2014 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Technologies for Use in California Waters

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EXECUTIVE SUMMARY

Nonindigenous species (NIS) pose significant risks to human health, the economy, and the environment. NIS are transported to new geographic locations outside of their native ranges through numerous human activities, including commercial shipping. Shipping is the most significant mechanism (i.e. vector) for the transport and introduction of aquatic NIS, accounting for or contributing to 79.5% of established aquatic NIS to North America (Fofonoff et al. 2003) and 74.1% across the globe (Hewitt and Campbell 2010). Commercial ships transport organisms through ballast water and vessel biofouling. It is estimated that more than 7000 species are moved around the world on a daily basis in ships' ballast water (Carlton 1999). Moreover, each ballast water discharge has the potential to release over 21.2 million individual free-floating organisms (Minton et al. 2005).

Prevention of species introductions through the management of human activities, such as commercial shipping, is considered the most protective and cost-effective way to address the NIS issue. To prevent the introduction and establishment of aquatic species via ballast water discharge, the California Legislature enacted the Coastal Ecosystems Protection Act (Act) in 2006 (Chapter 292, Statutes of 2006). Among its provisions, the Act requires the California State Lands Commission (Commission) to implement performance standards for the discharge of ballast water (California performance standards) and to regularly review the efficacy, availability, and environmental impacts of ballast water treatment technologies (Public Resources Code (PRC) section 71205.3). If technologies are not available to meet the California performance standards, the Commission must conduct an assessment of why they are unavailable. Reports are due to the California Legislature not less than 18 months prior to each implementation date for the performance standards.

The Commission previously conducted assessments of ballast water treatment technologies in 2007, 2009, 2010 and 2013 (see Dobroski et al. 2007, 2009; and Commission 2010, 2013). Commission (2013) found that no ballast water treatment technologies were available to meet the California performance standards. As a result, the California Legislature amended PRC section 71205.3 and delayed implementation of the performance standards for two years (Chapter 472, Statutes of 2013). This report serves as an update to Commission (2013) and reviews the availability of treatment technologies prior to the January 1, 2016 implementation of the California performance standards for existing vessels (ballast water capacity of 1500-5000 metric tons) and all new build vessels. However, the ballast water treatment efficacy findings stated herein may be considered broadly applicable to all vessel sizes.

This report reviews shipboard and shore-based ballast water treatment technologies. Shipboard ballast water treatment systems are installed onboard a vessel and integrated into the ballast water system. Shore-based reception and treatment facilities include barge- and/or land-based facilities that treat ballast water after it has been transferred from a vessel.

Shipboard Ballast Water Treatment Systems

The review of shipboard ballast treatment system efficacy is complicated by several factors. The California performance standards are discharge standards, and therefore it is necessary to measure the ability of shipboard treatment systems to meet the California performance standards by sampling ballast water at the point of discharge from vessels during normal operation. However, most system performance testing has been carried out at land-based facilities under conditions not wholly representative of actual vessel operations. Shipboard evaluations, which do mimic actual vessel operations, are less common. These land-based and limited shipboard tests are conducted in accordance with type approval guidelines/protocols that have been established to evaluate treatment system performance relative to the International Maritime Organization (IMO) and United States Coast Guard (USCG) ballast water standards.

The IMO and USCG standards (which are equivalent) allow a greater concentration of organisms to be discharged in ballast water than the California performance standards. Additionally, the California performance standards go above and beyond the IMO/USCG standards by limiting the discharge of total living bacteria and viruses in ballast water in order to protect public health and the environment.

Because of the differences between the IMO/USCG standards and the California performance standards, and the requirement for vessels to use treatment systems that are “type approved” to the IMO/USCG standards, there is no incentive for treatment technology developers to assess the ability of systems to meet the California standards. This, combined with a lack of data from treatment system performance on operational vessels, means it is not possible to determine if shipboard treatment systems are available to meet the California performance standards based solely on existing data. It is imperative that the Commission develop and adopt ballast water discharge sampling protocols through the rulemaking process to enable Commission staff, treatment manufacturers, and shipping companies to gather important data on the operation of shipboard ballast water treatment systems under actual operating conditions. These protocols will specifically address the California performance standards and will include the use of the best available methods of sample collection and analysis.

While it is not possible to determine if treatment systems meet the California standards based solely on IMO type approval performance data, the IMO data are the only ballast water treatment system performance data that are currently available to evaluate system efficacy. No ballast water treatment systems have yet applied for USCG type approval, and any preliminary data from this testing process have not been made public.
The IMO data indicate that available shipboard systems have efficacy (i.e. the capability to treat ballast water to levels equal to or better than the California performance standards) for select organism size classes (i.e. greater than 50 microns, *Escherichia coli*, intestinal enterococci, and *Vibrio cholerae*). For the remaining size classes in the California performance standards, systems cannot be proven to meet or are not capable of meeting the California performance standard for the 10–50 micron size class. In addition, there currently are no widely accepted methods available, and no treatment systems being tested, to assess total living bacteria or virus concentrations in ballast

water samples. Therefore, the Commission has determined that no shipboard ballast water treatment systems are available to meet the California performance standards.

Shore-Based Reception and Treatment Facilities

The review of shore-based reception and treatment technology found that there are no facilities in California or the U.S. that are capable of specifically treating NIS in ballast water. Staff analysis found that shore-based facilities are unavailable because: 1) California, the U.S. federal government and the IMO allow but do not require the discharge of ballast water to shore-based facilities; 2) collaborative efforts to implement the discharge standards among international, U.S., and state (including California) regulators and the shipping industry have focused on the use of shipboard ballast water treatment systems; and 3) treatment technology manufacturers have allocated available resources and research to the development of shipboard treatment systems.

In 2013, the Commission approved funding for a study to examine the feasibility of shore-based ballast water treatment facilities to enable vessels to meet the California performance standards. The request for proposals for this study was released by the project manager, the Delta Stewardship Council, in May 2014. This study remains in the contractor selection phase and is not expected to yield results until mid-2015. Once the report is complete, and if the results indicate feasibility, the development, construction, and commissioning of potential shore-based ballast water reception facilities in California may still take many years.

In light of the aforementioned information, it is clear that ballast water treatment technologies will not be available to enable implementation of the California performance standards for new build vessels and existing vessels with a ballast water capacity of 1500-5000 MT on January 1, 2016. Additional time is necessary for the completion of the shore-based treatment feasibility report and to enable sample collection and analysis protocol to be adopted through the rulemaking process. The sample analysis protocols will enable the necessary research to be conducted in order to fill existing data gaps and determine if ballast water treatment technologies are available to meet the California performance standards.

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ABBREVIATIONS AND TERMS

AMS	Alternate Management Systems
CFR	Code of Federal Regulations
Commission	California State Lands Commission
Commission (2013)	"2013 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters"
Convention	International Convention for the Control and Management of Ships' Ballast Water and Sediments
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
ICS	International Chamber of Shipping
IMO	International Maritime Organization
m^3/h	cubic meters per hour
MEPC	Marine Environment Protection Committee
ml	millimeter
NIS	nonindigenous species
NISA	National Invasive Species Act
NM	nautical mile
NPDES	National Pollutant Discharge Elimination System
RFP	request for proposals
U.S.	United States
USCG	United States Coast Guard
VGP	Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels
Water Board	State Water Resources Control Board
µg/l	micrograms per liter
µm	micrometer

DISCLAIMER

This report provides information regarding the availability of ballast water treatment technologies to meet the California performance standards for the discharge of ballast water (California performance standards). This report does not constitute an endorsement or approval of any treatment technology, system, system manufacturer or vendor by the California State Lands Commission (Commission) or its staff. Data regarding technologies under development or currently available on the market are presented for informational purposes. The Commission strongly recommends that any party wishing to purchase a treatment system consult with system vendors directly regarding system operational capabilities and third-party testing data. Any ballast water discharged into California waters must comply with the California Marine Invasive Species Act (Public Resources Code section 71200 et seq.) and associated regulations (Title 2 California Code of Regulations section 2270 et seq.) for preventing species introductions, as well as 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 §71205.3(b) requires the Commission to implement performance standards for the discharge of ballast water and to "prepare, or update, 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." If technologies are not available to meet the California performance standards for the discharge of ballast water (hereafter California performance standards), this report must contain an analysis of why they are unavailable.

Reports are due not less than 18 months prior to each implementation date for the performance standards. In 2013, the California Legislature, in response to the Commission report "2013 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters" (hereafter Commission (2013), Commission 2013), delayed implementation of the ballast water performance standards (see Table III-3). January 1, 2016, is the new implementation date for all newly constructed vessels (construction on or after January 1, 2016) and existing vessels with a ballast water capacity of 1500 – 5000 metric tons constructed prior to January 1, 2016. Thus the current report is due to the Legislature by July 1, 2014. However, because the central findings of this report are not affected by vessel size, the ballast water treatment efficacy information and conclusions stated here may be applied to all vessel sizes.

As the most recent technology assessment report was approved by the Commission and submitted to the California Legislature in June 2013, the current (2014) report shall serve as an update to Commission (2013). To reduce duplication, this report refers heavily to information found in Commission (2013).

II. INTRODUCTION

Nonindigenous Species

Nonindigenous species (NIS), also known as “introduced,” “invasive,” “exotic,” “alien,” or “aquatic nuisance” species, are transported outside their native ranges through numerous human activities. Aquaculture, live bait release, intentional sport fishing introductions, release of aquarium pet and live seafood specimens, transfer via recreational watercraft, association with marine debris, and accidental release from research institutions are just a few of the mechanisms, or “vectors,” by which organisms are introduced into United States (U.S.) waters (Weigel et al. 2005, Minchin et al. 2009). In coastal marine, estuarine, and fresh waters, commercial shipping is the most common vector for species introductions, accounting for or contributing to 79.5% of established NIS to North America (Fofonoff et al. 2003) and 74.1% across the globe (Hewitt and Campbell 2010). Commercial ships transport organisms through two primary mechanisms - ballast water and vessel biofouling.

Ballast water is necessary for many functions related to the trim, stability, maneuverability, and propulsion of large seagoing vessels (National Research Council 1996). Vessels may take on, discharge, or redistribute water during cargo loading and unloading, as they encounter rough seas, or as they transit through shallow coastal waterways. Typically, a vessel takes on ballast water as cargo is unloaded in one port to compensate for the weight imbalance, and will later discharge ballast water when cargo is loaded in another port. While taking on ballast water, organisms are inadvertently drawn into and held within a vessel’s ballast tanks. 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). Moreover, each ballast water discharge has the potential to release over 21.2 million individual live, free-floating organisms (Minton et al. 2005).

