CALIFORNIA STATE LANDS COMMISSION
REPORT ON
PERFORMANCE STANDARDS FOR
BALLAST WATER DISCHARGES
IN CALIFORNIA WATERS

PRODUCED FOR THE
CALIFORNIA STATE LEGISLATURE

By
M. Falkner, L. Takata, and S. Gilmore
California State Lands Commission
Marine Facilities Division
January 2006

EXECUTIVE SUMMARY

The Marine Invasive Species Act (Act) of 2003 revised and expanded The Ballast Water Management for Control of Nonindigenous Species Act of 1999. In accordance with the Act, the California State Lands Commission (Commission) was charged with several expanded responsibilities intended to prevent or minimize the introduction of non-indigenous species (NIS) from commercial vessels. Key among those responsibilities and specific to this report, the Commission is required to recommend specific performance standards to the State Legislature, in consultation with the State Water Resources Control Board (SWRCB) and in consideration of recommendations provided by an advisory panel (Public Resources Code Section 71204.9). Commission staff convened a cross-interest, multi-disciplinary Panel, and facilitated deliberations over the selection of standards based on best available technology economically achievable and designed to protect the beneficial uses of the waters of the State.

The report summarizes the advisory panel process and the variety of approaches used to guide considerations related to the protection of beneficial uses, economic achievability, and technological feasibility. All approaches provided some foundation for the development of the recommendations, but there are many information gaps, which affected the selection and implementation schedule of performance standards for California. While questions remain regarding the effectiveness and economic achievability of technologies and there is no strong scientific evidence that argues for a specific level of treatment, the Commission believes the adoption of performance standards by the State of California is essential to move technology development forward. Furthermore, the Commission believes that by setting a technology forcing standard and mandating the review of treatment technologies as they relate to the implementation schedule, the intent of the Act "to move the state expeditiously toward the elimination of the discharge of NIS into the waters of the state," (Section 71201(d) of the Public Resources Code) can be achieved. The Commission is also recommending that efforts and progress to meet these standards be monitored so that changes to these standards or the implementation schedule can be made as necessary. Finally, the comprehensive program detailed in this report will require legislation to authorize its implementation. California lawmakers could either codify these standards in legislation or require the Commission to develop and adopt regulations to implement the Commission's report. Lawmakers should also require best achievable technology, rather than best available technology, to ensure the final performance standard is achieved.

RECOMMENDATIONS: California should:

1. *Adopt the Interim Performance Standards put forward by the Majority Panel Report.* The interim standards proposed vary by organism size class, recommending a zero detectable standard for the largest organism size class (> 50µm). It appears these interim standards will be protective of state waters and more feasible than the ultimate goal of zero discharge standards for all size classes of organisms at this time. The Panel Report was beneficial for focusing on the fundamental problem: scientific information does not exist to determine whether any standard, short of zero, will prevent new introductions.

2. *Adopt the Implementation Schedule proposed by Majority Panel Report and adopted in the IMO (International Maritime Organization) Convention for the interim standards.* The phased implementation schedule will require that all vessels meet the interim standard by 2016. This implementation schedule considered the demand for shipyard services needed to retrofit existing vessels and construction of new vessels as well as the speed of technological development.

3. *Adopt the Final Performance Standard of zero detectable for all organism size classes by 2020.* The most protective standard possible, zero detectable discharge, was the stated goal of the Advisory Panel and the Commission. All vessels operating in California waters will be required to meet the final standard by 2020. This implementation schedule considers shipyard services, operational life of maritime fleet, and technology development.

4. *Require initial and periodic reviews of treatment technologies and management practices.* A review of treatment technologies and management options in consultation with stakeholders is necessary to determine whether appropriate technologies or management options are able to achieve the proposed interim and final standards. An initial review should occur no later than January 1, 2008, in advance of the first implementation date of January 1, 2009. A review should also occur no later than January 1, 2019, in advance of the implementation of

final standards. Continued review of alternative technologies and management practices should be required and conducted every three years beginning January 1, 2011. If, as a result of these periodic reviews, technologies are identified that exceed established performance standards, strengthening of those standards should be accomplished.

5. *Grandfather vessels with existing experimental treatment technologies that have been approved by the Commission and/or the USCG (United States Coast Guard).* Provide a 5-year extension to vessels that have participated in an approved program to test promising ballast water treatment technologies prior to the date that standards become effective.

