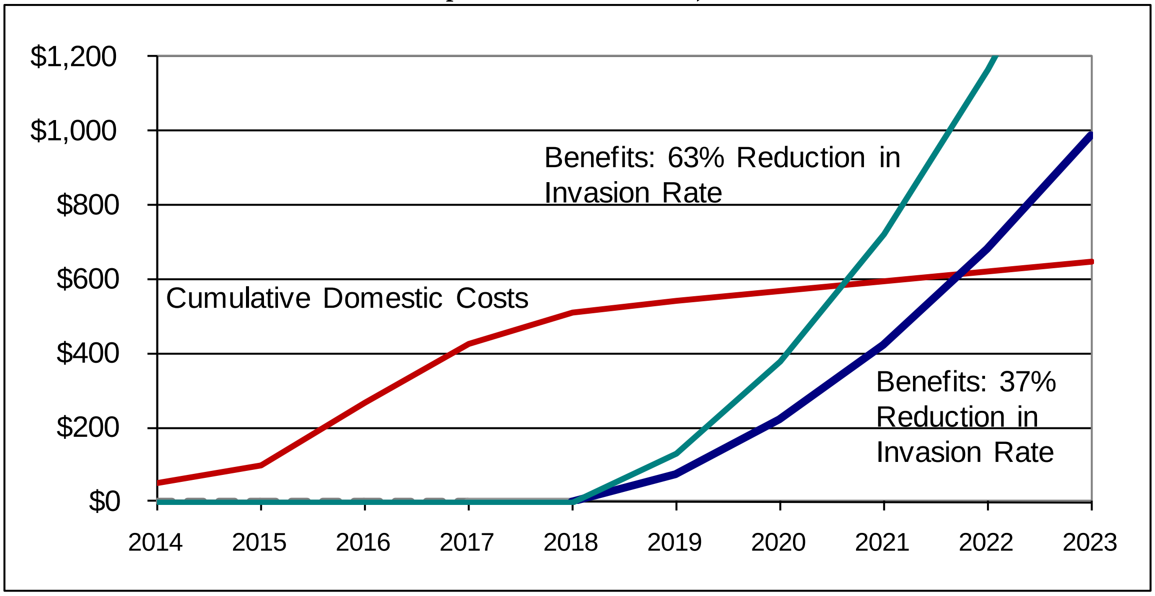


Comparison of Discounted Cumulative Benefits and Costs

Based on our projected invasions avoided, the breakeven point (discounted cumulative benefits equal or outweigh discounted cumulative costs) would be reached in 2020 for the Alternative 2 assuming a 63 percent reduction in the invasion rate and by 2022 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.

[44] 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.

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



Based on comments received on the NPRM, commenters noted that the BWDS would continue to accrue benefits after the 10-period of our analysis. For illustrative purposes, we present cumulative benefits and costs over a 20-year period of analysis in Appendix G.

6.1 Comparison of Alternative Phase-In Schedules

6.1.a. FR Phase-In Schedule for Costs and Benefits

The schedule for vessels installing ballast water management systems and producing benefits from the reduction in the introduction of invasive species can vary based on the assumed timing of implementation.

Based on the FR text, different groups of vessels have different compliance requirements:

Table 6.1 FR Phase-In implementation Schedule

	Vessel's Ballast Water Capacity	Vessel's Construction Date	Vessel's Compliance Date
New vessels	All	On or after January 1, 2014	On delivery
Existing vessels	Less than 1500 m^3	Before January 1, 2014	First scheduled drydocking after January 1, 2016
	1500-5000 m^3	Before January 1, 2014	First scheduled drydocking after January 1, 2014
	Greater than 5000 m^3	Before January 1, 2014	First scheduled drydocking after January 1, 2016

All new vessels constructed after January 1, 2014 must comply with the standard. For existing vessels, 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 existing vessels will be referred to as Type 1 vessels. Based on these assumptions we have calculated different compliance scenarios in order to determine potential variation in cost and benefit estimates due to the compliance schedule.

6.1.b. Compliance Comparison Between NPRM RA and FR RA

NPRM Primary Cost Scenario

Our analysis for the NPRM assumed that all vessels will comply with the standard by 2016, which follows the IMO Convention implementation schedule. We also assumed that some vessels will be required to convert by the end of 2014. Table 6.2 displays the fraction of vessels in each group scheduled to install management technology in each year as assumed in the NPRM analysis.

Table 6.2 NPRM Analysis Compliance Phase-In Assumption

Year	New Vessels	Type 1 Vessels	Type 2 Vessels
2012	100%	20%	30%
2013	100%	20%	30%
2014	100%	20%	40%
2015	100%	20%	N/A
2016	100%	20%	N/A
2017	100%	N/A	N/A
2018	100%	N/A	N/A
2019	100%	N/A	N/A
2020	100%	N/A	N/A
2021	100%	N/A	N/A

FR Primary Cost Scenario

For existing vessels, the FR ties the installation of ballast water management systems to the drydocking schedule of a vessel. For vessels in Type 1, the compliance date for a vessel is at the first scheduled drydocking after January 1, 2016. For vessels in Type 2, the compliance date for a vessel is at the first scheduled drydocking after January 1, 2014. Based on information from the Navigation and Vessels Inspection Circular (NVIC) 1-89 on the vessel drydocking requirements, we assume that a vessel is on a once per 2.5-year drydocking schedule for saltwater vessels. In the absence of information a the specific business model for vessel owners and operators, we assume that for Type 1 vessels, 40 percent will install during 2016, 40 percent during 2017 and 20 percent during the half year in 2018. Type 2 vessels will follow a similar pattern, only beginning in 2014. Table 6.3 presents the resulting schedule for compliance.

Table 6.3 FR Primary Scenario Compliance Assumption

Year	New Vessels	Type 1 Vessels	Type 2 Vessels
2014	100%	0%	40%
2015	100%	0%	40%
2016	100%	40%	20%
2017	100%	40%	N/A
2018	100%	20%	N/A
2019	100%	N/A	N/A
2020	100%	N/A	N/A
2021	100%	N/A	N/A
2022	100%	N/A	N/A
2023	100%	N/A	N/A

6.1.c. Alternative Compliance Scenarios for the FR RA

We looked into alternative compliance scenarios in order to access the sensitivity of the cost estimates to the percentage of vessels installing the BWMS in different years.

Scenario 1: In this scenario, we assume a more even (compared to Scenario 1) distribution of vessels complying with the FR requirements. This scenario might better represent vessel owners using their scheduled drydocking to install the BWMSs. In this case, for the Type 1 vessels, 30 percent will install during 2016, 30 percent during 2017 and 40 percent during the half year in 2018. Type 2 vessels will follow a similar pattern, only beginning in 2014. Table 6.4 presents the resulting schedule for compliance.

Table 6,4 FR Primary Scenario Compliance Assumption

Year	New Vessels	Type 1 Vessels	Type 2 Vessels
2014	100%	0%	30%
2015	100%	0%	30%
2016	100%	30%	40%
2017	100%	30%	N/A
2018	100%	40%	N/A
2019	100%	N/A	N/A
2020	100%	N/A	N/A
2021	100%	N/A	N/A
2022	100%	N/A	N/A
2023	100%	N/A	N/A

Scenario 2: In this scenario, we assume that the majority of the vessel owners will postopone the system installation until the last year. This would be expected industry behavior in order to minimize risks and costs. In this scenario, the Type 1 vessels, 20 percent will install during 2016, 20 percent during 2017 and 60 percent during the half year in 2018. Type 2 vessels will follow a similar pattern, only beginning in 2014. Table 6.5 presents the resulting schedule for compliance.

Table 6.5 FR Primary Scenario Compliance Assumption

Year	New Vessels	Type 1 Vessels	Type 2 Vessels
2014	100%	0%	20%
2015	100%	0%	20%
2016	100%	20%	60%
2017	100%	20%	N/A
2018	100%	60%	N/A
2019	100%	N/A	N/A
2020	100%	N/A	N/A
2021	100%	N/A	N/A
2022	100%	N/A	N/A
2023	100%	N/A	N/A

6.1.d. Comparison Between Different Cost Scenarios in the FR RA

The primary cost estimate represents the higher compliance costs since the majority of the vessels will have their systems installed in the first two years of the rule implementation.

While industry practice is to delay additional costs as long as possible, we assumed that the fleet will undergo system installations during routine drydocking for other regularly scheduled maintenance. As we postpone BWMS installations, the costs of the FR decrease (as shown in scenarios 1 and 2). The variation between the total and annual primary cost estimates and scenarios above are around only 1 percent.

Table 6. 6 Cost Comparison Between Different FR RA Scenarios
($ Mil, 7 Percent discount rate)

	Primary	Scenario 1	Scenario 2
Total Cost	$649	$642	$634
Annual Cost	$92	$91	$90

6.2 Comparison of NPRM Alternatives

As discussed earlier, in the Regulatory Analysis for the NPRM, Coast Guard considered five regulatory Alternatives, plus a Phase 2 Alternative. The FPEIS contains effectiveness information that allows us to calculate an estimate of benefits for Alternatives 3, 4 and 5. The FPEIS does not have a similar estimate of effectiveness for the Phase 2 Alternative; therefore we cannot calculate benefits for Phase 2 based on existing information. In addition, as discussed in Section 4.6, we cannot estimate the costs of meeting BWDS more strict than the IMO standard based on the level of uncertainty of system configuration, performance, and cost. Table 6.7 summarizes the comparison of the Alternatives considered in NPRM based on available cost and benefits data.

Table 6.7 Comparison of NPRM Alternatives
($ Mil., 7 Percent discount rate)

Alternative	Standard	Annual Benefits (Low Effectiveness)		Annual Costs ($Millions)
		Effectiveness	($ Millions)	
1	No Action	0%	$0	$0
2	IMO Standard	37%	$141	$92
3	10X IMO Standard	64%	$244	Data not available
4	100X IMO Standard	85%	$323	Data not available
5	Sterilization*	100%	$380	Data not available
Phase 2	1,000X IMO Standard (CA)	Data not available	Data not available	Data not available

Note: Benefits for alternatives 1-4 are based on low effectiveness estimates from the FPEIS. The FPEIS presents Alternative 5, Sterilization, as 100% effective. See FPEIS pages 4-13 (Table 4-2) and 4-16.

7 Final Regulatory Flexibility Act Analysis

7.1 Summary of the NPRM IRFA

The U.S. Coast Guard (USCG) performed an initial regulatory flexibility analysis (IRFA) 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. Below is a summary of our IRFA findings:

- There were an estimated 850 U.S. entities that would be affected by the rulemaking, these businesses operated 2,616 vessels affected by the NPRM;
- We estimated that of these 850 U.S. entities, 57 percent were 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 NPRM resulted 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; and,
- 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 Changes from the NPRM IRFA

Tables 7.1 and 7.2 present the comparison between the NPRM findings and revised FR findings. In the IRFA for the NPRM, we assumed 10-year and 20-year cost finance scenarios. The resulting analysis in the IRFA showed that 72 percent and 59 percent of the small entities (10-year finance and 20-year finance, respectively) would have an annual cost impact greater than 1 percent of annual revenue. For these estimates, we assumed that vessel owners would opt for the least expensive systems available.

Given the changes in the applicability (from the NPRM to the FR), there was a reduction in the number of vessels and entities affected by the rule. For this reason, we updated the revenue impacts from the IRFA and found that 69 percent and 56 percent of the small entities (10-year finance and 20-year finance, respectively) would have an annual cost impact greater than 1 percent of annual revenue. There was a reduction in economic impacts on small entities as a result.

Table 7.1 . Comparison of the NPRM and FR Number of Small Entities

Impact Range	NRPM		FR	
	10-yr Finance	20-yr Finance	10-yr Finance	20-yr Finance
≤ 1%	20	29	11	16
> 1 to ≤ 3%	16	12	11	7
> 3 to ≤ 5%	8	8	2	3
> 5 to ≤ 10%	8	11	2	3
> 10%	19	11	10	7
Total	71	71	36	36

Note: Totals may not add due to rounding.

Table 7.2 . Comparison of the NPRM and FR Installation Impact on Small Entities

Impact Range	NRPM		FR	
	10-yr Finance	20-yr Finance	10-yr Finance	20-yr Finance
≤ 1%	28%	41%	31%	44%
> 1 to ≤ 3%	23%	17%	31%	19%
> 3 to ≤ 5%	11%	11%	6%	8%
> 5 to ≤ 10%	11%	15%	6%	8%
> 10%	27%	15%	28%	19%
Total	100%	100%	100%	100%

Note: Totals may not add due to rounding.

7.3 Final Regulatory Flexibility Analysis

The Regulatory Flexibility Act of 1980 (Public Law 96-354) 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.”

When an agency promulgates a final rule under section 553 of the Regulatory Flexibility Act (RFA), after being required by that section or any other law to publish a general notice of proposed rulemaking, or promulgates a final interpretative rule involving the internal revenue laws of the United States as described in section 603(a), the agency must prepare a final regulatory flexibility analysis (FRFA) or have the head of the agency certify pursuant to RFA section 605(b) that the rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. The RFA prescribes the content of the FRFA in section 604(a), which we discuss below.

(1) a statement of the need for, and objectives of, the rule;

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 prevent 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. The objective 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.

(2) a statement of the significant issues raised by the public comments in response to the initial regulatory flexibility analysis, a statement of the assessment of the agency of such issues, and a statement of any changes made in the proposed rule as a result of such comments;

On August 28, 2009, we published a Notice of Proposed Rulemaking (NPRM) entitled Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters in the Federal Register (74 FR 44632). We summarized these comments in the Final Rule section *V. Discussion of Comments and Changes*. The great majority of the comments on the NPRM RA were from the inland, Great Lakes and coastwise industries. The commenters raised many different issues related to the ballast water operations, such as the use of municipal/potable water, technology costs, size limitations and underestimation of the affected population (for not including inland vessels and vessels under 100 feet due to the general applicability of the NPRM). Additionally, commenters expressed concern that the cost estimates for the proposed Phase 2 standard was not included in any of the supporting documentation or analysis. Remaining comments were on cost to foreign vessels, benefits, small entities analysis and uncertainties. The significant issues raised by the public comments on the IRFA were the following:

A) Cumulative Impact of Regulations on Small Businesses - One commenter noted that the Coast Guard did not take into account the cumulative impact of other Coast Guard regulations on small businesses. The commenter argued that the BWDS rule will impose more costs on top of the other regulations for affected passenger vessel operations.

For the proposed rule, the Coast Guard completed an Initial Regulatory Flexibility Analysis (IRFA). The specific statutory requirements of an IRFA can be found at 5 U.S.C. 603(b). Under these statutory requirements, we did not consider the cumulative impact of other Coast Guard regulations on small businesses or affected passenger vessel operations. The Coast Guard acknowledges that other Coast Guard regulations have imposed additional costs on vessel owners and operators subject to this rule, which contains revised applicability that excludes most vessels operating solely in coastwise trade as previously discussed.

Many of these published regulations are due to international agreements such as the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention for the Safety of Life at Sea (SOLAS). This rule also aligns with the International Convention for the Control and Management of Ships Ballast Water and Sediments (IMO BWM Convention). The U.S. responsibility as a party to these international agreements is to ensure the fulfillment of the requirements by promulgating regulations that are consistent with these agreements. If the Coast Guard does not fulfill its obligations under these international agreements, then it risks the consequences of noncompliance (e.g., reduced commerce and trade as a result of U.S. flag vessels on foreign voyage not compliant with international agreements).

