2017 BIENNIAL REPORT

ON THE

C A L I F O R N I A
MARINE INVASIVE SPECIES PROGRAM

PRODUCED FOR THE
CALIFORNIA STATE LEGISLATURE

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EXECUTIVE SUMMARY

The California Marine Invasive Species Program (MISP) is a multi-agency program designed to prevent the introduction of nonindigenous species into State waters from vessels 300 gross registered tons and above that are capable of carrying ballast water. The MISP was established by the Ballast Water Management for Control of Nonindigenous Species Act of 1999 and reauthorized and expanded by the Marine Invasive Species Act (MISA) of 2003. The purpose of the MISP is to move the state expeditiously towards elimination of the discharge of nonindigenous species into California waters (Public Resources Code section 71201(d)).

The California State Lands Commission (Commission), charged with MISP oversight and administration, takes a multi-faceted approach to advancing program goals, including:

- Developing sound, science-based policies in consultation with technical experts and stakeholders
- Tracking and analyzing ballast water and vessel biofouling management practices of the California commercial vessel fleet
- Enforcing laws and regulations to prevent introductions of nonindigenous species
- Conducting and facilitating outreach to promote information exchange among scientists, regulators, the shipping industry, and other stakeholders

This report to the California Legislature on MISP activities between July 1, 2014 and June 30, 2016, fulfills the reporting mandates set forth in Public Resources Code sections 71210 and 71212.

Nonindigenous Species and Vectors of Introduction

Nonindigenous species (NIS) are transported to new environments, both intentionally and unintentionally, through human activities. Once established, NIS pose significant threats to human health, the economy, and the environment. Attempts to eradicate species after they become established are often unsuccessful and costly. Hence, prevention of species introductions through vector management is the most effective way to protect California waters.

Shipping is the major vector by which aquatic NIS are transported around the globe and is responsible for up to 79.5 percent of established aquatic NIS introductions in North America (Fofonoff et al. 2003a). Commercial ships transport organisms through ballast water and vessel biofouling. Ballast water is used by ships to maintain stability at sea. When ballast water is loaded in one port and discharged in another, the entrained organisms are introduced to new regions. Vessel biofouling consists of the organisms attached to or associated with submerged or wetted vessel surfaces. Biofouling organisms are introduced to a new environment when they fall off their “host” structure or release larvae in the water as they reproduce.

Vessel Arrival Statistics at California Ports

The Commission collects information from qualifying vessel[1] arrivals at California ports to track NIS management patterns and compliance with the Marine Invasive Species Act. All vessels are required to submit a reporting form to the Commission twenty-four hours in advance of an arrival at a California port. These reports provide specific information about a vessel’s ballast water capacity, voyage particulars, and the origin (i.e. source) and management of ballast water to be discharged in California. For the July 2014 - June 2016 reporting period, 96 percent of forms were submitted as required.

During the reporting period, there were 18,126 qualifying arrivals at California ports. The distribution of arrivals by port and by vessel type remains consistent with previous reporting periods (Falkner et al. 2009, Takata et al. 2011, Scianni et al. 2013, Dobroski et al. 2015). The Los Angeles-Long Beach port complex (LA-LB) receives nearly half (48 percent) of all statewide vessel arrivals. The predominate vessel type arriving at California ports is the container vessel, accounting for 43 percent of all arrivals during this reporting period. More than one-third of arrivals (38 percent) at California ports originated from other California ports (e.g. travelling from LA-LB to the Port of Oakland); 22 percent of arrivals reported a last port of call in Asia (predominantly China, Korea, and Japan).

Ballast Water Management

Since 2004, 84 percent of arrivals, on average, at California ports have reported retaining all ballast water on board (i.e. not discharging) while in California waters. Retention is the most protective ballast water management strategy available to prevent species introductions from the ballast water vector.

The remaining 16 percent of vessel arrivals reported ballast water discharge in State waters. The total volume of ballast water discharged in the State from July 1, 2014, to June 30, 2016, was 19.7 million metric tons (MMT). The first half of 2016 saw the lowest recorded volume of ballast water discharged over the previous 12 years – 3.1 MMT. This is in contrast to the previous reporting period (July 1, 2012 – June 30, 2014) when more than 6.9 MMT of ballast water were discharged in California during the first half of 2014 – more than in any six-month time period over the previous 12 years.

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[1] A qualifying vessel is defined in Public Resources Code sections 71200(q) and 71201(a) as a vessel 300 gross registered tons or more that is capable of carrying ballast water.

Of the 19.7 MMT of ballast water discharged in California, 19.0 MMT (96.4 percent) was managed in compliance with ballast water management requirements. The majority of the noncompliant ballast water discharged (556,000 metric tons (MT)) underwent ballast water exchange in the wrong location (e.g., the ballast water was exchanged at 150 nautical miles (NM) from land instead of the required 200 NM). Water that undergoes ballast water exchange, even if in the wrong location, may reduce the risk of NIS introductions. Water that does not undergo any type of management represents the highest risk for NIS introductions from ballast water. From July 2014 through June 2016, 20.6 percent of noncompliant discharges by volume (148,000 MT) fell into this highest risk category.

Since 2012, a total of 214 vessels arriving at California ports reported having a shipboard ballast water treatment system. Of these vessels, 38 reported using their ballast water treatment system to treat ballast water discharged in California.

Implementation of the California Ballast Water Discharge Performance Standards

The Commission report "2014 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Technology for Use in California Waters" (Commission 2014) concluded that there were no ballast water treatment technologies currently available to meet the California ballast water discharge standards. Based on this conclusion, the California Legislature adopted Assembly Bill (AB) 1312 (Chapter 644, Statutes of 2015), which delayed the implementation of both the interim and final ballast water discharge performance standards. The California interim ballast water discharge performance standards are currently scheduled for implementation on January 1, 2020. The final standard of no detectable living organisms in ballast water discharge is set for implementation on January 1, 2030 (Public Resources Code section 71205.3).

There remain several challenges at the international and federal levels that are impacting California's implementation of the ballast water discharge performance standards that are outside of the Commission's control.

The International Maritime Organization's (IMO) "International Convention for the Control and Management of Ship's Ballast Water and Sediments" (BWM Convention) was ratified in September 2016 and will enter into force in September 2017. However, a December 2015 report on the implementation of the IMO ballast water performance standards (see MEPC 2015) showed that there is much work to be done prior to implementation. The IMO G8 Guidelines for approval of ballast water treatment systems need to be updated, and the 56 models of ballast water treatment systems that were type-approved under the existing IMO G8 Guidelines may not be operating as effectively as expected (MEPC 2015).

The United States Coast Guard (USCG) has not, as of October 1, 2016, approved any ballast water treatment systems for use in U.S. federal waters to comply with USCG ballast water discharge regulations. The lack of USCG type-approved ballast water treatment systems continues to create uncertainty with both regulators and the regulated community about how vessels will comply with federal ballast water discharge performance standards already in effect. Furthermore, in 2016, the USCG released a report stating that it is not practicable for the USCG to adopt a more stringent ballast water discharge standard citing the lack of approved technologies to meet the existing U.S. federal discharge standard (USCG 2016).

The U.S. Environmental Protection Agency (EPA) also has regulatory authority over ballast water and other discharges incidental to normal vessel operations. In 2015, the United States Court of Appeals for the Second Circuit ruled that the EPA acted arbitrarily and capriciously in setting the ballast water management provisions in the 2013 Vessel General Permit (*Natural Resources Defense Council v. U.S. Environmental Protection Agency* (2nd Cir. 2015) 808 F.3d 556). The Court remanded to EPA with instructions to revise the existing permit. The existing 2013 Vessel General Permit will remain in place until such time that a revised permit is issued. Based on communication with EPA staff, a draft of the revised Vessel General Permit is expected in mid-2017.

Despite international and federal uncertainty about ballast water treatment system performance and approvals, the Commission continues to move forward with plans to implement the California ballast water discharge performance standards. The Commission is currently funding a study of the feasibility of using shore-based ballast water reception facilities to enable vessels to comply with the California standards. Commission staff is also funding the development of ballast water discharge sampling tools and developing compliance assessment protocols that will enable Commission staff to assess shipboard ballast water treatment system performance. Commission staff is also testing rapid assessment tools to give quick, indicative readings on the efficacy of treatment systems and vessel discharge compliance. However, the Commission currently lacks the statutory authority to collect ballast water discharge samples for research (i.e. non-enforcement) purposes to test assessment protocols.

Hull Husbandry and Operational Practices Reported by the Shipping Industry

Vessel biofouling is a significant vector of NIS introductions. The Commission has been collecting data on the hull husbandry and operational practices of vessels since 2008 to gather data to inform the development of biofouling management regulations. All vessels that arrive at California ports must submit the Hull Husbandry Reporting Form (HHRF) once each year. In 2014 and 2015, 94 percent of vessels were in compliance with HHRF submission requirements, the highest compliance rate for any two-year period to date.

Many vessels use antifouling coatings to prevent the accumulation of biofouling. Between 2008 and 2015, at least 81 percent of vessels reported having antifouling coatings that were less than three years old. Antifouling coatings typically have an effective lifespan of five years, so these data suggest that the majority of vessels arriving at California ports are using coatings within the effective lifespan to prevent species accumulation.

When preventive management of biofouling fails (i.e. antifouling coatings are not effective), vessel owners or operators may use reactive measures, including vessel in-water cleaning, to remove attached organisms. An average of only 16 vessels per year are cleaned in-water in the LA-LB region. Most of the cleanings are occurring more than three nautical miles from land (i.e. outside of state waters) due to the State Water Resources Control Board prohibition of in-water cleaning of vessels with copper-based coatings in waters that are impaired for copper (Barta, R., pers. comm. 2016).

Despite industry efforts to manage the accumulation of biofouling on the underwater surfaces of vessels, some vessel operational practices continue to change in a way that increases the risk of NIS introduction. Since the recession of 2007, vessels have been sitting idle for longer periods due to reduced trade and cargo transport and are reducing travel speeds (i.e. slow steaming) to increase fuel efficiency. The longer a vessel sits idle in one place, the higher likelihood that biofouling will accumulate. The number of vessels that reported remaining in one place for durations of ten days or greater has increased 77 percent from pre-recession (2008) to current (2015), although this trend may be slowing. Likewise, the slower a vessel travels through the water, the less likely accumulated biofouling will be knocked off the vessel from the force of the water drag. Vessels typically reduce travelling speed to increase fuel efficiency and save money on fuel. The mean reported traveling speed of vessels arriving at California ports has decreased from 16.0 knots in 2008 to 14.3 knots in 2015, further increasing the risk of species introductions in California.

Data from Cooperating Agencies

The MISP is supported solely by a vessel arrival fee. The Board of Equalization collects and deposits the fee in the Marine Invasive Species Control Fund; the MISP does not receive any general fund dollars. The current fee of $850 per qualifying voyage arrival has been in place since 2009. The fee may be adjusted through regulation (to a maximum of $1,000 plus adjustments for inflation) to account for program budgetary needs. In January 2016, Commission staff determined that revenues will not meet the costs of the MISP as of 2018. Commission staff has made efforts to map business processes and increase efficiency of operations, but revenues still do not meet costs. Therefore, Commission staff recently began a rulemaking to increase the fee.

The California Department of Fish and Wildlife's Marine Invasive Species Program (CDFW-MISP) conducts species monitoring in California coastal waters to assess the effectiveness of vessel vector management requirements. In 2014 and 2015, CDFW-MISP funded the sampling of sites in the San Francisco Bay-Delta, Port Hueneme, Marina Del Rey, and Humboldt Bay. Identification of species and preliminary data analysis are ongoing.

Threats to California's Regulation of Vessel Vectors

California's ability to protect state waters from NIS introductions by vessel vectors is threatened by proposed federal legislation to preempt states' authority. The Vessel Incidental Discharge Act would give the USCG sole authority over the development and implementation of ballast water management requirements, as well as over the regulation of all incidental vessel discharges, including ballast water and discharges associated with vessel in-water cleaning. The Vessel Incidental Discharge Act was introduced in 2014 but stalled. In February 2015, the Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard met to discuss the impacts of vessel discharge regulations on U.S. shipping and fishing industries. In April 2016, the House Transportation and Infrastructure Subcommittee heard testimony from the USCG discussing both the regulation of ballast water discharges and the methods of analysis to determine the effectiveness of ballast water treatment systems. As of October 2016, no legislation has passed. Passage of the Vessel Incidental Discharge Act could cripple the Marine Invasive Species Program's ability to prevent nonindigenous species introductions in California.

The Commission continues to work with state partners throughout the U.S. to voice concerns about legislation that eliminates states' ability to address NIS with state-specific solutions. California must retain authority to protect its unique state waters through the MISP's implementation of ballast water and biofouling management requirements, inspection of vessels, and enforcement of California law.

Next Steps

Over the next two years, Commission staff will be working on a number of regulatory packages and other projects aimed at increasing the effectiveness and efficiency of the MISP. Regulations in various stages of development are:

- Marine Invasive Species Act enforcement and hearings process
- Ballast water discharge compliance assessment protocols
- Biofouling management
- Marine Invasive Species Control Fund fee increase
- Ballast water management for vessels arriving at California ports from ports located outside of the Pacific Coast Region
- Establishing a process for the Commission to review ballast water reception facilities for approval

In addition, Commission staff will begin working on an updated report to the Legislature on the efficacy, availability, and environmental impacts of ballast water treatment technologies. The report is due July 1, 2018, not less than 18 months prior to the implementation of the California ballast water discharge performance standards on January 1, 2020.

Finally, there are concerns in the regulatory, scientific, and environmental communities that existing ballast water treatment systems may not be able to operate reliably and effectively in fresh water (Briski et al. 2015; see Section 8 in this report for more details). Because of this, several states in the Great Lakes region, as well as New York, Oregon, and Canada, are in various stages of proposing rules to require ballast water exchange in addition to ballast water treatment for vessels carrying freshwater ballast that will be discharged to freshwater. California has two important ports, Sacramento and Stockton, which are potentially vulnerable to the ineffectiveness of ballast water treatment systems in freshwater. Commission staff will research the feasibility of pursuing ballast water exchange in addition to whatever a vessel uses to meet ballast water performance standards (e.g. treatment) as a management strategy for vessels arriving at the Ports of Sacramento and Stockton with ballast water sourced from another freshwater port.

As part of these efforts, Commission staff will continue to use all available resources to work proactively to move the state expeditiously towards elimination of the discharge of nonindigenous species into California waters.

TABLE OF CONTENTS

1. PURPOSE

The California State Lands Commission (Commission) prepared this report for the California Legislature pursuant to Public Resources Code sections 71210 and 71212. According to statute, the report must be updated biennially and, at a minimum, include:

- A summary and analysis of ballast water management practices reported by the shipping industry
- A summary and analysis of vessel monitoring and inspection information, including compliance rates
- A summary of recent research addressing the release of nonindigenous species (NIS) by vessels
- A summary of Commission sponsored research and programs to evaluate alternatives for treating or otherwise managing ballast water
- An evaluation of the effectiveness of the California Marine Invasive Species Program (MISP)
- Recommendations to improve upon the effectiveness of the program

Since the inception of the MISP in 2000, the California Legislature has expanded the purview of the program to include, among other responsibilities, ballast water discharge performance standards and the regulation of vessel biofouling. The Commission has expanded the biennial report accordingly to include:

- An update on the implementation of the ballast water discharge performance standards
- A summary and analysis of biofouling management practices reported by vessels arriving at California ports
- A summary of Commission sponsored research to address biofouling science, management, and treatment

This eighth biennial report to the California Legislature summarizes MISP activities from July 1, 2014 through June 30, 2016.

2. INTRODUCTION

2.1 Nonindigenous Species

Nonindigenous species (NIS) are organisms that pose significant threats to human health, the economy, and the environment. Nonindigenous species are intentionally and unintentionally transported through human activities to new habitats, such as California's marine, estuarine, and freshwater environments. Once a NIS is moved, becomes established in a new in geographic location, and causes impacts, it is considered 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. Tens of millions of dollars have been spent on control and eradication of NIS in California to reduce their impacts, including:

- Over $7 million between 2000 and 2006 to eradicate the Mediterranean green seaweed (*Caulerpa taxifolia*) from two small embayments (Agua Hedionda Lagoon and Huntington Harbor) in southern California (Woodfield 2006)
- $30.5 million since 2000 to manage the Atlantic cordgrass (*Spartina alterniflora*) in the San Francisco Bay-Delta (Latta, M., pers. comm. 2016)
- Close to $24 million to control zebra and quagga mussels in California since the species were first detected in 2007 (Volkoff, M., pers. comm. 2016)

These costs represent only a fraction of the cumulative expenses related to NIS control, because eradication is rarely successful, and control is an unending process.

2.2 Vectors: How are Nonindigenous Species Moved?

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

- aquaculture (Grosholz et al. 2012)
- aquarium trade (Williams et al. 2012)
- commercial shipping (Fofonoff et al. 2003a)
- live bait (Fowler et al. 2015)
- live seafood trade (Chapman et al. 2003)
- marine debris (Barnes 2002)
- recreational vessels (Ashton et al. 2012)

Each of these vectors contributes to aquatic NIS introductions, but shipping is the primary vector transporting species around the globe. Commercial ships directly transport aquatic NIS through ballast water discharges and the release of vessel biofouling. Ballast water and vessel biofouling are responsible for or have contributed to 79.5% of established aquatic NIS introductions in North America (Fofonoff et al. 2003a) and 81% in California (Ruiz et al. 2011).

2.2.1 Ballast Water

Vessels use ballast water to improve and maintain stability, balance, and trim. Ballast water is typically picked up in one port and discharged in another to counter the changes in weight the vessel experiences as cargo is loaded and offloaded.

As vessels move around the world, they pick up species in ballast water from one port and discharge them in different ports. Prior to the implementation of ballast water management practices, it was estimated that more than 7,000 species were moved around the world on a daily basis 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).

2.2.2 Vessel Biofouling

Vessel biofouling refers to an organism or a community of organisms that are attached to, or associated with, a vessel's wetted hard surfaces. Vessel biofouling includes attached (sessile) organisms such as barnacles, algae, and mussels, and also mobile organisms that associate with the attached organisms, such as worms, crabs, and small crustaceans.

As vessels transit from port to port, biofouling organisms can drop off or spawn (i.e. reproduce) resulting in the introduction of NIS. Vessel biofouling is considered a significant vector for aquatic NIS introductions in several regions, including Australia, the North Sea, and North America, specifically Hawaii and California (Ruiz et al. 2000a, 2011; Eldredge and Carlton 2002; Gollasch 2002).

2.3 Why the Concern? Nonindigenous Species Impacts

Once established in a new location, NIS have the potential to cause significant economic, environmental, or human health related impacts.

2.3.1 Economic Impacts

In freshwater and marine 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 2013, California’s ocean-based economy employed roughly 500,000 people and accounted for almost $41 billion of California’s total gross domestic product (NOEP 2016).

The zebra mussel (*Dreissena polymorpha*) has caused significant economic impacts in much of its introduced range. Zebra mussels were introduced to the Great Lakes from the Black Sea in the mid-1980s via ballast water discharge from commercial ships (Carlton 1993). The mussels attach to hard surfaces and can form dense populations (as many as 700,000 per square meter) that have clogged municipal water systems and electric generating plants.

In 2012, researchers calculated that zebra mussels cost the states surrounding the Great Lakes as much as $800 million annually from sportfishing reductions (Rothlisberger et al. 2012).

In California, zebra mussels are now established in San Justo Reservoir in San Benito County, and the closely related quagga mussel (*Dreissena bugensis*) is found in multiple locations in southern California, including the Colorado River Aqueduct System (USGS 2016). Thus far, over $24 million has been spent on control and management (Volkoff, M., pers. comm. 2016).

The water hyacinth (*Eichhornia crassipes*), a nonindigenous aquatic plant, has caused significant negative impacts to the Port of Stockton and several San Francisco Bay-Delta marinas. In 2014, shipping traffic to the Port of Stockton was restricted to daylight hours due to high densities of the plant in waterways. The Port spent $200,000 to mechanically remove the plant, and the shipping industry lost an estimated $300,000 due to delays in cargo operations (Wingfield, J., pers. comm. 2015). That same year, the City of Stockton cancelled its annual holiday boat parade, resulting in an estimated loss of $40,000 - $50,000 in tourism trade (KCRA 2014). The dense plant populations have restricted opportunities for local citizens to boat on California’s waterways, impacting recreation-based revenue generation.

In total, NIS are believed to account for up to $120 billion per year in losses across the United States (Pimentel et al. 2005).

2.3.2 Environmental Impacts

Nonindigenous species also significantly impact the local environment. Worldwide, 42% of threatened or endangered species are listed as such, in part, because of impacts from NIS (Pimentel et al. 2005). Zebra mussels have caused localized extinction of species (Martel et al. 2001) and declines in recreationally valuable fishes (Cohen and

Weinstein 1998). Nonindigenous species, like the zebra and quagga mussels, displace native organisms by crowding them out during competition for habitat or food. The mussels filter vast amounts of water and consume plankton. Plankton are tiny floating plants and animals that form the foundation of aquatic food webs, and zebra and quagga mussels have dramatically reduced plankton concentrations where they are invasive (Vanderploeg et al. 2010, Higgins and Vander Zanden 2010).

The overbite clam (*Potamocorbula amurensis*) spread throughout the San Francisco Bay within two years of detection in 1986. The clams consume 80% to 90% of zooplankton from the water column in the shallow portions of the San Francisco Bay (Greene et al. 2011), and have played a significant role in the reduction of phytoplankton in the San Francisco Delta (Kimmerer and Thompson 2014). By dramatically reducing zooplankton and phytoplankton abundances, the clam is believed to be contributing to the decline of several pelagic fish species in the Sacramento-San Joaquin River Delta, including the threatened delta smelt (Feyrer et al. 2003, Sommer et al. 2007, Mac Nally et al. 2010).

2.3.3 Human Health Impacts

In addition to economic and ecological impacts, NIS impact human health. For example, vessels and port areas have been connected to the spread of epidemic human cholera (Ruiz et al. 2000b, Takahashi et al. 2008). Ships are thought to have transported *Vibrio cholerae* (serotype O1) from Latin America to Mobile Bay, Alabama, in 1991. Due to the potential health impacts as a result of that introduction, nearly all Mobile Bay oyster beds closed during the summer and fall of 1991.

In 2016, the Iranian Ports and Maritime Organization issued emergency procedures for vessels arriving to Iran from Iraq because of the spread of cholera in Iraqi waters (Gard 2016). The emergency measures included mandatory offshore exchange of all ballast water on board and quarantine at anchorage of all vessels originating from Iraq until the ballast water was tested and cleared of cholera.

Like cholera, other micro-organisms introduced via ballast water discharge have the potential to impact human health, including:

- Human intestinal parasites (*Giardia lamblia*, *Cryptosporidium parvum*, *Enterocytozoon bieneusi*) (Johengen et al. 2005)
- 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)

In California, the Japanese sea slug (*Haminoea japonica*), a host for cercarial dermatitis (i.e. swimmer's itch), was first detected in San Francisco Bay in 1999. Since 2005, cases of swimmer's itch at Robert Crown Memorial Beach in Alameda, California, have occurred regularly and are associated with high densities of the Japanese sea slug (Brant et al. 2010). In 2013, the Alameda Department of Environmental Health issued a "Swimmer's Itch Advisory" to the public due to the high number of cases (ACEH 2014). Since 2013, there have been few reported cases; however, the potential for another outbreak remains.

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3. CALIFORNIA'S MARINE INVASIVE SPECIES PROGRAM

The California Marine Invasive Species Program (MISP) is a multi-agency program designed to reduce the risk of NIS introductions from vessels; the MISP consists of the Commission, the California Department of Fish and Wildlife's Office of Spill Prevention and Response, the State Water Resources Control Board (Water Board), and the Board of Equalization (BOE). The following section highlights the Commission's MISP role and activities. For a discussion of the relevant coordinating agencies, see Section 6 of this report (Coordinating Agency Data Analysis) and Appendix A (Structure and Function of the Marine Invasive Species Program).

3.1 The MISP's Role in the Implementation of the Commission's Strategic Plan

In 2015, the Commission adopted a strategic plan that will guide its course over the next five years (2016–2020) (see Commission 2015b). The plan directs the Commission's stewardship of the public lands and resources entrusted to its care. Among its key responsibilities is the protection and preservation of resources through its marine pollution prevention programs. The Commission's Marine Environmental Protection Division manages programs to prevent oil spills and marine invasive species introductions to protect state waters for the benefit of the people of the State of California.

The Strategic Plan has four Strategic Goals, including:

1. Lead innovative and responsible land and resource management
2. Meet the challenges of our future
3. Engage Californians to help safeguard their trust lands and resources
4. Cultivate operational excellence by integrating technology

Within each Strategic Goal, the Commission identifies strategies and key actions to guide implementation and establish accountability. While MISP staff strive to support all of the Commission's goals, the program's key areas of responsibility fall under goals one and three – "Lead innovative and responsible land and resource management" and "Engage Californians to help safeguard their trust lands and resources." The Key Actions specific to the MISP are discussed below.

Strategic Goal 1: Lead innovative and responsible land and resource management

Key Action 1.1.2: *Review existing safety standards and regulations for continued relevance and use the public rulemaking processes to amend or adopt new regulations to enforce lease compliance and promote environmental protection and public health and safety while reducing unnecessary bureaucracy*.

MISP staff works closely with the Commission's Legal Division to amend or adopt regulations to implement the Marine Invasive Species Act (Public Resources Code section 71200 et seq.) and promote environmental protection of State waters. MISP regulations in various stages of development and adoption include:

- Vessel biofouling management
- Marine Invasive Species Act enforcement process
- Ballast water management for vessel arriving from outside of the Pacific Coast Region
- Amendments to the vessel arrival fee
- Protocols to assess vessel compliance with the California ballast water discharge performance standards
- Establishing a process for the Commission to review ballast water reception facilities for approval

Key Action 1.1.3 *Implement Ballast Water Discharge Performance Standards and biofouling management strategies that prevent the introduction of nonindigenous species into State marine waters.*

The implementation of ballast water discharge performance standards and biofouling management strategies will establish strong, comprehensive vessel vector management requirements to prevent the introduction of NIS into California waters. Commission staff is working closely with a stakeholder Technical Advisory Group (TAG) to develop enforceable, science-based regulations to implement mandates established by the Legislature.

Ballast water discharge performance standards have been established in statute and adopted via regulation, but implementation will require available and effective treatment technologies and methods to assess vessel discharge compliance.

The implementation of biofouling management strategies continues to be a lengthy process, and has been shaped through productive discussions with the public and a variety of interested parties. MISP staff expects to establish biofouling management regulations in early 2017.

Strategic Goal 3: Engage Californians to help safeguard their trust lands and resources

Key Action 3.1.3 *Prioritize and effectively use targeted outreach and strategic partnerships to develop and enrich the lines of communication with the Commission's stakeholders.*

Marine Invasive Species Program staff works proactively to engage stakeholders in the development and implementation of major program initiatives. Staff rely heavily on input from TAGs that bring together interested parties involved in scientific research, the shipping industry, environmental organizations, and state, federal, and international agencies (see Appendix A for further discussion of TAGs).

In addition to TAGs, MISP staff educate and facilitate engagement with the regulated community at many conferences and meetings each year, including Commission-sponsored events such as the biennial Prevention First Symposium and Marine Environmental Protection Division Customer Service Meetings.

The Commission's Strategic Plan, coupled with its Legislative mandates, work together to provide MISP staff with specific direction on deliverables and a framework for enhanced environmental protection efforts. Staff will continue to protect the lands and resources entrusted to its care through balanced management, marine protection, and pollution prevention, as detailed throughout this report.

3.2 Recent Legislative Updates – Assembly Bill 1312

Governor Edmund G. Brown Jr. signed Assembly Bill (AB) 1312 (Chapter 644, Statutes of 2015) in 2015, which addressed several issues and made clarifying changes to the Marine Invasive Species Act. Specifically, AB 1312:

- Delayed the implementation of the California Interim and Final Ballast Water Discharge Performance Standards
- Changed the timing of submittal of the Ballast Water Management Report from "upon departure" to 24 hours prior to arrival at a California port or place
- Clarified vessel inspection and enforcement authority to include vessel biofouling, in addition to ballast water
- Authorized the Commission to adopt regulations that will place the ballast water management requirements for vessels arriving from outside the Pacific Coast Region into the California Code of Regulations, allowing for all ballast water management requirements to be in the same place

- Authorized the Commission to collect reporting form data from all vessels with installed ballast water treatment systems, not just those that are using them to discharge in California waters
- Repealed Public Resources Code sections 71204.2, 71207(a), and 71210.5, which were no longer applicable

3.3 The MISP's Management of Vessel Vectors

To prevent aquatic NIS from being unintentionally transported by vessels into the waters of California, the California Legislature created the Marine Invasive Species Program (see Dobroski et al. 2015 for a full description of the legislative history). The Marine Invasive Species Program has been tasked with:

- Directing research on vessel vectors of NIS
- Developing policy and regulations
- Monitoring vessel arrivals and management compliance
- Monitoring for species introductions into California waters
- Consulting amongst responsible agencies to address NIS management.

These tasks collectively form the tools used by the MISP to meet the program mandate to "move the state expeditiously towards elimination of the discharge of nonindigenous species into the waters of the state" (Public Resources Code section 71201(d)). The following sections highlight the MISP's efforts towards achieving this goal.

3.3.1 Ballast Water Management

To prevent the introduction of NIS from ballast water discharge, the Commission implements a comprehensive ballast water management program, which includes best management practices, ballast water management requirements, recordkeeping and recording procedures, and compliance assessment.

3.3.1.1 Best Management Practices

All vessel owners, masters, operators, and persons in charge must follow best management practices to minimize the release of NIS into California waters (see Public Resources Code section 71204). Vessels should:

- Discharge only the minimum amount of ballast water essential for operations
- Clean ballast tanks in accordance with applicable laws
- Rinse anchors and anchor chains when they are retrieved

Vessels must minimize the discharge of ballast water in:

- Marine sanctuaries
- Marine preserves
- Marine parks
- Coral reefs

Vessels must minimize uptake of ballast water in areas that are high risk due to the presence of NIS, such as:

- Areas known to have infestations or populations of nonindigenous organisms and pathogens
- Areas near a sewage outfall
- Areas for which the master, owner, operator, or person in charge of a vessel has been informed of the presence of toxic algal blooms
- Areas where tidal flushing is known to be poor or in turbid waters
- In darkness when bottom-dwelling organisms may rise up in the water column
- Areas where sediments have been disturbed, such as near dredging operations or where propellers may have recently stirred up sediment

3.3.1.2 Ballast Water Management Practices

Vessel owners and operators must manage their ballast water prior to discharge in California. To decrease the risk of NIS introductions, vessels shall do at least one of the following (Public Resources Code section 71204.3 and Title 2 California Code of Regulations section 2284):

- Retain all ballast water onboard the vessel
- Take on and discharge ballast water at the same location
- Exchange ballast water at a minimum specified distance offshore prior to discharge
- 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 or United States Coast Guard (USCG) accepted Alternative Management System (AMS)).
- Under extraordinary circumstances, exchange ballast water within an area agreed to in advance by the Commission in consultation with the USCG

Retention of all ballast water on board a vessel is the most protective NIS prevention strategy for this vector. Because no water is discharged, no organisms are released into the environment.

3.3.1.2.1 Ballast Water Exchange

For those vessels that must discharge ballast due to operational needs or safety concerns, ballast water exchange is the primary method of ballast water management. The requirements for ballast water exchange vary depending on where a vessel arrives from and the source of the ballast water. Before discharging ballast water, vessels arriving at a California port from a port or place:

- Outside of the Pacific Coast Region (PCR; Figure 1), or carrying ballast water sourced from outside the PCR, are required to complete a mid-ocean ballast water exchange at least 200 nautical miles (NM) from any land, including islands, in water at least 2,000 meters (m) deep (Public Resources Code sections 71200(i) and 71204.3(c))

- Within the PCR, with ballast water sourced within the PCR, are required to complete a ballast water exchange in near-coastal waters at least 50 NM from any land, including islands, in water more than 200 m deep (Title 2 California Code of Regulations section 2284)

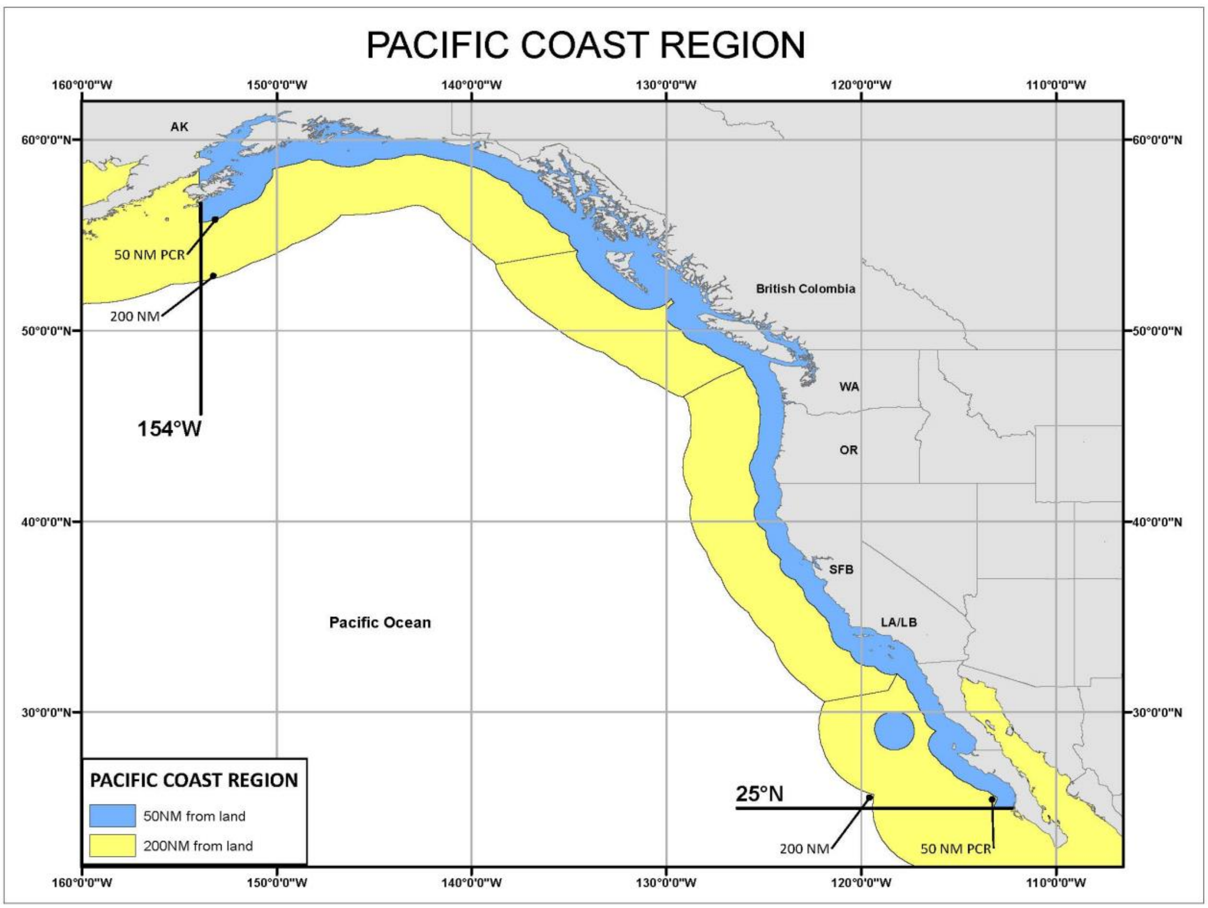

Figure 1. Map of the Pacific Coast Region

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 conducting exchange, and this management practice typically does not require any special structural modification. However, exchange also poses some challenges for vessels. A proper exchange can take many hours to complete due to ballast pump and piping capacities. In some circumstances, exchange may not be possible without compromising vessel safety due to adverse sea conditions or vessel design. Some vessels may be routed on short voyages, or voyages that remain within 50 NM of shore. In such cases, the exchange process may create a delay or require a vessel to deviate substantially from their route. This would cause additional fuel usage and increase air emissions.

Ballast water exchange eliminates between 70-99% of the organisms taken into a ballast tank (Parsons 1998, Zhang and Dickman 1999, USCG 2001, Wonham et al. 2001, MacIsaac et al. 2002). Therefore, even if a vessel reports exchanging 100% of its ballast water, there is a possibility that living coastal NIS will remain in the tank after exchange.

