2018 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) are organisms that pose significant risks to the economy, the environment, and human health. NIS are intentionally and unintentionally transported through human activities to new habitats, such as California's marine, estuarine, and freshwater environments. Once a NIS becomes established in a new geographic location and causes impacts, it is known as an “invasive species.”

Because attempts to eradicate invasive species are often unsuccessful and costly, prevention of species introductions by managing the vectors responsible for their movement is the most effective way to address them. In coastal environments, shipping is the most significant pathway for the transport and introduction of NIS.

To prevent the introduction of aquatic NIS from vessels, the California Legislature established the Marine Invasive Species Program (MISP). The MISP is a statewide multi-agency program that regulates ballast water discharge and biofouling on vessels arriving at California ports.

As part of California’s ballast water regulations, the California State Lands Commission (Commission) is authorized to implement ballast water discharge performance standards (California Performance Standards). The California Performance Standards set limits for the allowable concentration of living organisms in discharged ballast water. The California Performance Standards are set in statute and include “interim” and “final” standards and an implementation schedule, as follows:

- Interim standards
    - Newly built vessels constructed on or after January 1, 2020 – first arrival at a California port on or after January 1, 2020
    - Existing vessels constructed prior to January 1, 2020 – first scheduled drydocking on or after January 1, 2020
- Final standards
    - All vessels – January 1, 2030

Prior to implementing the interim California Performance Standards, the Commission is required to review the efficacy, availability, and environmental impacts, including the effect on water quality, of currently available technologies for ballast water treatment (Public Resources Code section 71205.3).

Based on all available data, there are currently no ballast water treatment technologies available to enable vessels to meet the interim California Performance Standards.

Shipboard Ballast Water Treatment
Commission staff reviewed testing data for 15 shipboard ballast water management systems (BWMS). The data were provided by BWMS manufacturers and United States Coast Guard (USCG)-approved Independent Laboratories. Based on the available data, BWMS can meet the interim California Performance Standards for *Escherichia coli*, intestinal enterococci, and *Vibrio cholerae*. Shipboard BWMS could not meet the interim California Performance Standards for all other organism size classes. Therefore, the Commission has determined that shipboard technology cannot meet the interim California Performance Standards.

Although Commission staff had sufficient data to determine that the interim California Performance Standards cannot be met, evaluating the efficacy of shipboard ballast water treatment technology at removing or killing organisms continues to be challenging. For example, the USCG BWMS type-approval process (the most detailed shipboard ballast water treatment technology evaluation protocol in the world) was developed to determine the ability of BWMS to meet the federal ballast water discharge standards, not the California Performance Standards. The USCG type-approval protocols do not:

- Evaluate BWMS performance for treating total living bacteria and total living viruses
- Adequately evaluate BWMS performance for treating living organisms 10-50 micrometers in minimum dimension to determine efficacy at meeting the interim California Performance Standards

Furthermore, the USCG has refused to release the testing data for approved BWMS which hinders the Commission's ability to determine if any BWMS can perform to a level better than the federal standards.

Shipboard Ballast Water Treatment plus Ballast Water Exchange
Ballast water exchange (BWE) plus ballast water treatment (BWT) combines two management approaches to reduce organism concentrations, change species compositions, and kill or remove organisms. In BWE plus BWT, ballast water is exchanged in mid-ocean waters and then treated through a BWMS to meet a ballast water discharge standard. Ballast water exchange plus BWT could considerably reduce the risk of vessel-mediated NIS introduction and establishment for all ports (Briski et al. 2013, Paolucci et al. 2015, Paolucci et al. 2017).

This approach is being implemented by the State of Oregon and the EPA, in the Great Lakes, because BWE plus BWT is more effective at protecting freshwater ports than treatment alone (Oregon DEQ 2017, EPA VGP 2013). Because both of these

jurisdictions require the practice of BWE plus BWT, Commission staff considers it a management option that is currently available for vessels.

The available research on the efficacy of BWE plus BWT is limited and does not address whether it could be used by vessels to meet the interim California Performance Standards. However, the potential for BWE plus BWT to improve the performance of BWMS and enable vessels to meet a standard lower than the USCG standards needs further investigation. Commission staff are finalizing the details of a study that examines the efficacy of exchange plus treatment to meet the California Performance Standards and the environmental effects of BWE plus BWT. The study will begin in mid-2019.

Shore-Based Ballast Water Reception and Treatment Facilities

There are no shore-based ballast water treatment facilities in California to enable vessels to comply with the interim California Performance Standards. In 2013, the Commission funded a study to assess the feasibility of shore-based ballast water treatment in California. The study, Glosten et al. (2018), was finalized in April 2018 and is currently the most comprehensive review of shore-based treatment options in California. The authors concluded that a network of treatment barges would be the best shore-based approach to enable vessels to meet the interim California Performance Standards.

According to the Study, such an approach would not come without impacts or costs. A barge-based network could lead to increased air emissions and congestion at California's ports. In the case of the South Coast Air Basin, these shore-based ballast water treatment activities could increase overall harbor craft air emissions by 2.5% to 5% (Glosten 2018). The 30-year lifecycle cost of building and operating a network of treatment barges is estimated at $1.45 billion. Marine vessel operators will bear an additional $2.17 billion in costs to retrofit vessels to support transfer of ballast to barges. The authors estimated that it will take a minimum of nine years to implement such a treatment network once the funding is secured.

Possible next steps may include pilot-scale testing of the ballast water treatment methods and scale-up to a treatment barge to assess system performance over various rates of ballast water transfer.

Additional Challenges

The Commission continues to face challenges with assessing the ability of ballast water treatment technologies to meet the interim California Performance Standards. This is because there are no suitable or practical methods to analyze ballast water for the following California Performance Standards:

- Organisms 10 to 50 micrometers in minimum dimension

- Total living bacteria
- Total living viruses

Recommendations

Based on the information presented in this report, the Commission recommends that the California Legislature review the existing ballast water discharge performance standards and consider alternative, feasible options to expeditiously move the state toward a reduction in the risk of species introductions from the ballast water vector.

Specific recommendations include:

1. Change the interim California Performance Standards to the USCG ballast water discharge standards set forth in Title 33 Code of Federal Regulations section 151.2030 with the associated implementation schedule; AND

2. Preserve the Commission's authority to adopt regulations that will require vessels that use a BWMS to also exchange ballast water prior to discharge.

   Recommendations 1 and 2 are the most expedient approach to implementing protective ballast water discharge performance standards in California. This approach takes advantage of the fact that the USCG discharge standards are already implemented, and most vessels that operate and discharge ballast water in U.S. waters must install USCG-approved BWMS.

   The Legislature can further strengthen the protection of California waters, by preserving the Commission's rulemaking authority to amend the ballast water management regulations to require vessels that use a BWMS to meet the discharge standards to also exchange ballast water prior to discharge. Based on existing research (Briski et al. 2015, Paolucci et al. 2017), the combination of ballast water exchange plus treatment will likely achieve higher levels of protection for state waters than through treatment alone.

3. Amend Public Resources Code section 71206(a) to enable Commission staff to sample ballast water and biofouling for research purposes in addition to compliance.

   Per Public Resources Code section 71206(a), Commission staff may take samples of ballast water and sediments only to assess compliance with the Marine Invasive Species Act. The Commission is not authorized to take ballast water samples for research purposes, which limits the ability of the Commission to collect valuable information about BWMS performance.

This recommendation would specifically address the Commission's authority to sample ballast water during the period between statutory adoption of the USCG performance standards and the date that vessels are required to comply with those standards. Commission staff can then begin sampling ballast water for research purposes to assess the concentration of living organisms in discharged ballast water. This data is critical to assess the real-world operational capabilities of BWMS.

4. Amend Public Resources Code section 71204.9(b)(1) to add the California Air Resources Board to the list of entities that must participate in the technical advisory panel as part of the development of the performance standards report; AND

5. Amend Public Resources Code section 71204.9(a)(1) and change the date that the report listed in 71204.9(a)(1) is due to the Legislature to July 1, 2025; AND

6. Amend Public Resources Code section 71204.9(b)(4) and require the technical advisory panel to submit recommendations to the Commission on or before December 30, 2024.

   Recommendations 4,5, and 6 work together and would require the Commission to produce a new report to the Legislature by July 1, 2025, evaluating California's ballast water discharge performance standards. The report to the Legislature would include:

   - Recommendations for achievable and measurable ballast water discharge performance standards
   - A determination on whether to continue to require BWE plus BWT
   - A determination on whether to proceed with requiring shore-based ballast water reception and treatment based on the results of forthcoming pilot studies (see below for further information)

   The results of the shore-based pilot study combined with the BWE plus BWT data and new data on the efficacy of BWMS will be used to determine the most feasible ballast water management approach that will move the state expeditiously towards the elimination of the discharge of NIS.

The Commission also intends to take the following actions based on existing authority:

1. Issue a request for proposals for a pilot project to test barge-based ballast water reception and treatment.

2. Fund a project to test the effectiveness of BWE plus BWT compared to BWT alone.

The recommended actions are necessary to fulfill the MISP's statutory mandate to move the state expeditiously toward elimination of the discharge of nonindigenous species into the waters of the state or into water that may impact the waters of the state, based on the best available technology economically achievable (Public Resources Code section 71201(d)).

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ABBREVIATIONS AND TERMS

AB	Assembly Bill
AMS	Alternate Management Systems
BWE	Ballast Water Exchange
BWMS	Shipboard Ballast Water Management System
BWT	Ballast Water Treatment
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CFU	Colony Forming Units
Commission	California State Lands Commission
California Performance Standards	California Ballast Water Discharge Performance Standards
EBP	Experience Building Phase, as part of the implementation of the IMO Ballast Water Convention
EPA	United States Environmental Protection Agency
FOIA	Freedom of Information Act
IMO	International Maritime Organization
IMO Ballast Water Convention	International Convention for the Control and Management of Ships' Ballast Water and Sediments
m^3	Cubic Meters
m^3/h	Cubic Meters per Hour
MISP	Marine Invasive Species Program
MEPC	Marine Environment Protection Committee
ml	Milliliter
MOU	Memorandum of Understanding
MPN	Most Probable Number
NIS	Nonindigenous Species
NISA	National Invasive Species Act
NM	Nautical Mile
NPDES	National Pollutant Discharge Elimination System
RFP	Request for Proposals
SB	Senate Bill

STEP	USCG Shipboard Technology Evaluation Program
U.S.	United States
USCG	United States Coast Guard
UV	Ultraviolet
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 is a review of the availability of ballast water treatment technologies to meet the California ballast water discharge performance standards. This report is not an endorsement or approval of any ballast water treatment technology, system manufacturer, or vendor by the California State Lands Commission or its staff. Data regarding technologies under development or currently available on the market are presented for informational purposes. The Commission 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 and all other applicable laws, regulations, and permits.

I. PURPOSE

Prior to implementing California's ballast water discharge performance standards (California Performance Standards), the California State Lands Commission (Commission) is required 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" (Public Resources Code section 71205.3). If technologies are not available to meet the 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.

Since the California Performance Standards were codified in 2006, five reports have been prepared and submitted to the Legislature (see Dobroski et al. 2007, 2009; and Commission 2010, 2013, 2014). Commission (2014) concluded that ballast water treatment technologies were not available to implement the interim California Performance Standards on January 1, 2016. As a result, the California Legislature passed AB 1312 (Chapter 644, Statutes of 2015), delaying the implementation of both the interim and final ballast water discharge performance standards as follows:

- Interim standards
    - Newly built vessels constructed on or after January 1, 2020: first arrival at a California port on or after January 1, 2020
    - Existing vessels constructed prior to January 1, 2020: first scheduled drydocking on or after January 1, 2020
- Final standards
    - All vessels: January 1, 2030

This report satisfies the requirement to report to the Legislature prior to the implementation of the interim California Performance Standards on January 1, 2020.

II. INTRODUCTION

Nonindigenous Species

Nonindigenous species (NIS) are organisms that pose significant threats to the economy, the environment, and human health. NIS are intentionally and unintentionally transported through human activities to new habitats, such as California's marine, estuarine, and freshwater environments. Once a NIS becomes established in a new geographic location and causes impacts, it is known as an “invasive species.”

Because attempts to eradicate invasive species are often unsuccessful and costly, prevention of species introductions through management of the vectors responsible for their movement is the most effective way to address NIS.

Aquatic Species Movement

Nonindigenous species are introduced into aquatic habitats through multiple pathways, including:

- Aquaculture (Grosholz et al. 2012)
- Aquarium trade (Williams et al. 2012)
- Commercial shipping (Fofonoff et al. 2003)
- Live bait trade (Fowler et al. 2015)
- Live seafood trade (Chapman et al. 2003)
- Marine debris (Barnes 2002, Carlton et al. 2017)
- Recreation (Ashton et al. 2012)

Each of these pathways contributes to aquatic NIS introductions, but shipping is the primary pathway transporting species around the globe. Aquatic NIS are transported through the specific mechanisms within the shipping pathway (i.e., vectors). The vectors are ballast water and vessel biofouling. Although vessel biofouling is an important contributor to the vessel-mediated spread of aquatic organisms, ballast water is the focus of this report.

Vessels use ballast water to improve and maintain stability, balance, and trim. Vessels take on, discharge, or redistribute ballast water during cargo loading and unloading, as they encounter rough seas, or as they transit through shallow coastal waterways. As vessels take on ballast water, they take on any organisms that are drawn in with the water. As vessels move around the world, they pick up species in water from one port and discharge them in different ports. This transfer of ballast water, and the organisms within it, results in the movement of many organisms from a “source” to a “destination.”

Prior to the implementation of ballast water management practices, it was estimated that more than 7,000 species were moved around the world daily in ballast water (Carlton 1999). The discharge of ballast water from a single vessel has the potential to release over 21.2 million individual organisms (Minton et al. 2005).

Invasive Species Impacts

Economic Impacts

In aquatic environments, NIS threaten aquaculture operations, recreational boating, agriculture, water conveyance, commercial and recreational fishing, marine transportation, and tourism, among other industries - all of which are essential to California's economy. In 2017, California's ocean-based economy employed roughly 542,000 people and accounted for almost $44 billion of California's total gross domestic product (NOEP 2018).