Additionally, for this rule, the Coast Guard is acting under the legislative mandates in NANPCA, as amended by NISA, to authorize the use of any alternative methods of BWM that are used in lieu of mid-ocean BWE. As previously discussed, these mandates require the Secretary of Homeland Security to ensure to the maximum extent practicable that aquatic nuisance species are not discharged into waters of the United States from vessels. 16 U.S.C. 4711(c)(2)(A). In addition, NISA requires the Secretary to assess and revise the Department's BWM regulations not less than every 3 years based on the best scientific information available to her at the time of that review, and potentially to the exclusion of some of the BWM methods listed at 16 U.S.C. 4711(c)(2)(D). 16 U.S.C. 4711(e). The Coast Guard is publishing this FR based on these mandates.

B) Number of Employees - Two commenters argued that, as a part of the financial burden, it is important for vessel companies to note the amount of employees/mariners they have.

The Coast Guard agrees with the commenters and would like to note that the number of employees is taken into consideration in the IRFA. The IRFA is in chapter 7 of the NPRM RA available on the docket. The IRFA's goal is to assess the proposed rule's impact on small entities. Company revenue and number of employees (as well as number of vessels) are variables used in the estimation of potential economic impacts to small businesses.

The Coast Guard has assessed the public comments received on the NPRM RA and has determined the more research is necessary to assess the practicability and impacts of phase two standard; and to better understand ballast water operations and technology available for the following vessels: small coastwise, Great Lakes and inland. As a result, the Coast Guard has made changes to the applicability and other requirements of the rule. Detailed explanation of these changes follows.

The FR contains a number of changes from the rule proposed by the NPRM (74 FR 44632). Below we discuss change in the FR that was related to the public comments on the NPRM IRFA. For a full discussion of comments and Coast Guard responses is found in the FR section V.B. Discussion of Comments.

(a) Changes in the Rule Applicability

In order to reduce the burden of this regulation over small coastwise and inland vessels and to allow more time to research these vessels' ballast water operations, the Coast Guard has made changes in the rule applicability. In the NPRM, the Coast Guard proposed requiring all vessels discharging ballast water into waters of the United States to comply with the BWDS. This included vessels operating solely in coastwise trade and on the internal waters of the United States. These vessels are not required to conduct a BWE under the existing Coast Guard regulations, and, as such, the proposal was correctly seen as an expansion of those regulations. Commenters raised a number of issues regarding the applicability of the NPRM. These issues included uncertainty as to whether any of the currently available BWMS could be successfully installed on non-seagoing vessels, the cost of installation of BWMS on these industries, and the benefit of requiring these vessels to install a BWMS. As a result of these comments, the Coast Guard removed some vessels which previously were not required to conduct BWE from the FR applicability. These vessels are seagoing vessels that do not operate beyond the U.S. Exclusive Economic Zone (EEZ), and are greater than 1,600 gross register tons (GRT) (3,000 gross tons (GT) (International Tonnage Convention (ITC)). Therefore, inland, Great Lakes vessels and small coastwise vessels (equal or smaller than 1,600 GRT) are not required to comply with the FR.

In addition, we revised 33 CFR §§ 151.1510 and 151.2025 to 1) clarify that discharge of ballast water into waters of the U.S. is a threshold requirement, and 2) include an additional BWM option for use of water from a public water supply, meeting certain EPA water quality standards. This adds flexibility to vessel owners and operators on installing a BWMS or other sources of ballast water (as long as this water meets EPA water quality standards).

The Coast Guard has determined that additional research and analysis is necessary to support the expansion of the rule applicability.

(b) Removal of Phase Two Standard

The Coast Guard has decided to move forward with the phase-one (IMO) standard while assessing the practicability of implementing a phase-two standard, gathers additional data on technology available to meet the phase-two standard for various vessel types, and develops a subsequent rule with the economic and environmental analysis necessary to support the phase-two standard. The decision to remove the more stringent standard from the FR should not be interpreted as a sign that the Coast Guard is reconsidering its intent to increase the protectiveness of the BWDS. To provide the public with as much information as possible on which to base comments, the Coast Guard will develop additional analyses regarding the potential costs, benefits, and environmental impacts of the proposed phase-two standard. When these analyses are completed, the Coast Guard will make them available for public comment, either via a notice of availability or in conjunction with a subsequent rulemaking published in the Federal Register.

Since the FR only includes the phase-one standard, the Coast Guard has omitted the grandfather provision and applicability reviews proposed in the NPRM. The Coast Guard expects to reconsider these provisions when we re-propose the phase-two standard in a notice or a subsequent rulemaking.

(c) Delay of Compliance Date for New Vessels

Even with the provision for acceptance of foreign type approvals, a process that is expected to be quicker than completing the full schedule of land-based and shipboard tests, the Coast Guard anticipates there will not be an adequate number of approved BWMS to allow vessel owners to meet the NPRM's proposed compliance date for new vessels. For this reason, the Coast Guard has pushed back the compliance date for new vessels from January 1, 2012, to January 1, 2014. The Coast Guard estimates this deferral could delay the compliance date for up to 600 newly constructed vessels.

The Coast Guard has also added a provision to both 33 CFR part 151 subparts C and D that will allow individual vessel owners to extend their compliance date if, despite the owner's efforts, he or she cannot meet the published compliance dates. This change is in response to commenters who argued that the compliance timelines included in the NPRM were too aggressive.

(3) the response of the agency to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration in response to the proposed rule, and a detailed statement of any change made to the proposed rule in the final rule as a results of the comments.[45]

The Coast Guard received comments from the SBA, Office of Advocacy, regarding the impact that the proposed rule will have on small entities. The comments provided by the SBA focused on small businesses within the tugboat, tow boat, and supply barge industries.

[45] This section of 604(a) has been added by the Small Business Jobs Act of 2010.

According to the SBA letter, these small businesses are concerned that the Coast Guard's economic analysis does not account for a significant number of vessels operated by small businesses. These businesses also contend that installing the required BWMS will not be economically feasible for the large number of vessels that discharge relatively small amounts of ballast water. The SBA also expressed concern about the cumulative effect of the proposed regulations should the phase-two standards be implemented without a longer grandfathering period than the five year period proposed. The SBA has made the following suggestions to improve the Coast Guard small entities analysis:

a. Expand the scope of regulatory flexibility analysis to include more vessels (vessels less than 100 feet in length, tugboat, towing and supply vessels).
b. Consider additional regulatory alternatives to increase flexibility for small business (such as exemption for vessels with relatively low-volume ballast tanks).
c. Include a grandfathering provision with the phase-two standards

The Coast Guard acknowledges the SBA concerns related to the vessels mentioned previously and is studying the BWM options for small vessels and vessels less than 1,600 gross tons that operate solely in coastwise trade and inland waters of the United States. The Coast Guard has received numerous comments from these industries and has revised the applicability of the rule. As noted earlier in this RA, the BWDS in this FR applies only to vessels entering waters of the United States from outside the EEZ, to coastwise vessels that are more than 1,600 gross tons, and to certain other seagoing vessels meeting specific size thresholds (see V.A. Summary of Changes from the NPRM).

Detailed statement of changes in the final rule as a result of the SBA, Office of Advocacy, comments as well as public comments are presented above in paragraph (2).

(4) a description of and an estimate of the number of small entities to which the rule will apply or an explanation of why no such estimate is available;

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 533 U.S. entities operating 1,459 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.[46] 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).[47]

[46] We used information and data from Manta (http://Manta.com) and ReferenceUSA (http://www.referenceusa.com).
[47] 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).

We used the employee size and revenue data to identify the number and type of entities affected by the rulemaking based on the NRPM random sample of 150 vessel owners.. Due to the changes in the applicability (from the NPRM to the FR), there was a reduction in the number of entities affected by this rule. We found 36 small entities and 7 entities with no available data. We estimate the number of small entities affected by this rulemaking is 43 (36 small and 7 with no data available). This corresponds to approximately 29 percent of small entities from the original NPRM sample. We found small entities affected by this rule to have multiple business lines. Some have a primary business line that is not unique to the maritime industry. Please, see Tables 7.1 and 7.2 for information on installation cost impact on small entities.

(5) a description of the projected reporting, recordkeeping and other compliance requirements of the 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; and

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.

(6) a description of the steps the agency has taken to minimize the significant economic impact on small entities consistent with the stated objectives of applicable statutes, including a statement of the factual, policy, and legal reasons for selecting the alternative adopted in the final rule and why each one of the other significant alternatives to the rule considered by the agency which affect the impact on small entities was rejected.

As described in section 7.4, the Coast Guard has made a number of changes from the rule proposed by the NPRM (74 FR 44632) after consideration of public comments. For a full discussion of comments and Coast Guard responses is found in the FR section V.B. Discussion of Comments. The following steps were taken by the Coast Guard to minimize the economic impact on small entities: changes in the rule applicability to exclude inland, Great Lakes vessels and small coastwise vessels (equal or smaller than 1,600 GRT), removal of Phase Two standard and delay compliance for new vessels providing additional time for small entities to plan for BWMS.

The Coast Guard has considered six alternatives. The Coast Guard took into account each one carefully before choosing the preferred alternative, based on the input provided through the scoping process, as well as the information developed through workshops, international discussions, and public comments. The alternatives include: maintaining the current BWE requirement or "No Action"; four alternatives that would establish different and increasingly stringent levels of maximum concentrations for living organisms in discharged ballast water (IMO standard, 10, 100 and 1,000 more strict than the IMO standard); and a one that essentially requires sterilization of ballast water. The IMO standard is the preferred alternative.

A. 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 Coast Guard. Some vessels cannot conduct mid-ocean ballast water exchange due to safety and voyage constraints. In addition, the Coast Guard has not yet approved any environmentally sound treatment methods. Thus, “No Action” means that the primary BWM practice for vessels would be to conduct mid-ocean exchange (BWE) when it is safe to do so and when the voyage permits. The Coast Guard 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.

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA), as amended by the National Invasive Species Act of 1996 (NISA), authorizes the Coast Guard to determine alternative methods of ballast water management for use in lieu of mid-ocean ballast water exchange (BWE). 16 U.S.C. 4711(c)(2)(D)(iii). NISA further stipulates that Coast Guard approved alternative BWM methods must be at least as effective as BWE in preventing or reducing the introduction of nonindigenous species (NIS) into waters of the United States. 16 U.S.C. 4711(c)(2)(D)(iii).

NISA also requires the Coast Guard to assess and revise its BWM regulations not less than every 3 years based on the best scientific information available to the Coast Guard at the time of that review, and potentially to the exclusion of some of the BWM methods listed at 16 U.S.C. 4711(c)(2)(D). 16 U.S.C. 4711(e). Determining whether an alternative method of BWM 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. Results from several studies have shown the effectiveness of BWE varies considerably and is dependent on vessel type (design), exchange method, ballasting system configuration, exchange location, and method of study. Some studies suggest that the efficacy of BWE is 80 to 99 percent per event (Dickman and Zhang 1999; Hines and Ruiz 2000; Rigby and Hallegraeff 1993; Smith et al. 1996; Taylor and Bruce 2000; Zhang and Dickman 1999). Other studies demonstrate that the volumetric efficiency of BWE ranges from 50 to 90 percent (Battelle 2003; USCG 2001; Zhang and Dickman 1999). Thus, vessels with very large starting concentrations of organisms in their ballast tanks might still have large concentrations of organisms after BWE. In addition, vessels are constrained by design or route from conducting BWE in compliance with existing regulations prior to the majority of arrivals into waters of the United States.

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 Coast Guard approval of ballast water management systems (BWMS). Additionally, setting a ballast water discharge standard (BWDS) would promote the development of innovative BWM technologies, facilitate enforcement of the BWM regulations, and assist in evaluating the effectiveness of the BWM program.

Therefore, in the FR, the Coast Guard amend 33 CFR part 151 by establishing a BWDS and 46 CFR part 162 by adding an approval process for BWMS intended for use onboard vessels to meet the BWDS.

B. Phase One – IMO Standard- Preferred Alternative

The preferred BWDS proposed is the same standard adopted by the International Maritime Organization (IMO) in 2004, *"International Convention for the Control and Management of Ships' Ballast Water and Sediments"* (BWM Convention). The Coast Guard leads the U.S. government delegation to the IMO, the organization responsible for improving maritime safety and preventing pollution from vessels. The Coast Guard coordinated U.S. participation in this effort with the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the U.S. Department of Defense, the U.S. Maritime Administration, the U.S. Department of Justice, and the U.S. Department of State.

This requirement is intended to meet the directives under NISA that requires the Coast Guard to ensure to the maximum extent practicable that nonindigenous species (NIS) are not introduced and spread into U.S. waters and that they apply to all vessels equipped with ballast tanks that operate in U.S. waters. 16 U.S.C. 4711(c)(1), (c)(2)A , (e) and (f). A full discussion of the legislative and regulatory history of the Coast Guard's actions to implement both NANPCA and NISA may be found in the NPRM for this rule, published on August 28, 2009. 74 FR 44632, 44633.

C. Standards More Stringent than the IMO Standard

The Coast Guard has decided to move forward with the phase-one (IMO) standard while assessing the practicability of implementing a phase-two standard, gathers additional data on technology available to meet the phase-two standard for various vessel types, and develops a subsequent rule with the economic and environmental analysis necessary to support the phase-two standard. The decision to remove this more stringent standard from this FR should not be interpreted as a sign that the Coast Guard is reconsidering its intent to increase the protectiveness of the BWDS.

Due to unavailability of data, the cost, benefit, and environmental impact analyses included in the NPRM did not specifically assess impacts related to the phase-two standard (although the analyses did include an evaluation of standards that are more stringent than the phase-one standard). Many commenters addressed this issue, noting that the lack of analyses made it impossible for them to comment on the phase-two standard in any meaningful manner.

To provide the public with as much information as possible on which to base comments, the Coast Guard will develop additional analyses regarding the potential costs, benefits, and environmental impacts of the proposed phase-two standard. When these analyses are completed, the Coast Guard will make them available for public comment, either via a notice of availability or in conjunction with a subsequent rulemaking published in the Federal Register.

The Coast Guard fully intends to issue a subsequent rule that will establish a more stringent phase-two discharge standard. To demonstrate our commitment, we are issuing this rule as an FR rather than as a final rule to show that the Coast Guard does not view publication of the phase-one standard as completing the agency's work in controlling the introduction and spread of NIS from ships' ballast water. In the FR, we are also reserving the regulatory provisions where the phase-two standard would be found.

D. 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. This alternative was considered as not viable at this time. Additional research is needed to obtain information on technology and potential environmental impacts.

8 References

Balcom, N. C. 1994. Asian Clam, Corbicula fluminea. *Aquatic Immigrants of the Northeast* (4): Connecticut Sea Grant College Program.

Bell, F.W., and M.A. Bonn. 2004. *Economic Sectors at Risk from Invasive Aquatic Weeds at Lake Istokpog*. Florida: The Bureau of Invasive Plant Management. Florida Department of Environmental Protection, Tallahassee, Florida. http://www.aquatics.org/pubs/economics.htm.

Maritime Activity Reports. 2005. Report: LNG Fleet Needs to Expand 66 percent. World Maritime News. http://www.marinelink.com/MembersNew/ViewStoryNR.asp?StoryID=200525 (accessed October 13, 2005).

Boyd, J.W. and H.S. Banzhaf. 2005. Ecosystem Services and Government Accountability: The Need for a New Way of Judging Nature's Value. *Resources* (Summer): 16-19. http://www.rff.org/rff/Documents/RFF-Resources-158_EcoServices.pdf (accessed November 3, 2005).

Buhle, E., Margolis, M. and J.L. Ruesink. 2003. Bang for the Buck: Cost-Effective Control of Invasive Species with Different Life Histories. Resource for the Future Discussion Paper 04-06. *Report No. R-051, 52*. La Jolla, CA.: Annual Report for California Sea Grant 2003.

Carlton, J. 2001. *Introduced Species in U.S. Coastal Waters, Pew Oceans Commission.* Virginia.