Once established, NIS can have severe ecological, economic, and human health impacts in the receiving environment. In San Francisco Bay, the overbite clam (*Corbula* *amurensis*) spread throughout the region's waterways within two years of being detected in 1986. The clam can account for up to 95% of the living biomass in some shallow portions of the bay floor (Nichols et al. 1990). By reducing the planktonic food base of the ecosystem, the clam is believed to be a major contributor to the decline of several pelagic fish species in the Sacramento-San Joaquin River Delta, including the threatened delta smelt (Feyrer et al. 2003, Sommer et al. 2007, Mac Nally et al. 2010). Worldwide, 42% of threatened or endangered species in 2005 were listed in part because of negative interactions with NIS (e.g. competition) (Pimentel et al. 2005).

One of the most infamous examples of an NIS causing severe impacts is the zebra mussel (*Dreissena polymorpha*). In the mid-1980s, the zebra mussel was introduced into the Great Lakes from the Black Sea via commercial ships. Zebra mussels attach to hard surfaces in dense populations (as many as 700,000 per square meter) that clog municipal water systems and electric generating plants, resulting in maintenance and repair costs of approximately one billion dollars per year (Pimentel et al. 2005). In such high densities, zebra mussels filter vast amounts of tiny floating plants and animals (plankton) from the water. Planktonic organisms are the foundation of aquatic food webs, and disruptions to this base occur throughout the invaded ecosystem. By dramatically reducing plankton concentrations and crowding out other species, zebra mussels have altered ecological communities, causing localized extinction of native species (Martel et al. 2001) and declines in recreationally valuable fish species (Cohen and Weinstein 1998). Zebra mussels have invaded San Justo Reservoir in San Benito County (CDFG 2012), and the closely related quagga mussels (*Dreissena bugensis*) have invaded multiple locations in southern California (USGS 2011). Over $21 million has already been spent or has been budgeted for the California Department of Fish and Wildlife and California State Parks to control zebra and quagga mussels in California since the species were first found in 2007 (M. Volkoff, pers. comm. 2014). These costs represent only a fraction of the cumulative expenses related to NIS control over time, because control and management of NIS are unending.

In addition to impacting the economy and the environment, NIS may pose a risk to human health. Vessels and port areas have been connected to the spread of epidemic human cholera in a number of instances (Ruiz et al. 2000b, Takahashi et al. 2008), including the transport of the toxigenic *Vibrio cholerae* serotype O1 from Latin America to Mobile Bay, Alabama in 1991. This introduction led to the closure of nearly all Mobile Bay oyster beds during the summer and fall of 1991, resulting in losses and damages estimated at $700,000 (Lovell and Drake 2009). Other microbes have been found in ships' ballast water, including the microorganisms that cause paralytic shellfish poisoning (Hallegraeff 1998), coral pathogens (Aguirre-Macedo et al. 2008), human intestinal parasites (*Giardia lamblia, Cryptosporidium parvum, Enterocytozoon bieneusi)* and the microbial indicators for fecal contamination (Escherichia coli and intestinal enterococci) (Reid et al. 2007).

Management of NIS

NIS management includes prevention, early detection, and rapid response for initial introductions, and eradication and control of established populations. Attempts to eradicate NIS after they have become established are often unsuccessful and costly (Carlton 2001). Between 2000 and 2006, $7.7 million was spent to eradicate the Mediterranean green seaweed (*Caulerpa taxifolia),* which is believed to have been introduced via the aquarium trade, from two small embayments in southern California (Woodfield 2006). This is one of the few known successful eradication efforts, likely because of early detection and a well-funded, coordinated, and rapid response. Control and management of existing populations are likewise expensive and labor-intensive. Since 2000, approximately $27.5 million has been spent in San Francisco Bay to control the Atlantic cordgrass (*Spartina alterniflora*) and monitor impacts on native species (P. Olofson, pers. comm. 2014). Prevention of species introductions through vector management is therefore considered the most protective and cost-effective way to address the NIS issue.

The majority of commercial vessels that discharge ballast water use open-ocean ballast water exchange as their primary method of NIS management. Ballast water exchange is the process of exchanging coastal water held within a vessel's ballast tanks with water from the open-ocean. Ballast water exchange has been the best compromise to decrease the risk of NIS movement and promote environmental safety while maintaining economic practicality. Most vessels are capable of conducting exchange, and this management practice rarely requires any special structural modification. During exchange, the biologically rich water that is taken on while a vessel is in port, or near the coast, is exchanged with the comparatively species-poor waters of the open ocean. Coastal organisms adapted to the conditions of bays, estuaries, and shallow coasts are not expected to survive and reproduce in the open ocean due to differences in the suitability of the habitats. Likewise, open ocean organisms are not expected to survive and reproduce in coastal waters (Cohen 1998).

Ballast water exchange has several limitations. Exchange typically eliminates between 70% and 99% of the organisms originally pumped into a ballast tank while the vessel is in, or near, port (Cohen 1998, Parsons 1998, Zhang and Dickman 1999, USCG 2001, Wonham et al. 2001, MacIsaac et al. 2002, Cordell et al. 2009). A proper ballast water exchange can take many hours to complete. In some circumstances, the exchange may not be possible without compromising vessel safety due to adverse sea conditions or antiquated vessel design. Furthermore, some vessels are regularly routed on short voyages, or voyages that remain within 50 nautical miles (NM) of shore. In these cases, the exchange process would cause the vessel to deviate from the most direct route, delay arrival, and burn additional fuel in order to comply with ballast water management requirements. Because of these limitations, ballast water exchange is considered an interim management tool. State, the U.S. Federal Government, and international authorities are working towards the implementation of performance standards for the discharge of ballast water to more effectively prevent the movement and introduction of NIS.

III. REGULATORY UPDATE

The various state, federal, and international authorities regarding ballast water management and the adoption of performance standards for the discharge of ballast water are discussed in detail in Commission (2013). Much of the regulatory regime discussed in Commission (2013) remains in place as of this current report. However, discussion and disagreements among and between stakeholders and regulatory agencies about the implementation of the International Maritime Organization (IMO) Ballast Water Management Convention and the U.S. federal discharge standards have come to the forefront in the intervening period. The following section outlines key updates or advances since Commission (2013).

International Maritime Organization

In 2004, the IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) (see IMO 2005). The Convention includes performance standards for the discharge of ballast water (described in Regulation D-2 of the Convention) with an associated implementation schedule based on vessel ballast water capacity and date of construction (see Tables III-1 and III-2).

The Convention, as adopted, will enter into force 12 months after ratification by 30 countries representing 35 percent of the world's commercial shipping tonnage (IMO 2005). As of June 25, 2014, 40 countries representing 30.25% of global commercial tonnage have ratified the Convention (IMO 2014). As of June 2014, The United States has yet to ratify the Convention. The Convention cannot be enforced upon any ship until it is ratified and enters into force (IMO 2007).

Due to ongoing concerns from the shipping industry about the implementation of the Convention, the IMO Marine Environment Protection Committee (MEPC), during its 65th meeting (May 2013), discussed a sub-committee proposal (see BLG 17/18 (Annex 6)) and agreed in principal with the establishment of a 2-3 year trial period after the Convention enters into force. During this trial period, methods of assessing discharge compliance with the D-2 standard (see Table III-1) would be tested and reviewed to ensure they are fit for purpose. Furthermore, nations would "refrain from applying criminal sanction or detaining the ship, based on [biological] sampling" (BLG 17/18 Annex 6). However, little information was provided as to how such a trial would be carried out. The U.S. delegation, represented by the United States Coast Guard (USCG), reserved its position (i.e. respectfully disagreed) on the principle of refraining from applying criminal sanctions on the basis of sampling, stating that the U.S. would not give up enforcement discretion.

Table III-1. Ballast Water Discharge Performance Standards

Organism Size Class	IMO Convention Regulation D-2[1]/U.S. Federal (USCG, EPA)	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 implementation dates for U.S. Federal (United States Coast Guard (USCG), U.S. Environmental Protection Agency (EPA)) and IMO ballast water discharge standards. See Table III-3 for implementation dates for California 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 IMO and U.S. Federal (USCG/EPA) Ballast Water Discharge 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]
	IMO	USCG/ EPA	
< 1500 metric tons	2009[2]	Dec. 1, 2013[3]	2016
1500 – 5000 metric tons	2009[2]	Dec. 1, 2013[3]	2014
> 5000 metric tons	2012[2]	Dec. 1, 2013[3]	2016

[1] The IMO Convention will apply 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). According to 33 Code of Federal Regulations (CFR) Part 151, Subpart D and EPA 2013 Vessel General Permit, existing vessels must meet the standards as of the first scheduled dry docking after January 1, 2014 or 2016, depending on the vessel's ballast water capacity.
[2] IMO recommends that member states delay enforcement of the Regulation D-2 standards until a vessel's first renewal survey following entry into force of the Convention (IMO 2013).
[3] USCG/EPA standards will be implemented upon delivery for new build vessels.

The implementation of the Convention was further addressed at the 28th General Assembly of the IMO in December 2013 where Resolution A.1088(28) was approved. Citing a desire to provide certainty to vessels regarding the timeline of enforcement of the Convention, the Resolution recommends that Member States delay enforcement of the Regulation D-2 standards until a vessel's first renewal survey after the Convention enters into force. Essentially, this would delay enforcement of the Regulation D-2 standards until after a vessel's subsequent dry docking after the Convention enters into force. This Resolution is only a recommendation, and not a mandatory agreement. Amendments cannot be made to the Convention until it enters into force.

At the 66th meeting of the MEPC in April 2014, shipping industry concerns were highlighted in a submission by the International Chamber of Shipping (ICS) and other shipowner organizations (MEPC 2014a). The ICS submission expressed a lack of confidence that ballast water treatment systems approved according to the IMO Guidelines for Approval of Ballast Water Management Systems (known as the G8

Guidelines) would consistently meet the Convention's Regulation D-2 standards. ICS argued for amendments to the G8 Guidelines to provide more "transparent, robust and fit-for-purpose testing of ballast water management systems that will give confidence to all stakeholders that type-approved systems have the ability to continue to operate effectively and consistently under all normally encountered operating conditions." The MEPC decided that the G8 Guidelines should not be amended until the Convention enters into force and that some shipowners' concerns had already been addressed by Resolution A.1088(28)). However, the MEPC recommended that a study on the implementation of the Regulation D-2 performance standards be conducted, including a look at treatment system performance, to provide facts as to how the G8 Guidelines could be improved and/or amended in the future (MEPC 2014b). A draft study plan will be brought to MEPC 67 (scheduled for October 2014) for discussion.