Tens of millions of dollars have been spent on management of NIS in California to reduce their impacts, including:

- Between 2000 and 2006, more than $7 million was spent to eradicate the Mediterranean green seaweed (*Caulerpa taxifolia*) from two small embayments (Agua Hedionda Lagoon and Huntington Harbour) in southern California (Woodfield 2006).
- Since 2000, approximately $34 million has been spent to manage the Atlantic cordgrass (*Spartina alterniflora*) in the San Francisco Bay-Delta (Olofson, P., pers. comm. 2018).
- In 2014, the Port of Stockton spent $200,000 to mechanically remove water hyacinth (*Eichhornia crassipes*), a nonindigenous aquatic plant from surrounding waterways, and as a result, the shipping industry lost an estimated $300,000 due to delays in cargo operations (Wingfield, J., pers. comm. 2015).

These costs represent only a fraction of the cumulative expenses related to NIS management because eradication is rarely successful, and control is an unending process. Nonindigenous species are believed to account for up to $120 billion per year in losses across the United States (Pimentel et al. 2005).

Environmental Impacts

Nonindigenous species significantly impact the environment of invaded areas. Worldwide, 42 percent of threatened or endangered species are listed because of impacts from NIS (Pimentel et al. 2005). Invasive zebra mussels (*Dreissena polymorpha*) have caused localized extinction of species (Martel et al. 2001) and declines in recreationally valuable fishes (Cohen and Weinstein 1998). Zebra mussels, and the closely related quagga mussel (*Dreissena bugensis*), filter vast amounts of

water and dramatically reduce plankton (tiny floating plants and animals that form the foundation of aquatic food webs) concentrations (Vanderploeg et al. 2010, Higgins and Vander Zanden 2010).

The overbite clam (*Potamocorbula amurensis*) spread throughout the San Francisco Bay estuary within the two years following its detection in 1986. The clam consumes 80 to 90 percent of zooplankton from the water column in the shallow portions of the San Francisco Bay (Greene et al. 2011) and also plays a significant role in local reductions of phytoplankton (Greene et al. 2011, Kimmerer and Thompson 2014). The dramatic decline in phytoplankton caused by *P. amurensis* is believed to be associated with the decline of several pelagic fishes in the Sacramento-San Joaquin River Delta, including the threatened delta smelt (*Hypomesus transpacificus;* Feyrer et al. 2003, Sommer et al. 2007, MacNally et al. 2010).

Human Health Impacts

In addition to economic and ecological impacts, NIS impact human health. For example, vessels and port areas are connected to the spread of epidemic human cholera (Ruiz et al. 2000, Takahashi et al. 2008). Ships are thought to have transported the seventh pandemic strain of *Vibrio cholerae* (serotype O1) from Asia to Latin America (where over 1 million people became ill and over 10,000 died) and then from Latin America to Mobile Bay, Alabama, in 1991 (Anderson 1991, McCarthy and Khambaty 1994, Tauxe et al. 1995). Due to the potential health impacts from that introduction, the Mobile Bay oyster beds closed during the summer and fall of 1991 (CDC 1993).

In 2001-02 *Vibrio cholerae* O1 was detected in seven percent of ballast water samples from ships arriving at Brazilian ports (ANVISA 2003). In 2003, Brazil successfully petitioned the International Maritime Organization (IMO) to include discharge standards for *Vibrio cholerae* and fecal indicator microbes in the International Convention for the Control and Management of Ships' Ballast Water and Sediments (hereafter: IMO Ballast Water Convention; Brazil 2003). In 2012, researchers at the Centers for Disease Control and Prevention called for greater efforts to prevent the ballast water transport of a different strain of cholera from Haiti to the United States (Cohen et al. 2012).

Like cholera, other micro-organisms harmful to humans are introduced via discharged ballast water including:

- Human intestinal parasites (*Giardia lamblia*, *Cryptosporidium parvum*, *Enterocytozoon bieneusi*) (Johengen et al. 2005, Reid et al. 2007)
- Microorganisms that cause paralytic shellfish poisoning (Hallegraeff 1998)
- Microbial indicators for fecal contamination (*Escherichia coli* and intestinal enterococci) (Reid et al. 2007)

- *Vibrio parahaemolyticus*, which infects shellfish and causes gastrointestinal illness in humans when ingested (Revilla-Castellanos et al. 2015)

III. CALIFORNIA'S RESPONSE TO NIS IN BALLAST WATER

To prevent the introduction of aquatic NIS from vessels arriving at California ports, the California Legislature established the Marine Invasive Species Program (MISP; Public Resources Code section 71200 et seq.). The MISP's statutory mandate is to "move the state expeditiously toward elimination of the discharge of nonindigenous species into the waters of the state or into water that may impact the waters of the state, based on the best available technology economically achievable" (Public Resources Code section 71201(d)).

The MISP is a multi-agency program made up of the Commission (program administration), California Department of Fish and Wildlife's Office of Spill Prevention and Response (species monitoring), State Water Resources Control Board (water quality), and Department of Tax and Fee Administration (fee collection). The MISP is funded solely by a vessel arrival fee (see Brown et al. 2017 for more information about the MISP).

Ballast Water Management

The Commission, as administrator of the MISP, implements a comprehensive ballast water management program that includes:

- Ballast water best management practices (see Public Resources Code section 71204 for a complete list)
- Ballast water management requirements
- Recordkeeping and reporting procedures for vessels
- Vessel inspections, compliance assessment, and enforcement

Prior to discharging ballast water in California, vessels must do one of the following to decrease the risk of NIS introductions (*See* Public Resources Code section 71204.3 and Title 2 California Code of Regulations (CCR) section 2284):

- Retain all ballast water onboard
- Take on and discharge ballast water at the same location
- Exchange ballast water at a minimum specified distance offshore prior to discharge (Ballast water exchange requirements vary based on a vessel's last port of call and the source of the ballast water (see Public Resources Code section 71204.3 and 2 CCR section 2284)).
- Discharge to a Commission-approved shore-based facility
- Use a Commission-approved alternative management method (e.g., use of U.S.-sourced potable water as ballast, United States Coast Guard (USCG) accepted Alternate Management System (AMS), or USCG-approved shipboard ballast water management system (BWMS))

- Under extraordinary circumstances, exchange ballast water within an area agreed to in advance by the Commission in consultation with the USCG.

Ballast Water Exchange

Ballast water exchange (BWE) is currently the most prevalent ballast water management method used by vessels discharging ballast water in California. During ballast water exchange, the biologically rich water that is loaded while a vessel is in port, or near the coast, is exchanged with the comparatively biologically poor waters of the open ocean. Coastal organisms adapted to the environmental conditions of bays, estuaries, and shallow coasts are not expected to survive or reproduce in the open ocean due to differences in biology and oceanography. Open ocean organisms are, likewise, not expected to survive in coastal waters (Cohen 1998).

Most vessels are capable of exchanging ballast water, and it typically does not require any special structural modification. However, BWE poses some challenges:

- A proper exchange can take many hours to complete due to ballast pump and piping capacities.
- Exchange may not be possible without compromising vessel safety due to adverse sea conditions or vessel design.
- Vessels may be routed on short voyages or voyages that remain close to shore (within 50 nautical miles (NM)). In such cases, the exchange process may create a delay or require a vessel crew to deviate substantially from the planned route, causing additional fuel usage and increased air emissions.
- Even if a vessel crew reports exchanging 100% of the vessel's ballast water, there is a possibility that living coastal NIS will remain in a ballast tank after exchange because ballast water exchange eliminates only between 70-99% of the organisms in ballast water and sediments (Parsons 1998, Zhang and Dickman 1999, USCG 2001, Wonham et al. 2001, MacIsaac et al. 2002, McCollin et al. 2007, McCollin et al. 2008).

Ballast Water Treatment

Treatment technologies that reduce the concentration of living organisms in discharged ballast water (such as BWMS) or that provide alternatives to discharge to state waters (such as shore-based reception and treatment facilities) should provide a higher level of protection from NIS introductions than BWE alone.

Currently, the Commission allows vessels to use BWMS in lieu of BWE if the BWMS has been accepted by the USCG as an AMS, is approved by the USCG, or if the vessel is testing a BWMS through the USCG Shipboard Technology Evaluation Program

(STEP) (see Section IV: International and Federal Response to NIS, below, for more information on AMS, type-approved BWMS, and STEP).

Ballast Water Management Plan, Recordkeeping, and Reporting

Ballast water management planning and recordkeeping are important components of the Marine Invasive Species Act (Public Resources Code section 71200 et seq.). All vessels must have on board a vessel-specific ballast water management plan that describes the management strategy employed by the vessel. A vessel's crew must be trained on the application of the management plan and proof of that training must be kept onboard. Vessels must have a separate ballast water log on board that outlines the ballast water management activities for each ballast water tank on board the vessel and demonstrates that the vessel crew has followed the management plan.

Vessel crews must report the vessel's ballast water management practices to the Commission at least 24 hours in advance of arrival at a California port to allow for risk assessment and compliance assessment. If a BWMS was used to manage a vessel's ballast water discharged into California waters, the crew must also report details about the system to the Commission on the *Marine Invasive Species Program Annual Vessel Reporting Form*.

California's Ballast Water Discharge Performance Standards

The California Legislature recognized that BWE was only an interim solution to prevent ballast water-mediated NIS introductions in California waters. As a result, the Legislature, through the Marine Invasive Species Act, required the Commission to recommend specific ballast water discharge performance standards. Performance standards set the allowable concentrations of various types and sizes (i.e., classes) of living organisms in discharged ballast water. The Marine Invasive Species Act mandates that the standards be based on the best available technology economically achievable and designed to protect the beneficial uses of the waters of the state.

Commission staff worked with a technical advisory panel to develop a set of ballast water discharge performance standards that would be more effective at preventing the discharge of living organisms in ballast water than could be achieved using BWE. The Commission, based on the technical-advisory panel's majority opinion, recommended performance standards to the Legislature in 2006. The California ballast water discharge performance standards (California Performance Standards) were codified in the Coastal Ecosystems Protection Act (Chapter 292, Statutes of 2006) and adopted as regulations by the Commission in 2007 (2 CCR section 2291 et seq.).

The interim California Performance Standards are presented in Table 1 with the IMO and U.S. federal standards for comparison. The final California Performance Standard

requires that any discharged ballast water has zero detectable living organisms for all organism size classes (Public Resources Code section 71205.3).

The California Performance Standards were originally to be phased-in between 2009 and 2016 to allow for the development of technologies that would enable vessels to meet the standards (see Dobroski et al. 2007 for original implementation schedule). Between 2007 and 2014, the Commission produced multiple reports for the California Legislature indicating that ballast water treatment technologies were not available to enable vessels to comply with the California Performance Standards. In response, the legislature delayed implementation of the California Performance Standards (AB 1312, 2015; SB 814, 2013; AB 1164, 2009; SB 1781, 2008)). The current implementation dates for the California Performance Standards, including both "interim" and "final" ballast water discharge performance standards, are as follows:

- Interim standards
    - Newly built vessels constructed on or after January 1, 2020: first arrival at a California port on or after January 1, 2020
    - Existing vessels constructed prior to January 1, 2020: first scheduled drydocking on or after January 1, 2020
- Final standards
    - All vessels: January 1, 2030

Table 1. Ballast Water Discharge Performance Standards

Organism Size Class	IMO D-2/U.S. Federal	California Interim
Organisms greater than 50µm [1] in minimum dimension	< 10 viable [2]/living [3]] organisms per cubic meter	No detectable living organisms
Organisms 10-50µm in minimum dimension	< 10 viable [2] or living [3] organisms per ml [4]	< 0.01 living organisms per ml
Living organisms less than 10µm in minimum dimension	No standard exists	< 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/100 ml or < 1 cfu/gram wet weight zoological samples

[1] Micrometer = one-millionth of a meter
[2] IMO language describing the condition of the organisms
[3] USCG language describing the condition of the organisms
[4] Milliliter = one-thousandth of a liter
[5] Colony-forming unit (CFU) is a standard measure of cultural heterotrophic bacterial numbers

IV. INTERNATIONAL AND FEDERAL RESPONSE TO NIS IN BALLAST WATER

The IMO and U.S. federal ballast water management requirements and discharge performance standards differ from the California Performance Standards.

International Maritime Organization

In 2004, the IMO adopted the IMO Ballast Water Convention (see IMO 2005). To enter into force, the IMO Ballast Water Convention required ratification by at least 30 countries representing at least 35% of world merchant shipping tonnage. The ratification threshold was achieved on September 8, 2016, and the Convention entered into force on September 8, 2017. As of October 2018, 77 countries representing 77.17% of the world's tonnage have signed onto the convention (IMO 2018a). The U.S. is not a signatory.

There are "D-1" and "D-2" ballast water management standards as part of the IMO Ballast Water Convention. The D-1 standard requires vessels to exchange their ballast water in the open ocean, at least 200 NM from the coast and in water at least 200 meters deep. The D-2 standards specify the maximum concentration of viable organisms allowed in ballast water discharged by vessels (Table 1). The timeline for implementation of the D-2 standards is presented in Table 2. Global implementation is expected by September 8, 2024 (MEPC 2017).

Table 2. IMO Ballast Water Convention Implementation Timeline for D-2 Standards

Vessel Age	Implementation Date
New Builds – Constructed after September 8, 2017	Upon delivery into service
Existing Vessels – Constructed prior to September 8, 2017	By the vessel's first International Oil Pollution Prevention Certificate (IOPPC) renewal survey after September 8, 2019

To meet the IMO D-2 performance standards, most vessels will need to install a BWMS. These systems must be approved by national authorities according to a process developed by the IMO (MEPC 2016). The IMO G8 Guidelines for approving BWMS includes testing on board a ship and in a land-based facility to confirm that the standards can be met. As of August 29, 2018, there are 75 BWMS approved in accordance with the IMO G8 Guidelines (IMO 2018b).