Carlton, J.T. 2001. *Introduced Species in U.S. Coastal Waters: Environmental Impacts and Management Priorities*. Virginia: Williams College and Mystic Seaport for the Pew Oceans Commission.

Carlton, J.T. 1995. Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta – Biological Study. *Report No. PB96-166525.* Washington D.C.: Final Report to the U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Carlton, J.T. 1999. The Scale and Ecological Consequences of Biological Invasions in the World's Oceans, in Invasive Species and Biodiversity Management. *Sandlund*. Ed. Schei & Viken. Dordrecht: Kluwer Academic Publishers.

Carlton, J. T. and J. B. Geller. 1993. Ecological Roulette: The Global Transport of Nonindigenous Marine Organisms. *Science* 261: 78–82.

Carlton, Reid, & van Leeuwen, H. 1995. *Shipping Study: The Role of Shipping in the Introduction of Nonindigenous Aquatic Organisms to the Coastal Waters of the*

United States (other than the Great Lakes) and an Analysis of Control Options, Washington: U.S. USCG.

Chesapeake Bay Program. 2008. Gould's Shipworm (Bankia gouldi) Field Guide. Bay Field Guy. http://www.chesapeakebay.net/bfg_shipworm.aspx?menuitem=14432

CSLC. 2005. Queries. *California State Lands Commission Ballast Water Management Database.* USCG: performed at our request.

Ciborowski, J. 2007. Indicator: Invasion of Zebra Mussels (Dreissena polymorprpha) and Quagga Mussels (Dreissena bugensis). *Biological Invasions* 8: 475-489.

Cohen, A. N. 1998. *Ships Ballast Water and the Introduction of Exotic Organisms into the San Francisco Estuary: Current Status of the Problem and Options for Management*. California: San Francisco Estuary Institute.

Cohen, A.N., and J. T. Carlton. 1995. Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta – Biological Study. *Report No. PB96-166525.* Washington D.C.: Final Report to the U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Cohen, A.N. and P.B. Moyle. 2004. *Summary of data and analyses indicating that exotic species have impaired the beneficial uses of certain California waters.* California: Report to California State Water Resources Control Board.

Cohen, A.N. and A. Weinstein. 1998. *The potential distribution and abundance of zebra mussels in California*. California: San Francisco Estuary Institute.

Colautti, R.I., I.A. Grigorovich, et al. 2003. Ballast-mediated animal introductions in the Laurentian Great Lakes: retrospective and prospective analyses. *Canadian Journal of Fisheries and Aquatic Sciences* 60 (6): 740-756.

Colgan, C.S. 2003. The Changing Ocean and Coastal Economy of the United States. Waves of Change: Examining the Role of States in Emerging Ocean Policy. *National Governor's Center for Best Practices Conference:* Briefing Paper.

Compass Maritime Services. 2006 Market Reports. Compass, LLC. http://www.compassmar.com/market.htm (accessed March 2006).

Connelly, N.A., C.R. O'Neill, B.A. Knuth, and T.L. Brown. 2007. Economic Impacts of Zebra Mussels on Drinking Water Treatment and Electric Power Generation Facilities. *Environ Manage* 40: 105–112.

Cook, G.D., Setterfield, S.A. and J.P. Maddison. 1996. Shrub invasion of a tropical wetland: Implications for weed management. *Ecological Applications* 6: 531–37.

Corn, M.L., Buck, E.H., Rawson, J. and E. Fischer. 1999. Harmful Non-Native Species. *Issues for Congress VII RL30123*: Final Report from CRS to the U.S. Congress.

Davis, A. and Moeltner, K. Valuing the Prevention of an Infestation: The Threat of the New Zealand Mud Snail in Northern Nevada. UNR Joint Economics Working Paper Series Working Paper No. 09-001. July 2009.

Deng, Y. 1996. *Present and Expected Economic Costs of Zebra Mussel Damages to Water Users with Great Lakes Intakes*. Ph.D. Dissertation. Ohio: The Ohio State University.

Didier, A.J. 2002. *The Pacific Coast Dungeness Crab Fishery*. Oregon: Pacific States Marine Fisheries Commission.

Drake, J. A., K. Choi, G. M. Ruiz, and F. C. Dobbs. 2001. Global Redistribution of Bacterioplankton and Virioplankton Communities. *Biological Invasions* 3: 193–99.

Drake, J A., G. M. Ruiz, B. S. Galil, T. L. Mullady, D. O. Friedmann, and F. C. Dobbs. 2002. Microbial Ecology of Ballast Water during a Transoceanic Voyage and the Effects of Open-Ocean Exchange. *Marine Ecology Progress Series* 233: 13-20.

Drissoll, P & et al. 1994. *The Effect of Aquatic Plants on Residential Shoreline Property Values at Gunterville Reservoir*: Tennessee Valley Authority and U.S. Army Corps of Engineers.

Economic Research Service. 2004. Infrastructure and Rural Development Policy. U.S. Department of Agriculture. http://www.ers.usda.gov/Briefing/Infrastructure/InfrastructureWater.htm.

Falkner, M., Takata, L. and S. Gilmore. 2005. Report on the California Marine Invasive Species Program. *California State Lands Commission.* California: Marine Facilities Division. http://www.slc.ca.gov (accessed October 27, 2005).

Feyrer, F., Matern, H.B. and P.B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco estuary. *Environmental Biology of Fishes* 67: (277-288).

Fofonoff, P.W., G.M. Ruiz, B. Steves, and J.T. Carlton. 2003.. In Ships or On Ships? Mechanisms of Transfer and Invasion for Nonnative Species to the Coasts or North America. *Invasive Species: Vectors and Management Strategies*: 153-182. Washington D.C.: Island Press.

Grumble, Ben. 2007. Testimony Before Water Resources and Environment Subcommittee of the House Transportation and Infrastructure Committee. Washington, D.C.: Environmental Protection Agency. http://www.epa.gov/ow/speeches/

Nazzaro, Robin M. 2005. Invasive Species Progress and Challenges in Preventing Introduction into U.S. Waters via the Ballast Water in Ships. *Testimony of Director Natural Resources and Environment, United States Government Accountability Office* (GAO-05-1026T). Washington D.C.: Subcommittee on Regulatory Affairs, Committee on Government Reform, United States House of Representatives.

Godwin, L.S. 2005. *Marine invasive species transported by vessel hull fouling: potential management approaches.*

Gollasch, S. 2004. Ballast water – the key vector for aquatic species invasions? PICES Annual Meeting http://www.pices.int/publications/presentations/PICES_13/PICES_13_S5/Gollasch_S5-1969.pdf (accessed November 8, 2005).

Grosholz, E., Olin, P., Williams, B. and R. Tinsman. 2001. Reducing Predation on Manila Clams by Nonindigenous European Green Crabs. *Journal of Shellfish Research* 20 (3): 913-919.

Grosholz, E.D. and G.M. Ruiz. 1995. Spread and potential impact of the recently introduced European green crab, Carcinus maenas, in central California. *Marine Biology* 122 (2): 239-247.

Hallegraeff, G.M. 1998. Transport of toxic dinoflagellates via ships' ballast water: Bioeconomic risk assessment and efficacy of possible ballast water management strategies. *Marine Ecology Progress Series* 168: (297-309).

Herbert Engineering Corporation. 1999a. Case Studies in the Evaluation of Ballast Water Exchange. *HEC Report 9824*. California: Alameda for the American Bureau of Shipping.

Herbert Engineering Corporation. 1999b. Ballast Water Management for Containerships: Implications for the Port of Oakland. *HEC Report 9824* California: Port of Oakland.

Hogden, N., Dacunha, N.M.C. and G.F. Oliver, eds. 1986. *Global Wave Statistics*. England: British Maritime Technology.

Holmes M. et al. 2005. Ballast Water Standards Discharge Standards *Report and Recommendation of the California Advisory Committee.* California: State Land Commission and the California Legislature. http://www.sfei.org/bioinvasions/ (accessed November 8, 2005).

Horsch, E. J. and D. J. Lewis. The Effects of Aquatic Invasive Species on Property Values: Evidence from a Quasi-Random Experiment. University of Wisconsin-Madison Department of Agricultural & Applied Economics. AGRICULTURAL & APPLIED ECONOMICS STAFF PAPER SERIES. Staff Paper No. 530: November 2008.

Hosking, S.G. and M du Preez. 2004. A cost-benefit analysis of the Working for Water Programme on selected sites in South Africa. *Water SA* 30 (2): 143-152.

Hunt, E.C. and B.S. Butman. 1994. *Marine Engineering Economics and Cost Analysis*: 1-4. Maryland: Cornwell Maritime Press.

Husain, M., et al. 2003. Ballast water treatment by De-oxygenation with elevated CO2 for a shipboard installation - a potentially affordable solution. *2nd IMO Ballast Water Treatment R&D Symposium*. London: IMO.

Hushak, L.J. 1997. Economics of Ruffe in the Great Lakes. *Proceedings of the International Symposium on Biology and Management of Ruffe*.

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: Ohio State University.

ICES. 2003. Harmful Aquatic Organisms in Ballast Water. *MEPC 49/2/21*: International Council for the Exploration of the Sea.

IMO. 2004. International Convention for the Control and Management of Ships' Ballast Water and Sediments. International Maritime Organization. http://www.imo.org/

Jenkins, Philip and Associates. 2001. *Economic Impacts of Aquatic Nuisance Species in the Great Lakes.* Burlington, Ontario: Report for Environment Canada.

King, Dennis. 2011. MEPC 62 special: The world can afford sustainable shipping. Sustainable Shipping, July 8 2011.

Kite-Powell, H. 2001. Marine Policy: Shipping and Ports. *Encyclopedia of Marine Sciences*. eds. J. Steele et al.: 2768-76. Academic Press.

Knight, I. T., C. S. Wells, B. Wiggins, H. Russel, K. A. Reynolds, and A. Huq. 1999. Detection and Enumeration of Fecal Indicators and Pathogens in the Ballast Water of Transoceanic Cargo Vessels Entering the Great Lakes. *Abstract Q-71* Washington, D.C.: Proceedings of the General Meeting of the American Society for Microbiology.

Lafferty, K.D. and A.M. Kuis. 1996. Biological control of Marine Pests. *In Ecology* 77 (7): 1989-2000.

Langeland, K.A. 1996. Hydrilla verticillata (L.F.) Royle (Hydrocharitaceae), The Perfect Aquatic Weed. *Castanea* 61: 293-304.

Lawrence, D.J. and J. R. Cordell. 2010. Relative contributions of domestic and foreign sourced ballast water to propagule pressure in Puget Sound, Washington, USA. *Biological Conservation* .143: 700–709.

Leigh, P. 1998. Benefits and Costs of the Ruffe Control Program for the Great Lakes Fishery. *Journal of Great Lakes Resources* 24(2): 351–60.

Leppäkoski, E., Gollasch, S., Gruszka, P., Ojaveer, H., Olenin, S.J., and V.Panov. 2002. The Baltic—a sea of invaders. *Can. J. Fish. Aquat. Sci.* 59: 1175–1188.

Locke, A., Reid, D.M., van Leeuwen, H.C., Sprules, W.G., and J.T. Carlton. 1993. Ballast Water Exchange as a Means of Controlling Dispersal of Freshwater Organisms by Ships. *Can. J. Fish. Aquat. Sci.* 50: 2086-2093.

Lodge, D. and D. Finnoff, Annual Losses to Great Lakes Region by Ship-borne Invasive Species at least $200 Million. July 2008. Fact Sheet available at http://www.glu.org/sites/default/files/lodge_factsheet.pdf.

Lovell, A.J. and S. F. Stone. 2005. The Economic Impacts of Aquatic Invasive Species: A Review of the Literature. *NCEE Working Paper #05-02*. Washington D.C.: U.S. Environmental Protection Agency.

Lovell, S.J., S.F. Stone, and L. Fernandez. 2006. The Economic Impact of Aquatic Invasive Species: A Review of the Literature. *Agricultural and Resource Economics Review.* 35 (1): 195-208.

Lupi, F., J. Hoehn, and G. Christie. Using an Economic Model of Recreational Fishing to Evaluate the Benefits of Sea Lamprey Control on the St. Mary's River. *Journal of Great Lakes Research* 29 (Supplement 1): 742-754.

MacIsaac, H.J., Robbins, T.C. and M.A. Lewis. 2002. Modeling ships' ballast water as invasion threats to the Great Lakes. *Can. J. Fish. Aquat. Sci.* 59:1245-1256.

MARAD. 2005. Reports and Surveys. http://www.marad.dot.gov/MARAD_statistics/ (accessed Sept. 29, 2005).

Maritime Research Inc. 2005. Internet Ship Register. Lloyd's Register. http://www.ships-register.com/ (accessed multiple times).

Matousek, R., et al. 2005. Electrolytic Sodium Hypochlorite System for Treatment of Ballast Water. *Transactions*: SNAME.

Maybee, M. 2001. Indigenous Peoples Update. *Great Lakes Aquatic Habitat News* 9 (6). http://glhabitat.org/news/glnews171.html

McIntosh, C.R., Shogren, J.F., and D.C. Finnoff, "Invasive Species and Delaying the Inevitable: Results from a Pilot Valuation Experiment." *Journal of Agricultural and Applied Economics*. 39(October 2007): 83-95.

Mecator Transport Group. 2005. Forecast of Container Vessel Specifications and Port Calls Within San Pedro Bay. *Final Report for the Ports of Long Beach and Los Angeles*. California: Herbert Engineering Corp. MDS Transmodal Ltd.

Mills, E. L., J. H. Leach, J. T. Carlton, and C. L. Secor. 1993. Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions. *Journal of Great Lakes Research* 19 (1): 1-54.

Minchin, D. 2002. Fouling and ship's hulls: how spawning events may result in exotic species spread. *CDQ Journal*. Washington D.C.: Report in Proceedings, 11th International Congress on Marine Corrosion and Biofouling.

Minton, M.S., Verling, E., Miller, A.W. and G.M. Ruiz. 2005 Reducing propagule supply and coastal invasions via ships: effects of emerging strategies. *Frontiers in Ecology and the Environment* 3 (6): 304-308.

Moody, M.E., and R.N. Mack. 1998. Controlling the spread of plant invasions: The importance of nascent foci. *Journal of Applied Ecology* 24: 1009–21.

Mooney, H.A. and R.J. Hobbs. 2000. Invasive Species in a Changing World. *Island Press*. Washington, D.C.

Mumpower, J. 1986. An Analysis of the De Minimis Strategy for Risk Management, *Risk Analysis.*

National Imagery and Mapping Agency. 2001. *Distances Between Ports*. Publication 51, Edition.

National Research Council. 1995. Understanding Marine Biodiversity: A Research Agenda for the Nation. *Committee on Biological Diversity in Marine Systems.* Washington D.C.: National Academy Press.

National Research Council of the National Academies (NAS). 2011. Assessing the Relationship Between Propagule Pressure and Invasion Risk in Ballast Water. Washington D.C.: National Academy Press.

Nichols, F.H., Thompson, J.K. and L.E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam, *Pomtamocorbula amurensis*. II: Displacement of a former community. *Marine Ecology Progress Series* 66 (95-101).

Noble, P. 2004. Marine Transport of Natural Gas – The Next Generation. *Presentation to the Northern California Section of SNAME*. California: SNAME.

O'Neill, C.R. 1996. Economic Impact of Zebra Mussels: Results of the 1995 National Zebra Mussel Clearinghouse Study, *Creissena polymopha*. *Technical Collection Reprint.* New York: Zebra Mussel Clearinghouse, New York Sea Grant Extension.

O'Neill, C.R. 1997. Economic Impact of Zebra Mussels – Results of the 1995 National Zebra Mussel Information Clearinghouse Study. *Great Lakes Research Review* 3 (1): 35-44.