Of final note is a document submitted by India (MEPC 2013a) regarding the use of port-based mobile ballast water treatment facilities. The document discusses cost effectiveness, environmental acceptability, economics, and biological efficacy of proposed port-based facilities for ships engaged in regional and coastal voyages. This submission is one of several over the past few years (see also MEPC 2013a, 2013b) suggesting an increase in interest in the use of port based reception facilities to meet the IMO's D-2 performance standards.

U.S. Federal Regulation of Ballast Water

In the U.S, at the federal level ballast water discharges are under the jurisdiction of both the USCG and the United States Environmental Protection Agency (EPA). Prior to February 6, 2009, ballast water was regulated solely by the USCG through rules developed under the 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. The EPA began regulating ballast water discharges in 2009 after a court decision required ballast water and other discharges incidental to the normal operation of vessels to be regulated under the Clean Water Act (CWA) (See Northwest Envtl. Advocates v. United States EPA, (N.D. Cal. Sept. 18, 2006, No. C 03-05760 SI)(2006

U.S. Dist. LEXIS 69476)). The USCG and EPA regulations and permits do not relieve vessel owners and operators of the responsibility of complying with applicable state laws and regulations.

USCG

The USCG regulates ballast water under title 33 of the Code of Federal Regulations (CFR) part 151. Per 33 CFR §151.2025, vessels that operate in the waters of the U.S. must use one of the following methods of ballast water management: 1) install and operate a USCG-approved ballast water management system; 2) use only water from a U.S. public water system as ballast; 3) perform ballast water exchange 200 NM from shore until a vessel is required to use an approved ballast water management system (Note: Alternate Management Systems (AMS) i.e. foreign, type-approved ballast water management systems accepted for use by the USCG may be used in place of exchange if installed prior to the date that a vessel must comply with the ballast water discharge standards); 4) retain all ballast water onboard the vessel; or 5) discharge ballast to an onshore facility or another vessel for treatment. The USCG does not approve onshore facilities. Onshore facilities are regulated by the EPA under the CWA and are subject to the National Pollutant Discharge Elimination System (NPDES).

The USCG regulations, as they pertain to ballast water discharge standards, provide exemptions for vessels that operate exclusively within the Great Lakes, exclusively within one Captain of the Port Zone, and for vessels less than 1600 gross registered tons in size that operate solely within the U.S. Exclusive Economic Zone.

The ballast water management methods described in 33 CFR §151.2025 must be implemented in accordance with the schedule found in 33 CFR §151.2035. Any vessels employing a USCG-approved ballast water management system must comply with the USCG ballast water discharge standards (see Table III-1). The USCG standards will be implemented for newly built vessels (i.e. vessels constructed on or after December 1, 2013) upon delivery. Existing vessels (i.e. vessels constructed before December 1, 2013) must comply with the discharge standards as of the first scheduled dry docking after January 1, 2014, or 2016, depending on the vessel's ballast water capacity.

USCG regulations (33 CFR §162.060) establish procedures to approve shipboard ballast water treatment systems for the purpose of complying with the ballast water discharge standards. The USCG approval process includes requirements for land-based and shipboard evaluations of shipboard ballast water treatment system performance. Land-based testing must be conducted in accordance with the EPA's Environmental Technology Verification Program "Generic Protocol for the Verification of Ballast Water Treatment Technology" (see EPA 2010). As of June 2014, the USCG has not received any complete applications for approval of shipboard ballast water treatment systems. Therefore there are no USCG-approved ballast water treatment systems currently available for vessel use in U.S. waters.

The USCG anticipated that it may take several years to approve treatment systems, so, as an interim measure, the USCG ballast water management regulations (33 CFR §151.2025) include a provision for vessels to use ballast water treatment systems that have been type-approved under a foreign flag administration and allowed by the USCG. These AMS may be used by a vessel for no more than five years from the date the vessel would otherwise be required to comply with the ballast water discharge standards in accordance with the USCG implementation schedule. AMS acceptance is not "USCG approval" of a ballast water management system, but rather a bridging strategy that temporarily accepts the use of previously-installed foreign type-approved ballast water treatment systems in U.S. waters. The USCG published an initial list of accepted AMS on April 16, 2013. The list is being updated on the USCG Homeport website (http://homeport.uscg.mil) as additional AMS are reviewed and accepted.

If, despite all best efforts, vessel owners are not able to comply with USCG ballast water management regulations, a vessel owner may request an extension of the implementation date for compliance with the discharge standards. Vessels with an approved extension must continue to comply with all other ballast water management requirements. As of June 25, 2014, the USCG has granted extensions to 144 vessels (see USCG Homeport for copies of all extension letters). The letters extend the date for compliance with the discharge standards to January 1, 2016.

EPA

The EPA regulates ballast water and other discharges incidental to the normal operation of vessels under the CWA through the NPDES (see Commission (2013) for more details). Under the NPDES, the 2013 Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP) was implemented on December 19, 2013, and expires December 18, 2018. The 2013 VGP requirements for the management of ballast water by vessels operating in U.S. waters are similar, although not identical, to USCG ballast water management regulations. The 2013 VGP requires vessels to comply with ballast water discharge standards in accordance with the implementation schedule set forth in the permit. Vessels must use one of the following ballast water management measures: 1) use a ballast water treatment system; 2) discharge ballast to an onshore treatment facility; 3) obtain water from a U.S. public water system or Canadian drinking water system for ballast; or 4) retain all ballast water onboard the vessel.

The ballast water discharge limits in the 2013 VGP are the same as the discharge standards established by USCG regulations (see Table III-1). The implementation schedule is similar to that established by the USCG regulations (see Table III-2). According to the 2013 VGP, vessels constructed after December 1, 2013 must meet the standards upon their delivery (and implementation of the permit - which took place on December 19, 2013). Existing vessels constructed before December 1, 2013, must meet the standards as of the first scheduled dry dock after January 1, 2014, or 2016, depending on the vessel's ballast water capacity. The EPA does not offer extensions of the implementation schedule.

The EPA does not approve ballast water treatment systems for use to comply with the 2013 VGP. Vessels must use systems that have been "shown to be effective by testing conducted by an independent third party laboratory, test facility or test organization" (VGP

2013). A USCG type-approved ballast water treatment system or AMS is deemed to meet the “shown to be effective” criterion. Vessel owners, operators, or crew must monitor their ballast water discharges for system functionality, equipment calibration, organism concentrations (*E. coli*, intestinal enterococci, and heterotrophic bacteria), and residual biocides and derivatives (as appropriate). These results must be reported to the EPA in annual monitoring reports.

The 2013 VGP exempts the following vessel types from the ballast water management measures: those vessels operating exclusively on the Great Lakes built before 2009; unmanned, unpowered barges; vessels engaged in short distance voyages (operating within one USCG Captain of the Port Zone or traveling less than 10 NM and crossing no barriers or obstructions); and inland and seagoing vessels less than 1600 gross registered tons. In addition, vessels enrolled in and meeting the requirements of the US Coast Guard’s Shipboard Technology Evaluation Program (STEP) are deemed to be compliant with the permit requirements for ballast water treatment.

Dual Federal Agency Regulation of Ballast Water

The existing dual federal agency regulation of ballast water under the National Invasive Species Act (NISA, as implemented by USCG) and the CWA (as implemented by the EPA) places vessels in a difficult situation. The USCG allows vessels to request an extension for compliance with the USCG discharge standards if treatment technologies are not available, while the EPA offers no such extension for compliance under the 2013 VGP. To address this situation, the EPA issued a memo on December 27, 2013, establishing an Enforcement Response Policy that, while not releasing vessels from responsibility under the CWA, establishes conditions under which the EPA will consider violations of the ballast water discharge standards in the 2013 VGP to be a “low enforcement priority.” However, while the EPA may not actively pursue enforcement of vessels for violation of the ballast water discharge standards in the 2013 VGP, under the CWA citizens may pursue legal action against CWA violators.

Recently, several articles have been written in trade journals discussing the confusing federal situation (see Mondaq 2014, K&L Gates 2014). The U.S. House Committee on Transportation and Infrastructure, Subcommittee on Coast Guard and Maritime Transportation convened a hearing on March 4, 2014, to address the conflicting EPA/USCG implementation of ballast water standards, among other topics. During the hearing, EPA and USCG representatives reiterated that each agency approaches the regulation of ballast water through the authority of differing federal statutes (the CWA and the National Invasive Species Act, respectively), and while the agencies continue to work together to ease the situation for the regulated industry, the requirements of those governing statutes do place restrictions on the actions of each agency.

Soon after the March 4, 2014 hearing, Senators Mark Begich (Alaska) and Marco Rubio (Florida), joined by 20 co-sponsors, introduced S. 2094, the Vessel Incidental Discharge Act. This bill would establish uniform national standards for the discharge of ballast water and other discharges incidental to the normal operation of a vessel. It would remove ballast water and vessel incidental discharges from regulatory authority under the CWA and place them solely under the jurisdiction of the USCG. Additionally, the bill would preempt state regulation of these discharges, including ballast water. States would only be permitted to enforce laws implementing state ballast water discharge standards more stringent than the federal standards if the state laws are in place at the time the federal bill is passed and if the Secretary of Homeland Security approves a state’s petition to retain those more stringent standards.

Potential Impacts of Federal Actions in California

Neither the NISA nor the CWA preempts states from implementing programs to manage the discharge of nonindigenous species from ballast water. Based on existing legislation, the California Marine Invasive Species Program faces no federal legal obstacle to continuing implementation of the ballast water management program and the California performance standards.

The lack of available USCG approved ballast water treatment systems, however, has become one of several major stumbling blocks to the implementation of the California performance standards. Until the USCG approves systems, many vessel owners are hesitant to install treatment systems on their vessels. The installation of treatment systems would be costly, and there is no guarantee that the system will ultimately be approved by the USCG for use in U.S. waters. While the California performance standards do not require vessels to utilize USCG approved systems for compliance, those same vessels must comply with USCG requirements.

The proposed Vessel Incidental Discharge Act (S. 2094) is perhaps more alarming because, if passed, it would strip authority from the Commission to regulate ballast water discharge, and potentially affect biofouling management, for vessels operating in California waters. While the Commission could request that California Governor Edmund G. Brown, Jr., petition the USCG for approval to maintain California's program should S. 2094 become law, there are no guarantees that the petition would be approved. Commission staff will continue to follow this bill closely.