Recognizing the challenges associated with implementing a global approach to managing ballast water, the IMO initiated "the experience-building phase (EBP) associated with the BWM Convention" (MEPC 2017). The purpose of the EBP is to

allow the IMO's Marine Environment Protection Committee (MEPC) to monitor the implementation of the Convention. The EBP includes data gathering and analysis to allow the MEPC to identify aspects of the Convention's implementation that are working well and issues that require further attention. The EBP includes a systematic and evidence-based process for reviewing and improving the Convention.

As part of the EBP, the MEPC has adopted certain non-penalization measures. These measures are intended to recognize and address the challenges associated with penalizing ship owners and operators that are not compliant with the D-2 standards but used an approved BWMS. These measures, however, do not prevent Port States from taking preventive actions to protect their environment, human health, property, and resources from the discharge of non-compliant ballast water.

U.S. Federal Programs and Legislation

In the U.S., both the U.S. Environmental Protection Agency (EPA) and the USCG have jurisdiction over regulating ballast water discharges. The EPA's authority is based on the Clean Water Act, and the USCG's authority is based on the National Invasive Species Act. The USCG and EPA regulations and permits do not relieve vessel owners or operators of the responsibility of complying with applicable state laws or regulations.

USCG

The USCG regulates ballast water under title 33 of the Code of Federal Regulations (CFR) part 151. Vessels that operate in U.S. waters must use one of the following ballast water management methods as required by 33 CFR § 151.2025:

1) Install and operate a USCG-approved BWMS
2) Use only water from a U.S. public water system as ballast
3) Exchange ballast water 200 NM from shore until a vessel is required to use an approved BWMS (Note: Alternate Management Systems may be used in place of exchange for up to 5 years after the date the vessel would otherwise be required to comply with the federal ballast water discharge standards if the BWMS was installed prior to the date that a vessel is required to comply with those standards) (See below for more information on AMS)
4) Retain all ballast water onboard the vessel
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 Clean Water Act and are subject to the National Pollutant Discharge Elimination System (NPDES).

The implementation schedule for the USCG ballast water management requirements is in Table 3.

Table 3. US Coast Guard Implementation Schedule for Approved Ballast Water Management Methods (33 CFR § 151.2035)

	Vessel ballast water capacity (m^3)	Vessel construction date	Vessel compliance deadline
New vessels	All	On or after Dec. 1, 2013	On delivery
Existing vessels	Less than 1,500	Before Dec. 1, 2013	First scheduled dry docking after Jan. 1, 2016
	1,500 - 5,000	Before Dec. 1, 2013	First scheduled dry docking after Jan. 1, 2014
	Greater than 5,000	Before Dec. 1, 2013	First scheduled dry docking after Jan. 1, 2016

The USCG ballast water discharge regulations provide exemptions for:

- Department of Defense and USCG vessels
- Foreign vessels in government or non-commercial service
- Non-seagoing vessels
- Seagoing vessels that operate exclusively within one Captain of the Port Zone that do not operate outside of the U.S. Exclusive Economic Zone
- Seagoing vessels that operate in more than one Captain of the Port Zone, and only uptake and discharge ballast water within one Captain of the Port Zone
- Seagoing vessels that operate in more than one Captain of the Port Zone, do not operate outside the U.S. Exclusive Economic Zone and are less than 1600 gross registered tons

USCG Approval of Ballast Water Management Systems

USCG regulations include established procedures for approving BWMS. The USCG type-approval process includes land-based and shipboard evaluations of BWMS performance by independent labs. Land-based testing must be completed based on the EPA's Environmental Technology Verification Program's "Generic Protocol for the Verification of Ballast Water Treatment Technology" (NSF International 2010) as incorporated by reference in 46 CFR section 162.060.

As of October 29, 2018, 11 BWMS have been approved by the USCG (Appendix 1). At least 10 other manufacturers have submitted applications for USCG type approval, and more than 20 other manufacturers in the process of testing their BWMS based on the USCG requirements.

Alternate Management Systems

The USCG anticipated that it would take several years to approve a full range of BWMS suitable for all the vessels types and sizes that are required to manage ballast water. As a result, the USCG developed an interim measure as an alternative to its ballast water management regulations (33 CFR § 151.2025). The alternative allows vessels to use BWMS that have been type approved by foreign countries in accordance with the IMO G8 Guidelines and accepted by the USCG as being at least as effective as ballast water exchange. These systems are known as Alternate Management Systems (AMS) and are not approved by the USCG.

The USCG developed the AMS option as a bridging strategy to temporarily accept the use of these IMO-approved systems in U.S. waters in lieu of ballast water exchange. AMS approvals are only valid for 5 years. As of October 12, 2018, there are 111 BWMS accepted as AMS (USCG 2018a).

Shipboard Technology Evaluation Program

In addition to AMS, the USCG facilitates the development and testing of BWMS through the Shipboard Technology Evaluation Program (STEP). The program provides vessel owners/operators the option to install an experimental BWMS to comply with USCG ballast water management requirements or assist with USCG type-approval testing of BWMS.

Vessels accepted into the USCG STEP can operate their BWMS with equivalency to the U.S. federal standards for up to the lifespan of the vessel or the system. Only a small number of vessels are enrolled in STEP with many of these vessels engaged in shipboard testing of a BWMS for the USCG type-approval process.

USCG Extension Program

Another interim compliance strategy available to vessel owners/operators is the USCG Extension Program. As part of this program, the USCG will grant an extension to the ballast water management compliance deadline for a vessel if the USCG:

- Receives a request from a vessel owner/operator
- Determines there is not a USCG-approved BWMS available for the subject vessel
- Determines there is not another approved ballast water management method available for the subject vessel

Prior to the availability of USCG-approved BWMS, over 12,000 vessels received extensions. Now that USCG-approved BWMS are available, the USCG may continue to

grant extensions under limited circumstances, and extensions may no longer align with a vessel's scheduled dry-docking dates. The length of extensions will be based on the information provided in the extension request and will be granted for a maximum of three years (Midgett 2017).

The USCG has begun focusing on enforcement because USCG-approved BWMS are available and compliance date extensions are being phased-out. For vessels past their compliance date, USCG will review ballast water management documentation, examine BWMS equipment condition and operation, and assess crew knowledge. Enforcement actions will generally follow a tiered approach that includes issuing Letters of Warning, Notices of Violation, civil penalty actions, suspension and revocation proceedings, and possibly criminal charges (Midgett 2017).

EPA

The EPA regulates ballast water and other discharges incidental to the normal operation of vessels under the Clean Water Act through the NPDES permitting program (see Commission (2013) for more details). Under the NPDES, the 2013 Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP) became effective on December 19, 2013 and expires December 18, 2018.

According to the 2013 VGP, vessels must meet the same ballast water discharge performance standards and implementation schedule as implemented by USCG (see Table 1 and Table 3, respectively). However, unlike the USCG, the EPA does not offer extensions to the implementation schedule.

The EPA does not approve BWMS for use to comply with the 2013 VGP. Vessels must use BWMS that have been "shown to be effective by testing conducted by an independent third-party laboratory, test facility or test organization" (EPA VGP 2013b). A USCG-approved BWMS or one that has received AMS designation by the USCG is deemed to meet the "shown to be effective" criterion. Vessel owners, operators, and crews 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.

In October 2018, the EPA stated that "the 2013 VGP will not be reissued prior to its December 18, 2018 expiration date but will be administratively continued and remain in effect until a new permit is issued." The EPA is targeting spring 2019 for the release of the next draft VGP permit.

EPA and USCG

Recognizing the challenges of administering dual U.S. federal ballast water regulatory programs, the EPA and USCG signed a memorandum of understanding (MOU)(EPA and USCG 2011), to improve coordination for preventing illegal discharges of pollutants from the more than 61,000 commercial vessels (including more than 9,000 foreign-flagged vessels) operating in U.S. waters. The MOU's intent is to improve cooperation between EPA and USCG on data tracking, training, monitoring, verifying compliance, and industry outreach.

EPA also acknowledges a key difference between EPA and USCG requirements, namely that the USCG allows vessels to request compliance extensions from the ballast water management requirements while the 2013 VGP does not. On December 27, 2013, the EPA issued an Enforcement Response Policy memo stating that the EPA does not release vessels from Clean Water Act responsibility but considers violations of the 2013 VGP ballast water discharge standards to be a "low enforcement priority" (EPA 2013). Violations are considered a "low enforcement priority" for vessels that have a USCG extension, are compliant with the provisions of that extension, and compliant with all other requirements in the 2013 VGP. While the EPA is not actively enforcing violations of the 2013 VGP ballast water discharge standards during this extension period, under the Clean Water Act, citizens may still pursue legal action against violators.

As the USCG has begun limiting extensions as more USCG-approved BWMS become available, the difference in enforcement between USCG and EPA is becoming less of an issue.

U.S. Federal Legislation

To address the dual EPA/USCG federal regulatory programs and additional state regulatory programs that apply to vessel discharges, Congress has drafted several pieces of legislation to consolidate regulation of vessel discharges into U.S. waters.

After several unsuccessful attempts to pass any of the proposed legislation in the 2011-2012, 2013-2014, and 2015-2016 legislative sessions, similar versions were introduced in 2017-2018 as the Commercial Vessel Incidental Discharge Act (S. 168 and H.R. 1154). A revised version, known as the Vessel Incidental Discharge Act (VIDA), was ultimately included as part of the Frank Lobiando Coast Guard Reauthorization Act of 2018 (Senate Bill 140) and was signed into law by the President on December 4, 2018.

The law:

- Designates EPA as the lead authority to establish national water quality standards for vessel discharges, including ballast water
- Designates USCG as the lead authority to implement and enforcement the national standards set by EPA
- Preempts state authority to adopt or implement state-specific management requirements or standards for vessel discharges, including ballast water
- Retains state authority to conduct vessel inspections and enforce the federal ballast water management requirements
- Retains state authority to collect fees and ballast water management reporting forms from vessels arriving at state ports

V. REVIEW OF BALLAST WATER TREATMENT TECHNOLOGY EFFICACY, AVAILABILITY, AND ENVIRONMENTAL IMPACTS

This section reviews the efficacy, availability, and environmental impacts, including the effects on water quality of three types of ballast water management and treatment technologies:

1. BWMS
2. BWE plus Ballast Water Treatment (BWT) with a BWMS
3. Shore or barge-based ballast water reception and treatment facilities

The findings in this section are based on the best available information and supersede the Commission's previous findings regarding the efficacy, availability, and environmental impacts of treatment technologies for vessels of all ballast water capacities.

Shipboard Ballast Water Management Systems

BWMS are designed to kill or remove organisms in ballast water. BWMS are installed and integrated into a vessel's onboard ballast water system. They are broadly applicable to vessels because vessel crews can flexibly manage ballast water while loading and unloading cargo and during underway operations, such as when navigating shoals.

Multiple studies and publications are available that discuss BWMS, their efficacy at treating ballast water to IMO and U.S. federal standards, and their commercial availability for shipboard installation (EPA SAB 2011; Albert et al. 2010; Commission 2010, 2013, 2014; Batista et al. 2017). A variety of stakeholder groups are dedicated to informing each other about ballast water management options and related regulations through reports, websites, guides, articles, and conferences.

Challenges with the Review of System Efficacy for BWMS

Commission staff continually seeks the best available data for reviewing the biological efficacy of BWMS. Currently, the best available data are collected during the USCG BWMS type-approval testing process which involves extensive land-based and shipboard evaluations of system performance.

Unfortunately, none of the land-based or shipboard data are available on the USCG's website. In a Freedom of Information Act (FOIA) request to the USCG, Commission staff requested the land-based and shipboard test data from USCG approved BWMS. The USCG denied the request claiming FOIA Exemption 4, which protects trade secrets and commercial or financial information obtained from a person that is privileged or confidential (USCG 2018c). Commission staff appealed the decision because:

- Data are not trade secrets or commercial or financial information
- Disclosure of the biological efficacy results of the land-based and shipboard tests for such systems would reveal no trade secrets

The public relies on USCG to approve BWMS that will reduce the risk of invasive species introductions into U.S. waters. However, without the BWMS test results, there is no way for the public, including state agencies, to review the grounds for USCG approval of a BWMS, including biological efficacy and environmental impacts.

As of October 31, 2018, Commission staff's appeal of the USCG FOIA decision remains unresolved. Additionally, several of this report's technical advisory panel members stated that their FOIA requests for this same data were also denied.

Efficacy

Although the USCG has not provided data on type-approved BWMS to Commission staff for this report, staff received new data on the biological performance of 15 BWMS from shipboard ballast water treatment technology manufacturers and USCG-approved Independent Laboratories. While it is encouraging to receive new data on BWMS performance, the review of the new data shows that shipboard technology remains unavailable to meet all the interim California Performance Standards.

The efficacy data, presented below by organism size class, were provided to Commission staff in a summarized and anonymized format. Commission staff does not have the original test reports.

<u>Organisms greater than 50µm in minimum dimension</u>

The interim California Performance Standard for organisms greater than 50µm in minimum dimension is "no detectable living organisms." This interim California Performance Standard does not specify the volume of water that must be sampled to determine if there are no detectable living organisms. The USCG requires that three cubic meters of ballast water be sampled to assess BWMS performance for the greater than 50µm organism size class during shipboard USCG type-approval testing (see 46 CFR § 162.060 for more information on shipboard USCG testing requirements). Therefore, Commission staff based all analyses of data for this organism size class on that sample volume.

The results from land-based and shipboard tests of BWMS based on the USCG type-approval testing protocols are summarized in Tables 4 and 5. The tables show the total number of tests of each BWMS and the percent of those tests that resulted in organism concentrations within specified ranges. The ranges are based on the number of living organisms observed per cubic meter of water.