O'Neill, C. R. 2000. Personal communication cited by Carlton, 2001. *New York Sea Grant Extension.* New York: National Aquatic Nuisances Species Clearinghouse.

Olson, L. J. and S. Roy. 2003. The Economics of Controlling a Biological Invasion. *Washington Post*, 03-06. Maryland: Department of Agricultural and Resource Economics, University of Maryland.

OMB. 2006. Gross Domestic Product and Deflators Used in Historical Tables. http://www.whitehouse.gov/omb/budget/fy2006/sheets/ hist10z1.xls (accessed October 26, 2005).

Oregon Dept. of Agriculture. http://oregon.gov/ODA/ (accessed October 28, 2005).

OTA. 1993. *Harmful Non-Indigenous Species in the United States.* Washington: U.S. Congress Office of Technology Assessment.

Parker, Simberloff, Lonsdale, Goodell, Wonham, Kareiva, Williamson, Von Holle, Moyle, Byers & Goldwa. 1999. Impact: Toward a Framework for Understanding the Ecological Effects of Invaders. *Biological Invasions*.

Pimentel, D. 2005. Aquatic Nuisance Species in the New York River Systems and the Great Lakes Basin: An Economic and Environmental Assessment. *Environmental Management* 35 (5): 692-701.

Pimentel, D., Zuniga, R. and D. Morrison. 2004 Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273-288.

Prince William Sound Regional Citizen's Advisory Council. 2004. Non – Indigenous Species of Concern for Alaska. Maryland.

PSIX. 2005. Port State Information eX change. United States Coast Guard. http://cgmix.uscg.mil/psix

Randall, A., and H. Gollamudi. 2001. Dealing with the analytical challenges of valuation: aquatic nuisance speciescontrol. *Revealing the Economic Value of Protecting the Great Lakes.* ed. A. Cangelosi Washington, D.C.: Northeast-Midwest Institute and National Oceanic and Atmospheric Administration.

ReferenceUSA. Omaha: Info USA. www.referenceusa.com (accessed March 2006)

Reynolds, K. A., I. T. Knight, C. S. Wells, I. L. Pepper, and C. P. Gerba. 1999. Detection of Human Pathogenic Protozoa and Viruses in Ballast Water Using Conventional and Molecular Methods. *Abstract Q-318.* Illinois: General Meeting of the American Society for Microbiology.

Ricciardi, A. 2001. Facilitative interactions among aquatic invaders: is an ‘invasional meltdown’ occurring in the Great Lakes? *Can. J. Fish. Aquat. Sci.* 58: 2513–2525.

Rigby, G., Hallegraaf, G. and A. Taylor. 2004. Ballast Water Heating Offers a Superior Treatment Option. *Journal of Marine Environmental Engineering* 7: 217-230.

Rockwell. H.W. 2003. Summary of a Survey of the Literature on the Economic Impacts of Aquatic Weeds. Aquatic Ecosystem Restoration Foundation. http://www.aquatics.org/pubs/economics.htm

Rosenberger, R., and J. Loomis. 2001. Benefit Transfer of Outdoor Recreation Use Values: A Technical Document Supporting the Forest Service Strategic Plan (2000 Revision*).* *Gen. Tech. Rep. RMRS-GTR-72* . Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Rodrigue, J-P & et al. The Geography of Transport Systems. New York: Hofstra University, Department of Economics & Geography. http://people.hofstra.edu/geotrans (accessed March 10, 2006).

Rudnick, D.A., Halat, K.M. and V.H. Resh. 2000. Distribution, Ecology and Potential Impacts of the Chinese Mitten Crab (*Eriocheir sinensis*) in San Francisco Bay. *Contribution No. 206*: 74. California: University of California Water Resources Center.

Ruiz, G.M. 2002. Ships as Vectors: Assessing the Role of Hull Fouling in Biological Invasions. *CDQ Journal*. Washington, D.C.: Report in Proceedings, 11th International Congress on Marine Corrosion and Biofouling.

Ruiz, G.M. and J.T. Carlton. 2003. Invasion Vectors: a conceptual framework for management. *Invasive Species: vectors and management strategies.*: eds. Ruiz G.M. and J.T. Carlton. Washington, DC: Island Press.

Ruiz, G.M. 2005. CSLC Meeting Notes. *Performance Standards Technical Advisory Panel Meeting #2*.

Ruiz, G.M., and P.W. Fofonoff. 2007. Current status of understanding about the effectiveness of ballast water exchange (BWE) in reducing aquatic nonindigenous species (ANS) introductions to the Great Lakes basin and Chesapeake Bay. *NOAA Technical Memorandum GLERL-142*. Washington, D.C.

Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J. and A.H. Hines. 2000. Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *Annual Review of Ecology and Systematics* 31: (481-531).

Ruiz, G.M., Rawlings, T.K., Dobbs, F.C., Drake, L.A., Mullady, T., Schoenfeld, S., Hug, A. and R.R. Colwell. 2000. Global spread of microorganisms by ships. *Nature* 408 (49-50).

Rup, M.P., Bailey, S.A., Wiley, C.J., Minton, M.S., Miller, A.W., Ruiz, G.M., and H.J. MacIsaac, 2010. Domestic ballast operations on the Great Lakes: potential importance of Lakers as a vector for introduction and spread of nonindigenous species. *Can. J. Fish. Aquat. Sci.* 67: 256–268.

Sember, W.J. 2005. The Role of Classification Societies in Design, Operation and Construction of LNG Carriers and Terminals. *GasTech*.

Simkanin, C., Davidson, I., Falkner M., Sytsma M., and G. Ruiz. 2009. Intra-coastal ballast water flux and the potential for secondary spread of non-native species on the US West Coast. Marine *Pollution Bulletin* 58: 366–374.

Smith, L.D., Wonham, M.J., McCann, L.D., Ruiz, G..M., Hines, A.H., and J.T. Carlton. 1999. Invasion pressure to a ballast-flooded estuary and an assessment of inoculant survival. *Biol. Invasions* 1: 67-87.

SNAME. 1998. Principles of Naval Architecture. *Society of Naval Architects and Marine Engineers*.

Strayer, D.L. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology*. 55 (Suppl. 1), 152–174

Stopford, M. 2002. Is the Drive For Ever Bigger Containerships Irresistible? Lloyds List Shipping Forecasting Conference. http://www.clarksonresearch.com/ (accessed March 10, 2006).

Swift, P. 2005. Industry Coalition Statement on ECJ Ruling on EU SSP Directive. Intertanko. http://www.intertanko.com (accessed March 17, 2006).

Tamburri, M. 2005. Personal communication.

Tamburri, M.N. and G.M. Ruiz. 2005. Evaluations of a Ballast Water Managmentto Stop Invasive Species and Tank Corrosion. *Transactions.* SNAME.

Transportation Research Board. 2004. The marine transportation system and the federal role : measuring performance, targeting improvement. *Special Report 279*: Committee for a Study of the Federal Role in the Marine Transportation System.

United Nations. Shipping Safe and Friendly. UN Atlas of the Oceans. http://www.oceansatlas.com/unatlas/uses/transportation_telecomm/maritime_trans/shipping_world_trade/shipping_safe_and_friendly.htm (accessed March 14, 2006).

U.S. Army Corps of Engineers. Lake Tahoe Region Aquatic Invasive Species Management Plan, California - Nevada. 2009.

U.S. Commission on Ocean Policy. 2004. *An Ocean Blueprint for the 21st Century: Final Report.* Washington, DC.: U.S. Commission on Ocean Policy. http://www.oceancommission.gov/documents/full_color_rpt/000_ocean_full_report.pdf

U.S. Congress, Office of Technology Assessment. 1993. Harmful Non-Indigenous Species in the United States. *OTA-F-565.*

US EPA. 2001. National Coastal Condition Report. *EPA-620/R-01/005.* Washington, D.C.: Office of Research and Development/Office of Water. http://www.epa.gov/owow/oceans/nccr/downloads.html

US EPA, Science Advisory Board (SBA). 2011. Efficacy of Ballast Water Treatment Systems: a Report by the EPA Science Advisory Board. Washington, D.C.

US General Accounting Office. 2002. Invasive Species: Clearer Focus and Greater Commitment Needed to Effectively Manage the Problem. *GAO-03-01*. Washington, D.C.

URS/Dames & Moore. 2000. *Feasibility of Onshore Ballast Water Treatment at California Ports.* California: URS Corporation/Dames & Moore, and San Francisco for the California Association of Port Authorities (CAPA).

U.S. Grains Council. Grain News 2 (4) U.S. Grain Council. http://www.grains.org/ (accessed November 7, 2005).

USCG: Standards Evaluation and Analysis Division. 2004. Regulatory Evaluation for the Final Rule. Mandatory Ballast Water Management Program for U.S. Waters. *Report USCG-203-14273*.

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.

USDA. Agricultural Container Indicators. http://www.ams.usda.gov (accessed October 31, 2005).

USGS: Center for Aquatic Studies. Progression of the zebra mussel (Dreissena polymorpha) distribution in North America. *Non-indigenous Plants and Animals Program.* Florida: USGS Florida Integrated Science Center. http://cars.er.usgs.gov/Nonindigenous_Species/ZM_Progression/zm_progression.html (accessed October 27, 2005).

Volpe, John. 2006. Ballast Water Discharge Standard, Draft Programmatic Environmental Impact Statement. Washington, D.C.: National Transportation Systems Center.

Windle, P.N. 1997. The OTA Report on Harmful Nonindigenous Species. Exotic Pests of Eastern Forests Conference. http://www.invasive.org/symposium/windle.html

Wonham, M.J., Walton, W.C., Ruiz, G.M., Frese, A.M. and B.S. Galil. 2001. Going to the source: role of the invasion pathway in determining potential invaders. *Ecol. Prog.* 215:1-12.

Wright, David, Dawson, R. and T. Mackey. 2003. Full-Scale Shipboard Trials of Ballast Water Treatment Systems in Baltimore Harbor. *9th International Conference on Marine Engineering Systems*. Helsinki.

Wright, David, Mackey, T. 2006. Shipboard and Dockside Trials of Ballast Water Treatment Technology. *Marine Environmental Engineering Technology Symposium*. Virginia.

Zo, Y., C. Grimm, M. Matte, G. Matte, I. T. Knight, A. Huq, and R. R. Colwell. 1999. Detection and Enumeration of Pathogenic Bacteria in Ballast Water of Transoceanic Vessels Entering the Great Lakes and Resistance to Common Antibiotics. *Abstract Q-317*. Chicago: General Meeting of the American Society for Microbiology.

Appendix A Ballast Water Tank Capacities and 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 2014 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[48]	65	64	64	61	60	61	-6.15	-1.24
Tanks[49]	7,229	7,381	7,419	7,661	7,901	8,209	13.56	2.58
Containers[50]	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[51]	57	63	63	73	69	66	12.12	2.59
Combination Vessels[52]	9,901	10,423	10,392	10,633	10,913	11,275	13.88	2.65
Fishing Vessels[53]	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

[48] Based on Clarkson Research Service (Source: U.S. Department of Transportation, Maritime Administration, Water Transportation Statistical Snapshot, May 2008)
[49] Based on MISLE database, includes tank barges and tank ships.
[50] Based on MISLE database, includes freight barges and freight ships.
[51] Based original data from Clarkson Research Service available at U.S. Department of Transportation, Maritime Administration, Water Transportation Statistical Snapshot (May 2008)
[52] Based on MISLE database, includes mobile offshore drilling units, oil recovery vessels and towing vessels.
[53] 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[54], 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%

[54] 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

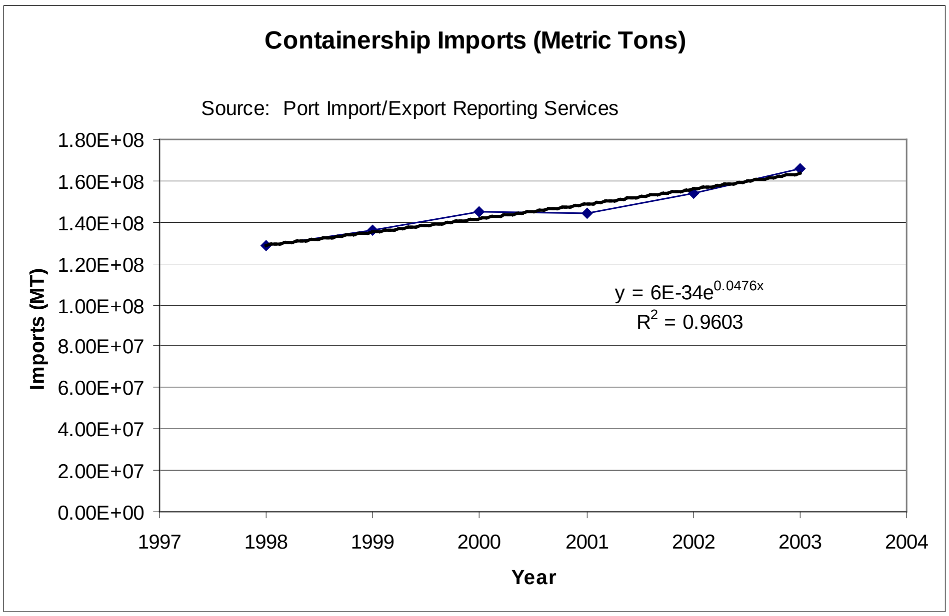
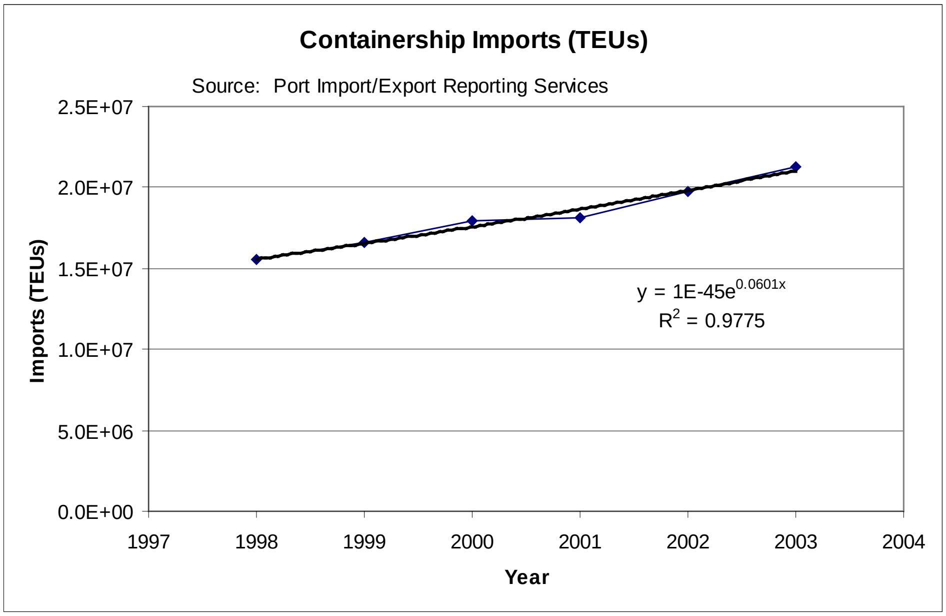


Figure A-2 Imports (TEUs) on Containerships, 1998-2003



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.

