2010 ASSESSMENT OF THE EFFICACY, AVAILABILITY AND ENVIRONMENTAL IMPACTS OF BALLAST WATER TREATMENT SYSTEMS FOR USE IN CALIFORNIA WATERS

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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 subsequent ballast water treatment technology assessment reports was approved by the Commission in December 2007 (see Dobroski et al. 2007) and December 2008 (see Dobroski et al. 2009a). This report summarizes the Commission's conclusions on the advancement of ballast water treatment technology development and evaluation during 2009 and the first half of 2010 and discusses ongoing activities of the Commission's Marine Invasive Species Program regarding the implementation of California's performance standards for the discharge of ballast water.

Vessels have several options for complying with the performance standards regulations. Over 80% of vessel voyages to California waters do not involve the discharge of ballast water. In these cases, the standards are met because all ballast water is retained on board the vessel. Retention is the most protective management strategy available because no organisms are released from the vessel via ballast water. Alternatively, vessels may discharge to a shoreside or barge-based ballast water reception facility. Although no such facilities currently exist in California, there has been recent interest by several companies in developing this option for vessels in California and along the West Coast. Finally, for vessels that cannot retain all ballast on board or discharge to a reception facility, shipboard ballast water treatment will likely be necessary to meet California's performance standards.

Progress continues to be made in the development and assessment of treatment systems (see Dobroski et al. 2007, Dobroski et al. 2009a). Both the quantity and the quality of the recently received data on system performance attest to this fact. The fields

of treatment technology assessment and compliance verification, however, are still evolving. Scientific methods to assess the concentration of certain types of viable organisms present in ballast water discharge still must be developed or refined so that Commission staff may rapidly assess vessel compliance with the ballast water performance standards. The Commission is currently funding research to address some of these knowledge gaps, however additional work is necessary to develop compliance verification protocols for use in California.

California's standards for bacteria and viruses pose a significant challenge. While methods exist to quantify total counts of bacteria and viruses (or virus-like particles) in a sample of ballast water, no techniques are available to assess the viability of all bacteria and viruses, as is required by the California performance standards. 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 Dobroski et al. 2009a, 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.

Commission staff reviewed 46 ballast water treatment systems for this report. Based on currently available information and using best assessment techniques, at least eight treatment systems have demonstrated the **potential** to comply with the Commission's performance standards (see Tables VI-1 and VII-1). Efficacy data for these systems indicate that at least one test met or exceeded California's performance standard for every testable organism/size category during either land-based or shipboard testing. Three of the eight systems show the **potential** to meet California's performance standards under more rigorous evaluation criteria. These three passed more than 50% of the time over multiple tests (3 or more) at either the land or shipboard scale (Tables

VI-3 and VII-1). Additional systems are close to demonstrating the potential for meeting California's standards, and Commission staff are awaiting data from these tests of system performance. Commission staff have consulted with the vendors of systems that have demonstrated the potential to comply with California's standards, and at this time, two vendors (Ecochlor and Qingdao Headway Tech.), are willing to self-certify that their systems will meet California's standards. Evaluations in this report do not constitute endorsement, approval, or guarantee that a ballast water treatment system will meet California's standards for all vessels and all scenarios.

It is important to note that, as a whole, treatment systems have undergone a relatively small number of tests, under a limited range of environmental conditions. This leads to inherent uncertainty regarding treatment system performance across the spectrum of potential variables, including ship type and source water properties (e.g. temperature, turbidity, salinity). This uncertainty is likely to persist over the next several years. In the absence of a significant worldwide effort to install and test treatment systems on multiple vessels and under all possible environmental scenarios, it is unreasonable to expect that sample sizes and available data will increase adequately in the near future to demonstrate, with a high level of confidence, that treatment systems will consistently meet California's performance standards under every potential situation and under all circumstances. However, continuing to wait for such information will only serve to delay progress. Due to the inherent uncertainty regarding treatment system performance and evaluation, the utilization of an adaptive management approach will be essential at all stages of implementation in order to move forward and protect California's aquatic resources from the impacts of species introductions.

Commission staff believe that, given the data currently available, multiple treatment systems have demonstrated the potential to meet California's performance standards for vessels with construction initiated on or after January 1, 2012, and a ballast water capacity greater than 5000MT. Practically speaking, vessels with this construction date will not be expected to meet the standards until construction is complete and they are operational, sometime in 2014 at the earliest. The lead time available for further technology development and refinement is sufficient to indicate that technologies will be available by the time these vessels are operational. At least three to four years will pass before any vessels in this size class will need to install treatment systems to meet California's standards.

All eight of the systems that have demonstrated the potential to meet California's standards are currently commercially available. Seven of these systems are marketed as having the capability to treat ballast water at pump rates over 2000 m^3/hr, which would accommodate over 80% of the vessels that operate in California with ballast water capacity over 5000 MT. The manufacturers of six systems attest that their products will operate at much higher pump rates. The three systems that show potential for meeting the standards under more rigorous consistency criteria can accommodate much higher pump rates of 4500 m^3/hr or more.

Treatment vendors and vessel operators will also need to assess the potential water quality impacts from treatment systems prior to operation in California waters. All ballast water discharges from vessels must comply with the U.S. Environmental Protection Agency's (EPA) 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. Commission staff recommends that treatment vendors also consult the Marine Invasive Species Program's "Ballast Water Treatment Technology Testing Guidelines," which were developed in conjunction with the State Water Resources Control Board (Water Board) and provide additional guidance on relevant California water quality control plans and objectives for vessels intending to discharge treated effluent in State waters. Based on the available data it is clear that not all treatment systems will meet the EPA water quality objectives, particularly for chlorine residuals. Currently, California defers to the EPA Vessel General Permit for regulation of chlorine residuals in discharged ballast water. The eight systems that show the potential to meet California's standards have undergone some toxicity testing, and have received environmental approvals from the International Maritime

Organization and/or the State of Washington. Vessel owners and operators will need to consult with the EPA and the Water Board to better assess the potential for water quality impacts from treatment system usage in California waters.

The Commission will continue to gather information on treatment system efficacy, availability and environmental impacts as California's standards are implemented and additional vessels install treatment systems for both experimental purposes and to meet state, federal and international ballast water management requirements. Commission staff is working closely with the shipping industry and treatment vendors to ensure a smooth transition to the new standards. Commission staff believe that sufficient evidence exists to demonstrate that systems will be available to implement the performance standards for new vessels with a ballast water capacity greater than 5000 MT in 2012. However, in recognition of the rapidly changing fields of technology development and performance assessment, Commission staff will prepare an update of this report by September 1, 2011. In preparation of the update, Commission staff will convene a scientific advisory panel to review the latest data on treatment systems and testing protocols and provide input regarding the availability of treatment systems in an effort to ameliorate concerns regarding the implementation of California's performance standards. While not required by statute, this update will verify that technology development is progressing on schedule to allow for the implementation of the standards beginning January 1, 2012.

At this time, Commission staff recommends that the Legislature allow the implementation of standards for new vessels with a ballast water capacity over 5000 MT to proceed on January 1, 2012. In addition, and in order to ensure full implementation and compliance verification as performance standards move forward, Commission staff also recommend that the Legislature: 1) Support staff involvement with the development of performance standards and evaluation of treatment technologies at the federal and international levels; and 2) Maintain the accessibility and funding levels of the Marine Invasive Species Control Fund, so research can be supported and methods developed for compliance verification as vessels with treatment systems begin to arrive to California.

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ABBREVIATIONS AND TERMS

Act	Coastal Ecosystems Protection Act
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CFU	Colony-Forming Unit
CSLC/Commission	California State Lands Commission
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
ml	Milliliter
MPCA	Minnesota Pollution Control Agency
MT	Metric Ton
NIS	Nonindigenous Species
nm	Nautical Mile
NPDES	National Pollution Discharge Elimination System
NRL	Naval Research Laboratory
PRC	Public Resources Code
Staff	Commission staff
STEP	Shipboard Technology Evaluation Program
TRC	Total Residual Chlorine
µm	Micrometer (one millionth of a meter)
USCG	United States Coast Guard
UV	Ultraviolet Irradiation
VGP	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
WDNR	Wisconsin Department of Natural Resources

DISCLAIMER

This report provides information regarding the ability and availability of ballast water treatment systems to meet California's performance standards for the discharge of ballast water. This report does not constitute an endorsement or approval by the California State Lands Commission (Commission) of any treatment system or system manufacturer. It is the responsibility of the vessel owner/operator to select treatment systems that will ensure that ballast water discharges are in compliance with California's performance standards for preventing species introductions and all other applicable laws, regulations and permits.

I. PURPOSE

This report was prepared for the California Legislature pursuant to Public Resources Code (PRC) Section 71205.3. Among its provisions, PRC Section 71205.3 requires the Commission to adopt performance standards for the discharge of ballast water and 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." California's performance standards for the discharge of ballast water were approved in 2007 (see California Code of Regulations (CCR), Title 2, Division 3, Chapter 1, Article 4.7). The Commission completed an initial ballast water treatment technology assessment report in 2007 (see Dobroski et al. 2007) and a revised report in 2009 (see Dobroski et al. 2009a). Additional reports are due to the California Legislature 18 months prior to each of the implementation dates for California's performance standards (see Tables III-1 and III-2). This report fulfills the legislative mandate to assess the availability of ballast water treatment technologies prior to the January 1, 2012 implementation of performance standards for newly built vessels with a ballast water capacity greater than 5000 metric tons (MT). The report summarizes Commission conclusions on the advancement of ballast water treatment technology development and discusses progress by Commission staff in implementing California's performance standards for the discharge of ballast water.

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 believed to be a major contributor to the decline of several pelagic fish species in the Sacramento-San Joaquin River Delta by reducing the plankton food base of the ecosystem (Feyrer et al. 2003, Sommer et al. 2007). In addition, many human pathogens and contaminant indicator microorganisms have been found in ballast tanks. These include human cholera (*Vibrio cholerae* O1 and O139) (Ruiz et al. 2000), the microorganisms that cause paralytic shellfish poisoning (Hallegraeff 1998), human intestinal parasites (*Giardia lamblia, Cryptosporidium parvum, Enterocytozoon bieneusi*) and microbial indicators for fecal contamination (*Escherichia coli* and intestinal enterococci) (Reid et al. 2007).

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, encounter rough seas, or 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 small embayments in southern California (Woodfield 2006). Unsuccessful eradication attempts for nuisance NIS generally evolve into control efforts that typically represent an expensive and continual economic commitment. Approximately $10 million is spent annually to control the sea lamprey (*Petromyzon marinus*) in the Great Lakes (Lovell and Stone 2005). Over $10 million has been spent to control the zebra mussel and quagga mussel in California waters since the species were first found in 2007 (Ellis, S., pers. comm. 2010). By the end of 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, USCG 2001, Wonham et al. 2001, MacIsaac et al. 2002). When performed properly, exchange has been 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 determines 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 unexchanged 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.

Until very recently, financial investment in the research and development of ballast water treatment systems had been limited, and the advancement of ballast water treatment technologies had been 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. Perhaps most importantly, 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. Such targets were needed so developers 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, many 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 availability of ballast water treatment technologies requires an understanding of the regulatory framework associated with the development and implementation of performance standards for the discharge of ballast water, including knowledge of mechanisms for the testing and evaluation of treatment systems to meet those standards. Currently, there are no formally adopted international, federal or state programs that include performance standards, guidelines 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 have recently made great strides towards the development of a standardized approach for the management of discharged ballast water. However, existing legislation, standards and guidelines still vary by jurisdiction. The following is a summary of current performance standards-related laws, regulations and permits, and a review of current and proposed processes for treatment system evaluation and compliance verification.

International Maritime Organization

In February 2004, after several years of development and negotiation, International Maritime Organization (IMO) Member States adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) (see IMO 2005). Among its provisions, 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 date of construction (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 May 31, 2010, twenty-five countries representing 24.28% of the world's shipping tonnage have signed the convention (IMO 2010). The Convention cannot be enforced upon any ship until it is ratified and enters into force (IMO 2007). Because the Convention was not ratified in time to enter into force before the first performance standards implementation date in 2009, the IMO General Assembly adopted Resolution A.1005(25) (IMO 2007). The resolution delays the date by which new vessels built in 2009 with a ballast water capacity of less than 5000 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). The resolution also calls for the IMO Marine Environment Protection Committee (MEPC) to address the impending implementation date for vessels constructed in 2010 (IMO 2007). In September 2009, another draft resolution was put forth to encourage the installation of ballast water treatment systems on new build ships based on the existing implementation dates even though the Convention has not yet been ratified (MEPC 2009j). That resolution was adopted at the 60th meeting of the MEPC in March, 2010. However, since the conditions of the resolution are not mandatory, the implementation dates for all other vessel size classes and construction dates 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 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)	2016
1500 – 5000 metric tons	2009 (IMO)[2] /2010 (CA)	2014
> 5000 metric tons	2012	2016

[1] In California, the standards apply 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).

In order to ensure globally uniform application of the requirements of the Convention, the IMO MEPC has adopted 14 implementation guidelines (Everett, R., pers. comm. 2010). Most relevant to this report, Guideline G8, “Guidelines for Approval of Ballast Water Management Systems” (MEPC 2008i), and Guideline G9, “Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances” (MEPC 2008f), work together to create a framework for the evaluation of treatment systems by the MEPC and Flag State Administration (the country or flag under which a vessel operates) (Figure III-1). Flag States (not the IMO) may grant approval (also known as “Type Approval”) to treatment systems that are in compliance with the Convention’s Regulation D-2 performance standards based upon recommended procedures detailed in Guideline G8 for full-scale land-based and shipboard testing. A treatment system may not be used by a vessel party to the Convention to meet the D-2 standards 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 first 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 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 recommendation of the GESAMP-BWWG.

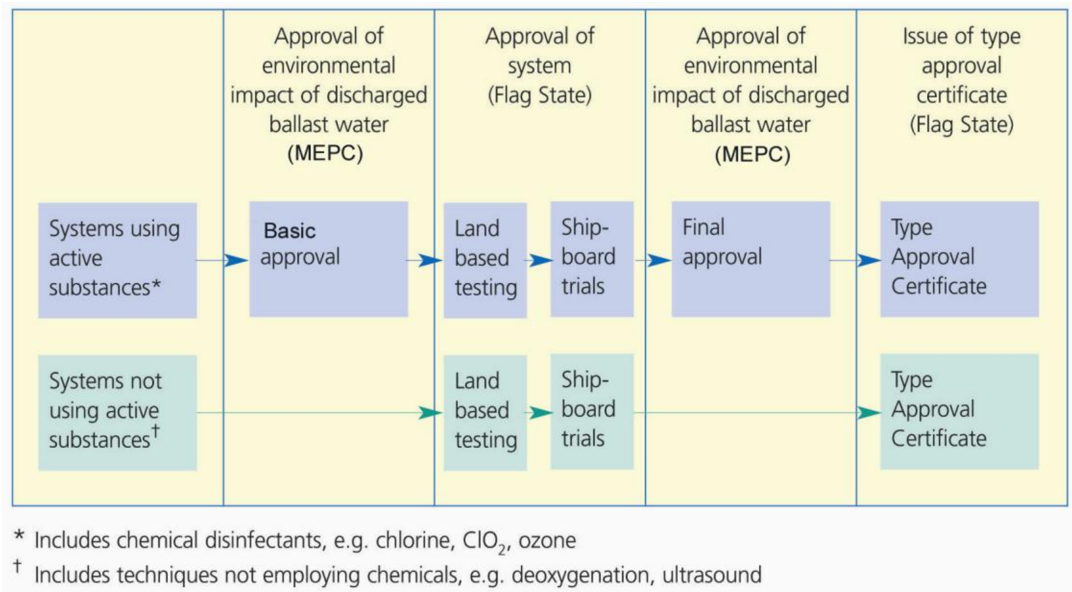

Figure III-1. Summary of IMO approval pathway for ballast water treatment systems. (Modified from Lloyd's Register (2007))

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.

Because the U.S. has not signed on to the Convention, the U.S. has neither reviewed nor submitted applications to IMO on behalf of any U.S. treatment technology vendors. 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, until the U.S. signs on to the Convention, and the Convention is ratified and enters 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 is relevant 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 of shipboard sampling points and equipment necessary to collect ballast water samples to assess compliance with the IMO Regulation D-2 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). In order to maintain international uniformity, Commission staff based California's regulations governing the collection of ballast water samples on IMO Guideline G2 (see pg. 18, California Legislation and Implementation of Performance Standards, for details).

U.S. Federal Legislation and Programs

Ballast water discharges in the United States are regulated by both the United States Coast Guard (USCG) and the United States Environmental Protection Agency (EPA). Prior to February 6, 2009, ballast water was regulated solely by the USCG through regulations found in Title 33 of the Code of Federal Regulation (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 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 at least as effective as exchange and is approved by the Commandant of the USCG. However, a target has not been developed to define the efficiency of exchange, preventing any evaluation of treatment systems against the efficacy of ballast water exchange. Without a specific target (or performance standard), the USCG has been unable to move forward on the approval of any treatment systems.

On August 28, 2009, the USCG proposed regulations that would establish federal performance standards for living organisms in ships' ballast water discharged in U.S. waters. The proposed regulations would amend 33 CFR Part 151 to include a two-phase ballast water discharge standard and associated implementation schedule. Phase one would require vessels to meet the IMO D-2 standard – a standard roughly 1000 times weaker than California's standards - by 2012, and phase two would require that discharged ballast comply with a standard 1000 times more stringent than IMO – roughly equivalent to California's standards - by 2016. The implementation of the phase two standard is contingent upon a review of the availability of technologies to meet that standard. The proposed regulations would also establish a program to approve ballast water management systems for use in U.S. waters. The public comment period closed on December 4, 2009. The USCG received thousands of comments on the contents of the proposed regulations, and it is possible that the proposed regulation could undergo substantial change before the final rule is issued. At this time, no date has been set for the release of the final regulation.

On February 6, 2009, the EPA joined USCG in the regulation of ballast water in U.S. waters. The EPA regulates ballast water, and other discharges incidental to normal vessel operations, through the Clean Water Act (CWA). This requirement stems from a 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, 40 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” (VGP). 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. The implementation of the permit was later delayed to February 6, 2009 to provide the regulated community with additional time to comply.

Under the VGP, 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 permit coverage. Vessels greater than 79 feet but less than 300 tons receive automatic permit coverage. In large part, the VGP maintains the current regulation of ballast water discharges by the USCG through 33 CFR Part 151. The VGP does not currently 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 the USCG rulemaking on ballast water performance standards, or if they are proposed independently by EPA. In either case, EPA would have to determine if treatment technologies are commercially available and economically achievable to meet standards in order to include them in the 2013 VGP.

The EPA VGP and the USCG regulations do not relieve vessel owners/operators (permittees) of the responsibility of complying with applicable state laws and/or regulations. Many states with authority to implement the CWA have added 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 VGP and the USCG regulations. This may result in vessels having to exchange ballast water to comply with federal management requirements under the VGP and USCG regulations and also treat ballast water to comply with state regulations. Federal legislation may be required to clarify this potentially confusing situation.

While the federal implementation of performance standards for the discharge of ballast water remains uncertain, two federal programs have been working 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 are authorized to operate the system to comply with existing 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, whichever is shorter. As of June 2010, six vessels have been accepted into STEP (USCG 2010). The lengthy STEP review process and recent uncertainties regarding testing protocols have delayed significant testing on STEP vessels thus far, however, the USCG has plans to streamline the review process for future applicants (USCG 2008). USCG plans to continue STEP even after the implementation of performance standards, as the STEP will serve to facilitate system shipboard testing for USCG approval, and will continue to promote vessel access for the research and development of promising experimental technologies (Moore, B., pers. comm. 2010; Everett, R., pers. comm. 2010).

The EPA ETV program is an effort to accelerate the development and marketing of environmental 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 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, ETV staff, in consultation with an advisory panel (of which Commission staff is a member), is currently developing a revised final treatment technology verification protocol, which was released in draft form for public comment in March 2010.