6. *Establish a testing and evaluation center that provides the industry, developers, and regulators an opportunity to take promising technologies to working prototypes.* The current State program does not have the expertise, equipment, facilities, or financial resources necessary for the testing and certification of treatment technologies. This infrastructure would substantially improve the effective implementation of performance standards and the ongoing evaluation of technologies once approved.

7. *Provide additional funding and personnel to expand biological surveys to assess the effectiveness of the State's Program.* In order to evaluate the effectiveness of performance standards or other management measures, long-term biological monitoring is needed. Such work is essential for determining how to change and enhance the Program to more effectively reduce invasions in California.

8. *Consider incentives to promote continued technology development.* Technology developers and the shipping industry are unlikely to continue development of technologies that exceed established standards. Positive inducements that are financially advantageous for the shipping industry could serve to facilitate the advancement of technologies towards the ultimate standard of zero discharge.

9. *Remove the sunset date in the enabling legislation.* Continuation of the Marine Invasive Species Program will be necessary to ensure the development of technologies and the proper implementation of the standards in the field.

ABBREVIATIONS AND TERMS

AB	Assembly Bill
Act	Marine Invasive Species Act
CA	California
CAPA	California Association of Port Authorities
CDFG	CA Department of Fish and Game
Commission	CA State Lands Commission
EEZ	Exclusive Economic Zone
GloBallast	Global Ballast Water Management Program
HR	House Bill
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
MISP	Marine Invasive Species Program
MOA	Memorandum of Agreement
MT	Metric Ton
NAISA	National Aquatic Invasive Species Act
NIS	Non-indigenous species
nm	Nautical mile
OR	Oregon
Panel	Performance Standards Advisory Panel
PRC	Public Resource Code
R & D	Research and Development
SB	Senate Bill
SHB	Substitute House Bill
SERC	Smithsonian Environmental Research Institute
SGBOSV	Study Group on Ballast Water and Other Ship Vectors
SWRCB	State Water Resource Control Board
TOC	The Ocean Conservancy
USCG	United States Coast Guard
UV	Ultraviolet Irradiation
WA	Washington

TABLE OF CONTENTS

I. PURPOSE

This report was prepared for the California Legislature pursuant to the Marine Invasive Species Act of 2003 (Act). The Act reauthorized and enhanced the original law, The Ballast Water Management and Control for Nonindigenous Species Act of 1999. In accordance with the Act, the California State Lands Commission (Commission) was charged with several expanded responsibilities. Key among them and specific to this report is to recommend performance standards for the discharge of ballast water into the waters of the state (Section 71204.9 of the Public Resources Code (PRC)). The performance standards will be based on best available technology economically achievable and be designed to protect the beneficial uses of state waters. This report discusses the status and future plans of the Commission's Marine Invasive Species Program, as required by the Act.

II. INTRODUCTION – NON-INDIGENOUS SPECIES AND BALLAST WATER

Non-indigenous species (NIS) are organisms that have been transported by human activities into regions where they did not occur in historical time, and successfully reproduce in the wild at their new location (Carlton 2001). Once established, such species can create negative economic, ecological, and human health impacts in their new environ. In coastal environments, commercial shipping is the most important vector for invasion, in one study accounting for one half to three-quarters of introductions to North America (Fofonoff et al. 2003). Shipping related transport of NIS in ballast water, and to a lesser extent bio fouling of hulls, anchor chains and sea chests, has been an important vector since the 1800s (National Research Council 1996). Large vessels are able to transport over five million gallons of ballast water per voyage.

Ballast water is necessary for many functions related to the trim, stability, maneuverability, and propulsion of large seagoing vessels (National Research Council 1996). As ballast water is transferred from "source" to "destination" ports, so are the many organisms taken into its tanks along with the port water. In this fashion, it is estimated that some 7000 plus organisms are moved around the world on a daily basis (Carlton 1999).

Attempts to eradicate NIS after they have become widely distributed are typically unsuccessful and costly (Carlton 2001). Control is likewise extremely expensive. For example, approximately $10 million is spent annually to control the sea lamprey (*Petromyzon marinus*) in the Great Lakes (Lovell and Stone 2005); $2.3 million was spent to suppress a recurrence of the Mediterranean green seaweed (*Caulerpa taxifolia)* in southern California during 2000-2001, and $2 million was spent in Washington to control Atlantic cordgrass (*Spartinia alterniflora*) between 1999-2001 (Carlton 2001). Prevention is therefore considered the most desirable way to address the issue.