3.3.1.2.2 Ballast Water Treatment

Although ballast water exchange is currently the primary method of ballast water management, it is considered an interim method due to its variable efficacy and operational limitations. Technologies that reduce the concentration of organisms in discharged ballast water (such as shipboard ballast water treatment systems) or that provide alternatives to direct discharge to state waters (such as shore-based reception and treatment facilities) are thought to provide a higher level of protection from NIS introductions than ballast water exchange, although this remains to be determined. Also, vessels using ballast water treatment systems or reception facilities could proceed along shorter routes, potentially saving time and avoiding the safety and stability issues related to ballast water exchange (although treatment technologies may pose their own risks for safety).

The Commission allows vessels to use ballast water treatment systems in lieu of ballast water exchange if the treatment system has been accepted by the USCG as an AMS or if the vessel is involved in the USCG Shipboard Technology Evaluation Program (STEP).

Alternative Management Systems are ballast water treatment systems that have been type-approved by foreign countries in accordance with the International Maritime Organizations (IMO) G8 "Guidelines for Approval of Ballast Water Management Systems" and accepted by the USCG as being at least as effective as ballast water exchange.

The USCG STEP facilitates the development of ballast water treatment technologies by providing:

- Vessels with incentives to install experimental ballast water treatment systems to comply with USCG ballast water management requirements
- USCG with the ability to collect data on the performance of treatment technologies

Vessels accepted into the USCG STEP program can operate their shipboard treatment technology with equivalency to the USCG ballast water discharge standards for up to the lifespan of the vessel or the system.

3.3.1.3 Ballast Water Management Plan, Recordkeeping, and Reporting

Ballast water management planning and recordkeeping are important components of the Marine Invasive Species Act. All vessels must maintain 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 also maintain a separate ballast water log that outlines the ballast water management activities for each ballast water tank onboard the vessel and verifies that the vessel crew has followed the management plan.

Vessels must also report their ballast water management practices to the Commission for compliance assessment. Prior to May 1, 2016, all vessels were required to submit the USCG Ballast Water Reporting Form (BWRF) to the Commission once per arrival. In May 2016, the USCG replaced the BWRF with the current Ballast Water Management Report (BWMR; OMB number 1625-0069; Appendix B). The BWMR must be submitted to the Commission twenty-four hours prior to arrival at a California port (Public Resources Code section 71205(a)). The BWMR details ballast water management information for each voyage. BWMR data is compiled and analyzed by Commission staff to assess vessel compliance with ballast water management requirements, to gather data on vessel traffic arriving at California ports, and to help assess the risk of NIS introductions from vessel vectors.

Vessels that use a ballast water treatment system to manage ballast water discharged into California waters must also complete and submit two additional reporting forms (California Code of Regulations section 2297.1):

- The Ballast Water Treatment Technology Annual Reporting Form must be submitted once annually within 60 days of receiving a written or electronic request from Commission staff
- The Ballast Water Treatment Supplemental Reporting Form must be submitted in addition to the BWMR every time a vessel uses its ballast water treatment system to treat ballast water discharged in California

3.3.2 Vessel Biofouling Management

In addition to ballast water, vessel biofouling is a significant vector of species introductions (Carlton and Hodder 1995). Vessels arriving at California ports are required to remove biofouling from their hulls and other wetted surfaces on a regular basis (Public Resources Code section 71204(f)(2)). Regular basis is defined as no longer than:

- The expiration of the vessel’s Safety Construction Certificate
- The expiration of the USCG Certificate of Inspection
- 60 months since the vessel’s last dry docking

Unlike the risk of NIS introduction from ballast water, which can be eliminated by retention, every vessel poses some level of biofouling-mediated species introduction risk because biofouling organisms can never be contained. However, the accumulation of biofouling can be reduced with specific management practices, such as:

- Antifouling hull coatings
- Marine growth prevention systems
- Cleaning or treating underwater surfaces

Antifouling coatings reduce the ability of organisms to attach to vessels. Biocidal antifouling coatings deter attachment of fouling organisms by slowly releasing toxic compounds (e.g., copper, zinc). However, these compounds can also be detrimental to native organisms in the surrounding environment, and many regions restrict their use. Antifouling coatings that do not contain biocides (e.g., silicone-based coatings) are also available. These foul-release coatings produce a smooth surface making it difficult for fouling organisms to remain attached once the vessel is underway.

In addition to using antifouling coatings to prevent or reduce biofouling accumulation, biofouling can be managed by cleaning or treating underwater portions of vessels while in the water. However, in-water cleaning can release paint debris and organisms off the vessel and into the water column and sediments, leading to potential water quality impacts and NIS introductions (see Section 5.7.1 for data on in-water cleaning in California).

Despite the use of antifouling and foul-release coatings and in-water cleaning, biofouling remains a significant vector by which NIS are transported to new regions (Coutts and Dodgshun 2007, Davidson et al. 2009a, Hopkins and Forrest 2010, Hewitt and Campbell 2010, Sylvester et al. 2011, Ruiz et al. 2011). Vessels that move at slow speeds, spend long periods in port, or whose operational profiles don't match the specifications of their antifouling coatings tend to accumulate more organisms (Coutts 1999). Once accumulated on a vessel, these organisms can be spread to new locations.

Vessel biofouling is not restricted to the smooth surfaces of the hull. Biofouling accumulation in "niche" areas is usually higher due to insufficient management and poor water flow (Coutts et al. 2003, Minchin and Gollasch 2003, Coutts and Taylor 2004, Davidson et al. 2009b, Frey et al. 2014). Niche areas include portions of the vessel such as:

- Dry-dock support strips
- Bow and stern thrusters
- Propellers
- Rudders
- Sea chests
- Worn or unpainted areas

To address the risk from vessel biofouling, the Commission is currently working on developing biofouling management regulations for vessels arriving at California ports. The Commission collects data on hull husbandry practices and other shipping activities that influence biofouling accumulation and survival. These data are collected from every vessel arriving at a California port through the Commission's HHRF (Appendix B), which is required to be submitted once annually.

3.4 California's Ballast Water Discharge Performance Standards

California's ballast water discharge performance standards, codified in 2006, are based on recommendations from a majority of a technical advisory panel that was convened by the Commission in 2005. The advisory panel consisted of scientists, regulators, representatives from the shipping industry, and environmental organizations. The standards were to be phased in over time to allow for the development of technologies that would enable vessels to meet the standards.

California has "interim" and "final" performance standards. The interim standards are comprised of numeric concentrations of living organisms of various size classes in discharged ballast water and vary from the federal discharge standards (Table 1). The final performance standard requires that any ballast water discharged has zero detectable living organisms for all organism size classes (Public Resources Code section 71205.3).

Prior to implementing the performance standards, the Commission is required to report to the Legislature on the efficacy, availability, and environmental impacts of currently available ballast water treatment technologies. Reports are due 18 months prior to each performance standard implementation date. As of September 2016, five reports have been prepared and submitted to the Legislature (see Dobroski et al. 2007, 2009; and Commission 2010, 2013, 2014). The next report is due on or before July 1, 2018, prior to the scheduled implementation of the “interim” standards on January 1, 2020.

Table 1. Ballast Water Discharge Performance Standards

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

The most recent review of ballast water treatment technologies was submitted to the Legislature in August 2014 (Commission 2014). This report analyzed options vessels may use to meet California's ballast water discharge performance standards, including discharge to a shore-based ballast water reception and treatment facility and treatment of all ballast prior to discharge by a shipboard ballast water treatment system. The Commission concluded that treatment technologies were not available to enable implementation of the California ballast water discharge performance standards by January 1, 2016.

As a result of the conclusions in the 2014 report, the California Legislature passed AB 1312 (Chapter 644, Statutes of 2015), which delayed the implementation of both the interim and final ballast water discharge performance standards. The new implementation schedule is as follows:

- Interim Standards
    - Newly built vessels – first arrival at a California port on or after January 1, 2020
    - Existing vessels – first scheduled drydocking on or after January 1, 2020
- Final performance standards for all vessels – January 1, 2030

3.4.1 Implementation of Ballast Water Discharge Performance Standards

Efforts to implement the California, as well as the U.S. (USCG and EPA) and international, ballast water discharge standards have all been met with complications due to:

- Equipment design limitations for vessels and ballast water treatment systems
- Regulatory inconsistencies
- Evaluation of treatment system performance for type-approval
- Evaluation of treatment system performance after systems are installed.

The installation of shipboard ballast water treatment technologies is often very complex and expensive. As such, industry has been hesitant to make large investments in new technology given the uncertainty over the implementation and enforcement of ballast water discharge performance standards.

The shore-based reception and treatment of ballast water is another way to potentially comply with ballast water discharge standards. While there have been studies investigating the use of shore-based ballast water reception and treatment, they have generally been small in scale. Therefore, the Commission is funding a study to evaluate the feasibility of shore-based ballast water reception and treatment facilities in California as a means for vessels to comply with the performance standards. The final report is expected in late-2017.

There are several remaining international and federal challenges with implementing California's ballast water discharge performance standards that are outside of the Commission's control (See discussion in Section 4, Emerging Issues).

3.6 Compliance Assessment

The Commission is mandated to inspect at least 25% of arriving vessels at California ports to assess compliance with the Marine Invasive Species Act (Public Resources Code section 71206). The Commission's Field Operations staff boards vessels to review and inspect vessel paperwork, interview the crew, and collect ballast water samples (see Structure and Function of the MISP, Appendix A, for more details). Commission staff also reviews vessel-submitted Ballast Water Management Reports to map ballast water management locations and ensure each vessel adheres to management requirements. Commission staff is in the process of developing compliance assessment protocols for biofouling management and ballast water discharge standards.

Enforcement of noncompliant vessel activities may occur through the imposition of administrative, civil, and criminal penalties. Enforcement is carried out in accordance with Public Resources Code section 71216 and the proposed regulations in Article 4.9 of Title 2 California Code of Regulations sections 2299.01 et seq., Marine Invasive Species Act Enforcement and Hearing Process.

4. EMERGING ISSUES

4.1 Vessel Vector Management

4.1.1 Federal/State Conflicts

Federal regulation of ballast water discharges in the U.S. is under the jurisdiction of both the USCG operating under the authority of the National Invasive Species Act and the U.S. Environmental Protection Agency (EPA) operating under the authority of the Clean Water Act. The dual federal agency regulation of vessel discharges has caused conflicting vessel requirements for some NIS management activities.

In March 2014, the U.S. House Committee on Transportation and Infrastructure's Subcommittee on Coast Guard and Maritime Transportation convened a hearing to address conflicting EPA and USCG ballast water regulations, among other topics. During the hearing, EPA and USCG representatives stated that the agencies approach the regulation of ballast water through the authority of separate federal statutes (the Clean Water Act and the National Invasive Species Act, respectively) and that they continue to work together to ease the tension for the regulated industry. However, it was stated that the requirements of those governing statutes place restrictions on the actions of each agency.

The Vessel Incidental Discharge Act (S. 2094) was introduced in 2014 in response to that congressional hearing. The proposed bill would:

- Establish a national standard for the discharge of ballast water and other discharges incidental to the normal operation of a vessel, including biofouling
- Eliminate ballast water and vessel incidental discharges from regulatory authority under the Clean Water Act and place them solely under the jurisdiction of the USCG
- Preempt state regulation of these discharges, including ballast water and discharges associated with vessel in-water cleaning

States would be permitted to enforce laws implementing state ballast water discharge standards more stringent than U.S. federal standards only if the state law was in place at the time the federal bill is passed <u>and</u> if the Secretary of Homeland Security approves a state's petition to retain those more stringent standards. The bill, S. 2094, was not passed before the 2013-14 U.S. Congressional Session ended in December 2014.

In 2015, the Vessel Incidental Discharge Act was reintroduced as S. 373 and H.R. 980. At its February 20, 2015 meeting, the Commission voted to formally oppose S. 373, as it would "preempt state authority to regulate incidental vessel discharges in state waters, thereby dismantling California's Marine Invasive Species Program and reducing California's protection from invasive species introductions into state waters" (Commission 2015a). In July 2015, Commission staff worked with staff from the Washington Department of Fish and Wildlife and the Oregon Department of Environmental Quality to submit multi-state letters in opposition to both H.R. 980 and S. 373. In addition, California, Oregon, and Washington jointly provided letters in April, May, and September 2016 opposing the Vessel Incidental Discharge Act.

Opposition to the Vessel Incidental Discharge Act is not restricted to the west coast states:

- In September 2015, the Great Lakes Legislative Caucus submitted a letter to Congress in opposition of the Vessel Incidental Discharge Act
- In May 2016, the Attorneys General of the states of Washington, Oregon, New York, Maine, Michigan, and Rhode Island submitted letters to Congress in opposition to the Vessel Incidental Discharge Act and associated amendments
- Also in May 2016, a coalition of 53 environmental organizations submitted a letter to the U.S. Senate in opposition to the inclusion of the Vessel Incidental Discharge Act in the Maritime Administration Authorization and Enhancement Act of 2017 (S. 2829)
- In June 2016, the Environmental Council of States, Association of Fish and Wildlife Agencies, Association of Clean Water Administrators, the National Association of State Boating Law Administrators, and the Association of State Wetland Managers wrote a letter to Congress in opposition to the Vessel Incidental Discharge Act
- In July 2016, the Governors of the States of Colorado, Minnesota, Montana, New York, California, Oregon, and Washington submitted a joint letter to Congress opposing the Vessel Incidental Discharge Act and its potential inclusion in the 2017 National Defense Authorization bill (H.R. 4909)

Congress continues to discuss the federal regulation of ballast water and other vessel incidental discharges. In February 2015, the Senate Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard met to discuss the impacts of vessel discharge regulations on U.S. shipping and fishing industries. In April 2016, the House Transportation and Infrastructure Subcommittee heard testimony from the USCG discussing both the regulation of ballast water discharges and the methods of analysis to determine the effectiveness of ballast water treatment systems.

No legislation has yet passed as of October 2016. However, there is a real possibility of preemption of state authority to manage vessel incidental discharges, including ballast water and biofouling discharges. Passage of the Vessel Incidental Discharge Act would preempt California's ability to prevent ballast water and biofouling mediated introduction of NIS into California's waters.

4.2 Ballast Water Management

4.2.1 International Maritime Organization Ballast Water Convention

The "International Convention for the Control and Management of Ships' Ballast Water and Sediments" (BWM Convention) was adopted in 2004 and enters into force 12 months after 30 countries and 35% of the worldwide tonnage ratify the convention. On September 8, 2016, Finland ratified the BWM Convention, pushing the total number of contracting States to 52, representing 35.14% of the world merchant shipping tonnage. Therefore, the BWM Convention will enter into force on September 8, 2017 (IMO 2016).

Implementation of the BWM Convention will be challenging. In December 2015, the IMO Marine Environment Protection Committee (MEPC) released a final report on a study of the implementation of the IMO ballast water discharge performance standards (MEPC 2015). The results of the study indicate that:

- Countries diverge in their interpretation of how to conduct ballast water treatment system testing and grant type-approval (per the IMO Guidelines for Approval of Ballast Water Management Systems (G8))
- There is a lack of publicly available documentation on the process of treatment system testing and data verification which hinders transparency and impairs confidence in the test results
- Existing installations of shipboard ballast water treatment systems are "irregularly operated and monitored"
- The lack of monitoring of existing installed treatment systems restricts useful evaluation of ballast water treatment system efficacy and environmental safety

The MEPC is updating the G8 Guidelines (MEPC 2015) for approval of ballast water treatment systems and will take the study results into consideration during this process.

The MEPC has not yet stated what will become of the more than 55 models of ballast water treatment systems that were type-approved under the existing G8 testing guidelines. These treatment systems have been installed on numerous ships operating worldwide, including ships operating in California waters. Based on the results of MEPC (2015), these systems may not be operating as effectively as expected.

4.2.2 USCG Type-Approval of Ballast Water Treatment Systems

The USCG regulations on ballast water discharge standards went into effect in 2013 (33 Code of Federal Regulations Part 151, Subpart D). However, as of October 1, 2016, the USCG has not approved any ballast water treatment systems for use in U.S. federal waters in compliance with those regulations. The lack of USCG type approved ballast water treatment systems continues to create uncertainty with both regulators and the regulated community about how and when federal ballast water discharge performance standards will be implemented.

The USCG, like California, currently accepts the use of Alternative Management Systems (AMS), which are ballast water treatment systems type-approved by foreign administrations. However, there is no guarantee that the AMS currently being used by vessels will receive USCG type-approval, particularly because the recent IMO study questions the performance of existing type approved ballast water treatment systems (MEPC 2015).

In addition, USCG type-approval was made more difficult by the USCG's refusal to allow the use of the Most Probable Number (MPN) method of analysis for some, but not all, of the tests of system performance. Four ballast water treatment system manufacturers appealed the decision, which was denied by the USCG on July 12, 2016 (USCG 2016). The USCG concluded that "the requested MPN test method does not meet the requirements of an alternative method stipulated in the [USCG] regulation."

As a result, any tests of treatment systems that used the MPN method of analysis need to be redone using a different analysis method. This further delays and jeopardizes the type-approval process for those systems that rely on the MPN method for test analysis.

Commission staff has discussed the USCG MPN decision with a technical advisory group. The TAG recommended that Commission staff continue to investigate the use of MPN for assessing compliance with California's ballast water discharge performance standards. There is disagreement in the scientific community as to the appropriateness of MPN as a method to measure compliance (Cullen and McIntyre 2016) with some of the standards. Commission staff will continue to track and participate in the debate.

On May 11, 2016, USCG issued a review conducted to determine whether technology to comply with ballast water discharge performance standards more stringent than the existing federal discharge standards could be practicably implemented (see USCG 2016). The brief review concluded that it is not possible to determine that a more stringent discharge standard could be met in the near future because no ballast water treatment systems have been approved to meet the current USCG discharge standard and because there is a lack of credible data on treatment system performance.

California does not require vessels to use USCG type-approved systems to meet California's ballast water discharge performance standards. Given that no treatment systems have yet been approved to meet existing federal discharge standards, which are less strict than California's performance standards, and that the USCG does not consider it practicable to implement a more stringent standard, there are serious concerns about the ability of shipboard ballast water treatment systems to meet California's interim standards.

4.2.3 EPA Implementation of 2013 Vessel General Permit

The EPA also regulates vessel discharges (including ballast water and biofouling) in federal waters. In 2015, the United States Court of Appeals for the Second Circuit ruled that the EPA acted "arbitrarily and capriciously" in setting the ballast water management provisions in the 2013 Vessel General Permit (*Natural Resources Defense Council v. U.S. Environmental Protection Agency* (2nd Cir. 2015) 808 F.3d 556.). Specifically:

- EPA acted arbitrarily and capriciously in setting Technology Based Effluent Limits based on the IMO ballast water discharge standards instead of based on the Best Available Technology economically achievable
- EPA failed to consider shore-based (i.e. onshore) ballast water treatment facilities even though such systems could be technologically available
- The narrative standards for the Water Quality Based Effluent Limits fail to provide sufficient ship owner guidance as to what is expected of them
- EPA failed to establish monitoring and reporting for Water Quality Based Effluent Limits

The Court remanded to EPA with instructions to revise the existing permit. The existing 2013 Vessel General Permit will remain in place until such time that a revised permit is issued. Based on communication with EPA staff, a draft 2018 Vessel General Permit is expected in mid-2017.

4.3 Biofouling Management

4.3.1 In-Water Cleaning

Biofouling management is either proactive (e.g. preventive anti-fouling coatings to reduce biofouling accumulation) or reactive (e.g. physical removal of any organisms that accumulate on a vessel's wetted surfaces through in-water cleaning or drydocking). Many vessels rely on both anti-fouling coatings and in-water cleaning or drydocking.

In-water cleaning has been subject to increased scrutiny over chemical (e.g., copper) and biological (e.g., NIS) pollution in recent years. Traditional in-water cleaning involves a large diver-controlled scrubbing brush that moves along a vessel's hull, scouring off accumulated organisms. The removed biological debris is typically not contained and may result in the dispersal and establishment of NIS (Hopkins and Forrest 2008, McClary et al. 2008, Hopkins et al. 2011). Additionally, the metallic biocides incidentally removed from the anti-fouling coating are also typically not contained and can result in chemical pollution in the surrounding water body.

Several recently developed in-water cleaning systems are capable of retaining the removed biological debris and biocides and pumping the waste through filtration and treatment systems prior to discharge. Several of these systems have been tested and approved in other countries.

The benefits of these systems include:

- Reduced risk of NIS introduction
- Reduced risk of chemical pollution
- Potential greater availability of in-water cleaning services in ports worldwide, especially at ports that currently restrict traditional in-water cleaning services
- Potential improved competitiveness of ports where these new in-water cleaning services are located because ship owners and operators may be able to conduct necessary hull husbandry maintenance during normal operations

The use of these new in-water cleaning systems in California has been limited due to State Water Board restrictions on cleaning vessels with copper-based coatings in state waters that are impaired for copper. However, select Regional Water Quality Control Boards are investigating locally permitting use of these systems through the National Pollutant Discharge Elimination System (commonly referred to as NPDES).

The San Francisco Bay Regional Water Quality Control Board has issued a Best Management Practices Fact Sheet that describes the requirements of an in-water cleaning system for it to be allowed for use within the San Francisco Bay (Water Board 2015).

In contrast, the Los Angeles and San Diego Regional Water Quality Control Boards still do not allow in-water cleaning of vessels with copper-containing anti-fouling coatings (even with use of the new generation in-water cleaning systems) within the Ports of Los Angeles, Long Beach, and San Diego. In-water cleaning is not allowed in these ports because these water bodies are copper impaired (Water Board 2010) and must therefore require more stringent discharge limits than for other water bodies that are not impaired (e.g., San Francisco Bay).

The Commission, Water Board, Regional Water Quality Control Boards, port authorities, and in-water cleaning service providers are discussing pathways toward permitting in-water cleaning throughout California.

4.3.2 Global Shipping Economics and Elevated NIS Introduction Risk

The recession of 2007 triggered a drop in consumer spending, which led to a decrease in the volume of goods being shipped worldwide. As a result, many ships were put into long-term layup (i.e. extended port residency periods). The increase in extended port residency periods, coupled with a decrease in vessel traveling speeds lead to an increased risk of biofouling-mediated NIS introductions (Dobroski et al. 2015). These changes in operational practices have been linked to increased biofouling accumulation and increased organism survival (Floerl and Coutts 2009, Coutts et al. 2010).

Although the global economy has mostly recovered from the recession of 2007 (Worstall 2015), the shipping industry is still experiencing a strong economic downturn due to (Ficenec 2016, Tovey and Agencies 2016):

- Overcapacity mixed with high debt due to aggressive ship ordering during the pre-recession era that resulted in too many ships for current cargo needs
- Low prices to ship goods
- Low oil prices
- Flat or reduced growth, especially in China
- Weak global demand for goods

The economic downturn in the shipping industry continues to influence vessel operations that may increase the risk of NIS introduction. For example, slow steaming practices (i.e. vessels traveling at reduced speeds) continue despite the low price of fuel (Barnard 2016, Wackett 2016). Vessel owners continue to place their vessels in long-term layup for extended port residency periods (Schuler 2015, OSJ 2016). Tank vessel owners have been storing oil on vessels at anchor for periods ranging from weeks to months, waiting until oil prices increase (Wallis and Khasawneh 2016). These actions are likely to increase the chance of vessel biofouling accumulation and transit survival, resulting in greater risk of NIS introduction at their next port of call if biofouling is not managed prior to going back into service (Floerl and Coutts 2009, Coutts et al. 2010). These operational practices have continued for vessels that arrived at a California port during 2014-2015 (see Section 5), resulting in elevated risk of NIS introduction into California's coastal and estuarine waters.

5. DATA COLLECTION AND ANALYSIS

The Marine Invasive Species Program uses vessel submitted data to guide the development of science-based policies to reduce the threat of NIS introductions. In addition, Public Resources Code section 71212 requires the Commission to summarize vessel management patterns and compliance with the requirements of the Marine Invasive Species Act to report to the Legislature. To accomplish this, Commission staff collect and analyze data from the following sources:

- Vessel submitted forms:
    - Ballast Water Management Report
    - Ballast Water Treatment Technology Annual Reporting Form
    - Ballast Water Treatment Supplemental Reporting Form
    - Hull Husbandry Reporting Form
- Vessel inspections conducted by Commission Field Operations staff
- Vessel arrival statistics received from:
    - Northern and Southern California Marine Exchanges
- Other information as needed from:
    - Shipping agents
    - Ports

The data are entered into a program database and analyzed for:

- Rates of compliance with mandatory reporting requirements (see *Reporting Compliance*)
- Patterns of vessel movements and arrivals (see *Vessel Traffic Patterns*)
- Patterns of reported vessel ballast water management and discharge (see *Ballast Water Discharge Patterns*)
- Rates of compliance with ballast water management requirements (see *Ballast Water Management Compliance*)
- Patterns of hull husbandry and vessel operational practices affecting biofouling accumulation and management (see *Biofouling Management Practices and Patterns*)

For purposes of data analysis and reporting, the six-month period from January through June of each year will be indicated as “a,” and the period from July through December will be indicated as “b.”

5.1 Reporting Compliance

Data Synopsis
• Ballast Water Reporting Forms/Ballast Water Management Reports were submitted for 96% of qualifying vessel arrivals between 2014b-2016a. • Hull Husbandry Reporting Form submission compliance was 93% in 2014 and 94% in 2015.

Under the Marine Invasive Species Act, the master, owner, operator, agent, or person in charge of a vessel is required to submit reports pertaining to the vessel's ballast water and biofouling management and, if applicable, any use of a ballast water treatment system.

A qualifying voyage arrival (hereafter referred to as an "arrival") for the purposes of reporting refers to all vessels 300 gross registered tons or more carrying or capable of carrying ballast water that arrive at a California port or place (Public Resources Code sections 71200(q) and 71201(a)).

5.1.1 Ballast Water Management Report

The Ballast Water Management Report is submitted prior to vessel arrival at each port of call in California. Commission staff has identified 19 port regions in California form which to collect and analyze reporting data (Figure 2).

Between 2014b-2016a, 96% of vessel arrivals at California ports submitted ether a BWRF or BWMR to the Commission (Figure 3). The Commission accepted the use of the expired BWRF until May 1, 2016, after which, only the BWMR was accepted. Eighty-four (84) percent of arrivals submitted their reporting forms on-time, which is an increase of 4% over the previous 2-year reporting period (see Dobroski et al. 2015).

Despite the increase in on-time form submissions, there was a 5% increase in the number of delinquent forms during the first half of 2016. Confusion in the shipping industry over changes in forms, as well as the Commission's change in the form submission timing requirements, could have played a role in the increased delinquency. Commission staff is providing education and outreach to vessels, agents, and owners, and increasing enforcement of violations to reduce the reporting delinquency.

Figure 2. California Port Regions Identified by Commission Staff

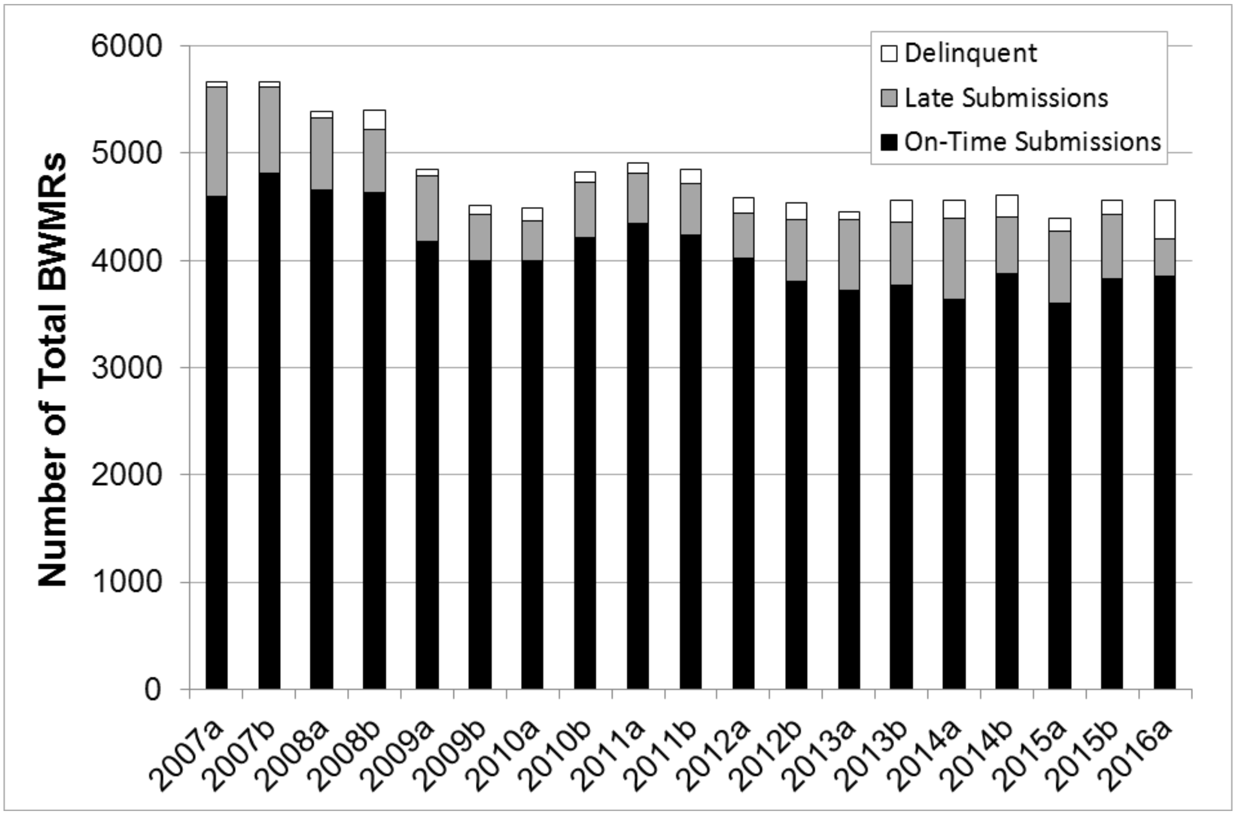

Figure 3. Number of Submitted Ballast Water Reporting Forms and Ballast Water Management Reports over the Past 9.5 Years (a = January to June, b = July to December)

5.1.2 Ballast Water Treatment Technology Reporting Forms

Title 2 of the California Code of Regulations section 2297.1 requires vessels that use a ballast water treatment system to treat ballast water discharged in California to submit two reporting forms (Appendix B):

- Ballast Water Treatment Technology Annual Reporting Form
- Ballast Water Treatment Supplemental Reporting Form

The Ballast Water Treatment Technology Annual Reporting Form (Annual Form) is submitted once per calendar year, and provides information about the type of ballast water treatment system used by the vessel. The Ballast Water Treatment Supplemental Reporting Form (Supplemental Form) is submitted on a per-arrival basis (as necessary) and details the volume of treated ballast water discharged in California waters by the vessel and any ballast water treatment system malfunctions that may have occurred.

Tracking submission compliance of the Annual and Supplemental Forms has been difficult due to confusion by the shipping industry over the specific requirements of when, and by whom, the forms should be submitted. Therefore, the data presented below represent only the forms received during the reporting period and do not reflect actual compliance rates or trends.

Commission staff is currently in the process of combining the annually submitted Hull Husbandry Reporting Form (HHRF, see below) and the Annual Form to streamline the submission process for vessels and allow for improved compliance tracking. Commission staff is also exploring ending the submission requirements for the Supplemental Form because this information is being captured by the new BWMR.

For the reporting period between 2014b and 2016a, 31 vessels reported discharging treated ballast water 69 times in California waters. The Commission received 20 Annual Forms in 2014, 34 in 2015, and 32 during 2016a. Note that this is an annual form submitted upon a vessel's first arrival to a California port in a calendar year. The numbers for 2016a do not imply that a similar number will be received during 2016b. The number of forms is being presented merely to show the number received to date.

5.1.3 Hull Husbandry Reporting Form

Every qualifying vessel arriving at a California port (see Title 2, California Code of Regulations section 2298) is required to submit the HHRF annually (Appendix B). The HHRF is an eleven-question survey that is divided into two sections:

- Vessel hull husbandry practices (e.g., dry docking and antifouling coating information)
- Voyage and operational characteristics that influence biofouling accumulation (e.g., traveling speed and extended port residency periods)

During 2008, the first year of the HHRF reporting requirement, only 72% of the vessels that arrived at California ports submitted the form as required. Beginning in 2009, Commission staff utilized the monthly notification system already in place for delinquent BWRFs/BWMRs to track and alert shipping agents and owners of HHRF deficiencies. This led to an overall HHRF submission compliance rate near or above 90% in each of the past seven years (2009-2015), with the highest compliance rate of 94% in 2015 (Figure 4).

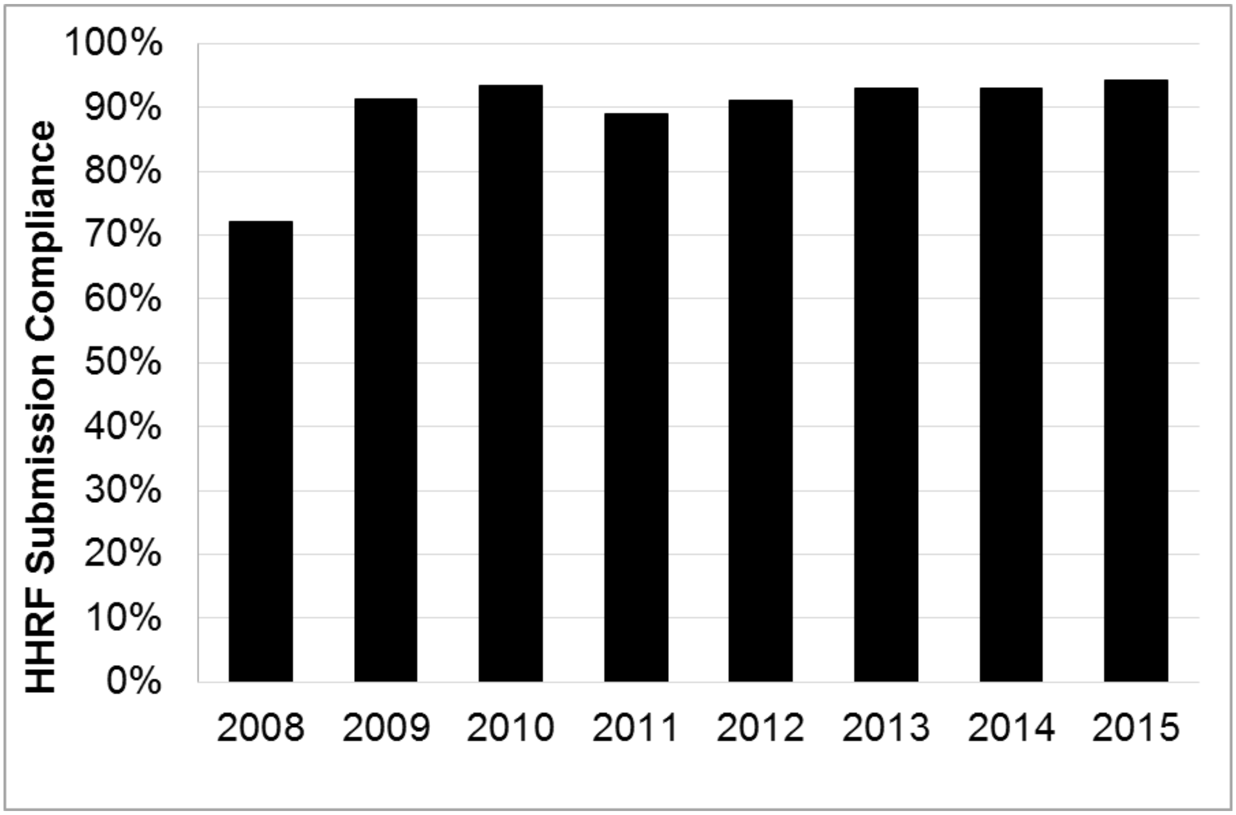

Figure 4. Percent Compliance for Annual Hull Husbandry Reporting Form Submission from 2008 through 2015

5.2 Vessel Traffic Patterns at California Ports

Data Synopsis

- The average annual number of vessel arrivals at California ports has decreased from 10,822 (2004-2008) to 9,055 (2009-2015).
- The Los Angeles-Long Beach (LA-LB) port complex consistently receives the greatest number of vessel arrivals in the State.
- 54% of arrivals at California ports come from ports within the Pacific Coast Region (PCR).
- The Ports of Oakland and LA-LB receive similar numbers of arrivals from PCR ports, but LA-LB receives nearly 16 times as many arrivals from non-PCR ports.
- 43% of arrivals at California ports are containerships; 22% are tank vessels.
- 96% of all containership traffic arrives at the Ports of Oakland and LA-LB.