U.S. States (Other than California)

Since Commission (2013), there have been very few changes to state programs within the U.S. specific to the implementation of performance standards for the discharge of ballast water.

In Minnesota, the State Disposal System Ballast Water Discharge General Permit covering Lake Superior and associated waterways was revised and reissued in October 2013. The revisions largely mirror the terms and conditions of EPA's 2013 VGP. Additionally, the permit requires vessels that are not subject to numeric discharge standards in the 2013 VGP (i.e. Great Lakes-only vessels) to meet numeric discharge standards by their first dry docking after March 30, 2018, or demonstrate that ballast treatment technology is not available (MPCA 2013). The state permit may be found at http://www.pca.state.mn.us/index.php/view-document.html?gid=20124.

All other state programs remain the same as discussed in Commission (2013).

California

The California Coastal Ecosystems Protection Act of 2006 established performance standards for the discharge of ballast water and an associated implementation schedule (see Tables III-1 and III-3). Vessels can comply with the California performance standards through: retention of all ballast onboard the vessel (the most protective management strategy available); discharge of ballast to an approved reception facility; use of an alternative, environmentally sound method of ballast water management approved by the Commission (such as water from a U.S. public water supply); or use of a shipboard ballast water treatment system.

The Commission is required to review the efficacy, availability, and environmental impacts of available ballast water treatment technologies. If technology is not available to meet the California performance standards, then the Commission must conduct an assessment of why the technology is not available. Reports were completed in 2007, 2009, 2010, and 2013 (see Dobroski et al. 2007, Dobroski et al. 2009, Commission 2010, and Commission 2013). The most recent report, Commission (2013), determined that no technology is available that meets all of the California performance standards. The report recommended delaying implementation of the California performance standards until such time that technology is available to meet the standards. When approving the report in June 2013, the Commission specifically directed staff to seek a two-year delay of implementation.

In response to the Commission's recommendation, the Legislature passed Senate Bill 814 (Chapter 472, Statutes of 2013) which delayed implementation of the California performance standards for two years (see Table III-3 for revised implementation schedule). It is important to point out that the implementation dates for the California performance standards are strict implementation dates – vessels must comply as of January 1 in the year of compliance. This implementation schedule differs from USCG/EPA and IMO where vessels must comply as of the first scheduled dry docking after the date of compliance, as treatment system installation often requires visiting a dry dock to complete all necessary ship modifications. As dry docking occurs roughly every five years, there is a large discrepancy between how implementation timelines are dealt with in California and the rest of the world.

Table III-3. Implementation Schedule for California's 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 on:
<1500 metric tons	January 1, 2016	January 1, 2018
1500-5000 metric tons	January 1, 2016	January 1, 2016
>5000 metric tons	January 1, 2016	January 1, 2018

Ballast water treatment technology assessment reports must continue to be submitted to the California Legislature 18 months prior to each performance standard implementation date. Thus after this current (2014) report, the next report will be due to the Legislature by July 1, 2016.

IV. REVIEW OF BALLAST WATER TREATMENT TECHNOLOGIES

Pursuant to PRC §71205.3(b), this report is mandated to review the efficacy, availability, and environmental impacts, including the effects on water quality, of available ballast water treatment technologies. If technology to meet the California performance standards are determined (in this review) to be unavailable, the Commission must conduct an assessment of why the technology is unavailable. As per statutory requirement, this report reviews the availability of ballast water treatment technology for existing vessels and those constructed prior to January 1, 2016 (ballast water capacity of 1500–5000 metric tons) and new build vessels constructed on or after January 1, 2016. However, the ballast water treatment technology findings stated in this report may be considered broadly applicable to vessels of any ballast water capacity. The findings in this report are based on the best available information and supersede earlier reported findings regarding the efficacy and availability of treatment technologies for vessels of all ballast water capacities.

For those vessels that must discharge ballast water in California, compliance with the California performance standards requires the removal and/or killing of organisms including viruses, bacteria, plants/algae, and animals. Ballast water treatment options include the use of a shipboard ballast water treatment system and/or discharge to a shore or barge-based ballast water reception and treatment facility. The selection of a treatment is complicated by several factors including the vessel type and the water quality conditions of the ballast water source (e.g. salinity and sediment load). Ship owners should also investigate treatment system engineering, safety concerns, training needs, energy requirements, and other factors specific to their vessel. The following subsections include information summarized from Commission (2013) as well as the limited new information obtained since that report.

Shipboard Ballast Water Treatment Systems

Shipboard ballast water treatment systems are installed onboard a vessel and integrated into a vessel’s ballast water system. These systems are designed to treat ballast water in order to limit NIS that may be subsequently discharged along with ballast water. Shipboard systems are considered broadly applicable because they allow flexibility for the management of ballast water during normal operations. For example, shipboard systems allow vessels to discharge ballast water while underway as necessary to navigate shoals. Shipboard systems are also important for vessels that need to discharge in offshore lightering zones during the transfer of cargo (EPA SAB 2011).

The installation and use of a shipboard ballast water treatment system is not without significant challenges, including “[vessel] vibration, small and busy crews, limited space and weight allowances, limited power, potentially increased corrosion rates and sometimes short voyages” which would limit the type of treatment systems that could be installed due to necessary chemical degradation and holding times (EPA SAB 2011). Also, existing vessels that must be retrofitted for the installation of treatment systems face additional challenges due to the probable reworking and relocating of existing installations (piping, electrical circuitry) and equipment.

Commission (2013) contains a detailed list of shipboard ballast water treatment system manufacturers, treatment system models, and the treatment methods that they utilize. Appendix A in this report contains an update of Table VII-1 from Commission (2013). There are at least 80 systems currently under development and/or available worldwide, many of which are undergoing testing to gain type approval under the IMO G8 Guidelines and/or USCG type approval protocols. As of April, 2014, forty-two systems have received type approval in accordance with the IMO G8 Guidelines (see MEPC 2014a). No systems have yet gained USCG type approval.

Commission staff continues to gather the latest information on shipboard ballast water treatment systems. Multiple studies and publications are available that discuss shipboard ballast water treatment systems, their efficacy, and whether they are commercially available for shipboard installation (see EPA SAB 2011, ABS 2010, Albert et al. 2010, Commission 2010, Commission 2013). A dedicated industry has also been developed to create reports, websites, guides, articles, and to host conferences to inform shipping industry stakeholders about ballast water treatment options and related ballast water management regulations. See Appendix B for a select list of available resources.

Efficacy

Challenges with the Review of System Efficacy

PRC §71205.3 requires that the Commission prepare a review of the efficacy of currently available technologies for ballast water treatment systems. However, PRC §71205.3 also states that if technologies to "*meet* [emphasis added] the performance standards" are not available, the Commission must include an assessment of why they are not available. The California performance standards are ballast water discharge standards (i.e. standards for organism concentrations in ballast water at the point of discharge from a vessel). Determining if technology is available to meet the standards requires that systems be reviewed based on concentrations of organisms in ballast water discharged from a vessel (i.e. not from a land-based test facility). A challenge in evaluating the true efficacy arises because treatment systems cannot be reviewed for their availability to meet the California performance standards if they are not installed on vessels. Until the Commission states that there are ballast water treatment systems that are efficacious with regard to the California performance standards, ship owners are unlikely to install treatment systems on their vessels based solely on the California performance standards.

The USCG acceptance of foreign-type approved ballast water treatment systems (i.e. Alternative Management Systems) as being at least as effective as ballast water exchange has provided a mechanism for ship owners to install ballast water treatment systems onboard their vessels for use in U.S. waters. Under PRC §71204.3(d), the Commission has allowed these USCG AMS to be used in place of ballast water exchange in California. At least 17 vessels are currently using AMS in place of exchange in California. However, the Commission has no formal procedure to determine if these AMS meet the California performance standards, as sampling protocols to collect ballast water samples and assess organism concentrations in the discharged ballast water have not yet been adopted. These sampling protocols are in draft form, and were developed in consultation with a technical advisory group in 2011-12. The proposed protocols went through the rulemaking process in 2012, but the rulemaking was not completed due to the need for additional scientific review. Staff intends to reintroduce the proposed sampling regulations within the next year. Until these sample collection and analysis protocols are adopted and data is gathered on treatment system performance at the point of ballast water discharge from operational of vessels, staff is left with a disconnect between the mandate to review treatment system efficacy and determine if treatment systems are available to meet the California performance standards.

Nevertheless, Commission staff is mandated to review treatment system efficacy. In the context of reviewing the efficacy of shipboard ballast water treatment systems, staff define "efficacy" as "the extent to which a specific intervention, procedure, regimen, or service [i.e. ballast water treatment system] produces a beneficial result [i.e. organism concentration consistent with the California performance standards] under ideal conditions [i.e. IMO type approval testing]" (modified from www.medilexicon.com). Staff conducted its review of the efficacy of shipboard ballast treatment systems based on the best available data from IMO type approval testing (i.e. the ideal conditions). Because data are not yet available from USCG type approval testing, the best available data on shipboard ballast water treatment system performance is from type approval testing conducted in accordance with the IMO G8 Guidelines.

It is important to note, though, that the California performance standards and the IMO/USCG performance standards differ in both the maximum concentrations of organisms allowed at discharge for certain organism size classes (greater than 50 microns (µm), 10-50 µm, *E. coli* and intestinal enterococci) and in the presence or absence of other standards (i.e. California has requirements for total living bacteria and viruses while IMO and USCG do not) (see Table III-1). Because of these differences, it will never be possible to determine if shipboard treatment systems are available to meet the California performance standards based solely on IMO or USCG type approval data. The IMO and USCG data will provide valuable information about treatment system efficacy, particularly to identify treatment systems that will not be able to meet California standards, but staff will not be able to conclusively determine if a shipboard treatment system meets California standards until systems are installed on vessels and sample collection and analysis protocols are adopted.

System Efficacy Review

Commission (2013) provided the California Legislature and interested stakeholders with a review of data from shipboard ballast water treatment systems tested on land and aboard ship.. The Commission determined that no ballast water treatment systems were available to meet all of the California performance standards (see Table VII-2 in Commission (2013)). For this report, Commission staff has received new data on the performance of one ballast water treatment system (Panasia; see Appendix C for summary of available data). While it is encouraging to receive new data on treatment system performance, the new data do not change the conclusions from Commission (2013). No shipboard ballast water treatment systems meet all of the California performance standards.