Table 4. Land-based test results for organisms in the greater than 50µm size class. The data are presented as the percentage of tests that resulted in living organisms observed within 4 ranges. The ranges are: no living organisms detected, less than or equal to 5 living organisms observed, more than five and less than 10 living organisms observed, and 10 or more living organisms observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of BWMS Tests			
		No Detection	≤5	>5<10	≥10
1	15	53.3	46.7	0	0
2	14	64.3	35.7	0	0
3	15	66.7	33.3	0	0
4	17	41.2	35.3	11.8	11.8
5	16	37.5	25	31.3	6.3
6	18	44.4	55.6	0	0
7	15	6.7	86.7	6.7	0
8	25	40	56	4	0
9	16	62.5	37.5	0	0
10	18	66.7	33.3	0	0
11	18	50	33.3	11.1	5.6
12	27	59.3	40.7	0	0
13	15	93.3	6.7	0	0
14	28	32.1	53.6	14.3	0
15	19	21.1	78.9	0	0

Table 5. Shipboard test results for organisms in the greater than 50µm size class. The data are presented as the percentage of tests that resulted in living organisms observed within 3 ranges. The ranges are: no living organisms detected, less than or equal to 5 living organisms observed, and more than five and less than living 10 organisms observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests		
		No Detection	≤5	>5<10
1	6	50	50	0
2	5	20	60	20
3	5	0	80	20
4	5	20	80	0
5	5	20	80	0
6	5	20	40	40
7	5	40	60	0
8	5	40	40	20
9	6	50	50	0
10		No Data		
11		No Data		
12		No Data		
13	5	60	40	0
14	5	0	60	40
15		No Data		

Because living organisms were detected in at least one shipboard and land-based test for all BWMS evaluated in this review, Commission staff determined that BWMS are currently not able to meet the interim California Performance Standard for organisms greater than 50µm in minimum dimension.

Organisms 10-50µm in minimum dimension

The interim California Performance Standard for organisms in the 10-50µm size class is 0.01 living organisms per milliliter. Commission staff cannot conclusively determine that any BWMS can meet the interim California Performance Standard for this size class because the available data are based on testing conducted to assess the ability of BWMS to meet the USCG standard for this size class (10 living organisms per milliliter).

The USCG performance standard is a less stringent standard than the interim California Performance Standard. Additionally, the interim California Performance Standard of 0.01 living organisms per ml is below the limit of detection based on the USCG-required

methods of sample analysis. Therefore, any BWMS with organisms detected in any test shows that a BWMS cannot meet the interim California Performance Standard.

The results from land-based and shipboard tests, based on the USCG type-approval testing protocols using epifluorescent microscopy, are summarized in Tables 6 and 7. The tables show the total number of tests for each BWMS and the percent of those tests that resulted in organism concentrations within specified ranges. The ranges are based on the number of living organisms observed per milliliter of water.

Table 6. Land-based test results for organisms in the 10µm to 50µm size class. The data are presented as the percentage of tests that resulted in living organisms observed within 3 ranges. The ranges are: no living organisms detected, less than or equal to 5 living organisms observed, and more than five and less than 10 living organisms observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests		
		No Detection	≤5	>5<10
1	15	0	100	0
2	15	33.3	60	6.7
3	15	6.7	80	13.3
4	17	17.6	82.4	0
5	16	81.3	18.8	0
6	20	10	90	0
7	15	46.7	53.3	0
8	28	3.6	92.9	3.6
9	16	31.3	68.8	0
10	18	38.9	50	11.1
11	18	72.2	27.8	0
12	27	0	92.6	7.4
13	15	80	20	0
14	24	8.3	25	66.7
15	19	31.6	63.2	5.3

Table 7. Shipboard test results for organisms in the 10µm to 50µm size class. The data are presented as the percentage of tests that resulted in living organisms observed within 4 ranges. The ranges are: no living organisms detected, less than or equal to 5 living organisms observed, more than five and less than 10 living organisms observed, and 10 or more living organisms observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests			
		No Detection	≤5	>5<10	≥10
1	5	0	80	20	0
2	5	40	60	0	0
3	5	20	80	0	0
4	5	80	20	0	0
5	5	80	20	0	0
6	10	0	70	20	10
7	7	28.6	71.4	0	0
8	5	0	80	20	0
9	6	33.3	66.7	0	0
10	5	40	60	0	0
11	0	No Data			
12	5	20	60	20	0
13	0	No Data			
14	1	0	100	0	0
15	0	No Data			

Some BWMS manufacturers and Independent Labs also provided Commission staff with data on system ability to remove or kill organisms in the 10-50 µm size class based on the most probable number (MPN) method of analysis. The MPN method is a standard practice for quantifying culturable organisms such as some phytoplankton, *Escherichia coli (E. coli),* and enterococci species. Although this method is not accepted by the USCG as part of its type-approval testing protocols, it is accepted by the IMO. The results from the data collected through MPN analysis are displayed in Table 8.

Table 8. Shipboard test results for organisms in the 10µm to 50µm size class where MPN was used for analysis. The data are presented as the percentage of tests that resulted in living organisms observed within 2 ranges. The ranges are: no living organisms detected, less than or equal to 5 living organisms observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests	
		No Detection	≤5
2	15	80	20
6	30	96.7	3.3
14	24	41.7	58.3

The results from the USCG type-approval testing and the MPN analyses show that all the BWMS reviewed did not meet the interim California Performance Standard for organisms 10-50 µm in minimum dimension. This is because at least one organism was detected in each test for all BWMS data reviewed.

Indicator Bacteria: *E. coli*, Intestinal Enterococci, and *Vibrio cholerae*

The interim California Performance Standard for *E. coli* is 126 colony-forming units (CFU) per 100 milliliters of water and for intestinal enterococci is 33 CFU per 100 milliliters of water. The limits of detection for *E. coli* and enterococci are different for freshwater versus brackish water and salt water. The limit of detection for *E. coli* and enterococci in freshwater is 1 CFU per 100 milliliters. The limit of detection for brackish and salt water is 10 CFU per 100 milliliters. *E. coli* data are presented in Tables 9 and 10, and intestinal enterococci data are presented in Tables 11 and 12.

The interim California Performance Standard for *Vibrio cholerae (V. cholerae)* is 1 CFU per 100 milliliters. The test results for *V. cholerae* are not presented in a table because no *V. cholerae* were detected in any tests.

Table 9. Land-based test results for *E. coli*. The data are presented as the percentage of tests that resulted in living organisms observed within 2 ranges. The ranges are: no detection of CFU, less than 126 CFU. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests	
		No Detection	<126
1	0	No data	
2	19	0	100
3	0	No data	
4	20	85	15
5	16	81.3	18.8
6	17	0	100
7	15	0	100
8	25	0	100
9	16	0	100
10	14	100	0
11	18	72.2	27.8
12	15	86.7	13.3
13	27	48.1	51.9
14	24	12.5	87.5
15	19	0	100

Table 10. Shipboard test results for *E. coli.* The data are presented as the percentage of tests that resulted in living organisms observed within 2 ranges. The ranges are: no detection of CFU, less than 126 CFU. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests	
		No Detection	<126
1	0	No Data	
2	0	No Data	
3	0	No Data	
4	2	100	0
5	5	100	0
6	5	0	100
7	5	0	100
8	5	0	100
9	6	0	100
10	4	100	0
11	0	No Data	
12	0	No Data	
13	5	0	100
14	5	0	100
15	0	No Data	

Table 11. Land-based test results for intestinal enterococci. The data are presented as the percentage of tests that resulted in living organisms observed within 3 ranges. The ranges are: no detection, less than or equal 33 CFU, and equal to or more than 33 but less than 100 CFU. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests		
		No Detection	<33	≥33<100
1	19	0	100	0
2	15	0	100	0
3	33	0	97	3
4	17	88.2	11.8	0
5	16	75	25	0
6	13	0	100	0
7	15	0	100	0
8	25	0	100	0
9	16	0	100	0
10	18	38.9	61.1	0
11	18	88.9	11.1	0
12	15	86.7	13.3	0
13	27	0	100	0
14	24	20.8	79.2	0
15	19	0	100	0

Table 12. Shipboard test results for intestinal enterococci. The data are presented as the percentage of tests that resulted in living organisms observed within 3 ranges. The ranges are: no detection of CFU, less than or equal 33 CFU observed, and equal to or more than 33 but less than 100 CFU. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests		
		No Detection	<33	≥33<100
1	5	100	0	0
2	5	0	100	0
3	5	0	80	20
4	5	80	20	0
5	5	100	0	0
6	5	0	100	0
7	5	0	100	0
8	5	0	100	0
9	5	0	100	0
10	2	100	0	0
11		No Data		
12		No Data		
13	5	5	0	100
14	5	5	0	100
15		No Data		

Based on the information reviewed, all the tests for all 15 BWMS resulted in treated ballast water discharge with concentrations that met the interim California Performance Standards for *E. coli*, intestinal enterococci, and *V. cholerae.*

It is important to note that neither IMO nor USCG type-approval testing protocols require a minimum number of bacteria in the intake water prior to treatment. Thus, in some cases, there may have been zero detected *E. coli*, intestinal enterococci, or *V. cholerae* in the intake water and then zero post-treatment. These tests are still considered as having met the discharge standard.

Total Living Bacteria

The interim California Performance Standard for total living bacteria is 1,000 living bacteria per 100 milliliters of water. There is no federal standard for total living bacteria, and BWMS manufacturers are not required to test for total living bacteria in the type - approval testing process.

Culturable heterotrophic bacteria are a sub-group of total living bacteria that able to be cultured. Independent Laboratories commonly test for culturable heterotrophic bacteria during land-based type-approval testing even though there is no federal standard for this type of bacteria.

Commission staff received land-based test data for 15 BWMS at treating culturable heterotrophic bacteria. There were no BWMS shipboard-test data provided to Commission staff for culturable heterotrophic bacteria. The information provided to Commission staff is presented in Table 13 as an indicator of potential system performance at killing or removing all bacteria. The results are presented as the number of CFU per milliliter. For a BWMS to be capable of meeting the interim California Performance Standard (1,000 living bacteria per 100 ml), the results would need to be no more than 10 CFU per milliliter.

Table 13. Land-based test results for culturable heterotrophic bacteria. The data are presented as the percentage of tests that resulted in living organisms observed within 3 ranges. The ranges are: no organisms detected, less than or equal to 100 CFU observed, and more than 100 CFU observed. Gradient shading represents percentages from 100% (dark blue) to 0% (white).

BWMS Number	Number of Tests	Percent of Tests		
		No Detection	≤100	>100
1	15	0	53.3	46.7
2	15	0	33.3	66.7
3	33	0	3	97
4	17	0	0	100
5	16	0	0	100
6	17	0	11.8	88.2
7	15	0	6.7	93.3
8	25	0	32	68
9	16	0	81.3	18.8
10	18	55.6	11.1	33.3
11	18	0	0	100
12	27	0	48.1	51.9
13	15	0	0	100
14	24	0	16.7	83.3
15	19	0	31.6	68.4

The results from the land-based tests of BWMS at treating culturable heterotrophic bacteria indicate that these systems would not meet the interim California Performance Standard.

Although the information on culturable heterotrophic bacteria is useful to gauge system performance at killing bacterial species, there remains no known method to quantify all living bacteria in a sample of water. Therefore, Commission staff cannot determine if any BWMS can meet the interim California Performance Standards for total living bacteria, and BWMS cannot be considered available to meet this standard.

Total Living Viruses

The interim California Performance Standard for total living viruses is 10,000 living viruses per 100 milliliters. As with the Commission (2014), Commission staff know of no practical methods to assess the interim California Performance Standard for total living viruses. No data were obtained by Commission staff on the ability of BWMS to treat all living viruses. Because there are no shipboard-test data available on the ability of BWMS to treat all living viruses in ballast water, BWMS cannot be considered available for vessels to meet this interim California Performance Standard.

Availability

Although USCG-approved BWMS are available for purchase and installation (see Appendix 1), none of these systems have been proven to meet all the interim California Performance Standards. Therefore, no technology can be considered available to enable implementation of the interim California Performance Standards on January 1, 2020.

Environmental Impacts

An effective BWMS must comply with the California Performance Standards and all applicable environmental safety and water quality laws. The discharge of treated ballast water should not impair water quality such that it impacts the beneficial uses (e.g., fishing and recreation) of California's waters. Detailed information about IMO, U.S. federal, and state environmental regulation of vessel discharges can be found in Commission (2013).

The BWMS data that were reviewed for biological efficacy were generated as part of the USCG type-approval testing process. The USCG type-approval testing protocols require BWMS manufacturers to demonstrate:

> The effectiveness of the [shipboard] BWMS for its intended use, appropriate dosages over all applicable temperatures, hazards of the [shipboard] BWMS, and means for protection of the environment, and

public health. This assessment must accompany the application package submitted to the Coast Guard. (USCG 2018b.)

The USCG has not yet publicly released any data (biological efficacy or environmental safety) on BWMS that have been type approved. Although Commission staff requested test data from the USCG, this request was denied. Therefore, Commission staff has not had access to all available environmental data for USCG type-approved BWMS when reviewing the environmental impacts of BWMS.

Fortunately, the EPA also collects data from vessels on the constituents of ballast water discharges. Any vessel that discharges ballast water in the U.S. must comply with effluent limits set forth in the 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 listed in the CWA section 401 certification (see EPA VGP 2013).

The 2013 VGP requires sample collection and analytical monitoring for vessels that operate a BWMS and discharge in U.S. waters. This monitoring includes several chemicals including total residual chlorine (see Table 16 for total residual chlorine discharge data). The data were provided to Commission staff by the EPA. For vessels discharging ballast water treated with chlorine, the concentration of total residual chlorine in the discharge shall not exceed 60 micrograms per liter (µg/l) in California's waters, except within enclosed bays (such as San Francisco Bay) or freshwater where the limit is 20 µg/l. More information is available at: http://www.waterboards.ca.gov/water_issues/programs/beaches/vssl_prmt.shtml.

Table 16. **Vessel self-monitoring data for Total Residual Chlorine submitted to the EPA.** The discharge monitoring data are presented as the concentration of Total Residual Chlorine within four ranges.

YEAR	Number of Vessels	Total Samples	Number of Samples within each Residual Chlorine Range			
			0	≥0<20 µg/l	≥20<60 µg/l [a]	≥60 µg/l [b]
2014	2	20	0	3	4	13
2015	8	64	27	5	19	13
2016	37	83	22	10	35	16
2017	80	196	62	32	47	55
TOTAL	**127**	**363**	**30.6%**	**13.8%**	**28.9%**	**26.7%**

a – Exceeds California Total Residual Chlorine limits for both freshwater (20µg/l) and ocean waters (60µg/l).
b – Exceeds California Total Residual Chlorine limits for freshwater and water within San Francisco Bay of 20µg/l.