5.2.1 Vessel Arrivals at California Ports

Commission staff tracks arrivals at California ports through data collected from vessel submitted reports and from the State’s two Marine Exchanges. Tracking vessel arrivals to California provides the base from which other analyses are performed.

For the two-year period between 2014b and 2016a, 18,126 vessels arrived at California ports. The number of vessel arrivals continues to linger near the post-recession low of 2009. Average annual vessel arrivals to California have decreased from 10,822 (2004-2008, pre-recession) to 9,055 (2009-2015, post-recession). While increasing slightly since 2009, the average number of arrivals per six-month period has been 4,653, with minimal variation (Figure 5).

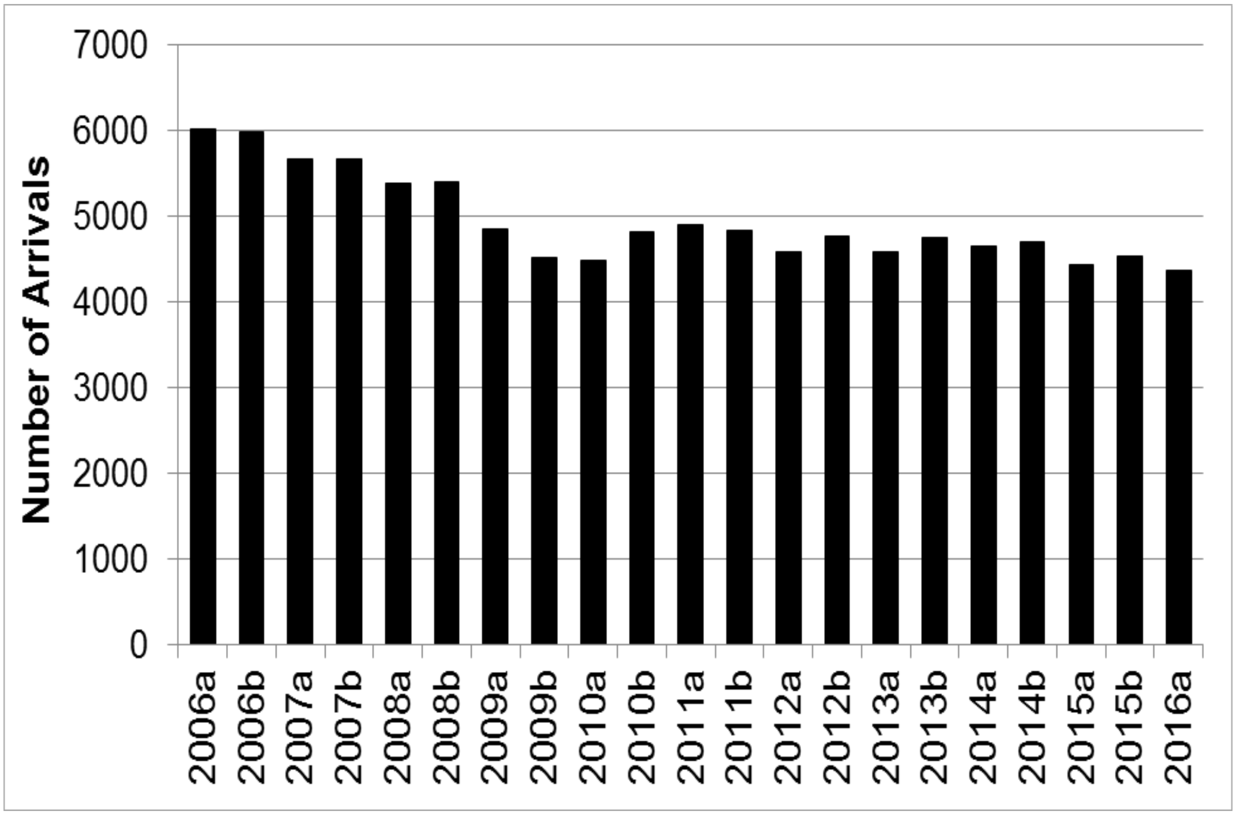

Figure 5. Number of Vessel Arrivals at California Ports (2006a-2016a; a = January to June, b = July to December)

Arrivals by port have remained consistent over several years of reporting (Figure 6; see Takata et al. 2011, Scianni et al. 2013, Dobroski et al. 2015). The Ports of Los Angeles and Long Beach (LA-LB) received nearly half (48%; 8,360) of all arrivals at California ports between 2014b and 2016a. The Port of Oakland had the second greatest number of arrivals to the State during the same time period (3,031). The Port of Richmond accounts for the third greatest number of arrivals (1,450) to California, followed by the marine oil terminals located in the Carquinez Strait (1,321).

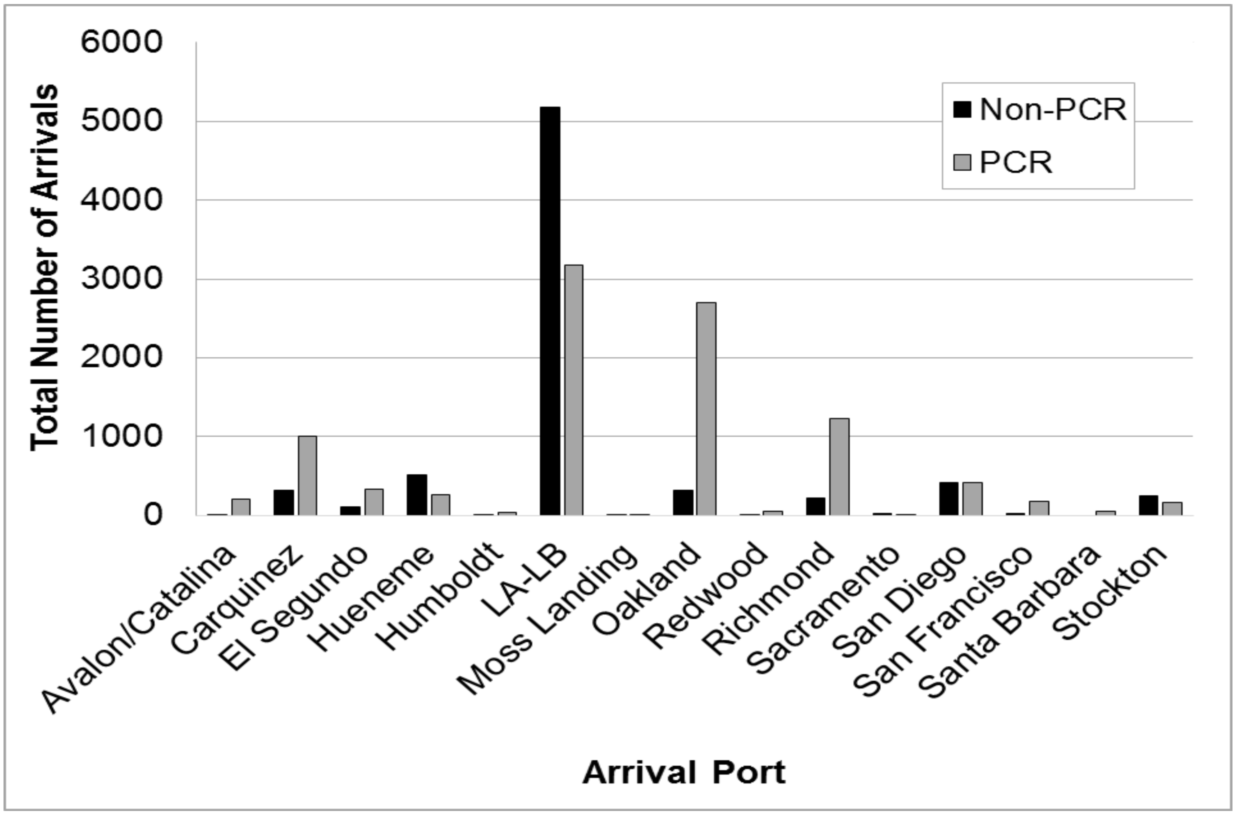

Figure 6. Distribution of Arrivals by Port for Voyages Originating from Inside and Outside the Pacific Coast Region (2014b-2016a; a = January to June, b = July to December)

The Port of Oakland received 15% fewer arrivals between 2014b and 2016a than in previous years, with 2,705 PCR arrivals and 326 arrivals from outside the PCR (Figure 6; see Figure 1 for map of the PCR); whereas the Port of LA-LB has maintained similar numbers as previous years, with 3,180 PCR arrivals and almost 16 times more non-PCR arrivals (5,180) than Oakland. Both Richmond and Carquinez received primarily PCR arrivals (1,234 and 1,008, respectively).

5.2.2 Vessel's Last Port of Call

Commission staff tracks the last port of call for each arrival to identify the required ballast water management for that voyage. The required ballast water management practice varies as a function of whether the last port of call and the ballast water source were from inside or outside the PCR (see Section 3.2). (Note: In some previous reports, PCR arrivals were referred to as "coastal" and non-PCR arrivals were referred to as "foreign").

Slightly more than half (54%) of all arrivals to California between 2014b and 2016a originated from ports within the PCR, similar to the previous reporting period (Dobroski et al. 2015). Of these arrivals from PCR ports, 38% originated from other California ports. The remaining PCR arrivals originated from ports outside of California, mainly from Oregon, Washington, and British Columbia.

The majority of non-PCR arrivals to California came from Asian ports, accounting for 22% of all arrivals, followed by 7% from Central America, and 6% from Mexican ports located outside of the PCR (Figure 7).

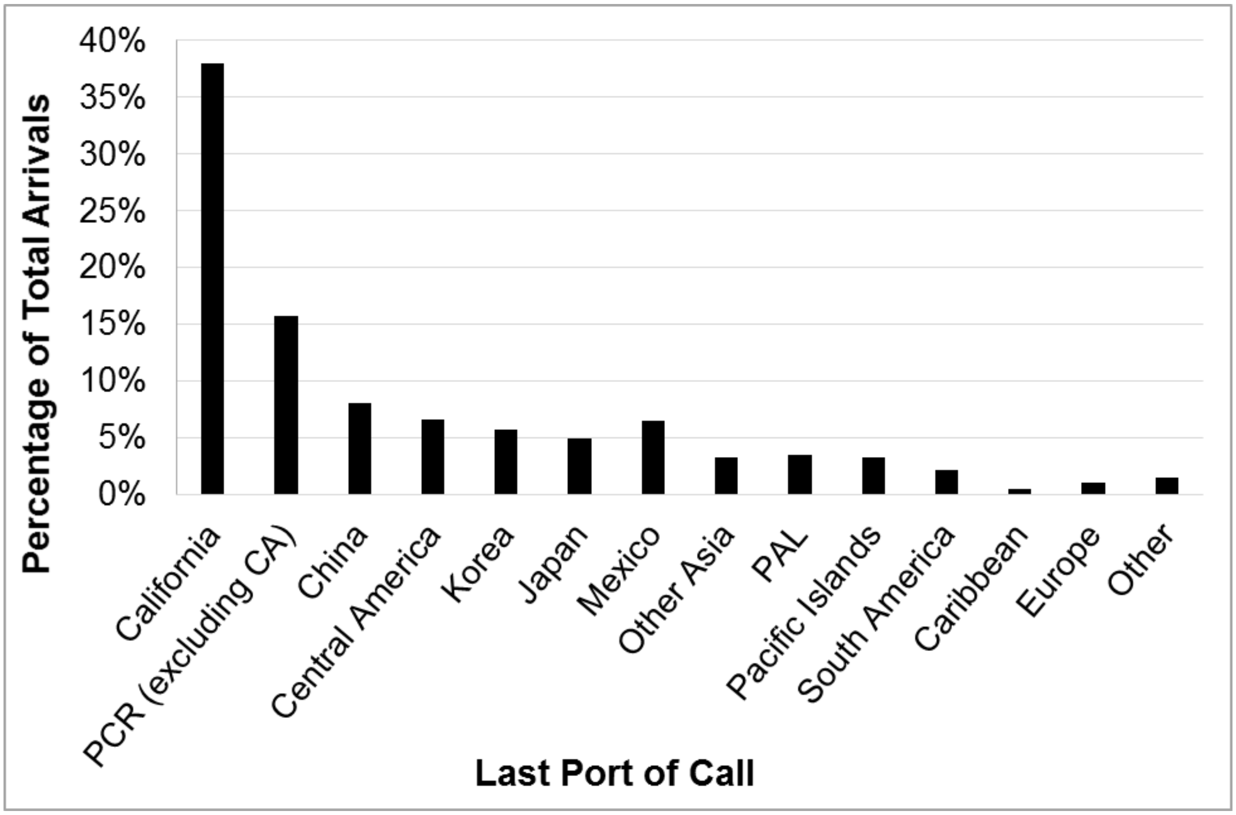

Figure 7. Last Port of Call for Arrivals at California Ports (2014b-2016a; a = January to June, b = July to December; PAL = Pacific Area Lightering)

5.2.3 Arrivals by Vessel Type

The types of vessels arriving at California ports vary based on differences in local industry, demand, and port infrastructure (e.g., the presence of container cranes). Container and tank vessels are the most common vessel types that arrive to California, representing more than two-thirds (43% and 22%, respectively) of all arrivals to the state between 2014b and 2016a (Figure 8).

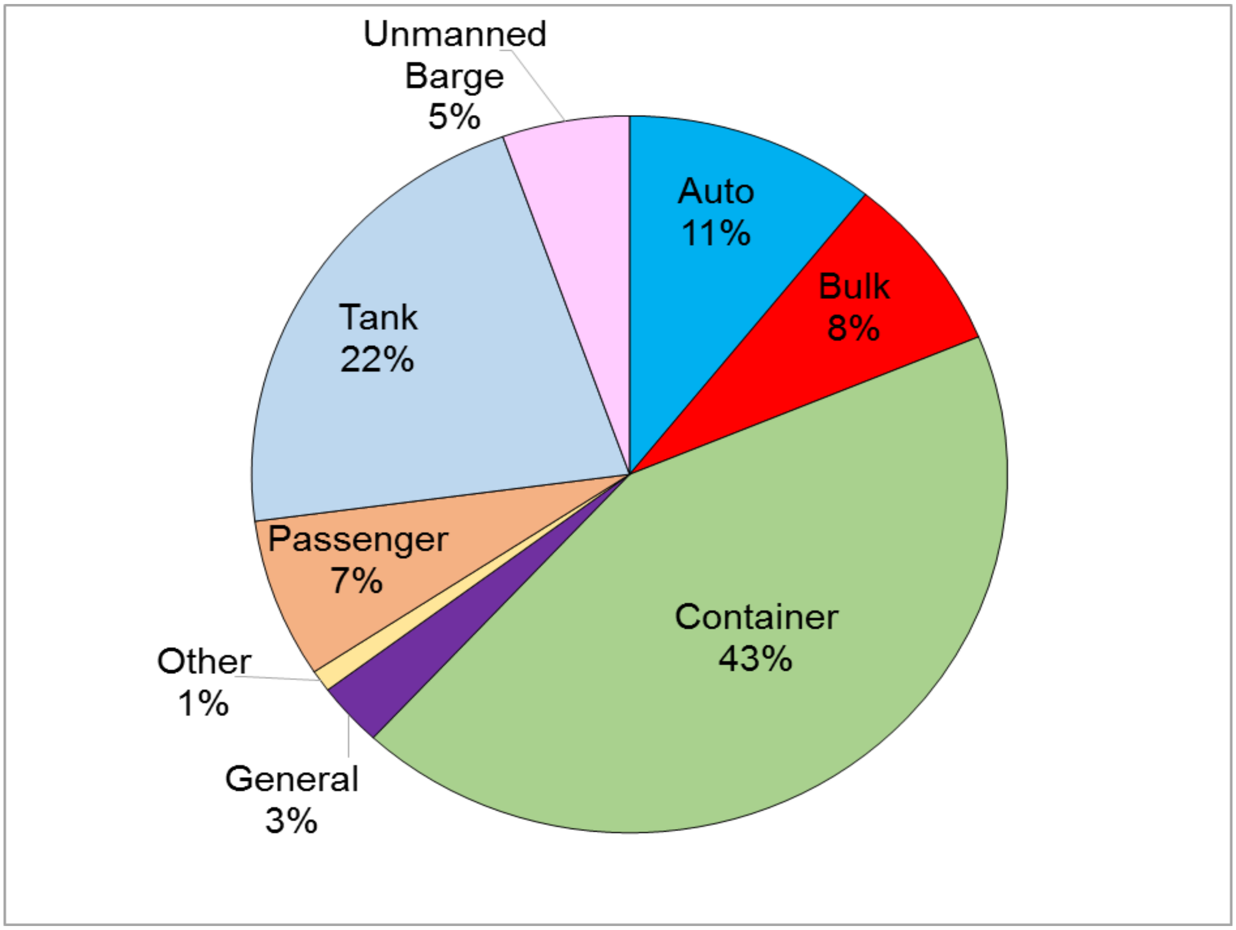

Figure 8. Percentage of Arrivals to California by Vessel Type (2014b-2016a; a = January to June, b = July to December)

The Ports of LA-LB and Oakland received 96% of all container vessel traffic to California (Figure 9 A, B). Forty-four percent of tank vessels arrived at LA-LB, with the remainder divided between Richmond (23%), Carquinez (17%), and the El Segundo offshore marine oil terminal (11%) (Figure 9 A, B). The Ports of LA-LB also received a preponderance of bulk (50%) and passenger vessel (57%) arrivals to California (Figure 9 A). Passenger vessels also arrived at Avalon\Catalina (17%), San Diego (11%), and San Francisco (11%). Auto carriers primarily arrived at LA-LB (27%), San Diego (26%), and Hueneme (25%). Unmanned barges predominately arrived at LA-LB (33%), Carquinez (30%), and Richmond (27%).

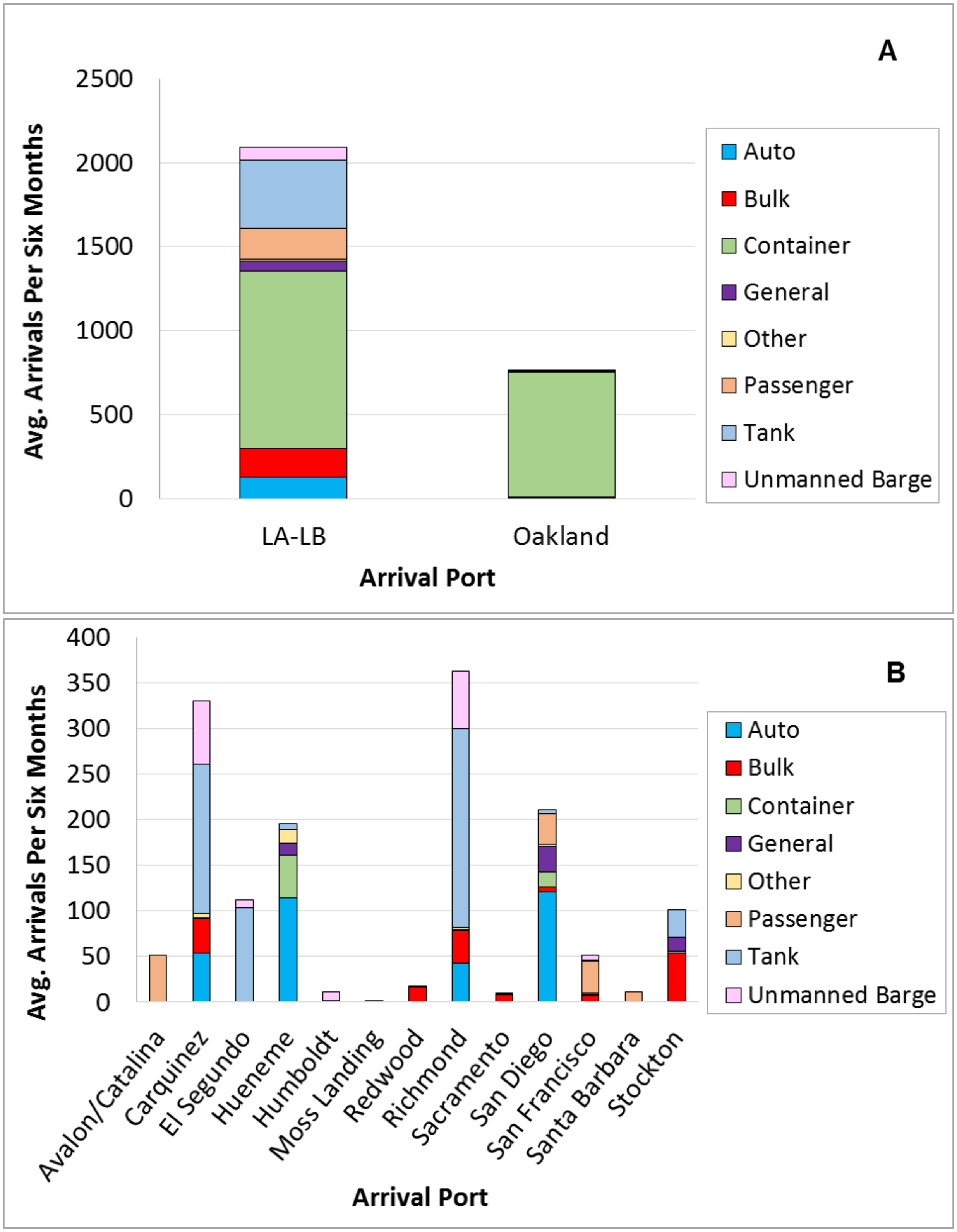

Figure 9. Average Number of Arrivals per Six-Month Period (2014b-2016a; a = January to June, b = July to December) by Vessel Type and Port (Oakland and LA-LB (A), all other California Ports (B); Note that the y-axis scale is not the same across graphs)

5.3 Ballast Water Discharge Patterns

Data Synopsis

- 84% of voyage arrivals to California per year reported retaining all ballast water on board, a pattern that has persisted since 2004.
- The total reported volume of ballast water discharged to state waters decreased during this reporting period, with the lowest volume ever reported in the first half of 2016.
- Bulk and tank vessels discharge the largest reported volumes of ballast water, on average, but both the number of arrivals discharging and the average volume of ballast water discharged decreased for both vessel types.

The risk of NIS introductions through ballast water discharge is influenced by several factors (Carlton 1996, Ruiz and Carlton 2003):

- Type of ballast water management
- Volume of ballast water released
- Age of the ballast water discharged (organisms often survive better when held for a short period of time)
- Degree of repeated inoculation (frequency with which ballast water is discharged in a given area)
- Similarity between source and recipient regions (biological, chemical, and physical characteristics at each port)

By examining geographic and volumetric patterns of ballast water discharge, Commission staff can assess the risk of species movement and establishment throughout California and help frame future policy and management recommendations.

Not every vessel that enters California discharges ballast water. Factors such as vessel type, cargo operations, and localized environmental conditions (e.g., weather) determine ballasting practices. Vessels that do not discharge ballast water pose no risk of NIS introductions from ballast water. Therefore, ballast water retention is the most protective management strategy for this vector. Since 2004, an average of 84% of arrivals per year have reported retention of all ballast water on board (i.e. no discharge) while in State waters (Figure 10).

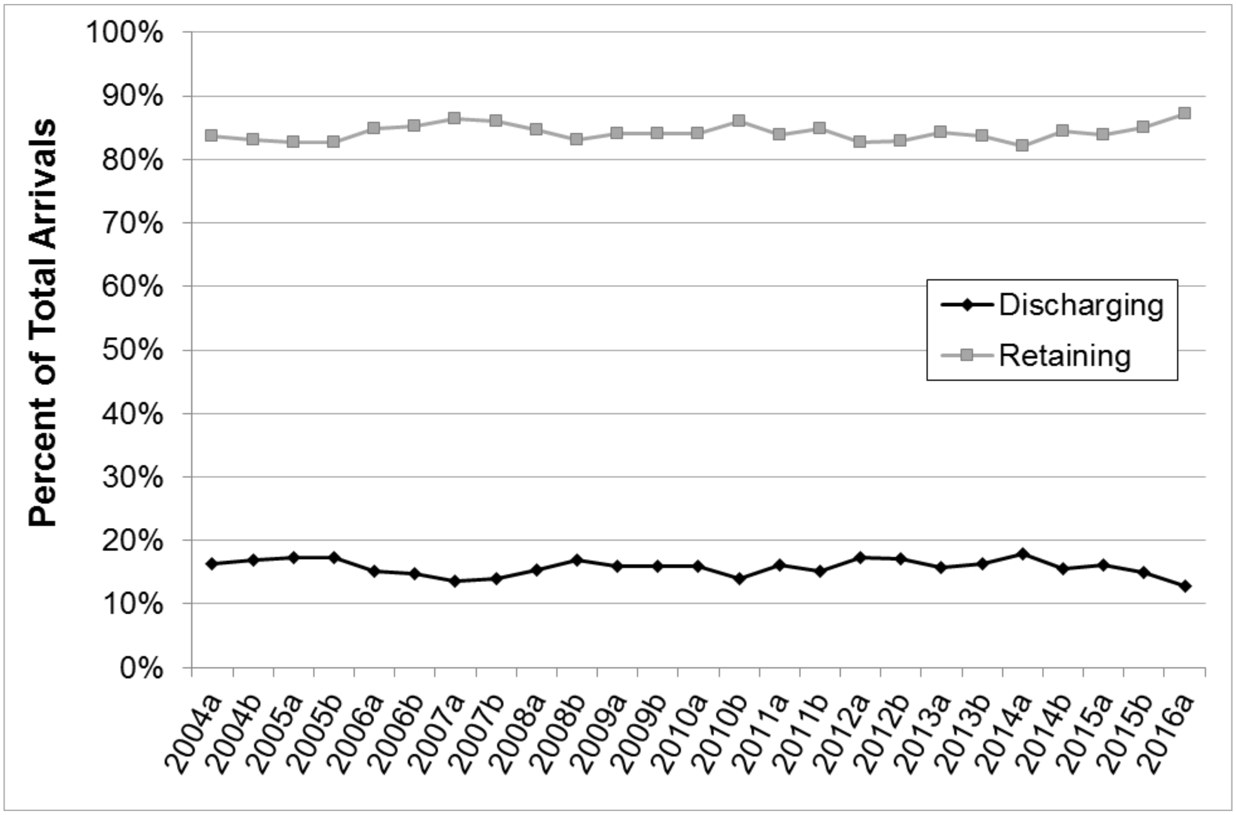

Figure 10. Reported Ballast Water Discharge vs. Retention (a = January to June, b = July to December)

From those vessels that have discharged ballast water in the state, the total volume of reported ballast water discharged steadily increased to a high in 2014a. Since that time however, reported ballast water discharge volume has declined (Figure 11). In 2016a, the reported volume of discharged ballast water was 3.1 million metric tons (MMT) - the lowest in any six-month time period over the past 12 years.

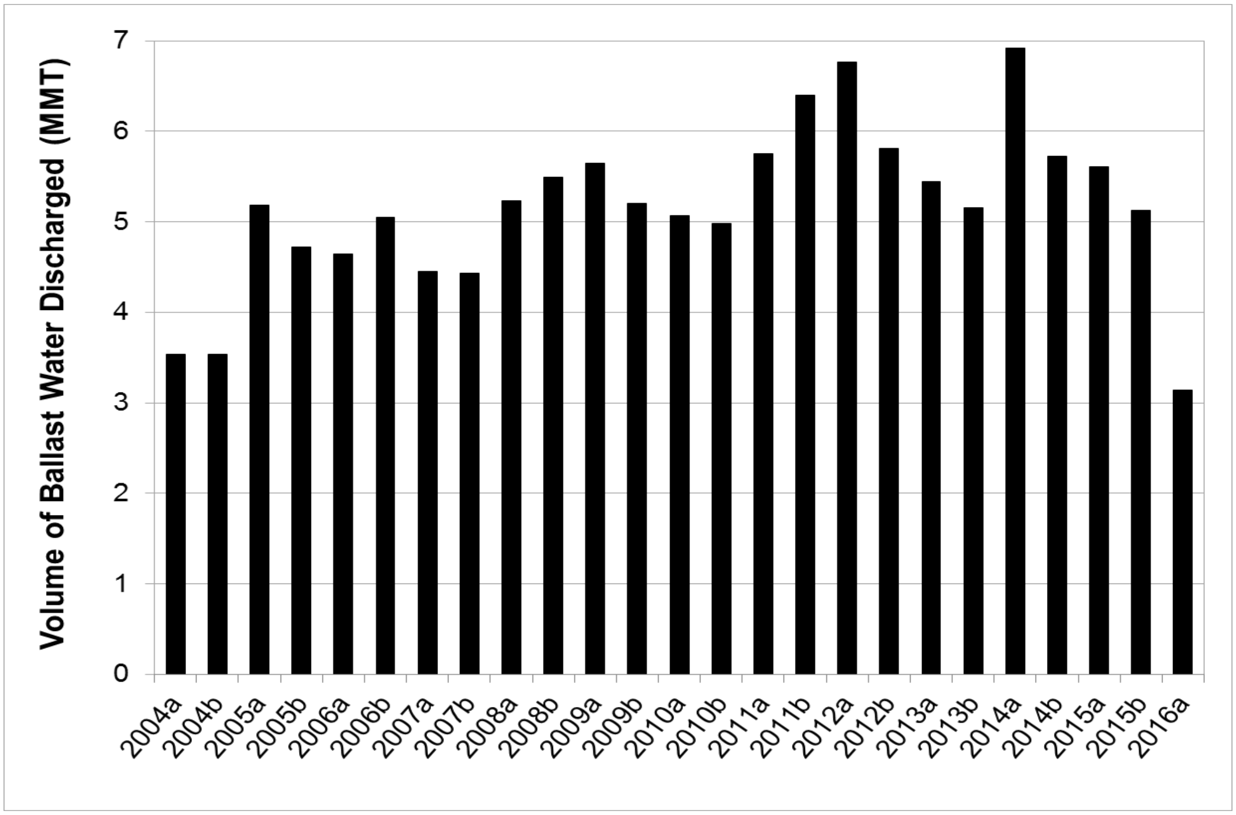

Figure 11. Total Reported Volume of Ballast Water Discharged (MMT) (a = January to June, b = July to December)

Following a similar pattern, the average reported volume of ballast water discharged per discharging vessel also declined since 2014a with a further drop in 2016a (Figure 12). Whether these patterns persist into the future remains to be seen.

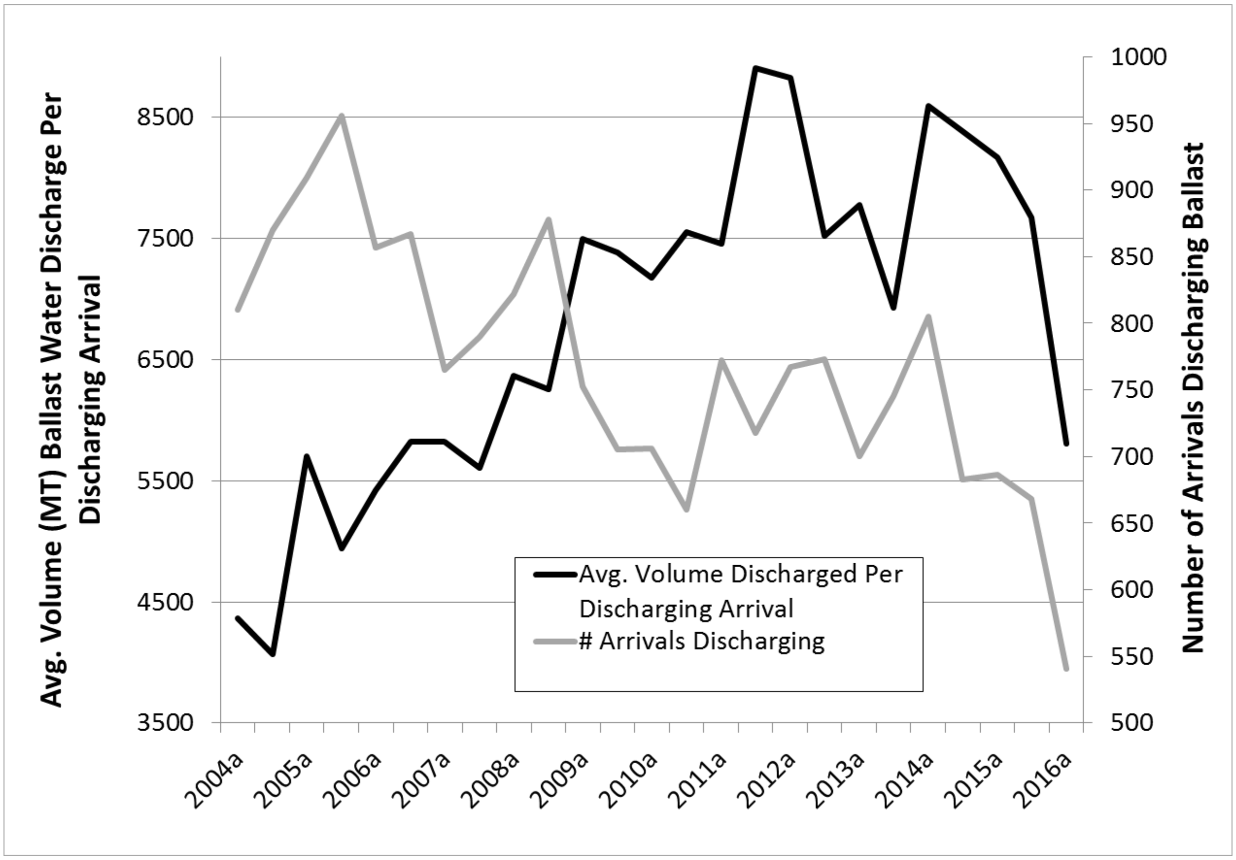

Figure 12. Average Volume of Reported Ballast Water Discharged per Arrival in MT. Average calculated using the number of vessels reporting discharging not the total number of arrivals (a = January to June, b = July to December). Note different scales of y-axes.

5.3.1 Ballast Water Discharge by Vessel Type

The total volume of ballast water discharged in California is driven, in large part, by bulk and tank vessels. Combined, bulk and tank vessels accounted for only 30% of vessel arrivals to California between 2014b-2016a (Figure 8), yet were responsible for 86% of total volume of ballast water discharged during that same time period (Figure 13, Table 2). During 2014b-2016a, bulk and tank vessel arrivals were down only 4% from 2012b-2014a; however, the percentage of bulk and tank vessel arrivals discharging ballast water was 63.5% from 2014b-2016a, down from 82.5% in 2012a-2014b. This drop in the proportion of tank and bulk vessel arrivals discharging ballast water likely contributed to the decrease in reported ballast water discharge volume (Figure 11).