The California performance standards are an “all-or-none set of standards,” in that if a vessel violates the standard for one organism class, then the California performance standards as a whole are not met. Shipboard treatment systems were evaluated in Commission (2013) for each individual organism size class standard. The review of available data indicate that treatment systems do not meet the California performance standards as a whole, but they do have efficacy, (i.e. the capability to treat ballast water to levels equal to or better than the California performance standards) for four of the seven organism size classes (see Appendix C for summary of available data). Systems have the capability to treat ballast water so that there are “no detectable living organisms” for the greater than 50 µm organism size class, based on shipboard sampling and analysis of three cubic meters of ballast water (the volume of water required under IMO and USCG type approval guidelines/protocols). Treatment systems are also able to treat ballast water to levels consistent with or better than the California standards in the *E. coli*, enterococci, and *Vibrio cholera* organism classes. These efficacy data are from testing conducted in accordance with the IMO G8 Guidelines. Systems cannot be proven to meet or are not capable of meeting the California performance standard for the 10–50 µm size class (i.e. 0.01 organisms per milliliter (ml)). In addition, there are currently, no practical methods available and no treatment systems being tested to assess total living bacteria or virus concentrations in ballast water samples (see Section V, Why Systems are Not Available, for further discussion).

For those systems that have shown efficacy for select organism size classes in the California performance standards, no system treats ballast water to the California standards one hundred percent of the time (see Appendix C). For the greater than 50 µm size class, no system produced treated ballast water with “no detectable living organisms” in all land-based tests. The type approval tests for the 10-50 µm size class also indicate that all but one system had some results that exceed the California performance standards. Therefore, while shipboard ballast water treatment systems can be considered to have efficacy for some of the California performance standards, none do so consistently.

Availability

Since the Commission’s first ballast water treatment technology assessment report (Dobroski et al. 2007), the number of shipboard treatment systems under development increased from 28 in 2007 to at least 80 in 2014. It is difficult to exactly quantify the number of systems under development worldwide because oftentimes treatment system developers and manufacturers do not release information during the research and development phase.

The large number of systems under development indicates a burgeoning industry striving to develop a wide range of technologies capable of meeting industry demand. A recent report by Frost and Sullivan (2013) estimates that there are 60,000 vessels worldwide that use ballast water during vessel operations and will most likely install ballast water treatment systems. The authors estimate that industry demand will drive $3.14 billion in ballast water treatment system sales by 2023, with a peak system installation period in 2018. Revenues from ballast water treatment system sales in 2013 topped $466.6 million (Frost and Sullivan 2013). Thus, treatment systems are available for purchase, and ship owners worldwide are proceeding with installations.

Commission (2013) discusses additional issues associated with shipboard treatment system availability including: the ability to retrofit vessels for treatment system installation; the need to accommodate various ballast water pump rates; and the support of a worldwide network of parts and service. These additional issues are important for ship owners to take into account in the selection of a ballast water treatment system, but they are secondary to the issues of availability and efficacy with respect to the California performance standards. Ultimately, staff has seen no improvement in the efficacy of shipboard treatment systems in meeting all of the California performance standards for the discharge of ballast water, and thus systems cannot be deemed available for use.

Economics

The economics of shipboard ballast water treatment system purchase, installation, and use is closely linked to the concept of availability. The use of ballast water treatment technologies to reduce the risk of NIS introductions will involve significant 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 for shipboard ballast water treatment systems are linked to vessel-specific characteristics including ballast water capacity, ballast pump rates, and available space. Additionally, retrofitting vessels already in operation (existing vessels) with shipboard ballast water treatment technologies will likely cost more than installation costs for newly built vessels, due to the likely necessity to rework and relocate existing installations (piping, electrical circuitry) and equipment. Nonetheless, the use of these treatment technologies will likely help minimize or prevent future introductions of NIS and associated economic impacts.

Many shipboard treatment system vendors are hesitant to release purchase 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. Even so, there are existing publically available resources that estimate the costs associated with purchasing shipboard treatment systems. The following are some cost estimates for the installation of shipboard treatment systems: 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). 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).

While the economic investment by the shipping industry in ballast water treatment technologies will be significant, the costs to treat ballast water may be negligible when compared to the total costs to control and/or eradicate NIS. Managing ballast water with treatment technologies will reduce the risk of new introductions, and thus reduce associated future costs for control and eradication. Control efforts are multi-year (typically unending) and have cost hundreds of millions of dollars in California alone (Carlton 2001, Pimentel et al. 2005, Woodfield 2006).

Environmental Impacts Assessment

An effective shipboard ballast water treatment system must comply with the performance standards for the discharge of living organisms in ballast water and all applicable environmental safety and water quality laws, regulations, and permits. The discharge of treated ballast water should not impair water quality such that it impacts the beneficial uses (e.g. fishing and recreation) of the State's receiving waters. The IMO, U.S. Federal Government, and state governments 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.

All vessels that discharge ballast water in the U.S. must comply with effluent limits set forth in the EPA 2013 VGP. In California, vessels must also comply with specific conditions added to the 2013 VGP by the State Water Resources Control Board (Water Board) through the Clean Water Act 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 CWA 401 certification (see EPA 2013). Of note to vessels discharging ballast water treated by chlorine or an electrolytic process, the total residual chlorine in the discharge shall not exceed 60 micrograms per liter (µg/l) in California ocean waters or 20 µg/l in freshwater or in enclosed bays such as San Francisco Bay. Vendors and vessel owners/operators should consult with the Water Board and EPA to ensure that vessel discharges comply with all other applicable effluent requirements included in the 2013 VGP. More information is available at http://www.waterboards.ca.gov/water_issues/programs/beaches/vssl_prmt.shtml).

Detailed information about IMO, U.S. federal, and state environmental regulation of vessel discharges can be found in Commission (2013). Commission staff has drawn on environmental reports from all levels of government in the assessment of potential environmental impacts, including effects on water quality, from ballast water treatment system use. As discussed in Commission (2013), the IMO has established an approval process through the G9 Guidelines for treatment technologies using active substances (i.e. chemicals) to ensure that systems are safe for the environment, ship, and personnel. Appendix A includes a list of all treatment systems reviewed by Commission staff for this report and the status of active substance approvals (either Basic or Final, as specified by the G9 Guidelines) as of the 66th MEPC meeting in April 2014. MEPC documents have been particularly useful in providing detailed information about active substance and residual chemical concentrations in treated ballast water. The public may access MEPC documents online at http://webaccounts.imo.org.

Commission (2013) presented data on ballast water treatment system effluent water quality and toxicity, including specific data relative to California's limits for total residual chlorine, for 34 treatment systems that utilize or generate active substances. Based on the data presented in Commission (2013), many of the shipboard treatment systems demonstrated that total residual chlorine (sometimes measured as total residual oxidants (TRO)) was neutralized in most systems by an adaptable and automated neutralization step. An assessment of all of the potential impacts from all possible chemicals and residuals associated with the use of these treatment technologies is beyond the scope of this report and is the purview of the California Water Board and the EPA.

The marine coatings industry has expressed concern over systems that utilize chlorine or chlorine compounds with regard to the impact of high chlorine concentrations on ballast tank protective coatings that are applied to prevent ballast tank corrosion. Further research is needed to accurately determine the maximum levels of chlorine and chlorine compounds that such coatings can withstand. Vessels that have already installed chlorine-based or chlorine-generated systems should be approached for initial qualitative information on treatment system effects on ballast tank corrosion-prevention coatings.

Contingency Planning

As performance standards for the discharge of ballast water are implemented worldwide, vessel owners and Port-State Control officials must consider options should shipboard ballast water treatment systems fail or are unable to be operated due to safety concerns. Shore-based reception and/or treatment facilities are important components of port contingency planning to prevent species introductions. If a shipboard treatment system fails, shore-based facilities could provide an important back-up location where unmanaged ballast water could be held or treated so that a vessel does not violate applicable discharge standards. Shore-based treatment facilities could even be equipped to allow vessels to exchange untreated ballast water for treated, “clean” ballast water. This would require treatment facilities to be present at ports (Tsolaki and Diamadopoulos 2010).

Additional options for contingency treatment include the use of portable chemical dosing equipment that could be used onboard a vessel in an emergency to distribute an active substance (e.g. chlorine) to the ballast tanks prior to discharge. This approach would require a neutralization step, as little time would be available for chemical residuals to degrade in the treated water before discharge occurs. The Commission has recently approved funding to the California Maritime Academy, working in conjunction with Moss Landing Marine Laboratories, The Glosten Associates, the National Park Service, and the U.S. Geological Survey, to conduct an evaluation of contingency/emergency ballast water treatment onboard the Academy’s training ship *Golden Bear*.

Shore-Based Ballast Water Reception and Treatment Facilities

Shore-based ballast water treatment includes reception and treatment facilities physically located on the shore, pier, or wharf that receive and treat ballast water from vessels through ship-to-shore connections or from barges that may move ballast water from the vessel to a shore-based treatment plant. Shore-based treatment provides an option for treatment technologies and methods, such as reverse osmosis, that are not feasible onboard vessels due to space and/or energy constraints.

Shore-based facilities offer multiple advantages for the treatment of ballast water, including: ease of regulation of a fixed discharge facility (verses mobile sources such as vessels); enhanced safety; reliability; compliance monitoring; and operation by dedicated trained personnel. Brown and Caldwell (2008) state that shore-based facilities “provide treatment flexibility, allowing additional treatment processes to be added or modified as regulations and treatment targets change.” Additional advantages of shore-based facilities may include cost and treatment efficacy (EPA SAB 2011).

However, the adoption of shore-based facilities is not without challenges. Vessels must have the appropriate piping and connections. An international standard would be preferable. The cost of these retrofits could be significant (CAPA 2000, King and Hagan 2013). Additionally, vessels must be able to discharge ballast at a rate that prevents vessel delays. To pump ballast water ashore at rates required for changes in cargo loading or discharging, additional piping and changes in pump size will likely be required. Ships may also need to discharge ballast water before reaching berth in order to navigate shallow water. Furthermore, a new extensive network of piping and associated pumps would be required to allow the movement of ballast water from vessels at berth to the treatment plants.

Availability

While ballast water discharge to reception facilities is permitted under the IMO Convention, USCG regulations, the EPA’s 2013 VGP , and state regulatory programs, including California, no shore-based treatment facilities designed to kill or remove organisms in ballast water currently exist or are in development in the U.S. Additionally, the current timetable for the implementation of performance standards may be faster than ballast water treatment facilities can be permitted, constructed, and in operation. Therefore, Commission staff cannot conduct a review of this management option at this time.

