2009 ASSESSMENT OF THE EFFICACY, AVAILABILITY AND ENVIRONMENTAL IMPACTS OF BALLAST WATER TREATMENT SYSTEMS FOR USE IN CALIFORNIA WATERS

PRODUCED FOR THE
CALIFORNIA STATE LEGISLATURE

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EXECUTIVE SUMMARY

The Coastal Ecosystems Protection Act (Act) of 2006 expanded the Marine Invasive Species Act of 2003 to more effectively address the threat of nonindigenous species introduction through ballast water discharge. The Act charged the California State Lands Commission (Commission) to implement performance standards for the discharge of ballast water and to prepare a report assessing the efficacy, availability, and environmental impacts, including water quality, of currently available ballast water treatment technologies. The performance standards regulations were adopted in October 2007, and the first technology assessment report was approved by the Commission in December 2007 (see Dobroski et al. 2007). In response to the recommendations in the 2007 report, the California Legislature passed Senate Bill (SB) 1781 (Chapter 696, Statutes of 2008) which delayed the initial implementation of the performance standards from January 1, 2009 to January 1, 2010. Additionally, SB 1781 required an update of the technology assessment report by January 1, 2009. This report summarizes the Commission's conclusions on the advancement of ballast water treatment technology development and evaluation during 2008, discusses future plans of the Commission's Marine Invasive Species Program regarding the implementation of California's performance standards for the discharge of ballast water, and makes recommendations to the Legislature.

Significant progress has been made in the development of treatment systems since the previous technology assessment report (see Dobroski et al. 2007). Both the quantity and the quality of the recently received data on system performance attest to this fact. The field of treatment technology performance evaluation, however, has not kept pace with the rapidly evolving ballast water treatment industry. Scientific methods to assess the concentration of viable organisms present in ballast water discharge still must be developed so that Commission staff may rapidly assess vessel compliance with the ballast water performance standards.

California's standards for bacteria and viruses pose a significant challenge, as no widely accepted methods exist to both quantify and assess the viability of all bacteria and

viruses in a sample of ballast water discharge. The best available technique for bacterial assessment involves the use of a subset or proxy group of organisms to represent treatment of bacteria as a whole. While this technique is not without some debate, it is scientifically supported by many experts in microbiology and technology assessment (see Appendix A). The viruses pose a greater challenge. Without strong evidence for the selection of proxy organisms in this size class, Commission staff believes that there are no acceptable methods for verification of compliance with the total viral standard at this time, and that the Commission should proceed with assessment of technologies for the remaining organism size classes in the standards.

Based on the available information and using best assessment techniques, Commission staff reviewed 30 ballast water treatment systems for this report. Staff believes that at least two treatment systems have demonstrated the potential to comply with California's performance standards. Many additional systems are close to completing system performance verification testing and will soon have data available for review. Commission staff expects that before 2010 several systems will be ready to meet California standards.

Over 20 systems are anticipated to be commercially available by the end of 2009 (Lloyd's Register 2008). Systems cannot clearly be deemed "available" for use, however, unless they have demonstrated the ability to meet California's performance standards. The treatment systems that met California's standards under the review for this report are commercially available at this time, and the several additional systems that are close to meeting all of California's standards are also commercially available.

Treatment vendors and vessel operators will also need to assess potential water quality impacts from treatment system usage in California waters. Commission staff, in consultation with the State Water Resources Control Board, has recently distributed to technology vendors a set of "Ballast Water Treatment Technology Testing Guidelines" that provides guidance on relevant water quality control plans and objectives for vessels intending to discharge treated effluent in State waters. Further guidance will be provided by the U.S. Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES) Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels, and the California-specific provisions added to the Vessel General Permit through the Clean Water Act Section 401 certification process. As of the writing of this report, however, those provisions were not available. Based on the available data it is clear that not all treatment systems will meet California's water quality objectives, particularly for chlorine residuals. Vessel owners and operators will need to consult with the Water Board to better assess the potential for water quality impacts from treatment system usage in California waters.

The Commission is preparing to implement the performance standards for new vessels with a ballast water capacity of less than 5000 MT in 2010. This review indicates that systems are or will soon be available to meet California's performance standards, particularly in light of the small number of new vessels that will likely need to meet the standards beginning in 2010. Commission staff is working closely with the shipping industry and treatment vendors to ensure a smooth transition to the new standards.

Commission staff is currently undertaking several projects to develop a comprehensive program for the implementation of California's performance standards including: 1) Developing protocols to verify vessel compliance with the performance standards; 2) Amending the performance standards regulations to bring the regulations in-line with recent changes in statute and to specify requirements for ballast water sample collection and analysis; 3) Revising the Ballast Water Treatment Technology Testing Guidelines, as necessary; and 4) Supporting the development of performance standards and a technology assessment program at the federal level.

Staff will conduct another assessment of available treatment technologies by July 1, 2010 in anticipation of the 2012 implementation date for new vessels with a ballast water capacity greater than 5000 MT.

At this time, the Commission recommends that legislation be adopted to:

1. Authorize the Commission to amend the ballast water reporting requirements via regulations.

In 2007, the Commission recommended that the Legislature provide the Commission with the authority to change the ballast water reporting requirements to include information on the timing of, and requirements for, treatment system use, deviations from suggested system operation, and certifications for operation from vessel classification societies and other organizations/agencies. The statute currently limits the Commission's ability to amend the existing ballast water reporting form or develop a new form to collect necessary information about treatment system usage. To address this challenge, the Legislature proposed and passed Assembly Bill 169 in 2008, which was later vetoed by the Governor along with hundreds of other bills, due to the late passage of the budget. Nonetheless, the need for more information about treatment system installation and usage remains. The Commission should be authorized to amend the ballast water reporting requirements to meet these needs.

2. Support continued research promoting technology development and performance evaluation.

Ballast water treatment is an emerging industry that will continue to develop as California's Performance Standards are progressively implemented and as new vessel types are built. The scientific evaluation of treatment technology performance is also in its infancy, and new methods and techniques will be necessary to assess discharge compliance. The research and development needed to meet and assess compliance with these standards will require substantial financial resources. Funds necessary to support these research needs could be obtained through three mechanisms: general funds, grants, or through the existing fees assessed on ships. The Commission and the Legislature should support future budget change proposals or other fiscal actions to ensure that the development of evaluation methods may keep pace with the advancement of treatment technologies and with the performance standards implementation.

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ABBREVIATIONS AND TERMS

AB	Assembly Bill
Act	Coastal Ecosystems Protection Act
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CSLC/Commission	California State Lands Commission
CTR	California Toxics Rule
Convention	International Convention for the Control and Management of Ships' Ballast Water and Sediments
CWA	Clean Water Act
EEZ	Exclusive Economic Zone
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification Program
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GESAMP-BWWG	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection – Ballast Water Working Group
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
Michigan DEQ	Michigan Department of Environmental Quality
MPCA	Minnesota Pollution Control Agency
MT	Metric Ton
NEPA	National Environmental Policy Act
NIS	Nonindigenous Species
nm	Nautical Mile
NPDES	National Pollution Discharge Elimination System
NRL	Naval Research Laboratory
PRC	Public Resources Code
SB	Senate Bill
Staff	Commission staff
STEP	Shipboard Technology Evaluation Program
TRC	Total Residual Chlorine
TRO	Total Residual Oxidant
USCG	United States Coast Guard
UV	Ultraviolet Irradiation
Vessel General Permit	Vessel General Permit for Discharges Incidental to the Normal Operation of Commercial Vessels and Large Recreational Vessels
Water Board	California State Water Resources Control Board
WDFW	Washington Department of Fish and Wildlife
WET	Whole Effluent Toxicity

I. PURPOSE

This report was prepared for the California Legislature pursuant to the Coastal Ecosystems Protection Act of 2006 (Act). Among its provisions, the Act added Section 71205.3 to the Public Resources Code (PRC) which required the California State Lands Commission (Commission) to prepare and submit to the Legislature, "a review of the efficacy, availability, and environmental impacts, including the effect on water quality, of currently available technologies for ballast water treatment systems." The initial technology assessment report, "Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters," was approved by the Commission in December 2007 and submitted to the California Legislature (see Dobroski et al. 2007). In response to the recommendations in that report, the Legislature passed Senate Bill (SB) 1781 in 2008 (Chapter 696, Statutes of 2008) which amended PRC Section 71205.3 to delay the initial implementation of California's performance standards for the discharge of ballast water from January 1, 2009 to January 1, 2010. Additionally, the bill required an update of the initial technology assessment report by January 1, 2009 in anticipation of the implementation of the performance standards in 2010. This report summarizes Commission conclusions on the advancement of ballast water treatment technology development and assessment during 2008, discusses plans developed by Commission staff to implement California's performance standards for the discharge of ballast water, and makes recommendations to the Legislature.

II. INTRODUCTION

Nonindigenous Species and their Impacts

Also known as "introduced", "invasive", "exotic", "alien", or "aquatic nuisance species", nonindigenous species (NIS) are organisms that have been transported by human activities to a region where they did not occur historically, and have established reproducing populations in the wild (Carlton 2001). Once established, NIS can have serious human health, economic and environmental impacts in their new environment.

One of the most infamous examples is the zebra mussel (*Dreissena polymorpha*), which was introduced from the Black Sea to the Great Lakes in the mid-1980s (Carlton 2008) and was discovered in California in 2008 (California Department of Fish and Game 2008). This tiny striped mussel attaches to hard surfaces in dense populations that clog municipal water systems and electric generating plants, costing approximately $1 billion a year in damage and control for the Great Lakes alone (Pimentel et al. 2005). In San Francisco Bay, the overbite clam (*Corbula amurensis*) is thought to have contributed to declines of fish populations in the Sacramento-San Joaquin River Delta by reducing the availability of the plankton food base of the ecosystem (Feyrer et al. 2003). The Chinese mitten crab (*Eriocheir sinensis*), first sighted in San Francisco Bay in 1992, clogged water pumping stations and riddled levies with burrows costing approximately $1 million in 2000-2001 for control and research (Carlton 2001). In addition, the microorganisms that cause human cholera (Ruiz et al. 2000) and paralytic shellfish poisoning (Hallegraeff 1998) have been found in the ballast tanks of ships.

In marine, estuarine and freshwater environments, NIS may be transported to new regions through various human activities including aquaculture, the aquarium and pet trade, and bait shipments (Cohen and Carlton 1995, Weigle et al. 2005). In coastal habitats commercial shipping is an important transport mechanism, or “vector,” for invasion. In one study, shipping was responsible for or contributed to approximately 80% of invertebrate and algae introductions to North America (Fofonoff et al. 2003, see also Cohen and Carlton 1995 for San Francisco Bay). Ballast water was a possible vector for 69% of those shipping introductions, making it a significant ship-based introduction vector (Fofonoff et al. 2003).

Ballast water is necessary for many functions related to the trim, stability, maneuverability, and propulsion of large oceangoing vessels (National Research Council 1996). Vessels take on, discharge, or redistribute water during cargo loading and unloading, as they take on and burn fuel, as they encounter rough seas, or as they transit through shallow coastal waterways. Typically, a vessel takes on ballast water after its cargo is unloaded in one port to compensate for the weight imbalance, and will later discharge that water when cargo is loaded in another port. This transfer of ballast water from "source" to "destination" ports results in the movement of many organisms from one region to the next. In this fashion, it is estimated that more than 7000 species are moved around the world on a daily basis (Carlton 1999).

Ballast Water Management

Attempts to eradicate NIS after they have become widely distributed are often costly and unsuccessful (Carlton 2001). Between 2000 and 2006, over $7 million was spent to eradicate the Mediterranean green seaweed (*Caulerpa taxifolia*) from two embayments in southern California (Woodfield 2006). Approximately $10 million is spent annually to control the sea lamprey (*Petromyzon marinus*) in the Great Lakes (Lovell and Stone 2005). By 2010, over $12 million will have been spent in San Francisco Bay to control the Atlantic cordgrass (*Spartina alterniflora*) (Spellman, M., pers. comm. 2008). These costs reflect only a fraction of the cumulative expense over time as species control is an unending process. Prevention is therefore considered the most desirable way to address the NIS issue.

For the vast majority of commercial vessels, ballast water exchange is the primary management technique to prevent or minimize the transfer of coastal (including bay/estuarine) organisms. During exchange, the biologically rich water that is loaded while a vessel is in port or near the coast is exchanged with the comparatively species- and nutrient-poor waters of the mid-ocean (Zhang and Dickman 1999). Coastal organisms adapted to the conditions of bays, estuaries and shallow coasts are not expected to survive and/or be able to reproduce in the mid-ocean due to the differences in biology (competition, predation, food availability) and oceanography (temperature, salinity, turbidity, nutrient levels) between the two regions (Cohen 1998). Mid-ocean organisms are likewise not expected to survive in coastal waters (Cohen 1998).

Performance Standards for the Discharge of Ballast Water

Ballast water exchange is generally considered an interim tool because of its variable efficacy and operational limitations. Studies indicate that the effectiveness of ballast water exchange at eliminating organisms in tanks ranges widely from 50-99% (Cohen 1998, Parsons 1998, Zhang and Dickman 1999, U.S. Coast Guard 2001, Wonham et al. 2001, MacIsaac et al. 2002). When performed properly, exchange is considered an effective tool to reduce the risk of coastal species invasions (Ruiz and Reid 2007). However, new research demonstrates that the percentage of ballast water exchanged does not necessarily correlate with a proportional decrease in organism abundance (Choi et al. 2005, Ruiz and Reid 2007). Some vessels are regularly routed on short voyages or voyages that remain within 50 nautical miles (nm) of shore, and in such cases, the exchange process may create a delay or require a vessel to deviate from the most direct route. Such deviations can extend travel distances, increasing vessel costs for personnel time and fuel consumption.

In some circumstances, ballast water exchange may not be possible without compromising vessel or crew safety. For example, vessels that encounter adverse weather or experience equipment failure may be unable to conduct ballast water exchange safely. Unmanned barges are incapable of conducting exchange without transferring personnel onboard, a procedure that can present unacceptable danger if attempted in the exposed conditions of the open ocean. In recognition of these challenges, state and federal ballast water regulations allow vessels to forego exchange should the master or person in charge determine that it would place the vessel, its crew, or its passengers at risk. Though the provision is rarely invoked in California, the handful of vessels that use it may subsequently discharge un-exchanged ballast into State waters, presenting a risk of NIS introduction.

Regulatory agencies and the commercial shipping industry have therefore looked toward the development of effective ballast water treatment technologies as a promising management option. For regulators, such systems would provide NIS prevention including in situations where exchange may be unsafe or impossible. Technologies that eliminate organisms more effectively than mid-ocean exchange could provide a consistently higher level of protection to coastal ecosystems from NIS. For the shipping industry, the use of effective ballast water treatment systems might allow voyages to proceed along the shortest routes, in all operational scenarios, thereby saving time and money.