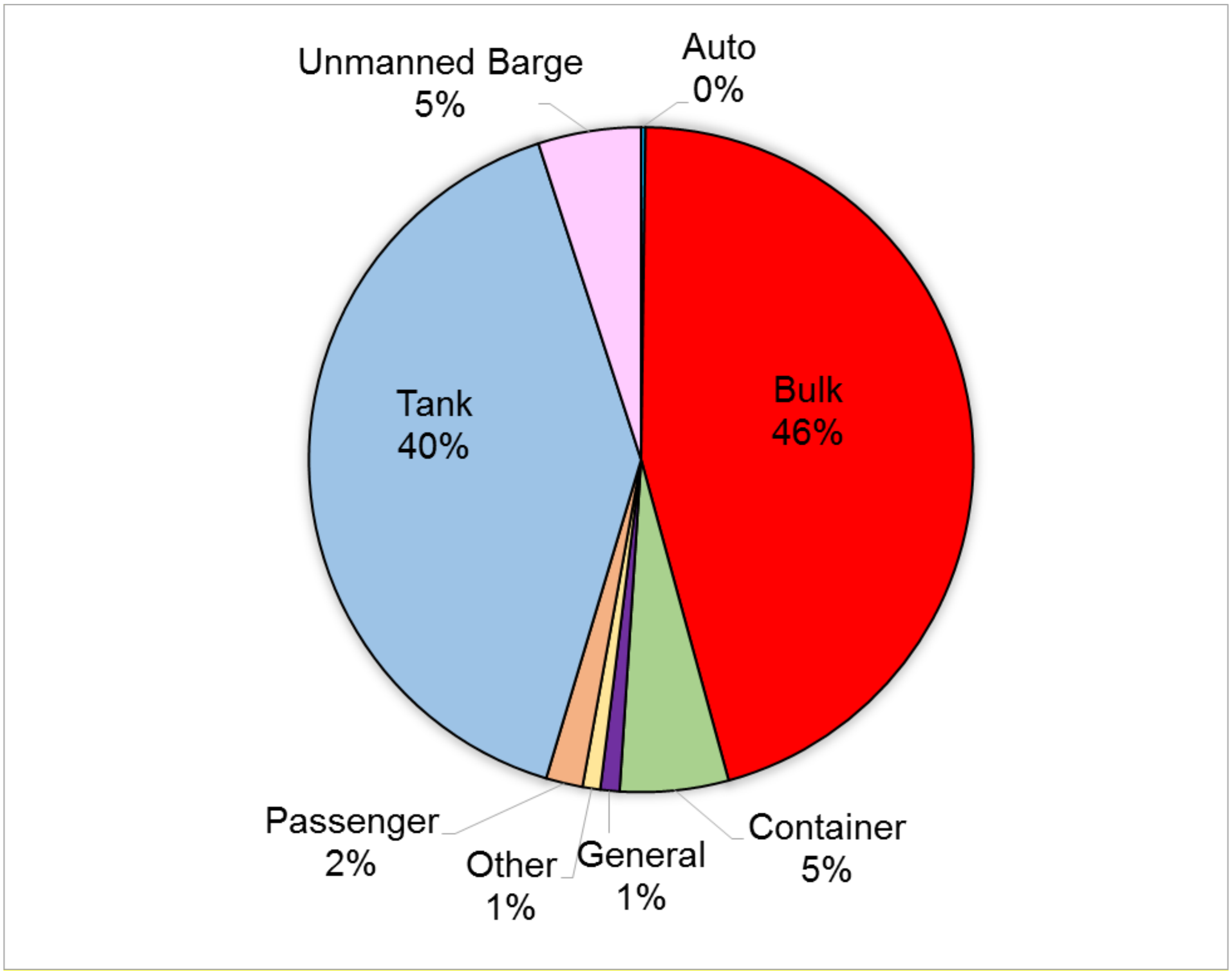

Figure 13. Percentage of the Volume of Reported Ballast Water Discharged by Vessel Type (2014b-2016a; a = January to June, b = July to December).

Table 2. Average Number of Arrivals and Reported Discharge Patterns by Vessel Type (2014b-2016a; a = January to June, b = July to December)

Vessel Type	Avg. Number of Arrivals Per 6-Month Period	Avg. Number Discharging Per 6-Month Period	Percent Discharging
Auto	464	6	1.3%
Bulk	346	154	44.6%
Container	1863	60	3.2%
General	124	15	11.7%
Other	43	7	15.2%
Passenger	311	90	28.8%
Tank	935	177	18.9%
Unmanned Barge	235	43	18.1%

Individual bulk vessels continue to discharge the largest average volume of ballast water than any other vessel type (Table 3). The average volume of ballast water discharged has recently decreased, however, from 14,724 MT in 2014a to 11,526.2 MT in 2016a (Table 3). This 22% decrease in the average volume of ballast water discharged per bulk vessel further explains the reported drop in total ballast water discharged in California in 2016a.

From 2014b-2016a, almost 29% of passenger vessels reported discharging ballast water, compared to 16% from 2010b through 2012a (see Table V-1 and Table V-2 in Scianni et al. 2013). The volume of ballast water discharged by passenger vessels remains low, however, compared to the volume discharged by other vessel types (Table 3). This increase in reported ballast water discharges may be partly attributed to a reported increase in passenger vessels with installed ballast water treatment systems discharging treated ballast water in California (see discussion below).

Table 3. Average Reported Volume of Ballast Water Discharged per Vessel by Vessel Type. Note 2016a is a six-month period, the remaining data represent full years.

Year	Auto		Bulk		Container		General	
	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)
2006	38	1,191.0	318	11,001.8	504	2,750.3	91	3,108.2
2007	33	713.5	271	10,542.7	451	2,495.3	96	3,674.2
2008	21	703.9	303	11,291.3	410	2,631.3	95	4,210.6
2009	7	872.9	321	11,801.7	306	3,025.1	65	5,860.6
2010	16	531.7	304	12,459.1	318	3,204.6	65	4,691.6
2011	3	126.4	373	13,338.2	262	3,686.4	67	5,322.5
2012	12	303.0	382	13,702.4	233	3,021.9	46	5,321.7
2013	9	246.4	384	13,322.3	186	3,241.7	36	3,790.7
2014	1	471.3	343	16, 464.8	152	1,631.6	34	1,053.2
2015	12	1,280.5	343	13,732.4	159	4,143.0	32	3,416.1
2016a	13	1,966.0	132	11,526.2	60	2,034.3	13	3,108.7

Year	Other		Passenger		Tank		Unmanned Barge	
	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)	# Discharging Vessels	Avg. Volume per Vessel (MT)
2006	23	4,803.0	25	639.9	486	11,597.0	232	2,576.6
2007	21	5,755.0	75	656.7	419	8,691.4	207	3,427.4
2008	18	6,409.4	144	602.8	543	8,919.4	180	4,423.9
2009	21	3,943.0	96	562.3	483	9,788.0	153	5,718.8
2010	9	4,944.0	52	463.0	441	9,477.8	162	4,633.7
2011	13	5,976.2	42	694.4	516	9,589.5	143	4,553.8
2012	19	1,171.6	162	826.5	558	9,164.8	125	5,237.9
2013	19	3,026.2	139	780.6	531	7,869.8	141	3,026.8
2014	20	3,544.0	105	846.8	551	9,519.4	54	4,403.4
2015	15	4,793.9	231	778.5	446	9,819.5	116	5,236.1
2016a	5	6,348.7	120	679.6	171	7,130.4	47	3,695.5

5.3.2 Ballast Water Discharge by Port

The data collected through BWRFs and BWMRs are analyzed for discharge patterns at each arrival port. The largest volume of ballast water is discharged at LA-LB, followed by Carquinez and Richmond (Figure 14). LA-LB had large numbers of discharging vessels from within and outside the PCR. The majority of vessels discharging in the San Francisco Bay ports and terminals of Oakland, Carquinez, and Richmond originated from within the PCR.

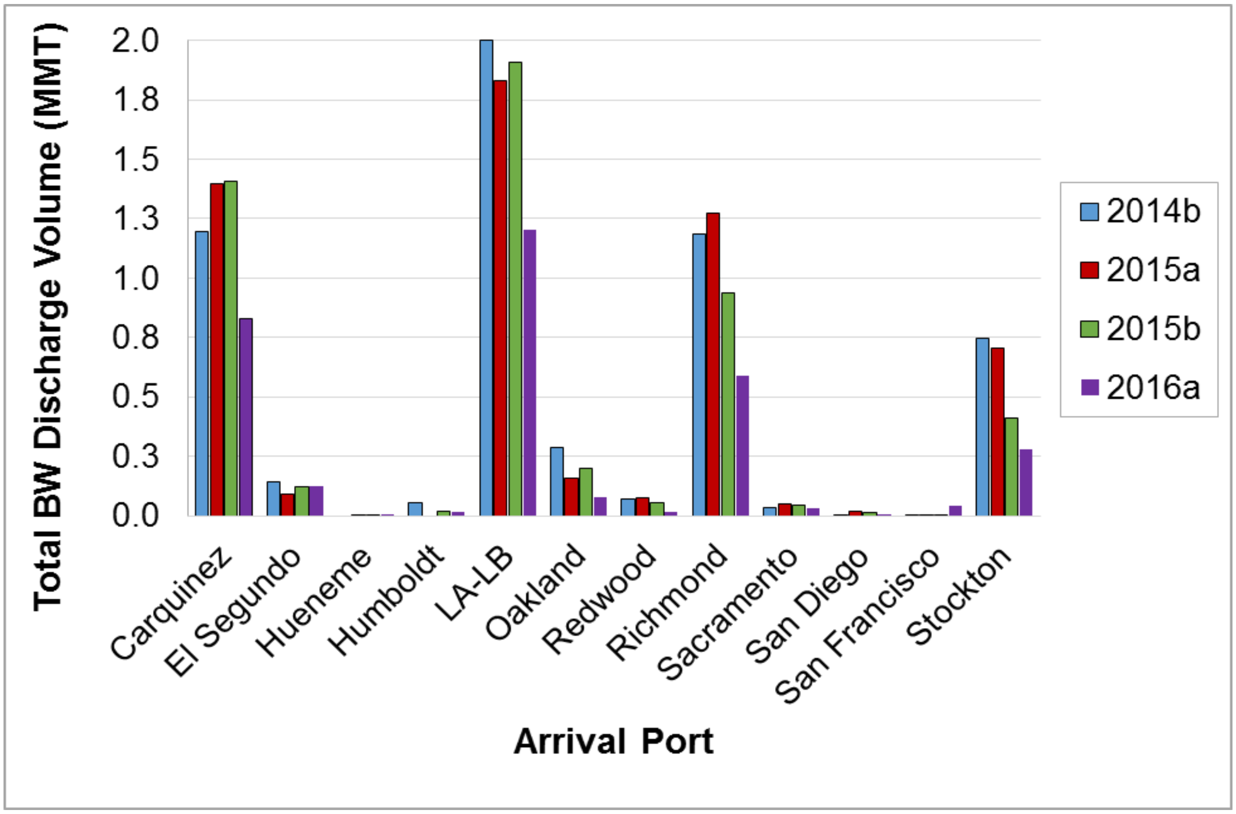

Figure 14. Total Volume of Reported Ballast Water Discharged by Port in MMT (2014b-2016a; a = January to June, b = July to December)

Regionally, the ports and marine oil terminals in the San Francisco Estuary (including San Francisco, Redwood City, Oakland, Richmond, Carquinez, Sacramento, and Stockton) received more discharged ballast water than those in Southern California (LA-LB, San Diego, Hueneme, and the El Segundo offshore marine oil terminal) - 12.1 MMT vs. 7.4 MMT, respectively.

The San Francisco Estuary discharge volumes are largely driven by tank vessels discharging ballast water at the marine oil terminals in Richmond and Carquinez, and bulk vessels discharging at Stockton and Carquinez. LA-LB receives most of its discharged ballast water from both bulk and tank vessels while El Segundo receives its discharged ballast water solely from tank vessels.

5.4 Ballast Water Management and Compliance

Data Synopsis

- 98% of reported ballast water carried into California waters is managed in compliance with the Marine Invasive Species Act.
- From 2014b-2016a, 19.7 MMT of ballast water was reported discharged in California, of which 19 MMT (96.4%) was managed in compliance with state requirements.
- 556,000 metric tons (MT) of improperly exchanged ballast was reported as discharged into California from 2014b-2016a
- 148,000 MT of unmanaged ballast water was reported as discharged into California from 2014b-2016a

Vessels needing to discharge ballast water into California waters must manage that water using one of the options described in Section 3. Most of the vessels that report discharging ballast water in California manage their ballast water by using ballast water exchange. Ballast water exchange requirements depend on a vessel’s last port of call and the source of the ballast water to be discharged (see Section 3.2).

5.4.1 Methods of Ballast Water Exchange

Vessels mostly use the flow-through (FT) or empty-refill (ER) methods to exchange ballast water prior to discharge. The method of exchange used by a vessel is based on ship and ballast tank engineering. For a detailed description of each type of exchange, see Dobroski et al. (2015).

During the current reporting period, 53% of the reported discharged ballast water volume was managed using ER, compared to 47% managed using FT (Figure 15). Some vessels failed to report on their BWRF or BWMR the type of management conducted. These data are shown as “unknown” and account for less than 1% of the data reported (Figure 15).

Properly exchanged ballast water can remove 95%-100% of the original source water (Hay and Tanis 1998) and reduce the concentration of coastal species in ballast tanks. However, FT has been shown to be significantly less effective than ER in reducing the number of coastal species in exchanged ballast tanks (Cordell et al. 2009). Vessels that conduct ballast water exchange using the less effective FT method are therefore more likely to discharge coastal organisms into California ports. However, as previously noted, the method of exchange is generally a function of vessel design. While it is important to track the method of exchange for information purposes, it is not feasible to have all vessels shift towards using ER to lower the risk of species introductions to California.

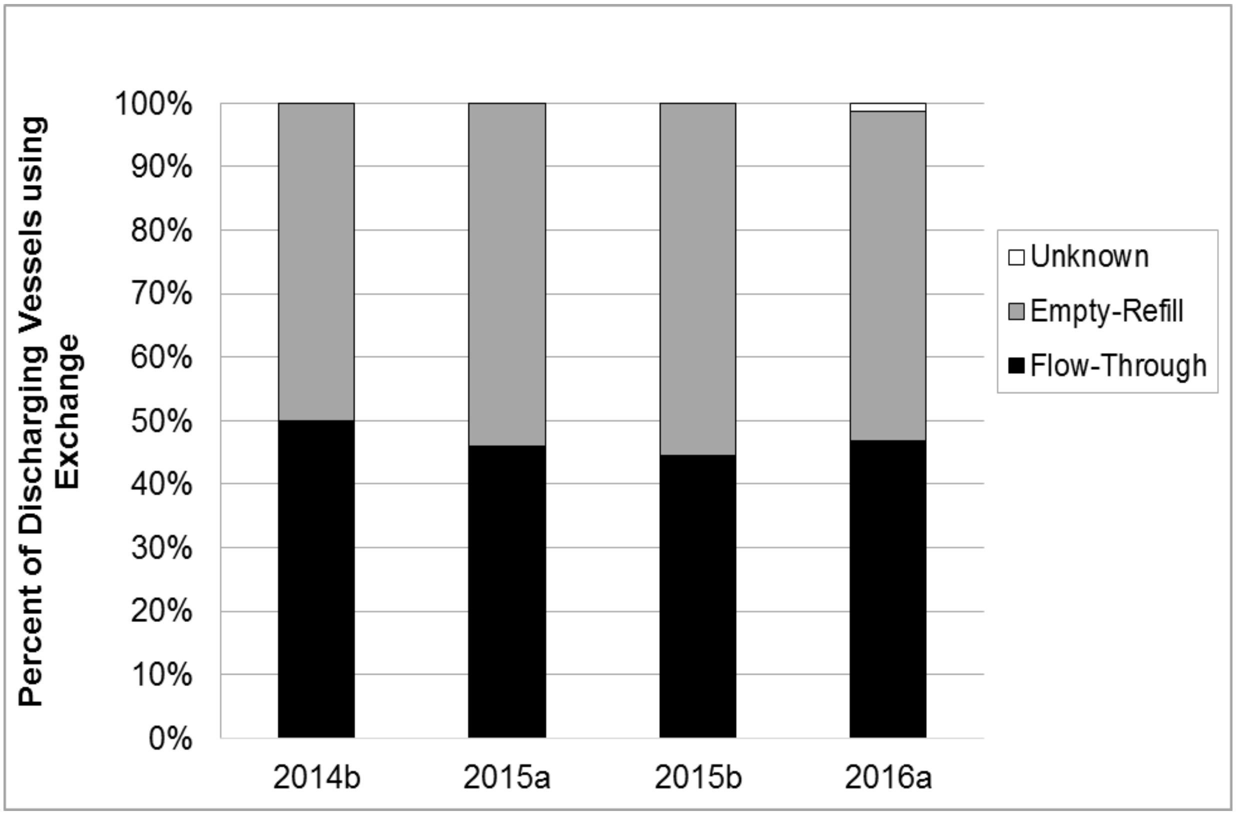

Figure 15. Method of Ballast Water Exchange Reported by Vessels Discharging Ballast in California (2014b-2016a; a = January to June, b = July to December)

5.4.2 Ballast Water Management Compliance

From 2014b-2016a, 98% of the 122 MMT of vessel-reported ballast water carried into California was managed (including retention) in compliance with State law.

Furthermore, the majority (79% of the total volume) of the noncompliant ballast water reported as discharged in coastal waters of California underwent some type of management (but not to legal standards), likely reducing the risk of NIS introductions when compared to unmanaged ballast.

During the reporting period, 19.7 MMT of ballast water was reported as discharged into California waters, and 96.4% (19.0 MMT) was in compliance with management requirements either through proper ballast water exchange or the use of an approved alternative management method (e.g. USCG accepted AMS) (Figure 16). The total volume of ballast water reported as discharged into California varies from year to year but had been steadily increasing over the past 11 years before the large decrease reported in 2016a (Figure 11). Despite this variability, the proportion of noncompliant discharges has steadily decreased over the same time period. For example, noncompliant discharges represented 23.8% of the total volume of ballast water discharged in California in 2006b, 4.7% in 2014a, and only 1.4% in 2016b.

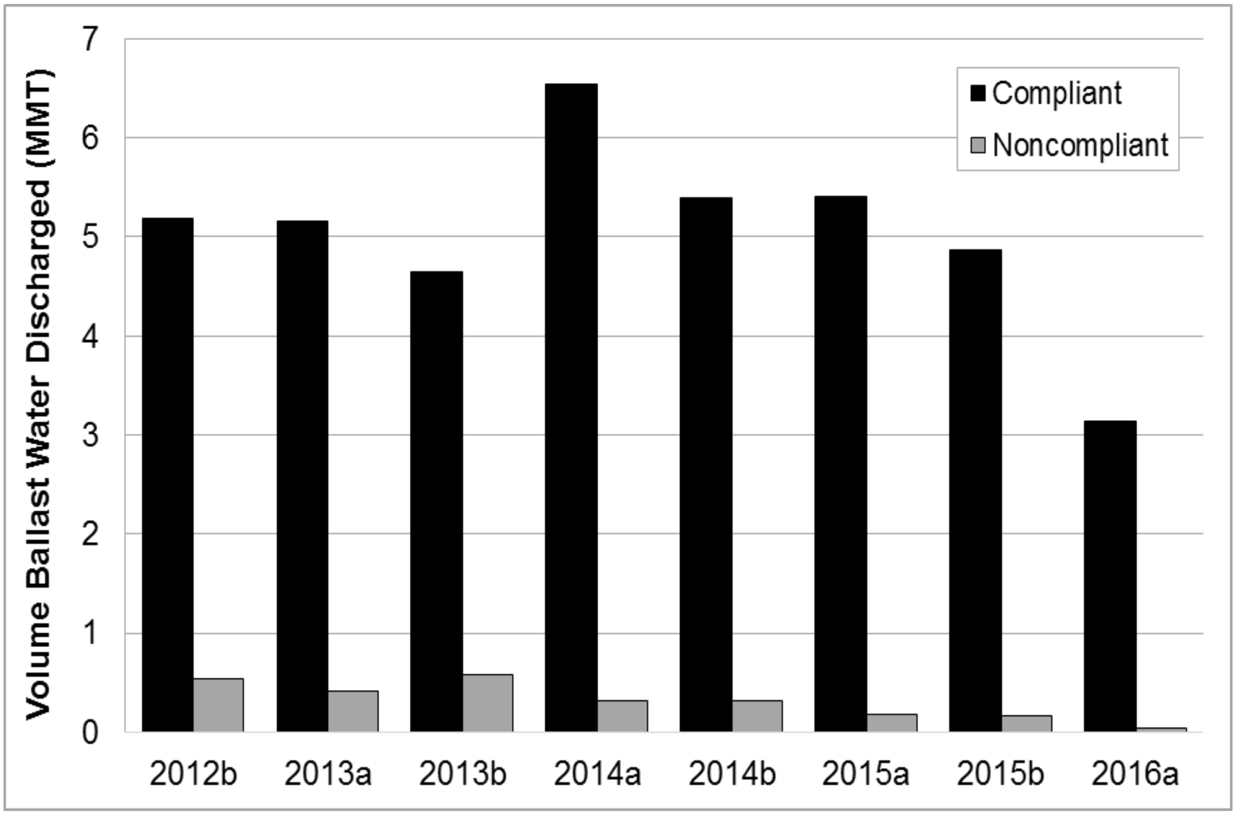

Figure 16. Volume of Compliant and Noncompliant Ballast Water in MMT Reported as Discharged by Six-Month Period (2012b-2016a; a = January to June, b = July to December)

5.4.3 Noncompliant Discharged Ballast Water

A total of 704,000 MT of noncompliant ballast water was reported discharged in California waters between 2014b-2016a, down from 1.8 MMT during the previous reporting period. The volume of noncompliant ballast water discharged into California waters per six-month period has dropped since July 2012 from 545,000 MT in 2012b to less than 50,000 MT in 2016a (Figure 16). This trend demonstrates the effectiveness of the MISP outreach and compliance program and the potential reduction of NIS introduction risk. However, any noncompliant ballast water discharged represents a significant risk.

Noncompliant ballast water falls into one of three categories:

- Ballast water that was exchanged in the wrong location (the exchange was not in mid-ocean or in near-coastal waters as required by Public Resources Code section 71204.3 or Title 2 California Code of Regulations section 2284(a)(1))
- Ballast water that was not managed

- Ballast water that was reported exchanged, but the location of exchange was unknown or unspecified (uncommon, and usually corrected through inquiring with vessel)

5.4.3.1 Ballast Water Exchange in the Wrong Location

Commission staff determines the location of ballast water source and exchange locations using vessel-reported coordinates and the Geographic Information Systems (GIS) software ArcMAP (ESRI 2011). This analysis accurately maps reported ballast management locations (latitude and longitude) and also helps MISP staff determine patterns and trends of noncompliance.

The majority of vessels in violation of California's ballast water management requirements reported performing ballast water exchange before discharging in the State, but in a location less than the required 50 or 200 NM from land (depending on the vessel's last port of call and the source of the ballast water). Ballast water exchanged at the required distance from land is more protective. Therefore, a noncompliant ballast water exchange (i.e. an exchange conducted too close to land) is likely to provide some benefit by reducing the concentration of coastal organisms in the ballast tanks.

The volume of ballast water exchanged in the wrong location prior to discharge accounted for 79% (556,000 MT) of total noncompliant ballast water during the current reporting period (Figure 17).

Most of the noncompliant ballast water exchanges (82% by volume) in the wrong location occurred along the west coast of North America. Although the actual volumes of improperly exchanged water fluctuate over time, there are three relatively constant hotspots along the North American west coast (Figure 18; see also Dobroski et al. 2015).

Vessels conducting improper exchanges are almost certainly attempting to comply with California regulations, but likely:

- Misinterpret the required exchange distances (i.e. assuming the required distance is from the mainland and not any land, including islands)
- Misunderstand the Pacific Coast Region's boundaries.

Between 2014b-2016a, the hotspot of noncompliant ballast water exchange (by volume) occurred off the coast of Baja California, specifically near Isla Todos Santos (Figure 18).

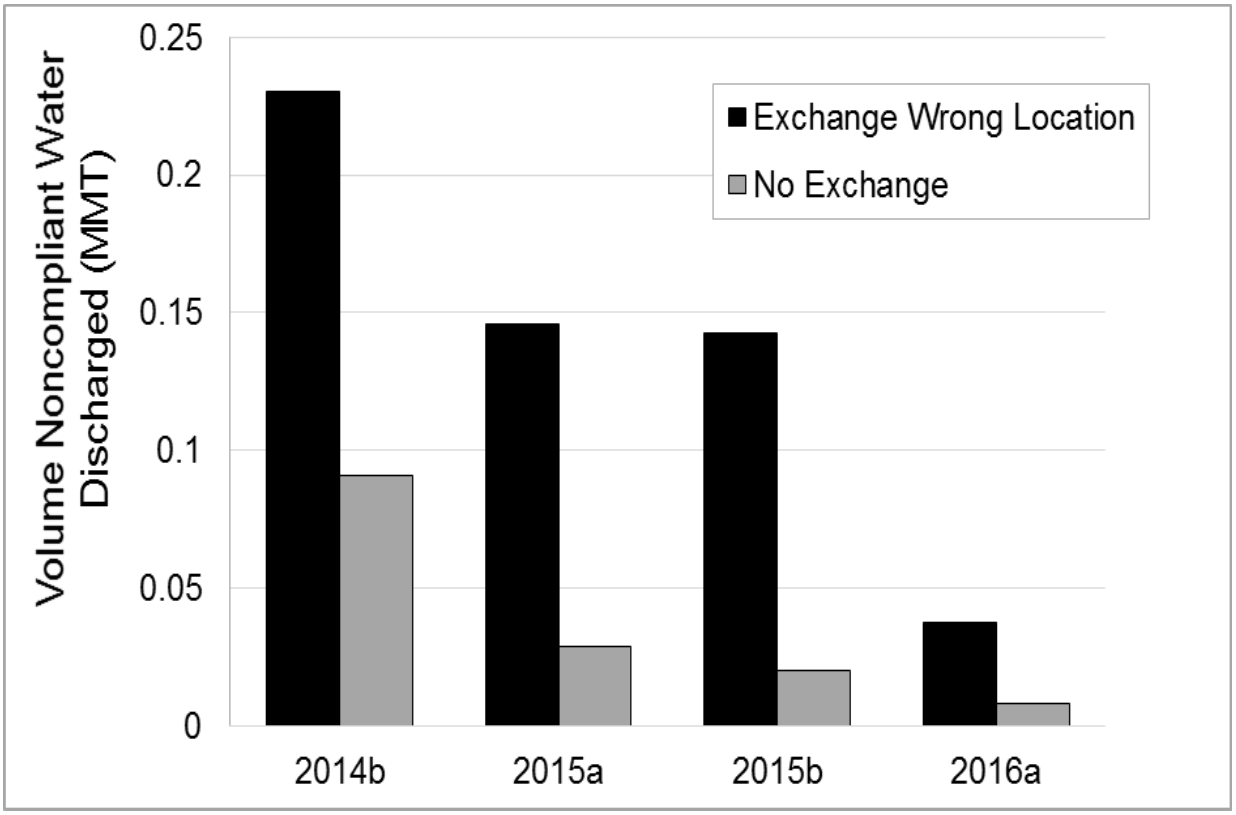

Figure 17. Volume (million metric tons, MMT) of reported noncompliant ballast water discharged by violation type (2014b-2016a; a = January to June, b = July to December)

There are a number of small islands situated off the coast of California and Baja California (e.g., the Farallones, Isla Guadalupe, and Isla Todos Santos). Vessels discharging ballast water originally sourced at ports in South America, Central America, and Mexico need to take these islands into account when calculating distance from land prior to conducting their exchanges.

Commission staff increased its outreach to these vessels to clarify management requirements. While the “hotspots” remained in generally the same place, the volume of ballast water discharged after being exchanged in the wrong place continued to decrease (Figure 17). The decrease in noncompliant exchange occurrences and volume during this reporting period are likely due to these outreach efforts.

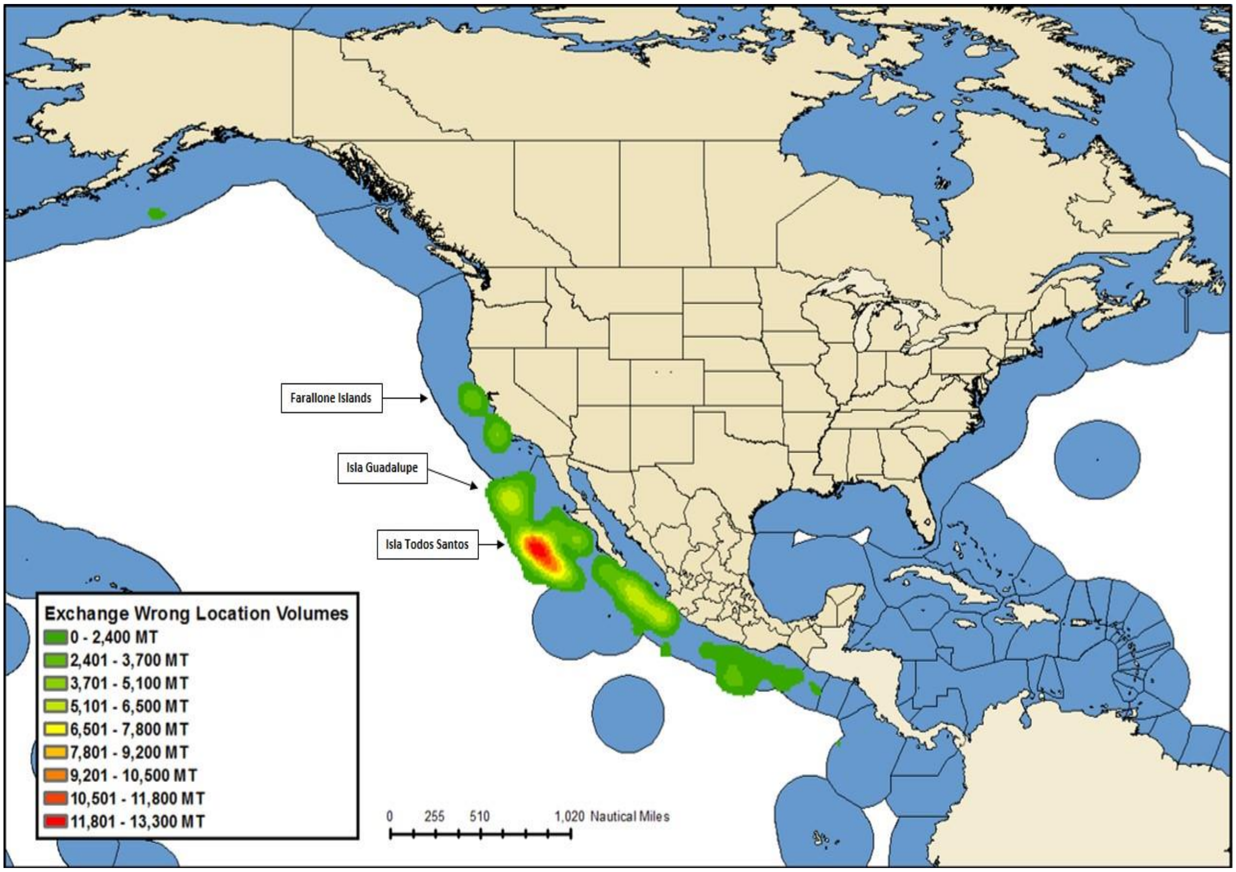

Figure 18. Vessel Reported Volumes and Locations of Noncompliant Ballast Water Exchanges located along western North America (2014b-2016a; a = January to June, b = July to December)

5.4.3.2 Unmanaged Discharges

Ballast water that was not managed (i.e. neither exchanged nor treated) made up 21% of noncompliant discharged volume during this reporting period (Figure 17). These discharges are the highest risk for ballast water-mediated NIS introduction to California. The geographic source of the unmanaged water is important for assessing the risk of NIS introductions because the establishment of introduced organisms may be influenced by the chemical, physical, and biological similarities between source and receiving waters.

Of the unmanaged ballast water reported as discharged into California waters, 98.5% originated from the west coast of North America. The west coast of North America can be divided into areas that share similar physical characteristics (e.g., temperature, salinity), as shown in Figure 19 (geographic classifications based on Spalding et al. 2007). Of the 148,000 MT (0.8% of the total volume of discharged ballast water) of unmanaged ballast water discharged into California:

- 51% (76,400 MT) originated from the cold temperate eastern Pacific, an area that expands from Alaska south to Point Conception
- 45% (66,800 MT) originated from the warm temperate eastern Pacific, an area characterized by warmer temperatures that roughly expands from the tip of the Baja California peninsula north to Point Conception in California
- 2.5% (3,700 MT) originated from the tropical eastern Pacific, an area from Central America north to the tip of Baja California

From 2014a through 2016b, only 750 MT (compared to 63,000 MT from 2012b-2014a) of unmanaged water (0.5% of the total volume of unmanaged water) originated from ports located in the cold temperate west Pacific, which roughly spans from the western Aleutian Islands south to China (Figure 19). The west Pacific is known to be a major source of NIS that have successfully established in California (Ruiz et al. 2000a), so such a low volume of unmanaged water from the area is a welcome sign.

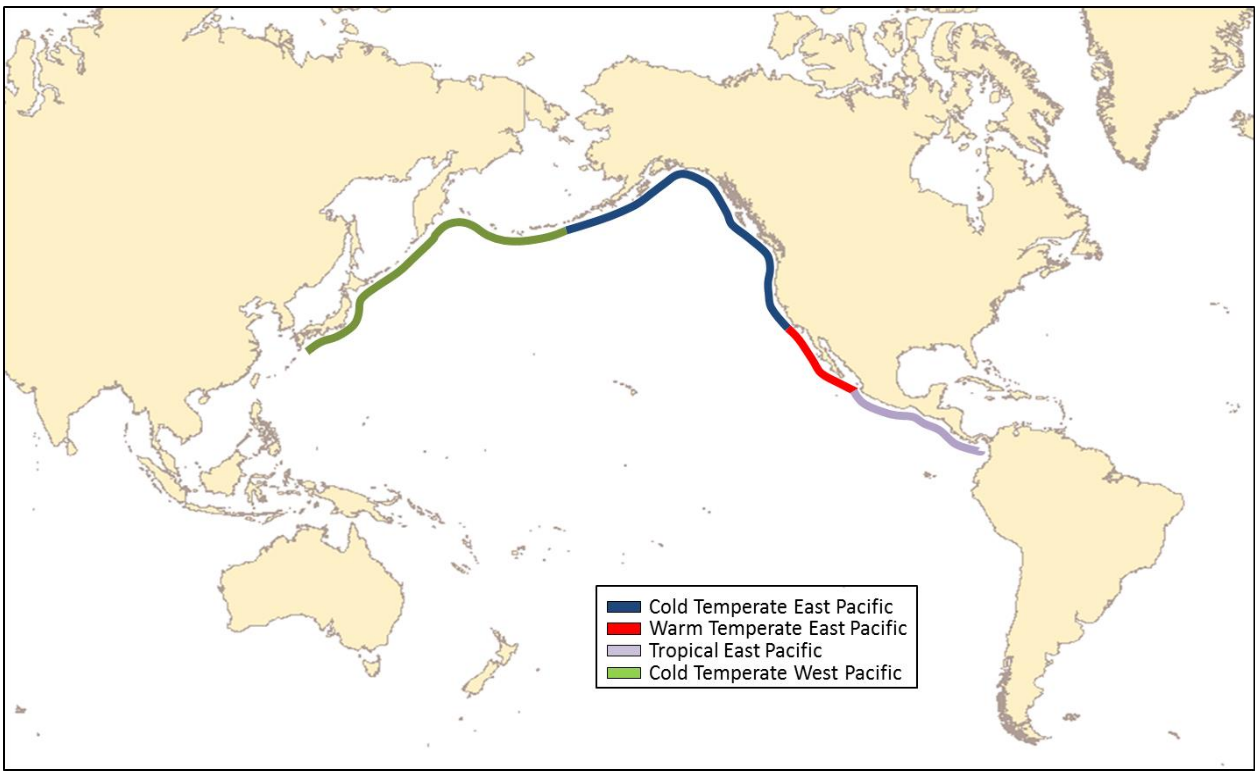

Figure 19. Most Common Geographic Source Regions for Unmanaged Ballast Water Discharged in California (2014b-2016a; a = January to June, b = July to December)

5.4.3.3 Noncompliant Ballast Water Discharge by Vessel Type

From 2014b–2016a, bulk and tank vessels discharged 92% of the total reported volume of noncompliant ballast water into the state. Tankers accounted for 41% and bulkers accounted for 51% of noncompliant discharges by volume.

The percent of noncompliant ballast water discharged from container vessels has decreased from 31.7% in 2004a (Falkner et al. 2007) to 2.7% during 2014b-2016a. This is despite the fact that container vessels have the greatest number of annual arrivals to California (accounting for nearly half (45%) of all vessel traffic to California since 2000).

General cargo, unmanned barges, and passenger vessels discharged 3.4%, 1.5%, and 0.7%, respectively, of all noncompliant ballast water (by volume) into the State between 2014b and 2016a.

5.4.4 Exemption from Ballast Water Management Due to Safety Concerns

Vessels can claim an exemption from California's ballast water management requirements if the safety of the vessel or its crew could be compromised by a management action (Public Resources Code section 71203). In such cases, vessels are not required to manage ballast water prior to discharge. While it is legal to discharge unmanaged ballast water when a safety exemption is claimed, the practice results in the discharge of high-risk water to the State.

Any vessel may find cause to claim a safety exemption. However, there are several unmanned barges that call on California ports multiple times per year that claim a safety exemption each time they discharge. The safety exemption is claimed because of concerns associated with transferring personnel to an unmanned barge to conduct ballast water exchange.

During this reporting period, seven unmanned barges claimed safety exemptions for 75 port calls and discharged a total of 18,145 MT of unmanaged ballast water into state waters. These unmanaged discharges, despite being compliant with the rules of safety exemptions, represent a high risk of species introductions into California waters and warrant additional attention. Unmanned barges typically operate on regular routes along the U.S. west coast, thus presenting an opportunity for repeated transfer and spread of NIS.