Efficacy and Environmental Impacts

Because there are no shore-based ballast water treatment facilities currently available, the efficacy and environmental impacts from this type of facility cannot be determined. Treatment efficacy data from existing water or wastewater treatment facilities may not be appropriate for comparison to the potential efficacy of shore-based ballast water treatment facilities. Ballast water contains organisms (such as plankton) not generally found in wastewater, and ballast water discharged in California is often sourced from marine or estuarine waters. Existing water and wastewater treatment facilities are generally designed to treat freshwater.

In California, the Water Board, not the Commission, regulates discharges from fixed facilities, such as water or wastewater treatment plants. Therefore shore-based facilities are not subject to the California performance standards. Vessels may comply with the standards through the act of discharging to a shore-based facility approved by the Commission. The approval process for these facilities remains to be established by regulation, but will no doubt focus on appropriate permitting of such a facility by the Water Board under CWA NPDES.

Additional information on advantages and disadvantages of shore-based treatment facilities is discussed in Commission (2013). It remains clear that more information about the feasibility of shore-based treatment as an option for vessels to comply with relevant discharge standards is necessary because, to date, only limited studies have been conducted, and no new information has emerged since Commission (2013) (see McMullin et al 2008, references in EPA SAB 2011, and King and Hagan 2013). To address the paucity of information on shore-based treatment facilities and what such facilities may represent for ballast water management in California, Commission staff has secured the services of the Delta Stewardship Council to issue a request for proposals (RFP) to conduct a study on the feasibility of such facilities in California. This study will include, but not be limited to: a literature review; an up-to-date economic and feasibility analysis of the resources needed to build and operate such facilities; an assessment of vessel retrofit needs for ships that intend to use shore-based treatment facilities; a comparative assessment of environmental impacts and effectiveness; and an assessment of the need for barge-based reception facilities for vessels that must discharge ballast in order to navigate shallow waterways. Information from this report may help direct research examining treatment options and regulatory approaches for the implementation of the California performance standards. The Delta Stewardship Council released the RFP for bid in mid-2014. A final report should be available by mid-late 2015.

V. WHY TREATMENT TECHNOLOGIES ARE NOT AVAILABLE

Commission staff has determined in its review that neither shipboard nor shore-based ballast water treatment technologies are available to meet the California performance standards (see Section IV, Assessment of Treatment Technologies). Per Public Resources Code section 71205.3, as part of this review if it is determined that existing treatment technologies are unable to meet the California performance standards, the report is to assess why such technologies are unavailable. The following section highlights some of the key reasons and challenges hindering the availability of effective treatment technologies and the treatment system efficacy review process.

Shipboard Ballast Water Treatment Systems

The assessment has found that shipboard ballast water treatment systems are available for purchase from vendors. Also, many of these systems appear capable of complying with select California water quality standards (e.g. chlorine). However, there are no systems available that have demonstrated, on a consistent basis, the ability to meet the California performance standards. More specifically, shipboard ballast water treatment systems cannot be considered available to meet the California performance standards because: 1) no ballast water treatment system has demonstrated efficacy for all of the California performance standards based on the best available data; 2) there are no suitable methods/technology to analyze ballast water samples to determine treatment system efficacy for some of the California performance standards; and 3) a lack of sampling/compliance protocols precludes the ability of the Commission to make a conclusive determination about the availability of shipboard ballast water treatment systems to meet the California performance standards.

Shipboard Ballast Water Treatment Systems Have Not Shown Efficacy with the California Performance Standards

The Commission determined that no ballast water treatment systems were available to meet all of the California performance standards (see Table VII-2 in Commission (2013)). However, the review of available data indicates that some treatment systems are capable of treating ballast water to levels equal to or better than the California performance standards for four of the seven organism size classes (see Appendix C for summary of available data), they do not meet the California performance standards as a whole.

Lack of Methods/Technology to Analyze Discharged Ballast Water Samples for Select Organism Size Classes

The review of ballast water treatment system efficacy is complicated by a lack of methods/technologies available to analyze samples to a level equal to some of the California performance standards organism concentrations. Based on available type approval testing data, staff can make determinations about whether treatment systems are capable of meeting the California performance standards organism concentrations for the greater than 50 µm size class and the human health indicator species (*E. coli*, intestinal enterococci, and *Vibrio cholera*) (see Commission 2013). However, the review of treatment system performance is constrained due to water sample analysis methods and technology that are either not sensitive enough or not available to evaluate water samples to a level equivalent to the numeric concentrations of the California performance standards. This is the case for the 10-50 µm size class, total living bacteria, and total living viruses.

Organisms 10 – 50 Microns in Minimum Dimension

The California ballast water performance standard for organisms 10-50 µm in minimum dimension is less than 0.01 living organisms per ml of discharged ballast water (i.e. 1 organism per 100 ml of discharged ballast). It is possible to determine when a treatment system does not produce treated water that satisfies the California performance standard for this size class because any organisms detected in a one ml sample would exceed the California performance standard of 0.01 organisms per ml. All ballast water treatment systems with data available for review failed to meet the California performance standards at least once during testing (see Appendix C). However, even if no detectable living organisms in this size class are observed in the treated water from a given system, staff cannot conclusively determine that a system meets the organism concentration of the California standard due to the practical limitations of currently available technology for the detection and enumeration of organisms in the 10-50 µm class. A statistical analysis of treated ballast water needs to be conducted to provide confidence that systems can treat water to the organism concentration in the California performance standard. The volume of sampled water that is necessary to conduct this statistical analysis for the 10-50 µm class is 1000 times greater than that required for the USCG type approval process. At this time, it is impractical to process such a large sample of water under the timeframe necessary to limit sampling-induced mortality and limit human error. Until samples can practically be analyzed to the level equal to the 10-50 µm size class standard, shipboard ballast water treatment systems cannot be reviewed for efficacy with this standard.

Total Living Bacteria

The California performance standard for total living bacteria is less than 1000 living bacteria per 100 ml. This standard is difficult to assess because there are no practical, widely-accepted methods to quantify total living bacteria in a ballast water sample. There are stains available that can be used to enumerate live and dead bacteria in ballast water samples, however these stains can leak from bacterial cells or attach to charged sediment/clay particles, thereby confounding results. Because of these concerns, the only available, practical, and reliable means of knowing that a bacterium is alive is to conduct grow-out (culture) experiments in the laboratory. Unfortunately, less than 10% of all bacteria species are capable of growing in the environmental conditions present in laboratories (i.e. the culturable heterotrophic bacteria) (Azam et al. 1983, Hobbie et al. 1977). Because samples cannot be analyzed for “total living bacteria,” treatment systems cannot be proven to be efficacious with the California performance standard.

Total Living Viruses

The California performance standard for total living viruses is less than 10,000 living viruses per 100 ml. No methods of sample analysis are available, at any scale, to assess total living virus concentrations in ballast water samples, thus no data are available to assess efficacy for this organism class. There are proxy or model viruses that can be used to investigate reductions in the concentration of viruses post water treatment. However, these existing methods do not currently enable direct counting of all viable viruses as is required by the California standard for this organism class. Because samples cannot be analyzed for “total living viruses,” treatment systems cannot be proven to be efficacious with the California performance standard.

Lack of Sampling/Compliance Protocols to Determine if Systems Meet the California Performance Standards

Ballast water treatment systems are unavailable, in part because of a lack of sample collection and analysis protocols. This causes a disconnect between the mandate to review treatment system efficacy and staff’s ability to determine if treatment systems are available to meet the California performance standards.

Shore-Based Ballast Water Treatment Technologies

Shore-based ballast water reception and treatment facilities specifically designed to receive and remove or kill NIS in ballast water are currently not available in California or the U.S. Staff analysis examined three inter-related reasons why shore-based facilities are unavailable: 1) California, the U.S. federal government (USCG and EPA), and the IMO allow, the discharge of ballast water to shore-based facilities to comply with applicable discharge standards. Vessels may elect to discharge to such facilities if they are available, but it is not required. 2) The shipping industry has the option to use shore-based facilities to comply with applicable discharge standards/regulations. However, collaborative efforts thus far among international, U.S. federal, and state (including California) regulators and the shipping industry to implement discharge standards have focused on the use of shipboard ballast water treatment systems as the preferred method to enable vessel compliance with state, federal and international discharge standards.3) Lacking a regulatory mandate and economic demand to develop shore-based facilities, treatment technology manufacturers have allocated available resources and research to the development of shipboard treatment systems.

While the IMO, USCG, EPA, California, other states, and the shipping industry have focused their attention on the use of shipboard treatment systems, the Commission recognizes that shore-based treatment may be an important tool for vessels to comply with the California performance standards. As such, in 2013 the Commission provided funding for a study that will examine the feasibility of shore-based ballast water treatment facilities for use in compliance with California's discharge requirements. The RFP for this study was released by the Delta Stewardship Council in May 2014 and is scheduled for completion in mid-late 2015.

VI. DISCUSSION

In 2013, following the recommendation of the Commission, the California Legislature passed Senate Bill 814 which delayed implementation of the California performance standards for the discharge of ballast water for two years due to a lack of available treatment technologies to meet the standards. This report has found that ballast water treatment technologies continue to be unavailable to meet the California performance standards. Existing shipboard ballast water treatment systems have not demonstrated efficacy with regard to meeting the California performance standards, and there are currently no shore-based ballast water reception facilities designed for the treatment of NIS in California or the U.S.

The Commission believes shore-based treatment should continue to be pursued as an option to enable vessel compliance with the California performance standards. To that end, the Commission is currently funding a study to evaluate the feasibility of shore-based reception and treatment facilities in California. This study remains in the contractor selection phase and is not expected to yield results until mid-2015. Once the report is complete and if the results indicate feasibility, the development, construction, and commissioning of potential shore-based ballast water reception facilities in California may still take many years.

The evaluation of shipboard ballast water treatment system biological efficacy continues to be a challenge. The adoption of the USCG type approval protocols in 2012 was forecast by many in the industry to spur a wave of treatment system testing and new technology development. This has not yet occurred. In response, USCG is currently approving requests by vessel owners for extensions of the implementation schedule for compliance with the ballast water discharge standards due to a lack of USCG approved ballast water treatment systems. More importantly, even if new data from the USCG type approval process were available, the USCG protocols were developed to determine the ability of shipboard ballast water treatment systems to meet the USCG discharge standards – not the California performance standards.

There is, and will continue to be, a disconnect between the best available data on shipboard ballast water treatment system efficacy (from IMO and USCG type approval testing) and the California performance standards. As discussed in Commission (2010), the Commission does not have the practical ability and resources to type approve ballast water treatment systems for use in California waters. Commission staff issued "Ballast Water Treatment Technology Testing Guidelines" in 2008, but have never received any data that specifically address the efficacy of shipboard treatment systems with respect to all of the California performance standards.