California requires vessels arriving from outside the US Exclusive Economic Zone (US EEZ) to manage their ballast water. Similar rules will become effective for vessels engaged in coastwise travel in March 2006. Management options include retention of ballast water, mid-ocean exchange, discharge to a shore-base treatment facility, or the use of an alternative treatment technology.

Ballast water exchange, the process of exchanging coastal water for mid-ocean water, is presently the most broadly applicable method for managing the risk of NIS introductions (Battelle 2003), though studies suggest that it may be of limited usefulness because its efficiency is inconsistent (Dickman and Zhang 1999, Parsons 1998, Cohen 1998) (See Section III, “The Need for Performance Standards”). During the process, biologically rich water loaded at the last port of call is flushed out of ballast tanks with the water from the open ocean, typically beyond 200 nautical miles (nm) from land. Organisms are generally less numerous in the open ocean, and it is expected that they will be poorly adapted to survive once discharged in the very different environmental conditions of a near shore port (Cohen 1998). Thus, in comparison to unmanaged ballast water, exchanged ballast is expected to reduce the risk of NIS introduction in a receiving port. Currently, ballast water exchange is the best compromise of efficacy, environmental safety, and economic practicality. The vast majority of vessels are capable of conducting exchange, and the management practice does not require any special structural modification to most of the vessels in operation.

III. THE NEED FOR PERFORMANCE STANDARDS

Currently, there are no federal or California performance standards for the discharge of ballast water. The need for standards, however, is important to provide a higher level of NIS protection, to drive the development of treatment technologies, and to facilitate commercial vessel operations. These needs are described in detail in this section.

Ballast water exchange efficiency ranges from 50-90% (U.S. Coast Guard 2001). Efficiency appears to be dependent on many factors such as ship design, ballast system configuration, and exchange location (Dickman and Zhang 1999, Battelle 2003). Due to these limitations most experts view ballast water exchange as a short-term solution, with the final resolution being a combination of treatment technologies and management options.

Current federal regulation requires that ballast water loaded outside the US EEZ be exchanged a minimum of 200 nautical miles (nm) offshore prior to discharge in U.S waters. California and other West Coast states have implemented similar requirements. Beginning March 2006 Commission approved regulations will go into effect that will require ballast water from the Pacific Coast Region (i.e., coastal waters located roughly between Cooks Inlet, Alaska and Baja California) be exchanged a minimum of 50 nm offshore before discharge in State waters. To conduct ballast water exchange at this distance offshore, a few vessels may have to modify routing on some voyages. Such deviations can extend travel distances, increasing vessel costs for personnel time and fuel consumption.

For some vessels under some circumstances, ballast water exchange can place a ship or its crew at risk (National Research Council 1996). For example, vessels that encounter adverse weather or experience equipment failure may be unable to conduct ballast water exchange safely. Some unmanned barges are incapable of conducting exchange without transferring personnel onboard; a procedure that, if attempted in the exposed conditions of the open ocean, can present unacceptable danger. In recognition of these possibilities, state (California [CA], Oregon [OR], and Washington [WA]) and federal ballast water regulations allow vessels to forego exchange should the master or person in charge determine that it would place the vessel, its crew, or its passengers at risk (CA Assembly Bill: AB 433 [2003], OR Senate Bill: SB 895 [2001], WA Substitute House Bill: SHB 2466 [2000]). Though the provision is rarely invoked in California, the handful of vessels that use it may subsequently discharge un-exchanged ballast into the state, presenting a NIS risk.

Both the regulatory community and the commercial shipping industry, therefore, look toward the development of an effective ballast water treatment technology as a promising management option. For regulators, such systems could provide NIS prevention, possibly even in situations where exchange may have been impossible. For the shipping industry, an effective ballast water treatment system might allow voyages to proceed along the shortest routes, in all operational scenarios, thereby saving time and money.

Despite these incentives, financial investment for the research and development (R&D) of ballast water treatment systems has been lacking, and the advancement of technologies has been slow. Barriers to furthering ballast water treatment technology include: the lack of protocols for testing and evaluating performance; inadequate communication between the R&D community, governments, and ship designers, builders and owners; cost of technology development; and equipment design limitations. However, the shipping industry, technology developers, and other investors point to the absence of a specific set of technology performance standards as a primary obstacle. Performance standards would set benchmark levels of organism discharge that a technology would be required to achieve for it to be deemed acceptable for use in California. Developers need these targets so they may design technologies to meet them (MEPC 49/2/1 2003). Investors are reluctant to devote financial resources towards conceptual or prototype systems without some indication that they may ultimately meet future regulations. For the same reason, vessel owners are hesitant to allow installation and testing of prototype systems onboard operational vessels. It is argued that the adoption of performance standards would address these fears, and accelerate the advancement of ballast treatment technologies.