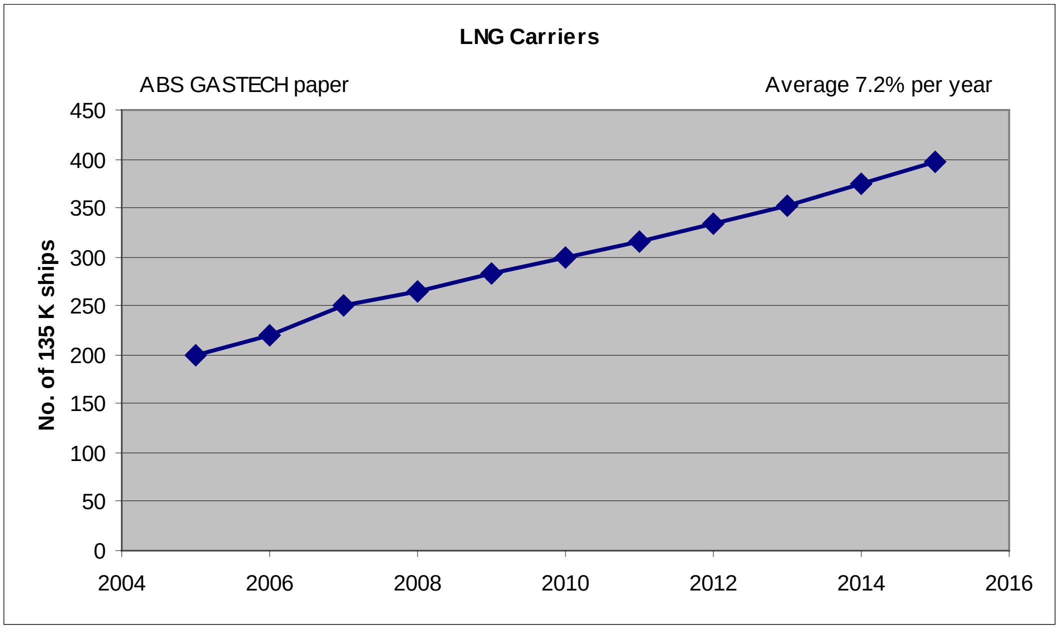
About 205 carriers need to be ordered, adding to the 182 vessels in service and 127 units already contracted to be built, to meet demand for existing and future LNG projects. In addition, as many as 105 vessels need to be ordered to meet demand for future projects and 100 vessels for current contracts.

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.

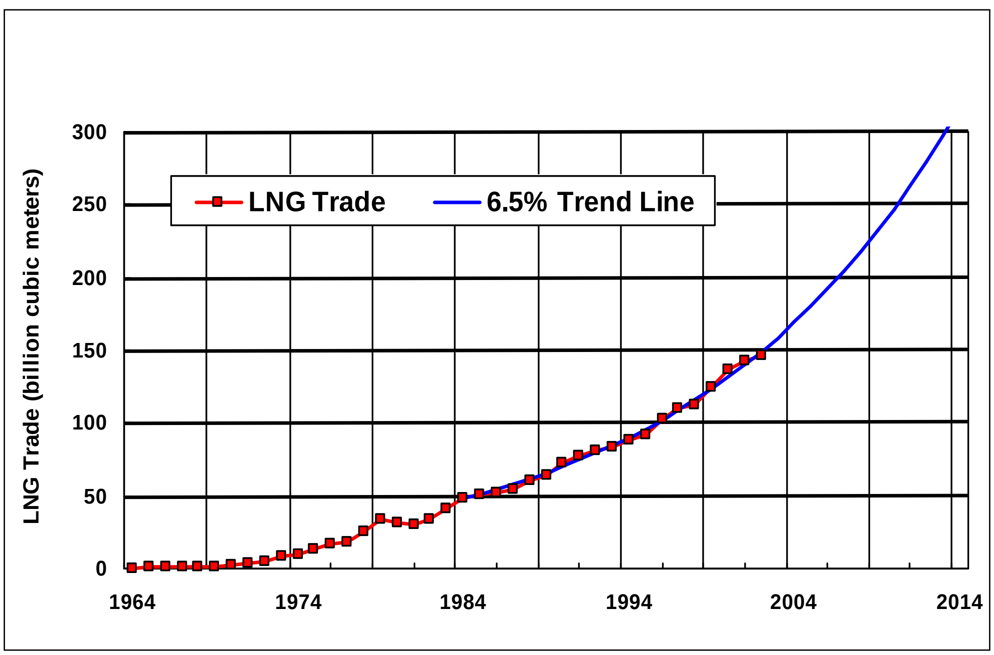
Figure A-3 LNG Fleet Growth (from ABS GASTECH paper) Based Upon 138K m^3 Capacity



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

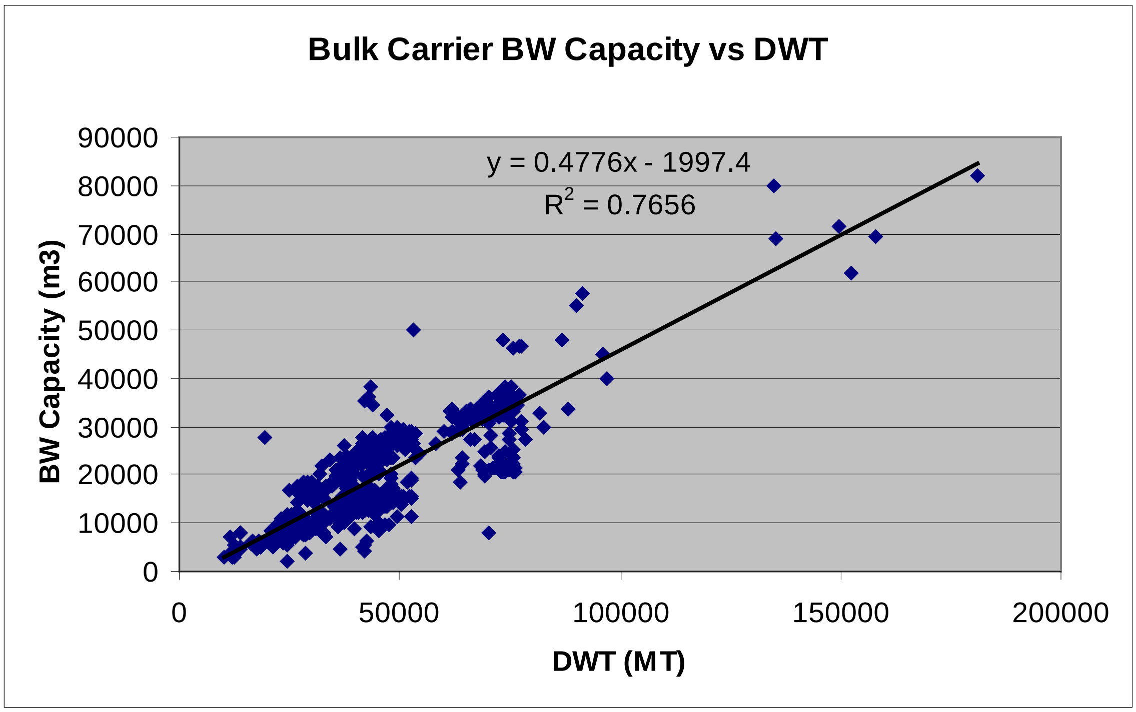


Figure A-6 Containership BW Capacity vs. TEU

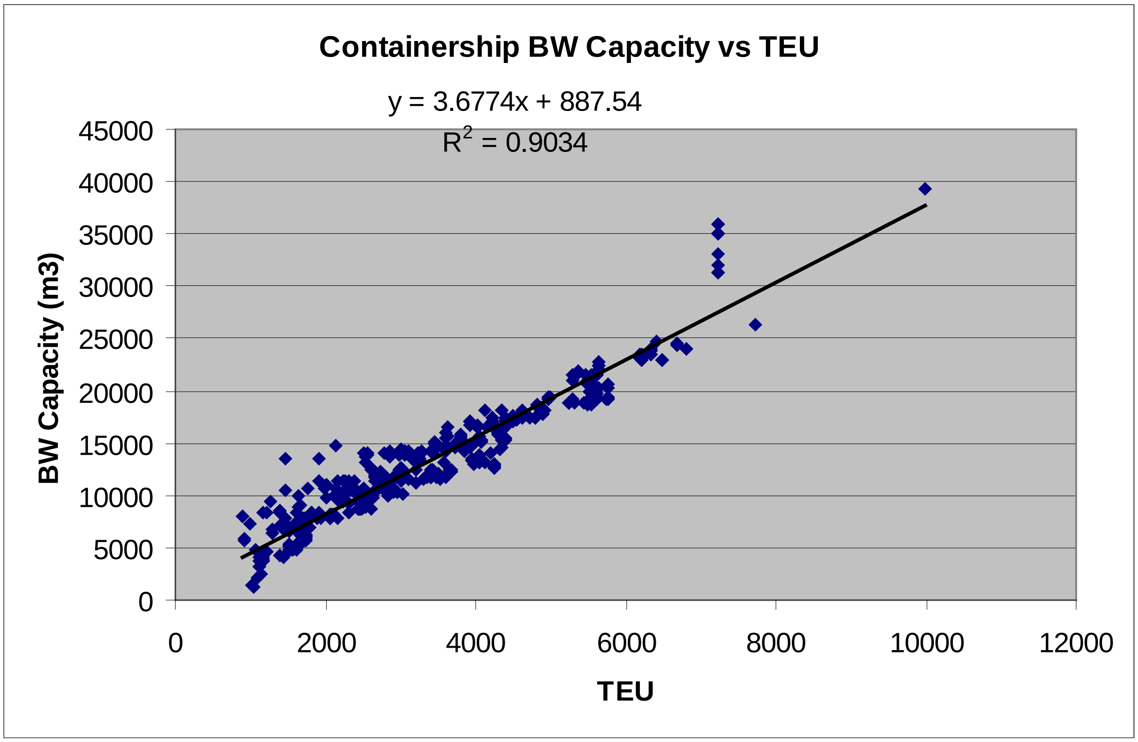
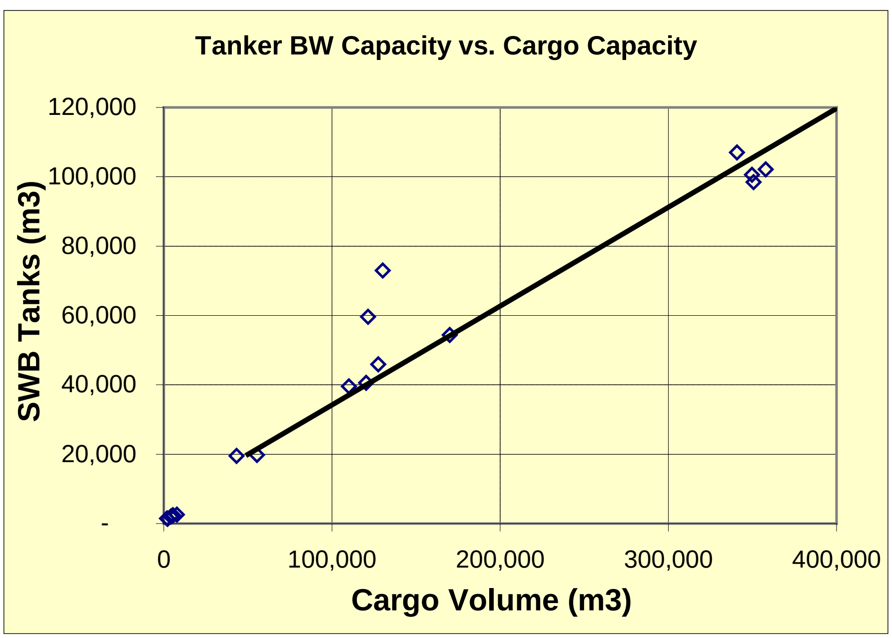


Figure A-7 Tanker BW Capacity vs. Cargo Capacity (from HEC data)



Number of Vessels Undergoing BWMS Installation over the Phase-in Period

Table A-8 presents the break-down between number of existing and new vessels undergoing installation over the phase-in period (complete information on vessels undergoing BWMS installation over the period of the analysis is presented on chapter 4, table 4.2)

Table A-8 Vessel undergoing installation during the phase-in period

Vessel Type	2014	2014	2015	2015	2016	2016	2017	2017	2018	2018
	Existing	**New**	**Existing**	**New**	**Existing**	**New**	**Existing**	**New**	**Existing**	**New**
Bulk Ships										
Handy Bulk	0	0	0	0	3.7	0	3.7	0	1.8	0
Panamax Bulk	0	0	0	0	2.0	0	2.0	0	1.0	0
Capesize	0	0	0	0	0.0	0	0.0	0	0.0	0
Tanker Ships										
Handy	0	0	0	0	4.4	0	4.4	0	2.2	0
Handymax-Aframax	0	1	0	1	7.5	1	7.5	1	3.8	1
Suezmax	0	0	0	0	3.1	0	3.1	0	1.5	0
VLCC	0	0	0	0	1.8	0	1.8	0	0.9	0
Container Ship										
Feeder	2	1	2	1	8.3	1	7.4	1	3.7	1
Feedermax	0	0	0	0	0.4	0	0.4	0	0.2	0
Handy	0	1	0	1	10.5	1	10.5	1	5.2	1
Subpanamax	2	2	2	2	19.9	2	18.7	2	9.4	3
Panamax	1	1	1	1	7.9	1	7.4	1	3.7	1
Postpanamax	0	1	0	1	12.1	1	12.1	1	6.1	1
Other Vessels										
Passenger ships	8	9	8	10	55.1	10	50.9	10	25.5	11
Gas carriers	0	0	0	0	2.4	0	2.4	0	1.2	0
Chemical carriers	0	1	0	1	9.5	1	9.5	1	4.7	1
RORO	6	4	6	4	24.1	4	21.0	4	10.5	4
Combination vessels	0	7	0	7	54.8	8	54.8	8	27.4	8
General Cargo	3	2	3	2	17.5	2	16.2	2	8.1	2
Fishing	4	6	4	6	34.0	6	31.9	7	16.0	7
OSVs	40	86	40	90	300.6	95	280.6	100	140.3	104
Total	**67**	**125**	**67**	**130**	**580**	**135**	**546**	**141**	**273**	**147**

Note: Totals may not add due to rounding.

Appendix B Ballast Water Exchange (BWE) Cost[55]

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 to 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.[56] 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 divided this cost by the estimated annual quantity of ballast pumped per year. HEC estimated 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,[57] 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 assumed this

[55] Methodology and sources provided by Herbert Engineering Corporation, information updated to 2007.

[56] 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.

[57] 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.[58] 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[59] to over $50[60] per hour for U.S. or European officers.[61] 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

[58] Based upon recent industry experience, it is assumed that vessels can maintain course and speed while performing BWE.
[59] Costs are loaded.
[60] 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 as a loaded wage rate for U.S.
[61] 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 expects 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.[62] HEC also used data from California,

[62] 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[63] 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.

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.

[63] 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[64] 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 believed, 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. HEC 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

[64] Percentages provided by Herbert Engineering Corporation

Appendix C 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 BWMS 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 BWMS 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 C-1 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 C-1 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 Table 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 BWMS 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 BWM 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 BWMS. 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 BWMS, will have little or no effect on charter rates. Over the longer run, the cost of shipping goods will reflect the costs of BWMS because ship owners must ultimately recapture their investment in order to remain commercially viable. We also found additional information suggesting similar findings in terms of the magnitude of global trade and the low impact of costs being passed on to consumers. [65]

[65] King, Dennis. 2011. MEPC 62 special: The world can afford sustainable shipping. Sustainable Shipping, July 8 2011 (http://www.maritime-enviro.org/news/King_Sustainable_Shipping_070811.pdf). King suggests that if the cost of ballast water regulations was passed along to global businesses and consumers, the price increase of imported goods will be minimal and statistically indistinguishable from no change.