U.S. State Legislation and Programs

States have taken two approaches to the implementation of ballast water management and specifically performance standards for the discharge of ballast water. Some states have specific authority granted by state legislation to establish performance standards either by regulation or permit. Other states have added specific provisions establishing performance standards to the VGP through the Section 401 certification process. The following is a summary of ballast water performance standards by state and how each has approached implementation.

CWA Section 401 Certifications Under the Vessel General Permit (VGP)

Section 401 of the Clean Water Act requires states to approve federal permits and allows states to add requirements, if necessary, above and beyond those present in the federal permit. A number of states established ballast water management programs in 2009 through the VGP. States that specifically included the establishment of performance standards in their 401 certification include: Illinois, Indiana, New York, Ohio, and Pennsylvania. Illinois, Indiana and Ohio require vessels to comply with the IMO D-2 standard (see Table III-1) by 2012 for newly built vessels or 2016 for existing vessels. Pennsylvania established a two-phase standard that requires vessels built prior to 2012 to install treatment systems that meet the IMO D-2 standard by 2012, and vessels built on or after 2012 to meet California's performance standards (roughly equivalent to1000 times the IMO D-2 standard). Finally, New York will require all vessels to install treatment systems that meet a standard roughly equivalent to 100 times the IMO D-2 standard by 2012. Vessels constructed on or after 2013 must install systems that meet California's performance standards.

Non-VGP State Ballast Water Programs that Include Performance Standards

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. In state waters, vessels must use treatment technologies in compliance with applicable requirements and conditions of use as specified by Michigan DEQ. Vessels using technologies not listed under the Michigan general permit may apply for individual permits if the treatment technology used is deemed, "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, all vessels (oceangoing and lakes-only) transiting 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).

Washington

The Washington Department of Fish and Wildlife (WDFW), in consultation with their stakeholder Ballast Water Work Group, completed a comprehensive rewrite of the state's ballast water management regulations, which became effective on July 26, 2009. The new rules and information on the state program can be found at: http://wdfw.wa.gov/fish/ballast/ballast.htm. WDFW has initiated new rulemaking to adopt permanent concentration-based standards. A priority for WDFW is to adopt standards that help bring the national and/or U.S. Pacific coast states into greater management consistency. The WDFW no longer independently approves treatment systems for use in state waters and now relies 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 standards to be adopted in early 2011 (Pleus, A., pers. comm. 2010).

Wisconsin

As of February 1, 2010, vessels that discharge ballast in Wisconsin waters must comply with the General Permit to Discharge under the Wisconsin Pollutant Discharge Elimination System. The permit was established by the Wisconsin Department of Natural Resources (WDNR) under authority provided by Chapter 283, Wisconsin Statutes. Among its provisions, the permit sets ballast water performance standards roughly equivalent to 100 times the IMO D-2 standard. All vessels constructed on or after 2012 must meet the Wisconsin Standard set forth in the permit. Existing vessels have until 2014 to comply. Prior to the implementation of the standards, WDNR will conduct an assessment of the availability of treatment systems to meet the Wisconsin standards. If the WDNR determines that treatment technologies are commercially unavailable, the permit requires vessels to comply with the IMO D-2 standard in place of the Wisconsin Standard. The existing implementation schedule remains the same.

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 (greater than 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 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.

The first technology assessment report (Dobroski et al. 2007) determined that technologies would not be available to meet California's discharge standards for new vessels with a ballast water capacity under 5000 MT by the original 2009 implementation date. In response, the Legislature passed Senate Bill 1781 in 2008 (Chapter 696, Statutes of 2008). Senate Bill 1781 amended PRC Section 71205.3(a)(2) and delayed 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. Senate Bill 1781 also required an additional assessment of available ballast water treatment technologies by January 1, 2009 (see Dobroski et al. 2009a) prior to the new

2010 implementation date. Dobroski et al. (2009a) determined that technologies that demonstrated the potential to meet California's performance standards were available. The report recommended that the Commission proceed with the initial implementation of the performance standards in 2010.

Implementing California's Performance Standards

As of January 1, 2010, newly built vessels (vessels for which construction began on or after January 1, 2010) with a ballast water capacity of less than 5000 MT that discharge ballast in California waters must comply with California's performance standards. Vessel construction often takes a year or more, and it is anticipated that the first vessels that must meet the performance standards will not begin to arrive in California until sometime during 2011. Commission staff have consulted with vendors to determine if treatment systems have been or will be purchased in order to meet this first implementation date. At this time, staff are not aware of any specific purchases. Many vessels in the midst of construction are leaving dedicated space for a ballast water treatment system so it may be installed at the last possible moment to ensure that the system purchased is the most up-to-date available. Commission staff are in the process of preparing protocols to assess compliance with the performance standards and will be ready to begin inspection of vessels once new build vessels that fall under the 2010 implementation date arrive in California waters.

Commission staff do not have the practical ability to test and approve ballast water treatment systems for use in California waters. Staff encourages the shipping industry to collaborate with treatment vendors and third party testing organizations to conduct performance verification testing and determine the best treatment solution for each vessel. Commission staff will focus on dockside inspection of vessels for verification of compliance with the performance standards (in accordance with PRC Section 71206). Vessel inspections will consist of both an administrative review of applicable ballast water management plans and reporting documents as well as the collection of ballast water samples for analysis. Vessels must currently keep an up-to-date ballast water management plan on board as well as copies of all ballast water reporting forms submitted to the Commission within the past two years. Dobroski et al. (2009a) recommended that additional authority be granted to the Commission in order to allow for the collection of specific information about the installation and use of ballast water treatment systems on vessels operating in California waters. This information is necessary to monitor the effective implementation of California's performance standards. In response to the recommendation in Dobroski et al. (2009a), Assembly Bill 248 (Chapter 317, Statutes of 2009) was passed in the fall of 2009, which provides the Commission with the authority to request the aforementioned information on forms to be developed by the Commission. Commission staff is currently in the process of adopting those forms through the rulemaking process.

During an inspection, once Commission staff has reviewed applicable vessel paperwork, a ballast water sample will be drawn from vessels intending to discharge in California waters. California's performance standards are a discharge standard, and thus samples must be drawn from the vessel's ballast water discharge piping. Most vessels do not have the equipment to take samples of ballast water from the discharge line. Therefore, the Commission developed regulations in the fall of 2009 that require vessels to install sampling ports (i.e. sampling facilities) as near to the point of discharge as practicable (2 CCR § 2297). In order to maintain international uniformity, the regulations are based on the IMO Guideline G2 for ballast water sampling with additional input provided by the USCG. The regulations establish design specifications for in-line sampling facilities and set requirements for where the sampling facilities should be installed on the discharge line (i.e. the sampling point). Vessels must install the sampling facilities by the same year that they must comply with California's performance standards.

Commission staff is currently in the process of refining procedures for analysis of the samples collected from the discharge line. Commission staff is working in consultation with technical experts and will make use of the best available scientific techniques to assess viable organism concentration for each of the standards. One issue of concern has been the development of sampling methods and procedures that will verify vessel compliance with an acceptable level of legal and scientific confidence (see King and Tamburri 2009). The bulk of these arguments are aimed at performance standards for the greater than 50 µm organism size class, specifically for standards that are defined as a given number of live organisms per cubic meter (e.g. IMO and proposed USCG standards). While sampling large volumes of ballast water (i.e. many cubic meters) are necessary to attain adequate statistical confidence to verify a given number of viable organisms are indeed present in each cubic meter, this argument is not necessarily appropriate for California's (as well as New York and Pennsylvania's) performance standards. California's performance standard for the greater than 50 µm organism size class is defined as "no detectable living organisms" and is technically not bound by any volumetric units or the confidence limits associated with those units. Therefore Commission staff believes it is appropriate to sample as large a volume as is feasible (whether that is 50 liters, 500 liters, 5000 liters, or any volume in-between) in order to verify compliance with California's unit-less performance standard. Although it is important to ensure that a reasonable volume of water is sampled during compliance verification, sampling methods must balance the desire for statistical confidence with practical, rapid, and relatively easy techniques for shipboard inspection. As the precision of sampling equipment and analytical techniques improve, Commission staff will regularly discuss sampling methodologies with other states, the federal government and the international community to stay up-to-date on advances in the technology to conduct compliance verification.

Finally, Commission staff will continue to gather information about treatment system development, installation, and use on board vessels, particularly as the standards are implemented for existing vessels and vessels with larger ballast water capacities. 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 have continued to provide valuable guidance and direction in the preparation of subsequent reports.

As with previous reports (Dobroski et al. 2007, 2009a), Commission staff conducted an exhaustive literature search to prepare this report. Staff focused its review on recently available scientific articles, performance verification reports, and water quality impact analyses 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 have proved to be extremely valuable opportunities to inform vendors about California’s performance standards requirements and to engage in dialogue about system performance verification testing and the Commission’s technology assessment reports.

Due to a rapid increase in the availability of new data on treatment system performance in mid-2009, and a desire by industry to receive updates on the latest technology developments, Commission staff conducted an interim assessment of available treatment technologies in October 2009 (see Dobroski et al. 2009b). The technology update was not legislatively mandated, and was not reviewed by the technical advisory panel. The update was intended as a resource for stakeholders interested in ballast water treatment systems for use in California waters. It also provided Commission staff with an opportunity to begin identifying and focusing on issues of concern for this 2010 legislatively mandated report.

For the preparation of this report, Commission staff compiled available data to develop a treatment system matrix (see Tables V-1, VI-1, VI-3, VI-4, VI-5, VI-6, VII-1 and Appendix A). The 2010 report addresses the availability of treatment systems for vessels with a ballast water capacity greater than 5000 MT. Industry has expressed concern about whether or not treatment systems will be able to effectively treat ballast water on these high volume/high flow rate vessels. Therefore, Commission staff included relevant data on treatment systems' maximum capacities and flow rates for this report. The data was summarized relative to the ballast water capacities and pump flow rates of the vessel fleet operating in California waters in order to determine if systems both meet California's performance standards and are available for this largest size class of vessels. As with previous reports, Commission staff also gathered the latest data on environmental impacts, including effects on water quality, and the economics of treatment system installation and operation. Upon completion of the data analysis, Commission staff drafted a preliminary report for review by the Commission's stakeholder advisory panel (see Appendix B for list of panel members), the Water Board and USCG. The advisory panel met in April 2010 to discuss the current report (see Appendix B for meeting notes). 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 kill organisms entrained in ballast water. Given the long history and use of wastewater treatment technologies, the design and production of ballast water treatment systems may seem simple. However, transferring such technological concepts to mobile, space- and energy-limited vessels has proven 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 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 barge- or land-based 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 capacities and/or dedicated port calls.

Shoreside treatment of ballast water is an appealing option, particularly from a regulatory perspective. Permitting and inspection of a fixed shoreside facility is significantly easier than the regulation of discharges from mobile sources such as vessels. Shoreside treatment also provides an option for treatment technologies and methods that are not feasible onboard vessels due to space and/or energy constraints, such as reverse osmosis. 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. Additionally, in the event that a shipboard treatment system fails or sea conditions prevent ballast water exchange, shoreside or barge-mounted treatment facilities could provide an important facility where unmanaged ballast water could be held or treated.

Shoreside treatment does pose several challenges, however. Vessels must have the appropriate piping or attachment mechanism to establish a connection with a shoreside facility. An international standard would be necessary to standardize the design of these connections in order to ensure that ships could connect to shoreside facilities throughout the world. Additionally, vessels must be able to discharge ballast at a rate that prevents vessel delays. The cost of these retrofits may be prohibitive (CAPA 2000). Additionally, current 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 require the acquisition of land for facility construction, and this would be complex and costly in California's densely populated coastal and port areas. Furthermore, 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.

To date only limited feasibility studies have been conducted on shoreside treatment (see references in Falkner et al. 2006). A recent study by McMullin et al. (2008) assessed the feasibility of shoreside treatment at the Port of Milwaukee. The authors concluded that shoreside treatment is a feasible alternative to shipboard treatment, but only under certain conditions. Since vessels must be retrofitted to allow the connection of shoreside pumps to the vessel's ballasting piping, an international standard would likely need to be created. Additionally, procedures would need to be developed for each vessel to maintain its stability and ensure safe deballasting rates during cargo loading.

Finally, due to space constraints, the authors determined that the most cost-effective and practical approach to shoreside treatment at the Port of Milwaukee would likely require vessels to discharge ballast to a barge to store or treat the ballast before disposal to land-based facilities. The authors caution against the extrapolation of the report's conclusions to port areas outside of Milwaukee, as each unique region presents its own set of challenges.

In California, shoreside treatment may be a good option for unique terminals such as those with limited but regular vessel calls (e.g. cruise ships). Nonetheless, one study specific to cruise ships indicated that due to the operational practices of cruise ships – many do not deballast in California - and with the current ballast water management and environmental regulatory requirements in California and the Port of San Francisco, there is little demand for shoreside treatment except in emergency situations (Bluewater Network 2006). Additional studies are necessary to determine the feasibility of and demand for shoreside treatment for other vessel types and across the State as a whole. These may include assessments by those involved in the wastewater treatment sector on whether existing technologies could meet California's performance standards.

Within the last six months, Commission staff have been contacted by companies interested in developing barge-based and/or shore-based reception facilities for use in California and along the West Coast. Commission staff will continue to work with these companies to ensure that as many options as possible are available to vessels in order to comply with California's performance standards. As of the writing of this report though, no barge- or land-based facilities are yet available for vessels operating in California waters. Because the vast 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 the 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 (in-line) during uptake or discharge 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. 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 water 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 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 for vessels and crew 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- and large-sized 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, or 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, 2009). 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 clog it. Backwash systems can discharge particles and organisms 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 used in ballast water treatment generally 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.

Chemical Treatment

A variety of chemicals (i.e. active substances) are available to kill organisms in ballast water. While the vast majority of chemicals are biocides, some chemicals function 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 electrochemical processes.

Chemicals used in ballast water treatment can generally 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 (National Research Council 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 products such as hydroxyl radicals, ozone or sodium hypochlorite 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 (National Research Council 1996, Faimali et al. 2006).

The ultimate goal of chemicals is to maximize organism 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 chemicals 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 neutralized to environmentally acceptable levels. Both of these times vary as a function of ballast water temperature, salinity, organic content and sediment load. As a result, certain chemicals may be more effective than others depending on ballast volume, voyage length, and water quality conditions. Additional concerns about chemical use specific to shipboard operation include corrosion of metals, 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 organisms present in ballast water. Like chemical treatment, physical treatment may occur on ballast uptake, during vessel transit or during discharge.

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 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 energy/heat available on a vessel (Rigby et al. 1999, Rigby et al. 2004). An alternative approach to heat treatment involves the use of microwaves (Balasubramanian et al. 2008). 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).

Ultraviolet (UV) irradiation is another physical method of sterilization that is commonly used in waste water treatment. UV damages genetic material and proteins, disrupting reproductive and physiological processes and can be highly effective against pathogens (Wright et al. 2006). Both low-pressure and medium-pressure UV systems have been used to treat ballast water on vessels. The pairing of UV light and a catalyst (e.g. titanium dioxide) results in an advanced oxidative process that generates hydroxyl radicals - an effective killing agent.

Additional methods of physical treatment include ultrasound, cavitation and deoxygenation. 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. Cavitation is another physical treatment method that uses mechanical forces to generate and collapse microscopic bubbles that crush or implode organisms in ballast water. 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 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 at sufficient levels in the discharged ballast.

Combination Treatment

The vast majority of ballast water treatment technologies kill 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 physical or chemical process(es).

Treatment Systems

Twenty-eight treatment technologies were reviewed in the first technology assessment report to the California Legislature (see Dobroski et al. 2007), and 30 treatment systems were reviewed in 2009 (see Dobroski et al. 2009a). For this report, Commission staff compiled and reviewed information on 46 shipboard ballast water treatment systems from developers and vendors located in 16 countries (Table V-1).

Thirty-four of the treatment systems reviewed here utilize a combination of treatment methods, and 32 of those combine 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 46 systems reviewed, 28 use an active substance in the treatment process (Table V-1). Specifically:

- 13 systems use chlorine or the electrochemical generation of sodium hypochlorite
- 7 systems use ozone
- 3 use advanced oxidation or electrochemical processes that generate an array of oxidants including bromine, chlorine, and/or hydroxyl radicals
- 1 system uses chlorine dioxide
- 1 uses ferrate
- 3 systems use other chemicals including a coagulant or biocides not identified at this time

All of the systems that use active substances require IMO Basic and Final Approval prior to operating in compliance with the IMO Convention. These systems will also require additional scrutiny to ensure compliance with all applicable requirements of the EPA Vessel General Permit.

The next most commonly used method of ballast water treatment amongst the 48 systems reviewed is UV irradiation. Fifteen treatment systems use UV as a means to kill or deactivate organisms found in ballast water. All of these systems combine UV treatment with filtration and/or hydrocyclonic mechanical separation methods. Four of these systems have an additional treatment step involving another physical or chemical process.

Only five systems use deoxygenation as a treatment method. Other approaches to ballast water treatment include a heat treatment technology and one that uses electrical pulses to kill organisms (Table V-1).

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

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
21st Century Shipbuilding Co. Ltd.	Korea	Blue Ocean Guardian	combination	filtration + plasma + UV	IMO Basic
Alfa Laval	Sweden	PureBallast	combination	filtration + advanced oxidation technology (hydroxyl radicals)	IMO Basic and Final, Type Approval (Norway)
Aquaworx ATC GmbH	Germany	AquaTriComb	combination	filtration + ultrasound + UV	IMO Basic
atg UV Technology	United Kingdom		combination	hydrocyclone + UV	
ATLAS-DANMARK	Denmark	ABTS	combination	filtration + biocide (ANOLYTE + CATHOLYTE)	
Auramarine Ltd.	Finland	Crystal Ballast	physical	UV-C irradiation	
Brillyant Marine LLC	USA		physical	electric pulse	
Coldharbour Marine	United Kingdom		physical	deoxygenation	
COSCO/Tsinghua University	China	Blue Ocean Shield	combination	hydrocyclone + filtration + UV	IMO Basic
DESMI Ocean Guard A/S	Denmark	DESMI Ocean Guard BWMS	combination	filtration + ozone + UV (advanced oxidation process)	IMO Basic
Ecochlor	USA	Ecochlor™ BWTS	combination	filtration + biocide (chlorine dioxide)	IMO Basic, STEP[1]
EcologiQ	USA/Canada	BallaClean	biological	deoxygenation	
Electrichlor	USA	Model EL 1-3 B	chemical	electrolytic generation of sodium hypochlorite	
Environmental Technologies Inc. (ETI)	USA	BWDTS	combination	ozone + sonic energy	
Ferrate Treatment Technologies LLC	USA	Ferrator	chemical	biocide (ferrate)	

[1] STEP Approval is an experimental use approval that applies to the combination of one vessel and one treatment system. While STEP enrollment includes a rigorous technical and environmental screening it is not a type approval process.

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

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Hamann Evonik Degussa[2]	Germany	SEDNA	combination	hydrocyclone + filtration + biocide (Peraclean Ocean)	IMO Basic and Final, Type Approval (Ger.)
Hamworthy Greenship Ltd.	U.K./Netherlands	SEDINOX	combination	hydrocyclone + electrolytic chlorination	IMO Basic and Final
Hi Tech Marine	Australia	SeaSafe-3	physical	heat treatment	New South Wales EPA
Hitachi/Mitsubishi Heavy Industries	Japan	ClearBallast	combination	coagulation + magnetic separation + filtration	IMO Basic and Final
Hyde Marine	USA	Hyde Guardian	combination	filtration + UV	WA Conditional, Type Approval (U.K.), STEP[1]
Hyundai Heavy Industries Co. Ltd. (1)	Korea	EcoBallast	combination	filtration + UV	IMO Basic and Final
Hyundai Heavy Industries Co. Ltd. (2)	Korea	HiBallast	combination	filtration + electrochlorination + neutralizing agent	IMO Basic
JFE Engineering Corp./ Toagosei Group	Japan	JFE-BWMS	combination	filtration + biocides (sodium hypochlorite) and neutralizing agent (sodium sulfite)	IMO Basic and Final
Kwang San Co. Ltd.	Korea	En-Ballast	combination	filtration + electrochlorination + neutralizing agent (sodium thiosulfate)	IMO Basic
MAHLE Industriefiltration GmbH	Germany	Ocean Protection System (OPS)	combination	filtration + UV	
MARENCO	USA		combination	filtration + UV	WA General Approval
Maritime Solutions Inc.	USA		combination	filtration + UV	
Mexel Industries	France	Mexel®	chemical	biocide	

[1] STEP Approval is an experimental use approval that applies to the combination of one vessel and one treatment system. While STEP enrollment includes a rigorous technical and environmental screening it is not a type approval process.
[2] The Hamann system was temporarily removed from the market due to toxicity concerns (effective 1/31/10).