Based on the data provided, residual chlorine from BWMS is a serious problem, as multiple vessels reported chlorine levels that exceed the California Total Residual Chlorine limits. These data indicate that not all vessels that use a BWMS will be able to comply with California's effluent limits for total residual chlorine. Commission staff will coordinate with the Water Board to monitor vessel discharges and enforce violations.

Vessel owners and operators should work with BWMS manufacturers to pick a system that will be able to meet California's total residual chlorine limits, and all other water quality standards, in ballast water discharge.

BWMS Review Conclusion

The interim California Performance Standards are "all-or-none" standards because a vessel that violates the standard for one organism class does not comply with the interim California Performance Standards. Although the testing data reviewed show that BWMS met the *E. coli*, intestinal enterococci, and *V. cholerae* standards, no system reviewed showed the ability to meet the interim California Performance Standards for >50 µm and 10-50 µm organisms. Therefore, shipboard BWMS are not available to implement the interim California Performance Standards.

Shipboard Ballast Water Treatment plus Ballast Water Exchange

Commission staff reviewed another approach being implemented by the State of Oregon and the EPA to prevent vessel-mediated NIS introduction and establishment. Ballast water exchange plus BWT combines two management approaches that reduce organism concentrations, change species compositions, and kill or remove organisms.

Ballast water exchange is the most widely used management option for vessels discharging ballast water in California (Brown et al. 2017). During BWE, the biologically-rich water that is loaded while a vessel is in port, or near the coast, is exchanged with the comparatively biologically-poor waters of the open ocean. Coastal organisms adapted to the environmental conditions of bays, estuaries, and shallow coastal waters are not well-suited to survive or reproduce in the open ocean due to differences in habitat suitability. Open ocean organisms are, likewise, not expected to survive in coastal waters (Cohen 1998).

Alone, BWE is not a ballast water management approach that will allow vessels to meet the interim California Performance Standards because it does not sufficiently reduce organism concentrations prior to discharge. Ballast water exchange can also be inconsistent in its effectiveness due to ballast tank design and residual ballast water and sediments that may contain high concentrations of organisms, resting cells, and cysts (Dickman and Zhang 1999, Zhang and Dickman 1999).

In BWE plus BWT, ballast water is exchanged in mid-ocean waters and then treated through a BWMS to meet a ballast water discharge standard. Ballast water exchange plus BWT could considerably reduce the risk of vessel-mediated NIS introduction and establishment for all ports (Briski et al. 2013, Paolucci et al. 2015, Paolucci et al. 2017).

Efficacy

The efficacy of BWE plus BWT relative to the interim California Performance Standards is not well studied. However, some studies have evaluated BWE plus BWT compared to BWT alone.

An EPA-funded study by the Naval Research Lab evaluated the effectiveness of BWE plus BWT compared to BWT alone in two trials for each method. No organisms were detected in either trial of the ballast water managed through BWE plus BWT (Drake et al. 2017). No organisms were detected in one trial of BWT alone. However, organisms were detected in the other trial of BWT alone, and the discharge concentrations exceeded the USCG standards.

In addition to the Naval Research Lab study, Commission staff examined the results of a peer-reviewed publication that compared the effectiveness of BWE plus BWT to BWT alone (see Briski et al 2015). Three trials tested the two management approaches on ballast water from freshwater ports. The results from these tests show that BWE plus BWT significantly reduced organism concentrations compared to BWT alone.

Ballast water exchange plus BWT may also enhance BWMS performance. Because open ocean water is generally less turbid and has lower organism concentrations, the Commission believes that BWMS will be more effective under these conditions; research would need to be done to test this hypothesis.

Availability
Ballast water exchange plus BWT is currently a requirement for vessels that discharge ballast water in several jurisdictions.

On January 19, 2017, the Oregon Environmental Quality Commission adopted revisions to Oregon ballast water management regulations. The new rules became effective March 1, 2017 and include "a requirement that vessels using USCG-approved BWMS must conduct an oceanic ballast exchange – in addition to meeting federal ballast discharge standards – for ballast tanks that were sourced with water less than or equal to 18 parts per thousand" (Oregon DEQ 2017). Based on the salinity levels of this Oregon regulation, vessels must exchange ballast water prior to discharge if that water is commonly classified as fresh or brackish.

In addition, the 2013 VGP requires vessels to exchange and treat their ballast water (to the federal discharge standards) before discharging in the Great Lakes if the vessel:

- Arrives from a port outside the Great Lakes
- Sourced ballast water in freshwater or brackish water

Both Oregon and the EPA state that BWE plus BWT is more effective at protecting freshwater ports than BWT alone (Oregon DEQ 2017, EPA VGP 2013). Because both of these jurisdictions currently require the practice of BWE plus BWT, Commission staff considers it a management option that is currently available for vessels. Additionally, although not currently a requirement in California, some vessels that arrive at California ports report using a BWMS in addition to exchange to meet California's existing ballast water management requirements.

Environmental Impacts
Ballast water exchange plus BWT may convey additional benefits beyond reducing vessel-mediated NIS introduction risk. Ballast tank sediment management may be improved by regularly suspending and flushing sediments from the tank during an

exchange (Johengen et al. 2005, Reid et al. 2007). Exchanging ballast water in mid-ocean may also replace potentially polluted foreign-port water with cleaner oceanic water. Ballast water exchange may also affect the environmental impacts from BWMS (particularly those systems that use chemical treatment processes) by altering the concentration of chemical constituents in the source water.

BWE plus BWT Conclusion
Ballast water exchange plus BWT is an option that is currently available for vessels to use. Although there has been limited research on BWE plus BWT, the benefits over BWT alone or BWE alone cannot be ignored. Ballast water exchange plus BWT is a method that:

- Has been shown to be significantly more effective than BWT alone
- Provides added benefits for ballast water tank flushing and avoiding the discharge of polluted water sourced from other ports

The available research on BWE plus BWT is limited and does not address whether it could be a method considered available for vessels to meet the interim California Performance Standards. However, the potential for BWE plus BWT to improve the performance of BWMS and enable vessels to meet a standard lower than the USCG standards needs further investigation. Commission staff are finalizing the details of a study that examines the efficacy of BWE plus BWT to meet the California Performance Standards and the environment impacts of BWE plus BWT. The study will begin in mid-2019.

Shore-Based Ballast Water Reception and Treatment Facilities
Shore-based treatment provides an option for treatment technologies and methods, such as reverse osmosis, that are not feasible onboard vessels due to space or energy constraints.

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 move ballast water from a vessel to a shore-based treatment plant
- Reception and treatment barges that receive ballast water from vessels, treat it on board the barge, and then discharge to the surrounding environment

Vessels may comply with the California Performance Standards by discharging ballast to a shore-based reception facility. However, no shore-based facilities designed to treat

nonindigenous species in ballast water are currently available in California or anywhere else in the United States.

Feasibility of Shore-Based Treatment

While no shore-based facilities are currently available, previous research on the feasibility of shore-based ballast water treatment has found encouraging potential for such facilities to manage ballast water. Unfortunately, these studies have been limited in scope, generally focusing on only one port or place or covering only a coarse level of analysis (see Literature Review (Task 1) in Glosten et al. 2018).

In 2013, the Commission approved funding to study the feasibility of shore-based reception and treatment facilities as an option for vessels to comply with the California Performance Standards (Commission Staff Report, Item 93, June 21, 2013). The contract was managed by the Delta Stewardship Council, which awarded the funds to a lead contractor (The Glosten Associates) based on a competitive bid process. The final report (hereafter referred to as Glosten et al. (2018)) was provided to the Commission in April 2018 and is available on the Delta Stewardship Council's website: http://deltacouncil.ca.gov/events/feasibility-study-shore-based-ballast-water-reception-and-treatment-facilities-california-1.

Study Approach

The Glosten et al. (2018) study covered five broad topic areas and was broken into thirteen separate tasks (Table 17). The findings from each task were reported separately and include background information, in-depth analysis, and calculations.

An independent science panel reviewed drafts of each report and provided written comments. The Delta Stewardship Council also hosted three public workshops (October 2015, August 2016, and October 2017) where the public and the independent science panel offered comments to the Glosten team on the draft Task Reports. These comments were addressed in each final Task Report.

Table 17. Category for each Task Report (taken from Glosten et al. (2018))

Task	Description
Literature Review	
1	Literature search on shore-based ballast water management.
Case Studies	
-	Interim memorandum scaling-up findings in Tasks 2 – 5 to assess the cost and practicality of land- based vs. barge-based alternatives for California.
2	Assess feasibility and required retrofitting of marine vessels to transfer ballast water to shore.
3	Assess modifications to ports and wharves to receive ballast water from marine vessels.
4	Assess shore-based alternatives for conveyance, storage, and treatment of ballast water.
Technical Feasibility	
5	Determine if shore-based treatment technologies could meet the CA Interim Standards.
6	Assess impact of ballast water outfalls and solid waste disposal from shore-based facilities.
7	Summarize pertinent permitting and legal requirements.
8	Comparative review of shipboard vs. barge-based ballast water management operations.
9	Assessment of current practices related to ballast water discharges in California.
Economic Feasibility	
10	Cost analysis of implementation from shipping industry and treatment operator perspectives.
12	Market implications.
Implementation	
11	Implementation timeline.
13	Additional findings, focusing on concept of statewide network of mobile treatment barges.

Glosten et al. (2018) used a case study approach to address the 13 tasks and to capture the wide range of vessel operations throughout California. The study examined five California ports as case studies (Table 18) to be representative of the range of variability in ports across the state. For each port, the authors examined various shore-based solutions including:

- Barges
- Land-based piping systems
- New treatment facilities
- The use of existing publicly-owned treatment works

Table 18. Case Study Summary (from Glosten et al. (2018))

Case Study	Methods Explored	Marine Vessels	Shore Reception Ballast Capacity
Port of Stockton, East Complex	New pipeline to exiting treatment plant	Bulk carriers	34,000 m3/day
Port of Oakland, TraPac Terminal	New pipeline to new on-site treatment plant	Containerships	22,500 m3/day
Port Hueneme, South Terminal Wharf 1	On-site storage with mobile treatment	Car carriers	4,000 m3/day
El Segundo Offshore Marine Terminal	Barge-based reception and treatment	Tankers and ATBs	32,000 m3/day
Ports of LA/LB, SA Recycling and Cruise Terminal	Barge-based reception to off-site treatment	Cruiseships and Bulk carriers	26,400 m3/day

Based on the case studies, Glosten et al. (2018) concluded that "statewide application of a land-based system of piping, storage tanks, and treatment plants was found to be impractical, as each instance presents unique arrangement, land-use, and permitting challenges." Instead the authors concluded that a "shore-based network of ballast water treatment barges therefore yielded the most cost-effective and practical means to receive, treat, and discharge most ballast water discharges in California to the CA Interim Standards." Therefore, the remainder of the study focused on analyzing the use of shore-based barge networks as a means for vessels to comply with the California Performance Standards.

Potential Solution: A Network of Treatment Barges

Glosten et al. (2018) proposed the following barge-based treatment option to enable vessels to comply with the California Performance Standards (see Table 19):

> An estimated twenty-four purpose-built barges would operate in service zones covering the entire state, with capacity to service the estimated 1,556 marine vessel ballast water discharges at an availability rate of 99%. Ballast water would be transferred from the discharging marine vessel to the barge by means of a hose, treating the ballast water as if it was a petroleum product with no leaks or spills allowed.

The authors noted that it is likely that a few remote port locations, such as Humboldt Bay, may develop a land-based solution instead of the barge-based solution due to cost and limited access to the barge-based network.

Table 19. Proposed Statewide Barge Network (from Glosten et al. (2018))

Zone Designation	Service Area	Small Barges (10,000 m^3 service)	Medium Barges (20,000 m^3 service)	Large Barges (35,000 m^3 service)	Total Barges
Zone 1	San Francisco Bay (North Part) and Humboldt Bay	1	1	2	4
Zone 2	San Francisco Bay (South Part) and Monterey Bay	2	-	2	4
Zone 3	Carquinez Strait and Suisun Bay	1	1	2	4
Zone 4	Stockton	-	1	2	3
Zone 5	Los Angeles/Long Beach and Vicinity	3	1	3	7
Zone 6	San Diego	2	-	-	2
TOTALS		**9**	**4**	**11**	**24**

Efficacy of Shore-Based Treatment

The efficacy of shore-based ballast water treatment facilities cannot be evaluated because there are none currently available in the U.S. However, Glosten et al. (2018) evaluated the potential efficacy of shore-based treatment using existing literature on treatment methodologies and performance (see Task Report 5 in Glosten et al. (2018) for full analysis).

Glosten et al. (2018) compared a range of shore-based ballast water treatment methods including:

- Three methods of mechanical separation - coagulation/flocculation/sedimentation, dual-media filtration, and membrane filtration
- One physical method of disinfection – ultraviolet (UV) irradiation
- Three chemical methods of disinfection - ozone, sodium hypochlorite, and electrochlorination

The study determined that "the most effective method combination for ballast water treatment was coagulation, flocculation, and sedimentation followed by membrane filtration and UV or chemical disinfection." Based on this treatment combination, Glosten et al. (2018) examined the potential efficacy of such a system.

> The efficacy of each technology and combination of technologies to meet the CA Interim Standards was determined primarily using estimated log

> zooplankton (microorganisms >50 µm), protist (50 µm > microorganism > 10 µm), bacteria, and virus inactivation values. It was estimated 5-log removal of zooplankton, protists, and bacteria and 7-log removal of viruses would be required to meet the CA Interim Standards.

After reviewing the available literature, Glosten et al. (2018) concluded that:

> There is little information on the removal of zooplankton and protists by dual-media membrane filtration; however, 5-log removal by both technologies was assumed in this study due to the large size of zooplankton and protists compared to the size of particles removed in dual-media and membrane filtration. This would need to be confirmed through field testing.
>
> Based on the available literature, it was found that the treatment trains including UV and chemical disinfection can achieve the required bacteria removal (5-log) but do not achieve the required virus inactivation (7-log).