Despite these incentives, until recently, financial investment in the research and development of ballast water treatment systems has been limited and the advancement of ballast water treatment technologies slow. Many barriers have hindered the development of technologies, including equipment design limitations, the cost of technology development, and the lack of guidelines for testing and evaluating performance. However, some shipping industry representatives, technology developers and investors considered the absence of a specific set of ballast water performance standards as a primary deterrent to progress. Performance standards would set benchmark levels for organism discharge that a technology would be required to achieve for it to be deemed acceptable for use in eliminating the threat of species introductions. Developers requested these targets so they could design technologies to meet the standards (MEPC 2003). Without standards, investors were reluctant to devote financial resources towards conceptual or prototype systems because they had no indication that their investments might ultimately meet future regulations. For the same reason, vessel owners were hesitant to allow installation and testing of prototype systems onboard operational vessels. It was argued that the adoption of performance standards would address these fears, and accelerate the advancement of ballast treatment technologies. Thus in response to the slow progress of ballast water treatment technology development and the need for effective ballast water treatment options, state, federal and international regulatory agencies have adopted or are in the process of developing performance standards for ballast water discharges.

III. REGULATORY AND PROGRAMMATIC OVERVIEW

A thorough evaluation of the status of ballast water treatment technologies requires not only an understanding of the regulatory framework associated with the development and implementation of performance standards for the discharge of ballast water, but also knowledge of mechanisms for the testing and evaluation of treatment systems to meet those standards. Currently, no comprehensive international, federal or state program exists that includes performance standards, guidelines and/or protocols to verify the performance of treatment technologies, and methods to sample and analyze discharged ballast water for compliance purposes. California, other U.S. states, the federal government, and the international community are working toward the development of a standardized approach to the management of discharged ballast water, however, at this time existing legislation, standards and guidelines vary by jurisdiction. The following is a summary of the status of performance standards regulations, treatment system evaluation, and discharge compliance verification as of the writing of this report.

International Maritime Organization

In February 2004, after several years of development and negotiation, International Maritime Organization (IMO) member countries adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) (see IMO 2005). Among its requirements, the Convention imposes performance standards for the discharge of ballast water (Regulation D-2) with an associated implementation schedule based on vessel ballast water capacity and status as a new or existing vessel (Tables III-1 and III-2).

The Convention will enter into force 12 months after ratification by 30 countries representing 35% of the world's commercial shipping tonnage (IMO 2005). As of September 30, 2008, 16 countries representing 14.24% of the world's shipping tonnage have signed the convention (IMO 2008). The Convention cannot be enforced upon any ship until it is ratified (IMO 2007). Because insufficient time remains to ratify the Convention and have it enter into force before the first performance standards implementation date in 2009, the IMO General Assembly adopted Resolution A.1005(25) on November 29, 2007. The resolution delays the date by which new vessels built in 2009 with a ballast water capacity of less than 5000 metric tons (MT) must comply with Regulation D-2 from 2009 until the vessel's second annual survey, but no later than December 31, 2011 (IMO 2007). For now, the implementation dates for all other vessel size classes remain the same as originally proposed (Table III-2).

Table III-1. Ballast Water Treatment Performance Standards

Organism Size Class	IMO Regulation D-2[1]	California[1,2]
Organisms greater than 50 µm[3] in minimum dimension	< 10 viable organisms per cubic meter	No detectable living organisms
Organisms 10 – 50 µm in minimum dimension	< 10 viable organisms per ml[4]	< 0.01 living organisms per ml
Living organisms less than 10 µm in minimum dimension		$< 10^3$ bacteria/100 ml $< 10^4$ viruses/100 ml
Escherichia coli	< 250 cfu[5]/100 ml	< 126 cfu/100 ml
Intestinal enterococci	< 100 cfu/100 ml	< 33 cfu/100 ml
Toxicogenic *Vibrio cholerae* (O1 & O139)	< 1 cfu/100 ml or < 1 cfu/gram wet weight zooplankton samples	< 1 cfu/100 ml or < 1 cfu/gram wet weight zoological samples

[1] See Table III-2 below for dates by which vessels must meet California Interim Performance Standards and IMO Ballast Water Performance Standards.
[2] Final discharge standard for California, beginning January 1, 2020, is zero detectable living organisms for all organism size classes.
[3] Micrometer – one-millionth of a meter
[4] Milliliter – one-thousandth of a liter
[5] Colony-forming unit – a measure of viable bacterial numbers

Table III-2. Implementation Schedule for Performance Standards

Ballast Water Capacity of Vessel	Standards apply to new vessels in this size class constructed on or after	Standards apply to all other vessels in this size class beginning in[1]
< 1500 metric tons	2009 (IMO)[2] /2010 (CA)[3]	2016
1500 – 5000 metric tons	2009 (IMO)[2] /2010 (CA)[3]	2014
> 5000 metric tons	2012	2016

[1] In California the standard applies to vessels in this size class as of January 1 of the year of compliance. The IMO Convention applies to vessels in this size class no later than the first intermediate or renewal survey, whichever occurs first, after the anniversary date of delivery of the ship in the year of compliance (IMO 2005).
[2] IMO has pushed back the initial implementation of the performance standards for vessels constructed in 2009 in this size class until the vessel's second annual survey, but no later than December 31, 2011 (IMO 2007).
[3] California Senate Bill 1781 (Chapter 696, Statutes of 2008) delayed the initial implementation of performance standards for vessels in this size class from January 1, 2009 to January 1, 2010.

In order to ensure global and uniform application of the relevant requirements of the Convention, the IMO Marine Environment Protection Committee (MEPC) has adopted 12 implementation guidelines (one additional guideline remains in draft form, see below for details) (Everett, R., pers. comm. 2008). Relevant to this report, the guidelines for the evaluation and approval of ballast water treatment systems were adopted at the 53rd session of the MEPC in July, 2005. Guideline G8, "Guidelines for Approval of Ballast Water Management Systems" (MEPC 2005a), and Guideline G9, "Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances" (MEPC 2005b), work together to create a framework for the evaluation of treatment systems by the MEPC and Flag State Administrations (i.e. the country or flag under which a vessel operates) (Figure III-3). Flag States (not the IMO) may grant approval (also known as "Type Approval") to systems that are in compliance with the Convention's Regulation D-2 performance standards based upon recommended procedures (as detailed in Guideline G8) for full-scale land-based and shipboard testing of the treatment system. A treatment system may not be used by a vessel party to the Convention to meet the D-2 standards in the Convention unless that system is Type Approved.

In addition to receiving Type Approval from the Flag State Administration, ballast water treatment systems using "active substances" must be approved by the IMO MEPC based upon procedures developed by the organization (IMO 2005). An active substance is defined by IMO as, "…a substance or organism, including a virus or a fungus, that has a general or specific action on or against Harmful Aquatic Organisms and Pathogens" (IMO 2005). For all intents and purposes, an active substance is a chemical or reagent (e.g. chlorine, ozone) that kills or inactivates organisms in ballast water. The IMO approval pathway for treatment systems that use active substances is more rigorous than the evaluation process for technologies that do not. As required by Guideline G9, technologies utilizing active substances must go through a two-step "Basic" and "Final" approval process. Active substance systems that apply for Basic and Final Approval are reviewed for environmental, ship, and personnel safety by the IMO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

(GESAMP) – Ballast Water Working Group (BWWG) in accordance with the procedures detailed in Guideline G9. The MEPC may grant Basic or Final Approval based upon the GESAMP-BWWG recommendation. Systems that do not use active substances (i.e. a system only using filtration) do not need Basic or Final Approval, and need only acquire Type Approval (Figure III-3).

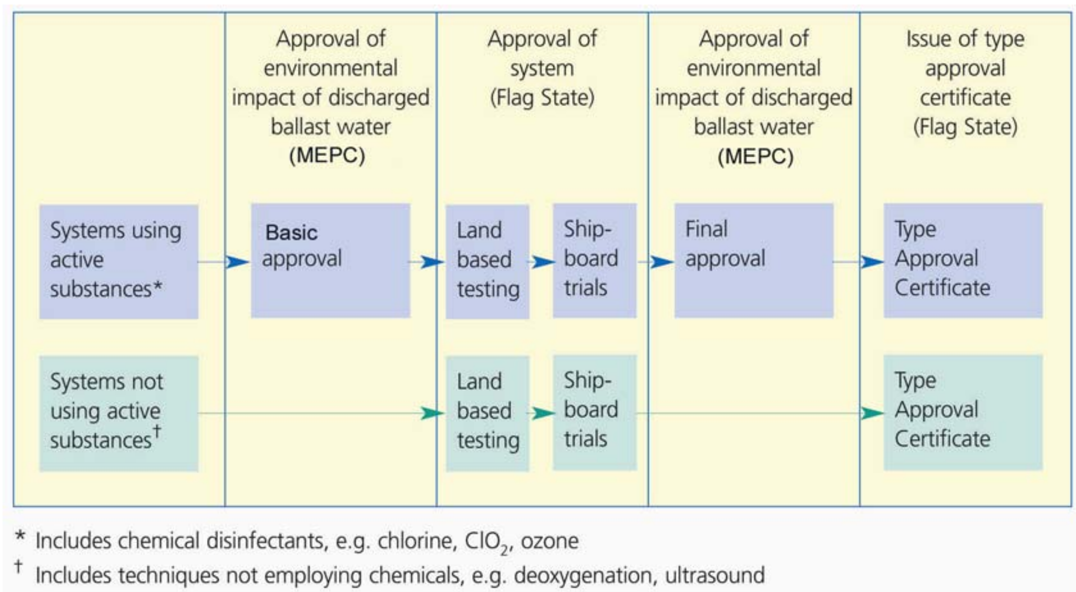

Figure III-3. Summary of IMO approval pathway for ballast water treatment systems. (Modified from Lloyd's Register (2007))

The entire IMO evaluation process (including approval for systems using active substances) has been estimated to take between six months and two years to complete (Everett, R., pers. comm. 2007, Lloyd's Register 2007). Once a ballast water treatment system has acquired Type Approval (and the Convention is ratified and in force), the system is deemed acceptable by parties to the Convention for use in international waters in compliance with Regulation D-2.

The U.S. has neither reviewed nor submitted applications to IMO on behalf of any U.S. treatment technology vendors thus far. Until the Convention is both signed by the U.S. and enters into force through international ratification, no U.S. federal agency has the authority (unless authorized by Congress) to manage a program to review treatment technologies and submit applications on their behalf to IMO. United States treatment vendors may approach IMO through association with other IMO Member States, and several have or are in the process of doing so. However, because the Convention has not yet been ratified, it does not have the force of international law, which draws into question the legality of MEPC approvals of treatment systems. While the U.S. is actively involved in developing and negotiating the various requirements of the Convention, until the U.S. signs on to the Convention, and it is ratified by enough member states to go into force, the U.S. is not party to the Convention requirements. Hence, vessels calling on U.S. ports have no authority to use systems approved through the IMO Type Approval process to meet U.S. ballast water management requirements.

One additional guideline related to the implementation of the IMO Convention bears mention here for its relevance to California’s ballast water management program. Guideline G2, the “Guidelines for Ballast Water Sampling,” provides valuable information, in the absence of U.S. federal guidance, on the location and equipment necessary to collect ballast water samples to assess compliance with the performance standards. Guideline G2 defines the preferred sampling point (i.e. the place in the ballast water piping where the sample is taken) and sampling facilities (i.e. the equipment installed to take the sample) for sample collection (BLG 2008). As California gets closer to the implementation of its own performance standards for the discharge of ballast water, these sampling guidelines will help direct the development of new California regulations and compliance verification procedures (see Section on California Legislation and Implementation of Performance Standards for details).

U.S. Federal Legislation and Programs

The authority to regulate ballast water discharges in the United States has recently shifted to include the U.S. Environmental Protection Agency (EPA) in addition to the U.S. Coast Guard (USCG). Beginning December 19, 2008, the EPA must regulate ballast water, and other discharges incidental to normal vessel operations, under the Clean Water Act (CWA). This requirement stems from the 2003 lawsuit filed by Northwest Environmental Advocates et al. against the EPA in U.S. District Court, Northern District of California, challenging a regulation originally promulgated under the CWA (Nw. Envtl. Advocates v. U.S. EPA, No. C 03-05760 SI, 2006 U.S. Dist. LEXIS 69476 (N.D. Cal. Sept. 18, 2006)). The regulation at issue, Title 40 of the Code of Federal Regulations (CFR) Section 122.3(a), exempted effluent discharges “incidental to the normal operations of a vessel,” including ballast water, from regulation under the National Pollution Discharge Elimination System (NPDES). The plaintiffs sought to have the regulation declared *ultra vires,* or beyond the authority of the EPA under the CWA. On March 31, 2005, the District Court granted judgment in favor of Northwest Environmental Advocates et al., and on September 18, 2006 the Court issued an order revoking the exemptive regulation (40 CFR. Section 122.3(a)) as of September 30, 2008. EPA filed an appeal with the Ninth Circuit U.S. Court of Appeals but was denied in July 2008 (Nw. Envtl. Advocates v. U.S. EPA, No. 03-74795, 2008 U.S. App. LEXIS 15576 (9th Cir. Cal. July 23, 2008)). In June 2008, EPA released for public comment the draft NPDES “Vessel General Permit for Discharges Incidental to the Normal Operation of Commercial Vessels and Large Recreation Vessels” (Vessel General Permit). All vessels greater than 300 gross registered tons, or with a ballast water capacity greater than 8 cubic meters, must submit a Notice of Intent with EPA in order to receive coverage under the permit. Vessels greater than 79 feet but less than 300 tons receive automatic permit coverage. In September 2008, the District Court granted a motion to delay the vacature of the 122.3(a) regulation from September 30 to December 19, 2008.

In large part, the draft NPDES Vessel General Permit maintains the regulation of ballast water discharges by the USCG through regulations found in 33 CFR Part 151. The USCG regulations, developed under authority of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, which was revised and reauthorized as the National Invasive Species Act of 1996, require ballast water management (i.e. ballast water exchange) for vessels entering U.S. waters from outside of the 200 nautical mile (nm) Exclusive Economic Zone (EEZ) of the U.S. Vessels may use onboard treatment systems to meet the current ballast water management requirements if that system is approved by the Commandant of the USCG, however, as of October 2008 no approval process was in place.

The draft NPDES Vessel General Permit does not include performance standards for the discharge of ballast water. Performance standards may be included in the next iteration of the permit (in 2013) based on the outcome of an anticipated USCG rulemaking on ballast water treatment standards, and if treatment technologies are determined to be commercially available and economically achievable to meet those standards. The lack of a federal discharge standard precludes the approval of any treatment system at the national level.