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	
Mitsui Engineering	Japan	SP-Hybrid BWMS Ozone	combination	filtration + mechanical treatment + ozone + neutralization	IMO Basic
NEI	USA	Venturi Oxygen Stripping (VOS)	combination	deoxygenation + cavitation	Type Approval (Liberia), STEP[1]
NK Co. Ltd.	Korea	NK-03 BlueBallast System	chemical	ozone + neutralization (thiosulfate)	IMO Basic and Final, Type Approval (Korea)
ntorreiro	Spain	Ballastmar	combination	filtration + electrochlorination + neutralization (sodium metabisulphite)	
Nutech 03 Inc.	USA	SCX 2000, Mark III	chemical	ozone	
OceanSaver	Norway	OceanSaver BWMS	combination	filtration + cavitation + nitrogen supersaturation + electrodialysis	IMO Basic and Final, Type Approval (Nor.)
OptiMarin	Norway	OptiMarin Ballast System	combination	filtration + UV	Type Approval (Norway)
Panasia Co. Ltd	Korea	GloEn-Patrol	combination	filtration + UV	IMO Basic and Final, Type Approval (Korea)
Pinnacle Ozone Solutions	USA	Aquatic enhancement system	combination	filtration + ozone + UV	
Qingdao Headway Tech Co. Ltd.	China	OceanGuard BWMS	combination	filtration + electrocatalysis + ultrasound	IMO Basic
Resource Ballast Technologies	South Africa	Unitor BWTS	combination	cavitation + ozone + sodium hypochlorite + filtration	IMO Basic and Final
RWO Marine Water Technology	Germany	CleanBallast	combination	filtration + advanced electrolysis	IMO Basic and Final

[1] STEP Approval is an experimental use approval that applies to the combination of one vessel and one treatment system. While STEP enrollment includes a rigorous technical and environmental screening it is not a type approval process.

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

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Severn Trent DeNora	USA	BalPure	chemical	filtration + electrolytic generation of sodium hypochlorite + neutralizing agent (sodium bisulfite)	WA Conditional, IMO Basic, STEP[1]
Siemens	UK/USA/Ger.	SiCure	combination	filtration + electrochlorination	IMO Basic
Sunrui CFCC	China	BalClor	combination	filtration + electrochlorination + neutralizing agent (sodium thiosulfate)	IMO Basic
Techcross Inc.	Korea	Electro-Cleen	chemical	electrochemical oxidation + neutralizing agent (sodium thiosulfate)	IMO Basic and Final, Type Approval (Korea)
Wartsila	Finland		combination	filtration + UV	

[1] STEP Approval is an experimental use approval that applies to the combination of one vessel and one treatment system. While STEP enrollment includes a rigorous technical and environmental screening it is not a type approval process.

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 can comply with the performance standards simply by retaining all ballast onboard while in California waters. Vessels that do discharge but use nontraditional sources for ballast water (such as freshwater from a municipal source) will likely meet the discharge standards without needing to use ballast water treatment systems. Alternatively, vessels may discharge to barge- or land-based reception and treatment facilities. Vessels that utilize riverine, estuarine, coastal or ocean water as ballast, however, will require ballast treatment prior to discharge. For these vessels, this assessment of treatment system efficacy, availability, and environmental impacts (as required by PRC Section 71205.3(b)) is necessary to understand if systems will be available prior to the implementation of performance standards for newly built vessels with a ballast water capacity greater than 5000 MT in 2012.

Efficacy

Treatment system performance (i.e. efficacy) can be defined as the extent to which a system removes or kills organisms in ballast water. For this report, Commission staff's specific focus is on ability of available treatment systems to meet or exceed California's performance standards for the discharge of ballast water (see Table III-1 for performance standards) for newly built vessels with a ballast water capacity greater than 5000 MT.

Previous reviews of treatment system efficacy (Dobroski et al. 2007, 2009a) faced several challenges. First and foremost, for many systems the lack of available data precluded any form of efficacy assessment. For systems with data available, inconsistent testing methodologies among systems, and occasionally between tests of a single system, made comparison of data nearly impossible. Results varied in scale (bench-top (i.e. laboratory) vs. pilot vs. full-scale) and location (dockside vs. shipboard), and until recently, were often presented in metrics incomparable with California's standards (e.g. as percent reduction instead of concentration of organisms).

An additional challenge when evaluating the available data has been the wide range of data sources. For some systems, data have been provided by vendors in brochures, on the web, or in vendor-authored reports, that have not been evaluated by independent third-parties. Recently, staff has seen a surge in the availability of performance verification data gathered by independent, scientific testing organizations. These independent reports generally provide the most robust, comprehensive review of system performance and environmental acceptability. However, variability remains among scientific testing organizations in terms of the types of analytical and statistical tests in use and methods of data presentation. Commission staff are working with vendors and testing organizations to encourage the standardization of data analysis and presentation.

For this assessment, Commission staff are providing the California Legislature and interested stakeholders with all available sources of information on treatment technology development and operation, including both vendor-supplied and third-party data from all testing scales and locations (lab-based, land-based and shipboard). In all instances, citations are provided for the original source of the data (Table VI-1 and Appendix A). This information is presented so that interested parties can review and evaluate all of the available data and data sources in order to make an informed decision about whether a treatment system may or may not be sufficient for their needs.

Commission staff were able to collect efficacy data on 27 of the 46 treatment systems reviewed in this report (Tables VI-1 and VI-3, Appendix A). As a reference for stakeholders, laboratory data on system performance is summarized in Appendix A. With the exception of the evaluation of system performance for inactivating *Vibrio cholerae*, laboratory data is not used for evaluation purposes in this report because of the large difference in scale between the laboratory and land-based and shipboard investigations. Six systems have only laboratory data available for review. The remaining twenty-one systems have been assessed for potential compliance with California's standards using large scale land-based and/or shipboard data.

No available dataset on treatment system performance can represent the efficacy of that system on all vessel types or under all possible voyage conditions. Many systems have not yet undergone full-scale shipboard testing (see Appendix A for breakdown of data by type of testing facility), the number of tests performed varies from system to system, and those that have been tested on vessels may have only been assessed on one ship or one type of ship under limited testing scenarios. Water condition variables, such as salinity level, turbidity, and temperature can affect the ability of a system to kill organisms. Some systems require minimum ballast water "holding times" for optimal performance, while others appear to perform poorly on extended voyages. The density or diversity (types) of organisms found at the ballast uptake location can also affect system performance. In essence, a system that fails to meet California's standards under one scenario (e.g. short voyage duration) may meet the standards perfectly well under a different one (e.g. longer voyage duration). The reverse situation may also be true.

Because of the limitations of testing data and the variable conditions present in the "real world," this report examines treatment system performance data to determine whether or not systems have demonstrated the **potential** to comply with California's performance standards. Commission staff do not have the practical ability to test and approve treatment systems for operation in California waters. Positive assessment for the purpose of this report does not guarantee system compliance when operated in California waters, nor does the report suggest or imply system approval. Vessel owners and operators should consult extensively with treatment system vendors to ensure that thorough system verification work has been conducted, and that the system is appropriate for the type and behavior of the vessel in question under normal ballasting conditions. Ultimately vessel owners/operators are responsible for complying with California's performance standards for the discharge of ballast water.

Staff considered the best available data and methods for assessing organism concentration and viability for each of the organism size classes in California's standards (see Table III-1). The latest data have generally been presented according to organism size class, however, some older data, not updated since previous reports, have been presented by organism type (i.e. zooplankton, phytoplankton). In an effort to standardize results among reports, staff evaluated 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. While these substitutions are not accurate in all instances (e.g. zooplankton species may be less than 50 µm in size), they were used solely for the purpose of this report and are not applicable to vessel compliance verifications.

Recent discussions over the implementation of the IMO and proposed federal standards have focused on whether or not methods and/or protocols exist to assess compliance with more stringent standards – such as California's standards. Specific concerns have focused on the volume of water necessary to assess compliance with the standards for organisms greater than 50 µm in size. California's standards for organisms greater 50 µm is defined as "nondetectable," and does not define a specific volumetric concentration. Many outside parties have reasoned that the volumes of ballast water required to determine compliance with this standard are not verifiable and too large to be practical for shipboard compliance verification. However, it is important to note that, unlike the IMO standard for the same size class, the standard for California is unitless. Whereas IMO defines its standard for organisms greater than 50 microns as less than 10 ***per cubic meter***, California's standard does not set forth a volume requirement. Therefore compliance and performance testing for this size class could occur with any volume of water, especially volumes that are realistic under shipboard operation. For the other organism classes, volumes specified in California's standards are not at issue. Commission staff are currently developing protocols to assess vessel compliance with California's standards (see Section IX Looking Forward). These protocols will address ballast water sample volumes and take into account both scientific rigor and practicality for shipboard inspection.

One challenge associated with the assessment of the bacteria and virus standards is that methods exist to quantify bacteria and viruses (or virus-like particles) in a sample of ballast water, however, no techniques are available to assess the viability of all bacteria and viruses, as is required by the California performance standards (see Dobroski et al. 2009a, Appendix A1 for discussions on this topic). To assess compliance with the bacterial standard, Commission staff used a representative group of organisms (culturable, aerobic, heterotrophic bacteria – hereafter culturable heterotrophic bacteria) to quantify potential compliance with the bacterial standard. Culturable heterotrophic bacteria were selected as a representative for the total bacterial concentration because, unlike total bacteria, there are reliable, widely-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 (Dobbs, F., pers. comm. 2008). Staff examined the ability of treatment system to reduce culturable heterotrophic bacteria to levels within the California standard of 1000 bacteria (in this case expressed as colony-forming units (CFU)) per 100 ml of ballast water. At an advisory panel meeting in 2008, panel members debated whether the culturable heterotrophic bacteria – a subset of all bacteria species - should be held to a different standard than that written in the law (see Dobroski et al. 2009a, Appendix C for discussion). Because culturable heterotrophic bacteria represent only a portion of the total population of bacteria (Giovannoni et al. 2007), it was argued that 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, this approach to setting a standard requires the selection of a uniform method to culture and quantify bacteria in order to assess the percent of culturable bacteria relative to the total population of all bacteria. Based on techniques available in 1990, culturable bacteria represented 1/10,000th of the total bacterial community present in seawater (Giovannoni et al. 2007). Newer techniques have allowed scientist to culture anywhere from two to sixty percent of bacterial cells in a given water body (Giovannoni et al. 2007). Until such time that a scientific authority clearly establishes the percent composition of culturable heterotrophic bacteria in marine or freshwater, Commission staff will continue to analyze all data using best available techniques and the numerical standard found in the law.

Analysis of viruses remains challenging at this time. While several representative organisms exists for viruses, their relationship to the greater population of all viral species is more tenuous than for bacteria (confer Culley and Suttle 2007). For the purposes of this analysis, Commission staff believes that no widely accepted technique is available to quantify or reliably estimate virus concentrations, 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.

Taking into account the limitations of the available data, staff determined the potential for treatment systems to comply with California's performance standards using two approaches. The first assessment approach, presented in Table VI-1, provides a broad review of the data on system performance from both land-based and shipboard testing. The second assessment approach, presented in Table VI-3, takes a closer look at the performance, specifically the success rate of those systems at demonstrating potential to meet California's standards.

In the first broad-scale assessment (presented in Table VI-1), staff accepted one test (averaged across replicates) with data less than the standard as indicative of a system's **potential** to comply with that standard. While this criterion is optimistic, it does highlight the rapid and encouraging development of treatment technologies. This approach is slightly more stringent than that taken in previous reports (Dobroski et al. 2007, 2009a) when systems were only required to meet the standard in one test replicate in order to demonstrate potential compliance. Because of this change in approach, and because laboratory data is no longer included in this analysis, readers should be cautioned against comparing the results in Table VI-1 in this report with table(s) in previous reports.

Systems with at least one test (averaged across replicates) at either land-based or shipboard scale in compliance with the performance standard are scored with a “Y” for having demonstrated the **potential** to comply with California’s standards (Table VI-1). Efficacy data with no tests demonstrating potential compliance with the standards are scored with a “N.” Systems that presented data for a given size class in metrics not comparable to the standards (e.g. as percent reduction instead of organism concentration) are classified as “Unknown.” Cells with hashing indicate lack of available data. The source(s) of the data for each system can be found in the Literature Cited section. See Appendix A for all laboratory data and for specifics about land-based and shipboard testing including number of tests and replicates for each system.

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

Systems with at least one land-based or shipboard test (averaged across replicates) in compliance with the performance standards are denoted by a “Y.”Non-compliance is denoted by a “N,” and those systems with data in metrics not directly comparable to the performance standards were designated as “Unknown.” A cell with hashing indicates that no data was available. Information about systems having only lab-scale data is provided in Appendix A.

Manufacturer	> 50 µm	10 - 50 µm	< 10 µm (bacteria)[1,2]	*E. coli*	Enterococci	*V. cholerae*	References[3]
21st Century Shipbuilding							Lab data only
Alfa Laval	Y	Y	Y	Y	Y	Y[4]	137,138,141
Aquaworx ATC GmbH							
atg UV Technology							
ATLAS-DANMARK							
Auramarine Ltd.	Y	N	N	Y[4]	Y	Y[4]	4,165
Brillyant Marine LLC							
Coldharbour Marine							
COSCO/Tsinghua Univ.							
DESMI Ocean Guard A/S							
Ecochlor	Y	Y	Y	Y	Y	Y[6]	76,133,148
EcologiQ							
Electrichlor							
ETI		N	N				73,74,75
Ferrate Treatment Tech.							Lab data only
~~Hamann Evonik Degussa~~[5]	~~Y~~	~~Y~~	~~Y~~	~~Y~~[4]	~~Y~~[4]	~~Y~~[4]	132,166
Hamworthy Greenship	Y	Y	Y	Y[4]	Y[4]	Y[6]	48,167
Hi Tech Marine	N	Unknown	Y	Y			32,51
Hitachi/Mitsubishi							
Hyde Marine	Y	Y	Y	Y[4]	Y[4]	Y[4]	134,192
Hyundai Heavy Ind. (1)							Lab data only
Hyundai Heavy Ind. (2)							Lab data only
JFE Eng.Corp./TG Corp.							
Kwang San Co. Ltd.							Lab data only

[1] Bacteria were assessed through examination of aerobic 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, non-detectable or unknown.

[5] Hamann system has been temporarily removed from the market due to toxicity concerns (effective 1/31/10).

[6] *Vibrio* testing conducted on live cultures in a lab.

Table VI-1 (contined). Summary of systems with available results for assessment of efficacy
Systems with at least one land-based or shipboard test (averaged across replicates) in compliance with the performance standards are denoted by a "Y."Non-compliance is denoted by a "N," and those systems with data in metrics not directly comparable to the performance standards were designated as "Unknown." A cell with hashing indicates that no data was available. Information about systems having only lab-scale data is provided in Appendix A.

Manufacturer	> 50 µm	10 - 50 µm	< 10 µm (bacteria)[1,2]	*E. coli*	Enterococci	*V. cholerae*	References[3]
MAHLE							
MARENCO	Y	N	Y				64,65,189
Maritime Solutions Inc.	N	N	Y	Y	Y	Y[4]	79
Mexel Industries							
MH Systems							Lab data only
Mitsui Engineering	N	Unknow n	Unknow n	Unknow n	Unknow n	Unknow n	56,58,59
NEI	Y	Unknow n	N	Y[4]	Unknow n	Y[4]	170,171,172
NK Co. Ltd.							
ntorreiro							
Nutech 03 Inc.	Y	N	Y	Y[4]	Y[4]	Y[4]	50,195
OceanSaver	Y	Y	Y	Y[4]	Y[4]	Y[4]	139,176
OptiMarin	Y	Y	Y	Y[4]	Y[4]	Y[4]	136,140
Panasia Co. Ltd.							
Pinnacle Ozone Solutions							
Qingdao Headway Tech.	Y	Y	Y	Y[4]	Y[4]	Y[4]	142,147
Resource Ballast Tech.	Y	N		Y	Y	Y[4]	2,3
RWO Marine Water Tech.	Y	Y		Y	Y	Y[4]	30,31
Severn Trent DeNora[5]	Y	Y	Y				49
Siemens	N	N	N	Y	Y	Y[4]	78
Sunrui CFCC							
Techcross Inc.	Y	Y	Y	Y[4]	Y[4]	Y[4]	62,63
Wartsila							

[1] Bacteria were assessed through examination of aerobic 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, non-detectable or unknown.
[5] System has added a filter since this data was collected.

Twenty-one treatment systems were reviewed for potential compliance with California's performance standards (Table VI-1). One system, produced by Hamann Evonick Degussa, was pulled from the market in January of 2010 due to toxicity concerns (see de Lafontaine et al. 2008, 2009 for toxicity data). The system's performance data and references are included in Tables VI-1, VI-3, VI-5 and VI-6 of this report for readers to examine. However, because it is currently not a practical option for installation on vessels, it is excluded from narratives and other tables that summarize the potential (efficacy) and availability of systems to meet California's standards.

In the largest organism size class (organisms greater than 50 µm in size), land-based or shipboard data was available for 20 systems, and 15 demonstrated the potential, in at least one test (averaged across replicates), to meet the required standard of no detectable living organisms in discharged ballast water (Table VI-2, Appendix A1). In the 10 – 50 µm size class, 21 systems were reviewed and 10 systems had at least one test that indicated compliance with the standard of less than 0.01 living organisms per ml (Appendix A2).

Table VI-2. Summary of potential treatment system performance (land-based and/or shipboard) 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 with Data Available [2]	20	21	19	18	17	17
Number Systems with Potential to Meet Standard[3]	15	10	13	16	14	15

[1] Bacteria examined using culturable heterotrophic bacteria.
[2] Of out of the 46 total systems assessed in this report, only 27 had testing results available for review, and 21 of those provided results of land-based and/or shipboard testing. Not all 21 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 test (averaged across replicates) demonstrating the potential to comply with the California performance standard (see Table III-1 for standards).

The results of analyses for human health indicator species (*Escherichia coli*, intestinal enterococci and *Vibrio cholerae*) and organisms less than 10 µm (bacteria) are encouraging (see Table VI-2, Appendices A3-A6). Most treatment systems are succeeding in killing human health indicator species. Eighteen systems provided results of *E. coli* concentration in treated ballast water (Appendix A3), and 16 demonstrated potential compliance. Seventeen systems tested for the presence of intestinal enterococci, and fourteen systems demonstrated potential compliance. (Appendix A4).

The low, and sometimes non-detectable, natural concentration of *Vibrio cholerae* in coastal waters makes it difficult to adequately assess system performance at eliminating this species. In land-based and shipboard data examined for this evaluation, the ambient pre-treatment concentrations of *Vibrio cholerae* were frequently so low they could not be detected, or were not reported (see footnote 4 in Table VI-1). In such cases, post-treatment data did not necessarily demonstrate a system's ability or inability to kill the microbe. Those systems that conducted laboratory analysis for *Vibrio cholerae* examined the efficacy of systems at treating live cultures (spiked concentrations) of *Vibrio* that would otherwise not be naturally present in waters used for land-based or shipboard testing. Such laboratory data provides as much, if not more insight into systems' ability to kill *Vibrio* as does data from land-based or shipboard tests. Thus, the evaluation of *Vibrio* data here included results from two laboratory studies (as noted in Table VI-1 and Appendix A5). Seventeen systems examined treated ballast water for toxicogenic *Vibrio cholerae,* and fifteen systems demonstrated potential compliance with the California performance standard (Appendix A5).