Despite the large volume of unmanaged ballast water discharged by select unmanned barges, most barge arrivals comply with ballast water management requirements. From 2014b–2016a, 95% of discharges by volume (953,000 MT) were managed in compliance with California law. For those unmanned barges unable to safely perform ballast water exchange, the use of either shore-based or shipboard ballast water treatment systems should be considered to reduce the risk of NIS introductions while minimizing threats to the safety of the vessel and its crew.

5.5 Ballast Water Treatment Technology Use in California

Data Synopsis

- Since 2012, 373 vessels arriving at California ports have reported, either to the Commission or the U.S. EPA, having a shipboard ballast water treatment system.
- Over that same time period, 38 vessels reported using a shipboard ballast water treatment system to manage 374,231 MT of ballast water discharged in California waters.

5.5.1 Vessels Reporting Shipboard Ballast Water Treatment Systems

Vessel owners and operators are installing shipboard ballast water treatment systems in anticipation of the implementation of IMO, U.S. federal, and state ballast water discharge performance standards. The Commission gathers information on the installation and use of ballast water treatment systems in California through the Ballast Water Treatment Technology Annual Reporting Form (Annual Form). Vessels must submit the Annual Form if discharging ballast water in California that was managed through use of a ballast water treatment system; however, many vessels submit the Annual Form even if they are not required to do so.

Since 2012, when Commission staff first began collecting data on ballast water treatment technology use, a total of 214 individual vessels have arrived at California ports and reported having a shipboard ballast water treatment system (Figure 20). An additional 159 vessels (for a total of 373) that have arrived at a California port and did not discharge (therefore were not subject to California reporting requirements) and reported having a shipboard ballast water treatment system to the U.S. EPA. The U.S. EPA began collecting information on shipboard ballast water treatment systems in 2014 as part of the reporting requirements in the 2013 Vessel General Permit.

While the number of shipboard ballast water treatment systems has increased year over year, the implications of this remain unclear because only vessels that discharge in California are required to report. Based on authority granted in AB 1312 (Chapter 644, Statutes of 2015), Commission staff is currently developing regulations that will require all vessels with a shipboard ballast water treatment system to report, whether they discharge or not.

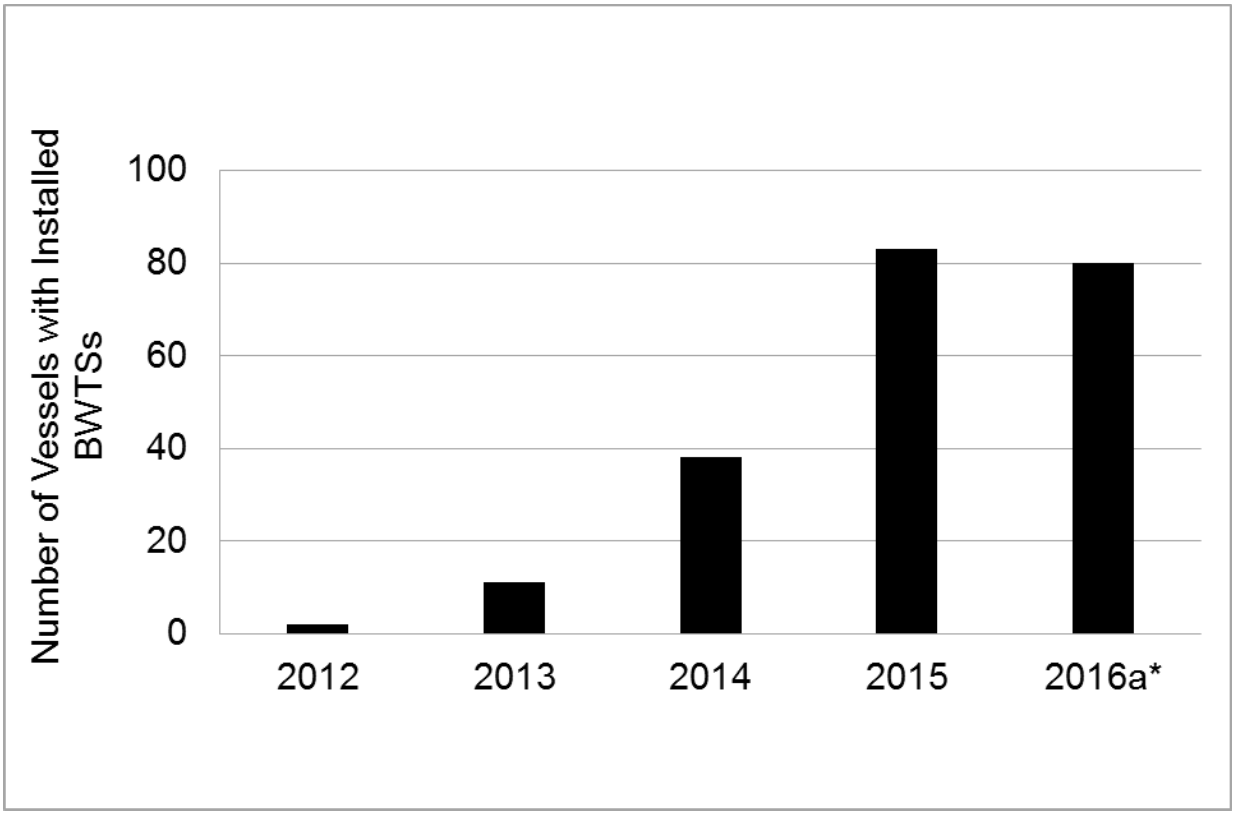

Figure 20. Number of Individual Vessels Reporting Having a Shipboard Ballast Water Treatment System. *2016a only includes forms received from January through June 2016 and this data set does not include data reported to the U.S. EPA.

It is anticipated that shipboard ballast water treatment system installations will continue to increase with the implementation of the BWM Convention, set to come into force on September 8, 2017, and as the USCG ballast water discharge performance standards, which have been in effect since 2013, become practicable.

5.5.2 Vessel Use of Shipboard Ballast Water Treatment Systems

Of the 214 vessels that reported having a shipboard ballast water treatment system to the Commission, 38 reported (via the BWMR or Supplemental Form) using their system to treat ballast water before or during discharge in California. Those 38 vessels discharged a total of 84 times for a total volume of 374,231 MT of treated ballast water (0.8% of total volume discharged).

The number of vessels that have reported using a shipboard ballast water treatment system to treat ballast water discharged in California is shown in Table 4. Several vessels have discharged treated ballast water on more than one arrival at a California port. A single passenger vessel with a ballast water treatment system has discharged treated ballast water 20 times. Although the vessel that has discharged 20 times is using its system frequently, it only releases an average of 528 MT of treated ballast water per discharge.

The reported shipboard ballast water treatment systems in Table 4 use several methods to kill organisms in ballast water. All of these systems incorporate a multi-step process that includes mechanical filtration followed by either ultraviolet radiation, oxidation, biocide, or electrochlorination (chlorination through electrolysis). For further information regarding available types of ballast water treatment systems and their methods of treatment, see the Commission's reports on the "Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters" (Commission 2013, 2014).

As the use of shipboard ballast water treatment systems increases, system performance data will need to be collected. The Commission currently lacks the authority to collect ballast water discharge samples for research purposes; Commission authority is restricted to compliance assessment sampling. However, staff need to gather data on system effectiveness and to test methods for collecting and analyzing ballast water samples. Therefore, Commission staff will pursue obtaining expanded authority to sample ballast water discharges.

Table 4. Vessel Reported Data on Shipboard Installation of Ballast Water Treatment Systems (n=number of discharges, MT = metric tons). Note that 2016a represents January – June 2016. These data do not imply a similar number will be received during 2016b (July – December 2016).

Vessel Type	Treatment Method	# of Vessels with Systems Installed	Reported Volume and Number of Discharges per Year							
			2013		2014		2015		2016a*	
			MT	*n*	MT	*n*	MT	*n*	MT	*n*
Auto	Electrochlorination	1								
	Oxidation	17							9546	1
	Ultraviolet Radiation	5								
Bulk	Biocide	10								
	Electrochlorination	27			73719	3	13923	1	14776	3
	Oxidation	6							3575	1
	Ultraviolet Radiation	22	20547	3	16185	2				
Container	Electrochlorination	29			24716	3				
	Oxidation	1								
	Ultraviolet Radiation	32					18001	8		
General	Electrochlorination	1								
	Oxidation	2								
	Ultraviolet Radiation	18			2378	1	4071	1	5335	3
Other	Biocide	2			4928	2	13312	2		
	Ultraviolet Radiation	1					4485	1		
Passenger	Oxidation	1			2322	1	991	1		
	Ultraviolet Radiation	7	366	1	392	1	5439	14	9667	18
Tank	Electrochlorination	27			4858	1	41408	5	64558	5
	Oxidation	4					3232	1		
Unmanned Barge	Oxidation	1							11500	1

5.6 Enforcement of MISA Requirements

5.6.1 Vessel Inspections

Under Public Resources Code section 71206, the Commission must assess compliance of any vessel subject to the MISA and associated regulations through a vessel inspection program. The program is operated out of the Commission's Marine Environmental Protection Division field offices in northern and southern California. For a description of the inspection process and procedures, see Dobroski et al. 2015.

Statewide, the Commission's Marine Safety personnel inspected 26% (4,669) of arrivals between 2014b and 2016a (Table 5), which is just over the mandate to inspect at least 25% of arriving voyages. Changes to the procedures by which vessels are prioritized for boarding have increased the number of inspections compared to previous reporting periods.

Between 2014b-2016a, 98.2% of inspected vessels were compliant with management requirements. The number of violations issued decreased from 114 between 2012b-2014a to 82 between 2014b-2016a, a 28% change from the previous reporting period. Of the 82 violations assessed between 2014a-2016b, 43% were administrative (paperwork, recordkeeping) and 57% were operational (ballast water management) (Table 5). Vessels found to have violations are cited and issued a notice of violation.

Table 5. Summary of Vessel Inspections and Violations (a = January to June, b = July to December)

	2014b	**2015a**	**2015b**	**2016a**
Number of Arrivals	4697	4423	4616	4566
Number of Inspections	1125	1229	1144	1171
Percent of Arrivals Inspected	24.0	27.8	24.8	25.6
Total Violations	25	22	17	18
Administrative	7	9	9	10
Operational	18	13	8	8

5.6.2 Enforcement through GIS Analysis of Vessel-Reported Data

MISP staff analyzes all vessel-submitted BWRF and BWMR data for compliance and enforcement of ballast water management requirements using GIS software. Every quarter, data for approximately 2,000 discharged ballast water tanks are analyzed to determine:

- Ballast water source
- Ballast water exchange location
- Whether proper ballast water management occurred

During 2014b-2016a, 58 ballast water management (operational) violations from 54 vessels were discovered using GIS analyses. These violations are in addition to those discovered during onboard inspections.

The 54 vessels with operational violations collectively discharged noncompliant ballast water from 265 individual ballast tanks. Because a vessel typically discharges multiple ballast water tanks, each of which can be managed independently, an individual vessel could be responsible for multiple operational violations.

Beginning in early 2014, MISP staff updated procedures for conducting quarterly GIS analyses of reported data and for notifying vessel owners and shipping agents of violations. The enhanced enforcement process has led to a significant increase in compliance for every quarter since January 2014 (Figure 21).

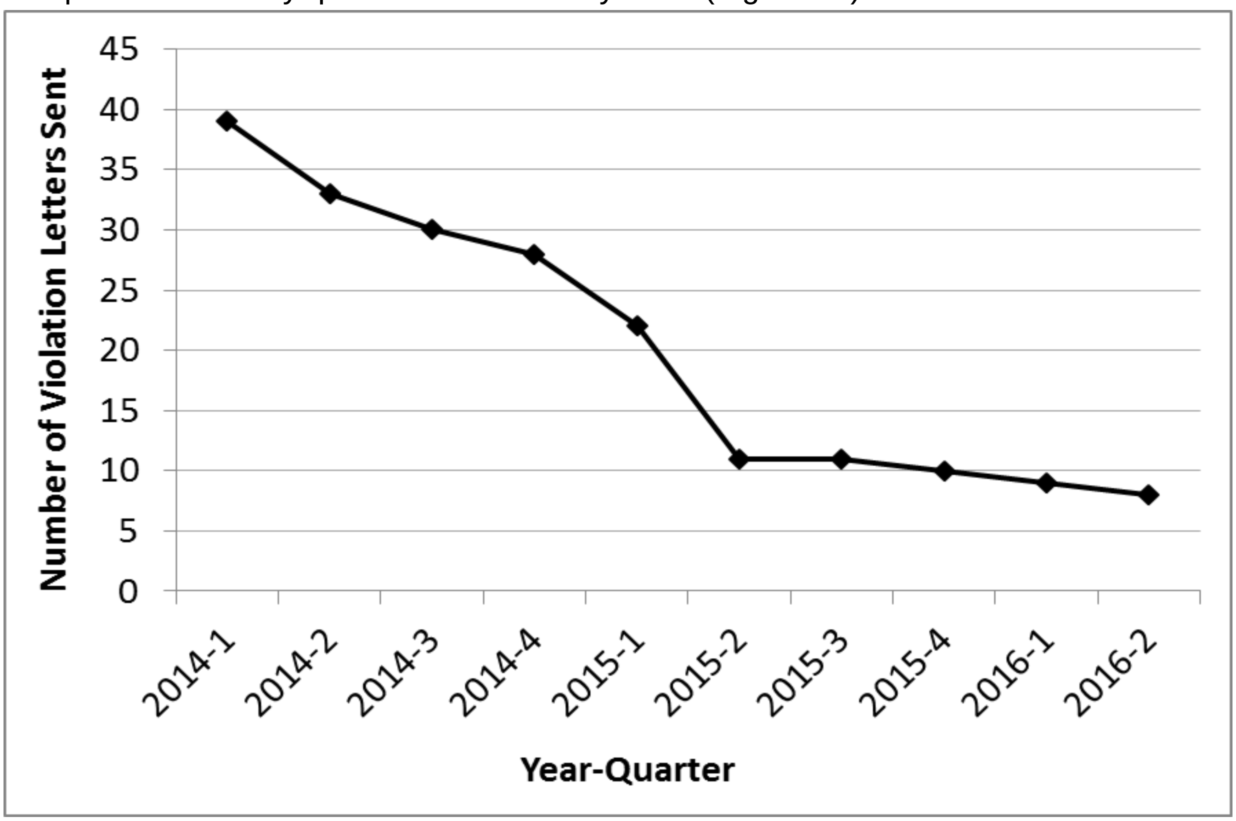

Figure 21. Number of Violation Letters Sent on a Quarterly Basis

5.7 Biofouling Management Practices and Patterns

Data Synopsis

- 63% of vessels that arrive at California ports, on average, report having antifouling coatings less than 2 years old.
- Between 11 and 20 vessels per year report being cleaned in-water within or adjacent to the Ports of LA and LB, and the majority of those vessels have copper-based antifouling coatings.
- The occurrence of vessel reported extended residency periods 10 days or more has increased 4% since 2013.
- The average reported traveling speed of vessels arriving at California ports decreased by 2.5% between 2013 and 2015, continuing a year over year reduction since 2008.

5.7.1 Hull Husbandry Practices of Vessels Arriving at California Ports

The Commission has collected information on vessel hull husbandry practices since 2008. All vessels that arrive at California ports must submit the HHRF once each year. The data present an annual snapshot of hull husbandry and operational practices of vessels that arrive at California ports.

5.7.1.1 Antifouling Coatings

From 2008 through 2015, an annual average of 63% of the vessels operating in California reported having coatings that were less than two years old. An annual average of 81% of vessels per year reported having coatings that were less than three years old (Figure 22).

An annual average of 1.5% of the vessels arriving at California ports reported coatings that are beyond their 3 to 5-year effective lifespan (depending on the coating and application thickness) (Figure 22). These vessels likely had coatings with ineffective biofouling protection and present an increased risk for NIS introduction when arriving at California ports.

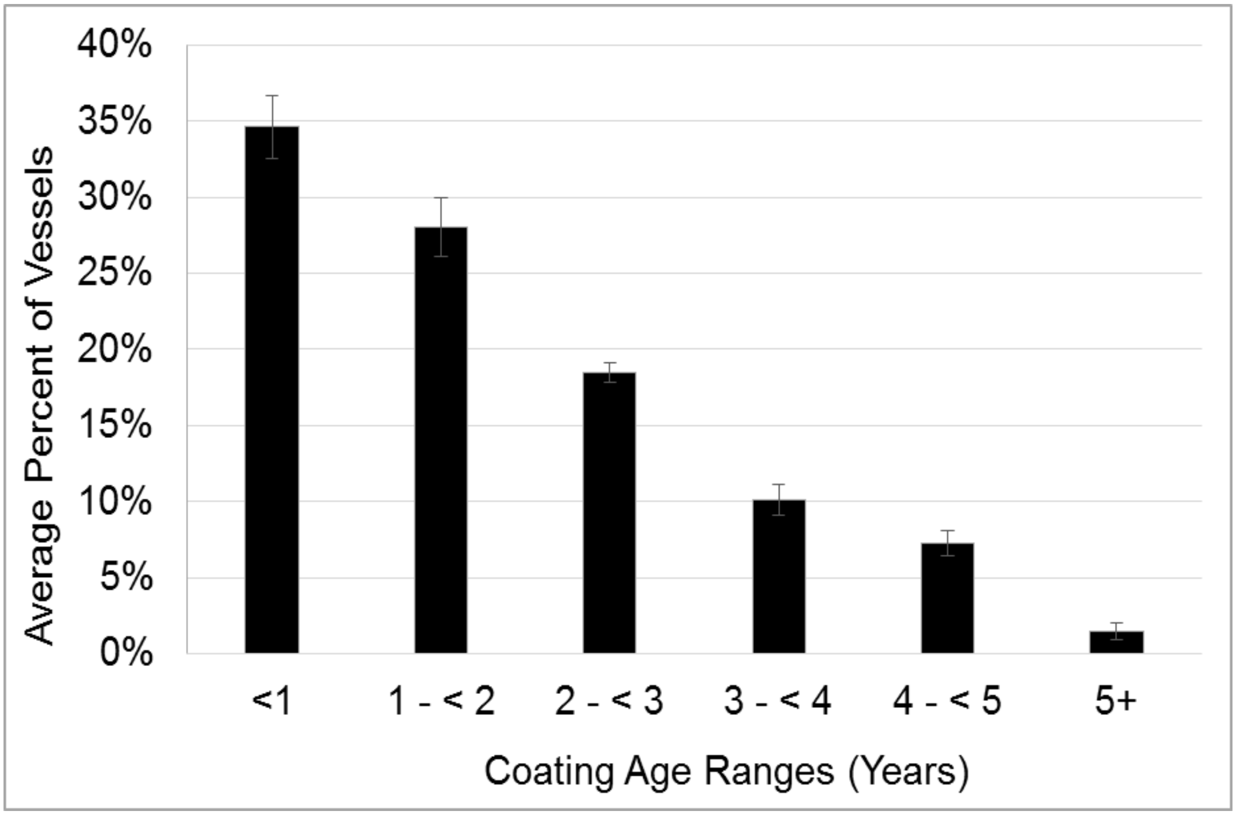

Figure 22. Average (± Standard Deviation) Coating Ages for Vessels Operating in California from 2008 through 2015

From 2008 through 2015, an annual average of 88% of vessels operating in California reported using biocidal coatings only (Figure 23), most being copper-based. The use of biocidal coatings increased 8% from 83% of vessels in 2008 to 91% of vessels in 2015. Small proportions of vessels used only foul-release coatings (2-5%) or a combination of foul-release coatings with targeted application of biocidal coatings in niche areas (3-4%; Figure 23).

Although passenger vessels account for only a small portion of the overall proportion of vessels arriving at California ports (2-3%), their combined use of foul-release coatings on the hull and biocidal coatings in niche areas has increased from 16% of vessels in 2008 to 49% in 2015. This 49% represents only 39 individual passenger vessels, but these vessels arrive frequently to California. This highlights a vessel type that is managing biofouling in a comprehensive way.

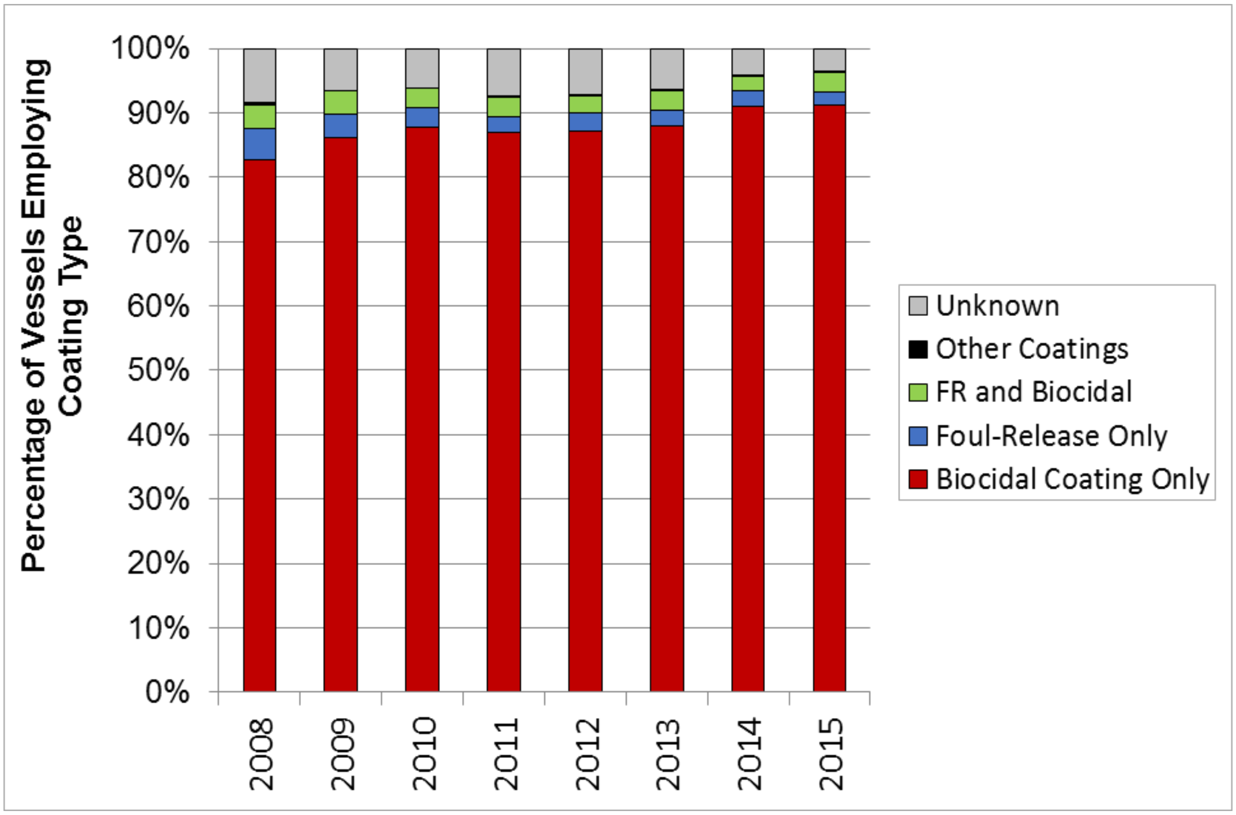

Figure 23. Antifouling Coating Use Reported By Vessels Operating in California from 2008 through 2015. (FR represents foul-release coatings; Other Coatings includes the use of coatings that do not have biofouling preventative properties)

5.7.1.2 In-Water Cleaning

Vessels reporting the use of in-water cleaning increased from 8% in 2008 to 17% in 2015. Bulk vessels, container vessels, and tank vessels accounted for the majority of reported in-water cleanings (Figure 24).

In-water cleanings were reported within 40 countries. In California, an annual average of 16 in-water cleanings occurred in or adjacent to LA-LB between 2008 and 2014. The Water Board prohibits in-water cleaning of vessels in areas impaired for copper, such as LA-LB, but vessels still report cleaning in LA-LB. Anecdotal evidence suggests that in-water cleanings of vessels with biocidal coatings are taking place outside of the ports and outside of the breakwater, beyond state waters, to avoid violating existing State Water Board prohibitions on the practice (Barta, R., pers. comm. 2016). However, it is impossible to determine the exact location with HHRF data. Most of the vessels reported to have been cleaned in LA-LB had copper-based or other biocidal coatings (Figure 25).

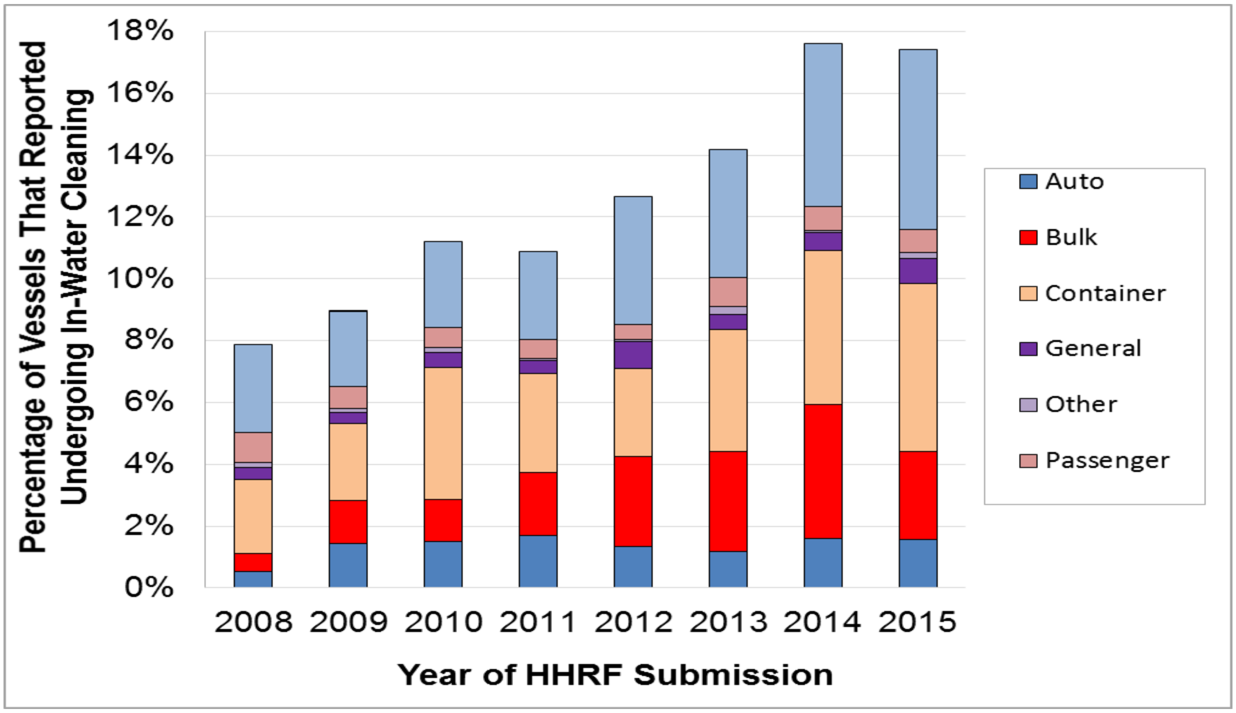

Figure 24. Percentage of Vessels that Reported Undergoing In-Water Cleaning since Most Recent Drydocking

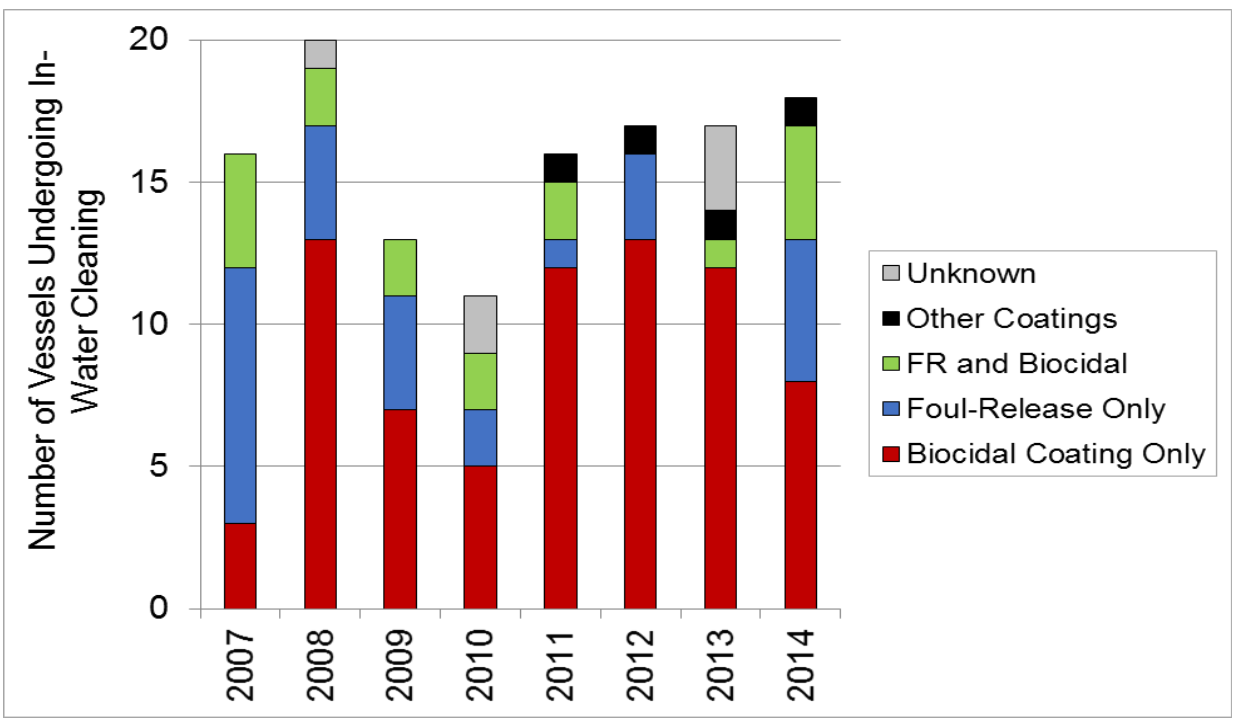

Figure 25. Number of Vessels Reporting In-Water Cleaning in or around the Ports of Los Angeles and Long Beach and the Type of Coatings Reported by Those Vessels. (FR represents foul-release coatings; Other Coatings includes the use of coatings that do not have biofouling preventative properties)

5.7.2 Operational Practices of the Commercial Fleet in California

A key component in assessing vessel biofouling risk is the length of time a vessel sits in one place. The longer a vessel remains in one place, the more opportunity for biofouling organisms to accumulate (Floerl and Coutts 2009).

The number of vessels reporting residency periods greater than ten days continues to increase, albeit more slowly than previously reported (Figure 26). Between 2008 and 2013, there was a 75% increase in the reported number of these prolonged residency periods (Dobroski et al. 2015). The increase between 2013 and 2014 was approximately 2%, similar to the 2% increase from 2014 to 2015 (Figure 26).

The largest increases from 2013 to 2015 were for residency periods:

- Between 10 and 20 days – 5% increase
- Between 30 and 45 days – 5% increase
- Between 45 and 60 days – 14% increase
- Between 90 and 120 days – 56% increase
- Greater than 120 days – 96% increase

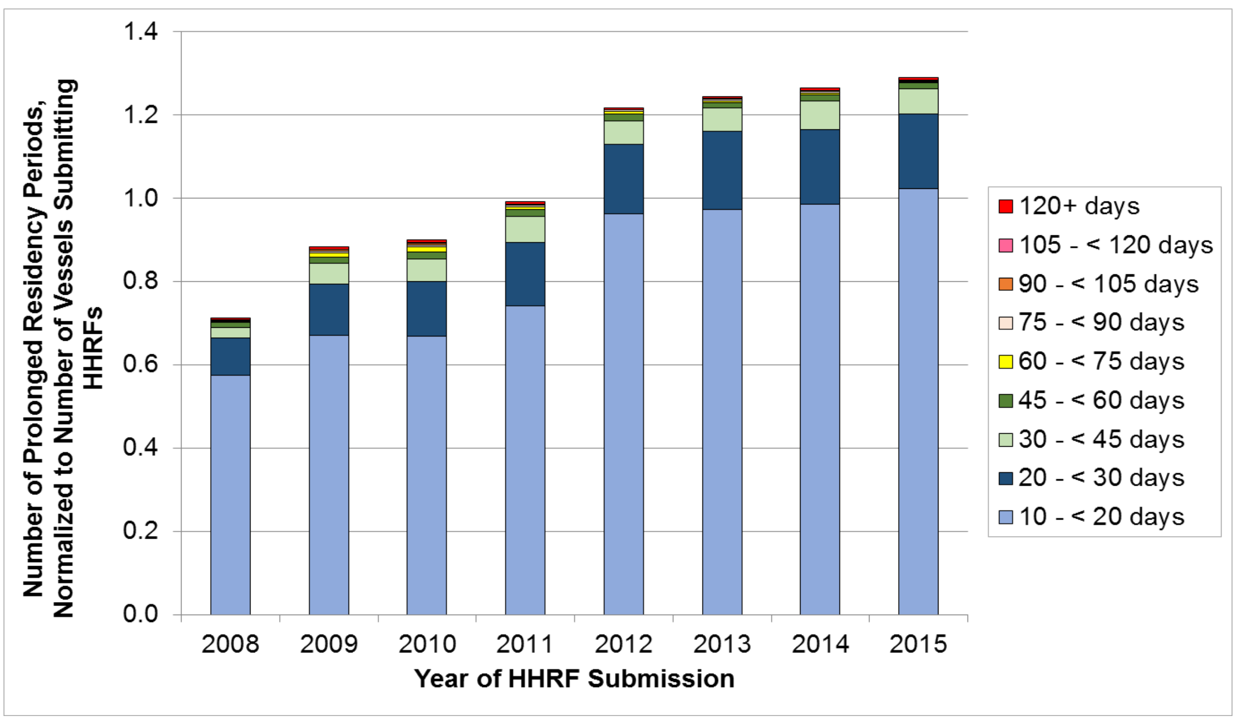

Figure 26. Number and Duration of Prolonged Residency Periods during Each Reporting Year for Vessels Operating in California. Note, data are normalized by number of vessels submitting HHRFs each year to allow for appropriate comparisons between years, and represent stationary periods occurring since a vessel's most recent dry docking or in-water cleaning.

Although there was a 4% increase in residency periods more than ten days between 2013 and 2015, changes varied by vessel type. Auto carriers (32% reduction) and bulkers (9% reduction) reported fewer prolonged residency periods in 2015 when compared to 2013 (Figure 27). Unmanned barges (162% increase) and the "other" vessel type (107% increase) reported the largest increases between 2013 and 2015. The 4% increase was mostly driven by container vessels (33% increase), the most common vessel type arriving at California ports or places (487 individual container vessels in 2015).