Appendix D Ballast Water Management System Costs for the Foreign Vessels

This appendix presents the information on the ballast water management 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 Management 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 BWMS vendors and therefore, the installation costs will be potentially lower than the costs incurred by the U.S. vessels. Tables D-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 D-1 Estimated Average Installed Cost ($000) for the Foreign Fleet by Vessel Category and BWMS

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[66]	250	300	250	225	165	252
OSVs[67]	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 D-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 management system presented on Table D-1. The low costs presented on the table below are

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

related to the cheapest management system available and the high costs are related to the most expensive management system available.

Table D-2 Installed Ballast Water Management 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 primary cost estimate for the foreign fleet assumes that these vessels will be subjected to the same phase-in schedule as the U.S. fleet (Table 1.2). Therefore, vessels built before 2014 with ballast capacities between 1,500 and 5,000 cubic meters and all new buildings will be required to meet the discharge standards under the rulemaking phase-in structure on the first drydocking after January 1, 2014. For the vessels that will comply with this rulemaking by 2014, we have assumed that 40 percent will install BWMS each year, in the first two years (2014 and 2015) and 20 percent in the last year of the compliance requirement (2016). In 2016, the remainder of the fleet built before 2014 will be required to meet the BWDS. In this case, we have assumed that 40 percent of the population will install the system in the first two years (2016 to 2017) and 20 percent in the last year of the compliance requirement (2018).. Given these assumptions and the projected fleet growth as defined in Chapter 2

(Table 2.3), the number of foreign vessels undergoing BWMS installations is as shown in Table D-3.

Table D-3 Number of Foreign Vessels Undergoing BWMS Installation by Year and Type

Vessel type	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Bulk carriers											
Handy	40.7	40.6	342.3	325.5	166.2	7.0	6.9	6.8	6.7	6.6	949.3
Panamax	5.2	5.1	173.2	172.4	87.9	3.4	3.3	3.3	3.2	3.2	460.2
Capesize	0.3	0.3	15.7	15.7	8.0	0.3	0.3	0.3	0.3	0.3	41.6
Tank ships											
Handy	23.9	24.0	46.8	37.4	21.4	5.5	5.6	5.8	5.9	6.1	182.4
Handy-Aframax	29.6	30.3	344.2	345.0	189.3	33.6	34.5	35.3	36.3	37.2	1115.1
Suezmax	4.2	4.3	48.5	48.7	26.7	4.7	4.9	5.0	5.1	5.2	157.3
VLCC	6.4	6.6	74.8	74.9	41.1	7.3	7.5	7.7	7.9	8.1	242.2
ULCC	0.7	0.7	7.8	7.8	4.3	0.8	0.8	0.8	0.8	0.8	25.2
Containerships											
Feeder	10.0	10.0	13.4	9.3	5.6	1.9	2.0	2.0	2.1	2.1	88.0
Feedermax	18.6	18.6	14.8	6.7	4.6	2.5	2.6	2.6	2.7	2.7	115.0
Handy	18.2	18.3	50.5	44.3	25.3	6.2	6.4	6.5	6.6	6.8	284.2
Subpanamax	7.7	7.9	77.4	77.6	43.0	8.5	8.7	8.9	9.0	9.2	387.9
Panamax	7.8	8.0	78.3	78.5	43.5	8.6	8.8	9.0	9.1	9.3	392.4
Postpanamax	12.2	12.5	122.4	122.7	68.1	13.5	13.7	14.0	14.3	14.6	613.5
Other vessels											
Passenger ships	50.7	51.0	43.9	23.2	16.7	10.3	10.7	11.0	11.4	11.8	240.7
Gas carriers	20.3	20.4	46.1	38.9	22.6	6.2	6.3	6.5	6.6	6.7	180.6
Chemical carriers	47.9	48.6	229.5	219.8	125.3	30.7	31.5	32.3	33.2	34.0	832.9
RORO	38.7	39.2	140.8	130.9	75.6	20.4	20.9	21.4	22.0	22.6	532.5
Combination vessels	3.2	3.2	9.5	8.5	4.9	1.4	1.4	1.4	1.5	1.5	36.5
General Cargo	44.1	44.3	99.5	83.8	48.6	13.4	13.7	14.0	14.2	14.5	390.3
Fishing	1.9	2.0	7.8	7.4	4.4	1.3	1.4	1.4	1.5	1.5	30.7
OSV	12.9	13.1	22.7	19.2	13.1	6.9	7.3	7.6	8.0	8.4	119.2
Total	**405**	**409**	**2010**	**1898**	**1046**	**195**	**199**	**204**	**208**	**213**	6787.7

Note: Totals may not add due to rounding

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

Table D-4 Installation Costs for the BWMS for Foreign Vessels ($Mil)

Vessel Type	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Bulk Carriers											
Handy Bulk	13.56	13.53	113.97	108.39	55.36	2.32	2.29	2.26	2.23	2.20	316.11
Panamax Bulk	1.88	1.86	62.87	62.57	31.89	1.22	1.21	1.19	1.18	1.16	167.04
Capesize	0.13	0.13	6.29	6.29	3.20	0.12	0.12	0.12	0.12	0.12	16.63
Tank Ships											
Handy	7.67	7.71	15.02	12.00	6.88	1.76	1.81	1.86	1.90	1.95	58.57
Handymax-Aframax	11.83	12.13	137.66	137.98	75.71	13.44	13.78	14.14	14.50	14.88	446.05
Suezmax	1.56	1.60	18.20	18.25	10.01	1.78	1.82	1.87	1.92	1.97	58.98
VLCC	3.37	3.46	39.25	39.34	21.58	3.83	3.93	4.03	4.13	4.24	127.16
ULCC	0.35	0.36	4.08	4.09	2.24	0.40	0.41	0.42	0.43	0.44	13.21
Containerships											
Feeder	1.65	1.65	2.22	1.54	0.93	0.32	0.33	0.33	0.34	0.35	9.65
Feedermax	4.38	4.39	3.50	1.58	1.09	0.60	0.61	0.62	0.63	0.65	18.05
Handy	4.28	4.31	11.91	10.46	5.97	1.47	1.50	1.53	1.56	1.59	44.60
Subpanamax	2.12	2.17	21.29	21.33	11.84	2.34	2.39	2.44	2.49	2.54	70.94
Panamax	2.15	2.19	21.54	21.58	11.98	2.37	2.42	2.47	2.52	2.57	71.77
Postpanamax	3.66	3.74	36.73	36.80	20.42	4.04	4.12	4.21	4.29	4.38	122.39
Other vessels											
Passenger ships	8.37	8.42	7.24	3.82	2.76	1.70	1.76	1.82	1.88	1.94	39.72
Gas carriers	10.44	10.50	23.75	20.04	11.62	3.20	3.26	3.33	3.39	3.46	93.00
Chemical carriers	13.66	13.86	65.40	62.64	35.70	8.76	8.99	9.22	9.46	9.70	237.39
RORO	9.14	9.24	33.23	30.90	17.85	4.81	4.93	5.06	5.19	5.33	125.68
Combination vessels	0.75	0.76	2.24	2.01	1.17	0.32	0.33	0.34	0.35	0.36	8.62
General Cargo	10.41	10.47	23.49	19.78	11.48	3.17	3.23	3.30	3.36	3.43	92.11
Fishing	0.32	0.33	1.28	1.22	0.72	0.22	0.23	0.24	0.25	0.26	5.06
OSVs	2.57	2.63	4.53	3.85	2.62	1.39	1.46	1.53	1.60	1.68	23.85
Total	114.27	115.44	655.67	626.47	343.01	59.59	60.93	62.31	63.72	65.18	2,166.59
Total PV 3%	110.94	108.82	600.04	556.61	295.89	49.90	49.54	49.19	48.84	48.50	1,918.25
Total PV 7%	106.79	100.83	535.23	477.93	244.56	39.70	37.94	36.26	34.66	33.13	1,647.05

Operating Costs of Ballast Water Management System

BWMS 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 D-5).

Table D-5 Estimated ballast water discharge in 2007

Vessel Type	# of Arrivasl	Total Ballast Water Discharged	Average Ballast Water Discharged per Vessel type
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[68]	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 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 average yearly amount of ballast discharge was determined, we multiplied these estimates by the number of vessels undergoing installation in Table D-3. Then multiply this

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

product by the cost presented in Table D -2 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 BWM (Table D-5) per vessel type.

Table D-6 displays the operating costs for all affected vessels in the population. The total operating costs covering the period of analysis is approximately $61 million and $47 million at 3 and 7 percent discount rates, respectively.

Table D-6 Annual Operating Costs for BWM ($Mil)

Vessel Type	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Vessel Type Sub-Total
Bulk Carriers											
Handy Bulk	0.072	0.144	0.750	1.326	1.620	1.632	1.644	1.656	1.668	1.680	12.191
Panamax Bulk	0.032	0.064	1.147	2.224	2.773	2.795	2.815	2.836	2.856	2.876	20.420
Capesize	0.001	0.002	0.050	0.099	0.123	0.124	0.125	0.126	0.127	0.128	0.907
Tank Ships											
Handy	0.029	0.059	0.116	0.162	0.188	0.195	0.202	0.209	0.216	0.224	1.600
Handymax-Aframax	0.304	0.615	4.148	7.689	9.632	9.976	10.330	10.693	11.065	11.447	75.899
Suezmax	0.175	0.354	2.385	4.421	5.538	5.736	5.939	6.148	6.362	6.581	43.638
VLCC	0.211	0.062	0.701	0.703	0.385	0.068	0.070	0.072	0.074	0.076	2.422
ULCC	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Containerships											
Feeder	0.001	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.009
Feedermax	0.002	0.005	0.007	0.008	0.008	0.009	0.009	0.009	0.010	0.010	0.076
Handy	0.029	0.058	0.139	0.211	0.251	0.261	0.271	0.282	0.292	0.303	2.098
Subpanamax	0.023	0.047	0.279	0.512	0.641	0.666	0.692	0.719	0.746	0.774	5.098
Panamax	0.005	0.010	0.057	0.104	0.130	0.136	0.141	0.146	0.152	0.158	1.038
Postpanamax	0.029	0.059	0.351	0.644	0.806	0.838	0.871	0.905	0.939	0.974	6.416
Other vessels											
Passenger ships	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.008
Gas carriers	0.035	0.070	0.150	0.218	0.257	0.268	0.279	0.290	0.301	0.313	2.183
Chemical carriers	0.019	0.039	0.132	0.221	0.272	0.285	0.297	0.310	0.324	0.338	2.238
RORO	0.001	0.002	0.005	0.008	0.009	0.010	0.010	0.011	0.011	0.012	0.077
Combination vessels	0.001	0.001	0.003	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.047
General Cargo	0.000	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.017
Fishing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
OSV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.004
Total	0.971	1.593	10.424	18.556	22.645	23.009	23.708	24.423	25.155	25.904	176.388
Total PV 3%	0.943	1.502	9.540	16.487	19.534	19.269	19.277	19.280	19.279	19.275	144.385
Total PV	0.908	1.392	8.509	14.156	16.145	15.332	14.764	14.214	13.683	13.168	112.271

7%											

Note: Total may not add due to rounding.

Total Costs of Ballast Water Management Systems for Foreign Vessels

In Table D-7, we estimate the total cost over the period of analysis for the foreign vessels. The total estimated cost was approximately $2.0 billion with a 3 percent discount rate and $1.6 billion with a 7 percent discount rate.

Table D-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
2014	$110.94	$106.79	6,975,800	$0.94	$0.91	$111.88	$107.70
2015	$108.82	$100.83	10,759,556	$1.50	$1.39	$110.32	$102.22
2016	$600.04	$535.23	74,183,840	$9.54	$8.51	$609.57	$543.73
2017	$556.61	$477.93	131,568,095	$16.49	$14.16	$573.10	$492.09
2018	$295.89	$244.56	159,811,057	$19.53	$16.15	$315.42	$260.71
2019	$49.90	$39.70	161,813,571	$19.27	$15.33	$69.17	$55.04
2020	$49.54	$37.94	166,832,339	$19.28	$14.76	$68.82	$52.71
2021	$49.19	$36.26	171,971,026	$19.28	$14.21	$68.47	$50.48
2022	$48.84	$34.66	177,232,781	$19.28	$13.68	$68.12	$48.34
2023	$48.50	$33.13	182,620,835	$19.28	$13.17	$67.77	$46.30
Total	**$1,918.25**	**$1,647.05**		**$144.38**	**$112.27**	**$2,062.64**	**$1,759.32**
Annualized	**$224.88**	**$234.50**		**$16.93**	**$15.98**	**$241.80**	**$250.49**

Comparison of Costs and Benefits of Ballast Water Management Systems Including Foreign Vessels

In Chapter 6 of this RA we compared the benefits of the FR to the estimated costs for the U.S. fleet only. In this chapter, we present the same comparison but now include the costs for the foreign fleet. It should be noted that this comparison does not include a valuation of benefits that would result from the reduced risk of invasions from foreign-flagged vessels on a global basis[69]. The annualized cost for foreign vessels over the 10-year period of 2014-2023 for the phase one standard is estimated to be $282 million at a 7 percent discount rate (Table D-7). Adding the annualized cost for foreign vessels to the annualized costs for U.S. ($92 million) we obtain a

[69] The benefits estimates presented in this RA only consider reductions in NIS invasions to U.S. waters. Installing and using ballast water treatment systems will also result in reductions in NIS invasions to foreign waters, from both U.S. and foreign-flagged vessels. We have not attempted to estimate the benefits that might accrue to waters other than those in the U.S.

total annualized cost of approximately $251 million at a 7 percent discount rate (Table D-8). The quantified benefits for the phase one standard ranges from $5 million to $470 million per year, with a mid range of $141-$240 million per year and high range of $276- $470 million per year (at a 7 percent discount rate). Thus, quantified benefits will only exceed the estimated costs for high range benefits estimate of High Effectiveness.

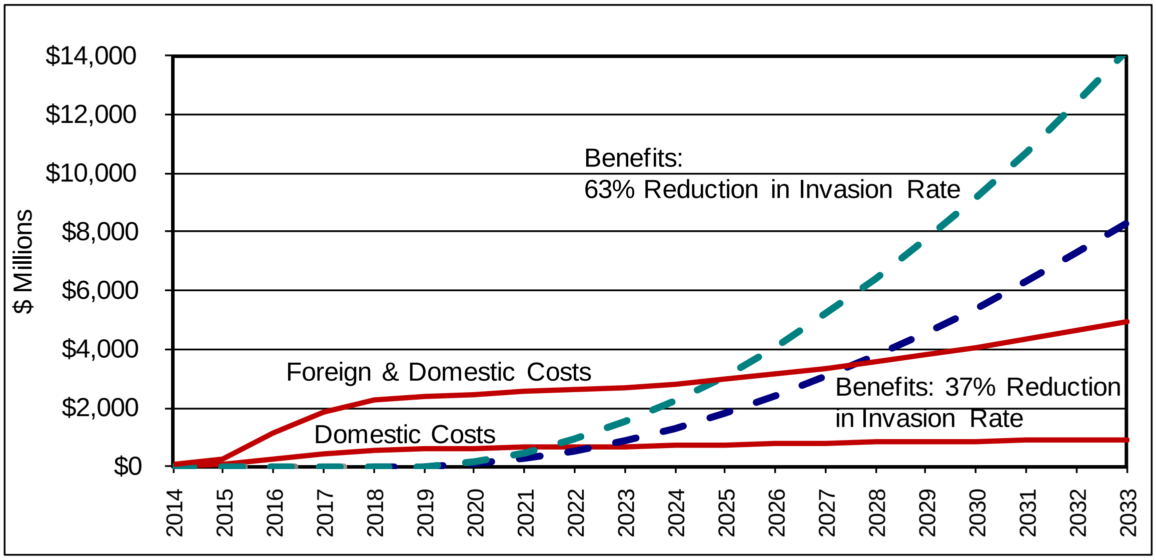
Table D-8 Total Cost of the Rulemaking to U.S. and Foreign Vessels ($Mil)

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
2014	$165.76	$159.57	7,258,222.86	$0.99	$0.96	$166.75	$160.52
2015	$130.04	$120.50	11,018,776.04	$1.55	$1.44	$131.60	$121.94
2016	$793.18	$707.51	76,986,014.36	$9.97	$8.90	$803.16	$716.41
2017	$740.25	$635.61	136,789,064.58	$17.27	$14.83	$757.52	$650.44
2018	$423.61	$350.14	166,424,588.16	$20.50	$16.95	$444.11	$367.08
2019	$85.58	$68.09	168,569,876.26	$20.24	$16.10	$105.82	$84.19
2020	$85.62	$65.58	173,825,737.05	$20.25	$15.51	$105.87	$81.09
2021	$85.67	$63.17	179,207,285.60	$20.26	$14.93	$105.93	$78.10
2022	$85.74	$60.85	184,717,818.82	$20.26	$14.38	$106.01	$75.23
2023	$85.83	$58.64	190,360,716.72	$20.26	$13.84	$106.09	$72.48
Total	$2,681.30	$2,289.65		$151.55	$117.83	$2,832.86	$2,407.48
Annualized	$314.33	$326.00		$17.77	$16.78	$332.10	$342.77

Comparison of Discounted Cumulative Benefits and Costs

When costs to foreign-flagged vessels are added to the domestic costs, the rule would reach the breakeven point (discounted cumulative benefits equal or outweigh discounted cumulative costs) by 2025 assuming a 63 percent reduction in the invasion rate and 2028 assuming a 37 percent reduction in the invasion rate. Figure D-1 illustrates the cumulative costs of the BWD in relationship to the cumulative damages avoided to U.S. waters.