Glosten et al. (2018) stated that virus inactivation could likely be achieved by increasing the dose of chemical disinfection or UV irradiation. The estimated organism removal values for the individual treatment processes and treatment combinations are summarized in Table 20.

Table 20. Removal of regulated ballast water organism size class by proposed treatment steps and treatment trains (taken from Glosten et al. (2018))

Physical Treatment		Mech./Chem. Treatment	Total System Removal
Coag./Floc./Sed. **Removal:** Org. > 50 µm = Low 50 ≥ Org. > 10 = Low Bacteria = Negligible Virus = Negligible	**Membrane Filtration** **Removal:** Org. > 50 µm = 5-log 50 ≥ Org. > 10 = 5-log Bacteria = 3-log Virus = Negligible	**UV Disinfection** **Removal:** Org. > 50 µm ≈ Low 50 ≥ Org. > 10 ≈ Low Bacteria = 2-log [1] Virus = 2-log, 4-log [2]	**Treatment Train: Coag./Membrane/UV** Org. > 50 µm = **5-log** 50 ≥ Org. > 10 = **5-log**. Bacteria = > **5-log** [1] Virus = **2-log, 4-log** [2]
		Chemical Disinfection **Removal:** Org. > 50 µm ≈ Low 50 ≥ Org. > 10 ≈ Low Bacteria = > 4-log [3] Virus = 1-log [4]	**Treatment Train: Coag./Membrane/Chem.** Org. > 50 µm **= 5-log** 50 ≥ Org. > 10 = **5-log** Bacteria = > **7-log** [3] Virus = **1-log** [4]

[1] Removal achieved at a UV dose of 60 mJ/cm^2
[2] 2-log and 4-log removal based on UV doses of 100 and 190 mJ/cm^2
[3] Removal based on a TRO ≥ 5 mg/L and HRT ≥ 10 hours
[4] Removal based on a TRO = 8.1 mg/L and HRT = 4 minutes

Glosten et al. (2018) stated that "the proposed treatment barge network is expected to be reliable and to provide the theoretical biological inactivation/removal efficiency to meet the stringent CA Interim Standards." However, "implementation on barges requires assessment in terms of footprint and will require further testing to confirm efficacy when shifting this technology from land."

Availability

While ballast water discharge to shore-based reception facilities is permitted under the IMO Ballast Water Convention, U.S. federal regulations and permits (USCG and EPA, respectively), and the California Marine Invasive Species Act, no shore-based treatment facilities designed to remove or kill organisms in ballast water currently exist in the U.S.

Glosten et al (2018) estimated that it would take a minimum of nine years to implement the suggested shore-based network of treatment barges in California (see Task Report 11 in Glosten et al. (2018) for full analysis). Specifically:

Full implementation of the barge-based treatment option is estimated to take place nine years from initial research and development of the barge-based treatment technologies, as shown in Figure 1.

The first six years will be occupied with the study of ballast water discharges, building and pilot testing of treatment barge prototype(s), development of transfer station standards, communication of requirements to marine vessels, development of the PPPs [public private partnerships], and contracting for the design/build of the treatment barges. Years 7, 8, and 9 will be occupied with phasing in the treatment barge network. Importantly, Year 1 starts only after budgets and plans have been put into place.

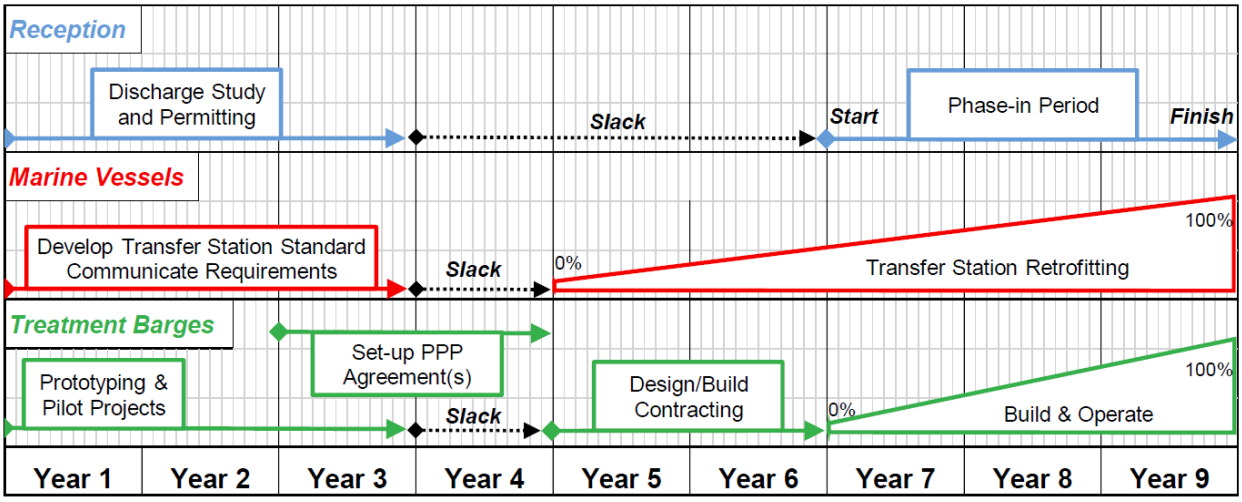

Figure 1. Overall implementation timeline (taken from Glosten et al. (2018))

Based on the lack of existing shore-based facilities and the estimated timeline for development and implementation of a barge-based treatment network, the Commission concludes that shore-based ballast water treatment is not available for implementation of the interim California Performance Standards beginning on January 1, 2020.

Environmental Impacts

Because there are no shore-based ballast water treatment facilities currently available in the U.S., the environmental impacts of this type of facility cannot be conclusively evaluated. However, Glosten et al. (2018) discussed the potential environmental impacts of a barge-based treatment network (see Task Report 8 in Glosten et al. (2018) for full analysis).

The authors focused on the environmental costs of implementing the network of treatment barges to enable vessels to comply with the interim California Performance Standards in comparison to the environment costs of vessels using BWMS to comply with the federal performance standards.

> While meeting these more stringent CA discharge standards has environmental benefits in terms of reducing threats from marine bio-invasions there are some environmental costs associated with meeting them. Specifically, the on-shore treatment plants/barges require twenty times the footprint and six times the power of current shipboard treatment plants that are only certified to meet the federal discharge standard. To some extent, therefore, employing shore-based treatment approaches that can meet more stringent CA discharge standards involves trading off one impact, reduction in potential aquatic invasive species introductions, for another, increased air pollution from larger treatment plants.

In other words, the stricter the ballast water discharge performance standard, the more energy required to power the treatment methods (e.g., UV irradiation, electrolysis) and the more air emissions generated in the process. Glosten et al. (2018) summarized this relationship in Figure 2.

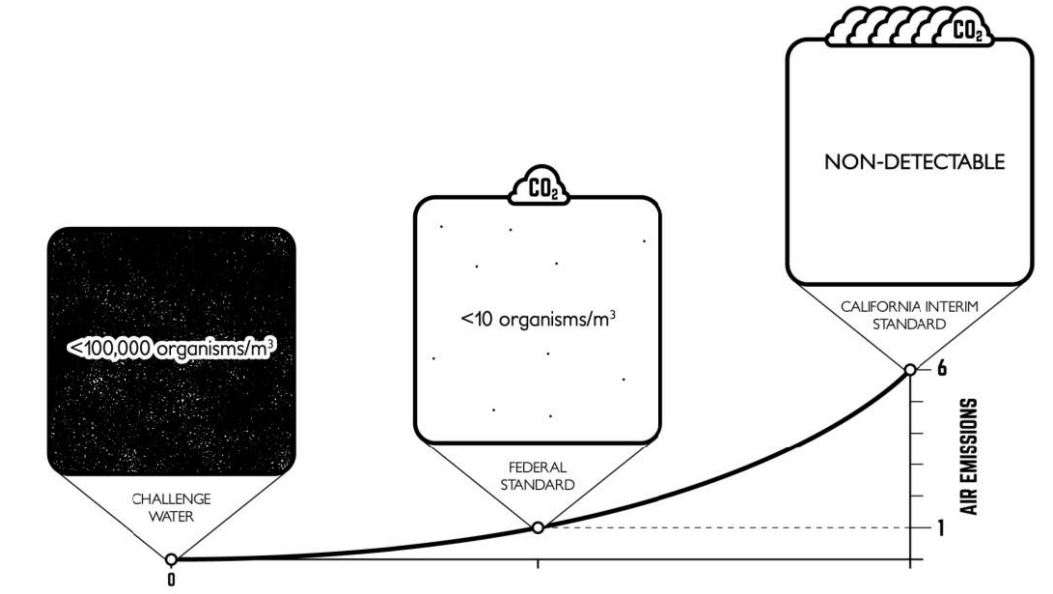

Figure 2. Increasing levels of organism reduction require increasing levels of energy which equates to air emissions (taken from Glosten et al. (2018))

Glosten et al. (2018) estimated that implementation of a network of treatment barges would increase harbor craft emissions in the South Coast Air Basin (including the Ports of Los Angeles and Long Beach and the El Segundo offshore marine oil terminal) by 2.6% to 5.1% (Table 21). The authors note that "some future considerations might relieve these estimates, including: use of alternative fuels such as LNG, decreases in treatment plant energy based on prototype trials, and scheduling of barge movements to reduce tug shifting distances."

Table 21. Contribution of shore-based ballast treatment to South Coast Air Basin Harbor Craft Emissions (taken from Glosten et al. (2018))

		CO	NOx+HC	PM
Tier III Engines	(gram/kW-hr)	5	5.8	0.14
Estimated Emissions				
Harbor craft, total	(MT)	486.6	828.5	26.7
Shore-based ballast treatment	(MT)	24.80	28.77	0.69
Contribution	***(%)***	***5.10%***	***3.47%***	***2.60%***

CO = Carbon monoxide
HC = Hydrocarbon
NOx = Nitrogen oxides
PM = Particulate matter

Port emissions may also increase due to port congestion from the additional tugs and barges needed to receive and process ballast water.

> Implementation of barge-based ballast water management from a network of treatment barges will increase the tug/barge traffic at California ports and would be expected to increase congestion in the busiest ports. This could happen in a myriad of ways. First, there will be tugs deploying and retrieving the fleet of ballast water treatment barges among the vessels requiring ballast water management services in the various harbors. It is anticipated that the tugs will not stand by the treatment barges during operations, but drop them off and then return for the barges upon completion of ballast water treatment operations. In areas such as San Francisco Bay and Port of Los Angeles/Port of Long Beach, with multiple ballast water discharge events per day, this will result in a significant increase in port traffic, which may lead to an increase in port congestion.

The authors did not discuss potential environmental impacts associated with the ballast water treatment process itself (i.e., potential chemical residuals in the discharged ballast water because of chemical disinfection). All of these environmental impacts will need to

be further analyzed in cooperation with the State Water Resources Control Board and the Air Resources Board to ensure that any treated ballast water discharges and associated air emissions are within allowable limits.

Economics

The economics of shore-based ballast water treatment is closely linked to the concept of availability. Glosten et al (2018) reviewed the economic feasibility of implementing a shore-based network of treatment barges to enable vessels to meet the interim California Performance Standards (see Task Report 12 in Glosten et al (2018) for full analysis):

> The 30-year lifecycle cost of building and operating a network of ballast water treatment barges capable of treating all ballast water discharged into California waters is estimated at $1.45 billion. Marine vessel operators will bear an additional $2.17 billion in costs to retrofit with the new transfer stations [ship-to-barge connections] along with undetermined labor costs to support the transfer operations.

These costs have market implications for the fleet of vessels operating in California:

> These costs are likely to be concentrated on a small percentage of marine vessels, have the largest impact on cargo exports, and disproportionately impact remote and low volume ports within California. As an example, under port-specific break-even pricing assumptions, a dry bulk carrier taking on grain exports in Stockton would need to pay an estimated $120,000 to offload its ballast water. This additional expense would be passed on directly to cargo exporters in California and points east, potentially diverting cargo to other California or non-California ports, or potentially rendering it non-economical to ship certain agricultural and other price- sensitive products. Avoiding such impacts would require establishing policies such as price-sharing or cost-sharing across all California ports.

It is important to note, however, that Glosten et al. (2018) analyzed only the cost-side of the cost-benefit balance. The costs of the investigated approach discussed in Glosten et al. (2018) would be borne by the shipping industry and potentially passed on to consumers. However, the costs to implement the suggested approach compared to the added benefit of improved prevention of species introductions was not investigated.

VI. WHY TREATMENT TECHNOLOGIES ARE NOT AVAILABLE

Commission staff has determined in its review that BWMS, BWE plus BWT, and shore-based ballast water treatment technologies are not available to enable vessels to meet the interim California Performance Standards (see Section V. Review of Ballast Water Treatment Technology Efficacy, Availability, and Environmental Impacts) by the 2020 implementation date. Per Public Resources Code section 71205.3, Commission staff assessed why these technologies are unavailable. The following section highlights some of the key reasons and challenges affecting the availability of BWMS, BWE plus BWT, and shore-based ballast water treatment technology and the Commission's review of ballast water treatment efficacy.

BWMS

Shipboard ballast water management systems are not available to meet the interim California Performance Standards because:

1) No BWMS has demonstrated efficacy for all the interim California Performance Standards based on the best available data.
2) Technology manufacturers are not testing their systems for the ability to meet the interim California Performance Standards.

These reasons are explained in greater detail below.

1) *No BWMS has demonstrated efficacy for all the interim California Performance Standards based on the best available data.*

For this review, Commission staff received ballast water treatment system performance data for 15 BWMS from ballast water treatment technology manufactures and USCG-approved Independent Laboratories. These land-based and shipboard testing data show that BWMS do not meet the interim California Performance Standards for the following organism size classes:

- Organisms greater than 50µm in minimum dimension – At least one living organism in this size class was detected in at least one shipboard and land-based test for each BWMS reviewed.
- Organisms 10-50 µm in minimum dimension – The available data show that all systems failed to meet the interim California Performance Standard for organisms 10-50 µm in minimum dimension.

BWMS were able to meet the interim California Performance Standards for *E. coli*, intestinal enterococci, and *Vibrio cholerae*, but a BWMS must be able to meet all the interim California Performance Standards. None did so.