The development and adoption, via regulation, of ballast water discharge sampling protocols is essential to enable Commission staff, treatment manufacturers, and shipping companies to gather important data on the operation of shipboard ballast water treatment systems under real world operating conditions. The adoption of sampling protocols must be paired with action by the California Legislature to amend the implementation schedule for the California performance standards. This will provide time for sampling and analysis of treated ballast water and further assessment of system efficacy. The data gathered would augment existing type approval data and help close the gap between system efficacy, as determined by the IMO/USCG type approval process, and the ability of treatment systems to meet the California performance standards. Until such time that these additional data become available, it will be impossible for Commission staff to accurately assess system efficacy and determine if shipboard ballast water treatment technologies are available to meet the California performance standards.

In light of the aforementioned information and based on the efficacy data presented in this review, it is clear that ballast water treatment technologies will not be available by January 1, 2016. This will inhibit implementation of the California performance standards for new build vessels and existing vessels, those constructed prior to January 1, 2016, with a ballast water capacity of 1500-5000 MT. Additional time is necessary to enable adoption of sampling protocol regulations and to conduct the necessary research to fill existing data gaps.

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VIII. APPENDICES

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Alfa Laval	Sweden	PureBallast 2.0/2.0 Ex	combination	filtration + advanced oxidation technology (UV + TiO2)	IMO Basic and Final, Type Approval (Norway)
Alfa Laval	Sweden	PureBallast 3.0	combination	filtration + advanced oxidation technology (UV + TiO_2)	Not approved, undergoing testing
AQUA Eng. Co. Ltd.	Korea	AquaStar™ BWMS	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic and Final, Type Approval (Korea)
Aquaworx ATC GmbH	Germany	AquaTriComb™	combination	filtration + ultrasound + UV	IMO Basic
ATLAS-DANMARK	Denmark	ABWS	combination	filtration + electrolysis (ANOLYTE + CATHOLYTE)	
Auramarine Ltd.	Finland	CrystalBallast®	combination	filtration + UV	Type Approval (Norway)
BIO-UV	France	BIO-SEA BWTS	combination	filtration + UV	Type Approval (France)
Brillyant Marine, LLC	USA	BrillyantSea™	physical	electric pulse	
Coldharbour Marine Ltd.	United Kingdom	Coldharbour BWTS	physical	deoxygenation	

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Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
China Ocean Shipping Company (COSCO)	China	Blue Ocean Shield	combination	hydrocyclone + filtration + UV	IMO Basic, Type Approval (China)
DESMI Ocean Guard A/S	Denmark	DESMI Ocean Guard OxyClean BWMS	combination	filtration + UV + ozone	IMO Basic and Final, Type Approval (Denmark)
DESMI Ocean Guard	Denmark	RayClean	combination	Filtration + UV	
Dow Chemical Pacific Pte Ltd.	Singapore	Dow-Pinnacle BWMS	combination	filtration + ozone + neutralization (sodium thiosulfate)	
Ecochlor	USA	Ecochlor® BWTS	combination	filtration + biocide (chlorine dioxide)	IMO Basic and Final, STEP[1], Type Approval (Germany)
EcologiQ	USA/ Canada	BallaClean	biological	deoxygenation	
Electrichlor	USA	Model EL 1-3 B	chemical	electrolytic generation of sodium hypochlorite	
Environmental Technologies Inc.	USA	BWDTS	combination	ozone + sonic energy	
Envirotech and Consultancy Pte. Ltd.	Singapore	BlueSeas BWMS	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic

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Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Envirotech and Consultancy Pte. Ltd.	Singapore	BlueWorld BWMS	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic
Erma First ESK Engineering Solutions S.A.	Greece	ERMA FIRST BWTS	combination	filtration + hydrocyclone + electrolysis + neutralization (sodium bisulfite)	IMO Basic and Final, Type Approval (Greece)
Ferrate Treatment Technologies LLC	USA	Ferrator	chemical	biocide (ferrate)	
GEA Wesfalia Separator Group CmbH	Germany	BallastMaster ultraV	combination	filtration + UV	IMO Basic, Type Approval (Germany)
GEA Westfalia Separator Group GmbH	Germany	BallastMaster ecoP	combination	filtration + electrolysis + neutralization (sodium thiosulphate)	IMO Basic
Hanla IMS Co., Ltd.	Korea	EcoGuardian™	combination	filtration + electrochlorination + neutralization (sodium thiosulfate)	IMO Basic and Final
Headway Technology Co. Ltd.	China	OceanGuard™ BWMS	combination	filtration + electrolysis + ultrasound	IMO Basic and Final, Type Approval (Norway)
Hi Tech Marine	Australia	SeaSafe-3	physical	heat treatment	New South Wales EPA
Hitachi Plant Technologies, Ltd.	Japan	ClearBallast	combination	filtration +flocculation	IMO Basic and Final, Type Approval (Japan)

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Manufacturer	*Country*	*System Name*	*Technology Type*	*Technology Description*	*Approvals*
Hwaseung R&A Co. Ltd.	Korea	HS-Ballast	chemical	electrolysis + neutralization (sodium thiosulfate)	IMO Basic
HyCa Technologies Pvt Ltd.	India	HyCator® BWT Reactor System	combination	filtration + electrochlorination + neutralization (sodium thiosulfate)	
Hyde Marine Inc.	USA	Hyde GUARDIAN Gold	combination	filtration + UV	STEP[1], IMO Basic, Type Approval (UK)
Hyundai Heavy industries Co. Ltd.	Korea	EcoBallast	combination	filtration + UV	IMO Basic and Final, Type Approval (Korea)
Hyundai Heavy industries Co. Ltd.	Korea	HiBallast	combination	filtration + electrolysis + neutralization	IMO Basic and Final, Type Approval (Korea)
JFE Engineering Corp.	Japan	JFE BallastAce	combination	filtration + biocide (sodium hypochlorite) + cavitation + neutralizing agent (sodium sulfite)	IMO Basic and Final, Type Approval (Japan)
JFE Engineering Corp.	Japan	JFE Ballast Ace with NeoChlor Marine™	combination	filtration + biocide (sodium hypochlorite) + neutralization (sodium sulfite)	IMO Basic and Final
Jiujiang Precision Measuring Technology Research Institute	China	OceanDoctor BWMS	combination	filtration + UV + photo-catalytic reaction	IMO Basic and Final
Katayama Chemical Inc.	Japan	SKY-SYSTEM®	chemical	biocide (Peraclean® Ocean) + neutralization (sodium sulfite)	IMO Basic

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Knutsen Ballastvann AS	Norway	KBAL BWMS	physical	pressure vacuum reactor + UV	Type Approval (Norway)
KT Marine Co., Ltd.	Korea	KTM-BWMS	combination	cavitation + electrolysis + neutralization (sodium thiosulfate)	IMO Basic
Kuraray Co. Ltd.	Japan	MICROFADE™ BWMS (formerly Kuraray BWMS)	combination	filtration + biocide (calcium hypochlorite) +neutralizing agent (sodium sulfite)	IMO Basic and Final, Type Approval (Japan)
Kwang San Co. Ltd.	Korea	BioViolet	combination	filtration + UV	None
MAHLE Industrial Filtration	Germany	Ocean Protection System	combination	filtration + UV	IMO Basic and Final, Type Approval (Germany)
MARENCO Tech. Gr.	USA	MARENCO BWTS	combination	filtration + UV	
Maritime Solutions Inc.	USA	MSI BWTS	combination	filtration + UV	
Mexel Industries	France	Mexel®	chemical	non-oxidizing biocide	
MH Systems	USA	MH BWT System	combination	deoxygenation (inert gas + CO_2)	

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Mitsui Engineering and Shipbuilding	Japan	SPO-SYSTEM	combination	filtration + mechanical treatment + biocide (Peraclean Ocean)	IMO Basic (from Peraclean MEPC 54)
Mitsui Engineering and Shipbuilding	Japan	FineBallast MF	physical	pre-filtration + microfiltration (membrane)	
Mitsui Engineering and Shipbuilding	Japan	FineBallast® OZ (formerly SP-Hybrid BWMS Ozone)	combination	filtration + mechanical treatment + ozone + neutralization	IMO Basic and Final, Type Approval (Japan)
NEI	USA	Venturi Oxygen Stripping (VOS)	combination	deoxygenation + cavitation	Type Approval (Liberia, Malta, Marshall Islands, Panama), STEP[1]
NK CO., LTD	Korea	NK- 03 BlueBallast	chemical	ozone	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 Mark I	combination	filtration + electrolysis (optional nitrogen supersaturation)	IMO Basic and Final, Type Approval (Norway)
OptiMarin	Norway	OptiMarin Ballast System	combination	filtration + UV	Type Approval (Norway)

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
OceanSaver	Norway	OceanSaver BWMS Mark II	combination	filtration + electrolysis	IMO Basic and Final, Type Approval (Norway), AMS
Panasia Co. Ltd.	Korea	GloEn-Saver™	combination	filtration + electrochlorination + neutralization (sodium thiosulfate)	IMO Basic
REDOX Maritime Technologies AS	Norway	REDOX AS BWMS	combination	filtration + ozone + UV	IMO Basic
Resource Ballast Technologies (Pty.) Ltd.	South Africa	Resource BWTS	combination	cavitation + ozone + sodium hypochlorite	IMO Basic and Final, Type Approval (South Africa)
RWO Marine Water Technology	Germany	CleanBallast	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic and Final, Type Approval (Germany)
Samkun Century Co. Ltd.	Korea	ARA Plasma BWTS	combination	filtration + plasma + UV	IMO Basic and Final, Type Approval (Korea)
Samsung Heavy Industries Co., Ltd.	Korea	Purimar™ BWMS	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic and Final, Type Approval (Korea)
Samsung Heavy Industries Co. Ltd.	Korea	Neo-Purimar™ BWMS	combination	filtration + electrolysis + neutralization (sodium thiosulfate)	IMO Basic and Final