The EPA's draft NPDES Vessel General Permit and the USCG regulations do not relieve vessel owners/operators (permittees) of the responsibility of complying with applicable state laws or regulations. Additionally, states with authority to implement the CWA may add specific provisions, including performance standards, for vessel discharges in state waters to the EPA's general permit through the CWA Section 401 certification process. Thus we do not expect to see any impact from the implementation of the NPDES permit on individual states' ability to implement performance standards for the discharge of ballast water in state waters, including California. Vessels will, however, have to comply with both state and federal regulations for ballast water management under the NPDES permit and the USCG regulations. This may result in vessels having to exchange ballast water to comply with federal management requirements under the CWA and the USCG regulations and treat ballast water to comply with state regulations. Legislation may be required to clarify this potentially confusing situation.

Several bills have been introduced in the U.S. House of Representatives and Senate in recent years to legislatively establish a national discharge standard. In 2007 the following bills were introduced:

- The Ballast Water Management Act of 2007 (H.R. 2423, S. 1578)
- Prevention of Aquatic Invasive Species Act of 2007 (H.R. 889)
- National Aquatic Invasive Species Act of 2007 (S. 725)
- Great Lakes Invasive Species Control Act (H.R. 801)
- Coast Guard Authorization Act of 2007 (H.R. 2830)

- Great Lakes Collaboration Implementation Act (S. 791, H.R. 1350)
- Aquatic Invasive Species Research Act (H.R. 260).

These bills seek to clarify the goals and role of the federal government in ballast water management. Several of the bills introduce performance standards that would be less stringent than California's standards. More importantly, however, many of these bills also introduce language that would preempt state laws and set back California's efforts to better manage ballast water discharges and other ship-mediated vectors of NIS introductions.

As of October 2008, only H.R. 2830 (the Coast Guard Authorization Act) has cleared its house of origin. Recently, the Senate Committee on Commerce, Science and Technology has been working with the House and states to draft ballast water legislation that would establish a federal discharge standard while allowing states, such as California, to retain authority over their ballast water management programs. This new language could either be inserted into the Senate USCG authorization bill (S. 1892), the House USCG bill currently in the Senate (H.R. 2830), a separate bill, or could be addressed in conference committee. Commission staff (staff) will continue to follow and assess the potential impacts of any new federal legislation on ballast water management and California's program.

While the federal implementation of performance standards for the discharge of ballast water remains uncertain in the near future, two promising federal programs are currently working proactively to support the development of treatment technologies and facilitate the testing and evaluation of those systems: 1) The USCG Shipboard Technology Evaluation Program (STEP), and 2) The EPA's Environmental Technology Verification (ETV) program.

The USCG STEP is intended to facilitate the development of ballast water treatment technologies. Vessel owners and operators accepted into STEP may install and operate specific experimental ballast water treatment systems on their vessels for use in

U.S. waters. In order to be accepted, treatment technology developers must assess the efficacy of systems for removing biological organisms, residual concentrations of treatment chemicals, and water quality parameters of the discharged ballast water (USCG 2004). STEP provides incentives for vessel operators and treatment developers to test promising new technologies. Vessels accepted into the program may operate the system to meet the USCG ballast water management requirements and will be grandfathered for operation under future ballast water discharge standards for the life of the vessel or the treatment system. During the summer of 2008, the draft environmental assessments for three vessels that applied to the program were released for comment. Those three vessels were accepted into STEP in the fall of 2008. One more vessel has applied to the program and is currently undergoing review. The USCG has plans to streamline the review process for future applicants (USCG 2008).

The EPA ETV program is an effort to accelerate the development and marketing of environmental technologies, including ballast water treatment technologies. The USCG and the EPA established a formal agreement to implement an ETV program focused on ballast water management. Under this agreement, the ETV program developed a draft protocol in 2004 for verification of the performance of ballast water treatment technologies. Subsequently, the USCG established an agreement with the Naval Research Laboratory (NRL) to evaluate, refine, and validate this protocol and the test facility design required for its use. This validation project resulted in the construction of a model ETV Ballast Water Treatment System Test Facility at the NRL Corrosion Science and Engineering facility in Key West, Florida. The innovative research conducted at the NRL facility is intended by the USCG to result in technical procedures for testing ballast water treatment systems for the purpose of approval and certification. Based on the information collected during the evaluation of the 2004 draft protocol, the ETV program, in consultation with an advisory panel (of which CSLC staff is a member), is currently developing a revised final treatment technology verification protocol which is expected to be released in late-2009 or early 2010 (Stevens, T., pers. comm. 2008).

U.S. State Legislation and Programs

Washington

The Washington Department of Fish and Wildlife (WDFW), in consultation with a Ballast Water Work Group, is working on a comprehensive rewrite of the state's ballast water management regulations in response to Washington state legislation passed in 2007 (see E2SSB 5923, the Aquatic Invasive Species Enforcement and Control Act). The new regulations are anticipated to replace the interim percent reduction-based performance standards with permanent concentration-based standards that are in-line with California regulations. These changes would help bring the U.S. Pacific coast states into greater management consistency. Additional revisions are also being made to Washington's treatment technology approval process. The WDFW will no longer independently approve treatment systems for use in state waters and will instead rely on regional, national or international approvals. Systems previously approved under the interim regulations will remain approved for their original period of use. WDFW staff expects the new regulations to be adopted in early 2009 (Pleus, A., pers. comm. 2008).

Michigan

Michigan passed legislation in June 2005 (Act 33, Public Acts of 2005) requiring a permit for the discharge of any ballast water from oceangoing vessels into the waters of the state beginning January 2007. Through the general permit (Permit No. MIG140000) developed by Michigan Department of Environmental Quality (DEQ), any ballast water discharged must first be treated by one of four methods (hypochlorite, chlorine dioxide, ultraviolet radiation preceded by suspended solids removal, or deoxygenation) that have been deemed environmentally sound and effective in preventing the discharge of NIS. Vessels must use treatment technologies in compliance with applicable requirements and conditions of use as specified by Michigan DEQ for use in state waters. Vessels using technologies not listed under the Michigan general permit may apply for individual permits if the treatment technology used is, "environmentally sound and its treatment effectiveness is equal to or better at preventing the discharge of aquatic nuisance species as the ballast water treatment methods contained in [the general] permit," (Michigan DEQ 2006).

Minnesota

Effective July 1, 2008, Minnesota state law (S.F. 3056) requires vessels operating in state waters to have both a ballast water record book and a ballast water management plan onboard that has been approved by the Minnesota Pollution Control Agency (MPCA) (MPCA 2008). Additionally, based on the authority in Minn. Stat. 115.07, Minn. R. 7001.0020, subp. D, and Minn. R. 7001.0210, and to implement the recently enacted legislation, the MPCA approved a State Disposal System general permit for ballast water discharges into Lake Superior and associated waterways in September 2008 (MPCA 2008). Under the permit, vessels that wish to discharge into Minnesota waters must comply immediately with approved best management practices. No later than January 1, 2012, new vessels will be required to comply with the IMO D-2 performance standards for the discharge of ballast water (see Table III-1), and existing vessels will be required to comply with those standards no later than January 1, 2016 (MPCA 2008).

California Legislation and the Implementation of Performance Standards

Review of Legislation

California's Marine Invasive Species Act of 2003 directed the Commission to recommend performance standards for the discharge of ballast water to the State Legislature in consultation with the State Water Resources Control Board (Water Board), the USCG and a technical advisory panel (see PRC Section 71204.9). The legislation directed that standards should be selected based on the best available technology economically achievable, and should be designed to protect the beneficial uses of the waters of the State.

In 2005, Commission staff convened a cross-interest, multi-disciplinary panel consisting of regulators, research scientists, industry representatives and environmental organizations and facilitated discussions over the selection of performance standards. Many sources of information were used to guide the performance standards selection including: biological data on organism concentrations in exchanged and un-exchanged ballast water, theories on coastal invasion rates, standards considered or adopted by other regulatory bodies, and available information on the efficacy and costs of experimental treatment technologies. Though all sources and panel members provided some level of insight, none could provide solid guidance for the selection of a specific set of standards that would reduce or eliminate the introduction and establishment of NIS. At a minimum, it was determined that reductions achieved by the selected performance standards should improve upon the status quo and decrease the discharge of viable ballast organisms to a level below quantities observed following legal ballast water exchange. Additionally, the technologies used to achieve these standards should function without introducing chemical or physical constituents to the treated ballast water that may result in adverse impacts to receiving waters. Beyond these general criteria, however, there was no concrete support for the selection of a specific set of standards. This stems from the key knowledge gap that invasion risk cannot be predicted for a particular quantity of organisms discharged in ballast water (MEPC 2003), with the exception that zero organism discharge equates to zero risk.

The Commission ultimately put forward performance standards recommended by the majority of the Panel because they encompassed several desirable characteristics: 1) A significant improvement upon ballast water exchange; 2) In-line with the best professional judgment of scientific experts that participated in the development of the IMO Convention; and 3) Approached a protective zero discharge standard. The proposed interim standards were based on organism size classes (Table III-1). The standards for the two largest size classes of organisms (>50 micrometers (µm; one-millionth of a meter) in minimum dimension and 10 – 50 µm in minimum dimension) were significantly more protective than those proposed by the IMO Convention. The majority of the Panel also recommended standards for organisms less than 10 µm including human health indicator species and total counts of living bacteria and viruses. The recommended bacterial standards for human health indicator species, *Escherichia coli* and intestinal enterococci, are identical to those adopted by the EPA in 1986 for recreational use and human health safety (EPA 1986). The standards for total living bacteria and viruses have not been adopted by any other state, federal or international administration or agency. The implementation schedule proposed for the interim standards was similar to the IMO Convention (Table III-2). A final discharge standard of zero detectable organisms was recommended by the majority of the Panel. The Commission included an implementation deadline of 2020 for this final discharge standard.

The Commission submitted the recommended standards and information on the rationale behind its selection in a report to the State Legislature in January of 2006 (see Falkner et al. 2006). By the fall of that same year, the Legislature passed the Coastal Ecosystems Protection Act (Chapter 292, Statutes of 2006) directing the Commission to adopt the recommended standards and implementation schedule through the California rulemaking process by January 1, 2008. The Commission completed that rulemaking in October, 2007 (see 2 CCR § 2291 et seq.).

In anticipation of the implementation of the interim performance standards, the Coastal Ecosystems Protection Act also directed the Commission to review the efficacy, availability and environmental impacts of currently available ballast water treatment systems by January 1, 2008. The review and resultant report was approved by the Commission in December, 2007 (see Dobroski et al. 2007). Additional reviews must be completed 18 months prior to the implementation dates for all other vessel classes and 18 months before the implementation of the final discharge standard on January 1, 2020 (see Table III-2 for full implementation schedule). During any of these reviews, if it is determined that existing technologies are unable to meet the discharge standards, the report must describe why they are not available.

In response to the recommendations in the initial technology assessment report (Dobroski et al. 2007), the Legislature passed SB 1781 in 2008 (Chapter 696, Statutes of 2008). SB 1781 amends PRC Section 71205.3(a)(2), delaying the implementation of the interim performance standards for new vessels with a ballast water capacity of less than 5000 MT from January 1, 2009 to January 1, 2010. Commission staff is currently preparing a rulemaking package to bring the performance standards regulations (2 CCR § 2291 et seq.) in-line with statute. SB 1781 also requires an additional assessment of available ballast water treatment technologies by January 1, 2009 (this report) in anticipation of the standards implementation in 2010.

Implementing California's Performance Standards

Commission staff is in the process of instituting a comprehensive plan for the implementation of California's performance standards. The delay of initial implementation of the standards from January 1, 2009 to January 1, 2010 has provided technology developers with the necessary time to prepare systems for sale and installation on vessels in order to meet California's performance standards. The delay also provided Commission staff with additional time to compile information about treatment system operation and safety, develop procedures for treatment system evaluation, and begin development of vessel compliance verification protocols.

As discussed in Dobroski et al. (2007), the Commission will not be approving ballast water treatment systems for use in California waters. Instead, the Commission will focus on dockside inspection of vessels for verification of compliance with the performance standards (in accordance with PRC Section 71206). Nonetheless, Commission staff believes that before systems enter the commercial marketplace, it is in the best interest of the State and concerned stakeholders that systems undergo a thorough performance, safety and environmental impact evaluation. Therefore, Commission staff has developed ballast water treatment technology testing guidelines to bridge the gap between treatment system development and operation in California waters.

The "Ballast Water Treatment Technology Testing Guidelines" (Appendix A) provide technology vendors with a standardized approach to evaluating treatment system performance relative to California's discharge standards and water quality objectives. Commission staff developed these protocols in consultation with the Water Board, USCG, ETV program staff and an expert panel of scientists (Appendix A1). System verification testing according to these guidelines is not required by the Commission, however staff strongly encourages technology vendors to conduct verification testing according to these guidelines to ensure a uniform, cost-effective, scientifically-rigorous, independent assessment of system performance and environmental safety. The results generated from system evaluation according to these guidelines will provide Commission staff and potential treatment technology customers with a valuable upfront assessment of the ability of systems to meet California's performance standards and water quality objectives. The guidelines and an associated information sheet were completed and distributed in October, 2008. Initial response from industry has been positive, although it is still too early to determine whether or not these guidelines have influenced the testing methods and verification protocols used by vendors and testing organizations.

While the testing guidelines will provide useful information about the potential of treatment system to meet California's performance standards, they are not a substitute for in-the-field sampling and discharge compliance verification. Commission staff is currently in the process of developing procedures for use by the Commission's Marine Safety Personnel to verify vessel compliance with the performance standards. The compliance verification procedures, to be developed in consultation with technical experts, will make use of the best available techniques to assess organism concentration for each of the standards.

It is expected that the best available techniques to assess vessel compliance with the performance standards will change over time as technology advances. The Commission will need to clarify the manner by which it holds vessels accountable for meeting the standards to ensure that vessels compliant under the current set of verification protocols will not fail compliance in the future simply because the sensitivity of assessment techniques improves. This may be accomplished by grandfathering installed treatment systems under a specific set of compliance verification techniques. Further discussion will be necessary to determine how such a grandfathering system might work while remaining protective of California's waters and consistent with the law.

Commission staff is also developing regulations regarding the selection of sampling points (i.e. location) and sampling facilities (i.e. equipment) on vessels for compliance verification purposes. According to PRC Section 71206 Commission staff is mandated to “take samples of ballast water and sediment from at least 25 percent of the arriving vessels…and make other appropriate inquiries to assess the compliance of any vessel subject to this division.” The new regulations will specify that ballast water samples must be taken during ballast water discharge (per 2 CCR § 2291 et seq.). Additionally, the regulations will offer guidance on the selection of sampling facilities so as to reduce or eliminate the possibility of artificially-induced organism mortality (that may skew compliance assessment) associated with passage through the sampling apparatus. Commission staff expects to complete this rulemaking in 2009.