IV. THE PERFORMANCE STANDARDS AND REQUIREMENTS OF THE MARINE INVASIVE SPECIES ACT

In response to the slow progress of ballast water treatment technology development and the need for effective ballast water treatment options, California's Marine Invasive Species Act of 2003 (Section 71204.9 of the PRC) required the California State Lands Commission to recommend specific performance standards to the State Legislature, in consultation with the State Water Resources Control Board and in consideration of recommendations provided by an advisory panel. The legislation lists three generalized criteria upon which the standards(s) shall be based:

- Protection of the beneficial uses of the waters of the state
- Best available technology
- Economic achievability

"Beneficial uses" is a term used widely in water quality plans mandated by the federal Clean Water Act and the State's Porter-Cologne Water Quality Act. In general, beneficial uses fall into four broad categories of water-related utilization: recreational, aquatic life protection, fish and shellfish consumption, and municipal and agricultural supply (Moore pers. com.). NIS presents a threat to sub-components of all of these categories (Table IV-1).

Commission staff utilized several approaches to guide considerations related to beneficial uses protection, economic achievability, and technological feasibility. All

Beneficial Use	NIS Carried by Ships that Impact Use (Example)
Agricultural supply	Zebra mussel
Cold freshwater habitat	Round goby
Ocean, commercial and sport fishing	Round goby, Shrimp virus
Estuarine habitat	Amur river clam *(Potamocorbula)*
Freshwater replenishment	
Groundwater recharge	
Industrial service supply	Zebra mussel
Marine habitat	Japanese shore crab
Fish migration	Chinese mitten crab
Municipal and domestic supply	Zebra mussel
Navigation	Zebra mussel
Industrial process supply	Zebra mussel
Preservation of rare and endangered species	Chinese mitten crab
Water contact recreation	Cholera, Other pathogens, Toxic dinoflagellates
Noncontact water recreation	Zebra mussel
Shellfish harvesting	Green crab, Cholera, Toxic dinoflagellates, Invertebrate pathogens
Fish spawning	Fish pathogens, Chinese mitten crab (siltation from burrowing into banks)
Warm freshwater habitat	Asian swamp eel
Wildlife habitat	Pathogens to wildlife

Table IV-1. Current and likely threats posed by non-indigenous species to beneficial uses in the San Francisco Estuary.

(From: Prevention of Exotic Species Introductions to the San Francisco Bay Estuary: A total maximum daily load report to the U.S. EPA. California Regional Water Quality Control Board, San Francisco Bay Region 2000.)

provided some foundation for the development of recommendations, but all were severely limited in the extent to which they could direct the determination of a specific set of standards. These approaches are summarized briefly below, and detailed in dedicated sections of this report. The overarching goal of this report is to present the pros, cons, and caveats of each, and therefore elucidate the rationale through which the final recommendations were selected.

- **The "dose-response" relationship (for ballast water introductions)**: Dose-Response is the predictive relationship between the number of organisms in a ballast tank and the chances of a successful invasion in a recipient port. The nature of this relationship is unknown, presenting a central challenge to the development of other scientifically based approaches for determining discharge standards (See Section VII, "Scientific Considerations").

- **Biological protection**: Biologically Protective based standards would reduce organism discharge from ballast water to a level that would prevent establishment of most or all NIS. The lack of knowledge on the dose-response relationship severely limits the utility of this approach (See Section VII, "Scientific Considerations").

- **Natural invasion rate**: Natural Invasion Rate based standards would reduce organism invasions from ballast water to a level that approximates a frequency of invasion that might occur in the absence of modern human forces. A rate was discussed by the advisory panel, but was based on a coarse assumption of the dose-response relationship, had not been subject to scientific peer review, and had not been academically published (See Section VII, "Scientific Considerations").

- **Improve upon the status quo (ballast water exchange)**: Standards based upon the status quo would reduce organism densities in ballast tanks to levels much lower than those observed in properly exchanged ballast water. This approach could establish a minimum threshold for performance standards, but it could not indicate what might be an acceptable upper threshold (See Section VII, “Scientific Considerations”).

- **Technological availability:** Technological availability based standards evaluate the capabilities of technologies currently available. Since the development of ballast treatment technologies has been slow, very few technologies were available for examination. None have been subject to satisfactory evaluative testing that enable comparisons of their capabilities under a range of real-world conditions (See Section VIII, “Best Available Treatment Technologies”).