2) *Technology manufacturers are not testing their systems for the ability to meet the interim California Performance Standards*

One of the reasons that BWMS are not available to meet the California Performance Standards involves the federal regulation of equipment on board vessels engaged in interstate commerce.

Vessels will be allowed to use a BWMS to comply with the interim California Performance Standards once they are implemented. However, California cannot require BWMS to be installed and operated on board a vessel because the Supreme Court of the United States has held that federal law (46 U.S.C. § 3703) preempts state regulation of the "the design, construction, alteration, repair, maintenance, operation, equipping, personnel qualification, and manning of [vessels]." (*United States v. Locke* (2000) 529 U.S. 89, 111.)

Because states cannot require BWMS to be installed and used, and to avoid conflicts with federal law, California set ballast water discharge performance standards to protect California waters from vessel-mediated NIS introductions. Vessel owners may select the ballast water management method, including shipboard or shore-based technology, that is appropriate for each vessel to meet the California Performance Standards.

An additional challenge from a state regulation perspective is that vessels must use a USCG type-approved BWMS to manage ballast water prior to discharge in U.S. waters. The USCG codified the process for approving BWMS in 46 C.F.R. section 162.060. This detailed type-approval process evaluates the ability of a BWMS to achieve the U.S. federal standards (see Table 1 for list of standards). However, the USCG type-approval testing process does not assess if a BWMS can meet the California Performance Standards because the US federal standards are less stringent than the California Performance Standards.

Because California cannot require the installation of BWMS on board a vessel and the USCG requires vessels to use a USCG type-approved BWMS, there is no incentive for BWMS manufacturers to test the ability of their BWMS to meet the California Performance Standards. To date, Commission staff knows of no BWMS manufacturer that has tested the ability of their BWMS to meet the interim California Performance Standards in shore-based or shipboard evaluations.

In summary, California and other states are limited in their ability to implement stricter ballast water discharge standards.

- The States cannot require vessel owners to install specific equipment, including BWMS, on board their vessels to comply with state law.
- Once subject to the federal ballast water discharge standards, vessels must use USCG type-approved BWMS to discharge ballast in U.S. waters.
- The USCG standards are less strict than the California Performance Standards, and the USCG type-approval-testing process does not adequately address all the California Performance standards (e.g., total living bacteria and viruses).
- Shipboard ballast water management system manufacturers are not conducting land-based or shipboard evaluations of BWMS that address any standard stricter than the USCG ballast water discharge standards.
- California does not have adequate data to evaluate the ability of a BWMS to meet the stricter standard.

Ballast Water Exchange plus Ballast Water Treatment
While BWE plus BWT is a management option that is required in some jurisdictions, it cannot be considered available to meet the interim California Performance Standards because there is limited data on its efficacy and environmental impacts.

California also faces regulatory hurdles to implement BWE plus BWT. As previously mentioned, California cannot require vessels to install and use a BWMS. If California wishes to implement BWE plus BWT, the state would need to take a similar approach to Oregon and require vessels to meet a ballast water discharge standard in addition to requiring vessels to exchange ballast water.

Finally, the Commission would need to amend the ballast water management requirements through the rulemaking process and adopt the requirement for vessels to conduct exchange in addition to meeting a ballast water discharge performance standard. As part of any rulemaking, the Commission would need to provide public notice about the rulemaking, discuss the efficacy of BWE plus BWT, and address stakeholder concerns about feasibility and safety.

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 anywhere else in the U.S. Commission staff 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 BWMS as the preferred method to enable vessel compliance with applicable 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 recognized that shore-based treatment may be an important tool for vessels to comply with the California Performance Standards.

As a result, in 2013, the Commission provided funding for a study that examined the feasibility of shore-based ballast water treatment facilities for use as an option to prevent NIS introductions from ballast water discharges.

The study was completed in April 2018. A summary of the components of the report is available in Section V of this report. Although the study is complete, a shore-based option will not be available for vessels by 2020, the date the interim California Performance Standards are scheduled to be implemented.

Additional Challenges to Implementing the California Performance Standards
The Commission also continues to face challenges in assessing the ability of ballast water treatment technologies to meet the interim California Performance Standards because there are no suitable methods to analyze ballast water samples for some of the California Performance Standards, including:

- Organisms 10-50µm in minimum dimension
- Total living bacteria
- Total living viruses

Organisms 10 – 50 µm *in Minimum Dimension*
The interim California Performance Standard for organisms 10-50 µm in minimum dimension is less than 0.01 living organisms per milliliter of discharged ballast water (i.e., 1 organism per 100 ml of discharged ballast water). 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 BWMS with data available for review failed to meet the California performance standard for this organism size class at least once during testing (see Tables 6 and 7). 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 Performance 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 test results needs to provide confidence that systems can treat water to the organism concentration in the interim 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, BWMS cannot be reviewed for efficacy with this standard.

Total Living Bacteria
The interim California Performance Standard for total living bacteria is less than 1,000 living bacteria per 100 ml. The only available, practical, and reliable means of determining that a bacterium is alive is to grow it in a laboratory (i.e., to culture it). Unfortunately, less than 10% of all bacteria species can be grown in laboratories (i.e., the culturable heterotrophic bacteria) (Azam et al. 1983, Hobbie et al. 1977).
It is not possible to prove that a treatment system can meet this interim California Performance Standard because there are no available methods to analyze ballast water samples for “total living bacteria.”

Total Living Viruses
The interim California Performance Standard for total living viruses is less than 10,000 living viruses per 100 ml. Because of a lack of analytical methods for this organism size class, the Commission funded a study by Michigan State University to assess all available techniques for detecting and enumerating viruses. In the literature review of the study, the investigators did not find any methods that can detect and enumerate total living viruses.

The Michigan State University study examined four methods of analysis on four specific viruses that can be concentrated and enumerated. Although the study showed success in concentrating and enumerating these four viruses, concentrating and enumerating all living viruses in a ballast water sample is impractical. Separate concentration and

enumeration techniques are necessary for each specific virus, and it is impractical and currently impossible to know all the viruses that may be present in a ballast water sample.

Therefore, “total living viruses” cannot be quantified by existing methods and Commission staff cannot assess the ability of treatment technologies to meet this performance standard.

VII. CONCLUSIONS

In 2015, following the recommendation of the Commission, the California Legislature amended the Marine Invasive Species Act (Chapter 644, Statutes of 2015) and delayed implementation of the interim California Performance Standards until January 1, 2020, due to a lack of available ballast water treatment technologies to meet the interim California Performance Standards.

As of August 2018, there are still no BWMS, combination of ballast water management methods, or shore-based ballast water treatment technologies available for vessels to meet the interim California Performance Standards.

Challenges to Implementing the California Performance Standards

An impediment to the Commission implementation of the interim California Performance Standards is the lack of suitable methods to analyze ballast water samples for some of the California Performance Standards, including:

- Organisms between 10µm and 50µm in minimum dimension
- Total living bacteria
- Total living viruses

For organisms between 10µm and 50µm in minimum dimension, there are no practical methods that can be used to analyze samples in the timeframe necessary to limit organism mortality. For total living bacteria and total living viruses, there are no methods to assess the concentration of all living organisms in these size classes in discharged ballast water.

The Commission will remain unable to determine if any ballast water treatment technologies can meet these California Performance Standards unless there are forthcoming scientific breakthroughs on methods to assess the concentration of all living organisms for these size classes.

Shipboard Ballast Water Management System

Evaluating the biological efficacy of BWMS continues to be challenging. The USCG BWMS type-approval process - the most detailed evaluation protocol in the world - was developed to determine the ability of BWMS to meet the USCG discharge standards, not the California Performance Standards. The USCG type-approval protocols do not:

- Evaluate BWMS performance for treating total living bacteria and total living viruses

- Evaluate BWMS performance for treating living organisms 10-50 µm in minimum dimension with adequate levels of statistical confidence to determine efficacy to the interim California Performance Standard

Furthermore, the USCG has refused to release the test data for USCG-approved BWMS. This hinders the public's ability to confirm that BWMS can meet the federal discharge standards and Commission staff's ability to assess if BWMS can meet any standard stricter than the federal standards.

Commission staff was provided with USCG type-approval testing data for 15 BWMS from manufacturers and USCG-approved Independent Laboratories. These data were anonymized and grouped into general performance categories. The data enabled Commission staff to sufficiently evaluate shipboard technology and determine that BWMS cannot meet the interim California Performance Standards.

Ballast Water Exchange plus Ballast Water Treatment

The Commission has very limited evidence that BWE plus BWT can enable vessels to meet the interim California Performance Standards. However, existing data demonstrate that BWE plus BWT is a ballast water management approach that:

- Has been shown to be considerably more effective than BWT alone
- Provides water quality benefits over BWT alone, as exchange flushes ballast tanks of polluted water sourced from other ports

Additionally, BWE plus BWT is a ballast water management method that is currently required in some jurisdictions (e.g., Oregon, Great Lakes). The Commission is planning a study to address questions related to the efficacy and environmental effects of BWE plus BWT.

Shore-Based Ballast Water Reception and Treatment Facilities

There are currently no shore-based ballast water reception and treatment facilities in California to enable vessels to comply with the interim California Performance Standards.

In 2013, the Commission funded a study to assess the feasibility of shore-based ballast water treatment in California. The study by Glosten et al (2018) was finalized in April 2018 and currently provides the most comprehensive review of shore-based treatment options in California. The authors concluded that a network of treatment barges would be the best approach to enable vessels to meet the interim California Performance

Standards. They estimated that it will take a minimum of nine years to implement such a treatment network once the funding is secured.

If the Commission, with support of the Legislature, pursues implementation of this barge-based treatment network, per Glosten et al. (2018), the next steps would be:

- Identify a shore-based treatment system technology through a pilot study. The pilot study would test various treatment system types for ability to treat ballast water.
- Perform a demonstration project that includes one large and one small treatment barge and at least one low- and one high-transfer-rate marine vessel modification. The project would develop and demonstrate hardware and procedures for making the barge-ship connections, assess the efficacy and costs of the barge treatment plant, and evaluate the barge effluent characteristics.
- Secure permits for the operation of the planned barge network, including study and characterization of the ballast water effluent and solids disposal.
- Develop a ballast water transfer station standard [i.e., the ship-to-barge connection]. This might include coordination with the International Standards Institute so that vessels may use the same connection in other ports, should other locations also implement this practice.
- Establish requirements and timeline for marine vessels that will discharge ballast water in California to be outfitted with compliant ballast water transfer stations. Such modifications are only practical during a ship's drydocking period, which are typically on a five-year schedule. As such, it will take at least five years from implementation for all vessels to achieve such connections.
- Establish a public-private partnership model to incentivize one or more commercial entities to build and operate a network of treatment barges. This should include close interaction with port facilities on issues of berthing and servicing these barges. This should revisit the zoning of the barges to find an optimal solution.

VIII. RECOMMENDATIONS

Based on the information presented in this report, the Commission recommends that the California Legislature review the existing California Performance Standards and consider alternative, feasible options to expeditiously move the state toward a reduction in the risk of species introductions from the ballast water vector.

Specific recommendations include:

1. Change the interim California Performance Standards to the USCG ballast water discharge standards set forth in 33 CFR section 151.2030 with the associated implementation schedule; AND

2. Preserve the Commission's authority to adopt regulations that will require vessels that use a BWMS to also exchange ballast water prior to discharge.

   Recommendations 1 and 2 are the most expedient approach to implementing protective ballast water discharge performance standards in California. This approach takes advantage of the fact that the USCG discharge standards are already implemented, and most vessels that operate and discharge ballast water in U.S. waters must install USCG-approved BWMS.

   The Commission will use its rulemaking authority to amend the ballast water management regulations to require vessels that use a BWMS to meet the discharge standards to also exchange ballast water prior to discharge. Based on existing research (Briski et al. 2015, Paolucci et al. 2017), the combination of BWE plus BWT will likely achieve higher levels of protection for state waters than through BWT alone. As part of the rulemaking process, Commission staff will address stakeholder concerns about the feasibility and safety of this approach.

3. Amend Public Resources Code section 71206(a) to enable Commission staff to sample ballast water and biofouling for research purposes in addition to compliance.

   Per Public Resources Code section 71206(a), Commission staff may take samples of ballast water and sediments only to assess compliance with the Marine Invasive Species Act. The Commission is not authorized to take ballast water samples for research purposes, which limits the ability of the Commission to collect valuable information about BWMS performance.

   Worldwide, there is a lack of available data on the real-world performance of BWMS. Most of the Commission's knowledge about BWMS performance comes

from prescribed performance tests that do not always reflect the variety of biological, chemical, and physical conditions of vessels' ballast tanks as they travel around the world. This data gap could partially be addressed by authorizing the Commission to sample any vessel subject to the Marine Invasive Species Act for any parameters determined to be appropriate to assess the nature of ballast water discharges.

This recommendation would specifically address the Commission's authority to sample ballast water during the period between statutory adoption of the USCG performance standards and the date that vessels are required to comply with those standards. Some vessels currently have extensions to compliance with the USCG performance standards, and those vessels may not be subject to the discharge standards for several years. If the research sampling recommendation is approved by the Legislature, Commission staff could begin sampling treated discharged ballast water immediately, instead of having to wait multiple years before having the authority to sample for compliance purposes. This data is critical to assess the real-world operational capabilities of BWMS.

After staff has a data set on the efficacy of BWMS treatment alone and BWE plus BWT, staff will convene a technical advisory panel to review the new data and recommend new ballast water discharge standards and an implementation schedule to the Legislature through the process in recommendations 4, 5, and 6 below.

4. Amend Public Resources Code section 71204.9(b)(1) to add the California Air Resources Board to the list of entities that must participate in the technical advisory panel as part of the development of the performance standards report; AND

5. Amend Public Resources Code section 71204.9(a)(1) and change the date that the report listed in 71204.9(a)(1) is due to the Legislature to July 1, 2025; AND

6. Amend Public Resources Code section 71204.9(b)(4) and require the technical advisory panel to submit recommendations to the Commission on or before December 30, 2024.