Finally, the effective implementation of California’s performance standards will require regular monitoring of the treatment technologies as performance standards are implemented. Commission staff will continue to gather information about treatment system development, installation, and use on board vessels. This information will guide the development of new regulations which take into account development within the rapidly advancing ballast water treatment technology industry.

IV. TREATMENT TECHNOLOGY ASSESSMENT PROCESS

Public Resources Code (PRC) Section 71205.3 directs the Commission to prepare, "a review of the efficacy, availability, and environmental impacts, including the effect on water quality, of currently available technologies for ballast water treatment systems." In accordance with the law, the Commission has consulted with, “the State Water Resources Control Board, the United States Coast Guard, and the stakeholder advisory panel described in subdivision (b) of [PRC] Section 71204.9.” This stakeholder panel also provided guidance in the development of the performance standards report to the California Legislature (Falkner et al. 2006).

During the preparation of the initial technology assessment report (Dobroski et al. 2007), Commission staff received input from a small technical workgroup prior to consulting with the stakeholder advisory panel. The workgroup met in May 2007 to assess the current availability of treatment systems, the efficacy of those systems, and any potential environmental and water quality impacts. This group included individuals with expertise in ballast water treatment technology development, water quality and biological monitoring and evaluation, naval architecture and engineering, and technology efficacy analysis (see Dobroski et al. 2007 for workshop participants and summary). The conclusions drawn during the workshop in 2007 continued to provide valuable guidance and direction in the preparation of the current report.

As with the initial technology assessment report, Commission staff conducted an exhaustive literature search to prepare this report. Staff focused its review on recently available scientific papers and performance verification reports from independent testing organizations. Staff also contacted treatment technology vendors in order to gather the most up-to-date information about system development, testing and approvals. On several occasions, staff held meetings in person with technology vendors. These face-to-face gatherings proved to be extremely valuable opportunities to inform vendors about California's performance standards requirements and engage in dialogue about performance verification testing and the Commission's technology assessment report.

Commission staff compiled the available data to develop a treatment system matrix (see Tables V-1, VI-1, VI-3, VI-4, and Appendix B). Upon completion of the data analysis, Commission staff drafted a preliminary report for review by the Commission's stakeholder advisory panel (see Appendix C for list of panel members), the Water Board and USCG. The advisory panel met in October, 2007 to review the initial technology assessment report (see Dobroski et al. 2007), and met in October, 2008 to review the current updated report (Appendix C). Advisory panel discussions were considered by staff to help guide the development of this final report.

V. TREATMENT TECHNOLOGIES

The goal of ballast water treatment is to remove or inactivate organisms entrained in ballast water. Given societal experience with wastewater treatment technologies, the design and production of ballast water treatment systems may seem simple in concept, but has instead proved to be difficult and complex in practice. A system must be effective under a wide range of challenging environmental conditions including variable temperature, salinity, nutrients and suspended solids. It must also function under difficult operational constraints including high flow-rates of ballast water pumps, large water volumes, and variable retention times (time ballast water is held in tanks). Treatment systems must be capable of eradicating a wide variety of different organisms ranging from viruses and microscopic bacteria, to free-swimming plankton, and must operate so as to minimize or prevent impairment of the water quality conditions of the receiving waters. The development of effective treatment systems is further complicated by the variability of vessel types, shipping routes and port geography.

Two general platform types have been explored for the development of ballast water treatment technologies. Shoreside ballast water treatment occurs at a facility following transfer from a vessel. Shipboard treatment occurs onboard vessels through the use of technologies that are integrated into the ballasting system. Shipboard treatment systems are attractive because they allow flexibility to manage ballast water during normal operations, while shoreside treatment may be a good option for vessels with small ballast water capacity and/or dedicated port calls.

The shoreside treatment of ballast water is an appealing option because of the potential similarity in design to waste water treatment systems, however, shoreside treatment poses several challenges. Current shoreside wastewater treatment plants are not equipped to treat saline water (Water Board 2002, Moore, S., pers. comm. 2005). If existing municipal facilities are to be used for the purposes of ballast water treatment, they will need to be modified, and a new extensive network of piping and associated pumps will be required to distribute ballast water from vessels at berth to the treatment plants. The establishment of new piping and facilities dedicated to ballast water treatment, while technically feasible, would be complex and costly in California port areas. Shoreside treatment is not feasible for vessels that must take on or discharge ballast water while underway, for example, if the vessel must adjust its draft to navigate through a shallow channel or under a bridge. The cost of retrofitting of vessels to discharge ballast to shoreside facilities at a rate that prevents vessel delays in port might also be prohibitive (CAPA 2000).

On the other hand, shoreside treatment does provide options for treatment technologies and/or methods that are not feasible onboard vessels due to space and/or energy constraints, such as reverse osmosis. Additionally, shoreside treatment facilities could be staffed by trained wastewater engineers instead of ships' crew who may not be specifically trained in the operation and maintenance of water treatment facilities. To date, however, only limited feasibility studies have been conducted on shoreside treatment (see references in Falkner et al. 2006). Shoreside treatment has been generally considered a good option for unique terminals such as those with limited but dedicated vessel calls (e.g. cruise ships). Nonetheless, one study specific to cruise ships indicated that due to the operational practices of cruise ships and the current regulatory requirements in California and the Port of San Francisco there is little demand at this time for shoreside treatment except in emergency situations (Bluewater Network 2006). Additional studies will be necessary to determine feasibility of and demand for shoreside treatment for other vessel types and across the State as a whole. This may include assessments by those involved in the wastewater treatment sector on whether existing technologies could meet California's performance standards. Because the majority of time, money, and effort in the development of ballast water treatment technologies during recent years has been focused on shipboard treatment systems, we will focus on shipboard systems for the remainder of this report.

Shipboard systems allow for greater flexibility during vessel operations. Vessels may treat and discharge ballast while in transit, and thus will not need to coordinate vessel port arrival time with available space and time at shoreside treatment facilities. As with shoreside treatment, however, shipboard treatment systems face their own set of challenges. They must be engineered to conform to a vessel's structure, ensure crew safety, and withstand the vibrations and movements induced by the vessel's engine and rough seas. Additionally, shipboard systems must be effective under transit times that range from less than 24 hours to several weeks, and must treat ballast water in compliance with water quality requirements of recipient regions.

The timing and location of shipboard ballast water treatment can be varied according to the needs of the treatment system and the length of vessel transit. Ballast water may be treated in the pipe during uptake or discharge (in-line) or in the ballast tanks during the voyage (in tank). While mechanical separation (such as filtration) generally occurs during ballast uptake in order to remove large organisms and sediment particles before they enter the ballast tanks, other forms of treatment may occur at any point during the voyage. Some treatment systems treat ballast water at multiple points during the voyage, such as during uptake and discharge.

Because of the wide range of variables associated with shipboard ballast water treatment, the identification of a single treatment technology for all NIS, ships, and port conditions is unlikely. Each technology may meet the objective of killing or inactivating NIS in a slightly different manner, and each could potentially impact the water quality of the receiving environment through the release of chemical residuals or alterations to water temperature, salinity, and/or turbidity. Thus a suite of treatment technologies will undoubtedly need to be developed to treat ballast water industry-wide and across all ports and environments.

Treatment Methods

The development of ballast water treatment systems that are effective, environmentally friendly and safe has been a complex, costly and time consuming process. At the root of many treatment systems are methods that are already in use to some degree by the wastewater treatment industry. A preliminary understanding of these treatment methods forms the basis for more detailed analysis and discussion of ballast water treatment systems. The diverse array of water treatment methods currently under development for use in ballast water treatment can be broken down into five major categories: mechanical, chemical, physical, biological and combination.

Mechanical Treatment

Mechanical treatment traps and removes mid-size and large particles from ballast water. Mechanical treatment typically takes place upon ballast water uptake in order to limit the number of organisms and amount of sediment that may enter ballast tanks. Common options for mechanical treatment include filtration and hydrocyclonic separation.

Filtration works by capturing organisms and particles as water passes through a porous screen or filtration medium, such as sand or gravel. The size of organisms trapped by the filter depends on the mesh size in the case of screen or disk filters, and on the size of the interstitial space for filtration media. In ballast water treatment, screen and disk filtration is more commonly used over filter media, however, there has been some interest in the use of crumb rubber as a filtration medium in recent studies (Tang et al. 2006). Typical mesh size for ballast water filters ranges from 25 to 100 µm (Parsons and Harkins 2002, Parsons 2003). Most filtration-based technologies also use a backwash process that removes organisms and sediment that become trapped on the filter, and can discharge them at the port of origin before the vessel gets underway. Filter efficacy is a function not only of initial mesh size, but also of water flow rate and backwashing frequency.

Hydrocyclonic separation, also known as centrifugation, relies on density differences to separate organisms and sediment from ballast water. Hydrocyclones create a vortex that cause heavier particles to move toward the outer edges of the cyclonic flow where they are trapped in a weir-like device and can be discharged before entering the ballast tanks (Parsons and Harkins 2002). Hydrocyclones in use in ballast water treatment trap particles in the 50 to 100 µm size range (Parsons and Harkins 2002). One challenge associated with hydrocylone use, however, is that many small aquatic organisms have a density similar to sea water and are thus difficult to separate using centrifugation.

Chemical Treatment

A variety of chemicals (i.e. active substances) are available to kill or inactivate organisms in ballast water. While the vast majority of chemicals are biocides, some chemicals may be used to clump or coagulate organisms in order to assist with their mechanical removal. Chemical treatment may take place during ballast uptake, vessel transit, or discharge. Chemicals may be stored onboard in liquid or gas form, or they may be generated on demand through electrolytic or electrochemical processes.

Chemical biocides can be classified into two major categories: oxidizing and non-oxidizing. Oxidizing agents (e.g. chlorine, chlorine dioxide, bromine, hydrogen peroxide, peroxyacetic acid, ozone) are commonly used in the wastewater treatment sector and work by destroying cell membranes and other organic structures (NRC 1996, Faimali et al. 2006). Electrochemical oxidation combines electrical currents with naturally occurring reactants in seawater and/or air (e.g. salt, oxygen) to produce killing agents. For example, electrochemical oxidation can produce reactants such as hydroxyl radicals, ozone or sodium hypochlorite (chlorine) that are capable of damaging cell membranes. Non-oxidizing biocides, including Acrolein®, gluteraldehyde, and menadione (Vitamin K3), are reported to work like pesticides by interfering with an organism's neural, reproductive or metabolic processes (NRC 1996, Faimali et al. 2006).

The ultimate goal of chemical biocides is to maximize organism inactivation or mortality while minimizing environmental impact. Environmental concerns surrounding chemical use in ballast water focus on the impacts of residuals or byproducts in treated discharge on receiving waters. The effective use of chemical biocides in ballast water treatment requires a balance between the amount of time required to achieve inactivation of organisms, with the time needed for those chemicals and residuals to degrade or be treated to environmentally acceptable levels. Both of these times vary as a function of ballast water temperature, organic content and sediment load. As a result, certain chemicals may be more effective than others based on ballast volume, voyage length, and water quality conditions. Additional concerns about chemical use specific to shipboard operation include corrosion, safety (personnel and ship safety), and vessel design limitations that impact the availability of space onboard for both chemical storage and equipment for dosing.

Physical Treatment

Physical treatment methods include a wide range of non-chemical means to kill or inactivate organisms present in ballast water. Like chemical treatment, physical treatment may occur on ballast uptake, during vessel transit or during discharge. Examples of physical treatment of ballast water include heat treatment, ultraviolet irradiation, ultrasonic energy and some forms of deoxygenation.

Rigby et al. (1999, 2004) discuss the use of waste heat from the ship's main engine as a mechanism to heat ballast water and kill or inactivate unwanted organisms during vessel transit. However, it would be difficult to heat ballast water to a sufficient temperature to kill all species of bacteria due to lack of sufficient surplus energy/heat on a vessel (Rigby et al. 1999, Rigby et al. 2004). An alternative approach to heat treatment involves the use of microwaves. Currently such a treatment technology would be prohibitively expensive (up to $2.55/$m^3$), but additional research and development may reduce costs to acceptable levels (Boldor et al. 2008).

Ultrasound (ultrasonic treatment) kills through high frequency vibration that creates microscopic bubbles that rupture cell membranes (Viitasalo et al. 2005). The efficacy of ultrasound varies based on the intensity of vibration and length of exposure. Ultraviolet (UV) irradiation is another method of sterilization that is commonly used in waste water treatment. UV damages genetic material and proteins which disrupts reproductive and physiological processes. UV irradiation can be highly effective against pathogens (Wright et al. 2006).

Deoxygenation involves the displacement or stripping of oxygen with another inert gas such as nitrogen or carbon dioxide. This process is primarily physical in nature, although the addition of carbon dioxide may trigger a chemical response and result in a reduction in ballast water pH (Tamburri et al. 2006).

Biological Treatment

By far, the least common method of ballast water treatment involves the use of biological organisms to directly kill or produce conditions that will kill or inactivate organisms present in ballast water. These treatment organisms are considered an "active substance" according to the IMO definition (IMO 2005). One example of biological treatment is the use of yeast to produce low-oxygen (hypoxic) conditions in ballast tanks. In this instance, yeast cells extract the available oxygen in the ballast water tank during cell replication (Bilkovski, R., pers. comm. 2008). The resultant hypoxic environment is toxic to the remaining organisms in the ballast tank. Vendors of biological treatment systems will likely need to address how systems will meet the performance standards, as the organisms responsible for producing the desired killing effect on NIS may trigger non-compliance if detected in the discharged ballast.

Combination Treatment

Several treatment technologies inactivate organisms by combining mechanical, chemical, physical and/or biological treatment processes, and are categorized as "combination treatment" in this report. In combination treatment, any single treatment method may not be sufficient to treat the ballast water to required standards, but in combination the methods produce the desired result. For example, while filtration is rarely sufficient to remove organisms of all size classes from ballast water, and UV irradiation may be insufficient to deactivate dense clusters of organisms, paired together they may be an effective method of ballast water treatment. The most common combined treatment methods pair mechanical removal with a physical or chemical process.

Treatment Systems

Twenty-eight treatment technologies were reviewed in the first technology assessment report for the California Legislature (see Dobroski et al. 2007). As of the writing of this report, one treatment vendor (L. Meyer Gmbh) appears to no longer be active in the international market, and was therefore removed from the list of reviewed systems

(Table V-1). Two manufacturers - Hamann and Evonik Degussa - were condensed into one listing because their treatment system is a combined effort. The Japan Association of Marine Safety was renamed as Mitsui Engineering, and four vendors - ATG Willand, EcologiQ, Panasia, and the Toagosei Group - were added to the list based on new information (Table V-1). Thus for this report, Commission staff compiled and reviewed information on 30 shipboard ballast water treatment systems developed in 10 countries (Table V-1).