Lastly, available data was analyzed for compliance with the bacterial standard of 1000 bacteria or CFU per 100 ml (Table VI-1, Appendix A6). Nineteen systems analyzed system performance at treating culturable heterotrophic bacteria, and 13 demonstrated potential compliance with the standard. As described earlier in this section, methods are not available to assess compliance with the viral standard at this time.

Based on this first assessment approach, eight ballast water treatment systems have demonstrated the **potential** to comply with California's performance standards. These systems are Alfa Laval, Ecochlor, Hamworthy Greenship, Hyde Marine, OceanSaver, OptiMarin, Quingdao Headway Tech., and Techcross Inc. These eight systems have at least one test (averaged across replicates) that can meet each of California's performance standards, excluding the viral standard. Though data for the Hamann Evonik Degussa system also demonstrate the potential to meet California's performance standards using this first assessment approach, the system was pulled from the market in early 2010 and is currently not a viable option for use on ships.

Passage of a single land-based or shipboard test may not be sufficient as a sole indicator for which systems will or will not comply with California's standards when operated under the variable conditions present on vessels. This analysis does, however, provide a good summary of the development status of treatment systems, and this information should be used by stakeholders to further investigate treatment systems that may comply with California's performance standards. A positive assessment for the purpose of this report, however, does not constitute Commission approval or endorsement, nor does it relieve the vessel owner/operator of the responsibility for 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 of interest, under normal ballasting conditions.

A second, more rigorous assessment approach takes a closer look at the performance rates of those systems with available land-based and shipboard data (Table VI-3). The assessment presents the available data in fraction form, with the number of tests that demonstrated potential compliance with California's standards in the numerator, and the total number of tests in the denominator. This more detailed presentation provides the opportunity to discriminate between systems that have demonstrated higher rates of potential compliance versus those that may need to undergo additional testing or development to consistently meet California's performance standards.

Table VI-3. Detailed analysis of system performance at land-based (Land) and shipboard (Ship) testing scales. Data presented as number of tests that have demonstrated potential to meet standard/total number tests conducted. References for each system are listed in Table VI-1.

	>50		**10 - 50**		**<10 (bacteria)**		***E. coli***		**Enterococci**		***Vibrio***	
	Land	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**
Alfa Laval	8/10	1/4	3/10	1/4	0/8	2/2	10/10	4*/4	10/10	4*/4	10*/10	4*/4
Auramarine	4/6	--	0/7	--	0/2	--	1*/1	--	1/1	--	1*/1	
Ecochlor	8/15	1/1[1]	9/11	1/1[1]	8/11	1/1[1]	10/10	1/1[1]	11/11	--	(1/1 lab)	Unk
ETI			0/3	--	0/3	--	--	--	--	--	--	--
Hamann[2]	*16/19*	*4/5*	*17/18*	*0/5*	*1/13*	*3/4*	*12/12*	*4*/4*	*12/12*	*4*/4*	*1*/1*	--
Hamworthy	5/5	--	3/5	--	2/5	--	5*/5	--	5*/5	--	(2/3 lab)	
Hi Tech	--	0/2	--	Unk	5/6	--	6/6	--	--	--	--	--
Hyde	1/10	3/3	0/10	1/3	5/10	3/3	10*/10	3*/3	10*/10	3*/3	--	3*/3
MARENCO	3/4	--	0/1	--	2/3	--	--	--	--	--	--	--
MSI	0/5	--	0/5	--	3/5	--	5/5	--	5/5	--	5*/5	--
Mitsui	0/4	0/1	Unk	Unk	Unk	Unk	Unk	--	Unk	--	Unk	--
NEI	1/5	1/2	0/1	Unk	0/2	0/2	0/1	2*/2	0/1	Unk	--	2*/2
Nutech	0/3	2/3	0/2	0/3	3/3	2/2	--	3*/3	--	3*/3	--	3*/3
OceanSaver	2/14	1/3	5/14	0/2,Unk	5/5	--	14*/14	3*/3	9*/14	3*/3	14*/14	3*/3
OptiMarin	8/12	0/8	6/12	2/8	2/12	--	12*/12	8*/8	12*/12	8*/8	12*/12	8*/8
Qingdao	4/13	3/3	8/13	3/3	9/13	3/3	13*/13	3*/3	13*/13	3*/3	13*/13	3*/3
RBT	3/3	0/2	0/3	0/2	--	--	3/3	2*/2	--	2/2	3*/3	2*/2
RWO	2/2	--	1/2	--	--	--	2/2	--	2/2	--	2/2	--
Severn Trent	3/5[1]	--	2/5[1]	--	4/4[1]	--	--	--	--	--	--	--
Siemens	0/3	--	0/3	--	0/3	--	3/3	--	3/3	--	3*/3	--
Techcross	8/11	3/3	9/11	3/3	4/4	Unk	10*/10	3*/3	11*/11	2*/2	11*/11	3*/3

* Concentration at intake was zero, non-detectable or unknown.
[1] Vendor has added a filter since system testing was conducted.
[2] The Hamann system was removed from the market (effective 1/31/10).

The data presented in Table VI-3 are highly variable. Some systems reliably meet the standards during land-based testing, but fail to do so during shipboard testing. The reverse is also true. Others have demonstrated the potential to meet the standards in 100% of tests, but have only undergone one or two tests. As described earlier, much of the performance data for human health indicator species was collected when the initial pre-treatment concentration of microbes, particularly *Vibrio cholerae,* was zero, non-detectable or unknown. The IMO G8 Guidelines do not require testing organizations to "spike" testing water with microbes due to safety concerns. Testing can proceed in the absence of natural populations of these species. However, the conclusions drawn from these tests may be of questionable value because they do not demonstrate how effectively a system may eliminate such microbes under detectable concentration conditions. Conversely, data from laboratory tests that spike water with microbes before treatment provide valuable insight to the efficacy of systems to kill bacteria, *E. coli*, intestinal enterococci, and/or *Vibrio cholerae*.

In order to determine if systems are available to meet California standards on a consistent basis, Commission staff reviewed the data (Table VI-3) for systems that have conducted three or more tests per standard (land-based or shipboard) and have demonstrated the potential to meet each of the CA standards at least 50% of the time. Two treatment systems – Qingdao Headway Tech. and Techcross - meet these more rigorous criteria. Qingdao demonstrated the potential to meet California's standards in all shipboard tests (see Table VI-3), and Techcross demonstrated the potential to meet California's standards more than 70% of the time for all land-based tests. One additional system – Ecochlor – met the standard over 50% of the time for all organism classes during land-based testing, but was only tested once for *Vibrio cholerae* in the laboratory. Though this does not meet the more rigorous criteria of three tests or more, the laboratory test did involve evaluating system efficacy under spiked concentrations of *Vibrio* above levels present in the pre-treatment tests of other systems. As noted earlier, such laboratory testing provides as much, if not more insight into a system's ability to kill *Vibrio* as does data from land-based or shipboard tests. Thus, the

Commission believes Ecochlor system also shows potential to meet California's standards under this more rigorous assessment.

Overall, this review of system performance indicates that progress is being made in the development of treatment systems to meet California's performance standards for the discharge of ballast water. Eight systems have demonstrated the potential (in at least one test) to meet California's performance standards (Table VI-1). A more stringent review indicates that two systems have demonstrated the potential to meet California's standards greater than 70% of the time over multiple tests. A third system meets all but the *Vibrio* standard greater than 50% of the time over multiple tests. However, that system did met the *Vibrio* standard in a single laboratory test using spiked concentrations of the bacteria above the pre-treatment levels present in land-based or shipboard tests of nearly all other systems. Thus, this third system also shows potential to meet California's standard using the more stringent assessment approach. No system has yet met California's standards 100% of the time for both land-based and shipboard testing. As noted repeatedly throughout this document, evaluations in this report do not constitute endorsement, approval, or guarantee that a ballast water treatment system will meet California's standards for all vessels and all scenarios.

Commission staff have consulted with the vendors of systems that have demonstrated the potential to comply with California's standards, and at this time, two vendors (Ecochlor and Qingdao Headway Tech.), are willing to self-certify that their systems will meet California's standards. California does not require this certification for operation in California waters, but this certification may help assuage some concerns by vessel owners/operators about the availability of systems for use. Ultimately, however, vessel owners/operators must closely scrutinize the available data to ensure that systems will meet California's standards on a regular basis given the configuration of the vessel, piping/water flow requirements, normal transit routes and water quality conditions.

Availability

Many factors play into system availability including industry demand (i.e. how many ships need to buy systems) and commercial availability (i.e. are there enough systems being sold to meet industry demand). Of the eight systems that demonstrated the potential to meet California's standards, all eight are commercially available at this time (see Lloyd's Register 2010). As noted in the efficacy section, the Hamann Evonik Degussa system was pulled from the market in 2010 due to toxicity concerns. It is more difficult to gauge how many vessels with a ballast water capacity greater than 5000 metric tons will be built that will need to purchase systems for the implementation of the standards in 2012. As shown in Figure VI-1, the majority the vessels calling on California ports have a total ballast water capacity of greater than 5000 MT.

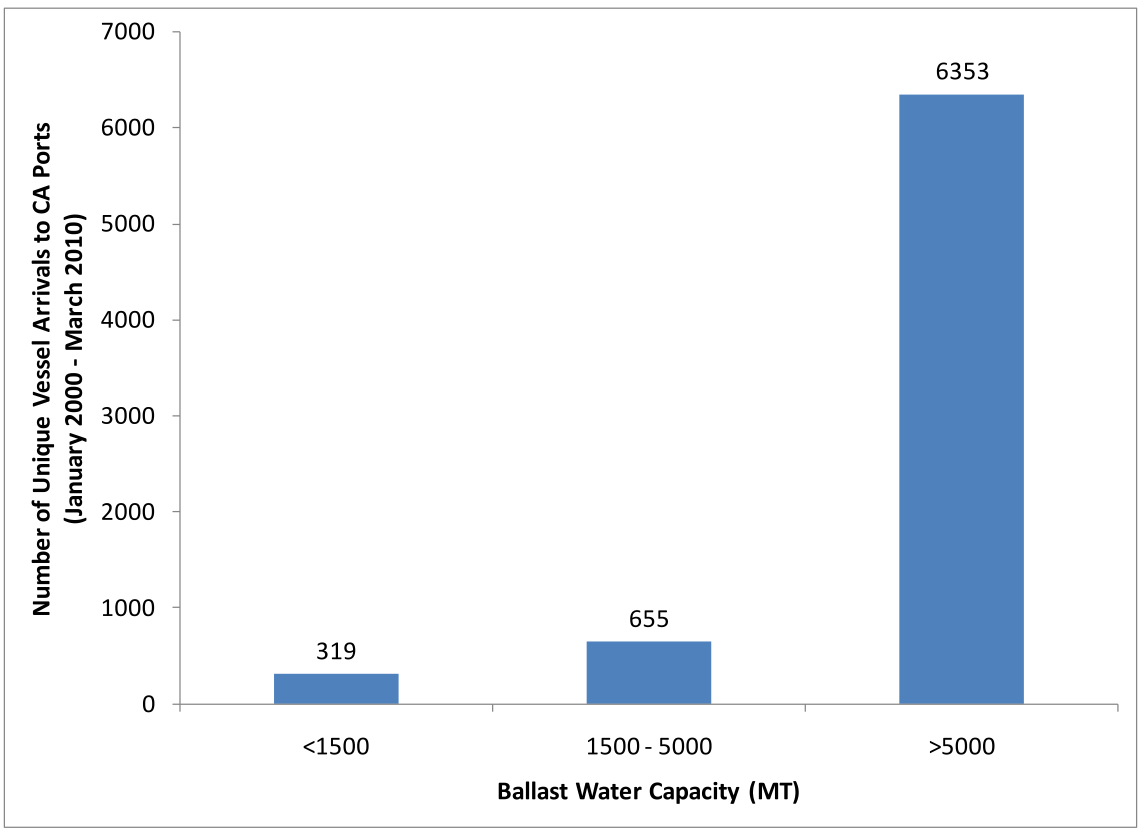

Figure VI-1. Number of unique vessels that arrived to California ports between January, 2000 and March, 2010 as a function of ballast water capacity (MT).

Between January 2000 and March 2010, 6353 unique vessels with a ballast water capacity greater than 5000 MT arrived at California ports (Figure VI-1). Presuming a

20-year vessel replacement cycle (Reynolds, K., pers. comm. 2010), approximately 5% (=318) of these 6353 vessels may be replaced by new vessels and be required to meet the performance standards in 2012. As only 20% of vessels, on average, discharge ballast in California waters (Falkner et al. 2007), an even smaller number of vessels (~ 64) will likely require treatment system usage. Distributed among the eight treatment systems that have demonstrated the potential to comply with California's performance standards and are commercially available, that equates to about eight systems per treatment vendor. That number would certainly fall within treatment system manufacturing capabilities. For example, Alfa Laval sold over thirty treatment systems in the last year (Marinelink 2010). However, caution should be made in interpreting these statistics, as the number of vessels in production and visiting California waters may vary based on economic conditions, and not all treatment systems are equally appropriate for all vessels.

System support is as 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 (2010) 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. Vendors claim that service will be available worldwide. Only time will tell, however, how well existing support networks can deal with this influx of new machinery, and if system support services will be adequate as California's performance standards are implemented for vessels with a ballast water capacity greater than 5000 MT in 2012.

While commercial availability and industry demand are two important components of this assessment of availability, the specific purpose of this report is to assess the availability of ballast water treatment systems for newly built vessels with a ballast water capacity greater than 5000 metric tons. The 2009 technology assessment report (see Dobroski et al. 2009a) did not specifically address the capacity of systems to treat large volumes of water – as will be necessary for this upcoming largest size class of vessels.

Systems must be able to treat all ballast on a vessel prior to discharge. For systems that treat on uptake and/or discharge - which includes all of the systems that have demonstrated the potential to meet California's standards (Table VI-4) – the total volumetric capacity of the vessel is not the determining factor. Instead, the treatment system must be able to keep pace with the flow rate of the vessel's ballast water pumps. Commission staff analyzed data on the number of ballast water pumps and the maximum pump rates for the fleet of vessels that call on California ports. It is difficult to pinpoint an average system treatment rate necessary for these vessels because, depending on a vessel's piping configuration, a vessel may need one system per pump or one system to treat water coming in or out from all pumps. Figures VI-2 and VI-3 illustrate the range of ballast water pump rates on vessels with a ballast water capacity of greater than 5000 MT that operate in California waters. The figures include both vessels that have discharged and have not discharged ballast in California waters, because all vessels have the potential to discharge ballast at some point either due to cargo operations or safety concerns. Figure VI-2 shows the maximum single pump rate per vessel, and Figure VI-3 shows the maximum combined pump rate per vessel.

Table VI-4. System Capacity and Timing of Treatment for Systems that Have Demonstrated Potential to Meet California's Performance Standards

System Manufacturer	**Timing of Treatment**	**Maximum System Capacity**
Alfa Laval	Uptake and Discharge	2500 m^3/h
Ecochlor**	Uptake	Unlimited (>13000 m^3/h)
Hamworthy Greenship	Uptake	1000 m3/h per pump
Hyde Marine	Uptake and Discharge	6000 m^3/h
OceanSaver	Uptake	Unlimited (>6000 m^3/h)
OptiMarin	Uptake and Discharge	3000 m^3/h
Qingdao Headway Tech.**	Uptake and Discharge	4500 m^3/h
Techcross**	Uptake and Discharge	Unlimited (>5000 m3/h)

**Demonstrated potential to meet California's standards under more rigorous evaluation criteria: Showed potential more than 50% of the time in 3 or more tests.

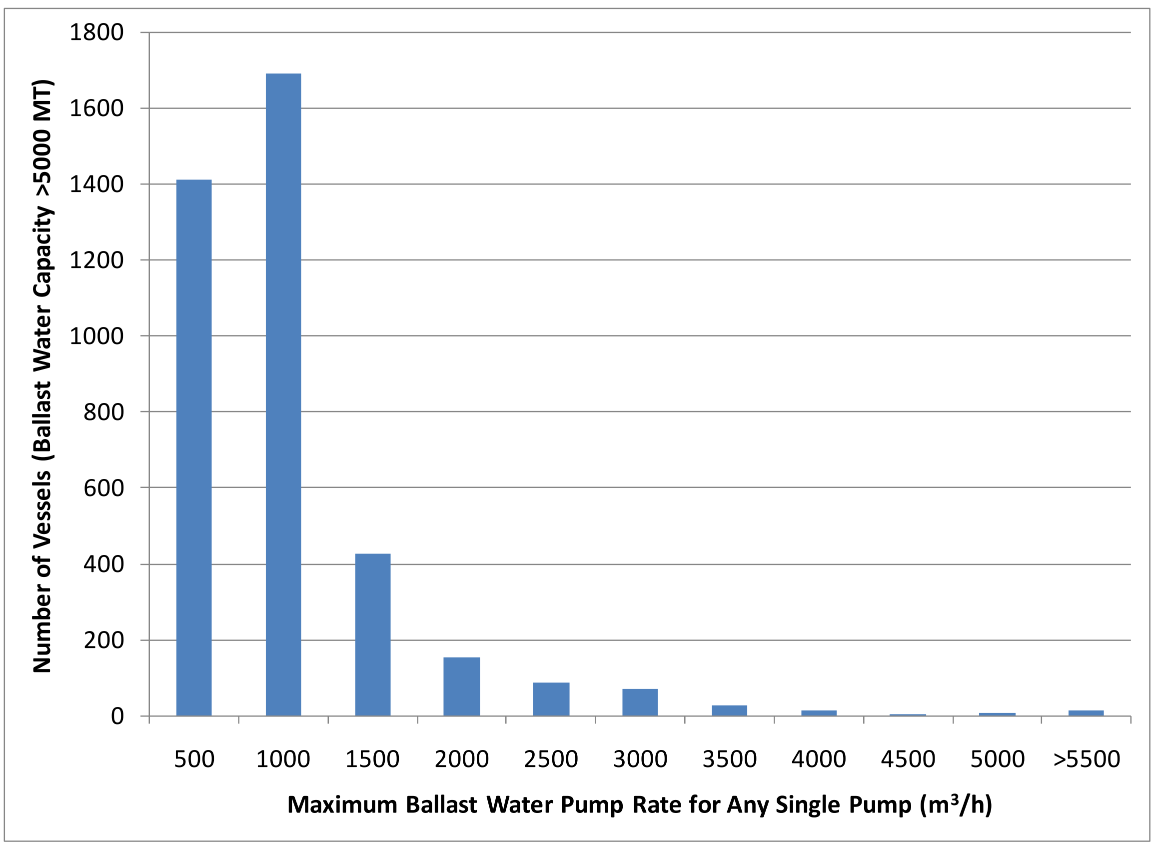

Figure VI-2. Histogram of number of vessels with a total ballast water capacity greater than 5000 MT that have visited California ports and their maximum ballast water pump rate for any single pump (m^3/h).