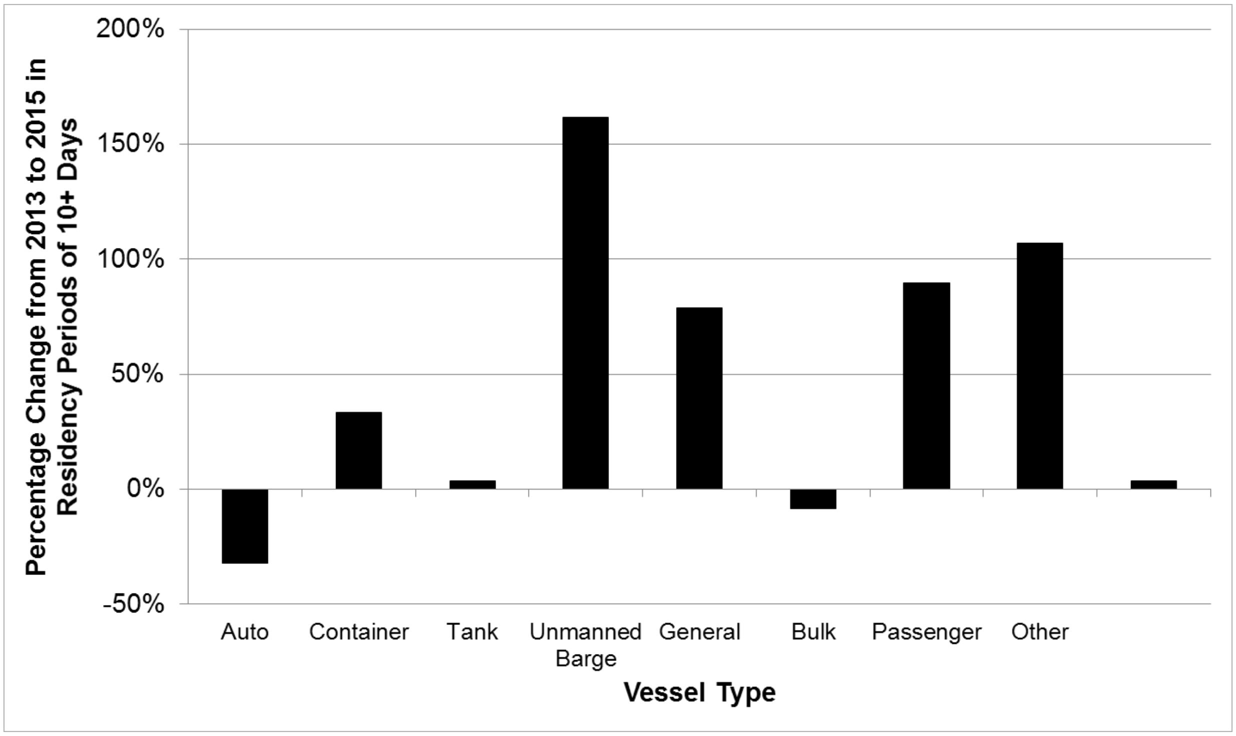

Figure 27. Percentage Change in the Number of Prolonged Residency Periods of 10 Days or Greater by Vessel Type from 2013 to 2015. Data are normalized by number of vessels submitting HHRFs each year to allow for comparisons between years and represent stationary periods occurring since a vessel's most recent dry docking or in-water cleaning.

Vessel traveling speeds continue to drop year over year. Average reported traveling speeds dropped from 2013 to 2015 by 2.5%, from 14.61 knots in 2013 to 14.25 knots in 2015 (Figure 28). This 0.36 knot decrease represents an estimated fuel savings of 2.04 metric tons per day (Bialystocki and Konovessis 2016).

The HHRF data from 2014 and 2015 indicate continued increase in extended residency periods and decrease in traveling speeds for vessels arriving at California ports. These trends continue to increase the likelihood of biofouling accumulation and, therefore, the risk of NIS introduction. To decrease the risk of biofouling mediated NIS introduction for vessels arriving at California ports, biofouling management regulations need to be adopted and implemented.

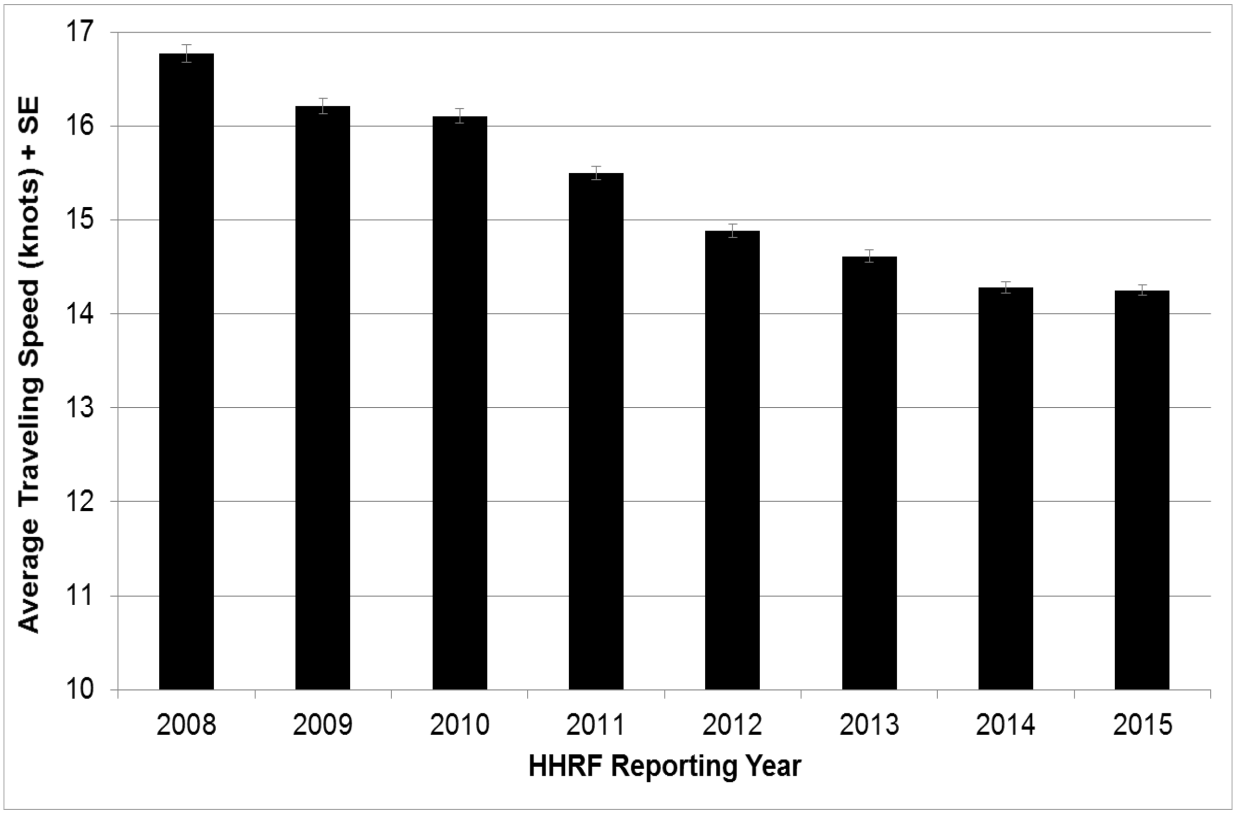

Figure 28. Average (± standard error) Traveling Speed Reported by Vessels Arriving at California Ports from 2008-2015

6. COOPERATING AGENCIES: DATA ANALYSIS

6.1 Board of Equalization

The Board of Equalization (BOE) collects a fee from the owner or operator of each vessel that arrives at a California port or place from a port or place outside of California (Table 6, Public Resources Code section 71215). The fee is currently $850 per qualifying voyage and is deposited into the Marine Invasive Species Control Fund. Vessels moving from one port or place in California to another are not assessed a fee for the additional arrivals within the State. Once a vessel leaves state waters, it will be assessed the fee upon next arrival to a California port or place. The Marine Invasive Species Control Fund supports all Marine Invasive Species Program operations and personnel. The MISP receives no General Fund dollars.

Table 6. Annual Summary of Collected Marine Invasive Species Program Fees

Year	Voyages Billed	Voyages Reported[a]	Total Voyages	Fees Billed ($)	Fees Reported ($)	Total Fees ($)	Payments Recd. for Period[b] ($)
2000	5,870		5,870	2,735,134		2,735,134	2,724,072
2001	5,263	510	5,773	2,105,200	204,000	2,309,200	2,307,593
2002	4,599	921	5,520	1,376,600	277,200	1,653,800	1,645,350
2003	4,668	1,013	5,681	933,600	202,600	1,136,200	1,134,962
2004	5,858	1,123	6,981	2,788,000	535,100	3,323,100	3,296,523
2005	6,161	1,157	7,318	2,873,800	535,200	3,409,000	3,374,372
2006	6,247	1,161	7,408	2,498,800	464,400	2,963,200	2,956,348
2007	5,997	1,199	7,196	2,398,800	479,600	2,878,400	2,863,459
2008	5,578	1,133	6,711	2,753,750	557,825	3,311,575	3,273,822
2009	5,023	866	5,889	3,324,325	574,100	3,898,425	3,856,119
2010	5,067	899	5,966	4,306,950	764,150	5,017,100	5,009,473
2011	5,174	930	6,104	4,397,900	790,500	5,188,400	5,143,239
2012	4,479	767	5,246	3,807,150	651,950	4,459,100	4,356,722
2013	4,753	819	5,572	4,070,050	696,150	4,766,200	4,662,171
2014	4,864	768	5,632	4,134,400	652,800	4,787,200	4,697,234
2015	4,764	753	5,517	4,049,400	633,250	4,682,650	4,517,499
2016a[c]	2,409	414	2,823	2,039,150	351,900	2,391,050	2,317,124
TOTAL	**87,202**	**14,493**	**101,695**	**50,956,809**	**8,421,725**	**59,378,534**	**58,527,347**

a "Voyages Reported" are vessel operators/owners that self-report to BOE once a month.
b Actual amounts received may exceed amount billed because of penalties and interest charges.
c Amounts may be understated until return processing is complete.

The BOE receives daily reports from the Marine Exchanges of Southern California and the San Francisco Bay Region. The reports provide a list of all arrivals at California ports. These reports are reviewed by BOE to identify arrivals that are subject to the fee. Vessel accounts are billed based on the arrival information.

Between July 1, 2014, and June 30, 2016, an average of 400 vessel arrivals were billed per month. The average collection rate was 97% (Table 6). There are currently 6,505 vessel accounts registered with the BOE.

6.2 California Department of Fish and Wildlife Marine Invasive Species Program

Since 2000, the California Department of Fish and Wildlife's Marine Invasive Species Program (CDFW-MISP) has monitored portions of California's coastal waters to inventory the aquatic communities. The results of the inventories are used to:

- Measure the status and trends of NIS introductions in coastal marine and estuarine ecosystems
- Understand the distribution and patterns of spread of NIS among California coastal and estuarine habitats
- Assess the vectors of introduction and spread of NIS
- Detect changes in the patterns (rate, spread, prevalence) of NIS in response to management strategies and shifts in vector management

6.2.1 Sampling Methods

During 2012-2016, CDFW-MISP contracted with the Smithsonian Environmental Research Center's Marine Invasions Laboratory (SERC) to survey hard substrate (epifaunal), soft sediment (infaunal), and water column (plankton) communities in several bays and harbors (Figure 29).

Hard substrate communities were sampled using settling plates (a sampling device used to allow organisms to settle and grow) deployed over a three-month period at ten sites each in Humboldt Bay, Port Hueneme, Marina del Rey, and San Francisco Bay. San Francisco Bay was also sampled in 2014, 2015, and 2016. At least 50 settling plates were collected from each site for species identification. Additional plates were also collected for genetic analysis. To date, the plates through the 2015 sampling efforts have been analyzed, resulting in over 10,000 organism samples for visual (morphological) identification and over 6,000 for molecular (genetic) identification.

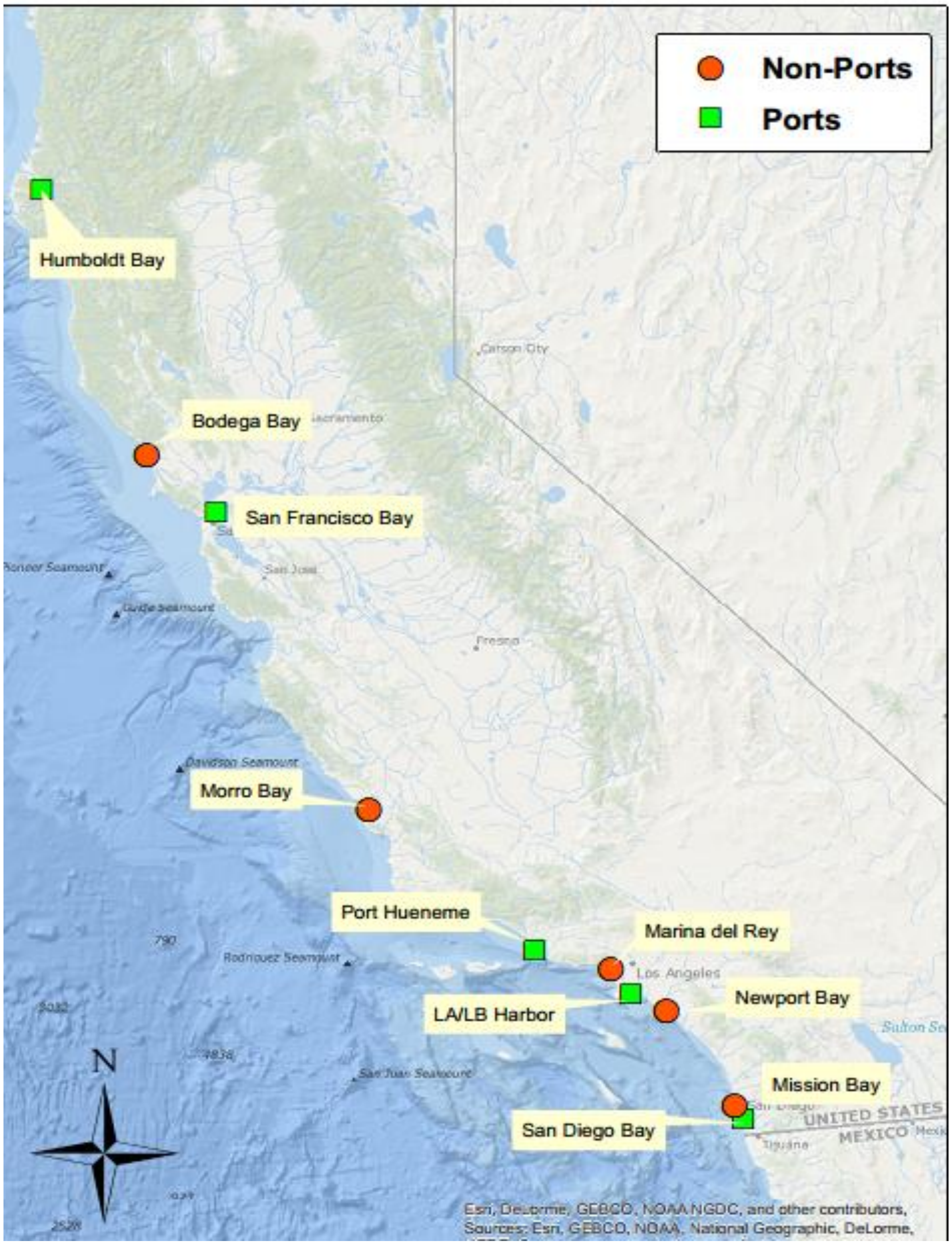

Figure 29. Primary Estuaries for NIS Monitoring, 2012-2016. Green squares signify commercial ports (Ports), red circles signify non-commercial ports (Non-Ports).

Soft-sediment (e.g., sand and mud) communities were sampled from three different water depths in Humboldt Bay during 2015 and in San Francisco Bay in 2014, 2015, and 2016. Fifty samples were collected in San Francisco Estuary each year. In Humboldt Bay, 50 samples were collected, for a total of 150 samples. Species identifications and sediment grain size analysis (done to determine type of sediment) for all samples have been completed, and the results have been published (Jimenez and Ruiz 2016).

Plankton samples were collected from Humboldt Bay, San Francisco Bay, Port Hueneme, and Marina del Rey in 2015. Plankton was also sampled in San Francisco Bay in July 2016. Plankton samples were analyzed and identified using both molecular and visual techniques.

Further study is needed to understand the dynamics of NIS spread from estuaries to outer coastal habitats. To determine the feasibility of examining the outer coast regions for NIS, CDFW-MISP funded pilot intertidal and subtidal (submerged) surveys.

During 2014 and 2015, ten rocky intertidal sites and eight subtidal sites in the counties of Marin, San Mateo, Santa Cruz and Monterey in Central California were sampled to try and detect the presence of the invasive bryozoan *Watersipora* spp. *Watersipora* was observed at four of the eight subtidal survey sites and at four of the ten rocky intertidal survey sites. This survey provides baseline measures for further monitoring of changes in the distribution and abundance of this species over time. *Watersipora* is one of the few known NIS that has successfully established populations on the outer coast.

6.2.2 Results

From 2014-2016 two NIS not previously reported in California estuaries were detected. An unknown species of the bryozoan *Watersipora* was detected at three sites in San Diego Bay, one site in Mission Bay, and one site in Morro Bay. Genetic analyses are ongoing to determine what the exact species is and if it is introduced. A bryozoan of the genus *Fredericella* was found at three low salinity sites in San Francisco Bay-Delta. Taxonomists are reviewing archived specimens from San Francisco Bay-Delta to determine if the *Fredericella* species may have been present and undetected in earlier surveys, a possibility given that sampling of the low salinity zones in the San Francisco Bay-Delta has only recently been increased. *Fredericella* is most likely spread through fish-stocking, trailered boats, fishing gear, and ornamental aquatic plants (Fofonoff et al. 2003b)

Repeated surveys of the hard and soft substrates and the plankton community over multiple years in the San Francisco Estuary have detected very few newly introduced NIS. Genetic analysis of the planktonic community is ongoing and has potentially found a few as yet undetected NIS, but those identifications are still in the process of being verified. Given the scale of the surveys and the contrast to past studies that documented an increasing rate of new NIS detections in California estuaries, particularly San Francisco Bay (Cohen and Carlton 1998), the dearth of new NIS is encouraging and not likely to be a result of undersampling.

Most importantly, when compared to the rate of NIS introductions to California as a whole (Ruiz et al. 2011), these results show a decline in the rate of new invasions in recent years. The apparent decrease in the rate of new invasions in California coastal waters will be the focus of ongoing sampling and analysis. CDFW-MISP will test if the slowing rate of new invasions is real, and, if so, determine whether this change is the result of commercial vessel vector management or other factors, such as shipping patterns or environmental changes.

6.3.3 Next Steps

As CDFW-MISP continues monitoring coastal waters, several approaches will be emphasized, with the goal to evaluate the efficacy of the MISP's ballast water and biofouling vector management program. These components include:

- *Bay and Estuary Sampling.* Continue annual measures in multiple habitats in San Francisco Bay. Add annual sampling in the Ports of Los Angeles and Long Beach which are major hubs for commercial vessel traffic in southern California.

- *Genetic Approaches for NIS Detection*. Genetic analysis will continue to complement morphological identifications as well as help create a statewide DNA barcode library. CDFW-MISP will also continue to provide support for the development of increasingly efficient and sensitive genetic analyses that will allow the sampling of many more estuaries than current funding typically supports.

- *Spill-Over Assessments*. To evaluate possible spread of NIS from estuaries to outer coastal regions, sampling will focus on natural substrate adjacent to estuaries. Surveys will build on the CDFW-MISP's recent pilot study and will target algal species, in addition to *Watersipora* species.

6.3.4 California's Nonindigenous Species Database

CDFW-MISPs database of California non-native marine organisms (CANOD) merged with SERC's National Exotic Marine and Estuarine Species Information System (NEMESIS) in 2015, to form the web-based California Non-Native Estuarine and Marine Organism database (Cal-NEMO, http://invasions.si.edu/nemesis/calnemo/intro.html).

In Cal-NEMO, data are publicly available, with the added benefit of individual species profiles enhanced by images, world invasion history (distribution and observations), ecology, impacts, and interactive maps for over 200 species introduced into the coastal waters of the state.

The relocation of the database affords the benefits of a larger centralized database with long-term technical support provided by SERC, resulting in cost-efficiency for the CDFW-MISP. The database continues to be updated as new species are discovered and new research becomes available, including data from the CDFW-MISP surveys.

7. COLLABORATIVE AND FUNDED RESEARCH

The Marine Invasive Species Program is mandated to "move the state expeditiously toward elimination of the discharge of nonindigenous species into the waters of the state" (Public Resources Code section 71201). The MISP implements this directive through funding, conducting, and collaborating on research that advances the development of strategies to prevent the introduction of NIS from ballast water and vessel biofouling. Specifically, Public Resources Code section 71213 requires the Commission to:

> *". . . identify and conduct any other research determined necessary to carry out the requirements of this division. The research may relate to the transport and release of nonindigenous species by vessels, the methods of sampling and monitoring of the nonindigenous species transported or released by vessels, the rate or risk of release or establishment of nonindigenous species in the waters of the state and resulting impacts, and the means by which to reduce or eliminate a release or establishment . . . "*

The Commission has funded research addressing several NIS-related issues to reduce or prevent the occurrence of NIS introductions into California waters. This section summarizes the Commission's research efforts over the last two years (2014b-2016a).

7.1 Ballast Water Research

The implementation of ballast water discharge performance standards at the state, federal, and international levels is rapidly approaching, underscoring the need to investigate the suitability of compliance assessment technologies and ballast water treatment methods. To address this need, the Commission has investigated new technologies and approaches to implementation and compliance assessment through funding, conducting, and collaborating on targeted research. The four projects described in this section, funded by the Commission over the past two years, are either in progress or were recently completed by:

- The Delta Stewardship Council
- The California State University, Maritime Academy
- The Glosten Associates
- Michigan State University
- The Royal Netherlands Institute for Sea Research

A brief discussion of each of these studies is presented below.

7.1.1 The Delta Stewardship Council – Shore-Based Ballast Water Treatment Feasibility Study

Per Public Resources Code section 71204.3, vessels may comply with California's pending ballast water performance standards by discharging ballast to a shore-based reception facility. However, there are currently no shore-based facilities in California or the United States that are designed to treat nonindigenous species in ballast water. 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.

In June 2013, the Commission provided funding for a feasibility study to investigate the use of shore-based treatment and reception facilities as an option for vessels to comply with the California ballast water discharge performance standards. The contract is managed by the Delta Stewardship Council. The study is being conducted in three main phases, with a public forum and independent scientific review after completion of each phase.

A public meeting was held in October 2015 after the completion of the literature review. A second public meeting was held in August 2016 after completion of further benchmarks. A final report is expected in late-2017. Information on the progress of the study can be found on the Delta Stewardship Council's website: http://deltacouncil.ca.gov/feasibility-study-shore-based-ballast-water-reception-and-treatment-facilities-california-0

7.1.2 California State University, Maritime Academy – Ballast Responder

In 2014, the Commission provided funds to the California State University, Maritime Academy's Golden Bear Facility to evaluate a portable ballast water treatment technology that could be used by a vessel to manage ballast water in emergency or contingency situations (e.g., equipment failure). The "Ballast Responder" was developed through a collaboration among the U.S. Geological Survey, the National Park Service, and a maritime engineering firm, The Glosten Associates. The Ballast Responder uses a three-step process to kill organisms in ballast tanks:

1. A mixing device is lowered into a ballast tank
2. An active substance (e.g., sodium hypochlorite) is added to the ballast tank being mixed

3. A neutralizing agent is added to render the treated ballast water safe for discharge to local waters

The Golden Bear Facility determined the most effective dose and holding time for the active substance and evaluated the effectiveness of the Ballast Responder at decreasing organism concentrations in ballast water. Once the most effective dose and holding time were determined, the Ballast Responder was evaluated to assess efficacy relative to the USCG ballast water discharge performance standards. The study was completed in December 2015.

The ballast water discharged after being treated with the Ballast Responder met USCG discharge standards in seven of the twelve tests. In tests where the final 15% to 20% of the discharge was excluded from sampling and analysis, the Ballast Responder met USCG discharge standards in eleven of the twelve tests; these results show that there is a potential pool of organisms left in the last part of a ballast water discharge, and further study is required to address treating these organisms.

Additional work will be necessary to further develop the Ballast Responder, however, this study concluded that the Ballast Responder has the potential to reduce the risk of ballast water mediated introductions of aquatic invasive species on a contingency basis.

7.1.3 Michigan State University – Enumerating Viruses in Ballast Water

In 2014, the Commission found that no ballast water treatment technologies were available to meet the California ballast water discharge performance standards (Commission 2014). One reason for this finding was that available methods to enumerate viruses in ballast water did not exist, which limits both the availability of treatment systems to meet the California standards and the Commission's ability to assess vessel discharge compliance with the standards.

The Commission provided funding to Michigan State University and The Royal Netherlands Institute for Sea Research to identify the availability and feasibility of methods to enumerate viruses in ballast water.

The four-phase study consists of:

- Phase 1: A review of natural aquatic viral abundances in different water types and their relation to the California ballast water discharge performance standards
- Phase 2: An evaluation of the detection limits for viruses in ballast water using current counting techniques

- Phase 3: A laboratory based evaluation of the ability of commonly used ballast water treatment technologies (i.e. ultraviolet radiation and chlorination) to reduce the concentration of viruses
- Phase 4: An investigation of the viral concentrations in a variety of samples previously collected and preserved during ballast water treatment system type-approval tests. These samples were not previously analyzed because of the lack of a viral standard in the IMO ballast water discharge performance standards.

Two phases of the project are complete as of October 1, 2016. Based on the review in the first phase, virus particles in offshore marine water ranges from 3 million to 52 billion virus particles per liter (median of 2.6 billion virus particles per liter). This suggests that in order for vessels to meet California's interim ballast water discharge performance standards, more than a 1.5 to 5.7 log removal of viral particles is needed. Log removal is a term commonly used in the drinking water treatment industry. The 1.5 to 5.7 log removal equals a 95% to 99.9997% decrease in viral particles in each liter or water.

The second phase reviewed several methodologies for enumerating viruses in ballast water, which are summarized in Table 7.

Table 7. Review of available methods for enumerating viruses in ballast water (for a full explanation of each of the methods, see Kim et al. 2016).

Method	Accuracy[1]	Specificity[2]	Mobility[3]	Time[4]	Labor[5]	Cost[6]
Plaque	Medium	Excellent	Excellent	High	High	Low
Most Probable Number	Good	Excellent	Excellent	Low	High	Low
Transmission Electron Microscopy	Good	Poor	Poor	Medium	Medium	High
Epifluorescence microscopy	Poor	Poor	Poor	Medium	Medium	Medium
Flow cytometry	Excellent	Poor	Excellent	High	Medium	Low
Molecular	Excellent	Excellent	Poor	Low	Medium	High

[1]Accuracy shows repeatability of the method.
[2]Specificity indicates how specific a method is for individual organisms.
[3]Mobility shows how viable it is to move the equipment and use it at field stations or onboard vessels.
[4]Time indicates how much time is required before producing results.
[5]Labor indicated the amount of man hours are needed to produce results
[6]Cost indicates costs per sample.

The third and fourth phases are due in 2017.

7.1.4 Rapid Assessment Tools for Ballast Water Treatment System Performance – MISP Staff

Several rapid assessment tools designed to detect non-compliance (the tools are not precise enough to measure compliance) with the IMO/U.S. federal ballast water discharge standard for the 10-50µm organism size class. Rapid assessment tools are hand-held, fast, and simple to use, and require minimal end-user training.

Rapid assessment tools provide an indicative “red light-green light” relative to a discharge standard (note: most of these tools are being developed for the U.S. federal or international standards, not the California standards). A “green light” indicates the concentration of organisms in the vessel’s ballast water may not exceed the discharge standard, whereas a “red light,” indicates the discharge standard is likely exceeded and additional sampling would be needed to verify non-compliance and proceed with enforcement.

In 2014, MISP staff sampled the ballast tanks of eight vessels and ran parallel analyses of the water using three different rapid assessment tools. To compare how the results from the rapid assessment tools correlate to the actual number of organisms in a sample, staff counted the number of organisms under a microscope. Results from this study were mixed. Some variation was found between organism counts and the rapid assessment tool readings. The variation was attributed to the large number of non-target organisms present in the untreated water samples collected.

To reduce variation and understand how the tools should operate as intended, MISP staff began comparing the rapid assessment tools using ballast water that had undergone treatment on board operational vessels in late 2015. The comparisons are ongoing, but the results, coupled with reports from parallel studies (Gollasch 2015, Bradie 2016), will help guide the Commission in selecting the most appropriate rapid assessment tool. Rapid assessment tools will be critical components of vessel inspections to determine possible non-compliance with ballast water discharge performance standards.

7.2 Vessel Biofouling Research

The Commission also investigates the risk of vessel biofouling-mediated NIS introductions into California. Three projects are in progress or recently completed, and involve:

- Smithsonian Environmental Research Center
- University of Waikato (New Zealand)

- USCG
- Naval Surface Warfare Center
- University of Maryland Center for Environmental Science
- San Jose State University
- California State University Council on Ocean Affairs, Science, and Technology

A brief discussion of each of these studies is presented below.

7.2.1 Assessing the Role of Copper Tolerance in Biofouling Invasion Risk around California

In 2015, the Commission funded San Jose State University to investigate the prevalence of copper tolerance in biofouling organisms and the role that copper tolerance may play in NIS introduction risk.

This research intended to evaluate copper tolerance and NIS introduction risk on several levels:

- Prevalence and strength of copper tolerance across natural communities of biofouling organisms (native and NIS)
- Copper tolerance in the presence of varying levels of background (ambient water) pollution levels, looking at patterns at sites with differing water quality parameters
- Copper tolerance in the presence of varying levels of vessel traffic, from heavily trafficked commercial ports, to moderately-trafficked recreational vessel marinas, to infrequently trafficked offshore islands

Copper is toxic at certain concentrations, and its presence can make an underwater surface inhospitable to most biofouling organisms. Copper-based antifouling coatings are used by vessel owners and operators to prevent vessel biofouling. Although the presence of effective copper-based antifouling coatings will prevent most biofouling organisms from accumulating on a vessel's underwater surfaces, some organisms have proven to be more tolerant of copper than others and are not as affected by copper-based antifouling coatings.

Copper tolerance in fouling species is a concern when evaluating the risk of vessel biofouling-mediated NIS introductions because the use of copper-based antifouling coatings is the primary tool to prevent vessel biofouling. This may inadvertently provide copper-tolerant organisms with a competitive advantage, allowing them to accumulate on a vessel's underwater surfaces. The potential outcome of this copper tolerance is that vessels using copper-based antifouling coatings may actually facilitate the transport and introduction of some organisms.

Funding for this project supported sampling at Santa Catalina Island, across several sites ranging from the highly trafficked Avalon harbor to relatively remote sites across the island. Sampling was completed in 2015, and the data are currently under analysis. Commission staff expects a final report in late 2016.

7.2.2 Vessel Biofouling Waterline Evaluations to Improve Pre-Arrival Risk Assessments
The Commission's MISP hosted summer interns in 2015 and 2016 through a partnership with the California State University's Council on Ocean Affairs, Science, and Technology. The interns worked on a project involving an evaluation of the extent of biofouling along the waterlines (air-water interface) of 86 vessels that arrived at California ports. Waterline biofouling extent was evaluated in relation to the vessel's operational and maintenance history to identify which maintenance or operational practices were correlated with extensive waterline biofouling.

The goal of this research was to identify vessel maintenance or operational practices that could potentially indicate heavy waterline biofouling (and possible biofouling on other underwater surfaces). These indicators may be used during pre-arrival risk assessments to prioritize vessel inspections.

The interns' results showed that several maintenance or operational metrics are potential indicators of the presence of heavy waterline biofouling:

- Antifouling coating age (older coatings yield more biofouling) – strongest relationship
- Vessel traveling speed (slower speeds yield more biofouling) – weak relationship
- Number of freshwater ports visited since the vessel's most recent hull cleaning (more freshwater ports visited yields less biofouling) – weak relationship
- Number of tropical ports – weak relationship

Some of the relationships between biofouling extent and vessel practices were restricted to certain vessel types (e.g., bulk, tank vessels; Edmiston 2015, Dornblaser 2016).

The absence of biofouling at a vessel's waterline is not always an indicator of an absence of biofouling on the other underwater surfaces, but the presence of heavy biofouling at the waterline is often correlated with underwater biofouling (Davidson et al. 2014). These results will help inform future risk-based vessel boarding and inspection prioritization.

7.2.3 Assessing the Drivers of Ship Biofouling Management

Commission staff coauthored a review article titled “Mini-review: Assessing the drivers of ship biofouling management – aligning industry and biosecurity goals” (see Davidson et al. 2016), published in the peer-reviewed journal Biofouling in February 2016. This review focused on the similarities and differences in priorities and considerations for biofouling management between the shipping industry, regulatory agencies charged with reducing the risk of shipping-mediated NIS introductions, and researchers focused on biological invasion ecology.

Although the shipping industry and environmental protection regulators share an interest in effective vessel biofouling management, their interests often diverge on the type and extent of biofouling management efforts. Shipping industry concerns are most often focused on underwater surfaces that influence drag and operational efficiency (e.g., hull sides) and most often overlook the recesses and appendages that contribute to the variety of niche areas found on a vessel. These niche areas are often hotspots for extensive communities of biofouling organisms and are typically the primary focus for environmental protection regulatory agencies and biofouling management efforts.

This review concluded that industry and regulatory concerns need to be aligned as much as possible for the benefit of both groups. One specific area that will improve cross-disciplinary biofouling management is better integration and collaboration on biofouling assessment and data collection. Using similar metrics when evaluating biofouling extent will allow more data sharing and more powerful datasets to improve management efforts for all sectors.

8. REVIEW OF CURRENT VESSEL VECTOR RESEARCH

Public Resources Code section 71212(e) requires the Commission to include a summary of ongoing NIS vessel vector research in its Biennial Reports. This review summarizes selected peer-reviewed journal articles published between July 2014 and June 2016 that examine the science and management of NIS introductions via ballast water and vessel biofouling.

8.1 General Vessel Vector and NIS Research

Seebens et al. (2016) modeled ship movements and environmental conditions to predict the spread of established marine NIS. The authors compared their model's predictions against historical data on the spread of marine NIS and found that the model was accurate 77% of the time. The authors found that the spreading dynamics of NIS follow a common pattern - initial invasion in the most suitable habitat followed by spreading to neighboring habitats. The model also predicted that warming temperatures due to climate change will elevate the invasion probabilities for temperate regions, particularly in North America.

Ruiz et al. (2015) characterized the invasion history for coastal marine ecosystems in North America over an 11-year period from 2000-2010. The authors found that 71 of the 450 known, established marine and estuarine NIS in North America were first discovered since 1999. They note that surveys required to study the history of species invasions are limited, meaning the actual number of established NIS in North America is likely higher than observed in this study.

The authors also discuss the importance of commercial shipping as the source of many NIS introductions. They found that 200 out of the 450 established marine and estuarine NIS in North America have been introduced through commercial shipping. Sixteen percent of these introductions were solely attributed to ballast water, and 30% were contributed solely to vessel biofouling, once again underscoring the importance of appropriate ballast water and biofouling management strategies to prevent species introductions.

Jimenez and Ruiz (2016) examined the species composition of soft-sediment communities in San Francisco Bay at 10 sites by sampling the high salinity, muddy bottomed shallow subtidal zone. They found these communities to be dominated by NIS, accounting for 76% of all organisms detected during their sampling. This study provides a baseline for both the abundance of organisms and the number of species in the San Francisco Bay soft-sediment subtidal habitats.

8.2 NIS Risk Assessments and Management Prioritization

Risk assessments are valuable tools for resource managers. Having a sturdy risk assessment in place allows for better resource allocation and prioritization of management decisions. The following studies highlight the importance of risk assessments when dealing with the management of NIS introductions.

Mandrak and Cudmore (2015) analyzed the value that risk assessments can provide to aquatic invasive species programs. The importance of a sturdy risk assessment process allows for optimal allocation of limited resources to combat NIS. The authors state that risk assessments are beneficial to identify the NIS that present the highest risk of negative impacts and the pathways by which they are transported. Risk assessments can also be used to determine effective management practices, policies, and legislative actions to reduce risk. This is done by conducting risk assessments before and after a management action, such as a regulatory listing, providing an opportunity to understand what influence the action had.

McGeoch et al. (2016) suggest considering sensitive and susceptible habitats when conducting risk assessments of NIS and prioritizing for the distribution of program resources. The authors discussed the importance of considering sensitive and susceptible habitats along with species and pathways (i.e. vectors) when prioritizing for the management of biological invasions. Currently, species-based prioritization is the common practice among managers. This is likely because species can be directly associated with negative economic, societal, and ecosystem impacts. Pathway prioritization is often used when it is difficult to predict which species are likely to arrive in an area. The authors suggest that prioritizing risk assessments based on site is beneficial because the risk of NIS introduction and establishment is unevenly distributed across different regions and ecosystems.

Muirhead et al. (2015) investigated the expected change in risk of species introductions likely to occur as vessel routes and operations change. For example, the recent Panama Canal expansion will potentially increase the risk of NIS introductions on the Gulf and East coasts of the United States. The models and simulations that the authors used for this study predict changes in the volume of ballast water discharged, wetted surface area of a vessel's hull, and frequency of vessel arrivals on all coasts of the U.S. The authors modeled these various changes in patterns of vessel operations for a period of five years following the expansion of the Canal and determined that the East Coast will experience an estimated 99% increase in ballast water discharged and 182% increase in total wetted surface area. The Gulf Coast will experience an estimated 78% increase in ballast water discharged and 172% increase in total wetted surface area according to their model. The authors also ran the model to predict the effect of the canal expansion on the West Coast and found a 10% decrease in both ballast water discharged and total wetted surface area.