Twenty-one of the treatment systems reviewed here utilize combination treatment methods, 18 of which pair mechanical treatment with another treatment method(s). Aside from mechanical separation, the most common method used in ballast water treatment systems is chemical. Of the 30 systems reviewed, 18 use a chemical in the treatment process (Table V-1). Specifically, six systems use chlorine or the electrolytic generation of sodium hypochlorite, one uses chlorine dioxide to treat ballast water, four systems use ozone, one uses ozone and electrolytic chlorination, one uses ferrate, one uses a proprietary mixture of peracetic acid, hydrogen peroxide and acetic acid (Peraclean Ocean), and three use advanced oxidation or electrolytic processes that can generate an array of oxidants including bromine, chlorine, and/or hydroxyl radicals (Table V-1).

The next most commonly used method of ballast water treatment amongst the 30 systems reviewed is UV irradiation. Six treatment systems use UV as the primary means to kill or deactivate organisms found in ballast water. All of these systems pair UV treatment with either filtration or hydrocyclonic mechanical separation methods.

Only three systems used deoxygenation as the major form of treatment. Technology treatment categorized as “other” include systems that used various methods including a non-oxidizing biocide (menadione), a heat treatment technology, and one technology using a combination of coagulation and magnetic separation (Table V-1).

Table V-1. Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Alfa Laval	Sweden	PureBallast	combination	filtration + advanced oxidation technology (hydroxyl radicals)	IMO Basic and Final Type Approval (Norway)
ATG Willand	United Kingdom		combination	hydrocyclone + UV	
Ecochlor	USA	Ecochlor™ BW Treatment System	combination	filtration + biocide (chlorine dioxide)	IMO Basic
EcologiQ	USA/Canada	BallaClean	biological	deoxygenation	
Electrichlor	USA	Model EL 1-3 B	chemical	biocide (electrolytic generation of sodium hypochlorite)	
Environmental Technologies Inc.	USA	BWDTS	combination	ozone + sonic energy	
Ferrate Treatment Technologies LLC	USA	Ferrator	chemical	biocide (ferrate)	
Greenship Ltd	Netherlands	Sedinox	combination	hydrocyclone + electrolytic chlorination	IMO Basic
Hamann Evonik Degussa	Germany	SEDNA System	combination	hydrocyclone + filtration + biocide (Peraclean Ocean)	IMO Basic and Final, Type Approval (Ger.)
Hi Tech Marine	Australia	SeaSafe-3	physical	heat treatment	Queensland EPA
Hitachi	Japan	ClearBallast	combination	coagulation + magnetic separation + filtration	IMO Basic
Hyde Marine	USA	Hyde Guardian	combination	filtration + UV	WA Conditional
JFE Engineering Corp.	Japan	JFE BWMS	combination	filtration + biocide (sodium chlorine) + cavitation	
MARENCO	USA		combination	filtration + UV	WA General Approval
Maritime Solutions Inc.	USA		combination	filtration + UV	

Table V-1 (Continued). Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
MH Systems	USA	BW treatment system	combination	deoxygenation + carbonation	
Mitsubishi Heavy Industries	Japan	Hybrid System	combination	filtration + electrolytic chlorination	
Mitsui Engineering	Japan	Special Pipe	combination	mechanical treatment + ozone	IMO Basic
NEI	USA	Venturi Oxygen Stripping (VOS)	combination	deoxygenation + cavitation	Type Approval (Liberia)
NK-O3	Korea	BlueBallast	chemical	ozone	IMO Basic
Nutech 03 Inc.	USA	SCX 2000, Mark III	chemical	ozone	
OceanSaver	Norway	OceanSaver BWMS	combination	filtration + cavitation + nitrogen supersaturation + electrodialysis	IMO Basic and Final
OptiMarin	Norway	OptiMarin Ballast System	combination	filtration + UV	
Panasia Co. Ltd	Korea	GloEn-Patrol	combination	filtration + UV	IMO Basic
Resource Ballast Technologies	South Africa	RBT Reactor	combination	cavitation + ozone + sodium hypochlorite + filtration	IMO Basic
RWO Marine Water Technology	Germany	CleanBallast	combination	filtration + advanced electrolysis	IMO Basic
SeaKleen (Hyde)	USA	SeaKleen	chemical	biocide (menadione)	
Severn Trent DeNora	USA	BalPure	chemical	electrolytic generation of sodium hypochlorite + neutralizing agent (sodium bisulfite)	WA Conditional
Techcross Inc.	Korea	Electro-Cleen	chemical	electrochemical oxidation + neutralizing agent (sodium thiosulfate)	IMO Basic and Final
Toagosei Group	Japan	TG BallastCleaner TG Environmentalguard	combination	filtration + biocides (sodium hypochlorite) and neutralizing agent (sodium sulfite)	IMO Basic

VI. ASSESSMENT OF TREATMENT SYSTEMS

The Coastal Ecosystems Protection Act required the adoption of regulations to implement performance standards for the discharge of ballast water. Over 80% of voyages to California ports report that they do not discharge ballast into California waters (Falkner et al. 2007). These vessels will comply with the performance standards simply by retaining all ballast onboard. Vessels that do discharge but use nontraditional sources for ballast water (such as freshwater from a municipal source or treated grey water) will likely meet the discharge standards without the need for onboard ballast water treatment systems. Vessels that utilize coastal or ocean water as ballast, however, will require ballast treatment prior to discharge. For these vessels, the assessment of treatment system efficacy, availability, and environmental impacts (as required by PRC Section 71205.3(b)) is an important step towards understanding if systems will be available prior to the implementation of the interim performance standards for newly built vessels with a ballast water capacity of less than 5000 MT beginning in 2010.

Efficacy

During the preparation of the initial technology assessment report, the evaluation of ballast water treatment system performance (i.e. efficacy) was a challenge for a number of reasons. First and foremost, the lack of available data precluded any form of assessment for many systems. For those systems with data for review, the inconsistency in testing methodologies among systems and occasionally between tests of a single system made comparison of data impossible. Results often varied in scale (pilot vs. full-scale) and location (laboratory vs. dockside vs. shipboard), and were frequently presented in metrics incompatible with California's standards (i.e. as percent reduction instead of concentration of organisms). Perhaps most importantly, the majority of the available information was not subject to rigorous evaluation by independent, third-party scientific testing organizations.

While some of these challenges remain, most notably the lack of information for some systems, Commission staff has seen a significant improvement in the quantity and particularly the quality of available data. Many treatment vendors and developers are in the midst of full-scale land-based and shipboard evaluations of treatment system performance in order to receive Type Approval before the ratification and implementation of the IMO Convention. As a result, there is more data available for Commission staff to review than for the previous report. Much of this new research is being conducted by independent, third-party testing organizations and is presented using methods and in metrics directly comparable to California's standards. Therefore the quality of the new information is substantially higher than seen previously, and the data directly lends itself to comparison against California's performance standards.

Commission staff compiled and reviewed all available literature and performance data in order to assess system potential to meet California's performance standards (see Table III-1 for performance standards). While all of the new data was presented according to organism size class, some of the data that has not been updated since the previous report is presented by organism type (i.e. zooplankton, phytoplankton). In an effort to standardize results, staff evaluated any data on zooplankton abundance as representative of the largest size class of organisms (greater than 50 µm in size), and phytoplankton abundance was evaluated on par with organisms in the 10 – 50 µm size class. These substitutions were solely for the purpose of this report and will not be applicable to future compliance verifications. Ultimately, Commission staff gathered efficacy data on 20 of the 30 technologies reviewed in this report (Table VI-1, Appendix B).

Staff evaluated the data in light of the best available methods and techniques for assessing organism concentration and viability for each of the size classes in California's performance standards. The technical advisory panel that guided the development of the "Ballast Water Treatment Technology Testing Guidelines" assisted Commission staff with the production of a table (see Table 5-1 in Appendix A) listing commonly accepted methods of organism enumeration and viability determination for each of the organism size classes. While this list is not all-inclusive, it provides a framework that guided staff's critical evaluation of data on treatment system efficacy.

As a whole, the field of treatment performance assessment, like that of treatment technology development, is still emerging. Scientists are striving to find rapid, innovative techniques that can be used by both scientists and regulatory agencies to assess vessel discharge compliance with the relevant performance standards. Because California's performance standards for organisms less than 10 micrometers in size (bacteria and viruses, but not including protists) have not been adopted by any other regulatory entity in the world, there is not a worldwide push to develop assessment techniques for these organisms. Currently, there are no available techniques to both quantify and assess the viability of all bacteria and viruses in a sample of ballast water (see Appendix A1 for discussions on this topic).

To assess compliance with the bacterial standard, Commission staff used a proxy group of organisms (culturable, aerobic, heterotrophic bacteria – hereafter culturable heterotrophic bacteria) to represent the larger group of all bacteria. Culturable heterotrophic bacteria were selected as a proxy for total bacteria because, unlike total bacteria, there are reliable, well-accepted standard methods to both enumerate and assess viability of these organisms. Culturable heterotrophic bacteria are a well-studied group of bacteria, and research is being conducted to examine the relationship between their populations and the larger pool of bacterial species (see Appendix A1, Dobbs, F., pers. comm. 2008). Staff examined the data on treatment system performance at reducing culturable heterotrophic bacteria to levels within the California standard of 1000 bacteria (in this case expressed as colony-forming units) per 100 ml of ballast water. At a subsequent advisory panel meeting, members debated whether such a proxy group of organisms should be held to a different standard than that written in the law (see Appendix C for discussion). For instance, because heterotrophic bacteria are a subset of all bacteria they should be held to a standard in proportion to their relative abundance in nature (for example if heterotrophic bacteria represent 10% of the total population of bacteria, the standard for assessment using this proxy group might be more appropriate if set at 10% of 1000/100 ml or 100 CFU/100 ml). However, until such a debate is settled, Commission staff will continue to analyze all data using best available techniques and the numerical standard found in the law.

Analysis of viral species is challenging at this time. While several representative organisms exists for viruses (see discussions in Appendix A1), their relationship to the greater population of all viral species is more tenuous than for bacteria (confer Culley and Suttle 2007). One option for future analyses involves the use of a subset of viruses known as bacteriophages (viruses that infect bacteria) (see Appendix A), but further discussion will be necessary to determine how this proxy organism could be analyzed to broadly represent treatment of viral species. For the purposes of this analysis, Commission staff believes that no widely accepted technique or proxy is available, and thus systems were not evaluated for compliance with the viral standard. Staff will continue to monitor the development of new assessment techniques for all organism size classes and incorporate them into future technology assessment reports.

Staff summarized the potential for all reviewed treatment systems to meet both the IMO and California performance standards (as assessed using best available methods) in Table VI-1. A positive compliance assessment for the purpose of this report, however, does not relieve the vessel owner/operator of the responsibility of complying with California’s performance standards for the discharge of ballast water. Potential treatment system customers should consult extensively with vendors to ensure that thorough system verification work has been conducted and that the system is appropriate for the type of vessel under normal ballasting conditions.

Table VI-1. Summary of systems with available results for assessment of efficacy

Systems with at least one replicate in compliance with the performance standards are denoted by a "Y" in the appropriate column in Table VI-1. Non-compliance is denoted by an "N," and those systems with data in metrics not directly comparable to the performance standards were designated as "unknown." A blank cell or hashing indicates that no data was available.

Manufacturer	> 50 µm		10 - 50 µm		< 10 µm (bacteria)		*E. coli*		Enterococci		*V. cholerae*		Reference[3]
	IMO	CA	IMO	CA	IMO	CA[1,2]	IMO	CA	IMO	CA	IMO	CA	
Alfa Laval	Y	Y	Y	Y	N/A	N	Y	Y	Y	Y	Y[4]	Y[4]	1,68,93,94
ATG Willand					N/A								
Ecochlor	Y	Y	Y	Y	N/A	Y	Y	Y	Unknown		Y	Y	63,100
EcologiQ					N/A								
Electrichlor					N/A								
ETI			Y	N	N/A	N							59,60,61,62
Ferrate Treatment Tech.	Unknown				N/A		Y	N	Y	N	Y	Y	22
Greenship	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y			25,115
Hamann Evonik Degussa	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y			38,91,130
Hi Tech Marine	Unknown		Unknown		N/A								41
Hitachi	Y	Y	Y	Y	N/A		Y	Y					75
Hyde Marine	Y	Y	Unknown		N/A	N	Y	Y	Y[4]	Y[4]			56,57,139
JFE Engineering Corp.					N/A								
MARENCO	Y	Y	Y	N	N/A	Y							51,52,136
Maritime Solutions Inc.					N/A								
MH Systems	Unknown				N/A						Unknown		42
Mitsubishi Heavy Ind.					N/A								
Mitsui Engineering	Y	N	Y	Unknown	N/A	Unknown	Unknown		Unknown		Unknown		46,48,49
NEI	Y	Y	Y	Unknown	N/A	N	Y	Y	Y	Y	Y	Y	119,120,121
NK-03					N/A								
Nutech 03 Inc.	Y	Y	Y	N	N/A	Y	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]	Y[4]	40,105,141
OceanSaver	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	6,95,124
OptiMarin	Y	Y	Y	Y	N/A	Y	Y	Y	Y	Y	Y[4]	Y[4]	11,47,92,135
Panasia Co.					N/A								
Resource Ballast Tech.					N/A								
RWO Marine Water Tech.	Y[5]	Y[5]	Y[6]	Y[6]	N/A		Y	Y	Y	Y			71
SeaKleen (Hyde)	Y	Y	Y	Y	N/A	Unknown	Y	Y	Y[4]	Y[4]			8,21,36,57
Severn Trent DeNora	Y	Y	Y	Y	N/A	Y							39
Techcross Inc.	Y	Y	Y	Y	N/A		Y	Y	Y	Y	Y[4]	Y[4]	50,69
Toagosei Group					N/A								

[1] Bacteria were assessed through examination of culturable heterotrophic bacteria (expressed as colony forming units).

[2] No methods exist to quantify and assess the viability of viruses at this time.