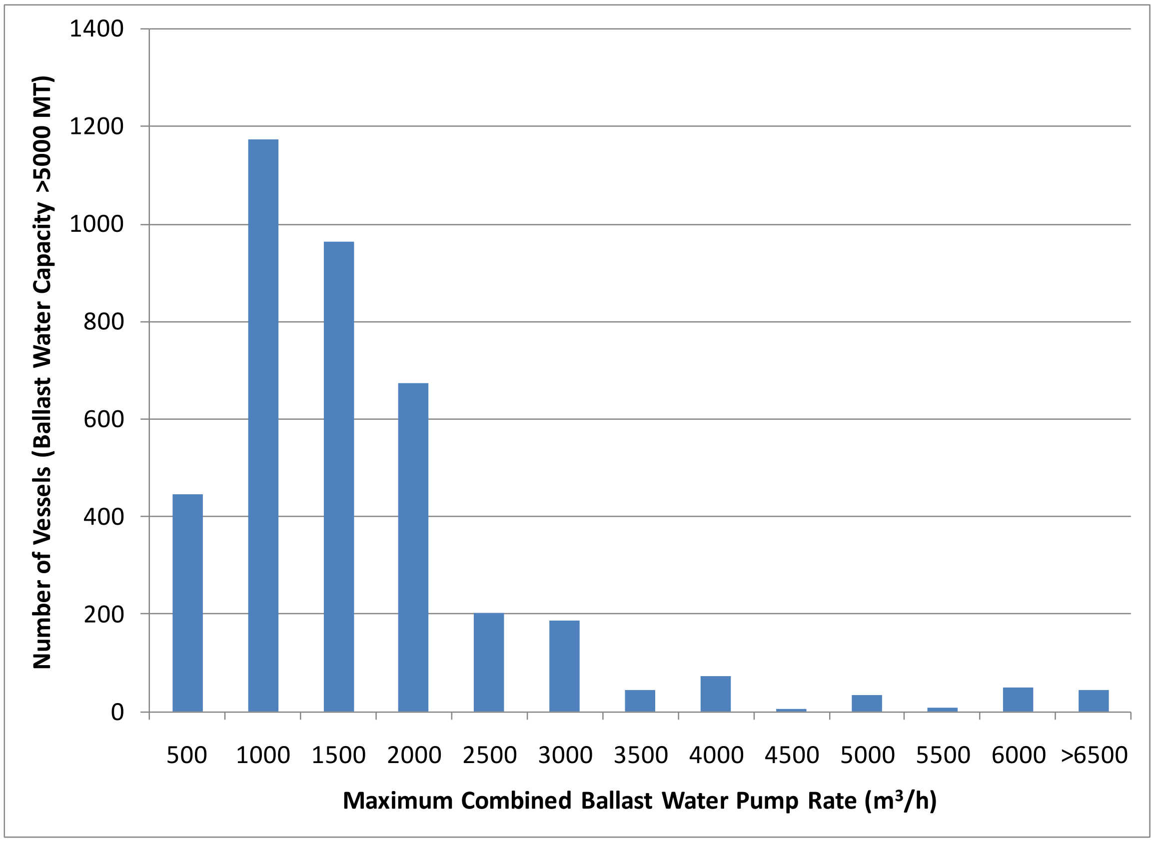

Figure VI-3. Histogram of number of vessels with a total ballast water capacity greater than 5000 MT that have visited California ports and their maximum combined ballast water pump rates (m^3/h).

Taking into account both single and combined pump rates, the majority of vessels operating in California waters will need treatment systems that operate at rates between 250 and 3000 m^3/h. A closer look at vessel pump rates reveals that treatment systems with a maximum rate of 2000 m^3/h will accommodate over 80% of those vessels with a ballast water capacity of greater than 5000 MT that operate in California waters. Based on vendor supplied data (Table VI-4), seven of the treatment systems that have demonstrated the potential to meet California's performance standards are commercially available and are able to treat ballast water at a rate of 2000 m^3/h. All three of the systems that show potential for meeting the standards under the more rigorous consistency criteria can accommodate much higher pump rates of 4500 m^3/h or more. Many systems are modular, and vendors note that systems can be combined to accommodate a wide variety of flow rates. Therefore vessel owners and operators should consult with treatment vendors to determine if systems are available to treat the appropriate flow rates given the piping and tank configurations of each vessel.

For systems that do not treat on uptake and/or discharge, total ballast water capacity, and not ballast pump flow rate, is the determining factor for system size. Of the 46 systems reviewed in this report, only six treat ballast in-tank during the voyage (see Lloyd's Register (2010) for additional information on timing of treatment), and none of these systems have demonstrated the potential to meet California standards. At this time there is insufficient information available to evaluate whether or not these systems will be able to accommodate the range of ballast water capacities of vessels operating in California waters. As these systems undergo additional testing, Commission staff will gather information in order to assess the ability of these systems to treat the largest size class of vessels operating in California waters.

Environmental Regulation and Impact Assessment

An effective ballast water treatment system must consistently comply with both performance standards for the discharge of ballast water and applicable environmental safety and water quality laws, regulations and permits. The discharge of treated ballast should not impair water quality so it impacts the 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 46 treatment systems reviewed here.

International

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” based 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 chemical 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 2008f). 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 2008f).

Federal

Outside of the 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 impacts assessment process (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 VGP for discharges from vessels employing ballast water treatment systems.

The effluent limits and best management practices described in the VGP 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. Code § 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 (TRC; instantaneous maximum = 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). Systems that use biocides or produce derivatives which lack applicable EPA Water Quality Criteria must conduct Whole Effluent Toxicity testing to determine chronic toxicity levels. Systems that do not meet the Water Quality Criteria or chronic toxicity limits may be required to cease discharging and must apply for coverage under an individual NPDES permit.

Vessels participating in the STEP must comply with the VGP and additionally conform to the environmental compliance requirements associated with STEP participation including: 1) Compliance with the National Environmental Policy Act 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).

States

As discussed in Section III, several states established ballast water management programs and performance standards requirements through the Section 401 certification of the Vessel General Permit. This certification also provided states a mechanism to set water quality criteria for ballast water discharges. Chlorine was a toxicant of concern for many states, particularly those located on the Great Lakes. Several states chose to establish limits for Total Residual Chlorine (TRC) in ballast discharges that were substantially more stringent than the limit established by the VGP (= 100 µg/l). Massachusetts, for example, set a TRC limit of 10 µg/l in discharges from experimental treatment systems. Several states also established conditions requiring evaluation of acute and chronic impacts from treated discharges.

State of Washington

The State of Washington's evaluation of environmental impacts from the discharge of treated ballast water has proved an invaluable resource to Commission staff. The Washington State Department of Ecology developed a framework for "Establishing the Environmental Safety of Ballast Water Biocides" in 2003, and revised it in 2008 to be included as Appendix H in the *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* manual (Washington State Department of Ecology 2008, available at http://www.ecy.wa.gov/pubs/9580.pdf). Thus far, three systems have completed toxicity testing in accordance with Washington requirements (Table VI-5).

The tests used in the Washington State framework for evaluating ballast water biocides include EPA-approved acute and sensitive life stage toxicity tests on invertebrate, fish and algal species. One ISO test on growth inhibition of a marine diatom is also required in order to be consistent with international testing requirements. 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 EPA chronic tests or Washington State tests using Pacific herring may also be 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 (Washington State Department of Ecology 2008).

California

California does not have a formal environmental impact evaluation process for the discharge of ballast water that has undergone treatment. Vessels that discharge in California waters must comply with the applicable provisions of the EPA's VGP including any California-specific conditions added by the State Water Resources Control Board through the Section 401 certification process. California's Section 401 certification requires that vessel discharges contain no hazardous wastes as defined in California law or hazardous substances as listed in the certification letter (see Water Board 2009). Discharges may not contain an oily sheen, noxious liquid substance residues, and detergents may not be used to disperse hydrocarbon sheens. For more information go to http://www.swrcb.ca.gov/water_issues/programs/index.shtml and review the section on vessel discharges under the clean beaches/ocean programs.

Environmental Assessment of Treatment Systems

Staff has compiled environmental assessment reports and water quality data reported to the IMO, as well as information made available to the State of Washington and Commission staff, to assess available 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 to the VGP and California water quality objectives.

Of the 46 treatment systems reviewed for this report, 28 use a biocide or chemical additive in the treatment process (Table VI-5), and will therefore require monitoring of discharges for chemical residuals. An assessment of the potential impacts from all possible chemicals and residuals associated with the use of these treatment technologies cannot be adequately addressed in this report and is the purview of the California Water Board and the EPA. Instead, Commission staff has focused this environmental assessment on total residual chlorine (TRC) concentrations in discharged ballast water because both the VGP and the Water Board (through the California Ocean Plan; see Water Board (2005)) have identified TRC as a particular concern due to its widespread toxicity to all organisms. Currently, California defers regulation of TRC in discharged ballast water to the EPA through the VGP. All vessels that discharge ballast in California waters must comply with the EPA VGP limit for TRC (= instantaneous maximum of 100 µg/l in discharged waters). Vendors and vessel owners/operators must consult with the Water Board and EPA to ensure that vessel discharges comply with all other applicable effluent requirements.

Table VI-5 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 the EPA water quality objective for TRC in ballast water discharge (= instantaneous maximum of 100 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 twelve treatment systems have received Final Approval from IMO (Table V-1, VI-5).

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 two systems - Hamann Evonik Degussa (removed from the market in 2010) and Ecochlor (Albert, R., pers. comm. 2010). FIFRA, however, does not apply to 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 exception provides significant room for systems to operate in U.S. waters without any kind of federal biocide regulation except as provided by the VGP, and at this time, it is uncertain how EPA will enforce the permit’s provisions.

Table VI-5. 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 EPA Vessel General Permit.

Manufacturer	Active Substance	Toxicity Testing Conducted	Environmental Related Approvals	VGP TRC Compliant? (100 ug/l)	Source
21st Century Shipbuilding	superoxide, oxygen radical,hydroxyl radical, electron, ozone	X	IMO Basic	Y	117
Alfa Laval	free radicals	X	IMO Basic and Final	Y	86,135,137
Aquaworx ATC Gmbh	n/a (UV, cavitation bubble)	X	IMO Basic	Y	111
atg UV Technology	n/a (UV)				
ATLAS-DANMARK	hyplochlorous acid, ozone, hydrogen peroxide,chlorine dioxide, hydrogen, sodium hydroxide				125
Auramarine Ltd.	n/a (UV)	X			4
Brillyant Marine LLC					
Coldharbour Marine	n/a (deoxygenation)				
COSCO/Tsinghua Univ.	n/a (UV)	X	IMO Basic		105
DESMI Ocean Guard A/S	hydroxyl radical, ozone	X	IMO Basic		115
Ecochlor	chlorine dioxide	X	IMO Basic, Rec WA Cond.[1]	Y	97,124
EcologiQ	yeast	X			6
Electrichlor	sodium hypochlorite				
ETI	ozone	X			75
Ferrate Treatment Tech.	ferrate				
Hamann Evonik Degussa[2]	Peraclean Ocean (peracetic acid, hydrogen peroxide, acetic acid)	X	IMO Basic & Final, EPA Reg., Rec. WA Conditional[1]		90,132
Hamworthy Greenship	free active chlorine, total residual chlorine	X	IMO Basic and Final	Y	93,100,109
Hi Tech Marine	n/a (heat)		New South Wales EPA		175
Hitachi/Mitsubishi	triiron tetraoxide, poly aluminum chloride, poly acrylamide sodium acrylate	X	IMO Basic and Final		88,108
Hyde Marine	n/a (UV)	X			
Hyundai Heavy Ind. (1) EcoBallast	n/a (UV)	X	IMO Basic and Final		107,114
Hyundai Heavy Ind. (2) HiBallast	chlorine, bromine, sodium hypochlorite, sodium hypobromite, hypochlorous acid, hypobromous acid,	X	IMO Basic	Detection limit of tests above EPA standard	119
JFE Eng. Corp./TG Group	sodium hypochlorite	X	IMO Basic and Final	Y	100,116

Blank cells indicate that data was not available

[1] 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.

[2] The Hamann Evonik Degussa system was temporarily removed from the market in 2010 due to environmental concerns regarding the toxicity of Peraclean Ocean in freshwater and cold water (see de Lafontaine et al. 2008, 2009).

Table VI-5 (Continued). 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 Vessel General Permit

Manufacturer	Active Substance	Toxicity Testing Conducted	Environmental Related Approvals	VGP TRC Compliant? (100 ug/l)	Source
Kwang San Co. Ltd.	Cl_2, hypochlorous acid, hypobromous acid, sodium hypochlorite, sodium hypobromite	X	IMO Basic	Detection limit of tests above EPA standard	120
MAHLE Ind. GmbH	n/a (UV)				
MARENCO	n/a (UV)				
Maritime Solutions Inc.	n/a (UV)				
Mexel Industries	yes, unknown				
MH Systems	n/a (deoxygenation)				
Mitsui Engineering	ozone	X	IMO Basic	N	84,104,114
NEI	n/a (deoxygenation)	X			11
NK Co. Ltd.	ozone, total residual oxidant	X	IMO Basic and Final	Y	98,106,114
ntorreiro	yes, unknown				
Nutech 03 Inc.	ozone	X		N	195
OceanSaver	free and total residual oxidant	X	IMO Basic and Final	Y	95,101,146
OptiMarin	n/a (UV)	X		Y	136
Panasia Co.	n/a (UV)	X	IMO Basic and Final	Y	91,94,110
Pinnacle Ozone Solutions	ozone				
Qingdao Headway Tech	hydroxyl radical, hypochlorous acid, hypochlorite, hydrogen peroxide	X	IMO Basic	Y	121,126,147
Resource Ballast Tech.	ozone, hydroxyl radicals, hypochlorite	X	IMO Basic and Final	N	87,112,124
RWO Marine Water Tech.	hydroxyl radicals, free active chlorine	X	IMO Basic and Final	N	89,103,114
Severn Trent DeNora	sodium hypochlorite, sodium bisulfite	X	IMO Basic, Rec. WA Conditional[1]	Y	49,122
Siemens	sodium hypochlorite, sodium hypobromite, oxygenated species, oxygen, hydrogen	X	IMO Basic	Y	78,113
Sunrui CFCC	hypochlorite, hypobromite, chloramines, bromamines	X	IMO Basic		118
Techcross Inc.	hypochlorite, hypobromite, ozone, hydroxyl radicals, hydrogen peroxide	X	IMO Basic and Final	Y	83,96,100
Wartsila	n/a (UV)				

Blank cells indicate that data was not available

[1] 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 availability for use in California waters is dependent on its ability to meet all of the EPA's and California's environmental laws, regulations and permits for vessel discharges - not simply the performance standards. While it is the purview of the EPA and the Water Board to review and regulate the effluent from treatment systems used on vessels, Commission staff is working to educate technology vendors, particularly those from foreign countries, about the EPA's water quality objectives. Staff also encourages vendors to consult with the Water Board to ensure that systems meet California's Section 401 provisions in the VGP.

As a first step towards assessing system environmental impacts, staff has attempted to compile data on 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 46 systems reviewed, 21 have data available for TRC in the treated effluent. Based on the available data, 14 appear to meet the EPA VGP objective (California defers to the EPA VGP for regulation of TRC in vessel discharges) of 100 µg/L or less of TRC (Table VI-5). Of the eight systems that demonstrated the potential to meet California's performance standards for the discharge of ballast water and that are commercially available, seven have data demonstrating TRC compliance with the EPA VGP objective. The only system without TRC data, Hyde, uses a filtration/UV system that should not generate any chlorine residuals. Clearly, not all treatment systems will meet California's and EPA's stringent water quality standards. However, it is difficult to assess at this time whether systems are simply unable 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 and federal 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 costs of NIS introductions 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). NIS can also cause direct economic losses by reducing yield (i.e. aquaculture), reducing the value of commodities, increasing health care costs, or by reducing tourism-based revenues. For example, evidence strongly indicates that a toxogenic strain of *Vibrio cholera* was transported via ships from South America to the U.S. Gulf coast in 1991, resulting in the closure of Mobile Bay (Alabama) shellfish beds. Economic damages for the short-term localized closure are estimated at over $700,000 (Lovell and Drake 2009). Prince Edward Island oyster operations in Canada lose approximately $1.5 million annually due to mortality caused by the nonindigenous seaweed *Codium fragile* (Colautti et al. 2006). The rate of new introductions is increasing (Cohen and Carlton 1998, Ruiz and 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 2010a). California's natural resources contribute significantly to the coastal economy. For example, in 2007 total landings of fish were over 380 million pounds, valued at more than $120 million (NOEP 2010b). Squid, the top revenue-generating species in 2007, brought in almost $30 million (NOEP 2010b). Millions of people visit California's coasts and estuaries each year, spending money on recreational activities that are directly related to the health of the ecosystem. Annually, over 150 million visits are made to California's beaches: approximately 20 million for recreational fishing, over 65 million for wildlife viewing, and over 5 million for snorkeling or scuba diving (Pendleton 2009). Direct expenditures for recreational beach activities alone likely exceed $3 billion each year (Kildow and Pendleton 2006). In total, the tourism and recreation industries 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 fish hatcheries and aquaculture, recreational boating, and marine transportation.

The use of ballast water treatment technologies to combat NIS introductions will involve economic investment on the part of ship owners. This investment 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) 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 because system prices still represent research and development costs and do not reflect the presumably lower costs that would apply once systems are in mass production. In the 2010 Lloyd’s Register report, only 22 of 41 technologies profiled provided estimates of system capital expenditures (equipment and installation) and half (20) provided estimates of system operating expenditures (parts, service, and energy usage; Table VI-6). 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 $20,000 and $630,000 with an average cost of $291,000 (Lloyd’s Register 2007, Lloyd’s Register 2010, Commission data from technology vendors 2007-2008) – down $96,500 from 2009 (see Dobroski et al. 2009a). A 2000 m^3/h capacity system ranges from $50,000 to $2,000,000 with an average cost of $892,500 per system (Lloyd’s Register 2007, Lloyd’s Register 2010, Commission data from technology vendors 2007-2008). The average cost of the large capacity systems has not changed since Dobroski et al.

(2009a). Operating costs range from negligible, assuming waste heat is utilized, to \$1.50 per m^3 with an average of \$0.07 per m^3 (Lloyd's Register 2007, Lloyd's Register 2010, Commission data from technology vendors 2007-2008) – down \$0.06 per m^3 since 2009 (see Dobroski et al. 2009a).

Treatment systems will likely increase the cost of a new vessel by 1-2%. For example, a new 8200 TEU (twenty-foot equivalent unit) container ship built by Hyundai Samho Heavy Industries costs approximately \$120 million per vessel (Pacific Maritime 2010). Installation of the most expensive treatment system currently available at \$2.0 million (as indicated in Table VI-6) 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-6. Summary of capital and operating cost data for select treatment systems. Unless otherwise noted, source of data is Lloyd's Register (2010).

Manufacturer	Capital Expenditure *(Equipment & Installation)*			Operating Expenditure *($ per m3, unless otherwise noted)*
	200 m^3/h *($ in thousands)*	**2000 m^3/h** *($ in thousands)*	**Other** *($ in thousands)*	
21st Century Shipbuilding				
Alfa Laval				0.015[1]
Aquaworx ATC				
atg UV Technology				
ATLAS-DANMARK	180	850		
Auramarine Ltd.				0.040
Brillyant Marine LLC	300	2000		
Coldharbour Marine				
COSCO/Tsinghua Univ.				
DESMI Ocean Guard				
Ecochlor	500	800		0.080
EcologiQ			<50[1]	1 - 1.50[1]
Electrichlor	350			.019
ETI		500		cost of power
Ferrate Treatment Tech.				
~~Hamann Evonik Degussa~~				~~0.2~~
Hamworthy Greenship				
Hi Tech Marine	150	1600	16.5 – 300[1] *(equipment only)*	nil[2]
Hitachi/Mitsubishi		400		
Hyde Marine	250	1200	174 – 503[1]	<.020
Hyundai Heavy Industries (1) – Ecoballast				
Hyundai Heavy Industries (2) – HiBallast				
JFE Eng. Corp./TG Corp.				0.053
Kwang San Co. Ltd.				
MAHLE				
MARENCO	145	175		0.0006 - 0.001
Maritime Solutions Inc.				
Mexel Industries	20	50		
MH Systems	500	1500		0.06
Mitsui Engineering			100[1] *(installation only)*	0.15[3]
NEI	249	670		0.13
NK Co. Ltd.	250	1000		0.007
ntorreiro				
Nutech 03 Inc.	250	450		0.32
OceanSaver	288	1600		0.06[3]

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

Table VI-6 (Continued). Summary of capital and operating cost data for select treatment systems. Unless otherwise noted, source of data is Lloyd's Register (2010).