Overall the authors expect that vessel traffic to ports on the East and Gulf coasts will increase, which will correspondingly increase the risk of NIS introductions to those areas. The risk of introduction will also be affected by the survivorship of NIS during transport. The authors discussed the possibility for organisms in the ballast water tanks to be less likely to survive the longer transfers to the East and Gulf coasts. On the other hand, they discussed the possibility of biofouling organisms surviving at a higher rate due to the quicker transfer through the Panama Canal, with the addition of the third set of locks.

Verna et al. (2016) completed a comprehensive statewide risk assessment of ballast water-borne marine invasions for Alaska. Alaska is expected to experience changes in marine invasion dynamics as a result of increased regional vessel traffic, the opening of Arctic trade routes, and proposed coastal developments. The authors found that approximately 80% of the ballast water discharged in Alaska during the study period (2009-2012) was sourced from the west coast of North America, including heavily invaded areas such as San Francisco Bay, of which only 38% of the total ballast water was managed prior to discharge. Based on this, the authors conclude there is an increase in the risk of ballast water-mediated NIS introductions in Alaska's coastal waters from the increased regional vessel traffic.

Hughes and Ashton (2016), surveyed the hull of the research vessel *RRS James Clark Ross* in Antarctica following its transit through scouring sea-ice. The authors found that the majority (about 99%) of the hull was free of biofouling organisms after the sea-ice transit. However, they found in-tact, living biofouling organisms in some small niche areas that are not affected by the scouring action of the sea ice. The authors suggest that the ability of some NIS to survive the transit to Antarctica in combination with the increasing vessel traffic and declining duration of sea ice will increase the risk of marine invasions in the area.

8.3 Ballast Water Research

As the implementation date of international, federal, and state ballast water discharge performance standards draws near, research on ballast water has focused on ballast water sampling, compliance assessment, and the efficacy of ballast water treatment systems in different types of water.

Costa et al. (2016) attempted to calculate the appropriate sampling regimes (e.g., volume of water to be collected) for a ballast water tank that has a varied distribution of organisms. The authors determined that the current IMO-recommended sampling methods (i.e. G8 guidelines) will require unreasonably large volumes of water to be tested. They also discussed the collection of continuous samples (sampling water for the entire length of the discharge) in an effort to obtain representative samples, which they concluded will yield an impractically large number of samples. Because of this, the authors suggest that innovative sampling and analysis methods, such as high-volume particle imaging instruments, are necessary to process large numbers of samples.

First et al. (2016) examined if the concentration of three sizes of marine planktonic organisms (greater than 50 micrometer (µm), 10 to 50 µm, and culturable bacteria less than 10 µm) react similarly to simulated ballast water treatment. As vessels use ballast water treatment systems to meet numeric discharge standards, regulating agencies will need to perform compliance assessment analyses to determine if discharge standards are met. In this study, the organisms in the different size classes responded similarly to the different treatments (with some exceptions in the heterotrophic bacteria), which led the authors to suggest that regulating agencies could use a single organism size class to predict the responses of organisms across the board.

Briski et al (2015) addressed the concern that existing ballast water treatment systems may not be able to operate reliably and effectively in fresh water. Ballast water exchange provides a high level of protection against NIS introductions from/to fresh water ports due to organism mortality resulting from salinity shock. Organisms adapted to live in fresh water will not survive in high salinity mid-ocean water. Absent the high salinity water from mid-ocean ballast water exchange, any freshwater organisms that remain after the ballast water is treated with an onboard treatment system could directly invade freshwater habitats upon discharge. The potential ineffectiveness of ballast water treatment systems in fresh water could increase the risk of NIS introductions in California's freshwater ports of Stockton and Sacramento.

To increase the level of environmental protection for freshwater ports, the authors, in a previous study (Briski et al. 2013), conducted a land-based evaluation of how well the combination of ballast water treatment plus mid-ocean exchange would be at removing freshwater organisms from ballast water. Their results demonstrate strong potential benefits in the combined management strategy for reducing the risk of NIS introductions.

To determine if the results from the old study would be the same on an operational vessel, the authors conducted a comparable ship-based test of ballast water exchange plus treatment with a ballast water treatment system. Like their land-based study, the authors found that the ballast water treatment plus exchange combination significantly reduced the risk of introduction. They also observed that the species that remained in the ballast water tanks after the combined strategy were mainly marine species that would likely not survive in fresh water. The authors concluded that ballast water treatment in combination with ballast water exchange would reduce the risk of NIS introductions when the ballast water source and discharge locations are both freshwater.

8.4 Biofouling Research

Studies on vessel biofouling research published during the reporting period evaluated the presence and composition of biofouling assemblages and different management techniques.

Revilla-Castellanos et al. (2015) examined whether biofouling is a potential vector for pathogenic bacteria. The authors sampled three commercial vessels and seven port structures in Ensenada, Mexico. They detected a well-known food-borne human pathogen (*Vibrio parahaemolyticus*) on several of the Ensenada docks and on the hulls of ships with homeports based in Japan and South Korea. Pathogens of the genus *Vibrio* have been known to be transported through ballast water, but this is one of the first studies examining the possibility of their transport through biofouling. Based on their findings, the authors conclude that biofouling has the potential to transport harmful human pathogens.

Hunsucker et al. (2014) describe the community composition of diatoms (a type of microscopic algae) on in-service vessels with a foul-release (e.g., silicone) coating. They investigated the diatom distribution in:

- Horizontal zonation of the hull
- Vertical zonation of the hull
- Niche areas
- Areas with damaged coatings
- Copper based and foul-release coatings

The authors found that the distribution of diatoms was affected by the shear stress they experience on the different areas on the ship. The authors also found that the foul-release coating had higher numbers of diatom species attached compared to coatings that rely on heavy metals to deter biofouling settlement (e.g., copper self-polishing copolymer coating). They concluded that diatom species which are able to attach to vessel hulls and withstand the hydrodynamic forces present a risk of being introduced into a new environment.

Ashton et al. (2016) used barnacles, a well-known biofouling organism, to study the extent to which commercial vessels disperse biofouling species. The authors collected barnacles from 15 commercial vessels in several ports in California, Alaska, Oregon and Guam and identified them to the lowest possible taxonomic level. The authors collected 40 separate barnacle species, some of which are known to have a cosmopolitan distribution and some that were found outside of their known distribution.

The authors calculated the potential number of barnacle species arrivals per year to U.S. ports based on the number of vessel arrivals (100,000) multiplied by the average number of barnacle species found per vessel (6.8). Based on this, the authors predict a total of about 680,000 separate arrival events per year for barnacle species to U.S. ports. They also noted that this is a low estimate because it is unlikely that all barnacle species on a vessel were sampled or successfully identified. These findings highlight the ability of barnacle species to be spread easily to different regions, and it also underlined the potential for biofouling organism introductions to California waters.

Tribou and Swain (2015) investigated the effectiveness of removing the accumulation of biofouling with hull grooming using rotating brushes on several different vessel coatings. The results of the study demonstrate that weekly cleaning (the only length of time measured) with brushes removed organisms from all coatings that were tested and prevented biofouling accumulation on the ablative copper and foul-release coatings. However, as the frequency of cleaning decreased, the brushes were not able to remove organisms that already settled. These findings suggest that proactive in-water cleaning may benefit some vessels as it will likely not allow organisms to settle and grow.

9. CONCLUSIONS AND NEXT STEPS

The data from vessel-submitted reporting forms and Commission-funded research have strengthened the knowledge and ability of the Commission to prevent NIS introductions from commercial vessels. However, there are steps that remain to be taken to fulfill new legislative directives and to continue to "move the state expeditiously toward elimination of the discharge of nonindigenous species into the waters of the state."

The following section summarizes important vessel management trends from the current reporting period and highlights challenges to be addressed over the next two years by the Commission working together with MISP sister agencies and stakeholders.

9.1 Ballast Water Management

Eighty-four percent (84%) of the 18,126 qualifying arrivals at California ports between July 2014 and June 2016 retained all ballast water on board. These arrivals posed no risk for species introductions associated with ballast water discharges.

For those vessels that discharged ballast water, the total reported volume discharged decreased from 23.3 MMT in 2012b-2014a to 19.7 MMT in 2014b-2016a. Most of the decrease occurred in 2016a, where the reported volume of discharged ballast water in California was 3.1 MMT. That is the lowest amount reported for any six-month period over the last 12 years.

The total volume of discharged ballast water in California is driven, in large part, by bulk and tank vessels. Combined, bulk and tank vessels accounted for only 30% of vessel arrivals to California between 2014b-2016a, yet they were responsible for 86% of the total volume of reported ballast water discharged during that same time period. During 2014b-2016a, bulk and tank vessel arrivals were down only 4% from 2012b-2014a. However, the proportion of bulk and tank vessel arrivals discharging has decreased from 82.5% between 2012a-2014b to 63.5% in this reporting period. This drop in tank and bulk vessel arrivals discharging ballast water likely contributed to the decrease of reported ballast water discharge volume in 2014b-2016a.

Industry compliance with California's ballast water management requirements is high. Of the more than 19.7 MMT of ballast water discharged in California between 2014b-2016a, 96% (19 MMT) was properly managed prior to discharge. Most of the noncompliant discharged ballast water (556,000 MT) underwent exchange but at a distance less than required by law. The remaining volume of noncompliant ballast water discharges (148,000 MT) was unmanaged prior to discharge and represents the highest risk of NIS introduction from the ballast water vector.

Increased outreach and enforcement efforts by Commission staff has led to a dramatic reduction in the volume of noncompliant ballast water discharged in California's waters. Likewise, the number of violations issued to vessels over the past two years has steadily declined from 39 in the first quarter of 2014 to 6 in the second quarter of 2016 (Figure 21).

There remain several roadblocks outside of the Commission's control regarding the implementation of California's ballast water discharge performance standards. California does not require vessels to use USCG type approved ballast water treatment systems to meet California's ballast water discharge performance standards. However, no treatment systems have yet been approved to meet existing federal discharge standards, which are less strict than California's performance standards, and the USCG does not consider it practicable to implement a more stringent standard. There are serious concerns about the ability of available ballast water treatment systems to meet California's interim standards.

9.1.1 Next Steps for Ballast Water Management in California

1. <u>Pursue statutory authority to collect ballast water samples for research purposes from vessels equipped with ballast water treatment systems</u>

   The use of shipboard ballast water treatment systems to treat ballast water discharged to California waters is increasing. This trend will likely accelerate as more vessels install ballast water treatment systems to comply with the recently ratified IMO BWM Convention. In addition, the USCG has recently received applications for type approval of shipboard ballast water treatment systems and will hopefully begin issuing type approvals of treatment systems to meet the U.S. federal ballast water discharge standards in the near future.

   Consequently, there is a need for Commission staff to understand how these shipboard ballast water treatment systems are performing on vessels that arrive and discharge ballast water at California ports. To date, there has been minimal sampling worldwide of vessels to assess the performance of ballast water treatment systems once installed and in use. Current sampling and testing of the efficacy of ballast water treatment systems generally occurs either in land-based or shipboard facilities in highly controlled environments as part of the type approval process. If these treatment systems are not operating as intended and are used to manage ballast water discharged in California, this leaves California vulnerable to an increased risk of ballast water-mediated NIS introductions.

Unfortunately, the Commission does not have the authority to collect ballast water discharge samples for research purposes. Sampling is limited to compliance assessment (Public Resources Code section 71206(a)). Commission staff has worked with several shipping companies since 2012 to assess the performance of shipboard ballast water treatment systems including recent analyses of efficacy with rapid assessment tools (see Section 8). However, it has been difficult to get vessels to participate on a voluntary basis.

It is imperative that Commission staff has the authority to conduct research to assess the effectiveness existing ballast water treatment systems and evaluate methods that may be used to determine vessel compliance with the forthcoming California ballast water discharge performance standards (see below). Therefore, Commission staff will pursue obtaining authority to board vessels for the purpose of:

- Collecting samples from vessels using shipboard ballast water treatment systems to understand how these systems are performing under normal vessel operations
- Develop and test sampling and analysis tools that assess ballast water treatment system performance

2. <u>Adopt and test protocols to assess compliance with the California ballast water discharge performance standards</u>

California's ballast water performance standards, like the U.S. federal standards, are discharge standards. Therefore, it will be necessary for Commission staff to collect ballast water samples upon discharge from vessels to assess compliance. In 2012, Commission staff developed draft ballast water sample collection and evaluation protocols. These draft protocols were developed in consultation with a technical advisory group (TAG) of scientists specializing in ballast water research, state and federal ballast water regulators, representatives from the shipping industry, and non-governmental environmental groups.

In 2013, at the direction of the Commission, staff distributed the proposed collection protocols to an additional panel of scientists for independent scientific review. Feedback on the draft protocols was largely positive. Staff incorporated the comments and reconvened the TAG on December 3, 2015, for discussion of the revisions. The revised draft protocols will be released for an informal public comment period in early 2017. Commission staff plans to begin the rulemaking process to adopt the compliance assessment protocols in mid-2017.

3. Update the Commission's assessment of treatment technologies to meet California's interim ballast water discharge performance standards

   Public Resources Code section 71205.3 requires the Commission to regularly review the efficacy, availability, and environmental impacts of ballast water treatment technologies. Reports are due to the California Legislature not less than 18 months prior to each implementation date for the ballast water discharge performance standards.

   Commission staff has previously conducted five assessments of available ballast water treatment technologies (Dobroski et al. 2007, 2009; Commission 2010, 2013, 2014) and found that no ballast water treatment technologies were available to meet the California performance standards. As a result, the Legislature passed AB 1312 (Chapter 644, Statutes of 2015) to amend Public Resources Code section 71205.3 and delay the implementation of the performance standards until January 1, 2020. The next ballast water treatment technology assessment report is due on or before July 1, 2018. The report will include results from the Commission funded shore-based ballast water treatment feasibility study, which is expected to be completed in late 2017.

4. Develop regulations to establish a process to approve facilities in California for the reception of discharged ballast water.

   Public Resources Code section 71204.3(e) allows vessels to discharge ballast water to a reception facility approved by the Commission. However, there is currently no formal process by which interested parties or facilities can apply for Commission approval, nor are there procedures in place detailing the criteria the Commission will use to approve such facilities.

   The Commission is currently funding a feasibility study on the use of shore-based ballast water treatment facilities to enable vessels to comply with California's ballast water discharge performance standards. Based on the results of this study, there may be an influx of requests to discharge ballast water to reception facilities (should they be available). Therefore, it is critical that the Commission develop and adopt regulations establishing the process and procedures that will be required for review and approval of any potential reception facilities.

Commission staff anticipates beginning the rulemaking process in early 2017 in consultation with the State Water Resources Control Board.

5. Adopt regulations regarding the management of ballast water for vessels arriving from outside of the Pacific Coast Region
   Currently, ballast water management requirements for vessels arriving from outside the Pacific Coast Region (PCR) reside in statute (Public Resources Code section 71204.3) while the requirements for vessels arriving from within the PCR reside in regulation (Title 2 California Code of Regulations section 2284).

   AB 1312 (Chapter 644, Statutes of 2015) provided authority to the Commission to adopt regulations that will place the ballast water management requirements for vessels arriving from outside the PCR into the California Code of Regulations. This move will place all ballast water management requirements in one place, which should provide greater clarity for the regulated industry. Commission staff expects to begin this rulemaking process in early 2017.

6. Investigate the potential continuation of ballast water exchange for vessels arriving at California's freshwater ports after the implementation of ballast water discharge performance standards.
   As vessels increase their use of ballast water treatment systems to manage discharge, there are growing concerns in the regulatory, scientific, and environmental communities that these systems are not be able to operate reliably and effectively in fresh water (Briski et al. 2015). The use of mid-ocean ballast water exchange is protective against NIS introductions from ballast water discharges from or to freshwater ports. Organisms adapted to live in fresh water will not survive in high salinity mid-ocean water (Santagata et al. 2008). Absent the high salinity water from mid-ocean ballast water exchange, any freshwater organisms, such as quagga or zebra mussels, that remain after the ballast water is treated with a treatment system could potentially invade freshwater habitats upon discharge.

   Oregon, as well as Canada and several states in the Great Lakes region, are in various stages of proposing ballast water exchange plus treatment for vessels carrying freshwater ballast that will be discharged to fresh water ports. California has two freshwater ports, Sacramento and Stockton, which are vulnerable to the ineffectiveness of ballast water treatment systems in fresh water.

Commission staff will pursue ballast water exchange plus treatment as a management strategy for vessels arriving at the Ports of Sacramento and Stockton.

9.2 Biofouling Management

The Commission has been collecting data on the management of vessel biofouling since 2008 through the HHRF. These data help Commission staff identify gaps in shipping industry management practices and the vessel activities that result in an increased risk of NIS introduction. Furthermore, these data represent the most extensive and complete dataset of biofouling-influencing vessel practices in the world. Commission staff has provided targeted subsets of these data to help other states and countries with development of biofouling management strategies.

During each of the prior eight years (2008 – 2015), at least 81% of the vessels operating in California reported antifouling coatings that were generally within the effective lifespan of these coatings. The use of biocidal coatings is the dominant biofouling management strategy used by at least 83% of vessels operating in California.

The type(s) of antifouling coating(s) applied to a vessel is an important component of an effective biofouling management strategy. There are different types of coatings available on the market, most of which have been designed for specific vessel operational profile characteristics (e.g., speed, trading area). Understanding the prevalence of different coating types is useful for identifying the current biofouling management strategies of the vessels that operate in California and the potential risk of NIS introductions they pose.

Two risk factors for increased biofouling accumulation, identified during the last reporting period (see Dobroski et al. 2015), have persisted in vessels arriving at California ports. They are:

- Increased residency periods
- Reduction in travelling speeds

Long residency periods enhance the possibility that vessels will accumulate extensive and diverse biofouling communities prior to arrival to California. HHRF data indicate a 75% increase in the number of residency periods of 10 days or greater between the 2008 (pre-recession period) and 2013 (post-recession period) reporting years. The increase between 2013 and 2014 was approximately 2%, similar to the 2% increase from 2014 to 2015.

Additionally, slow steaming is likely to increase survivorship of existing biofouling communities on the underwater surfaces of vessels. The steady reduction in traveling speeds (i.e. slow steaming), which has been occurring since 2008 continued from 2014-2015. Although not as dramatic as the 13% reduction from 2008-2013 (Dobroski et al. 2015), the 2014-2015 travelling speeds are down an additional 2.5% from 2013.

The continued influence of increased extended residency periods and reduced travelling speeds will likely increase the risk of ships arriving to California with extensive, healthy biofouling communities that are able to readily invade.

9.2.2 Next Steps for Biofouling Management:

1. Develop and adopt biofouling management regulations
   The Commission initiated a biofouling management rulemaking effort in September 2011 (see Notice Register 2011, Volume 37-Z). The proposed biofouling management regulations went through several public comment periods and subsequent revisions. However, the Administrative Procedures Act's one-year deadline passed prior to completion. After several rounds of document review, Commission staff initiated the rulemaking process for a second time in May 2015. The regulation package was approved by the Commission in December 2015. In January 2016, the regulation package was withdrawn due to administrative errors. The new draft of the regulations was provided to the TAG for an informal document review. Commission staff anticipates completion of this rulemaking in early 2017.

   Commission staff will continue consulting with a biofouling TAG to develop and adopt biofouling management requirements. The new requirements will be based on best preventive practices and will include performance standards for vessels not utilizing these best practices. In addition, Commission staff will develop compliance assessment protocols for the biofouling management regulations.

2. Develop a risk assessment matrix to identify high priority vessels for biofouling management inspection and outreach

   As the Commission moves towards adopting and implementing biofouling management regulations, staff will need to develop a weighted risk assessment matrix to categorize high priority vessels for inspection and outreach. This approach will enable staff to focus limited resources on the inspection of vessels that represent the greatest risk of NIS introduction. A key step in creating this matrix is determining which vessel maintenance and operational practices to include for predicting a high risk, priority vessel. Commission staff continues to work with regulatory partners in New Zealand and Australia in the process of implementing new biofouling management policies to identify factors to include in these pre-arrival risk assessments. Staff expects to complete this risk assessment matrix as an internal policy for prioritizing inspections and to have it in place by the time the biofouling management regulations described above become effective.

3. Evaluate the effectiveness of biofouling management technologies

   Commission staff will continue collaborating with regional and international partners to evaluate the effectiveness of proactive (e.g., anti-fouling coatings and marine growth prevention systems) and reactive (e.g., in-water cleaning technologies with recapture/treatment) biofouling management tools. Understanding the effectiveness of management tools on different vessel types and different operational profiles is critical to the Commission's implementation of policies to reduce the risk of biofouling-mediated introductions of NIS.

   New technologies that collect and remove biofouling debris and heavy metal biocides from antifouling coatings are being developed and used worldwide. The use of these technologies in California could help to reduce the overall risk of NIS introductions while severely reducing the release of chemical pollutants into California waters.

   Commission staff will continue to coordinate with the State Water Board and Regional Water Quality Control Boards to identify a path forward for reviewing and approving the use of these technologies in California waters.

9.3 MISP's Role in Vessel Vector Management

California's MISP will look to build on its successes in managing the introduction of NIS from vessels to California waters over the coming years. The management of vessel vectors tends to focus individually on either ballast water or vessel biofouling management. However, there are several areas where those individual vessel vector management issues overlap. It is essential that the MISP, as well as the regulated community, take steps to address the vessel, as a whole, as a vector of NIS introduction.

MISP staff is taking steps to ensure that the program operates as effectively and efficiently as possible, uses the best-available science to adopt and implement comprehensive strategies to manage and regulate NIS introductions from vessels, and improves both outreach and enforcement efforts to ensure compliance with management requirements to continue successfully managing vessel vectors.

9.3.1 Next steps in Comprehensive Vessel Vector Management for the Marine Invasive Species Program

1. Continue to oppose efforts to minimize the authority of California's Marine Invasive Species Program

   As discussed (Emerging Issues, Section 4), there is pressure in the U.S. Congress to address overlapping EPA and USCG jurisdiction over vessel discharges, including ballast water. As a result, the Vessel Incidental Discharge Act (VIDA) was introduced in 2014 to develop a uniform national ballast water discharge standard, among other things, and give the USCG sole authority over the development and implementation of ballast water management requirements. The bill also proposes to preempt state regulation of vessel discharges, including ballast water and discharges associated with vessel in-water cleaning.

   To date, no legislation has passed. However, there is a real risk of preemption of state authority to manage vessel ballast water and biofouling discharges. Adoption of the VIDA could cripple the Marine Invasive Species Program's demonstrated ability to prevent NIS introductions and protect California's coastal waters for the beneficial use of the public. Commission staff will continue to monitor the VIDA and will report to the Governor's Office and Legislature as necessary.

2. Implementation of the Marine Invasive Species Act Enforcement and Hearing Process Regulations

   In 2016, the Commission approved regulations to establish an administrative enforcement process for violations of the Marine Invasive Species Act. Article 4.9, titled the Marine Invasive Species Act Enforcement and Hearing Process, establishes policies and procedures that the Commission's Executive Officer shall undertake to assess administrative civil penalties that are mandated by Public Resources Code section 71216.

   Commission staff will continue to finalize the regulations under the Administrative Procedures Act and prepare for their implementation in early 2017. These preparations will include outreach to the regulated community and modification of internal procedures related to the notification and enforcement of violations.

3. Increase the vessel arrival fee to address shortfalls in the Marine Invasive Species Control Fund

   Commission staff, as the administrators of the Marine Invasive Species Control Fund (see Appendix A, Structure and Function of the Marine Invasive Species Program), regularly review fund status for solvency. In January 2016, staff determined that revenues will not meet the costs of the MISP as of 2018. Commission staff has made recent efforts to map business processes and increase efficiency of operations, but revenues still do not meet costs. Commission staff met with a TAG to discuss program budgets in April 2016.

   Projections provided by the maritime industry suggest that there will be a decrease in the number of qualifying voyages through year 2020 (MISP TAG meeting notes, April 6, 2016). Based on these projections, the Commission and TAG concluded that the fee could be set at one thousand dollars ($1,000) per qualifying voyage, beginning in early 2017. The fee increase will cover the MISP costs while maintaining a practical reserve through fiscal year 2019/2020.

   The proposed regulations to revise the fee were published in the Notice Register on September 23, 2016, and Commission staff anticipates completion of this rulemaking in early 2017.

4. Hazard Analysis and Critical Control Point Planning

   Hazard Analysis and Critical Control Point (HACCP) planning is a process that can be used to identify and correct NIS management gaps. HACCP is a five-step process used to reduce the risk of unwanted hazards from occurring. The HACCP process examines activities to determine if a hazard may occur. For activities that require interaction with the natural environment, one hazard is the unintentional movement of organisms, which after becoming established, may impact the economy, the environment, or human health.

   HACCP has been used around the world by the food industry for decades as a proactive method to ensure product purity. The National Sea Grant Program first adapted HACCP to reduce the risk of spreading NIS and help fish processors comply with federal seafood safety regulations. The use of HACCP to prevent the spread of NIS is an American Society for Testing and Materials (ASTM) International standard under the Standard Guide for Conducting Hazard Analysis-Critical Control Point Evaluations (ASTM E2590-09).

The application of the HACCP process has been identified as a potential solution to addressing voyage-based risk assessments (SAB 2011). To decrease the risk of vessels spreading NIS via the ballast water and biofouling vectors HACCP can:

- Determine specific points to apply management actions
- Define and monitor details of vessel-specific management activities
- Provide a back-up plan for instances when management activities are not operating as intended or cannot be used
- Manage the risk of individual vessels as vectors for spreading NIS

Commission staff is developing a plan to use HACCP to better prevent species introductions by working with staff from the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration.

APPENDIX A: STRUCTURE AND FUNCTION OF THE MARINE INVASIVE SPECIES PROGRAM

The California Marine Invasive Species Program (MISP) is a multi-agency program that strives to prevent the introduction of nonindigenous species (NIS) from vessels that arrive at California ports. 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 waters 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 made up of the State Lands Commission (Commission), the California Department of Fish and Wildlife, the State Water Resources Control Board, and the Board of Equalization.

- The Commission is the administrator of the MISP and is tasked with developing and implementing vessel vector management policies (see below for a detailed description of the Commission MISP).

- The California Department of Fish and Wildlife's Office of Spill Prevention and Response monitors and gathers data on species to maintain an inventory of NIS populations in the coastal and estuarine waters of the state. These data are used in conjunction with information on vessel arrivals and NIS management practices to assess the effectiveness of the MISP.

- The State Water Resources Control Board consults with MISP sister agencies on topics related to water quality and toxicity. More recently, the Commission has worked with the Water Board on the implementation of the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels and on policies related to in-water cleaning of vessels in California.

- The Board of Equalization collects a fee from qualifying voyages to support all MISP activities (see Public Resources Code sections 71215(b)(2) and 71215(c)). All fees are deposited into the Marine Invasive Species Control Fund. The MISP does not receive any General Fund dollars.

The Commission's MISP

To effectively carry out the administrative and operational requirements of the Marine Invasive Species Act (Public Resources Code section 71200 et seq.), the Commission's

MISP is separated into three primary functional components: program management and policy development, data administration, and field operations (Figure 30).

Program Management and Policy Development

The MISP program management and scientific staff develop NIS prevention policies for vessel ballast water and biofouling vectors, and:

- Recommend policy proposals to the Legislature
- Propose and implement regulations
- Coordinate and fund research
- Analyze data to assess vessel compliance
- Prepare and update reports for the Legislature

The MISP management and scientific staffs work closely with sister MISP agencies; state, federal, and international regulatory agencies/authorities; technical advisory groups; non-governmental organizations; researchers; and the shipping industry. By consulting with other regulatory jurisdictions (states, federal, international), the MISP increases efficiency, regional and international consistency, and effectiveness by sharing successes and failures. MISP staff members participate on numerous working groups, advisory panels, and committees including (but not limited to):

- California Agencies Aquatic Invasive Species Team
- Pacific Ballast Water Group
- State of Washington's Ballast Water Working Group
- State of Oregon's Shipping Transport of Aquatic Invasive Species Task Force
- State of Hawaii's Alien Aquatic Organism Taskforce
- Western Regional Panel on Aquatic Nuisance Species
- Great Lakes Ballast Water Collaborative

The MISP management and scientific staffs assemble Technical Advisory Groups and Panels (TAGs or TAPs) to exchange information and ideas for the implementation of legislative mandates. TAGs are an effective outreach tool to keep stakeholders abreast of Commission actions and activities. These groups review the best available science and provide a forum for affected stakeholders to voice support and concerns in the development of rulemakings and policy recommendations. TAGs include representatives from the maritime industry, ports, state, federal, and international agencies, environmental organizations, and research institutions. The MISP administrative program has assembled TAGs for the development and review of:

- Regulations to establish ballast water management requirements within the Pacific Coast Region

- Performance standards for ballast water discharge
- Regulations for ballast water discharge compliance assessment
- Regulations for biofouling management
- Changes to the MISP fee
- Forms to collect vessel biofouling and ballast water treatment technology data
- Reports assessing the ability of ballast water treatment systems to meet the California performance standards

Data Administration

The MISP data administration staff inputs data from ballast water and biofouling management reporting forms. More than 800 forms are submitted every month. Data from Ballast Water Reporting Forms/Ballast Water Management Reports are matched with arrival data from the Marine Exchanges of the San Francisco Bay Region and Los Angeles/ Long Beach. Between July 1, 2014 and June 30, 2016, over 18,100 Ballast Water Reporting Forms/Ballast Water Management Reports were received, reviewed, entered into the program database, and reconciled with actual port arrival data. Staff also tracks ballast water treatment technology reporting forms and Hull Husbandry Reporting Form submission and compliance. Submitted forms are reviewed for inconsistencies and are then entered into the MISP database. Quality control procedures are followed to ensure accuracy of data entry.

MISP staff reconciles the data received against vessel arrival data to determine if reporting requirements have been met. Notices are sent to owners, operators and agents when vessels fail to submit required forms or submit inconsistent, incorrect, or questionable data. These vessels are also flagged for follow-up by Field Operations staff.

The data administration staff also maintains contact with ship owners, officers, and agents to relay information about MISP requirements. They coordinate with the Commission's Field Operations personnel to request data from or distribute information to vessels.

Field Operations

Commission Field Operations staff is the primary means of assessing vessel compliance and distributing information to vessel personnel. They implement an extensive inspection program, including vessel boarding, monitoring, and outreach to enforce MISP laws and regulations. MISP Field Operations personnel are based out of offices located in northern and southern California.

Education and outreach during vessel inspections is key to maintaining the high rate of compliance with California's management, reporting, and recordkeeping requirements (see Section 5 for compliance data). During inspections, staff examines the vessel's ballast water management plan, logbooks, and required MISP reporting forms. Vessel reporting and recordkeeping errors are identified and crew are instructed in proper recordkeeping, as needed. Commission staff members are also available to respond to questions from vessel crew members.

Additionally, ballast water samples are collected from select ballast tanks intended for discharge. The samples are analyzed for salinity (a measure of the salt concentration in water) as an indicator for compliant ballast water exchange.

Vessels that violate the reporting, recordkeeping, or management requirements are cited and targeted for re-inspection, as necessary. Citations are given to the vessel crew and an enforcement letter is sent to the vessel owner.

In addition to assessing compliance with the requirements of the MISP, Field Operations staff plays a key role in MISP activities by facilitating access to vessels, with the cooperation of vessel operators, for researchers engaged in data collection for NIS research. This assistance is important due to heightened security levels at ports.

<u>The Shared Role of Outreach</u>

One of the key components of the success of the MISP is the close communication, coordination, and outreach between Commission staff, the maritime industry, and other state, federal, and international agencies. Outreach is a role shared by everyone in the MISP (Figure 30). By establishing and maintaining relationships with the diverse groups that play a role in preventing new introductions of NIS, MISP staff helps work towards improved compliance within the regulated community, development of well-informed policy decisions, and the utilization of management tools and strategies based on the best available science.

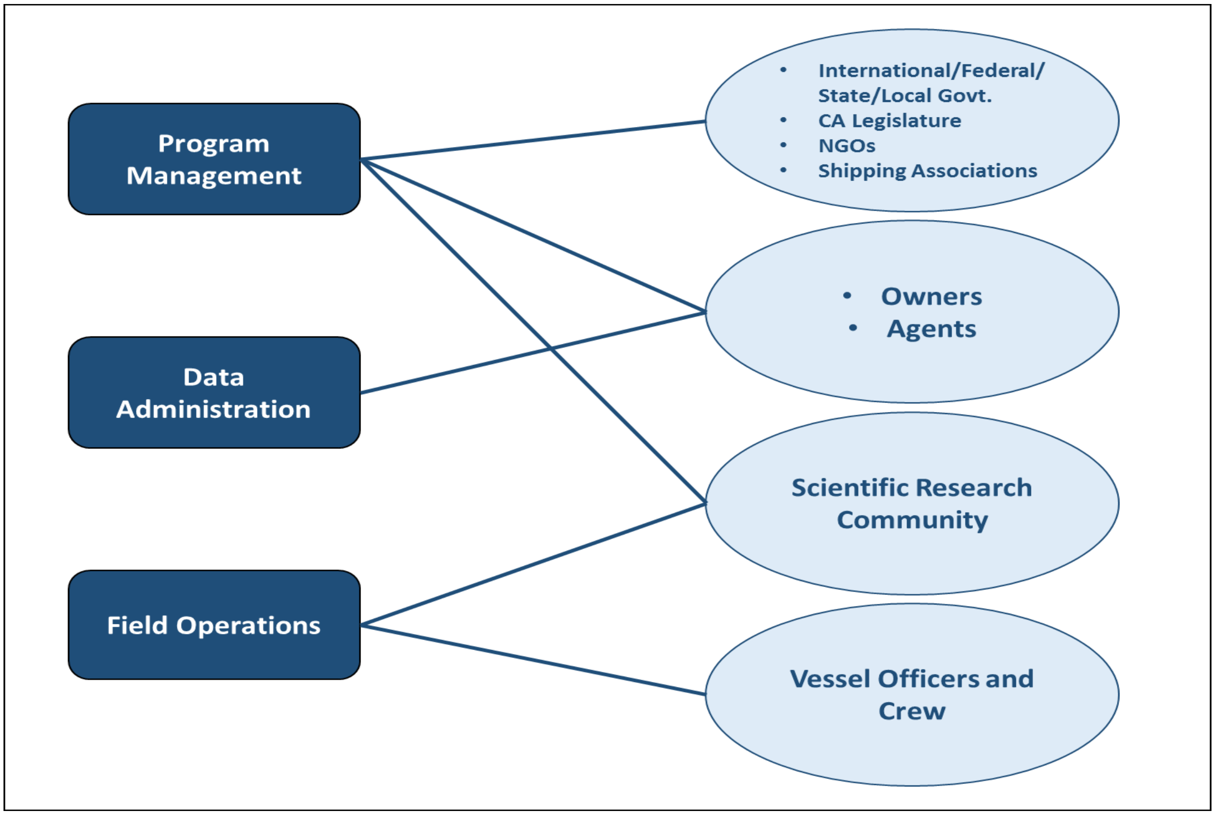

Figure 30. Marine Invasive Species Program Information Exchange with Stakeholders

MISP staff makes presentations at conferences and for workgroups involved with invasive species science and management. Such participation is particularly important given the global nature of shipping and the methods of transporting NIS. In many cases, MISP staff members are invited to participate due to their extensive knowledge and experience with vessel vector management. Since June 2014, presentations have been given at numerous local, state, national, and international meetings, including:

- Marinas and Antifouling Strategies Interagency Coordinating Committee
- International Paint and Printing Ink Council Antifouling Coordinating Committee Annual Meeting
- Society of Environmental Toxicology and Chemistry Southern California Meeting
- Bay-Delta Science Conference
- California Ocean Day
- Commission Marine Environmental Protection Division Customer Service Meetings
- National Oceanic and Atmospheric Administration Aquatic Invasive Species Workshop
- Long Beach Ballast Water Summit
- International Water Association

- Ship Operations Cooperative Program Meeting
- State of the Estuary
- BWMTech North America
- National Estuarine Research Reserve Hazard Assessment Critical Control Point Workshop
- California State Lands Commission’s Prevention First Symposium
- Coastal and Estuarine Research Federation
- Western Regional Panel on Aquatic Nuisance Species Annual Meeting

APPENDIX B: REQUIRED MISP REPORTING FORMS

OMB number 1625-0069
Exp. date: 31-Dec-2018

Ballast Water Management Report

Vessel Information

Vessel name

ID number **IMO number**

Country of Registry **Select country**

Owner/operator

Type **Select vessel type** Gross Tonnage

Ballast water volume units **Select units**

Total ballast water capacity Number of tanks on ship

Onboard BW Management System

Voyage Information

Arrival port (port and state) **Select state**

Arrival date

Last port (port and country) **Select country**

Next port (port and country) **Select country**

Total ballast water on board Number of tanks in ballast

Number of tanks discharged

Alternative BW management conducted, per instructions from COTP ☐

Certificate of accurate information

By checking this box, I attest to the accuracy of the information provided and that ballast water management activities were in accordance with the ballast water management plan required by CFR 151.2050(g). ☐

Responsible Officer's name and title

Report type **Select report type**

Submitted by Contact information

Ballast Water History

On the following page(s), provide the ballast water history for each tank discharged into the waters of the United States or to a reception facility, en route to or at the arrival port. Vessels entering the Great Lakes or Hudson River (north of George Washington Bridge) from beyond the US EEZ must also provide the history for empty tanks that underwent alternative management.