[3] Numbered references can be found in Literature Cited section

[4] Concentration at intake was zero or non-detectable

[5] *Artemia* cysts only

[6] *Tetraselmis suecica* only

In the largest organism size class (organisms greater than 50 µm in size), 19 systems provided data and 15 demonstrated potential, in at least one testing replicate, to meet the required standard of no detectable living organisms per cubic meter of discharged ballast water (Table VI-2, Appendix B1). Similar results were seen in the 2007 report (Dobroski et al. 2007) when 14 systems were designated as compliant for this largest size class of organisms. In the 10 – 50 µm size class, 18 systems were reviewed and 11 systems had at least one test replicate that indicated compliance with the requirement of less than 0.01 living organisms per milliliter (ml) (Table VI-2, Appendix B2). This is an increase of 3 systems since 2007.

The results of analyses for human health indicator species (*Escherichia coli*, intestinal enterococci and *Vibrio cholerae*) and organisms less than 10 µm (bacteria and viruses) are varied. Several more vendors have completed assessment of system performance at eliminating human health indicator species since the 2007 report. Fifteen systems provided results of *E. coli* concentration in treated ballast water (Appendix B3). Fourteen of those were comparable to the California standard, and 13 demonstrated compliance – up from 10 in the 2007 report. Fourteen systems tested for the presence of intestinal enterococci, and eleven systems demonstrated potential compliance compared to three in 2007 (Appendix B4). Finally, ten systems examined treated ballast water for toxicogenic *Vibrio cholerae* and eight systems demonstrated potential compliance with the California performance standard (Appendix B5). Although this is an increase in both the number of systems testing for the presence of *Vibrio cholerae* and the number in compliance since the 2007 report, the low, and sometimes non-detectable, concentration of *Vibrio cholerae* in coastal waters makes it difficult to adequately assess system performance at eliminating the species.

As previously mentioned, the assessment bacteria and viruses relative to California's standards in treated ballast water has been problematic due to a lack of techniques to both enumerate and evaluate the viability of all bacterial and viruses in ballast water. A technical panel of experts that has assisted Commission staff with the development of the treatment technology testing guidelines (see Appendix A) recommend that the bacterial standard be assessed using culturable heterotrophic bacteria as a proxy group of bacterial organisms. Available data was analyzed for compliance with the bacterial standard of 1000 bacteria or CFU per 100 ml (Table VI-1). Fourteen systems analyzed system performance at treating culturable heterotrophic bacteria and twelve presented results in a metric comparable to the standard (CFU/100 ml) (Appendix B6). Eight demonstrated compliance with the standard. Many additional treatment vendors have conducted analyses of treated ballast water for culturable heterotrophic bacteria, but have not yet provided those data to Commission staff.

Results for the number (counts) of viruses or virus-like particles in ballast water samples either pre- or post-treatment were only available for two systems and only using bacteriophages (Appendix B7). Further discussion is required before staff can assess how phage concentrations relate to the total pool of viral species in ballast water and compliance with California's standards. These numbers are simply recorded for now. On a theoretical note, experts variously refer to "viruses" as "virus-like particles", and "virus-sized particles," but no term is fully agreed upon within the scientific community (Dobbs, F., pers. comm. 2008). None of the systems that have provided information on virus assessment have defined what they referred to as a virus. Furthermore, some scientists contend that infectivity must be proved before calling an object a virus—and we cannot know simply by looking at one in a ballast water sample that it is infective. Staff will continue to follow advances in the field of viral science and will assess how future technology developments will impact our ability to assess compliance with the viral standard.

Table VI-2. Summary of Potential Treatment System Performance with Respect to California Performance Standards

	Organisms Greater than 50	Organisms 10 – 50	Organisms less than 10 (bacteria)[1]	*Escherichia coli*	Intestinal enterococci	*Vibrio cholerae*
Total Systems that provided Results[2]	19	18	14	15	14	10
Number Systems that Meet Standard[3]	15	11	8	13	11	8

[1] Bacteria examined using culturable heterotrophic bacteria (1000 CFU/100 ml)
[2] Of out of the 30 total systems assessed in this report, only 20 had testing results available for review. Not all 20 covered testing under each of the organism size classes. The total number of systems with results in a given size class is indicated in this category.
[3] This category reflects the number of systems with at least one replicate of system testing in compliance with the California performance standards (see Table III-1 for standards).

As seen in Table VI-1, 20 treatment systems have results available for analysis of system efficacy; the potential for the remaining ten systems to meet the California standards is not clear at this time. For those systems with results, sixteen systems demonstrated the potential to meet at least 1 out of seven performance standards organism size classes, fifteen systems met at least 2 size classes, fourteen systems met at least 3 size classes, eleven systems met at least 4 size classes, eight systems met at least 5 size classes, and two systems met 6 size classes (Table VI-1, Appendix B). Systems cannot be assessed for compliance with the viral standard at this time. Thus at least two systems, OceanSaver and OptiMarin, are capable of meeting all standards that can be assessed using the best available techniques and methods at this time. Overall, this is a marked improvement since 2007.

Commission staff expects several additional systems will meet California's standards in the near future. Many systems utilize similar treatment methods (i.e. chlorination/de-chlorination) and may likely produce similar types of results. Therefore a specific treatment method which has been shown to be effective for one system may likely be effective for a similar system for which data is lacking but which uses the same treatment method. While Commission staff did not assess system compliance in Table

VI-1 based on this assumption (i.e. in the absence of specific data from a particular system), the number of systems potentially capable of meeting California's performance standards is likely greater than directly evident based on currently available data.

Availability

An assessment of the availability of ballast water treatment systems requires an understanding of the relationship among many elements including the number of vessels that will be impacted by the performance standards (i.e. industry demand), commercial availability, and the relationship between government approval of systems and overall market demand for treatment technologies. Commercial availability is not simply a function of whether or not a system is available for purchase; it is also dependent on sufficient production of systems to meet demand and the availability of customer support. System availability is also influenced by the presence of an available market (i.e. demand) to purchase treatment systems. This market, in turn, will depend upon the development of mechanisms for systems approval, particularly at the federal and international levels, as vessel operators may be hesitant to purchase systems without government assurance that such systems will meet applicable standards. For the purposes of this report, however, treatment system availability is ultimately linked to system performance - the ability of a system to treat ballast water to a level in compliance with California's performance standards.

Industry Demand

The California performance standards have a phased implementation schedule similar to that of the IMO Convention (see Table III-2). The phased implementation provides greater time for large and/or existing vessels to execute plans for system installation including possible retrofits of vessel structures and machinery. The first implementation date for California will affect only new vessels built on or after January 1, 2010 with a ballast water capacity of less than 5000 MT. The number of new vessels that must meet the performance standards beginning in 2010 will greatly influence how quickly treatment vendors must have their systems available for sale. Lloyd's Register (2008) estimates that in 2009, worldwide construction will commence on 540 new vessels with a ballast capacity of less than 5000 MT. Presumably, a similar number of vessels will be constructed (i.e. as defined by keel laid date or commencement of major conversion) beginning in 2010, although no specific estimates are currently available. Exactly how many vessels will ultimately operate and discharge ballast in California waters is difficult to determine, however the numbers are expected to be relatively small.

Examination of the number of vessels that have previously arrived in California provides some insight into, and a very conservative estimate of, the number that must be prepared to meet the performance standards in 2010. Between January 2000 and August 2008, 908 unique vessels with a ballast water capacity less than 5000 MT arrived at California ports (Figure VI-1). Presuming a 20-year vessel replacement cycle, approximately 5% (45) of these 908 vessels may be replaced by new vessels and be required to meet the performance standards in 2010 (Reynolds, K., pers. comm. 2007). As only 20% of vessels, on average, discharge ballast in California waters (Falkner et al. 2007), an even smaller number of vessels (~ 9) will likely discharge in California waters and require treatment system usage. In the class of vessels with a ballast water capacity greater than 5000 MT, 5682 unique vessels arrived at California ports between January, 2000 and August, 2008 (Figure VI-1). Again, assuming a 5% yearly replacement rate, 284 vessels will likely be replaced with new vessels and be required to meet the performance standards beginning in 2012. Clearly, a much smaller number of new vessels will be required to meet the standards beginning in 2010 than in 2012, however, the precise number is less clear.

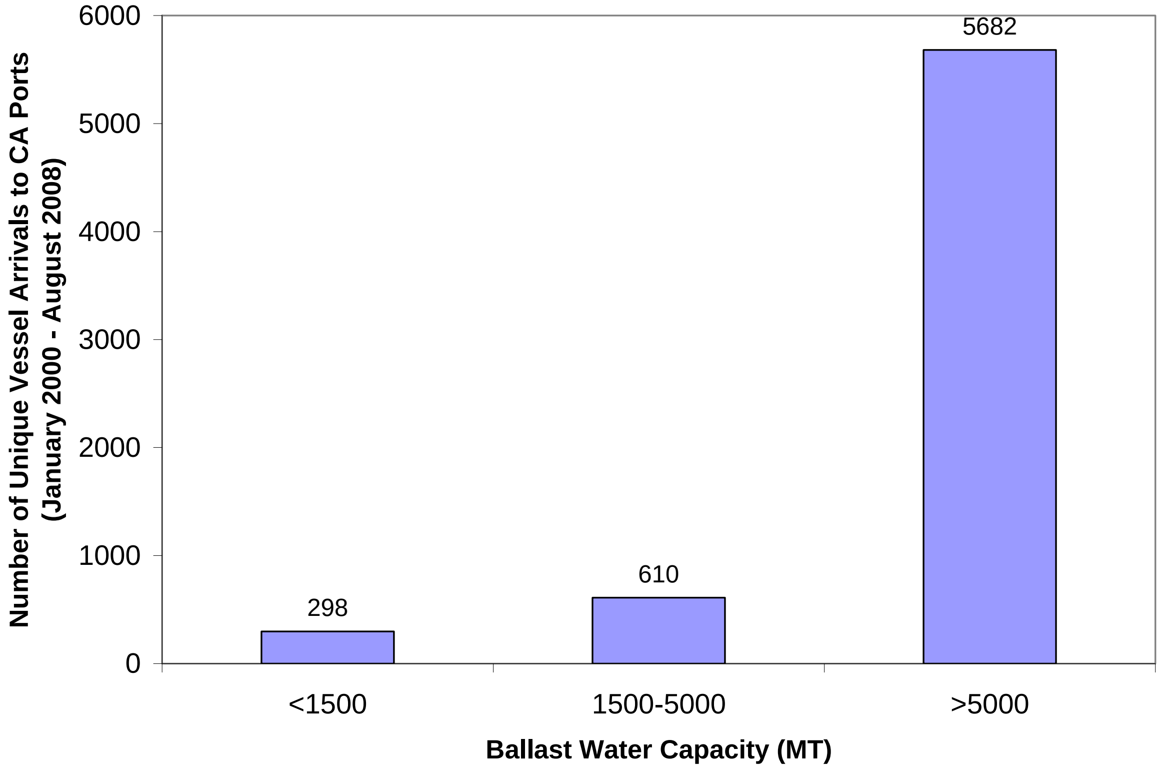

Figure VI-1. Number of unique vessels that arrived to California ports between January, 2000 and August, 2008 as a function of ballast water capacity (MT).

Assessing industry demand at any given time is further complicated by factors such as the timing of when a vessel owner chooses to purchase a treatment system. Vessel owners, particularly of existing vessels with later implementation dates, may choose to purchase a system earlier than required by the standards implementation date so that installation dovetails with drydock and repair schedules. In this case, estimates of demand based solely on the standards implementation dates are likely inaccurate. Commission staff will continue to follow trends in vessel visits to California and treatment system purchase and installation, particularly as the performance standards are implemented for newly built vessels, and will assess system availability for existing vessels in future reports.

Commercial Availability

System vendors will need to have systems commercially available by the time the initial interim performance standards take effect in 2010. The definition of commercial availability differs depending on who you talk to. Many treatment vendors consider commercial availability to be the time when systems are available for sale and purchase. Vessel owners, however, may not consider systems to be commercially available until all required approvals (IMO or otherwise) are in place (see Market Availability below for further explanation). In 2008, 23 treatment technology vendors provided Lloyd's Register with an actual or anticipated date of commercial availability. Ten companies reported that their systems were commercial availability by 2007, four expected to be commercial availability in 2008, seven anticipated availability in 2009 and two in 2010 (Lloyd's Register 2008). Similar data collected by Commission staff indicate that as of October 2008 at least 12 technology vendors consider their systems to be commercially available. On the other hand, only three systems have currently received Type Approval as required by IMO (Table V-1).

In addition to having systems ready for purchase, treatment vendors will also need to produce sufficient quantities of those systems to meet market demand. Several of the large, multinational technology vendors already produce many other products for the maritime industry and have a pre-existing infrastructure in place that may be modified to globally produce and support ballast water treatment systems (Reynolds, K., pers. comm. 2007). However, it is more difficult to gauge the ability of small technology vendors to meet projected production and support needs of the shipping fleet. Treatment vendors may be able to space out delivery of systems for new vessels with a ballast capacity less than 5000 MT over a couple of years while infrastructure and production are brought up to speed, as even the largest marine corporations require significant lead time for existing marine product lines (Reynolds, K., pers. comm. 2007). While vessels in this size class are subject to the standards as of 2010, the construction of large commercial vessels can take several years, and many of those vessels may not actually be ready for treatment system installation and operation until 2011 or later.

System support is equally important as commercial availability. Following installation, system developers will need to have personnel and infrastructure in place to troubleshoot and fix problems that arise during system operation. Maritime trade is a global industry, and vessel operators will need to have global support for onboard machinery. The Lloyd's Register (2008) report does not address the issue of after-purchase support of systems. The initial influx of systems into the marketplace will no doubt challenge developers to provide adequate service. Larger companies entrenched in the maritime logistics or equipment industries may already be prepared to respond to technological challenges and emergencies as they arise, but smaller ballast water treatment vendors may face an initial period to ramp up service and access to replacement parts. It is currently unclear if system support service will be adequate as the first of California's performance standards is implemented in 2010, and if a lack of service could impact commercial availability.

Market Availability

The availability of ballast water treatment systems is not only a function of commercial availability but also of market demand to purchase those technologies. Previous discussions addressed one aspect of demand - the number of vessels that will be required to meet the performance standards beginning in 2010. However, demand may also be influenced by the availability of systems that have received government approval to operate in a given water body.

In the U.S., the lack of a regulatory framework for the approval of ballast water treatment systems at the federal level is a major hindrance to the demand for systems. While California law requires initial compliance with the interim performance standards beginning in 2010, shipping companies may be hesitant to purchase treatment systems with little or no assurance that the system will be permitted to operate in federal waters. As of October 2008, neither the EPA nor the USCG has a ballast water treatment approval program in place. Vessels cannot use treatment systems to comply with the federal ballast water management requirements unless they are approved. Therefore, unless these federal agencies begin to approve systems before 2010, a vessel intent on discharging ballast in California after arriving from outside of the 200 nm Exclusive Economic Zone will need to conduct a mid-ocean exchange to comply with federal ballast water management requirements and will additionally be required to treat that water to meet California requirements. This conflict in ballast management regulation between federal and state governments will no doubt cause confusion and may even temper demand to install treatment systems onboard vessels. While it is extremely unlikely that all vessels that visit California can refrain from discharging all ballast, the implementation of the performance standards regulations in California may spur renewed interest in developing ballast water management plans that will limit ballast water discharges in the state.