Manufacturer	Capital Expenditure *(Equipment & Installation)*			Operating Expenditure *($ per m3, unless otherwise noted)*
	200 m^3/h *($ in thousands)*	**2000 m^3/h** *($ in thousands)*	**Other** *($ in thousands)*	
OptiMarin	290	1280		
Panasia Co. Ltd.				
Pinnacle Ozone Solutions	200	500		0.013
Qingdao Headway Tech.				0.0018
Resource Ballast Tech.	275	700		
RWO Marine Water Tech.				
Severn Trent DeNora	630	975		0.020
Siemens	500	1000		0.0085 - 0.010
Sunrui CFCC				
Techcross Inc.	200	600		0.003
Wartsila				

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

VII. DISCUSSION AND CONCLUSIONS

Recognizing the threat to California's waters from nonindigenous species, California's legislature enacted legislation in 2006 requiring the Commission to implement performance standards for the discharge of ballast water. Those standards, set forth in statute and adopted via regulation, set limits for the concentration of viable organisms in discharged ballast water. The standards will be implemented on a graduated time schedule based on a vessel's ballast water capacity and year of construction. Vessels have several options for complying with the performance standards regulations. Over 80% of vessel voyages to California waters do not involve the discharge of ballast water. In these cases, compliance with the regulations is achieved because all ballast water is retained on board the vessel. Alternatively vessels may discharge to a shoreside or barge-based ballast water reception facility. Although no such facilities currently exist in California, there has been recent interest by several entities in developing this option for vessels operating in California and along the West Coast. Finally, for vessels that cannot retain all ballast on board or discharge to a reception facility, shipboard ballast water treatment will likely be necessary to meet California's performance standards. Per PRC Section 71205.3, the purpose of this report is to assess the efficacy, availability and environmental impacts of ballast water treatment systems prior to the implementation of California's performance standards for newly built vessels with a ballast water capacity greater than 5000 MT beginning on January 1, 2012.

Ballast water treatment is an emerging and quickly expanding 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 hurdles remain for the full implementation of all of California's performance standards, significant progress has been made in the development of treatment systems since previous technology assessment reports (see Dobroski et al. 2007, 2009a). Both the quantity and the quality of the recently received data on system performance attest to this fact.

Treatment system performance data has improved in recent years, however it is important to note that systems have undergone a relatively small number of tests, under a limited range of environmental conditions. This leads to inherent uncertainty regarding treatment system performance across the spectrum of potential variables, including ship type and source water properties (e.g. temperature, turbidity, salinity). This uncertainty is likely to persist over the next several years. In the absence of a significant worldwide effort to install and test treatment systems on multiple vessels and under all possible environmental scenarios, it is unreasonable to expect that sample sizes and available data will increase adequately in the near future to demonstrate, with a high level of confidence, that treatment systems will consistently meet California's performance standards under every potential situation and under all circumstances. However, continuing to wait for such information will only serve to delay progress. Due to the inherent uncertainty regarding treatment system performance and evaluation, the utilization of an adaptive management approach will be essential at all stages of implementation in order to move forward and protect California's aquatic resources from the impacts of species introductions.

Similar to the ballast water treatment industry, the fields of treatment technology assessment and compliance verification are still evolving, and recent discussions have centered on whether or not methods and/or protocols exist to assess compliance with California's standards. California's standards for organisms greater than 50 µm in size is set as "nondetectable." In discussions related to the International Maritime Organization standard, external parties have reasoned that the volumes of ballast water required to determine compliance with any standard more stringent than 10 organisms per cubic meter are not testable. However, it is important to note that California's standard for organisms greater than 50 µm is unitless. There are no volume requirements set forth in the standard. Therefore, compliance and performance testing can occur with any volume of water. The volumes of water sampled for the remaining size classes are small enough so that they do not pose an issue.

The bacteria and virus standards do pose a challenge. While there are currently widely-accepted methods for assessing viability for a subgroup of total bacteria, Commission staff believes that there are no acceptable methods for verification of compliance with the virus standard and that the Commission should proceed with assessment of technologies for the remaining six standards. Commission staff have considered all of these issues while evaluating treatment systems for compliance with California's standards.

Based on currently available information and using best assessment techniques, at least eight treatment systems have demonstrated the **potential** to comply with the Commission's performance standards (Table VII-1). Efficacy data for these systems indicate that at least one test met or exceeded California's performance standard for every testable organism/size category during either land-based or shipboard testing. Systems that met California's *Vibrio* standard in laboratory tests that involved spiked concentrations of the microbe above levels generally found in land- or ship-based testing were considered indicative of a system's performance at the land or shipboard scales. Three of the eight systems show the **potential** to meet California's performance standards under more rigorous evaluation criteria. These three passed more than 50% of the time over multiple tests (3 or more) at either the land or shipboard scale (Table VII-1). Additional systems are close to demonstrating the potential for meeting California's standards, and Commission staff are awaiting data from these tests of system performance.

Commission staff believe that, given the data currently available, multiple treatment systems have demonstrated the potential to meet California's performance standards for vessels with construction initiated on or after January 1, 2012, and a ballast water capacity greater than 5000MT. Practically speaking, vessels with this construction date will not be expected to meet the standards until construction is complete and they are operational, sometime in 2014 at the earliest. The lead time available for further technology development and refinement is sufficient to indicate that technologies will be available by the time these vessels are operational. At least three to four years will pass before any vessels in this size class will need to install treatment systems to meet California's standards.

Current federal law will continue to require ballast water exchange as the primary management method. Thus, in order to comply with both California and federal law, many vessels that must discharge in California will need to first exchange ballast water according to federal requirements for distance from shore and depth, and utilize a ballast water treatment system to reduce organisms to levels at or below California's standards. Though seemingly duplicative, the execution of exchange along with or before treatment will likely serve to improve the efficacy of systems. The concentrations of organisms in the open ocean (where exchange will occur) will be lower than concentrations in nearshore areas. Since the shipboard and land-based data utilized for this report tested treatment systems with comparatively organism-rich water from nearshore areas, it is expected that system performance will be improved if open ocean exchange is conducted before treatment. Open ocean waters also generally exhibit lower levels of turbidity, organic matter, and human pathogens/pathogen indicators, which should also serve to improve system performance and reduce organism levels at discharge.

All eight of the systems that have demonstrated the potential to comply with California' standards (see Table VII-1) are currently commercially available. Seven should be able to treat at ballast water pump rates over 2000 m^3/hr, which would accommodate over 80% of the vessels that operate in California with ballast water capacity over 5000 MT. The manufacturers of six systems attest that their products will operate at much higher pump rates. Of the three systems that show potential for meeting the standards under more rigorous consistency criteria, all can accommodate much higher pump rates of 4500 m^3/hr or more.

Table VII-1. Summary of assessment for ballast water treatment systems with potential to meet California's performance standards. **Denotes systems which demonstrated potential to meet standards more than 50% of the time over 3 or more tests. See tables V-1, VI-1, VI-3, VI-4, VI-5, VI-6, and Section VI text for more information.

System Manufacturer	Max System Capacity (Pump Rate)	General Approvals *(Non-California)*	Environmental Approvals	VGP Total Residual Chlorine Compliant	Costs: Initial *($ in Thousands)*		Costs: Operating *($ per m^3)*
					200 m^3/hr	**2000 m^3/hr**	
Alfa Laval	2500 m^3/hr	Type Approval (Norway)	IMO Basic & Final	Yes			0.015
Ecochlor**	>13,000 m^3/hr	USCG STEP[1], WA Conditional[1]	IMO Basic, USCG STEP[1], WA Conditional[1]	Yes	500	800	0.080
Hamworthy Greenship	1000 m^3/hr (per pump)		IMO Basic & Final	Yes			
Hyde Marine	6000 m^3/hr	WA Conditional[1], Type Approval (UK), USCG STEP[1]	(UV System) USCG STEP[1], WA Conditional[1]	N/A	250[2]	1200[2]	<0.020
OceanSaver	>6000 m^3/hr	Type Approval (Norway)	IMO Basic & Final	Yes	288	1600	0.06
OptiMarin	3000 m^3/hr	Type Approval (Norway)	(UV System)	Yes	290	1280	
Quingdao Headway Tech**	4500 m^3/hr		IMO Basic	Yes			0.0018
Techcross**	>5000 m^3/hr	Type Approval (Korea)	IMO Basic & Final	Yes	200	600	0.003

[1] USCG STEP and WA Conditional approvals require that systems demonstrate levels of efficacy and environmental acceptability. Acceptance into STEP constitutes an experimental use approval that applies to the combination of one vessel and one treatment system. STEP requires compliance with the EPA Vessel General Permit, the National Environmental Policy Act, and requires vessels to obtain other applicable permits. STEP is not a Type Approval process. Washington State Conditional Approval requires data from specific laboratory and effluent toxicity tests. See text for more detail.
[2] Additional initial costs for the Hyde Marine system not noted in table are $174-503 thousand.

NOTE: These systems demonstrate the potential to meet California's performance standards, however, this does not constitute an approval or endorsement of any system.

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. Overall, 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 meet water quality standards set forth in the EPA Vessel General Permit. However, information gaps related to system impacts to receiving waters still exist. Commission staff continues to work with the Water Board to track the implementation of the 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 EPA and the Water Board to assess the potential for water quality impacts and treatment system compliance with water quality requirements in federal and California waters.

Most of the eight treatment systems that demonstrate the potential to meet California's standards have received one or more approvals from other regulatory entities, which involve the demonstration of specific levels of efficacy and/or minimization of environmental impact. Four have received both IMO Basic and Final approval for the use of active substances. Two additional systems have received USCG STEP and Washington State Conditional approvals, which require certain levels of performance efficacy, and/or environmental toxicity testing. Available data indicate that all eight systems either meet the EPA VGP total residual chlorine limit or do not produce chlorine in the treatment process. Though systems must ultimately meet all requirements of the U.S. EPA and the California Water Board, in addition to California's performance standards, in order to operate in California waters, the available environmental data reviewed for this report is promising. While STEP, IMO and/or Washington Conditional approvals do not constitute authorization for use in California (California does not require these approvals nor will California provide approvals), approvals from other regulatory entities may allow operation of such systems on routes outside of California.

The Commission will continue to gather information on treatment system efficacy, availability and environmental impacts as California's standards are implemented and additional vessels install treatment systems for both experimental purposes and to meet state, federal and international ballast water management requirements. The ballast water treatment industry is evolving rapidly. In December 2007, the Commission report (see Dobroski et al. 2007) indicated that no technologies had demonstrated the potential to meet California's standards. Less than four years later, this report indicates that eight systems have demonstrated the potential to meet the standards. Given that several years remain before the next class of vessels must be prepared to meet California's standards, Commission staff believe that sufficient evidence exists to demonstrate that systems will be available. However, in recognition of the rapidly changing fields of technology development and performance assessment, Commission staff will prepare an update of this report by September 1, 2011. In preparation of the update, Commission staff will convene a scientific advisory panel to review the latest data on treatment systems and testing protocols and provide input regarding the availability of treatment systems in an effort to ameliorate concerns regarding the implementation of California's performance standards. While not required by statute, this update will verify that technology development is progressing on schedule to allow for the implementation of the standards beginning January 1, 2012.

VIII. RECOMMENDATIONS

1. **Move forward with January 1, 2012 implementation date of California's performance standards for new vessels with a ballast water capacity greater than 5000 MT.**
   Based on the available information, the Commission recommends that the implementation of performance standards for new vessels with a ballast water capacity greater than 5000 MT proceed on January 1, 2012. This review indicates that systems will be available to meet California's performance standards, and those systems are available for use on vessels with a ballast water capacity greater than 5000 MT. 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. The Commission intends to proceed with the implementation of the standards as set forth in statute and in regulation. While not required by statute, Commission staff will conduct an update of this technology assessment by September 1, 2011 to ensure that progress in technology development is sufficient to allow for the implementation of the standards beginning January 1, 2012. The next legislatively mandated report is due July 1, 2012 in anticipation of the 2014 implementation date for existing vessels (those built before 2010) with a ballast water capacity of between 1500 MT and 5000 MT.

2. Support Commission staff involvement with the development and implementation of performance standards at the federal and international levels.

Commercial shipping is an international industry; any single ship may operate throughout several regions of the world. Ideally, performance standards that align both at the federal and international levels are preferable to a patchwork of standards adopted by individual states. Commission staff have been working 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. 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. Additionally, due to California's role as a world leader in the implementation of ballast water management regulations, Staff has recently been invited to participate in meetings hosted by the European Union to discuss the future implementation of the IMO Convention and rules for ballast water management in European waters. Staff expects to be asked to provide information and guidance about the

Commission's Marine Invasive Species Program during conferences and outreach events held throughout California, the U.S. and internationally.

The development of U.S. Federal and international policies and regulations related to performance standards frequently take place in locations outside of California (esp. Washington D.C.) and occasionally, at international venues. With ongoing prohibitions on out-of-state and out-of-country travel, Commission staff can often only participate in such discussions when it is possible to do so via teleconference. Often teleconferencing is not an option, and the development of federal or international policies simply move forward without input from California. When presentations over the telephone are possible, sound quality is poor, presentation via power point is problematic, and audience question and answer sessions are difficult. Engagement in discussion or dialogue in-person at meetings and conference is extremely effective. The Legislature is encouraged to support Commission Staff participation in such important meetings and conferences, particularly in instances where travel expenses are covered by third parties.

3. Maintain accessibility to Marine Invasive Species Program funds to address immediate research needs related to the development of methods to assess compliance with California's performance standards.

Additional research is needed to develop new techniques and refine existing methods to assess treatment system performance and verify vessel compliance with California's performance standards. Scientific methods do not currently exist to assess the viability and quantity of all living bacteria and viruses in ballast water samples. The development of these techniques is necessary for the full implementation and verification of California's performance standards. Sampling methods must balance the need for statistical confidence with practical, rapid, and relatively easy techniques for shipboard inspection. Research must be conducted to determine the most effective way of achieving adequate sampling confidence that are practicable for regulators and do not unduly burden vessel operators.

As performance standards are implemented, the need for practical and rapid onboard methods to assess compliance will quickly become critical. It is anticipated that vessels with operating treatment systems will begin arriving to the state as early as next year (2011). Though the Marine Invasive Species Program is funded through a programmatic fee and does not draw from the general fund, it has been subject to the same cuts that have applied to many California agencies. The legislature should ensure that MISP funds dedicated to priority research needs are not compromised, particularly given the current budget climate.

IX. LOOKING FORWARD

Ballast water treatment remains a burgeoning industry that will undergo significant development as the IMO, proposed federal, and California's performance standards are progressively implemented and as new vessel types are built. Staff is currently engaged with numerous activities to ensure the comprehensive implementation and enforcement of California's performance standards for the discharge of ballast water:

Staff is developing draft protocols for use by the Commission's marine safety personnel to verify vessel compliance with the performance standards. Commission staff is consulting with scientists and industry experts in order to determine the volumes of ballast water that must be sampled and to select the best available methods for organism enumeration and viability assessment taking into account practicality, cost effectiveness, accuracy and precision, acceptance by the scientific community, and ability to withstand legal scrutiny. The draft compliance verification protocols describe administrative inspection procedures, including review of relevant reporting forms and ballast water logs, and methods for on-site sampling of ballast water discharges. The performance standards compliance protocols will be tested on vessels over the next several months in conjunction with regular vessel inspections conducted by the

Commission's marine safety personnel. This process will be challenging, as few vessels that operate in California waters have installed ballast water treatment systems or sampling ports for collection of treated discharge samples. Commission staff will seek out every possible sampling opportunity in order to refine the draft protocols in preparation for the arrival of the first vessels that must meet California's performance standards. These vessels will likely arrive in California waters in 2011.

To augment the administrative component of the ballast water inspections, Commission staff has developed two ballast water treatment technology reporting forms. These forms will require information on ballast water treatment system installation and use in California waters. This information will be valuable to the Commission's marine safety personnel as they inspect ballast water treatment systems onboard vessels. The data will also be used by Commission staff to evaluate the implementation of the performance standards in California waters. Assembly Bill 248 (Chapter 317, Statutes of 2009) provided Commission staff with the authority to develop these forms. Staff met with an advisory panel to discuss the contents of the forms before implementing the forms via the California rulemaking process. The 45-day public comment period for the rulemaking closed in March, 2010. Based on comments, staff revised the forms. The 15-day comment period on the revisions closed in July, 2010. Staff expects the final forms to be approved and adopted by the fall of 2010.

Research Needs

In addition to the aforementioned activities being conducted by Commission staff to implement California's performance standards, staff is also working with scientists and industry experts to identify and address gaps in our understanding of ballast water treatment methods and system evaluation, particularly at the shipboard level. Eight systems evaluated in this report have demonstrated the potential to meet California's performance standards, but many systems still require further development and evaluation, and many have not yet been tested on vessels. The proposed USCG ballast water treatment system approval process will involve shipboard evaluation of treatment systems, and therefore vessel owners and operators must continue to make their vessels available for the shipboard testing of experimental treatment systems. A greater understanding of how treatment systems function on vessels will be particularly important as existing vessels, those built before 2010, will be retrofitted with treatment systems beginning in 2014 to comply with California's performance standards. 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.). Funding from state, federal and international organizations will be necessary to advance this important shipboard work.

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XI. APPENDICES

APPENDIX A

Ballast Water Treatment System
Efficacy Matrix

Forty-six ballast water treatment systems were reviewed by Commission staff for compliance with the California performance standards. Twenty-seven systems had data on system efficacy available for review. Staff included data from shipboard, dockside and laboratory studies of system performance. 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. Results presented as percent reduction in organism abundance or as concentration of pigments or biological compounds associated with organism presence were noted, but these metrics were not comparable to the performance standards.

In the following tables, systems with at least one test (averaged across replicates) in compliance with the performance standard are scored as meeting California standards. Efficacy data with no tests demonstrating potential compliance with the standards are scored as not meeting California standards. Systems that presented data for a given organism size class but presented the results in metrics not comparable to the standards are classified as “Unknown.” For example, a system that presented results of system efficacy as percent reduction of zooplankton abundance could not be compared against the California standards, and thus ability of the system to comply with the standards is unknown. Open cells indicate lack of data for a given organism size class. Compliance with the bacteria standard was assessed using the concentration of culturable heterotrophic bacteria in discharged ballast water. Due to the lack of available methods to both quantify and assess the viability of all viruses, systems cannot be assessed for compliance with the viral standard at this time. The source(s) of the data for each system can be found in the Literature Cited section of the main report.

Appendix A1 Organisms > 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/cubic meter	Methods	Reference
21 Century Shipbuilding	Laboratory	2	1	Unk	Unk	0 - 10	Unk	117
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	1	0	-	-	Unk (% Reduction)	Visual Assesment	82
	Land-Based	10	8	6	Y	0 - 26	Microscope/mobility	137
	Shipboard	4	1	12	Y	0 - 3	Microscope/mobility	138
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
atg UV Technology	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	3	Y	Y	0 - 19.3	Unk	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory[1]	2	2	2	Y	0 - $3.5x10^5$	Visual, Neutral Red Stain	148
	Land-Based	15	8	-	Y	0 - 81	Visual Assess, Neutral Red	133
	Shipboard[1]	1	1	3	Y	0-5	Visual Assessment	76
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ETI	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknow n, [1] = Filter added to system since testing conducted

Appendix A1 Organisms > 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/cubic meter	Methods	Reference
Hamann AG Evonik Degussa	Laboratory	2	2	Y	Y	0	Visual Assesment	44,182
	Land-Based	19	16	Y	Y	0-0.7	Visual Asses., Neutral Red	132
	Shipboard	5	4	3	Y	0-1.1	Visual Asses., Neutral Red	132
Hamworthy Greenship	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5	Y	Y	0	Visual Assessment	167
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	2	0	-	-	Unk (% mortality)	-	51
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	1	0	Y	Y	-	Visual Assessment	70
	Land-Based	10	1	Y	Y	0 - 7.3	Visual, Neutral Red Stain	134
	Shipboard	3	3	9	Y	0	Visual, Neutral Red Stain	192
Hyundai Heavy Industries (1)	Laboratory	2	2	9	Y	0	Unk	107
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	2	2	9	Y	0	Unk	119
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	0	Unk	Y	160-180	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory	-	-	-	-	-	-	-
	Land-Based	4	3	3	Y	0 - 1.57	Visual Assessment	64,65,189
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	0	5	Y	6 - 2170	Microscope/Mobility	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown

Appendix A1 Organisms > 50 µm								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/cubic meter**	**Methods**	**Reference**
MH Systems	Laboratory	11	10	Y	Y	Unk (No Units)	Visual Assessment	41,52
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	4	0	3-5	Y	BD, $2 \times 10^5 - 1.4 \times 10^6$	Visual Assessment	58,59
	Shipboard	1	0	-	Y	8	Visual Assessment	56
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	1	Y	Y	0, Unk (% Survival)	Visual Assessment	170,171
	Shipboard	2	1	Y	Y	0 - 7	Visual Assessment	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	3	0	4	Y	$1.2 \times 10^2 - 1.2 \times 10^4$	Visual Assessment	154
	Land-Based	3	0	Y	Y	Unk (% Live)	Visual Assessment	50
	Shipboard	3	2	12	Y	0 - 150	Visual Assessment	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	14	2	3	Y	0-135	Visual Assessment	139
	Shipboard	3	1	3	Y	0 - 9720	Visual Assessment	176
OptiMarin	Laboratory	1	0	-	Y	> 0	Visual Assessment	57
	Land-Based	12	8	3	Y	0-144	Microscope/Mobility	136
	Shipboard	8	0	9	Y	1.4 - ~5500	Visual Assessment	140
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	4	3	Y	0 - 15.3	Microscope/Mobility	142
	Shipboard	3	3	Y	Y	0	Microscope/Mobility	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3	Unk	Y	0	Microscope/Mobility	3
	Shipboard	2	0	3	Y	0.6 - 1.1	Microscope/Mobility	3
RWO Marine Water Tech	Laboratory	1	1	-	-	0	Visual Assessment	85
	Land-Based	2	2	N	Y	0	"Standard Operating Proc."	30,31
	Shipboard	-	-	-	-	-	-	-
Unk = Unknown, BD = Below Detection Limits								

Appendix A1 Organisms > 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/cubic meter	Methods	Reference
Severn Trent[1]	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	3	3-4	Y	0 - ~4x10^5	Visual Assessment	49
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	0	5	Y	15-57	Microscope/Mobility	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	11	8	3	Y	0-6	Visual Assessment	62
	Shipboard	3	3	3	Y	0	Visual Assessment	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

[1] System has added a filter since testing was conducted.