- **Economic achievability:** Economic Achievability based standards are based on what may be economically achievable. The panel examined cost estimates of prototype shipboard technologies, cost estimates of shore-based technologies, and the economic health of the shipping industry. Available estimates were extremely coarse, limiting the utility of this information (See Section IX, “Economic Achievability”).

- **National / international consistency:** Because merchant shippers engage in worldwide trade, standards that align with national or international performance standards would be operationally preferable to a patchwork of individual standards adopted by individual states. The merits and deficiencies of proposed and existing standards were examined (See Section VI, “Summary of Other Programs with Performance Standards”).

V. PERFORMANCE STANDARDS ADVISORY PANEL PROCESS

The Act (PRC Section 71204.9) directs the Commission to consult with a Performance Standards Advisory Panel (Panel) during the development of recommendations for performance standards. Commission staff therefore convened a cross-interest, multi-disciplinary Panel, and facilitated discussions over the selection of standards. The Panel was to make recommendations to the Commission regarding the content, issuance, and implementation of ballast water performance standards.

Beginning in February 2005, Commission staff solicited invitations for Panel participants. As specifically mandated in Section 71204.9 of the PRC, representatives of the Department of Fish and Game (CDFG), State Water Resources Control Board, and the United States Coast Guard were contacted. In addition, researchers, representatives from non-government organizations, resource-related government agencies, and the maritime industry were also invited, including the United States Fish and Wildlife Service, The Ocean Conservancy (TOC), the Association of California Water Agencies, Matson Navigation, the Pacific Merchant Shipping Association, Chevron Shipping, and the Smithsonian Environmental Research Center (SERC). The USCG, as mandated by the National Invasive Species Act of 1996, is involved in efforts to establish federal standards and therefore declined to participate in the Advisory Panel. (See Appendix A for a complete list of participants).

Five meetings were held between March 7th and August 8th 2005 (See Figure V-1), during which information sharing, discussions, and deliberations took place regarding criteria for the selection of ballast treatment performance standards, and potential frameworks for their implementation. The Panel voted for a set of performance standards based on organism size class, and an implementation schedule.

Detailed information on topics discussed during Panel meetings are described in dedicated sections of this report. Major topics covered were:

- Biological data on organism concentrations in unmanaged, and properly exchanged (managed) ballast water (Section VII, “Scientific Considerations”) (See Table V-1, columns 2 and 3)

- Theories on invasion rates and invasion success for NIS transported in ballast water (Section VII, “Scientific Considerations”) (See Table V-1, column 8)

- Performance standards considered and/or adopted by the International Maritime Organization, other U.S. States, and proposed federal legislation. (Section VI,