Availability for Use in California

Commercial availability should not, however, at any time be confused with a system's capability to meet California's performance standards. Systems that may be deemed commercially available and ready for sale by technology vendors must demonstrate system efficacy to vessel owners/operators who will purchase those systems and to regulatory agencies. Systems that have received IMO approval for active substances and Type Approval may be available for purchase in compliance with the IMO D-2 standards, but for the purposes of this report, those systems are not deemed "available" for use in California until they demonstrate system efficacy and environmental safety in compliance with California's performance and water quality standards. Based on the information reviewed for this report, at least two systems, OceanSaver and OptiMarin, are both commercially available and have demonstrated the potential to comply with California's performance standards that can be currently quantified using best available assessment techniques (see previous discussion in Efficacy section). Several additional systems are close to completing performance verification testing and/or receiving Type Approval, and Commission staff believes that these systems will be available for use in California prior to the initial implementation of the performance standards in 2010.

Environmental Regulation and Impact Assessment

An effective ballast water treatment system must comply with both performance standards for the discharge of ballast water and applicable environmental safety and water quality laws and regulations. The discharge of treated ballast should not impair water quality so as to impact the designated beneficial uses of the State's receiving waters (e.g. recreation, fisheries, fish/wildlife habitat). The IMO, federal government and individual states have developed specific limits for discharge constituents and/or whole effluent toxicity evaluation procedures in order to protect the beneficial uses of waterways from harmful contaminants. Commission staff has drawn on the environmental review of ballast water treatment systems and active substance constituents from all levels of government (international, federal, state) in the assessment of environmental risk from the 30 treatment systems reviewed here.

International Maritime Organization Regulation

As discussed in Section III (Regulatory Overview), the IMO has established an approval process through Guideline G9 for treatment technologies using active substances (i.e. chemicals) to ensure systems are safe for the environment, ship, and personnel. The two-step process is comprised of an initial “Basic Approval” utilizing laboratory test results to demonstrate basic environmental safety, followed by “Final Approval” upon evaluation of the environmental integrity of the full-scale system.

Guideline G9 of the Convention requires applicants to provide information identifying: 1) Chemical structure and description of the active substance and relevant chemicals (byproducts); 2) Results of testing for persistence (environmental half-life), bioaccumulation, and acute and chronic aquatic toxicity effects of the active substance on aquatic plants, invertebrates, fish, and mammals; and 3) An assessment report that addresses the quality of the tests results and a characterization of risk (MEPC 2005b). Systems that apply for Basic and Final Approval are reviewed by the IMO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) – Ballast Water Working Group (BWWG) in accordance with the procedures detailed in Guideline G9. The Guideline does not address system efficacy, only environmental safety (MEPC 2005b).

Federal Regulation

Outside of USCG’s Shipboard Technology Evaluation Program (STEP), ballast water treatment systems are not currently approved for use in compliance with federal ballast water management requirements. Consequently, there is no formal environmental assessment approval program (like that of IMO) for ballast water treatment systems at the federal level. EPA, however, recognizes that ballast water treatment systems will be used both experimentally at the federal level and in compliance with state ballast water management requirements, and has therefore included provisions in the draft NPDES Vessel General Permit for discharges from vessels employing ballast water treatment systems.

The effluent limits and best management practices described in the draft NPDES Vessel General Permit are specific to those treatment systems that make use of biocides. Under the permit, all biocides that meet the definition of a “pesticide” under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA; 7 U.S.C. § 136 *et seq*.) must be registered for use with the EPA. Biocides generated onboard a vessel solely through the use of a “device” (as defined under FIFRA) do not require registration. Additionally, the permit sets a limit for Total Residual Chlorine (100 µg/l) in ballast water discharge, and states that discharges of other biocides or residuals must not “exceed acute water quality criteria as listed in EPA’s 1986 Quality Criteria for Water [the Gold Book], or any subsequent revisions” (EPA 2008). Furthermore, EPA requested public comment on whether it was appropriate to include Whole Effluent Toxicity (WET) standards in the permit to complement or to serve in lieu of complying with chemical monitoring. Though the permit had not been released at the time of this report, it is possible that EPA will include WET monitoring options. In lieu of complying with the aforementioned conditions, vessels that discharge ballast containing biocides or chemical residuals may apply for an individual NPDES permit.

Vessels participating in the STEP must comply with the NPDES Vessel General Permit and additionally conform to the environmental compliance requirements associated with STEP participation including: 1) Compliance with the National Environmental Policy Act (NEPA) process; 2) Due diligence by the applicant in providing requested biological and ecological information and obtaining necessary permits from regulatory agencies; and 3) A provision that systems found to have an adverse impact on the environment or present a risk to the vessel or human health will be withdrawn from the program (USCG 2006).

State of Washington Regulation

The Washington State Department of Ecology developed a framework for "Establishing the Environmental Safety of Ballast Water Biocides" in 2003 and revised it in 2005 to be included as Appendix H in the *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* manual (Washington State Department of Ecology 2005). Thus far, three systems have completed toxicity testing in accordance with Washington requirements (Table VI-3).

The tests used in the Washington State framework for evaluating ballast water biocides include EPA-approved acute, chronic and sensitive life stage toxicity tests on invertebrate, fish and algal species. If treated ballast water might be discharged more than once in the same location during a week or in sensitive marine areas in the state, then additional tests are also required to determine the biocide environmental safety. The results of the toxicity testing are used to set system discharge conditions such as maximum concentration or minimum degradation time (Marshall, R., pers. comm. 2007).

California Regulation

California does not have a formal environmental evaluation process for ballast water treatment systems. Vessels that discharge in California waters will need to comply with the applicable provisions of the EPA's NPDES Vessel General Permit including all California-specific conditions added by the State Water Resources Control Board through the Section 401 certification process. As of the writing of this report, the permit conditions included in the 401 certification were not available.

All vessels using treatment technologies that make use of biocides should also ensure that any residuals or reaction by-products in treated ballast water discharges meet applicable water quality objectives as outlined in the California Ocean Plan (Water Board 2005), Regional Water Quality Control Board Basin Plans, the EPA's California

Toxics Rule (CTR) and the associated State Implementation Policy for the CTR. Vessel owners/operators will need to consult with Water Board staff regarding the development and implementation of monitoring programs for all relevant discharge constituents. The “Ballast Water Treatment Technology Testing Guidelines” that were distributed to treatment vendors in October 2008 were developed in consultation with the Water Board, and summarize the water quality objectives and acute and chronic water toxicity criteria that systems will need to comply with when discharging in California waters (see Appendix A).

Environmental Assessment of Treatment Systems

Staff has compiled environmental assessment reports and water quality data reported to the IMO and the State of Washington, as well as information made available to Commission staff, to assess the treatment systems for potential environmental impacts to California waters. The IMO active substance approval documents, in particular, have proved to be a valuable resource to assess a treatment system’s broad-scale environmental safety prior to comparison of specific system effluent constituents with California’s water quality objectives.

Of the 30 treatment systems reviewed for this report, 19 use a biocide or chemical additive in the treatment process (Table VI-3), and will therefore require monitoring of discharges for chemical residuals under the EPA’s NPDES Vessel General Permit and the State’s Ocean Plan. As discussed in Section V (Treatment Technologies), eighteen of the 19 systems that use chemicals employ a chemical oxidant or oxidative technology as the active substance to kill or inactivate organisms in ballast water (Table VI-3). An assessment of the potential impacts from the wide variety of chemical residuals associated with the use of oxidants by each technology cannot be adequately addressed in this report and is the purview of the Water Board and EPA. Instead, Commission staff has focused this environmental assessment on Total Residual Chlorine (TRC) concentrations in discharged ballast water because both EPA (through the draft NPDES Vessel General Permit) and the Water Board (through the California Ocean Plan) have identified TRC as a particular concern due to its widespread toxicity to all organisms. Vendors and vessel owners/operators will need to consult with the Water Board and EPA to ensure that vessel discharges comply with all other applicable effluent requirements.

Table VI-3 lists the active substances and summarizes the status of environmental approvals/assessments for each of the technologies reviewed in this report. Where applicable, the available data has been analyzed to determine whether or not treated ballast would comply with California's water quality objective for chlorine in ocean waters (= instantaneous maximum of 60 µg/l in discharged waters).

Many systems have initiated toxicity testing of treated discharges and have applied to IMO for Basic and Final Approval. The IMO Basic Approval application, however, may include data from general literature review or laboratory analysis of system toxicity. Until such time that a system submits a full dossier of whole effluent toxicity data as required for IMO Final Approval, it will be difficult to anticipate the potential environmental impacts to California waters from the discharge of treated ballast from a fully functioning treatment system. Currently only four treatment systems have received Final Approval from IMO (Table VI-3).

The "pesticide" registration requirement under FIFRA is one mechanism to regulate and assess the impacts to U.S. federal waters from biocide use in treatment systems. The thorough chemical safety analysis and registration process required under FIFRA has been completed by one system (Hamann Evonik Degussa), and a few others are in the process of completing the process. FIFRA has a loophole, however, for chemicals that are generated onsite and used in place (e.g. generated and used by a vessel). Most treatment systems using biocides generate that chemical through onboard electrochemical processes, and thus will not be subject to FIFRA registration. This FIFRA loophole provides significant room for systems to operate in U.S. waters without any kind of biocide regulation except as provided by the NPDES Vessel General Permit, and at this time, it is uncertain how EPA will enforce the permit's provisions.

Table VI-3. Summary of environmental assessment and approval of treatment systems

Note: Table does not address whether or not toxicity testing was performed in accordance with the California Ocean Plan

Manufacturer	Active Substance	Toxicity Testing	Environmental Related Approvals	CA TRC Compliant[1]	Source
Alfa Laval	free radicals	X	IMO Basic and Final	Y	73,93
ATG Willand	n/a (UV)				
Ecochlor	chlorine dioxide	X	IMO Basic, Rec WA Cond.[2]	Y	84
EcologiQ	yeast	X			3
Electrichlor	sodium hypochlorite				
ETI	ozone	X			62
Ferrate Treatment Tech.	ferrate				
Greenship	free active chlorine, total residual chlorine	X	IMO Basic		80,86
Hamann Evonik Degussa	Peraclean Ocean (peracetic acid, hydrogen peroxide, acetic acid)	X	IMO Basic & Final, EPA Reg., Rec. WA Conditional[2]		77,91
Hi Tech Marine	n/a (heat)		Queensland EPA		123
Hitachi	triiron tetraoxide, poly aluminum chloride, poly acrylamide sodium acrylate	X	IMO Basic		75
Hyde Marine	n/a (UV)				
JFE Engineering Corp.	sodium chlorine				
MARENCO	n/a (UV)				
Maritime Solutions Inc.	n/a (UV)				
MH Systems	n/a (deoxygenation)				
Mitsubishi Heavy Ind.	free active chlorine				72
Mitsui Engineering	ozone	X	IMO Basic		69
NEI	n/a (deoxygenation)	X			10
NK-03	ozone, total residual oxidant	X	IMO Basic	Y	85
Nutech 03 Inc.	ozone	X		N	141
OceanSaver	free and total residual oxidant	X	IMO Basic and Final	Y	82,87,99
OptiMarin	n/a (UV)	X		Y	92
Panasia Co.	photon		IMO Basic		78,81
Resource Ballast Tech.	ozone, hydroxyl radicals	X	IMO Basic	N	74
RWO Marine Water Tech.	hydroxyl radicals, free active chlorine	X	IMO Basic	N	76,79
SeaKleen	menadione (Vitamin K3)	X			8
Severn Trent DeNora	sodium hypochlorite, sodium bisulfite	X	Rec. WA Conditional[2]	Y	39
Techcross Inc.	hypochlorite, hypobromite, ozone, hydroxyl radicals, hydrogen peroxide	X	IMO Basic and Final	Y	83,86
Toagosei Group	sodium hypochlorite, sodium sulfite	X	IMO Basic		86

Blank cells indicate that data was not available

[1] CA Ocean Plan instantaneous maximum for Total Residual Chlorine = 60 micrograms/liter (µg/l)

[2] WA Dept. of Ecology Water Quality Program has recommended Conditional Approval of the system to WA Dept. Fish and Wildlife. As of the writing of this report, approval has not been granted.

A system's feasibility for operation in California is inherently based on its ability to meet all of California's requirements regarding discharges, not simply the performance standards. While it is the purview of the Water Board to review and regulate the effluent from treatment systems, Commission staff is working to educate technology vendors, particularly those from foreign countries, about California's water quality objectives. The "Ballast Water Treatment Technology Testing Guidelines" were recently distributed and summarize the pertinent information for vendors. Staff will also work closely with the Water Board to ensure that vendors are made aware of California's Section 401 provisions in the NPDES Vessel General Permit, once released. In the meantime, staff has attempted to compile data on Total Residual Chlorine (TRC) in treated effluent because of its broad-scale toxicity, and because so many systems use chlorine and related byproducts in the treatment process. Of the 30 systems reviewed, thirteen use chlorine in the treatment process or may have chlorinated residuals in treated effluent. Based on the available data, seven appear to meet California's objective of 60 µg/L of residual chlorine (Table VI-3). Clearly, not all treatment systems will meet California's stringent water quality standards. However, it is difficult to assess at this time whether systems are simply not able to meet the standards or whether additional water quality data must be gathered from operation of full-scale systems under real world scenarios. Commission staff will continue to work with the Water Board, vessel owners/operators and technology vendors to ensure that systems are tested with California's water quality objectives in mind and that the information is made available to interested parties.

Economic Impacts

An assessment of the economic impacts associated with the implementation of performance standards and the use of treatment technologies requires consideration not only of costs connected with the purchase, installation and operation of treatment systems, but also the impacts related to the control and/or eradication of NIS if performance standards are not met. As discussed in the Introduction (Section II), the U.S. has suffered major economic losses as a result of attempts to control and eradicate NIS (aquatic and terrestrial; Carlton 2001, Lovell and Stone 2005, Pimentel et al. 2005). The rate of new introductions is increasing (Cohen & Carlton 1998, Ruiz & Carlton 2003) which suggests that economic impacts will likely increase as well.