Figure D-1 Comparison of Cumulative Costs and Benefits (7% Discount Rate, $2007, Mid-Point Benefit per Invasion Estimate)



Appendix E Information Provided by Public Comments

We received several comments from the public providing data on the BWMS costs during the NPRM public comment. We present the information submitted by the public in table E-1. For the standard and applicability of the FR, equipment and installation costs provided by the public are consistent with the costs in the RA. Therefore, there was no need to modify the range of costs used by Coast Guard due to the publicly supplied cost data. Some of the cost data provided by the public and presented below is related to vessels that are now excluded from the FR, such as Great Lakes and inland vessels. This data was not used on the FR analysis, but will be incorporated into any future applicable analyses.

Table E-1 Cost Information on BWMS Provided by Public Comments

Comment	Equipment Costs	Installation Costs	O & M Costs (per year)	System size	Retrofitting costs	System	Shipyard costs (per vessels)
1	$400K - $580K	-	-	-	-	-	-
2	$250K - $580K	10% of equipment cost	-		-		-
3	$600K - $700K	25% - 75% of equipment cost	-	$1200 m^3/h$ - $1500 m^3/h$	-		-
4	-	-	-	-	$20 million		-
5	$200K - $250K	-	-	-	-	UV	-
6	$750K	-	-	-	-	Filter	-
7	$640K- 1.67Mil	$134K	$21K per system	-	-	-	-
8	$250K - $2mil	$2.5 - $500K	-	-	-	-	-
9	-	-	-	-	-	-	$50K - 100K
10	>$500K	-	$85K - $875K	-	-	-	-

Appendix F Aquatic NIS Invasion Process

This Appendix provides a brief summary of the scientific understanding of the aquatic NIS invasion process. It highlights the factors and events related to the introduction and successful establishment of aquatic NIS transported by a vector (e.g., ballast water). This analysis was prepared to provide the technical foundation for the Programmatic Environmental Impact Statement (PEIS) developed in support of the United States Coast Guard (USCG) Ballast Water Discharge Standard (BWDS) rulemaking. For the purposes of the FPEIS, the analysis focuses on the transport of individual organisms in ballast water and release into a new location (introduction), and the evaluation of whether these individuals provide the basis for successful population growth and survival (establishment).

NIS introduction occurs when a species survives transport by a vector and is released into a new environment. Establishment occurs when the introduced species reproduces and spreads in its new environment. Thus, in simple terms, it is assumed that NIS are introduced when individual organisms are transported in ballast water and released into a new, non-native, location, whereas establishment occurs when introduced NIS establish a viable population. Impacts occur when an introduced species establishes a population that alters the ecology, food web, or fisheries, or otherwise disrupts the natural ecosystem or socioeconomics of an environment or region.

Many factors affect the survival, spread, and proliferation of introduced species, including basic climatic factors and food resources, the nature of the reproductive biology of a species, and the presence or absence of competitors, predators, and parasites (Carlton 1996). The dispersal of introduced NIS occurs through vectorsF[70]F – the physical means or agent for transporting a species. In broad terms, the successful establishment of NIS involves seven sequential events, each having an associated probability of occurrence: (1) interface of species with transport vector; (2) vector take-up (engaging) of specific species; (3) survival of the transport event; (4) release from vector; (5) initial survival upon release; (6) establishment of first reproducing population; and (7) establishment of long-term reproducing populations.

Each of these events is briefly described below, in a summary largely drawn from Carlton (1985). Some of these events may not be directly relevant to the discussion of potential impacts of BWDS, but they help in presenting the overall context of the NIS invasion process:

1. Probability of interfacing with transport vector – species in the water column may or may not be immediately adjacent to the vessel at the moment the vessel is in a position to engage the local biota by drawing in ballast water. There is large temporal and spatial variability (determined by currents, tides, temperatures, salinity, stochastic events such as storms, as well as random probability) of the probability of interfacing with the transport vector, which can change within minutes to hours (as well as seasonally and annually). This temporal and spatial variability of the probability of interface determines which species are or are not in the available species pool for transport to a different location.

[70] Vector is the physical means or agent by which a species is transported. Ballast water is the vector of interest in this rulemaking, but many others exist and play an important role in the dispersal of NIS worldwide, including ships' hulls (fouling organisms), drilling platforms and dry docks, fisheries activities, and the aquarium pet industry.

2. Probability of transport vector engaging specific species – only a subset of the pool of available species immediately next to the vessel are actually taken into the vessel. That is, being adjacent to the ship and within the effective zone of a vessel's ballast water intake at the time of ballasting does not necessarily result in uptake. For example, species such as some shrimp and fish actively detect a water current (like the one created by the uptake of ballast water) and swim away from it. In addition, other species may not be engaged in the water flow as readily as others, even when acting as passive particles (e.g., planktonic organisms), due to their size, shape, or relative density.

3. Probability of surviving the transport event – a substantial number of factors interact to determine the probability of a transported species surviving before being released. For example, the uptake process (including injury due to physical contact with the ship and its systems), light, temperature, salinity, oxygen, food, voyage duration, and other variables during transport all play an important role. Given the fact that there are thousands of species being transported in ballast water, it is particularly difficult to characterize the probabilities, except in very broad terms (i.e., the large variability in terms of the type of organisms entrained as well as the physical conditions in the ballast water, creates both 'species specific' and 'voyage specific' probabilities).

4. Probability of being released – not all species transported are released; for example, organisms in a ballast tank may not leave the ballast tank, if not all of the water is discharged, or if the organisms in question are fouling species that attach themselves to the inside of the tank or imbed in the sediment that collects in the ballast tank. Organisms in a ballasted cargo hold are always either fully discharged (since the cargo now replaces 100% of the ballast water) or die in transport (organisms that have settled on the cargo hold walls die of exposure, desiccation, or smothering by the cargo) (Carlton 2005). It is important to distinguish between these two different ballast systems (ballast tank and ballastable cargo hold) because of the long-term potential of ballast water in ballast tanks to not result in complete release after each voyage, which can then lead to colonies of living organisms in ballast tanks that remain there for a considerable period of time. These organisms could essentially re-seed the ship with larvae or other propagules, and pose a risk for future introductions even without new ballasting.

5. Probability of initial survival upon release – regardless of inoculum size (the number of released individuals of any life stage), most released species (and perhaps all released species for most discharge events) do not survive after release. In addition, the discharge process can also result in injury to transported organisms due to physical contact with the ship systems. The scientific community does not have a complete understanding of the reasons for this, although some of the many potential causes include post-transport physiological weakness, post-transport starvation, physiological mismatch with the new environment once released, predation (consumption) at the release site, and competition with the resident biota. Over the decades, numerous vessels arriving in U.S. coastal waters have discharged millions of organisms (e.g., diatoms, copepods, worm larvae), which have appear to result in relatively few invasions. This fact is interpreted by the scientific community as the result of failure of initial survival. However, there is no

certainty in this, as many other factors could be coming into play, including: many of the organisms could have survived but not reproduced, and therefore failed to establish permanent populations; invasions could simply be overlooked for abundant, but poorly studied organisms and as such not recognized as invaders (seriously skewing our appreciation of the extent of invasions); or some established species that are considered rare may have population levels so low that they are below our ability to detect them without targeted searches.

6. Probability of establishing the first reproducing population – as a general proposition, the probability that a species reproduces and becomes successfully established is positively related to the number of individual organisms that are introduced. Thus, the number of organisms of a particular species released via ballast water is a potentially important determinant of the probability that a population establishes its first reproducing population. However, it is important to highlight that the probability that an inoculum may result in an established population may also be largely dependent on dilution of the inoculum, hydrodynamics of water flow, and local microtopographic features, which affect the distribution of introduced organisms in the new environment. Those factors affect the ability to reproduce by influencing the probability that organisms of the same species interact with each other. However, there are a number of life stages and sexual and asexual reproductive modes which may characterize organisms in BW. For example, the presence of ovigerous females, bacteria, and spore-releasing organisms can result in elevated reproductive potential of the species in the receiving waters and is independent of the number of organisms released.

7. Probability of establishing long-term reproducing populations – the establishment of long-term reproducing populations is dependent on a wide range of biological and physical variables. In addition, it is important to note that there is no scientific consensus about the meaning of "long-term" reproducing populations. For example, there are many scientists who, observing a new invader with multiple populations in a specific ecosystem and with multiple generations represented, argue that sampling needs to be conducted some time in the future (5 or 10 years) to verify whether the species is still present before concluding that long-term establishment has occurred.

While each event is important and must be realized for invasion success, the most critical event for prevention of invasions is release. If the numbers released are sufficiently low that establishment does not occur the invasion is prevented.

Predicting Invasion and Potential Impacts of NIS

Biological and physical interactions in aquatic ecosystems are highly complex. Aquatic organisms are not static, isolated entities that merely occupy space in the water column or the benthic environment of aquatic ecosystems; they interact dynamically with their physical, chemical, and biological environment as components of an ecosystem. In addition, there is very limited information about the biology and ecology of the majority of aquatic species. The BWDS rulemaking is national in nature and thus applicable to widely diverse aquatic ecosystems throughout the U.S., thus increasing the relevance of the limitations of our knowledge for analyzing the alternatives in the FPEIS. These limitations, together with the variability involved in the transport of aquatic organisms via ballast water, makes it extremely difficult to predict which NIS from a potential pool of thousands of species are likely to be delivered, which NIS are likely to become successfully established, and which NIS are likely to significantly affect the invaded ecosystems.

The introduction and establishment of species into a new environment is so complex and full of variability and uncertainty, that it has been called “a game of ecological roulette” (Carlton and Geller 1993). The complexities associated with – and the limited knowledge of – the invasion process make predicting which organisms arrive, their origin, the time of their arrival, and whether they survive, persist, spread, and proliferate, an exceptionally challenging problem.

Invasion rates vary dramatically with region and propagule delivery (vector) history. One of the main factors to be considered in the current context is the large variability in the densities of organisms transported via ballast water. Sampling studies show that organism densities in ballast water can range from very low (as little as 1 individual per cubic meter) to very high (thousands per cubic meter) (Carlton 2001, Cohen 1998). Low observed densities are generally associated with sampling schemes targeting multicellular forms or larger protists. In many cases, however, the bacterial and viral components may exist in higher concentrations. Furthermore, the potential number of organisms released by a given vessel could be considerable depending on the total amount of BW discharged. In addition, survival varies greatly in transits. However, in general, the longer the voyage, the more organisms die. Exceptions are species that reproduce in situ in the water column or that reproduce from the ballast benthic communities and shed larvae into the water column, and organisms that go into a resistant or dormant stage such as dinoflagellates cysts that can persist in the sediments when stressful conditions are intolerable for vegetative or reproductive stages.

The extinction threshold (or conversely, the minimum number of organisms necessary for successful establishment) is unknown for most species under most conditions. For many organisms, the initial population sizes required for successful establishment upon release may be much lower than generally predicted. In theory, even a single organism, if monoecious, hermaphroditic, or parthenogenic, could establish a successful population. Many species that have such cycles have been found to be capable of successful establishment (Sakai et al. 2001) because they only need one individual to invade a new environment (Davis 2005). Thus, it is very difficult to determine whether a very small initial population size or a very large one led to successful establishment of a particular NIS.

Understanding this would require detailed knowledge of the precise life stage of the specific species in question that would be released, in what numbers, into what ecosystem, and with what hydrodynamicF[71]F conditions at the moment of release. Unfortunately, (most of the time, for most species, for most release events, at most places), only limited information is available, thus

[71] In invasive species ecology, the "lagoonal hypothesis" argues that a few individuals can find themselves in a retention system that prevents loss due to export, such that a population can become established from a very small initial population size. This can be interpreted as meaning that most species simply do not successfully become established because upon release the individuals become so dispersed that the organisms do not locate each other to reproduce (not applicable to asexually reproducing species) even if some of these individuals survive and settle as transient species and establish an initially successful population. Thus, local (stochastic) events may facilitate invasion from a very small number of released organisms.

limiting the possibility of providing a more definitive assessment of the probability of invasion (Carlton 2005). It follows from the discussion above (e.g., in theory even a single organism of a particular species can lead to successful establishment) that it is impossible to accurately predict whether individuals of unknown species in a given vessel on a given voyage will become successfully established when released in a new environment, or go extinct.

An additional complicating factor is that a large number of species are not studied to determine their potential invasive capacity in a new environment. Some of the main ecological factors that determine the invasive capacity of organisms in a new environment include niche availability, lack of predation, resource abundance, and competitive advantage.

For example, the shore crab *Hemigrapsus sanguineus* is of no particular concern in its native Asia, but it became a highly invasive species (with significant ecological impacts) when introduced to the U.S. Atlantic coast in the 1980s. In the 19 years since its discovery at Cape May, NJ in 1988, it has spread and can now be found in large numbers from Maine to the Carolinas. Further, detailed studies in Japan reveal that this crab is strictly a rocky shore (intertidal) species in its native range. However, on the U.S. Atlantic coast, it has become established in no fewer than five different habitats (USGS 2006). This was not a predictable outcome; thus, the invasion potential and impact of this species (and potentially many others) was not predictable from knowledge of its biology and ecology in its native environment (Carlton 2005).

The context provided above sets the broader stage of the invasion process, and summarizes the variables that need to be considered to analyze the alternatives and their potential implications. It is important to clarify that, while (in general) the likelihood that any given individual of a particular species might go through all the steps previously described and become successfully established in the long-term is quite low, the likelihood that a vessel will release live organisms from ballast water is high.

Current scientific knowledge makes predicting the fate of even a single population for even well studied organisms a very challenging problem. Indeed, Ludwig (1999) has argued that it is essentially impossible. The problem is even more challenging in the context of assessing the aggregate effect of the BWDSs (specified under the alternatives) on the rate at which NIS are introduced and become established in waters of the United States. This is because the populations of concern are difficult to identify and not well-studied. Predicting the ecological or economic impacts of NIS that successfully become established is even more challenging because cause and effect relationships would need to be established and well-defined (Carlton 2001) and the current poorly resolved state of scientific knowledge makes the latter very difficult. It is important to clarify that the difficulty lies in the prediction of which species will become established and the nature and extent of their subsequent impacts, even if the likelihood of organisms being released is considerable.