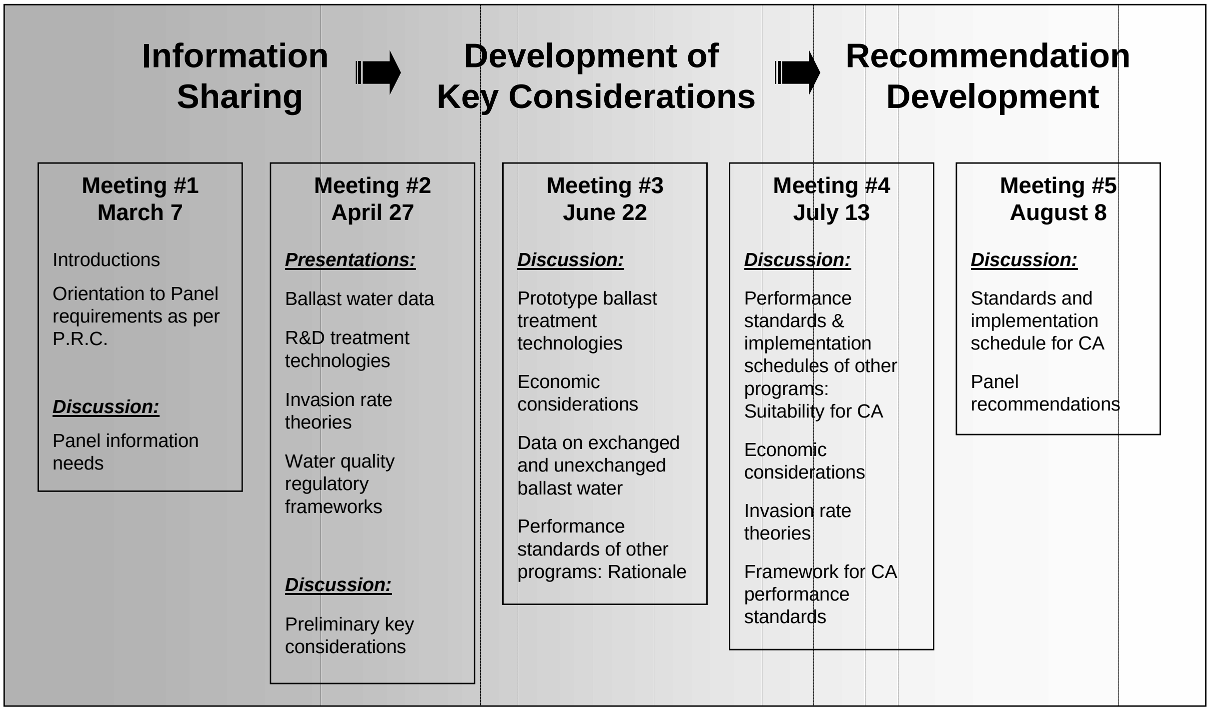

Figure V-1: **Overview of major discussion areas and approximate timing during Performance Standards Advisory Panel meeting process.**

"Summary of Other Programs With Standards") (See Table V-1, columns 4-7 and 10)

- Implementation schedules considered and/or adopted by the International Maritime Organization, other U.S. States, and proposed federal legislation (Section VI, "Summary of Other Programs With Standards")
- Current and projected capabilities of shipboard prototype ballast treatment technologies. (Section VIII, "Best Available Treatment Technologies")
- Theoretical capabilities of shore-based treatment technologies (Section VIII, "Best Available Treatment Technologies")
- Estimated costs of current and future technologies, and the economic health of the shipping industry (Section IX, "Economic Achievability")

Table V-1. Comparison table of possible performance standards.

Side-by-side comparison of potential performance standards and the concentration of unmanaged and exchanged ballast water, arranged by increasing stringency from left to right. Aside from organism concentrations in ballast water (columns 2-3), columns represent standards that have been: considered or adopted internationally (columns 4 & 6); adopted by other U.S. states (columns 8 & 10); proposed in federal legislation (column 5 & 9); or considered independently by the Performance Standards Advisory Panel (column 7). Values in Columns 2 through 8 are the number of organisms per unit of water for each size class of organism. Organism size classes are measured in microns (µm), which is a unit of length equal to one millionth of a meter. Organism size class units have different units of water for each group of organisms (per m^3 = cubic meter, mL = milliliter, and 100 mL). One cubic meter (m^3) is equal to one metric ton (column 1).

1 Organism Size Class (Units)	2 Conc. in unmanaged ballast water	3 Conc. in properly exchanged ballast water [1]	4 IMO	5 U.S. Senate Bills 363/1224	6 U.S. position at IMO	7 Estimated natural invasion rate	8 Michigan	9 U.S. House and Senate Bills H.R. 1591/S.770	10 Washington
>50 µm (/m^3)	10^2	10^1	10	10^{-1}	10^{-2}	10^{-3}	0[2]	95%[3] 99%[4] (99.9%) Reduction	95% reduction
10-50 µm (/mL)	10	1	10	10^{-1}	10^{-2}	10^{-4}	0[2]	95%[3] 99%[4] (99.9%) Reduction	99% reduction
<10 µm (/100 mL)	10^8	10^7	250 E. coli 100 I.enterococci 1 V. cholera	126 E. Coli 33 I.enterococci 1 V. cholera	126 E. Coli 33 I.enterococci	10^3-10^4	0[2]	-	99% reduction

[1] Expected concentrations of organisms that would remain if exchange were done according to IMO guidelines
[2] No discharge of NIS or attain a permit to certify acceptable treatment preventing discharge of NIS
[3] House Bill proposes interim standards of 95% reduction for all vessels
[4] Senate Bill proposed interim standards of 99% reduction on existing vessels and 99.9% reduction for new vessels
m^3 = cubic meter, mL = milliliter

The Panel agreed that the key concepts important for the development of performance standards were:

- Consistency at a national or regional level.
- At present, there is no concrete biological evidence that can guide the selection of specific performance standards beyond the efficacy of ballast water exchange.
- Because the development of ballast water treatment systems is currently in its infancy, the insight they provide for future capabilities is limited. While current technological capabilities should be kept in mind, focus should be placed on selecting standards that will drive technologies to meet them.