California had the largest ocean-based economy in the U.S. in 2004, ranking number one for employment, wages and gross state product (NOEP 2007). California's natural resources contribute significantly to the coastal economy. For example, in 2007 total landings of fish were over 380 million pounds, bringing in more than $120 million (NOEP 2008). Squid, the top revenue-generating species in 2007, brought in almost $30 million (NOEP 2008). The health of coastal natural resources is also closely tied to the tourism and recreation industries which accounted for almost $12 billion of California's gross state product in 2004 (NOEP 2007). NIS pose a threat to these and other components of California's ocean economy including commercial fisheries, aquaculture, sport and recreational fisheries, tourism and recreation, and education.

The use of ballast water treatment technologies to combat NIS introductions will involve economic investment on the part of ship owners. This investment in treatment systems reflects not only initial capital costs for the equipment and installation, but also the continuing operating costs for replacement parts, equipment service and shipboard energy usage. Cost estimates are strongly linked to vessel-specific characteristics including ballast water capacity, ballast pump rates and available space. Additionally, the retrofit of vessels already in operation (existing vessels) with ballast water treatment technologies may cost significantly more than installation costs for newly built vessels due to: 1) The necessity to rework existing installations (plumbing, electric circuitry); 2) Non-optimal arrangement of equipment that may require equipment be broken into pieces and mounted individually; 3) Relocation of displaced equipment; and 4) The time associated with lay-up (Reynolds, K., pers. comm. 2007). Nonetheless, the use of these treatment technologies will help minimize or prevent future introductions of NIS and relieve some of the future economic impacts associated with new introductions.

Many treatment technology vendors are hesitant to release costs at this point because system prices represent research and development costs and do not reflect the presumably lower costs that would apply once systems are mass produced. In the 2008 Lloyd's Register report, only 16 of 29 technologies profiled provided estimates of system capital expenditures (equipment and installation) and half (14) provided estimates of system operating expenditures (parts, service, and energy usage; Table VI-4). Commission staff has also acquired some data on capital and operating costs. Capital expenditure costs are dependent on system size. A 200 cubic meters per hour (m^3/h) capacity system may require an initial capital expenditure between $145,000 and $780,000 with an average cost of $387,500 (Lloyd's Register 2007, Lloyd's Register 2008, Commission data from technology vendors 2007-2008). A 2000 m^3/h capacity system ranges from $175,000 to $2,300,000 with an average cost of $894,600 per system (Lloyd's Register 2007, Lloyd's Register 2008, Commission data from technology vendors 2007-2008). Operating costs range from negligible, assuming waste heat is utilized, to $1.50 per m^3 with an average of $0.13 per m^3 (Lloyd's Register 2007, Lloyd's Register 2008, Commission data from technology vendors 2007-2008).

Treatment systems will likely increase the cost of a new vessel by 1-2%. For example, a new 8500 TEU (twenty-foot equivalent unit) container ship built by Seaspan Corporation costs approximately $132.5 million per vessel (Seaspan Corporation 2007). Installation of the most expensive treatment system currently available at $2.3 million (as indicated in Table VI-4) would increase the cost of that vessel by 1.7%. Many treatment technology developers claim that their systems will last the life of the vessel, so the capital costs for treatment systems should be a one-time investment per vessel.

While the economic investment by the shipping industry in ballast water treatment technologies will be significant, when compared to the major costs to control and/or eradicate NIS, the costs to treat ballast water may be negligible. Treating ballast water with treatment technologies will help to prevent further introductions and lower future costs for control and eradication. Additional studies will be necessary to obtain actual economic impacts associated with treating ballast water.

Table VI-4. Summary of capital and operating cost data for select treatment systems. Unless otherwise noted, source of data was Lloyd's Register (2008).

Manufacturer	Capital Expenditure (Equipment & Installation)			Operating Expenditure
	200 m3/h ($ in thousands)	2000 m3/h ($ in thousands)	Other ($ in thousands)	($ per m3, unless otherwise noted)
Alfa Laval				0.015[1]
ATG Willand				
Ecochlor	500	800		0.08
EcologiQ			<50[1]	1-1.50[1]
Electrichlor	350			0.019
ETI		500		0.005
Ferrate Treatment Tech.				
Greenship	300	2300		
Hamann Evonik Degussa				0.2
Hi Tech Marine	780	1600	16.5 – 300[1] *(equipment only)*	nil[2]
Hitachi		400		
Hyde			174 – 503[1]	0.01
JFE Engineering				0.04
MARENCO	145	175		0.0006-0.001
Maritime Solutions Inc.				
MH Systems	650	950		0.06
Mitsubishi				
Mitsui			100[1] *(installation only)*	0.15[3]
NEI	360	690		0.15
Nutech 03	288	150		0.32
OceanSaver		1600		0.06[3]
OptiMarin	430	1800		
Panasia				
Resource Ballast Technologies	200	500		
RWO Marine				
SeaKleen (Hyde)				
Severn Trent	350	500		0.013
Techcross	297	559		0.003
Toagosei Group				

[1] Source: Communications with technology vendors (2007-2008).
[2] Assumes waste heat utilized
[3] Source: Lloyd's Register (2007)

VII. CONCLUSIONS

Ballast water treatment remains an emerging industry. New technologies continue to be developed and existing ones refined in search of the most effective methods to reduce and/or eliminate the spread of nonindigenous species via ballast water release. While some hurdles remain to the full implementation of all of California's performance standards, significant progress has been made in the development of treatment systems since the previous technology assessment report (see Dobroski et al. 2007). Both the quantity and the quality of the recently received data on system performance attest to this fact.

Like the ballast water treatment industry, the fields of treatment technology assessment and compliance verification are still evolving. Commission staff has been working closely with a panel of technical experts in order to develop a set of ballast water treatment technology testing guidelines. The guidelines provide vendors with a summary of California's performance standards, relevant water quality objectives and toxicity criteria. Moreover, they provide some initial guidance on the selection of methods and techniques to assess system compliance with California's discharge standards.

The selection of best available assessment techniques for the guidelines has also informed staff's evaluation of system efficacy data for the purposes of this report. Challenges remain in assessing system compliance with the standards for organisms that are less than 10 micrometers in size – the bacteria and viruses. The best available technique for bacterial viability assessment involves the use of a subset or proxy group of organisms to represent treatment of bacteria as a whole. While this technique isn't without some debate, it is scientifically supported by many experts in microbiology and technology assessment (see Appendix A). Viruses pose a greater challenge. Without strong evidence for the selection of proxy or representative organisms in this size class, Commission staff believes that there are no acceptable methods for verification of compliance with the standard and that the Commission should proceed with assessment of technologies for the remaining six standards.

Based on the available information and using best assessment techniques, Commission staff believes that at least two treatment systems have demonstrated the potential to comply with the Commission's performance standards. Many additional systems are close to completing system performance verification testing and will soon have data available for review. Commission staff expects that before 2010 several systems will be ready to meet California standards.

The treatment systems that meet California's standards under the review for this report are commercially available at this time. The additional systems that are close to meeting California's standards are also commercially available. Many of these systems also expect to receive IMO Type Approval in 2009, and thus these systems will be considered available for use both in California waters and in compliance with the IMO Convention, upon ratification.

The IMO approval pathway for systems utilizing active substances has been a resource for information about the potential environmental impacts from the discharge of treated ballast water. The number of systems that have received IMO Final approval remains small at this time, however, and thus environmental impact analysis of whole effluent toxicity remains hampered by a lack of data. The data available on Total Residual Chlorine concentration in treated ballast effluent makes it clear that not all systems will comply with California's water quality standards but also that additional information is necessary. The recently distributed treatment technology testing guidelines will inform vendors about California's water quality objectives and toxicity criteria and should influence environmental assessment of system discharges in the near future. Commission staff is also working closely with the Water Board to track the implementation of the NPDES Vessel General Permit in California and assess the acceptability of discharges under this new regulatory program. Ultimately, treatment vendors and vessel operators will need to consult with the Water Board to better assess the potential for water quality impacts from treatment system usage in California waters.

In conclusion, the Commission is preparing to implement the performance standards for new vessels with a ballast water capacity of less than 5000 MT in 2010. This review indicates that systems are or will soon be available to meet California's performance standards, particularly in light of the small number of new vessels that will likely need to meet the standards beginning in 2010. Commission staff is developing verification procedures to assess vessel compliance with the performance standards, and is working closely with the shipping industry and treatment vendors to ensure a smooth transition to the new standards. Staff will conduct another assessment of available treatment technologies by July 1, 2010 in anticipation of the 2012 implementation date for new vessels with a ballast water capacity greater than 5000 MT.

VIII. LOOKING FORWARD

Staff is currently engaged in the following activities to establish a comprehensive program for the implementation and enforcement of California's performance standards for the discharge of ballast water.

1. Develop protocols to assess vessel compliance with the performance standards

Staff must develop protocols for use by the Commission's marine safety personnel to verify vessel compliance with the performance standards. Commission staff will consult with a technical advisory panel in order to select the best available methods for organism enumeration and viability assessment taking into account ease of use, cost effectiveness, accuracy, precision and acceptance by the scientific community. The compliance verification protocols will describe on-site sampling, the handling of samples between vessel and testing laboratory (chain of custody), mechanisms for the identification and approval of independent laboratories to conduct the sample analysis, and requirements for reporting of compliance by laboratories to the Commission. The protocols are expected to be complete in mid-2009.

2. Amend performance standards regulations

Staff must make several amendments to the performance standards regulations during the next year. The passage of SB 1781 delayed the initial implementation of the standards from 2009 to 2010. The regulations must now be amended to maintain consistency with the statute. The proposed rulemaking will be presented to the Commission for approval in December, 2008.

Additionally, the advisory panel has brought to light potential issues with the use of best available assessment techniques to determine vessel compliance with the performance standards. It is possible that vessels may install systems compliant with the standards using today's assessment techniques, only to discover that the system is out of compliance at a future date when new and potentially more accurate assessment techniques are developed. The cost and burden to the industry is too great to risk having systems, operating at the same level as when they were installed, become out of compliance shortly after installation. The Commission must address how to account for changing compliance verification techniques without requiring vessels to frequently update costly ballast water treatment systems. One option would be to grandfather treatment systems under the compliance verification protocols in use during system installation. The specifics of this process have yet to be determined, but will likely need to be clarified via regulation in 2009 prior to the implementation of the performance standards in 2010.

Finally, Commission staff must amend the regulations to guide the selection of specific locations and sampling devices needed for onboard sample collection to verify compliance with California's performance standards. According to PRC Section 71206, Commission staff is mandated to inspect and take samples of ballast water and sediment from at least 25% of the arriving vessels to California ports in order to assess compliance with the law. The proposed changes are necessary because not all vessels are currently designed to include sampling "ports" for in-line collection of ballast water discharge. Staff has made efforts in the development of the proposed regulations to maintain consistency with proposed language for ballast water sampling in the IMO

Convention. Preliminary response from industry has been positive. Commission staff expects to complete the rulemaking process in 2009.

3. Revise ballast water treatment technology testing guidelines, as necessary

Commission staff developed the "Ballast Water Treatment Technology Testing Guidelines" in 2008 to promote a uniform, cost-effective, scientifically-rigorous, independent assessment of treatment system performance and environmental safety. In an effort to standardize ballast water treatment evaluation, the testing guidelines draw on the EPA's draft ETV protocols for ballast water performance verification. EPA is currently in the process of revising the draft ETV protocols and expects to release the next version in late-2009 or 2010. As the ETV protocols are updated, Commission staff will revise the testing guidelines in order to eliminate variability between the proposed federal technology evaluation program and California's recommended guidelines. Staff is also working with the Water Board staff to stay informed about the proposed provisions in the State's 401 certification of the NPDES Vessel General Permit and any changes to the California Ocean Plan or relevant monitoring programs associated with vessel discharges. Commission staff will update the testing guidelines as new information becomes available.

4. Support the development of performance standards and ballast water treatment technology performance verification protocols at the federal level

Commercial shipping is an international industry; any single ship may operate throughout several regions of the world. Ideally, performance standards should align both at the federal and international level and is preferable to a patchwork of standards adopted by individual states. Commission staff continues to work with the federal government, including the U.S. Congress, USCG and EPA, on the development of federal performance standards and treatment technology performance verification protocols. Commission staff has consulted with congressional staffers about proposing California's performance standards as the national standards. Additionally, staff participates on both the EPA ETV program Ballast Water Technical Panel and Stakeholder Advisory Panel. These panels are working with ETV program staff and the

USCG to finalize the technology verification protocols for ballast water treatment systems.

IX. RECOMMENDATIONS TO THE LEGISLATURE

The Commission recommends that the Legislature take the following actions to enhance the Commission's ability to effectively implement California's performance standards and to continue to prevent or minimize the introduction of NIS in California waters.

1. Authorize the Commission to amend the ballast water reporting requirements via regulations

In the previous treatment technology assessment report (see Dobroski et al. 2007), Commission staff recommended that the Legislature provide the Commission with the authority to develop a form via regulations to acquire information about ballast water treatment system installation and use onboard vessels. Currently, PRC Section 71205 specifies that voyage information must be submitted to the Commission on a form developed by the United States Coast Guard. However, PRC Section 71205 does not accommodate the Commission's need to develop a form to collect additional information about the use of ballast water treatment systems on board vessels, specifically: the timing of and requirements for treatment system use, deviations from suggested system operation, certifications for operation from vessel classification societies and other organizations/agencies, or additional information as deemed necessary by Commission staff in consultation with an advisory panel. Assembly Bill 169 was introduced in 2008 and passed by lawmakers to address the recommendation that the Commission be granted the authority to develop a form on ballast water treatment system use via the rulemaking process. The bill was not opposed by any organization, but was vetoed by the Governor, along with hundreds of other bills due to the delay in passage of the budget. Nonetheless, as the performance standards are implemented, the need for more information about treatment system installation and usage remains. The Commission should be authorized to amend ballast water reporting requirements to gather additional information about treatment system operation.

2. Continue to support research promoting technology development and performance evaluation.

Ballast water treatment remains a burgeoning industry that will undergo significant development as the IMO and California's performance standards are progressively implemented and as new vessel types are built. In 2012, the standards will go into effect for new vessels with the largest ballast water capacity (over 5000 MT), and technologies will need to be able to effectively inactivate organisms under high volume and pump rate conditions. Existing vessels built before 2010 will need to be retrofitted for approved treatment systems by 2014 or 2016 (depending on ballast water capacity). Those technologies must be installable under limited space conditions, and must be able to integrate with the existing engineering of ships (piping, electrical, computer, etc.). While several of the systems evaluated in this report meet or come close to meeting California's Standards, many must still be evaluated on vessels. Additionally, research is needed to develop new scientific methods and refine existing methods to assess treatment system performance and verify vessel compliance with California's performance standards. Funds necessary to support these research needs could be obtained through three mechanisms: general funds, grants, or through the existing fees assessed on ships. The Commission and the Legislature should support future budget change proposals or other fiscal actions as necessary to fund this important research.

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