Submit report via e-mail **Submit report on-line**

California State Lands Commission
Marine Invasive Species Program
Ballast Water Treatment Technology Annual Reporting Form
Public Resources Code Section 71205(g)
July 1, 2010

Vessel Name:	
Official / IMO Number:	
Responsible Person's Name and Title:	
Date Submitted (DD/MM/YYYY):	

Treatment System Information

1. List the treatment system installed on board the vessel:

   Manufacturer/Company: ____

   Product Name: ____

   Model Number: ____

   1a. Mode(s) of Action (check all that apply):

Filtration ☐	Cavitation ☐	Hydrocyclone ☐	Deoxygenation ☐
Active Substance/Biocide ☐	Ultra Violet Irradiation ☐	Heat ☐	
Other ☐, please describe:			

   1b. List all substances (i.e. chemicals, biocides, flocculants, neutralization agents) created or used by the treatment system (if any), and indicate whether or not the Material Safety Data Sheet is kept on board for each substance.

Substance	MSDS on Board?
	Yes ☐ No ☐ N/A ☐
	Yes ☐ No ☐ N/A ☐
	Yes ☐ No ☐ N/A ☐
	Yes ☐ No ☐ N/A ☐
	Yes ☐ No ☐ N/A ☐
	Yes ☐ No ☐ N/A ☐
N/A ☐, No substances used by system.	

1

California State Lands Commission
Ballast Water Treatment Supplemental Reporting Form
Public Resources Code Section 71205(g)
July 1, 2010
ALL VESSELS MUST ALSO SUBMIT BALLAST WATER REPORTING FORM

IS THIS AN AMENDED REPORTING FORM? Yes ☐ No ☐

Vessel Information	**Voyage Information**
Vessel Name:	Arrival Port:
Official/IMO Number:	Arrival Date (DD/MM/YYYY):

Ballast Water Treatment

1. Did the treatment system experience any malfunction that affected the treatment of ballast water to be discharged at this arrival port?

   Yes ☐ , please provide the following information:

   Date of malfunction (DD/MM/YYYY): ______

   Explain the malfunction: ______

   If applicable, how was the situation resolved? ______

   No ☐

2. Ballast Water Treatment History. Provide information for all ballast tanks that will be discharged at arrival port. Enter additional tanks on page 2. One tank per line. If none, go to Question #3.

	BW Source			**BW Discharge**			**BW Treatment**		
Tanks/ Holds	Date (DD/MM/YY)	Port or Lat-Long	Volume (Units)	Date (DD/MM/YY)	Port or Lat-Long	Volume (Units)	Date of 1st treatment (DD/MM/YY)	Date 2nd treatment (if applicable) (DD/MM/YY)	Volume Ballast Treated (Units)
			m3			m3			m3
			m3			m3			m3
			m3			m3			m3
			m3			m3			m3
Ballast Water Tank Codes: Forepeak = FP, Aftpeak = AP, Double Bottom = DB, Wing = WT, Topside = TS, Cargo Hold = CH, Other = O									

3. Responsible Officer's Name and Title: ______

1

California State Lands Commission
Marine Invasive Species Program
Hull Husbandry Reporting Form
Public Resources Code – 71205(e) and 71205(f)
June 6, 2008

Part I: Reporting Form

Vessel Name:
Official / IMO Number:
Responsible Officer's Name and Title:
Date Submitted (**Day/Month/Year**):

Hull Husbandry Information

1. Since delivery, has this vessel ever been removed from the water for maintenance?
   Yes ☐ No ☐

   a. If Yes, enter the date and location of the most recent out-of-water maintenance:

Last date out of water (**Day/Month/Year**):	
Port or Position:	Country:

   b. If No, enter the delivery date and location where the vessel was built:

Delivery date (**Day/Month/Year**):	
Port or Position:	Country:

2. Were the submerged portions of the vessel coated with an anti-fouling treatment or coating during the **out-of-water** maintenance or shipbuilding process listed above?

Yes, full coat applied ☐
Yes, partial coat ☐ Date last full coat applied (**Day/Month/Year**)
No coat applied ☐ Date last full coat applied (**Day/Month/Year**)

3. For the most recent **full coat** application of anti-fouling treatment, what type of anti-fouling treatment was applied and to which specific **sections** of the submerged portion of the vessel was it applied?

Manufacturer/Company:
Product Name:

Applied on **(Check all that apply)**: Hull Sides☐ Hull Bottom☐ Sea Chests☐
Sea Chest Gratings☐ Propeller☐ Rope Guard/Propeller Shaft☐
Previous Docking Blocks☐ Thrusters☐ Rudder☐ Bilge Keels☐

Manufacturer/Company:	
Product Name:	

Applied on **(Check all that apply**): Hull Sides☐ Hull Bottom☐ Sea Chests☐
Sea Chest Gratings☐ Propeller☐ Rope Guard/Propeller Shaft☐
Previous Docking Blocks☐ Thrusters☐ Rudder☐ Bilge Keels☐

Official / IMO Number: _____

Manufacturer/Company:	
Product Name:	

Applied on **(Check all that apply**): Hull Sides☐ Hull Bottom☐ Sea Chests☐
Sea Chest Gratings☐ Propeller☐ Rope Guard/Propeller Shaft☐
Previous Docking Blocks☐ Thrusters☐ Rudder☐ Bilge Keels☐

4. Were the sea chests inspected and/or cleaned during the **out-of-water** maintenance listed above? If no out-of-water maintenance since delivery, select Not Applicable. **Check all that apply**.

Yes, sea chests inspected☐ Yes, sea chests cleaned☐
No, sea chests not inspected or cleaned☐ Not Applicable☐

5. Are Marine Growth Protection Systems (MGPS) installed in the sea chests?

Yes☐ Manufacturer:	Model:
No ☐	

6. Has the vessel undergone **in-water** cleaning to the submerged portions of the vessel since the last out-of-water maintenance period? Yes☐ No☐

a. If Yes, when and where did the vessel most recently undergo **in-water** cleaning (Do not include cleaning performed during out-of-water maintenance period)?

Date (**Day/Month/Year**):	
Port or Position:	Country:
Vendor providing cleaning service:	

Section(s) cleaned (**Check all that apply**):
Hull Sides ☐ Hull Bottom ☐ Propeller☐ Sea Chest Grating☐
Sea Chest☐ Bilge Keels ☐ Rudder☐ Docking Blocks☐
Thrusters ☐ Unknown ☐

Cleaning method: Divers ☐ Robotic ☐ Both ☐

7. Has the propeller been polished since the last **out-of-water** maintenance (including shipbuilding process) or **in-water** cleaning?

Yes ☐	Date of propeller polishing (**Day/Month/Year**):
No ☐	

8. Are the anchor and anchor chains rinsed during retrieval? Yes ☐ No ☐

Voyage Information

9. List the following information for this vessel averaged over the last four months:

a. **Average** Voyage Speed (knots):
b. **Average** Port Residency Time (hours or days): **Hours** or **Days**

Official / IMO Number: _____

10. Since the hull was last cleaned (**out-of-water** or **in-water**), has the vessel visited:

a. Fresh water ports (Specific gravity of less than 1.005)?

Yes ☐	How many times?
No ☐	

b. Tropical ports (between 23.5° S and 23.5° N latitude)?

Yes ☐	How many times?
No ☐	

c. Panama Canal?

Yes ☐	How many times?
No ☐	

d. List the previous 10 ports visited by this vessel in the order they were visited (start with most recent). Note: If the vessel visits the same ports on a regular route, check here ☐ and list the route once (you do not have to use all 10 spaces if the route involves less than 10 ports; add more lines if regular route involves more than 10 ports). **List dates as (Day/Month/Year)**.

Port or Position:	Country:
Arrival date:	Departure date:
Port or Position:	Country:
Arrival date:	Departure date:
Port or Position:	Country:

Arrival date:	Departure date:
Port or Position:	Country:
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Port or Position:	Country:
Arrival date:	Departure date:
Port or Position:	Country:
Arrival date:	Departure date:

Official / IMO Number: _____

11. Since the **most recent** hull cleaning (out-of-water or in-water) or delivery, has the vessel spent 10 or more consecutive days in any single location (Do not include time out-of-water or during in-water cleaning).

No ☐ List the longest amount of time spent in a single location since the last hull cleaning:

Number of Days:	Date of Arrival (Day/Month/Year):
Port or Position:	Country:

Yes ☐ List all of the occurrences where the vessel spent 10 or more consecutive days in any single location since the last hull cleaning.

ABBREVIATIONS AND ACRONYMS

AB	Assembly Bill
AMS	Alternative Management System
Annual Form	Ballast Water Treatment Technology Annual Reporting Form
ASTM	American Society for Testing and Materials
BOE	Board of Equalization
BWM Convention	IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments
BWRF	Ballast Water Reporting Form
BWMR	Ballast Water Management Report
Cal-NEMO	California Non-Native Estuarine and Marine Organism Database
CANOD	California Aquatic Non-Native Organisms Database
CDFW	California Department of Fish and Wildlife
CDFW-MISP	California Department of Fish and Wildlife's Marine Invasive Species Program
cfu	colony-forming unit
Commission	California State Lands Commission
EPA	U.S. Environmental Protection Agency
ER	empty-refill
FT	flow-through
FY	Fiscal year
GIS	Geographic Information Systems
HACCP	Hazard Analysis and Critical Control Point
HHRF	Hull Husbandry Reporting Form
IMO	International Maritime Organization
LA-LB	Los Angeles-Long Beach port complex
m	meter
MEPC	Marine Environment Protection Committee
MISA	Marine Invasive Species Act
MISP	Marine Invasive Species Program
ml	milliliter
MMT	million metric tons
MPN	Most Probable Number
MT	metric tons
NEMESIS	National Exotic Marine and Estuarine Species Information System
NIS	nonindigenous species
NM	nautical miles
NPDES	National Pollutant Discharge Elimination System
PCR	Pacific Coast Region
SERC	Smithsonian Environmental Research Center

STEP	Shipboard Technology Evaluation Program
Supplemental Form	Ballast Water Treatment Supplemental Reporting Form
TAG	technology advisory group
TAP	technology advisory panel
µm	micrometer
U.S.	United States
USCG	United States Coast Guard
VIDA	Vessel Incidental Discharge Act
VGP	Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels
Water Board	State Water Resources Control Board (California)

LITERATURE CITED

ACEH (Alameda County Environmental Health). 2014. Swimmers Itch Advisory at Alameda's Crown Beach. Website: http://www.acgov.org/aceh/health_advisories.htm (accessed January 26, 2015).

Ashton, G., C. Zabin, I. Davidson, and G. Ruiz. 2012. Aquatic Invasive Species Vector Risk Assessments: Recreational vessels as vectors for non-native marine species in California. Prepared for Ocean Science Trust 75pp.

Ashton, G., I. Davidson, J. Geller, and G. Ruiz. 2016. Disentangling the biogeography of ship biofouling: barnacles in the Northeast Pacific. *Global Ecology and Biogeography*, 25(6): 739-750.

Barta, R. Personal communication, September 14, 2016.

Barnard, B. 2016. Carriers stick with slow-steaming despite fuel-price plunge. Journal of Commerce. Website: http://www.joc.com/maritime-news/container-lines/carriers-stick-slow-steaming-despite-fuel-price-plunge_20160401.html. Accessed July 25, 2016.

Barnes, D. 2002. Biodiversity: Invasions by marine life on plastic debris. *Nature*. 416:808-809.

Bialystocki, N. and D. Konovessis. 2016. On the estimation of ship's fuel consumption and speed curve: A statistical approach. *Journal of Ocean Engineering and Science* 1: 157-166.

Bradie, J. 2016. METEOR Voyage M116/2: Report on performance of ballast water collection and analysis devices. Prepared for BSH (German Federal Maritime and Hydrographic Agency): 130 pages.

Brant, S.V., A.N. Cohen, D. James, L. Hui, A. Hom, and E.S. Loker. 2010. Cercarial dermatitis transmitted by exotic marine snail. *Emerging Infectious Diseases* 16:1357-1365.

Briski, E., L.E. Allinger, M. Balcer, A. Cangelosi, L. Fanberg, T.P. Markee, N. Mays, C.N. Polkinghorne, K.R. Prihoda, E.D. Reavie, D.H. Regan, D.M. Reid, H.J. Saillard, T. Schwerdt, H. Schaefer, M. TenEyck, C.J.Wiley, S.A. Bailey. 2013. Multidimentional Approach to Invasive Species Prevention. *Environmental Science & Technology* 47: 1216-1221.

Briski, E., S. Gollasch, M. David, and S. Bailey. 2015. Combining ballast water exchange and treatment to maximize prevention of species introductions to freshwater ecosystems. *Environmental Science and Technology* 49: 9566-9573.

Carlton, J.T. 1993. Dispersal mechanisms of the zebra mussel (*Dreissena polymorpha*), Chapter 40, pp. 677 - 697, in: Thomas F. Nalepa and Donald W. Schloesser, editors, Zebra Mussels: Biology, Impacts, and Control. CRC Press, Inc., Boca Raton, Florida.

Carlton, J.T. and J. Hodder. 1995. Biogeography and dispersal of coastal marine organisms: experimental studies on a replica of a 16th-century sailing vessel. *Marine Biology* 121: 721-730.

Carlton, J.T. 1996. Pattern, process, and prediction in marine invasion ecology. *Biological Conservation* 78(1-2): 97-106.

Carlton, J.T. 1999. The scale and ecological consequences of biological invasions in the world's oceans. Pp 195-212 *In* Invasive Species and Biodiversity Management. O. Sandulund, P. Schei and A. Viken, eds. Kulwer Academic Publishers. Dordrecht, Netherlands.

Chapman, J. W., T. W. Miller and E. V. Coan. 2003 Live seafood species are recipes for invasion, *Conservation Biology*, 17:1386-1395.

Cordell, J., E. Sosik, M. Falkner, and C. Scianni. 2009. Characterizing risk associated with vessel fouling and non-indigenous species in Prince William Sound. Produced for the Prince William Sound Regional Citizens' Advisory Council. 68 pp.

Cohen, A.N. 1998. Ships' ballast water and the introduction of exotic organisms into the San Francisco Estuary: Current status of the problem and options for management. A report for CALFED and the California Urban Water Agencies. San Francisco Estuary Institute, Richmond, CA.

Cohen, A.N. and J.T. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. *Science* 279: 555-558

Cohen, A.N. and A. Weinstein. 1998. The potential distribution and abundance of zebra mussels in California. A report for CALFED and the California Urban Water Agencies. San Francisco Estuary Institute. 13pp.

Commission (California State Lands Commission). 2010. 2010 Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment

Systems for Use in California Waters. Produced for the California State Legislature.150pp.

Commission (California State Lands Commission). 2013. 2013 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters. Produced for the California State Legislature. 148pp.

Commission (California State Lands Commission). 2014. 2014 Assessment of the Efficacy, Availability, and Environmental Impacts of Ballast Water Treatment technologies for Use in California Waters. Produced for the California State Legislature. 70pp.

Commission (California State Lands Commission). 2015a. Resolution by the California State Lands Commission opposing federal legislation that would preempt states' authority to address incidental vessel discharges and eliminate the long-standing ability of states to protect their waters from invasive species introductions. Adopted by the California State Lands Commission on February 20, 2015.

Commission (California State Lands Commission). 2015b. California State Lands Commission Strategic Plan 2016-2020. December 18, 2015. 37pp. www.slc.ca.gov/About/Docs/StrategicPlan.pdf

Costa, E.G., R.M. Lopes, and J.M. Singer. 2016. Sample size for estimating the mean concentration. *Journal of Environmental Management* 180: 433-438.

Coutts, A.D.M. 1999. Hull fouling as a modern vector for marine biological invasions: investigation of merchant vessels visiting northern Tasmania. Thesis at Australian Maritime College. 283pp.

Coutts, A.D.M., K.M. Moore, and C. Hewitt. 2003. Ships' sea-chests: An overlooked transfer mechanism for non-indigenous marine species? *Marine Pollution Bulletin.* 46: 1504-1515.

Coutts, A.D.M. and M.D. Taylor. 2004. A preliminary investigation of biosecurity risks associated with biofouling on merchant vessels in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 38: 215-229.

Coutts, A.D.M. and T.J. Dodgshun. 2007. The nature and extent of organisms in vessel sea-chests: A protected mechanism for marine bioinvasions. *Marine Pollution Bulletin* 54: 875-886.

Coutts, A.D.M., R.F. Piola, M.D. Taylor, C.L. Hewitt, and P.A. Gardner. 2010. The effect of vessel speed on the survivorship of biofouling organisms at different hull locations. *Biofouling* 26(5): 529-553.

Cullen and MacIntyre 2016. On the use of the serial dilution culture method to enumerate viable phytoplankton in natural communities of plankton subjected to ballast water treatment. *Journal of Applied Phycology* 28. 279-298

Davidson, I.C., L.D. McCann, P.W. Fofonoff, M.D. Sytsma, and G.M. Ruiz. 2008. The potential for hull-mediated species transfers by obsolete ships on their final voyages. *Diversity and Distributions* 14: 518-529.

Davidson, I.C., C.W. Brown, M.D. Sytsma, and G.M. Ruiz. 2009a. The role of containerships as transfer mechanisms of marine biofouling species. *Biofouling* 25:645-655.

Davidson, I., G. Ashton, and G. Ruiz. 2009b. Biofouling as a vector of marine organisms on the US West Coast: a preliminary evaluation of barges and cruise ships. Aquatic Bioinvasion Research & Policy Institute. Final report for California State Lands Commission. 20 pp.

Davidson, I., C. Scianni, L. Ceballos, C. Zabin, G. Ashton, and G. Ruiz. 2014. Evaluating ship biofouling and emerging management tools for reducing biofouling-mediated species incursions. Produced for the California State Lands Commission. 36 pp.

Davidson, I., C. Scianni, C. Hewitt, R. Everett, E. Holm, M. Tamburri, and G. Ruiz. 2016. Mini-review: Assessing the drivers of ship biofouling management - aligning industry and biosecurity goals. *Biofouling*, 32(4): 411-428.

Dobroski, N., L. Takata, C. Scianni, and M. Falkner. 2007. Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters. Produced for the California State Legislature. 107 pp.

Dobroski, N., C. Scianni, D. Gehringer, and M. Falkner. 2009. Assessment of the Efficacy, Availability and Environmental Impacts of Ballast Water Treatment Systems for Use in California Waters. Produced for the California State Legislature. 173 pp.

Dobroski, N., C. Brown, R. Nedelcheva, C. Scianni, and J. Thompson. 2015. 2015 Biennial report on the California Marine Invasive Species Program. Produced for the California State Legislature. 99 pp.

Dornblaser, A. 2016. COAST Internship: Vessel Biofouling Management. Final Report prepared for the Marine Invasive Species Program of the California State Lands Commission. 13 pp.

Edmiston C. 2015. 2015 COAST Summer Internship: State Lands Commission's Marine Invasive Species Program Vessel Biofouling Management. Final Report prepared for the Marine Invasive Species Program of the California State Lands Commission. 12 pp.

Eldredge, L.G. and J.T. Carlton. 2002. Hawaii marine bioinvasions: A preliminary assessment. *Pacific Science* 56: 211-212.

ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Falkner, M., L. Takata, S. Gilmore and N. Dobroski. 2007. Biennial Report on the California Marine Invasive Species Program. Produced for the California State Legislature. 79 pp.

Falkner, M., N. Dobroski, C. Scianni, D. Gehringer, and L. Takata. 2009. 2009 Biennial report on the California Marine Invasive Species Program. Produced for the California State Legislature. 108 pp.

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

Ficenec, J. 2016. Zombie ships send maritime freight into worst crisis in living memory. The Telegraph. Website: http://www.telegraph.co.uk/finance/12108453/Zombie-ships-send-maritime-freight-into-worst-crisis-in-living-memory.html. Accessed July 25, 2016.

First, M. R., S. H. Robbins-Wamsley, S.C. Riley, and L.A. Drake. 2016. Towards minimizing transport of aquatic nuisance species in ballast water: D0o organisms in different size classes respond uniformly to biocidal treatment? *Biological Invasions* 18: 647-660.

Floerl, O. and A. Coutts. 2009. Potential ramifications of the global economic crisis on human-mediated dispersal of marine non-indigenous species. *Marine Pollution Bulletin* 58: 1595-1598.

Fofonoff, P.W., G.M. Ruiz, B. Steves, and J.T. Carlton. 2003a. In ships or on ships? Mechanisms of transfer and invasion for nonnative species to the coasts of North

America. Pp. 152-181. *In* Invasive species, vectors and management strategies. G.M. Ruiz and J.T. Carlton eds. Island Press, Washington D.C.

Fofonoff, PW. Ruiz GM, Steves B, & Carlton JT. 2003b. National Exotic Marine and Estuarine Species Information System. http://invasions.si.edu/nemesis/. Access Date: September 10, 2016

Fowler, A., A. Blakeslee, J. Canning-Clode, and W. Miller. 2015. Opening Pandora's bait box: A potent vector for biological invasions of live marine species. *Diversity and Distributions* 22:1-13.

Frey, M.A., N. Simard, D.D. Robichaud, J.L. Martin, T.W. Therriault. 2014. Fouling around: vessel sea-chests as a vector for the introduction and spread of aquatic invasive species. *Management of Biological Invasions* 5(1): 21-30.

Gard 2016. Gard Alert: Special ballast water exchange requirements in Iranian ports. http://www.gard.no/web/updates/content/20923087/gard-alert-special-ballast-water-exchange-requirements-in-iranian-ports. Accessed May 4, 2016.

Gollasch, S. 2002. The importance of ship hull fouling as a vector of species introductions into the North Sea. *Biofouling* 18: 105-121.

Gollasch, S., M. David, J. France, and P. Mozetic. 2015. Quantifying indicatively living phytoplankton cells in ballast water samples – recommendations for Port State Control. *Marine Pollution Bulletin* 101(2)

Greene, V.E., L.J. Sullivan, J.K. Thompson, W.J. Kimmerer. 2011. Grazing impact of the invasive clam Corbula amurensis on the microplankton assemblage of the northern San Francisco Estuary. *Marine Ecology Progress Series* 431: 183-193.

Grosholz, E., R.E. Crafton, R.E.Fontana, J. Pasari, S. Williams, and C. Zabin. 2012. Aquatic Invasive Species Vector Risk Assessments: An Analysis of Aquaculture as a Vector for Introduced Marine and Estuarine Species in California. Prepared for Ocean Science Trust 77pp.

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

Hay C. and D. Tanis. 1998. Mid ocean ballast water exchange: procedures, effectiveness and verification. A report prepared for the New Zealand Ministry of Fisheries. Cawthron Report No. 468. Cawthron Institute, Nelson. 66pp.

Hewitt, C. and M. Campbell. 2010. The relative contribution of vectors to the introduction and translocation of invasive marine species. Final Report prepared for the Australian Department of Agriculture, Fisheries and Forestry. 56 pp.

Higgins, S.N. and M.J. Vander Zanden. 2010. What a difference a species makes: A meta-analysis of dreissenid mussel impacts on freshwater ecosystems. *Ecological Monographs* 80:179-186

Hopkins, G.A. and B.M. Forrest. 2008. Management options for vessel hull fouling: an overview of risks posed by in-water cleaning. *ICES Journal of Marine Science* 65:811-815.

Hopkins, G.A. and B.M. Forrest. 2010. A preliminary assessment of biofouling and non-indigenous marine species associated with commercial slow-moving vessels arriving in New Zealand. *Biofouling* 26(5): 613-621.

Hopkins, G.A., B.M. Forrest, R.F. Piola, and P.A. Gardner. 2011. Factors affecting survivorship of defouled communities and the effect of fragmentation on establishment success. *Journal of Experimental Marine Biology and Ecology* 396:233-243.

Hughes, K.A. and G.V. Ashton. 2016. Breaking the ice: the introduction of biofouling organisms to Antarctica on vessel hulls. *Aquatic Conservation: Marine and Freshwater Ecosystems*. doi: 10.1002/aqc.2625

Hunsucker, K.Z., A. Koka, G. Lund, and G. Swain.2014. Diatom community structure on in-service cruise ship hulls. *Biofouling* 30 (9): 1133-1140.

Jimenez, H. and G.M. Ruiz. 2016. Contribution of non-native species to soft-sediment marine community structure of San Francisco Bay, California. *Biological Invasions* 18 (7).2007-2016

Johengen, T., D. Reid, G. Fahnenstiel, H. MacIsaac, F. Dobbs, M. Doblin, G. Ruiz, P. Jenkins. 2005. Assessment of Transoceanic NOBOB Vessels and Low-Salinity Ballast Water as Vectors for Non-indigenous Species Introductions to the Great Lakes. 287 pp.

KCRA. 2014. Green menace forces shutdown of Lighted Boat Parade. Website: http://www.kcra.com/news/Green-menace-forces-shutdown-of-Lighted-Boat-Parade/29893926. (accessed January 26, 2015).

Kim, Y., J. Welch, C. Brussaard, T. Gim, L. Peperzak, and J. Rose. 2016. Desktop study of the state-of-the-art concentration and enumeration methods for aquatic viruses. Report to the California State Lands Commission 51 pgs.

Kimmerer, W.J. and J.K. Thompson. 2014. Phytoplankton growth balanced by clam and zooplankton grazing and net transport into the low salinity zone of the San Francisco Estuary. *Estuaries and Coasts* 37:1202-1218.

Latta, M. Personal communication, July 14, 2016.

Mac Nally, R., J.R. Thompson, W.J. Kimmerer, F. Feyrer, K.B. Newman, A. Sih, W.A. Bennett, L. Brown, E. Flushman, S.D. Culberson, and G. Castillo. 2010. An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). *Ecological Applications* 20: 167-180.

MacIsaac, H.J., T.C. Robbins, and M.A. Lewis. 2002. Modeling ships' ballast water as invasion threats to the Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 59: 1245-1256.

Mandrak, N.E., and B. Cudmore. 2015. Risk assessment: Cornerstone of an aquatic invasive species program. *Aquatic Ecosystem Health and Management* 18: 312-320.

Martel, A.L., D.A. Pathy, J.B. Madill, C.B. Renaud, S.L. Dean, and S.J. Kerr. 2001. Decline and regional extirpation of freshwater mussels (Unionidae) in a small river system invaded by *Dreissena polymorpha:* The Rideau River, 1993-2000. *Canadian Journal of Zoology* 79: 2181-2191.

McClary, D., C. Phipps, and S. Hinni. 2008. Reproductive behaviour of the clubbed tunicate, *Styela clava*, in northern New Zealand waters. Prepared for BNZ Post-clearance Directorate. 40 pp.

McGeoch, M.A., P. Genovesi, P.J. Bellingham, M.J. Costello, C. McGrannachan, and A. Sheppard.2015. Prioritizing species, pathways, and sites to achieve conservation targets for biological invasion. *Biological Invasions* 18: 299-314.

MEPC (Marine Environment Protection Committee). 2015. Final report on the study on the implementation of the ballast water performance standard described in regulation D-2 of the BWM Convention. MEPC 69/4/4. December 11, 2015. 59pp.

Minchin, D. and S. Gollasch. 2003. Fouling and ships' hulls: How changing circumstances and spawning events may result in the spread of exotic species. *Biofouling* 19: 111-122.

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

Muirhead, J.R., M.S. Minton, W.A. Miller, and G.M. Ruiz.2015. Projected effects of the Panama Canal expansion on shipping traffic and biological invasions. *Diversity and Distributions* 21: 75-87.

NOEP (National Ocean Economics Program). 2016. State of the U.S. ocean and coastal economies. 2016 Update Website: http://www.oceaneconomics.org/LMR/fishSearch.asp. (accessed: July 29, 2016).

OSJ. 2016. OSV owners battle adverse market. Offshore Support Journal. Website: http://www.osjonline.com/news/view,osv-owners-battle-adverse-market_43792.htm. Accessed July 25, 2016.

Parsons, M.G. 1998. Flow-through ballast water exchange. Society of Naval Architects and Marine Engineers, Transactions 106: 485-493.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273-28

Reid, D.F., T.H. Johengen, H. MacIssac, F. Dobbs, M. Doblin, L. Drake, G. Ruiz, and P. Jenkins. 2007. Identifying, verifying and establishing options for best management practices for NOBOB vessels. Prepared for: The Great Lakes Protection Fund, the U.S. Coast Guard, and the National Oceanic and Atmospheric Administration. 173 pp.

Revilla-Castellanos, V.J., A. Guerrero, B. Gomez-Gill, E. Navarro-Barron, and M.L. Lizarraga-Partida. 2015. Pathogenic *Vibrio parahaemolyticus* isolated from biofouling on commercial vessels and harbor structures. *Biofouling* 31: 275-282.

Rothlisberger, J., D. Finnoff, R. Cooke, and D. Lodge. 2012. Ship-borne nonindigenous species diminish Great Lakes ecosystem services. *Ecosystems* 15: 463-476.

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

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

Ruiz, G.M. and J.T. Carlton. 2003. Invasion vectors: A conceptual framework for management. Pp. 459-498. *In* Invasive species, vectors and management strategies. G.M. Ruiz and J.T. Carlton eds. Island Press, Washington D.C.

Ruiz, G.M., P.W. Fofonoff, B. Steves, S.F. Foss, and S.N. Shiba. 2011. Marine invasion history and vector analysis of California: a hotspot for western North America. *Diversity and Distributions* 17: 362-373.

Ruiz, G.M., P.W. Fofonoff, B. P. Steves and J. T. Carlton. 2015. Invasion history and vector dynamics in coastal marine ecosystems: A North American perspective. *Aquatic Ecosystem Health & Management* 18:3, 299-311.

SAB (Science Advisory Board, U.S. Environmental Protection Agency). 2011. Efficacy of ballast water treatment systems: a report by the EPA Science Advisory Board. 154pp.

Santagata, S., Z. Gasiūnaite, E. Verling, J. Cordell, K. Eason, J. Cohen, K. Bacela, G. Quilez-Badia, T. Johengen, D. Reid, and G. Ruiz. 2008. Effect of osmotic shock as a management strategy to reduce transfers of non-indigenous species among low-salinity ports by ships. *Aquatic Invasions* 3:61-76

Scianni, C., C. Brown, A. Newsom, R. Nedelcheva, M. Falkner, and N. Dobroski. 2013. 2013 Biennial report on the California Marine Invasive Species Program. Produced for the California State Legislature. 157 pp.

Schuler, M. 2015. Containership owners rapidly idling vessels as market slows, Drewry says. gCaptain. Website: http://gcaptain.com/containership-owners-rapidly-idling-vessels-as-market-slows-drewry-says/. Accessed July 25, 2016.

Seebens, H., N. Schwartz, P. Schupp, and B. Blasius. 2016. Predicting the spread of marine species introduced by global shipping. *Proceedings of the National Academy of Sciences* 113: 5646–5651.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco estuary. *Fisheries* 32: 270-277.

Spalding, M.D., H.E. Fox, G.R. Allen, N. Davidson, Z.A. Ferdana, M. Finlayson, B.S.Halpern, M.A. Jorge, A. Lombana, S.A. Lourie, K.D. Martin, E. McManus, J. Molnar, C.A. Recchia, and J. Robertson. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. *BioScience* 57(7): 573-583.

Sylvester, F., O. Kalaci, B. Leung, A. Lacoursiere-Roussel, C. Clarke-Murray, F.M. Choi, M.A. Bravo, T.W. Therriault, and H.J. MacIsaac. 2011. Hull fouling as an invasion vector: can simple models explain a complex problem? *Journal of Applied Ecology* 48: 415-423.

Takahashi, C.K., N.G.G.S. Lourenco, T.F. Lopes, V.L.M. Rall, and C.A.M. Lopes. 2008. Ballast water: A review of the impact on the world public health. *Journal of Venomous Animals and Toxins Including Tropical Diseases* 14: 393-408.

Takata, L., N. Dobroski, C. Scianni, and M. Falkner. 2011. Biennial Report on the California Marine Invasive Species Program. Produced for the California State Legislature. 125 pp.

Tovey, A. and Agencies. 2016. Shipping industry faces worse storm than after financial crisis, warns Maersk boss. The Telegraph. Website: http://www.telegraph.co.uk/business/2016/02/12/shipping-industry-faces-worse-storm-than-after-financial-crisis/. Accessed July 25, 2016.

Tribou, M. and G. Swain. 2015. Grooming using rotating brushes as a proactive method to control ship hull fouling. *Biofouling* 31(4): 309-319.

USCG (United States Coast Guard). 2001. Report to Congress on the voluntary national guidelines for ballast water management. Appendix B: Status and trends of ballast water management in the United States. Biennial Report for the National Ballast Information Clearinghouse. 45 pp.

USCG (United States Coast Guard). 2016. 7/12/16: Final Action on Ballast Water Management System Appeals. Coast Guard Maritime Commons. Website: http://mariners.coastguard.dodlive.mil/2016/07/12/7122016-final-action-on-ballast-water-management-system-appeals/. Accessed: October 4, 2016.

USGS (U.S. Geological Survey). 2016. Zebra mussel and quagga mussel information resource page. Website: http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/. (accessed: August 15, 2016).

Vanderploeg, H.A., J.R. Liebig, T.F. Nalepa, G.L. Fahnenstiel, and S.A. Pothoven. 2010. *Dreissena* and the disappearance of the spring phytoplankton bloom in Lake Michigan. *Journal of Great Lakes Research* 36:50-59.

Verna, D.E., B.P. Harris, K.K. Holzer, and M.S. Minton. 2016. Ballast-borne marine invasive species: exploring the risk to coastal Alaska, USA. *Management of Biological Invasions* 7: 199-211

Volkoff, M. Personal communication, July 2016.

Wackett, M. 2016. Slow steaming still cheaper despite record low bunker prices. gCaptain. Website: http://gcaptain.com/slow-steaming-still-cheaper-despite-record-low-bunker-prices/. Accessed July 25, 2016.

Wallis, K., and R. Khasawneh. 2016. Crude tanker storage fleet off Singapore points to stubborn oil glut. Reuters. Website: http://www.reuters.com/article/us-asia-oil-storage-idUSKCN0YA129. Accessed July 25, 2016.

Water Board. 2010. 2010 Integrated Report (Clean Water Act Section 303(d) List/ 305(b) Report). State Water Resources Control Board. Website: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml. Accessed July 25, 2016.

Water Board. 2015. In-water vessel hull cleaning: Best management practice fact sheet – May 2015. State Water Resources Control Board. Website: http://www.waterboards.ca.gov/sanfranciscobay/publications_forms/documents/In-water_vessel_hull_cleaning_fact_sheet.pdf. Accessed July 25, 2016.

Williams, S., R.E. Crafton, R.E.Fontana, E.D. Grosholz, J. Pasari, and C. Zabin. 2012. Aquatic Invasive Species Vector Risk Assessments: A Vector of the Aquarium and Aquascape ('Ornamental Species') Trades in California. Prepared for Ocean Science Trust 87pp.

Wingfield, J., Personal communication, January 26, 2015.

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

Woodfield, R. 2006. Invasive seaweed threatens California's coastline – an update. Ballast Exchange: Newsletter of the West Coast Ballast Outreach Project 6: 10-11.

Worstall, T. 2015. The Great Recession is finally, definitively, over as GDP per capita beats peak. Forbes. Website: http://www.forbes.com/sites/timworstall/2015/07/28/the-great-recession-is-finally-definitively-over-as-gdp-per-capita-beats-peak/#51236d26411a. Accessed July 25, 2016.

Zhang, F. and M. Dickman. 1999. Mid-Ocean exchange of container vessel ballast water. 1: Seasonal factors affecting the transport of harmful diatoms and dinoflagellates. *Marine Ecology Progress Series* 176: 243-25