Management measures aimed at reducing the number of organisms released are implicitly or explicitly aimed at reducing the probability that a population will become established or, equivalently, increasing the probability that the relatively small initial population will become extinct after introduction. Thus, the BWDSs prescribed under the alternatives differ in the degree to which they reduce the number of organisms that are introduced via discharged ballast water. The number of individual organisms introduced will be referred to as the initial population size. Even when transport and release occur, ballast water management efforts that reduce the number of organisms released (such as the alternatives analyzed in the PEIS) can help to prevent successful establishment. As a general proposition, the probability that a population will become extinct is inversely related to the initial population size of the species of interest.

The PEIS used the Population Viability Analysis (PVA) to analyze the relationship between population size and extinction probability for this rulemaking. PVA refers to the use of quantitative methods to predict the likely future status of a population or collection of populations of conservation (or extinction) concern. PVA is performed by developing a mathematical model of the dynamics of the population of interest and using this model to predict the effect of varying the initial population size (or other factors) on extinction probability and other variables of interest in conservation (Boyce 1992). PVA is typically used to assess the conservation status of a particular population and therefore typically involves the development of a model of the dynamics of each population of interest separately. The PEIS presents a detailed discussion on the use of PVA (PEIS, Appendix A) and the model results. As a result of the PVA model used in the PEIS we were able to estimate reductions in the mean rate of successful INS introductions. The reduction in the mean rate was used in our benefits estimates in Chapter 5 of this document.

References:

Boyce, M. 1992. “Population Viability Analysis”. *Annual Review of Ecology and Systematics* 23: 481-506.

Carlton, J.T. 1985. “Transoceanic and Interoceanic Dispersal of Coastal Marine Organisms: The Biology of Ballast Water”. *Oceanography and Marine Biology Annual Review* 23: 313–371.

Carlton, J. T. 2001. Introduced Species in United States Coastal Waters: Environmental Impacts and Management Priorities. Pew Oceans Commission, Arlington, Virginia.

Carlton, J.T. 2005. Personal communication with José G. Mantilla by electronic mail. December 15, 2005.

Carlton, J.T. and Geller, J.B. 1993. “Ecological Roulette: The Global Transport of Nonindigenous Marine Organisms”. *Science*, 261(5117): 78-82.

Cohen, A.N. 1998. Ships’ Ballast Water and the Introduction of Exotic Organisms into the San Francisco Estuary. San Francisco Estuary Institute, Richmond, CA.

Davis, C. 2005. Personal communication with José G. Mantilla by electronic mail. December 15, 2005.

Ludwig, D. 1999. “Is It Meaningful to Estimate a Probability of Extinction?” *Ecology* 80(1): 298-310.

Sakai A.K., Allendorf, F.W., Holt, J.S., Lodge, D.M., Molofsky, J., With, K.A., Baughman, S., Cabin, R.J., Cohen, J.E., Ellstrand, N.C., McCauley, D.E., O' Neil, P., Parker, I.M., Thompson, J.N., and Weller, S.G. 2001. “The Population Biology of Invasive Species”. *Annual Review of Ecology and Systematics* 32 (1): 305-332.

USGS, 2006. “Nonindigenous Species Information Bulletin: Asian Shore Crab, Japanese Shore Crab, Pacific Crab, *Hemigrapsus sanguineus* (De Haan) (Arthropoda: Grapsidae)” http://cars.er.usgs.gov/Nonindigenous_Species/Asian_shore_crab/asian_shore_crab.html

Appendix G Alternative Analyses of Benefits (Economic Costs Avoided)

Summary of Benefits Assuming Benefits Deferred Until All Vessels Install Management Systems:

Table G-1 Benefits by Year Under Deferred Assumption – 7% ($Mil)

	7% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
2014	$0	$0	$0	$0	$0	$0
2015	$0	$0	$0	$0	$0	$0
2016	$0	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0	$0
2019	$3	$76	$150	$5	$130	$255
2020	$5	$144	$283	$9	$246	$482
2021	$8	$205	$402	$13	$349	$684
2022	$10	$258	$507	$16	$440	$863
2023	$11	$305	$599	$19	$520	$1,020
Total	$37	$989	$1,941	$63	$1,684	$3,304
Annualized	$5	$141	$276	$9	$240	$470

Table G-2 Benefits by Year Under Deferred Assumption – 3% ($Mil)

	3% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
2014	$0	$0	$0	$0	$0	$0
2015	$0	$0	$0	$0	$0	$0
2016	$0	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0	$0
2019	$3	$92	$181	$6	$157	$308
2020	$7	$181	$356	$12	$309	$606
2021	$10	$267	$525	$17	$455	$893
2022	$13	$350	$687	$22	$596	$1,170
2023	$16	$430	$844	$27	$733	$1,438
Total	$49	$1,321	$2,593	$84	$2,250	$4,416

Annualized	$6	$155	$304	$10	$264	$518

Several commenters expressed the view that Coast Guard did not fully account for all benefits that might result from a ballast water discharge standard in the 10-year period of analysis used in the NPRM RA. In response to these comments, we provide two alternative analyses of benefits – one that extends the comparison of benefits and costs over a longer, 20-year time period and one in which we assume that invasions are avoided before the entire fleet as installed management systems. For this alternative, we assume that the fraction of invasions avoided is proportional to the fraction of vessels (percent of fleet) that has installed management systems.

Summary of Benefits Assuming No Benefits Until Rule All Vessels Install Management Systems, 20-Year Period of Analysis:

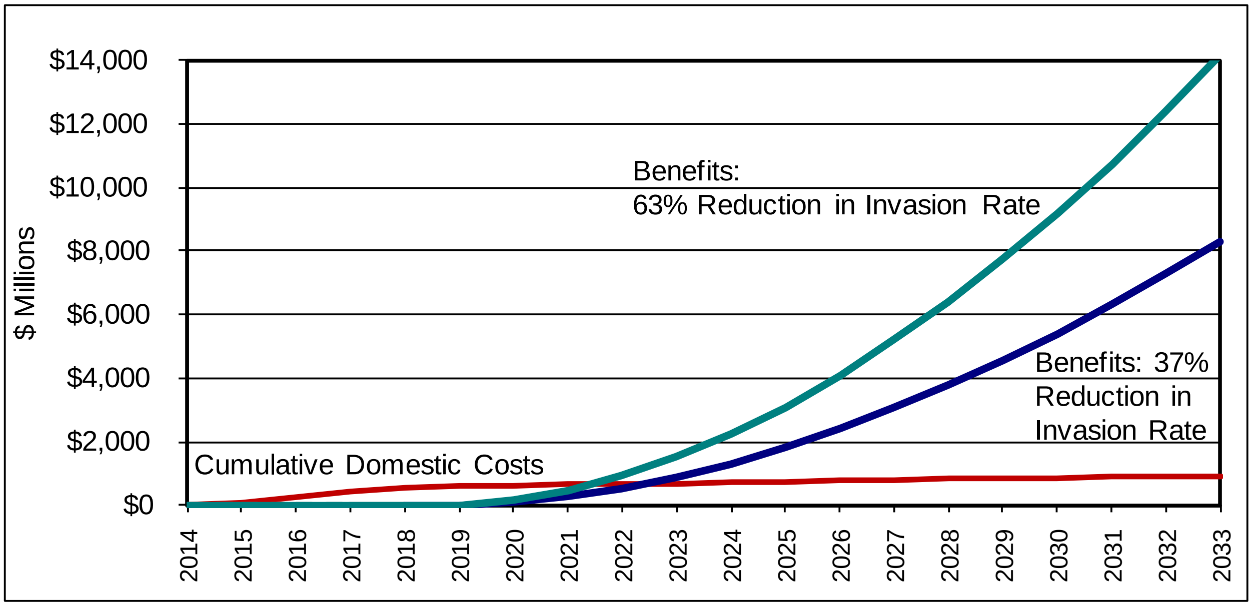
Table G-3 Benefits by Year Under Deferred Assumption, 20-Year Period of Analysis– 7% ($Mil)

	7% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	Low	Mid	High	Low	Mid	High
2014	$0	$0	$0	$0	$0	$0
2015	$0	$0	$0	$0	$0	$0
2016	$0	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0	$0
2019	$3	$76	$150	$5	$130	$255
2020	$5	$144	$283	$9	$246	$482
2021	$8	$205	$402	$13	$349	$684
2022	$10	$258	$507	$16	$440	$863
2023	$11	$305	$599	$19	$520	$1,020
2024	$13	$347	$680	$22	$590	$1,159
2025	$14	$383	$751	$24	$652	$1,279
2026	$15	$414	$812	$26	$705	$1,383
2027	$16	$440	$865	$28	$750	$1,472
2028	$17	$463	$909	$29	$789	$1,548
2029	$18	$482	$946	$31	$821	$1,611
2030	$19	$498	$977	$32	$848	$1,664
2031	$19	$510	$1,002	$32	$869	$1,706
2032	$19	$520	$1,021	$33	$886	$1,738
2033	$20	$528	$1,035	$33	$898	$1,763
Total	$208	$5,573	$10,939	$354	$9,490	$18,626
Annualized	$20	$526	$1,033	$33	$896	$1,758

Table G-4 Benefits by Year Under Deferred Assumption, 20-Year Period of Analysis– 3% ($Mil)

	3% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	Low	Mid	High	Low	Mid	High
2014	$0	$0	$0	$0	$0	$0
2015	$0	$0	$0	$0	$0	$0
2016	$0	$0	$0	$0	$0	$0
2017	$0	$0	$0	$0	$0	$0
2018	$0	$0	$0	$0	$0	$0
2019	$3	$92	$181	$6	$157	$308
2020	$7	$181	$356	$12	$309	$606
2021	$10	$267	$525	$17	$455	$893
2022	$13	$350	$687	$22	$596	$1,170
2023	$16	$430	$844	$27	$733	$1,438
2024	$19	$507	$996	$32	$864	$1,696
2025	$22	$582	$1,142	$37	$991	$1,945
2026	$24	$654	$1,283	$41	$1,113	$2,184
2027	$27	$723	$1,419	$46	$1,231	$2,416
2028	$29	$790	$1,550	$50	$1,344	$2,639
2029	$32	$854	$1,676	$54	$1,454	$2,853
2030	$34	$916	$1,797	$58	$1,559	$3,060
2031	$36	$975	$1,914	$62	$1,661	$3,260
2032	$38	$1,033	$2,027	$66	$1,758	$3,451
2033	$41	$1,088	$2,136	$69	$1,853	$3,636
Total	$352	$9,442	$18,533	$599	$16,077	$31,556
Annualized	$24	$635	$1,246	$40	$1,081	$2,121

Figure G-1 Cumulative Benefits and Costs Under Deferred Assumption, 20-Year Period of Analysis– 7%



We also calculated benefits assuming that the reductions in invasions would be proportional to the fraction of the fleet that had installed a management system. Under this assumption, benefits of the BWDS start accruing in the first year of the analysis (2014) as new vessels begin to install management systems. Under this assumption, the mid-range of annual benefits is $305-$519 million at 7 percent, in comparison to a range of $141-$240 million when we assume that benefits do not accrue until all vessels have installed treatment.

Table G-5 Benefits by Year Under Phased-In Assumption – 7% ($Mil)

	7% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	Low	Mid	High	Low	Mid	High
2014	$0	$3	$6	$0	$6	$11
2015	$1	$14	$28	$1	$24	$47
2016	$2	$54	$106	$3	$92	$180
2017	$4	$117	$230	$7	$199	$391
2018	$7	$189	$371	$12	$322	$632
2019	$9	$253	$497	$16	$431	$845
2020	$12	$309	$607	$20	$527	$1,034
2021	$13	$359	$705	$23	$611	$1,200
2022	$15	$402	$790	$26	$685	$1,345
2023	$16	$440	$864	$28	$749	$1,471
Total	$80	$2,141	$4,203	$136	$3,646	$7,157
Annualized	$11	$305	$598	$19	$519	$1,019

Table G-6 Benefits by Year Under Phased-In Assumption – 3% ($Mil)

	3% Discount Rate					
	Low Effectiveness - 37%			High Effectiveness - 63%		
Year	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**
2014	$0	$3	$6	$0	$6	$11
2015	$1	$15	$29	$1	$25	$49
2016	$2	$58	$114	$4	$99	$194
2017	$5	$131	$258	$8	$224	$439
2018	$8	$220	$432	$14	$375	$736
2019	$11	$306	$601	$19	$521	$1,023
2020	$14	$389	$763	$25	$662	$1,300
2021	$17	$469	$920	$30	$798	$1,567
2022	$20	$546	$1,071	$35	$929	$1,824
2023	$23	$620	$1,217	$39	$1,056	$2,073
Total	$103	$2,757	$5,412	$175	$4,695	$9,215
Annualized	$12	$323	$634	$21	$550	$1,080

Appendix H 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. 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 H-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 $1,060,000,000 annually updated to 2007 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 $1,060,000,000 annually updated to 2007 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 $1.060 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 ($19.6 million updated to 2007). O'Neill 1997 provided an estimate of $17.751 million per year for infrastructure owners and operators. 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 ($1.060 billion) and lower end ($19.538 million) is $539.769 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 $305.289 million updated (based on varying assumptions about the loss of yellow perch and walleye populations). We use the upper estimate of $305.289 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 $15.8 million.

- The calculated mid-range between the upper end ($305.3 million) and lower end ($15.8 million) is $160.547 million.

Aquatic Plants

- At the upper end, Pimentel 2005 estimates that the costs to control Eurasion milfoil is $400 million per year ($424.7 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 $4.5 million.

- The calculated mid-range between the upper end ($424.7 million and lower end ($4.5 million) is $214.6 million.

Summary

Table H-1 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$

Table H-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" 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	GAO estimates	Annual costs to the American power industry	$ 60,000,000	

Needed to Effectively Manage the Problem, October 2002, GAO-03-01.	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
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

New Zealand Mud Snail

Reference:	Source:	What is included in estimate?	Annual Cost	Price Level
Davis, A. and Moeltner, K. *Valuing the Prevention of an Infestation: The Threat of the New Zealand Mud Snail in Northern Nevada*. UNR Joint Economics Working Paper Series Working Paper No. 09-001. July 2009.	Original analysis	Welfare and expenditure losses to recreational fishermen for 3 possible policies to control New Zealand mud snail in the Truckee/Carson/Walker watershed	$ 17,000,000 to $40,000,000	2009

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

S. Lovell, S., Besedin, E., and E. Grosholz. Modeling Economic Impacts of the European Green Crab. American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007	Original analysis	Damage to commercial shellfishery including soft-shell clams, hard clams, Manilla clams, and mussels from green crab predation on the East Coast	$22,600,000	2006

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
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
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
Horsch, E. J. and D. J. Lewis. The Effects of Aquatic Invasive Species on Property Values: Evidence from a Quasi-Random Experiment. University of Wisconsin-Madison Department of Agricultural & Applied Economics. AGRICULTURAL & APPLIED ECONOMICS STAFF PAPER SERIES. Staff Paper No. 530: November 2008.	Original analysis	Hedonic estimate of the change in property values for lakeside property after infestation with Eurasian Watermilfoil (milfoil)	13% decrease in land values after invasion	2008

Regional Impacts of AIS

Reference:	Source:	What is included in estimate?	Annual Cost	Price Level
U.S. Army Corps of Engineers. Lake Tahoe Region Aquatic Invasive Species Management Plan, California - Nevada. 2009.	Original analysis	Average annual damages from AIS in the Lake Tahoe region in the categories of recreation, tourism, property values, water supply, boats/piers	$ 22,427,000	2009