Panel points of majority agreement regarding an implementation framework and specific organism concentrations for standards:

- Ballast water performance standards should establish the maximum allowable number of organisms that may be discharged following treatment.
- Performance standards should reduce the number of organisms to levels much lower than those achieved by ballast water exchange.
- Concentration based standards are preferable to percent reduction based standards, given the variable protection and problematic enforcement that the latter would present.
- As the most protective standard possible, zero discharge should be the ultimate goal for ballast treatment systems, though it was unclear if this was possible in the near term.
- Given the questionable short-term feasibility of zero discharge, interim performance standards should be set with a finite implementation schedule.
- The interim standards should be periodically reevaluated and, if needed, adjusted depending on the capabilities of treatment systems available. The feasibility of a zero discharge should also be revisited during these reviews.

- Any implementation schedule should take into account that the demand for available shipyards is high, and scheduling the fleet for treatment technology installations during dry-dock will be tight.
- Once performance standards are adopted, it will be crucial to develop a standardized set of protocols whereby ballast treatment technologies may be evaluated and compared.
- Long-term biological monitoring of NIS must be continued in order to evaluate the effectiveness of performance standards and other management measures after they are implemented.

The Panel submitted recommendations to the Commission in a Majority Panel Report (Appendix A), a Minority Panel Report submitted by the shipping industry (Appendix B), and a Minority Panel Position Letter was submitted by The Ocean Conservancy (Appendix C). These recommendations were considered by Commission staff during the formulation of final recommendations (Section X, "Conclusions and Recommendations"). Further information regarding the advisory panel can be found at: http://www.slc.ca.gov/Program_Pages/Program_Pages.htm.

VI. SUMMARY OF OTHER PROGRAMS WITH STANDARDS

The development of ballast water treatment standards has evolved significantly in the past five years. In early 2004, the International Maritime Organization (IMO) adopted a Convention on ballast water and sediment management that included performance standards (IMO 2005); the U.S. proposed standards at the same IMO Convention; federal lawmakers introduced several NIS related bills during 2005 that include performance standards; the Washington legislature adopted standards in 2000; and the Michigan legislature adopted standards in June 2005. During the development of recommendations for California, the Panel considered all accessible information related to the development of standards considered or adopted elsewhere. Tables V-1 and VI-1 summarize these standards and associated implementation schedules, which are discussed in more detail below.

Table VI-1. Summary of implementation schedules for IMO and Senate Bills 363/1224. Newly constructed vessels built by timeframes indicated in the middle column must meet standards once placed in active service. Older (existing) vessels must meet standards by deadlines indicated in the last column.

Ballast water capacity of vessel	Standards apply to new vessels in this size class constructed on or after	Standards apply to existing vessels in this size class beginning in
< 1500 metric tons	2009	2016
1500 – 5000 metric tons	2009	2014
> 5000 metric tons	2012	2016
*State of Washington requires vessels to either conduct an exchange or utilize an alternative treatment system that meets their mandated performance standard by July 1, 2007. Vessels operating in Washington can continue to utilize ballast water exchange after July 1, 2007. *State of Michigan prohibits oceangoing vessels from discharging ballast water containing NIS beginning 2007.		

International Maritime Organization Convention on Ballast Water – In February 2004 after several years of development and negotiation, IMO member countries adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments. Representatives from 74 countries, 1 associate member, 18 non-governmental organizations, and 2 intergovernmental organizations were present.

The Convention will enter into force 12 months after ratification by 30 countries that represent 35 percent of the world's commercial shipping tonnage (GloBallast 2004). The U.S. has not yet ratified the Convention.

The Convention imposes treatment standards that would limit the number of organisms that ships could discharge with their ballast water. During negotiations, the Study Group on Ballast Water and Other Ship Vectors (SGBOSV) on behalf of the International Council for the Exploration of the Sea (ICES) developed a global database on organism concentrations measured in the ballast water of commercial vessels. The information was summarized and considered during the development of ballast water standards of the Ballast Water Convention (MEPC 49/2/21 2003). A discussion of this summary is provided in Section VII, "Scientific Considerations".

The U.S. position at the IMO – In January 2004, representatives from the United States presented their recommended standards to the IMO Conference. The US delegation, in consideration of Marine Environment Protection Committee 49/2/21 urged the Conference not to settle for standards simply based on current technological capabilities. Rather, the U.S. recommended the Conference adopt environmentally sound, biologically protective, and enforceable standards that would encourage the development of technologies and management practices. The U.S. detailed rationale for protective ballast water discharge standards and made specific recommendations to the Conference (BWM/CONF/14 2004) (Table V-1).