Appendix A2 Organisms 10 - 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/ml	Methods	Reference
21 Century Shipbuilding	Laboratory	2	0	Unk	Unk	1	Unk	117
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	1	0	-	-	Unk (% Reduction)	Visual Assesment	82
	Land-Based	10	3	6	Y	0-92.5	Microscope/stain (CDFA_AM), MPN	137
	Shipboard	4	1	12	Y	0-1.7	Microscope/stain (CDFA_AM), MPN	138
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
atg UV Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	7	0	Y	Y	<0.1 - >240	MPN, plate counts	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory[1]	2	0	2	Y	<0.1 - >60, Unk ([Chl a])	Visual Assessment, MPN, [Chl a]	148
	Land-Based	11	9	N	Y	0.0 - 3.7	Visual, Sytox, flow cytometer, PAM fluorometer	133
	Shipboard[1]	1	1	3	Y	0-81	Visual Assessment, [Chl a]	76
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ETI	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	0	2-3	Y	1 - 1.5	Grow out (+, -), Flow cam	73,74,75
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unkown, MPN = Most Probable Number, 1 = Filter added to system since testing conducted

Appendix A2 Organisms 10 - 50 µm								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/ml**	**Methods**	**Reference**
Hamann Evonik Degussa	Laboratory	3	3	Y	Y	0 (100% Mortality)	Visual Assessment, Sytox Green	44,46,182
	Land-Based	18	17	3	Y	0 - <0.01	Flow Cytometer, Sytox stain	132
	Shipboard	5	0	3	Y	<0.1	Flow Cytometer, Sytox stain, PAM fluorometry	132
Hamworthy Greenship	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	3	Y	Y	0 - 7	Total Counts	167
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	2	Unk	Unk	Unk	Unk (% Mortality)	Unk	51
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	1	0	Y	Y	26 - 210	Visual Assessment, Coulter, MPN	70
	Land-Based	10	0	Y	Y	0.0 - 10.9	SYTOX Green, FCM, [Chl a]	134
	Shipboard	3	1	9	Y	0.002 - 0.10	Visual, [Chl a], Grow out, neutral red	192
Hyundai Heavy Industries (1)	Laboratory	2	2	9	Y	0	Unk	107
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	2	2	9	Y	0	Unk	MEPC 60/2/6
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	0	Unk	Y	1	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	0	3	Y	0.05 - 0.186	MPN, [Chl a], ^{14}C, PAM	64,65,189
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	0	5	Y	0.6-12	CDFA-AM, Chl a	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unkown, MPN = Most Probable Number

Appendix A2 Organisms 10 - 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/ml	Methods	Reference
MH Systems	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	4	Unk	3-5	Y	BD, 206.6 - 387.4, Unk	Visual Assessment (20 - 50um)	58,59
	Shipboard	1	Unk	Unk	Y	BD	Visual Assessment	56
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	0	Y	Y	Unk	[Chl a]	170,171
	Shipboard	4	Unk	Y	Y	443 - 593	Total Counts (Preserved), [Chl a], Regrowth	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	3	0	4	Y	Unk	[Chl a]	154
	Land-Based	2	0	Y	Y	22 - 190	Total Counts (Preserved)	50
	Shipboard	3	0	5	Y	0.016 - 4	[Chl a], Grow Out, Counts	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	14	5	3	Y	0-8.7	dilution, microscopy (CFDA stain), plate counts	139
	Shipboard	2	0,Unk	3	Y	0-2.8	Microscope (CFDA stain), Photosynethic rates	176
OptiMarin	Laboratory	1	0	-	Y	26 - 210	MPN, Coulter	57
	Land-Based	12	6	3	Y	0-92	Microscope/stain, MPN, agar plates	136
	Shipboard	8	2	9	Y	0 - 3.9	Serial Dilution, Counts, Grow out	140
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	8	3	Y	0-35	Serial dilution, CFDA-AM	142
	Shipboard	3	3	Y	Y	0.0007 - 0.003	Microscope/stain (CDFA), MPN	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	0	Unk	Y	0.32 - 2.7	FDA stain, Flow CAM	3
	Shipboard	2	0	3	Y	0.5 - 1.4	FDA stain, Flow CAM	2,3
RWO Marine Water Tech	Laboratory	1	1	Unk	Unk	0	Visual Assessment	85
	Land-Based	2	1	N	Y	0 - 1	"Standard Operating Proc."	30,31
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, MPN = Most Probably Number

Appendix A2 Organisms 10 - 50 µm

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/ml	Methods	Reference
Severn Trent[1]	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	2	3-4	Y	0.002 - 10, BD ([Chl a])	MPN, [Chl a]	49
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	0	5	Y	0.5-6.8	CFDA PAM, Chl a	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	11	9	3	Y	0-4	Light micro., epifluor. and fluorometer (FDA stain)	62
	Shipboard	3	3	3	Y	0	Light micro., epifluor. and fluorometer (FDA stain)	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, MPN = Most Probably Number, 1 = Filter added to system since testing conducted

Appendix A3 *E. coli*								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls used**	**# CFU/100 ml**	**Methods**	**Reference**
21 Century Shipbuilding	Laboratory	2	2	Unk	Unk	0	Unk	117
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	1	0	-	-	Unk (% Reduction)	-	82
	Land-Based	12	12	6	Y	0 - 800	Membrane filtration	137
	Shipboard	4	4*	9	Y	0*	Membrane filtration	138
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
atg UV Technology	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	1	Y	Y	<1	Unk	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10	N	Y	<0.1	NEN-EN-ISO 9308-1	133
	Shipboard[1]	1	1	3	Y	0 - ~21	Idexx Labs Colilert	76
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ETI	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	1	0	-	-	300	Idexx Labs QuantiTray MPN	22
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unkow n, MPN = Most Probable Number, 1 = Filter added to treatment system since testing conducted, * = Initial concentration at intake w as 0, unk or non-detectable

Appendix A3 *E. coli*								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls used**	**# CFU/100 ml**	**Methods**	**Reference**
Hamann Evonik Degussa	Laboratory	1	1	Y	-	0	Plate Counts	46
	Land-Based	12	12	3	Y	<0.1/ml	Membrane filtration	132
	Shipboard	4	4*	3	Y	<0.1/ml	Membrane filtration	132
Hamworthy Greenship	Laboratory	1	1	-	Y	>1000 - 3000	Plate Counts	29
	Land-Based	5	5	Y	Y	0 - 1	Unk	167
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	6	6	Y	Y	0	APHA 9222	32
	Shipboard	-	-	-	-	-	-	-
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10*	N	Y	<10	NEN EN ISO 9308-1	134
	Shipboard	3	3*	9	Y	0	Idexx Labs Colisure	192
Hyundai Heavy Industries (1)	Laboratory	2	2	9	Y	0	Unk	107
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	2	2	9	Y	0	Unk	119
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	2	Unk	Y	0	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5	5	Y	0	IDEXX kit, Membrane Filtration	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A3 ***E. coli***

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls used	# CFU/100 ml	Methods	Reference
MH Systems	Laboratory	7	0, Unk	Unk	Y	BD-420	IDEXX Colilert 18	41
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	0	3	Y	BD, Unk	Plate Counts	58
	Shipboard	-	-	-	-	-	-	-
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	0	Y	Y	10 - 160	Idexx Labs MPN Kit	170,171
	Shipboard	2	2*	Y	Y	<100	Idexx Labs MPN Kit	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	3	3*	11-12	Y	0*	IDEXX Labs MPN Kit	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	14	14*	3	Y	0-123	Membrane Filtration	139
	Shipboard	3	3*	3	Y	0*	Membrane Filtration	176
OptiMarin	Laboratory	-	-	-	-	-	-	-
	Land-Based	12	12*	3	Y	0-2	Membrane Filtration	136
	Shipboard	8	8*	9	Y	0	Membrane Filtration	140
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	13*	3	Y	<1	Plate Counts	142
	Shipboard	3	3*	Y	Y	0	Membrane Filtration	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3	Unk	Y	0	Unk	3
	Shipboard	2	2*	3	Y	0	"Standard methods"	3
RWO Marine Water Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	2	N	Y	<15 - 32	EN ISO 9303-3	30,31
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, MPN = Most Probable Number, BD = Below Detection Limits, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A3 *E. coli*

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls used	# CFU/100 ml	Methods	Reference
Severn Trent	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3	5	Y	0.10 - 0.20	Membrane Filtration	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10*	3	Y	0	Plate counts	62
	Shipboard	3	3*	3	Y	0	Plate Counts	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A4 Intestinal Enterococci

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# CFU/100 ml	Methods	Reference
21 Century Shipbuilding	Laboratory	2	2	Unk	Unk	0	Unk	117
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10	6	Y	0 - 4	Membrane filtration	137
	Shipboard	4	4*	10	Y	0	Membrane filtration	138
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
atg UV Technology	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	1	Y	Y	<1	Unk	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	11	11	N	Y	<1	NEN-EN ISO 7899-2	133
	Shipboard	-	-	-		-	-	-
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ETI	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	1	0	Unk	Unk	80	Idexx Labs QuantiTray MPN	22
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, * = Initial concentration at intake was 0, unk or non-detectable.

Appendix A4 Intestinal Enterococci

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# CFU/100 ml	Methods	Reference
Hamann Evonik Degussa	Laboratory	-	-	-	-	-	-	-
	Land-Based	12	12	3	Y	<0.1/ml	Membrane filtration	132
	Shipboard	4	4*	3	Y	<0.1/ml	Membrane filtration	132
Hamworthy Greenship	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5*	Y	Y	0	Unk	167
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10*	N	Y	<100	NEN EN ISO 7899-2	134
	Shipboard	3	3*	9	Y	0-3.4	Idexx Labs Enterolert	192
Hyundai Heavy Industries (1)	Laboratory	2	2*	9	Y	0	Unk	107
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	2	2	9	Y	0	Unk	119
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	2	Unk	Y	0	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5	5	Y	0	IDEXX kit, Membrane Filtration	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, * = Initial concentration at intake was 0, unk or non-detectable.

Appendix A4 Intestinal Enterococci								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# CFU/100 ml**	**Methods**	**Reference**
MH Systems	Laboratory	3	0	Unk	Y	90-350	IDEXX Enterolert	41
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	0	3	Y	BD, Unk	Plate counts	58
	Shipboard	-	-	-	-	-	-	-
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	0	Y	Y	36	Idexx Labs MPN Kit	170,171
	Shipboard	2	Unk	Y	Y	Unk	Idexx Labs MPN Kit	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	3	3*	11-12	Y	0*	Idexx Labs Enterolert	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	14	9*	3	Y	0-133	Membrane Filtration	139
	Shipboard	3	3*	3	Y	0*-9	Membrane Filtration	176
OptiMarin	Laboratory	-	-	-	-	-	-	-
	Land-Based	12	12*	3	Y	0	Membrane Filtration	136
	Shipboard	8	8*	9	Y	0	Membrane Filtration	140
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	13*	3	Y	0.3 - <1	Membrane Filtration	142
	Shipboard	3	3*	Y	Y	0.3 - 1	Membrane Filtration	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	2	2	3	Y	5.0 - 9.3	"Standad methods"	3
RWO Marine Water Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	2	N	Y	neg	Membrane Filtration	30,31
	Shipboard	-	-	-	-	-	-	-
Unk = Unknown, BD = Below Detection Limits, * = Initial concentration at intake was 0, unk or non-detectable								

Appendix A4 Intestinal Enterococci

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# CFU/100 ml	Methods	Reference
Severn Trent	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3	5	Y	1.00 - 2.22	IDEXX kit	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	11	11*	3	Y	0-5	Plate counts	62
	Shipboard	2	2*	3	Y	0	Plate counts	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A5 *Vibrio cholerae*								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/100 ml**	**Methods**	**Reference**
21 Century Shipbuilding	Laboratory	2	2	Unk	Unk	0	Unk	117
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	-	-	-	-	-	-	-
	Land-Based	10	10*	3	Y	<1*	Supplemented Agar Plates	137
	Shipboard	4	4*	9	Y	<1*	Supplemented Agar Plates	138
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
atg UV Technology	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	1*	Y	Y	<1	Unk	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory[1]	1	1	2	Y	0 (% cover)	Plate Counts	148
	Land-Based	-	-	-	-	-	-	-
	Shipboard[1]	1	0	3	Y	BD - ~1000	Unk	76
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ETI	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	1	0	Unk	Unk	108	Indexx Labs QuantiTray MPN	22
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, * = Initial concentration at intake was 0, unk or non-detectable, 1 = Filter added to system since testing conducted

Appendix A5 *Vibrio cholerae*

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/100 ml	Methods	Reference
Hamann Evonik Degussa	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	1*	N	N	0*	culture, molecular methods	166
	Shipboard	-	-	-	-	-	-	-
Hamworthy Greenship	Laboratory	3	2	Unk	N	0-1	TSB broth, incubation	48
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	3	3*	9	Y	0*	PCR	192
Hyundai Heavy Industries (1)	Laboratory	2	Unk	9	Y	BD	Unk	107
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	2	2*	9	Y	0	Unk	119
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	2*	Unk	Y	0	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5*	5	Y	0*	DFA	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A5 *Vibrio cholerae*

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/100 ml	Methods	Reference
MH Systems	Laboratory	1	Unk	3	N	Unk (% Reduction)	Plate Counts	52
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	0	3	Y	BD, Unk	Plate Counts	58
	Shipboard	-	-	-	-	-	-	-
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	2	2*	Y	Y	0	DFA	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	3	3*	11-12	Y	0*	Unknown	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	14	14*	3	Y	<1*	Plate counts (TCBS agar)	139
	Shipboard	3	3*	3	Y	0*	Plate counts (TCBS agar)	176
OptiMarin	Laboratory	-	-	-	-	-	-	-
	Land-Based	12	12*	3	Y	<1	Supplemented Agar Plates	136
	Shipboard	8	8*	9	Y	<1	Filtration, Plate count, PCR	140
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	13*	3	Y	<1	Membrane Filtration	142
	Shipboard	3	3*	Y	Y	0	Membrane Filtration	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3*	Unk	Y	0	Unk	3
	Shipboard	2	2*	3	Y	0	Unk	3
RWO Marine Water Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	2	N	Y	neg	APHA Std. Method	31,31
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, DFA = Direction Fluorescent Antibody, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A5 ***Vibrio cholerae***

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/100 ml	Methods	Reference
Severn Trent	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	3*	5	Y	0	DFA	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	11	11*	3	Y	0*	Plate counts (TCBS agar)	62
	Shipboard	3	3*	3	Y	0*	Plate counts (TCBS agar)	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, DFA = Direction Fluorescent Antibody, * = Initial concentration at intake was 0, unk or non-detectable

Appendix A6 Organims < 10 µm (Bacteria)								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/100 ml**	**Methods**	**Reference**
21 Century Shipbuilding	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Alfa Laval	Laboratory	1	0	-	-	Unk (% Reduction)	Visual Assesment	82
	Land-Based	8	0	6	Y	820/ml - 4x10^{8}/ml	Agar Plate Counts	137
	Shipboard	2	2	9	Y	480 - 800	Plate Counts, Difco marine agar	141
Aquaworx ATC Gmbh	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATG Willand	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
ATLAS-DANMARK	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Auramarine Ltd.	Laboratory	-	-	-	-	-	-	-
	Land-Based	1	0	Y	Y	80/ml - 1200/ml	Unk	4,165
	Shipboard	-	-	-		-	-	-
Brillyant Marine LLC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Coldharbour Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
COSCO/Tsinghua Univ.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
DESMI Ocean Guard A/S	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Ecochlor	Laboratory[1]	2	2	2	Y	0,Unk (% of control, % Plate cover)	Plate Counts, ^{3}H-leucine	148
	Land-Based	11	8	N	Y	<10 - 1700	plate, NEN-EN-ISO 6222:1999	133
	Shipboard[1]	1	1	3	Y	BD	Plate Counts, ^{3}H-leucine	76
EcologiQ	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-		-	-	-
Electrichlor	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ETI	Laboratory	1	0	3	Y	-	Plate Counts, BacLight	72
	Land-Based	3	0	2-3	Y	5x10^{7} - 1x10^{9}	Grow out (+, -), FCM/PicoGreen	73,74,75
	Shipboard	-	-	-	-	-	-	-
Ferrate Treatment Tech.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, BD = Below Detection Limits, FCM = Flow Cytometer, 1 = Filter added to system since testing conducted

Appendix A6 Organims < 10 µm (Bacteria)								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/100 ml**	**Methods**	**Reference**
Hamann Evonik Degussa	Laboratory	2	0	Y	Y	$3.8x10^{7}$ - $4.6x10^{7}$	Plate Counts, PicoGreen	182
	Land-Based	13	1	3	Y	<10/ml - 4.6 x 10^{7}	PicoGreen, Agar Plate	132
	Shipboard	4	3	3	Y	5-15/ml	heterotrophic bacteria, plate	132
Hamworthy Greenship	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	2	Y	Y	0 - 6000	Unk	167
	Shipboard	-	-	-	-	-	-	-
Hi Tech Marine	Laboratory	-	-	-	-	-	-	-
	Land-Based	6	5	Y	Y	1 - $1.9x10^{6}$	APHA 9215B, pour plate method	32
	Shipboard	-	-	-	-	-	-	-
Hitachi	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyde Marine	Laboratory	1	0	Y	Y	~5000 - 7000	Plate Counts	70
	Land-Based	10	5	Y	Y	<1000 - >100000	Plate Counts, AODC	134
	Shipboard	3	3	9	Y	1 - 148	Plate Counts	192
Hyundai Heavy Industries (1)	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Hyundai Heavy Industries (2)	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
JFE Engineering Corp	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Kwang San Co. Ltd.	Laboratory	2	2	Unk	Y	0	Unk	120
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MAHLE	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
MARENCO	Laboratory		-	-	-	-	-	-
	Land-Based	3	2	3	Y	0 - ~$5x10^{8}$	Plate Counts, Membrane Filtration	64,65,189
	Shipboard	-	-	-	-	-	-	-
Maritime Solutions Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	3	5	Y	116.88-7860	Plate Counts	79
	Shipboard	-	-	-	-	-	-	-
Mexel Industries	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Unk = Unknown, AODC = Acridine Orange Direct Counts, FCM = Flow Cytometer								