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Sea Knight	USA	INSITU BWMS	combination	deoxygenation + biological augmentation	
Severn Trent De Nora	USA	BALPURE® BP-500	chemical	filtration + electrochlorination + neutralizing agent (sulfur-based reduction)	IMO Basic and Final, STEP[1], Type Approval (Ger.)
Siemens	Germany	SiCure™	combination	filtration + electrochlorination	IMO Basic and Final
Shanghai Cyeco Environmental Technology Co., Ltd.	China	Cyeco™ BWMS	combination	filtration + UV	Type Approval (China)
Smart Maritime Solutions	Norway	BV Maritime Treatment System	combination	filtration + electrochlorination	
STX Metal Co. Ltd.	Korea	Smart Ballast BWMS	chemical	electrolysis + neutralization (sodium thiosulfate)	IMO Basic and Final
Sumitomo Electric Industries, Ltd.	Japan	Ecomarine™	combination	filtration + UV	
SUNBO Industries Co., Ltd.	Korea	Blue Zone™ BWMS	chemical	ozone + neutralization (thiosulfate)	IMO Basic
Sunrui Marine Environment Enginerring Co., Ltd.	China	BalClor™ BWMS	combination	filtration + electrochlorination + neutralizing agent (sodium thiosulfate)	IMO Basic and Final, Type Approval (China)

Appendix A. Shipboard Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Techcross Co. Ltd.	Korea	Electro-Cleen™ System	chemical	electrolysis + neutralizing agent (sodium thiosulfate)	IMO Basic and Final, Type Approval (Korea)
Van Oord B.V.	Netherlands	Van Oord BWMS	chemical	chlorine + neutralization (sodium bisulfite)	IMO Basic
Wärtsilä Corporation	Finland	Marinex UV BWMS	combination	filtration + UV	
Wärtsilä Hamworthy	Netherlands	AQUARIUS® EC BWMS	combination	filtration + electrolysis + neutratlization (sodium bisulfite)	IMO Basic and Final
Wärtsilä Hamworthy	Netherlands	AQUARIUS® UV	combination	filtration + UV	Type Approval (Netherlands)
Wuxi Brightsky Electronic Co. Ltd.	China	BSKY™ BWMS	combination	filtration + UV	IMO Basic and Final, Type Approval (China)

[1] STEP is a USCG 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.

Note: Based on MEPC 59/24 – Administrations may determine if shipboard ballast water treatment systems that make use of UV light produce active substances. Any system that makes use of an active substance must be reviewed according to the G9 Guidelines (see MEPC 2008e).

Appendix B.

Ballast Water Treatment Technology Resources
California Maritime Academy Golden Bear Facility
https://www.csum.edu/web/gbf/home

California State Lands Commission
http://www.slc.ca.gov/spec_pub/mfd/ballast_water/Ballast_Water_Default.html

Great Ships Initiative
http://www.greatshipsinitiative.org

International Maritime Organization
http://www.imo.org/OurWork/Environment/BallastWaterManagement/Pages/Default.aspx

Maritime Environmental Resource Center
http://www.maritime-enviro.org/

United States Coast Guard
https://homeport.uscg.mil/ballastwater

United States Environmental Protection Agency
http://cfpub.epa.gov/npdes/vessels/vgpermit.cfm

Ballast Water Management and Treatment Technology Guides
American Bureau of Shipping (ABS)
http://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/Rules&Guides/Current/187_BWT/Guide

BWTS Intelligence
http://www.ballastwater-treatment.org/

Det Norske Veritas (DNV)
http://www.dnv.com/bwm/

Germanischer Lloyd
http://www.gl-group.com/pdf/Ballast_Water_Management_flyer.pdf

Lloyd's Register
http://www.lr.org/Images/BWT0210_tcm155-175072.pdf

RWO
http://www.rwo.de/rwo/ressources/documents/1/25412,Ballast-Water-Guide-2013.pdf

Step-by-Step Guide to Ballast Water Management (BIMCO and Fathom)
http://fathom-ctech.com/guide/step-by-step-guide-to-ballast-water-management/14/

Appendix C. Shipboard treatment systems with reliable third-party collected land-based or shipboard test results from type approval or other third-party testing, for which success rates could be generated. The number of tests, averaged across replicates, demonstrated, on a limited basis, the ability to meet California's standards is presented in the numerator, and the total number of tests performed is presented in the denominator. Available test data for analysis of system efficacy were, in large part, collected under the type approval test regimens established by the IMO G8 Guidelines to determine each systems' ability to meet the IMO D-2 standard. Therefore not all data collection procedures and analysis methods are scaled appropriately for analysis with each of the California performance standards. Note for 10-50 µm size class: data that cannot be confirmed as meeting the California standards due to the limits of detection of existing sampling methods are indicated by "lim det." ***See Section IV for discussion of challenges associated with data analysis and reasoning behind presentation of the data as seen.***

Manufacturer	**>50 µm**		**10 – 50 µm**		**<10 µm (bacteria)**		***E. coli***		**Enterococci**		***Vibrio***		**Literature Cited[2]**
	Land	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	
Alfa Laval[1]	4/10	1/4	lim det (3/10)	lim det (1/4)	0/10	2/2	10*/10	4*/4	10*/10	4*/4	10*/10	4*/4	40, 42, 45
Auramarine	0/11	-	lim det (5/11)	-	0/11	-	11*/11	-	11*/11	-	11*/11	-	46
BIO-UV	0/4	-	0/4	-	1/4	-	4*/4	-	4*/4	-	4*/4	-	33
DESMI	5/11	2/3	0/11	Unk/3	11/11	-	11/11	3*/3	11/11	3*/3	11/11	3*/3	2, 3
Ecochlor	8/15	3/3	lim det (9/11)	lim det (3/3)	8/11	-	10/10	3/3	11/11	3/3	1/1(lab)	3*/3	9, 35
ERMA First	5/12	0/2	lim det (9/12)	lim det (2/2)	0/Unk[3]	-	10*/10	2*/2	10/10	2/2	-	2*/2	10, 11, 37
Hyde	1/10	3/3	lim det (4/10)	lim det (1/3)	5/10	3/3	10*/10	3*/3	10*/10	3*/3	-	3*/3	38, 55
JFE	6/11	3/6	lim det (11/11)	lim det (5/6)	3/11	4/6	11*/11	6/6	11/11	6/6	11*/11	6*/6	4, 16, 43,
MAHLE	1/11	4/4	lim det (4/11)	lim det (4/4)	11/11	4/4	11/11	4/4	11/11	4/4	-	4/4	6, 34
Marenco	3/4	-	0/1	-	2/3	-	-	-	-	-	-	-	28, 29, 54
MSI	0/5	-	0/5	-	3/5	-	5/5	-	5/5	-	5*/5	-	30
NEI	1/5	1/2	0/1	Unk	0/2	0/2	0/1	2*/2	0/1	Unk	-	2*/2	51, 52

Appendix C. Shipboard treatment systems with reliable third-party collected land-based or shipboard test results from type approval or other third-party testing, for which success rates could be generated. The number of tests, averaged across replicates, demonstrated, on a limited basis, the ability to meet California's standards is presented in the numerator, and the total number of tests performed is presented in the denominator. Available test data for analysis of system efficacy were, in large part, collected under the type approval test regimens established by the IMO G8 Guidelines to determine each systems' ability to meet the IMO D-2 standard. Therefore not all data collection procedures and analysis methods are scaled appropriately for analysis with each of the California performance standards. Note for 10-50 µm size class: data that cannot be confirmed as meeting the California standards due to the limits of detection of existing sampling methods are indicated by "lim det." ***See Section IV for discussion of challenges associated with data analysis and reasoning behind presentation of the data as seen.***

Manufacturer	>50 µm		10 – 50 µm		<10 µm (bacteria)		*E. coli*		Enterococci		*V. cholorae*		Literature Cited[2]
	Land	Ship	Land	Ship	Land	Ship	Land	Ship	Land	Ship	Land	Ship	
NK-03	5/14	1/5	lim det (9/14)	lim det (4/5)	0/14	1/1	10*/10	5*/5	10*/10	5*/5	10*/10	5*/5	17, 19
Nutech	0/3	2/3	0/2	0/3	3/3	2/2	-	3*/3	-	3*/3	-	3*/3	15, 56
OceanSaver	0/11	1/3	Unk/11	lim det (1/3)	0/10	-	11*/11	3*/3	11*/11	3*/3	11*/11	3/3	48, 49, 53
OptiMarin	8/12	0/8	lim det (6/12)	lim det (2/8)	2/12	-	12*/12	8*/8	12*/12	8*/8	12*/12	8*/8	39, 41
Panasia	5/13	0/4	lim det (7/13)	lim det (2/4)	0/2	0/1	12*/13	4/4	12/13	4/4	13*/13	4*/4	18, 20, 21, 22, 23
Qingdao	4/13	3/3	lim det (8/13)	lim det (3/3)	9/13	3/3	13*/13	3*/3	13*/13	3*/3	13*/13	3*/3	44, 50
Resource Ballast Technologies	2/2	2/3	lim det (1/2)	0/3	-	-	2/2	3*/3	2/2	3/3	2/2	3*/3	1, 8
RWO	0/13	4/5	lim det (6/13)	lim det (3/3)	7/13	-	13*/13	5*/5	13*/13	5/5	13*/13	5*/5	7, 47
Severn Trent	9/16	2/4	lim det (13/16)	0/3	10/11	2/4	16*/16	4/4	16/16	4/4	5*/5	4*/4	5, 31, 36
Siemens	0/10	-	lim det (5/10)	-	0/10	-	10/10	-	7/10	-	10*/10	-	14, 32

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Manufacturer	**>50 µm**		**10 – 50 µm**		**<10 µm (bacteria)**		***E. coli***		**Enterococci**		***V. cholorae***		**Literature Cited[2]**
	Land	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	**Land**	**Ship**	
Techcross	8/11	4/4	lim det (9/11)	lim det (3/4)	5/5	1/1	11/11	4/4	11/11	4*/4	11*/11	4*/4	24, 25, 26, 27
Wartsila Hamworthy (Aquarius UV)	-	0/2	-	lim det (2/2)		-	-	2/2	-	2*/2	-	2*/2	12, 13

[*] **Concentration at intake was unknown, non-detectable, or zero in at least one test. As discussed in Section IV, the IMO G8 Guidelines and ETV protocols for assessing ballast water treatment system performance have no minimum influent concentration requirements to conduct system performance tests for these organisms.**

[1] These data include land-based testing of system v. 2.0 and shipboard testing of system v. 1.0. DNV did not require shipboard testing of v. 2.0. Additional testing was conducted at Great Ships Initiative in 2010 but is not summarized here because the system was a hybrid between versions 1 and 2 and not a system currently on the market. For more info see GSI (2011).

[2] Numbered references can be found in the Literature Cited section.

[3] Unknown - minimum, and maximum values provided, but not the total number of tests.

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