Recommendations 4,5, and 6 work together and would require the Commission to produce a new report to the Legislature by July 1, 2025, evaluating California's ballast water discharge performance standards. The report to the Legislature would include:

- Recommendations for achievable and measurable ballast water discharge performance standards
- A determination on whether to continue to require BWE plus BWT
- A determination on whether to proceed with requiring shore-based ballast water reception and treatment based on the results of forthcoming pilot studies (see below for further information)

The results of the shore-based pilot study combined with the BWE plus BWT data and new data on the efficacy of BWMS will be used to determine the most feasible ballast water management approach that will move the state expeditiously towards the elimination of the discharge of NIS.

The Commission also intends to take the following actions based on existing authority:

1. Issue a request for proposals for a pilot project to test barge-based ballast water reception and treatment.

   In line with recommendations from the Technical Advisory Panel for this report and based on Glosten et al. (2018), the next step toward implementation of a shore-based ballast water treatment option is to conduct a pilot study. The Commission receives funds from the Marine Invasive Species Control Fund each year to support research, and Public Resources Code section 71210 specifically calls upon the Commission, in consultation with the Water Board, the USCG, and stakeholders, to sponsor pilot programs to evaluate alternatives for treating or otherwise managing ballast water. The Commission will work with the identified agencies and stakeholders to guide the development of a request for proposals and to seek partners to engage in this important project.

2. Fund a project to test the effectiveness of BWE plus BWT compared to BWT alone.

   Commission staff are working closely with the Golden Bear Research Center at the California State University Maritime Academy to develop a sampling plan for evaluation of the efficacy of BWE plus BWT. The Commission will review this project for funding in late 2018 or early 2019.

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APPENDIX 1

List of USCG Type Approved ballast water management systems as of 26 October 2018.
https://www.dco.uscg.mil/Portals/9/MSC/BWMS/BWMS_Approval_Status_26OCT18.pdf

Initial Application Received	Manufacturer (Country)	Model	Independent Lab	System Type	Capacity	Certificate Issued* (Amended)
20 Sep 2016	Optimarin (Norway)	OBS/OBS Ex	DNV GL	Filtration + UV	167 – 3,000 m3/h	02 Dec 2016 (03 Nov 2017)
21 Sep 2016	Alfa Laval (Sweden)	Pure Ballast 3	DNV GL	Filtration + UV	150 – 3,000 m3/h	23 Dec 2016 (21 Dec 2017)
23 Sep 2016	TeamTec OceanSaver AS (Norway)	OceanSaver MK II	DNV GL	Filtration + Electrodialysis	200 – 7,200 m3/h	23 Dec 2016 (18 Oct 2017)
24 Jan 2017	Sunrui (China)	BalClor	DNV GL	Filtration + Electrolysis	50 – 8,500 m3/h	06 Jun 2017 (05 Jan 2018)
31 Mar 2017	Ecochlor, Inc. (USA)	Ecochlor BWTS	DNV GL	Filtration + Chemical Injection	500 – 16,200 m3/h	10 Aug 2017 (26 Apr 2018)
02 May 2017	Erma First (Greece)	Erma First FIT	Lloyds Register	Filtration + Electrolysis	100 – 3,740 m^3/h	18 Oct 2017
31 Oct 2017	Techcross, Inc. (Republic of Korea)	Electro-Cleen	Korean Register	Electrolysis	150 – 12,000 m^3/h	05 Jun 2018
28 Sep 2017	Samsung Heavy Industries Co.,	Purimar	Korean Register	Filtration + Electrolysis	250 – 10,000 m3/h	15 Jun 2018 (20 Jul 2018)
12 Mar 2018	BIO-UV Group (France)	BIO-SEA B	DNV GL	Filtration + UV	55 – 1,400 m^3/h	20 Jun 2018
09 Apr 2018	Wärtsilä Water Systems, Ltd.	Aquarius EC	DNV GL	Filtration + Electrolysis	250 – 4,000 m^3/h	30 Aug 2018
31 May 2018	Hyundai Heavy Industries Co.,	HiBallast	DNV GL	Filtration + Electrolysis	75 – 10,000 m^3/h	26 Oct 2018

*Some manufacturers have requested multiple amendments to their Type Approval Certificates. The first date is the date when the original certificate was issued, and the date in parentheses is the date of the current amendment. Copies of Type Approval Certificates can be found at http://www.dco.uscg.mil/msc/Ballast-Water/TACs/, or by visiting the USCG Approved Equipment List at: http://cgmix.uscg.mil/Equipment/Default.

List of ballast water management systems that are under review by USCG as of 26 October 2018.
https://www.dco.uscg.mil/Portals/9/MSC/BWMS/BWMS_Approval_Status_26OCT18.pdf

Under Review						
Application Received	**Manufacturer (Country)**	**Model**	**Independent Laboratory**	**System Type**	**Capacity**	**Certificate Issued* (Amended)**
03 Mar 2018	De Nora (USA)	BALPURE	Lloyd's Register	Filtration + Electrolysis	400 – 7,500 m^3/h	Pending
16 Mar 2018	Alfa Laval (Sweden)	PureBallast 3	DNV GL	Filtration + Ultraviolet	150 – 3,000 m_3/h	23 Dec 2016 (21 Dec 2017)
22 Mar 2018	Optimarin (Norway)	OBS/OBS Ex	DNV GL	Filtration + Ultraviolet	167 – 3,000 m_3/h	02 Dec 2016 (03 Nov 2017)
29 Mar 2018	JFE Engineering Corporation (Japan)	BallastAce	Control Union	Filtration + Chemical Dosing	500 – 3,500 m^3/h	Pending
30 Mar 2018	Panasia Co., Ltd. (Republic of Korea)	GloEn-Patrol	DNV GL	Filtration + Ultraviolet	50 – 6,000 m^3/h	Pending
09 May 2018	Headway Technology Co., Ltd. (People's Republic of China)	OceanGuard	DNV GL	Filtration + Electrolysis	65 – 5,200 m^3/h	Pending
20 Jul 2018	Envirocleanse, LLC (USA)	inTank	DNV GL	Electrolysis + Chemical Injection	Up to 200,000 m^3	Pending
30 Aug 2018	NK BMS Co., Ltd. (Republic of Korea)	NK-O3 BlueBallast II	Lloyd's Register	Ozone	200 – 8,000 m^3/h	Pending
27 Sep 2018	NK BMS Co., Ltd. (Republic of Korea)	NK-O3 Blue-Ballast II Plus	Lloyd's Register	Ozone	200 – 8,000 m^3/h	Pending
18 Oct 2018	DESMI Ocean Guard A/S (Denmark)	CompactClean	Lloyd's Register	Filtration + Ultraviolet	135 – 1,500 m^3/h	Pending

*Some manufacturers have requested multiple amendments to their Type Approval Certificates. The first date is the date when the original certificate was issued, and the date in parentheses is the date of the current amendment. Copies of Type Approval Certificates can be found at http://www.dco.uscg.mil/msc/Ballast-Water/TACs/, or by visiting the USCG Approved Equipment List at: http://cgmix.uscg.mil/Equipment/Default.aspx

Appendix 2

Technical Advisory Panel Meeting Notes

Date: 12 Sept 2018 **Location:** Hercules, CA

Participants:

John Berge – Pacific Merchant Shipping Association
Jon Stewart - Maritime Advisors
Lorna McFarlane – State Water Resources Control Board
Sienna Courter – San Francisco Bay Keeper
Lisa Swanson – Matson Navigation
Satu Tari – Matson Navigation
Chris Brown – California State University, Maritime Academy
Jackson Gross – UC Davis
Gary Gersten - Washington Department of Fish and Wildlife
Lee Kindberg - Maersk
Sharon Shiba – California Department of Fish and Wildlife
Tim Schott – California Association of Port Authorities
Elizabeth Hackley – Royal Caribbean
Nick Welschmeyer – Moss Landing Marine Laboratories
Sande George – Cruise Lines International Association
Jack Faulk – U.S. Environmental Protection Agency
Spencer Schilling – Herbert Engineering
Kevin Reynolds – Glosten Associates
Richard Everett – U.S. Coast Guard

Topics and Notes

1) **Summary of report**

- Shipboard technology:
    - Based on reviewed data, ballast water management systems (BWMS) did meet California (CA) standards for the indicator bacteria species (*E. coli*, intestinal enterococci, *Vibrio cholerae*)
    - For total living bacteria, there is no data to analyze and no method to quantify.
    - Data reviewed for greater than 50 and 10-50 micron size classes showed that systems did not meet the CA performance standards.
    - Jon Steward (JS): frustration for not getting data from USCG is general, lack of transparency. All the requests have been denied, not just the Commission's.

    - John Berge (JB): from summary data, do you feel confident that the conclusions are representative of the rest of the systems that you may not have data for?
    - Jonathan Thompson (JT)/Nicole Dobroski (ND): from the combination of data, we think we have a comprehensive data set and we think the results are representative.
    - JS: Data showed in the report covers most of the methods of treatment. I think the methods are well represented to get to a conclusion.
    - Chris Brown (CB): Data from the 9 USCG type-approved systems are not necessarily included in the 15 systems reviewed in the report.
    - JB: This is a snapshot of the status now.
    - Jackson Gross (JG): Can you differentiate between marine vs freshwater tests? It could be interesting for people that have specific questions.
    - JT: We can show the results separated by salinity as an appendix or provide information as requested.
    - Sienna Courter (SC): Any data from the EPA annual reports? EPA gave us data on the indicator species.
    - JB: Do you intend to include a volumetric requirement for the standards? ND/JT: needs to be discussed
- Why shipboard technology is not available:
    - Tech manufacturers are not testing the ability of their systems to meet CA standards. We have no data specific to CA standards.
    - JS: This is an important topic and needs to be highlighted in the report. It is a continuing impediment to meet the CA standards.
    - Rich Everett (RE): That is a consequence of lack of support to evaluate systems to meet treatment levels beyond the federal standards. No financial incentive to do it. There is nothing comparable to what was done for the Clean Water Act. Suggest identifying this issue as a major impediment in the report.
    - ND: MISP has a $6M total budget, only $300K for research, not nearly enough to support testing to the CA standards.
    - JG: The data reviewed in the report shows that most of the systems won't even pass the IMO standards. To clearly see this, it would be useful to show data by treatment system in all size classes side by side.
    - System manufacturers want to reach maximum capability. The challenge is to find the equilibrium with space, energy, waste products, testing time. The problem is not that the manufacturers don't want to reach maximum capacity, but the challenges and restrictions associated with the construction and practical use of the systems.
    - JS: The methods of analysis to test for a higher standard don't exist practically speaking. Even if a vendor can build it, there is no testing capacity. The report needs to be clear that there is more than one obstacle.

    - ND: We can say if the water is not compliant, but we can't say if the system can meet standards.
    - Sharon Shiba (SS): Why were the standards adopted in the first place? ND responded with history.
    - JS: Some manufacturers at the time said they could meet the standards.
    - Lisa Swanson (LS): The standards that can't be meet should be removed.
    - Lorna McFarlane (LM): Similar issue at the Water Board with toxicity testing (standards below limit of detection).
- Shore-based treatment:
    - No facilities available
    - JS: 9 years for implementation assuming conceptual design actually meets the standard.
    - Lee Kindberg (LK): How to determine the number or barges? And how to deal with small ports?
    - Kevin Reynolds (KR): locate the barges in key locations and analyzing past data. Trying to cover 99% of ballast discharge based on probability.
    - LK: What about space availability? In some locations you need to use a hybrid system.
    - JS: Consider economic impact to the industry at the moment to make a recommendation. Duplicate costs when vessels have to meet CA and federal standards.
    - KR: Economic impact is well detailed in the final shore-based report.
    - Shore-based is not an option for the interim standards implementation on January 1, 2020.

2) Recommendations:

- Recommendation 1:
    - RE: Statement 1st recommendation (exchange plus treatment) is not necessarily true.
    - LS: Thinks exchange plus treatment is a big request for the industry. Some vessels can't plan in advance if they are going to discharge ballast and they already invested in a BWMS.
    - JS: Is there any data to supports that both ballast water exchange (BWE) and treatment is better?
    - TAG requests greater discussion about why the Commission is making the recommendation for BWE plus treatment.
    - JS: Some new vessels are not designed to do exchange.
    - ND: Can you provide us some info to back up that?
    - KR: Strong endorsement of recommendation 1. Technology is available, implementing and enforcing will be very protective, much more than stringent standards. Ocean water is really easy to treat, more than murky

(estuarine) water. Not much information on practicality of BWE plus treatment, however a lot of data support efficacy.
    - Nick Welschmeyer (NW): Strongly support recommendation 1, waiting for this to happen since 2004. Suggest splitting recommendation 1 in 2 and remove recommendations to delay implementation of other standards.
    - Spencer Schilling: Safety could be an issue.
    - JS: re Safety: BWE is not going to be as normal anymore since is not going to be required internationally, so that lead to lack of training and it may become a huge safety issue.
    - ND: Implementation schedule: according to USCG all vessels are subject now. How to track CG extensions?
    - JB: Suggest making the recommendations broader and less specific before putting them in statute.
    - SC: Emphasize more the results of the 2 studies cited regarding the efficacy of the use of both BWE and treatment together.
    - JT: What will it look like if CA follows the USCG schedule?
- Recommendation 2:
    - JT: Clarify the implementation dates regarding recommendation 1. Do we want to reevaluate the standards instead of delaying them?
    - JS: It may be a good idea to include in this recommendation that if in the next review the standards cannot be met, the standards need to be changed.
    - LS: Why don't we change the standards now?
    - KR: if we want to get there (the existing interim CA standards) in 2030, we have to start now. With the current technology and no incentives, we will have same results then as now.
    - JB: We need more definitive answers/studies about the risks to justify keeping the current standards.
    - JS: How is the state is going to enforce? No standardized methods to test compliance. For smaller size classes, already existing EPA approved tests but no current methods exist to test compliance for the other size classes.
- Recommendation 5:
    - Include that this is part of an international initiative to gather data.
    - CB: We need to work towards a standardized compliance assessment protocol.
- Recommendation 6:
    - Work on how to ensure low air emissions.

ND: Next steps – finalize report, present to the Commission for approval, and provide to Legislature.