Appendix A6 Organims < 10 µm (Bacteria)								
Manufacturer	**Location**	**# Tests**	**# Tests Met Std**	**Replicates**	**Controls**	**# Organisms/100 ml**	**Methods**	**Reference**
MH Systems	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Mitsui Engineering	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	0	3	Y	BD, Unk	Plate Counts	58
	Shipboard	1	0	-	Y	BD	Plate Counts	56
NEI	Laboratory	-	-	-	-	-	-	-
	Land-Based	2	0	Y	Y	> $1x10^8$	FCM	170,171
	Shipboard	2	0	Y	Y	$7.3x10^7$ - $7.9x10^7$	FCM	172
NK-O3	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
ntorreiro	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Nutech O3 Inc.	Laboratory	3	3	4	Y	$\leq 10^1$ - 10^8	Plate Counts, Membrane Filtration	154
	Land-Based	3	3	Y	Y	$3x10^{-1}$ - $3x10^2$	Plate Counts, Membrane Filtration	50
	Shipboard	2	2	9-12	Y	0	Plate Counts, Filtration	195
OceanSaver	Laboratory	-	-	-	-	-	-	-
	Land-Based	5	5	3	Y	0 - $8.2x10^5$/ml	Plate Counts	139
	Shipboard	-	-	-	-	-	-	-
OptiMarin	Laboratory	2	0	Unk	Y	~ $5x10^3$ - ~$7x10^3$	Plate Counts	57
	Land-Based	12	2	3	Y	9-220/ml	Agar Plate Counts	136
	Shipboard	-	-	-	-	-	-	-
Panasia Co.	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Pinnacle Ozone Solutions	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Qingdau Headway Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	13	9	3	Y	30 - 19000	Plate Counts	142
	Shipboard	3	3	Y	Y	243 - 590	Plate Counts	147
Resource Ballast Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
RWO Marine Water Tech	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Unk = Unknown, FCM = Flow Cytometer, BD = Below Detection Limits								

Appendix A6 Organims < 10 µm (Bacteria)

Manufacturer	Location	# Tests	# Tests Met Std	Replicates	Controls	# Organisms/100 ml	Methods	Reference
Severn Trent[1]	Laboratory	-	-	-	-	-	-	-
	Land-Based	4	4	3-4	Y	$<1 - 10^{10}$	Plate Counts, Membrane Filtration	49
	Shipboard	-	-	-	-	-	-	-
Siemens	Laboratory	-	-	-	-	-	-	-
	Land-Based	3	0	5	Y	169100 - 1515200	Plate Counts	78
	Shipboard	-	-	-	-	-	-	-
Sunrui CFCC	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-
Techcross Inc.	Laboratory	-	-	-	-	-	-	-
	Land-Based	4	4	3	Y	0 - 500	plate counts, DAFI stain	63
	Shipboard	3	Unk	3	Y	Unk	Fluorescent microscopy (DAFI)	62
Wartsila	Laboratory	-	-	-	-	-	-	-
	Land-Based	-	-	-	-	-	-	-
	Shipboard	-	-	-	-	-	-	-

Unk = Unknown, 1 = Filter added to system since testing conducted.

APPENDIX B

California State Lands Commission
Advisory Panel Members

Ryan Albert	U.S. Environmental Protection Agency
Marian Ashe (2007 only)	California Department of Fish and Game
John Berge	Pacific Merchant Shipping Association
Dave Bolland	Association of California Water Agencies
Brad Chapman (2007,2009)	Chevron Shipping Company
Sejal Choksi	San Francisco Baykeeper
Andrew Cohen	San Francisco Estuary Institute
Tim Eichenberg (2007 only)	The Ocean Conservancy
Richard Everett	United States Coast Guard
Naomi Feger	San Francisco Bay Regional Water Quality Control Board
Andrea Fox	California Farm Bureau Federation
Dominic Gregorio	State Water Resources Control Board
Marc Holmes	The Bay Institute
Rian Hooff	Oregon Department of Environmental Quality
Bill Jennings	The DeltaKeeper
Edward Lemieux	Naval Research Laboratory
Karen McDowell	San Francisco Estuary Project
Steve Morin	Chevron Shipping Company LLC
Allen Pleus	Washington Department of Fish & Wildlife
Darrin Polhemus	State Water Resources Control Board
Kevin Reynolds	The Glosten Associates
Greg Ruiz	Smithsonian Environmental Research Center
Spencer Schilling	Herbert Engineering Corp.
Sharon Shiba	California Department of Fish and Game, OSPR
Jon Stewart	International Maritime Technology Consultants Inc.
Lisa Swanson	Matson Navigation
Mark Sytsma	Portland State University
Drew Talley (2007, 2009)	San Francisco Bay National Estuarine Research Reserve
Kim Ward (2007, 2009)	State Water Resources Control Board
Nick Welschmeyer	Moss Landing Marine Laboratory

California State Lands Commission
2010 Treatment Technology Assessment Report
Technical Advisory Panel
April 15, 2010
Meeting Notes

Attendees

Sharon Shiba, California Department of Fish and Game

Steve Morin, Chevron Shipping

Maurya Falkner, California State Lands Commission

Jackie Mackay, California State Lands Commission

Nicole Dobroski, California State Lands Commission

Lynn Takata, California State Lands Commission

Gary Gregory, California State Lands Commission

Kevin Mercier, California State Lands Commission

Cameron Baker, Herbert Engineering

Tom Burke, California State Lands Commission

Rian Hooff, Oregon Department of Environmental Quality

Lisa Swanson, Matson Navigation

Nick Welschmeyer, Moss Landing Marine Laboratories

John Berge, Pacific Merchant Shipping Association

Ryan Albert, U.S. Environmental Protection Agency

Purpose of Meeting

California Public Resources Code requires that the California State Lands Commission produce a report for the state legislature reviewing the efficacy, availability and environmental impacts of ballast water treatment systems 18 months before the implementation dates for California's performance standards for ballast water discharge. The purpose of this meeting is to review and discuss a draft report evaluating treatment systems for new build vessels with a ballast water capacity over 5000 metric tons (MT), before the implementation date on January 1, 2012.

Report Timeline

This draft report was provided to this Technical Advisory Panel (Panel) during the week of April 5th. Today's meeting will focus on discussion of major content issues for that draft. To maximize discussion time, the TAG is requested to submit editorial type comments via email by April 23, rather than discuss them at this meeting. Following this meeting, the goal will be to complete a revised draft in early May that will be provided to Commission executive staff for review. A draft final version will be posted for public comment on the Commission website two weeks before the Commission meeting (currently scheduled for June 28^{th}). Public comments may be submitted in writing before the Commission meeting or comments may be submitted in person during the public comment portion at the meeting. The final, Commission-approved report is due to the California State Legislature by July 1, 2010.

Highlights of the Draft Report

The format of this report is based on the previous 2009 assessment report that evaluated treatment systems for new build vessels with ballast water capacity less than 5000 MT. Revisions/updates for the 2010 draft include:

- New information on related State and Federal programs
- This report covers 46 systems – ranging from chemical to UV filtration systems (majority).
- **Efficacy:** The quality and quantity of testing data from treatment vendors has improved, including better 3^{rd} party testing data and more large scale land-based facility testing. Though most testing has been done to meet International Maritime Organization (IMO) standards and requirements, the data also addresses California's standards.
- Robust and widely accepted test procedures still do not exist for viral standards, so the systems were not evaluated against California's viral standard.
- Nine systems appear to have the potential to comply with California's standards, though California will not be approving systems. Commission staff reviewed the available data, and if at least one replicate met CA standards, the system was considered to have the "potential" to comply. Ultimately, it is up to vessel

owners/operators working with vendors to select systems that are appropriate for their vessels' routes and water conditions.

- Of the 9 systems, 8 are commercially available. The one that is not is the Hamann system, which was pulled from production due to potential toxicity problems. It is not clear if they will continue to pursue the system.
- **Availability:** The ability of systems to handle large ballast water capacities was considered a potentially new issue with the current class of vessels, and was investigated by staff. However, since most systems treat on uptake and/or discharge, the ballast water uptake/discharge rates of ballast pumps were found to be a more important factor than total ballast water capacity in determining the availability of systems. Systems must be able to keep pace with ballasting rates. Data on pump rates of vessels visiting California was reviewed, and in general, most systems are designed to keep up with observed pump rates.
- **Environmental Impacts:** Current requirements are the purview of the U.S. Environmental Protection Agency's (EPA) Vessel General Permit and California additions through the Clean Water Act Section 401 Certification process. These issues are the purview of the California State Water Resources Control Board (Water Board) rather than the Commission, but staff did evaluate systems against the chlorine discharge standard, since several systems use it as an active substance. Most systems that use chlorine can comply with chlorine standard, but not all. Currently the systems that may not comply did not provide adequate or appropriate data. For example, the detection limits of the tests measuring chlorine residuals was not sensitive enough to determine compliance with EPA standards. Commission staff is encouraging vendors to consult with Water Board to make sure they meet these and other water quality requirements.
- **Economics:** Costs have not changed significantly from the 2009 report. There has been a slight drop in price for smaller capacity systems (200 cubic meters per hour), and it is likely that research and development costs will decrease as vessels begin purchasing and installing them. The average cost of larger capacity systems has not changed since the last report.

- The MISP plans on taking an adaptive management approach for implementing performance standards
- No specific recommendations to the State Legislature are included in this report.

Update on Related Marine Invasive Species Program (MISP) Activities

In 2010 the performance standards went into effect for new build vessels with a ballast water capacity less than 5000 MT. Since these are new vessels, they probably won't call to California ports until 2011. Commission staff is currently completing a rulemaking for reporting forms that will be required of vessels using treatment systems in California waters. These are expected to be approved by the Office of Administrative Law in early August. These forms will be required as systems are used and standards are implemented in California.

MISP staff provided comments on U.S. Coast Guard (USCG) proposed rule for performance standards, and are working with the EPA on Environmental Technology Verification (ETV) protocols for land-based ballast water treatment system testing. Staff are also consulting with federal, state, and international entities on the implementation of performance standards, and compliance verification.

Major Panel Comments & Discussion (Paraphrased and Edited)

Berge: Since much of the data provided by vendors is based on the IMO G8 testing protocols, how can it be used to gauge a system's potential to meet California's much more stringent standard?

- **Dobroski:** Vendors are providing data, rather than saying simply "yes" or "no" to meeting the IMO standard. Commission staff used this data to see if it also meets California's standards. While there are issues around volumes necessary to test at certain levels of statistical significance, those volumes are unwieldy and impractical. No one is providing data on that level, nor is testing occurring at that level.

Berge: The industry is concerned about this, because it isn't clear if these systems can meet California's standards if testing protocols required are ultimately different from IMO's.

- **Falkner:** In discussions with folks from land-based testing facilities, it appears that results from systems they have tested are very accurate, you are probably getting good numbers with their data. The bigger issue is how to translate shore-based testing to the efficacy of a system on a ship, and how compliance verification will be completed. Though that problem applies to IMO, the USCG, as well as California.
- **Dobroski:** The majority of systems that appear to meet CA standards are going through the robust, go-to land-based facilities/testing organizations such as NIOZ (Royal Netherlands Institute for Sea Research) or NIVA (Norwegian Institute for Water Research).
- **Welschmeyer**: The IMO G8 testing protocols are probably not appropriate to evaluate California's standards.
- **Dobroski**: Some systems have met standards in only one replicate, but some have made it for many replicates. Our goal is to demonstrate potential compliance – really it depends on the vessel type, its route, etc. to select a truly appropriate system.

Berge: Comments to the USCG proposed rule by University of Maryland scientists (Tamburri, Wright) attest that no system has been proven to meet standards better than IMO. When the industry approaches vendors, they now say they are not confident they can meet anything more stringent than IMO. This report is providing the information that systems can meet California's performance standards. There appears to be a disconnect there.

- **Falkner**: Perhaps we need to chat again with vendors and see if they still believe they can meet CA standards (they have claimed in the past that they could).

- **Dobroski**: Oceansaver has told us that they can meet California's standards. It is possible that vendors may not being totally honest, as they want governments to go ahead with implementing standards laws.
- **Falkner**: Depending on what kind of feedback we get from vendors, perhaps we need to reevaluate our report. We don't want to impose a law that no one can meet.

Berge: Is it possible to give CSLC more flexibility/control without going through the legislature which is too slow? As it stands we have to guess two years in advance on what will happen with advancing technologies. It would be better if it can be dealt with more nimbly by the Commission.

- **Gregory:** There is probably not support for that amongst the Commission. The report does need to address the current and real situation, and we'll have to decide what a recommendation from this report might say.
- **Berge:** The intention would not be to change the standard in statute, but to have more flexibility with implementation extensions. This issue has only recently come about – vendors are now realizing they must be more honest to shipping companies about the capabilities of their systems, or they eventually have no one buying their systems.
- **Baker:** There doesn't appear to be a system that can meet the standards 100% of the time. Vendors will probably say this too. They probably won't say that their system will meet a standard unless it passes tests 99% of the time. If the data from the 2009 CSLC report indicates that two systems passed one test (replicate) out of five, are we saying that this will meet CA's standard? Most people will not agree.
- **Falkner:** At this point we say such systems have the "potential". A huge problem in the past has been limited data. Since then data has gotten much better, so perhaps we should verify from vendors how confident they are that they can meet CA standards, and how often and under what circumstances they think their systems can do it.

- **Gregory:** From a legal perspective, 75% compliance isn't good enough. If I was a ship owner, I wouldn't like that either. Short of a legislative change, we (CSLC) don't have the authority to say at 75% compliance you're okay. You're either in compliance or not. From a practical perspective, if no one can comply, we may have to look into changing the standards.
- **Falkner:** From the perspective of this report, it is important to know at what level systems can comply, and what situations are better or worse.
- **Berge:** The fact is that shipping lines will install systems that meet IMO standards and show promise to meet CA standards too. I don't think looking into this issue will stop progress.

Welschmeyer: Is the topic of concern that the CSLC report is too optimistic? Is there something wrong with being too optimistic? I agree that testing to non-detect is not possible to do well at the moment, but is there something misleading or detrimental about the report's claims? Aren't we doing a disservice to the currently rapid and wonderful progress of treatment technologies if we are not optimistic?

- **Berge:** In discussions with Washington, DC folks on the debate surrounding what's achievable consistently, it has come up that you as a ship owner/operator can be held legally accountable, even if you're hearing different stories about a system's capabilities from vendors, the USCG and CSLC (and others). From a public policy perspective, if you are to be held legally liable, you need a higher level of assurance than "probably."
- **Gregory:** We should call it as straight as possible, and not be overly optimistic. If ship owners can't find a vendor that will say they can meet CA's standard, and we say they can, it's a problem.
- **Hooff:** The crux of the issue is what measuring stick is used to evaluate systems. The report started during a time when there was a lack of data available. So, the measure of at least one replicate may have been appropriate back then, but it may be that that stick needs to be revised now that more data is available. Perhaps as data gets better, the reports need to step up evaluation criteria. This report isn't being misleading, because it's using the same

measuring stick as in the past, but perhaps it's time to use a different one. Regardless, these reports provide an excellent service to managers like me and ship owners as well, with all the information included.

- **Berge:** Agrees that the information is great, but the conclusion is very optimistic, and conclusions are what policymakers/legislators focus on, not all the details.
- **Swanson:** Matson engineers are not putting systems on ships unless they have better assurances (certifications or vendor assurance). It is a big problem that California is not approving systems. If you look only at the conclusions or tables in this report (as policy makers do) there will be misunderstandings.
- **Welschmeyer:** I appreciate that honesty is needed but at same time it's heartening to see now that vendors are having a chance to meet someone's standards somewhere. There's an optimism also amongst labs testing for standards. It's going to get more difficult that California has standards that are impossible to measure with statistical certainty, but does that mean that the state and the vendors should throw up their arms and give up efforts to protect the environment at the levels that we want to? We're on our way to doing something that is environmentally wise and constructive.
- **Berge:** To be fair, though, someone will be found liable, and the only party bearing that burden is the shipping industry.
- **Berge:** Aren't systems that are meeting the IMO standards really designed to meet zero?
- **Falkner:** Yes, and in discussions with folks at NIOZ, systems are either going way beyond IMO or completely crashing and burning. There's very few that are barely meeting IMO.

Baker: Optimism is good, but I am having difficulty with the conclusion that we are there [ready to meet the CA standard]. In my opinion, we are not.

- **Falkner:** A big difficulty is that we have to put a report out 18 months in advance of an implementation date, so we have to pontificate a bit, which is hard.
- **Berge:** Could we state something in the conclusions like there are indications for compliance potential, however it's questionable that systems can meet the

standards consistently under a regulatory regime? It's one thing to say that promising systems are out there, but consistency is difficult.

- **Falkner:** But no system is going to work 100% of the time, that's not realistic. Even when a system doesn't work, the CSLC policy has always been to try to work with industry to meet the intent/letter of the law.
- **Berge:** However, there's a concern for the industry over citizen lawsuits

Swanson: How does the viral standard play out? It's not testable, but the standard remains as is. That will be a problem if we have to install systems now that may have to meet a viral system later. Again, lack of certification by California is a problem.

- **Gregory:** There are lots of things on ships that, if operated according to established rules, are accepted by regulatory entities.
- **Swanson:** It doesn't seem like this program is going that way. You're not certifying. It's up to ships to self-certify, yet we've got a standard we can't test for. It's all on the shipping industry, there's nothing that puts responsibility on the vendor.
- **Gregory:** Disagrees. It's dependent on the contract established by the vendor and ships. MSDs are like that, oily water separators are that way, etc…
- **Berge:** Perhaps it should be written into the report that a contract must be established between vendor and ship owner.
- **Shiba:** If something is not testable, then is it considered non-detectable, and so meets the standard? At the time that viruses become testable, perhaps then you change the law and allow the Commission to make a determination about grandfathering.
- **Gregory:** Recall that performance standards were meant to be technology pushing, if it can't be developed it must be go to the legislature for addressing.
- **Berge:** Those caveats should be added to the conclusion.
- **Morin:** I understand the concept of contracts like MSDs, but the issue is that those have been around for decades. If I ask for an indemnity clause from a vendor, and they say no, then what do we do?
- **Gregory:** Then there's no system that can be considered available.

- **Falkner:** This isn't the first "new technology" issue for ships. How was this done in the past?
- **Gregory:** What about air emissions? The manufacturer is certifying that the engine will meet standards if operated properly, and vessels get fined if they don't meet them. It's the same thing – engines are not certified by a regulatory agency. A ship owner would be crazy to buy a system that the manufacturer won't certify for meeting a requirement. The regulatory scheme here is the same. The indemnification issue is up to shipping companies.
- **Berge:** If we get to the point that vendors will certify and provide indemnification, we'd be comfortable.

Berge: On availability, did you look at service and repair worldwide?

- **Dobroski:** That section (included in the last report) was removed from this report. The 9 systems mentioned here claim that they will be available worldwide for service. We can put that information back in the report.

Hooff: Are the max pump rates in Figure 6.2-6.3 for all vessels? What if you just break out the only the 20% that discharge?

- **Dobroski:** Pump rates were analyzed for all vessels visiting California with a ballast water capacity over 5000 MT, but not broken down by dischargers vs. nondischargers.
- **Falkner:** About 75% of vessels operating in CA don't discharge, but vessels are not consistent on when they do or don't. They can go years without discharging, then suddenly do. That's why we used all ships.
- **Hooff:** Suggest adding that clarifying language.
- **Falkner:** Given time constraints, we might be able to look at vessel activity history, and refine the data.

Berge: Are there any vessels under 5000 MT that have installed systems?

- **Dobroski:** Not that we're aware of, but vendors have said they've gotten inquiries. But vessels that visit California are only a small percentage of all vessels out there.

Welschmeyer: The report contained all elements of the issue very nicely. Is a very complex problem – I've come to appreciate all the content included, and have found many ideas I would have never thought of on my own. It is very spot on, including the optimism. I generally feel that all vendors/developers are doing such a much better job than before.