Proposed federal legislation – Congressional attention towards invasive species, ballast water management, and associated performance standards is currently very intense. Four bills were introduced during the 2005 session: Senate Bills 363, 770, and 1224 and House Bill 1591.

U.S. Senate Bill S. 363 (proposed Ballast Water Management Act of 2005) and U.S. Senate Bill 1224 (proposed National Oceans Protection Act of 2005) contain identical performance standards that are more protective than those adopted by IMO, while adopting the implementation schedule of the IMO Convention (Tables V-1 and VI-1). The standards proposed were a result of consultation with the US negotiation team for the IMO conference and in consideration of the Marine Environment Protection Committee (MEPC) scientific findings (Fraenkel pers.com.). Both bills are currently under discussion in the Senate's Committee on Commerce, Science, and Transportation. These bills include a preemption of state law regarding performance standards that would affect future California action on this issue.

The National Aquatic Invasive Species Act, (NAISA) of 2005, was introduced into the Senate (S. 770) and House (H.R. 1591) on April 13, 2005. There are subtle differences regarding proposed performance standards between these bills. While both propose adoption of final standards via regulations and interim standards based on a percent reduction metric, the House version proposes interim standards of 95% reduction of organisms for all vessel types within 18 months, whereas the Senate version proposes an interim standard of 99% reduction for existing vessels and a 99.9% reduction for new vessels. Neither bill proposes different standards for organism size classes, nor do they propose standards for bacteria, viruses, or virus-like particles.

Washington - Washington Department of Fish and Wildlife established interim ballast water discharge standards to provide a target for technology developers (WAC 220-77-095). The inactivation or removal of 95 percent of zooplankton and 99 percent of phytoplankton and bacteria in ballast water is required. The Washington law states that after July 1, 2007, discharge of ballast water is allowed only if there has been an open sea exchange or the ballast water has been treated to meet the standards.

Michigan – Michigan passed legislation in June 2005 that would prohibit the discharge of any waste or waste effluent into the waters of the state unless a permit is obtained beginning January 2007. For oceangoing vessels, the law prohibits the discharge of NIS unless an environmentally sound technology has been utilized by the vessel that both prevents the discharge of NIS and has been approved by the State (Michigan SB 332).

VII. SCIENTIFIC CONSIDERATIONS

In order to ensure that recommendations were based on the best available science, several biological/ecological concepts were considered by the Panel and the Commission staff. Field data and theories on ballast water organism densities and invasion patterns were examined. Considerations focused on the merits, drawbacks, and limitations of each for determining potential performance standards. Every concept provided some degree of guidance; however, none could point to a single standard.

Ballast water treatment standards can be established via one of two measurement methodologies: a percent reduction, or a specific concentration. A percent reduction scenario poses several problems. The density of organisms varies depending on source port; therefore, a percent reduction requirement would produce varying discharge concentrations for any given vessel depending on the characteristics of the source water (Figure VII-1). For similar reasons, percent reduction standards are not practicably enforceable. Samples of both the initial source water concentrations as well as discharge concentrations would be needed to verify a specific removal rate. Percent reduction is not based on either biological (level of protection to reduce/prevent introductions) or technical grounds (detection limits of sampling equipment).

Concentration based standards, in contrast, would specify a specific concentration of organisms that could be discharged following treatment, regardless of source port concentrations (Figure VII-1). Concentration based standards allow for the consideration of both a protection level to reduce risk, as well as technical consistency, such as detection limits. California laws also use concentration-based standards to protect water and air quality. The Panel and the Commission therefore support the adoption of performance standards that are concentration based (a certain number of organisms per unit of water), rather than percent reduction based (e.g. 99% removal).

Based on the scientific reports developed for the IMO Convention and subsequent consultation with scientific experts, the Panel determined that organism concentration standards should be established according to organism size classes. A size class framework provides a technical balance between biological protection and the necessary practicability of compliance monitoring. The size categories established by the IMO roughly separate ballast water organisms into biological types: macrozooplankton, (>50 µm) (very small, free-floating or drifting animals, e.g. jelly fish), phytoplankton (10-50 µm) (very small, free-floating or drifting plants, e.g. blue-green algae), and bacteria and virus-like particles (<10 µm) (See Table V-1 in Section V, “Performance Standards Advisory Panel Process”).

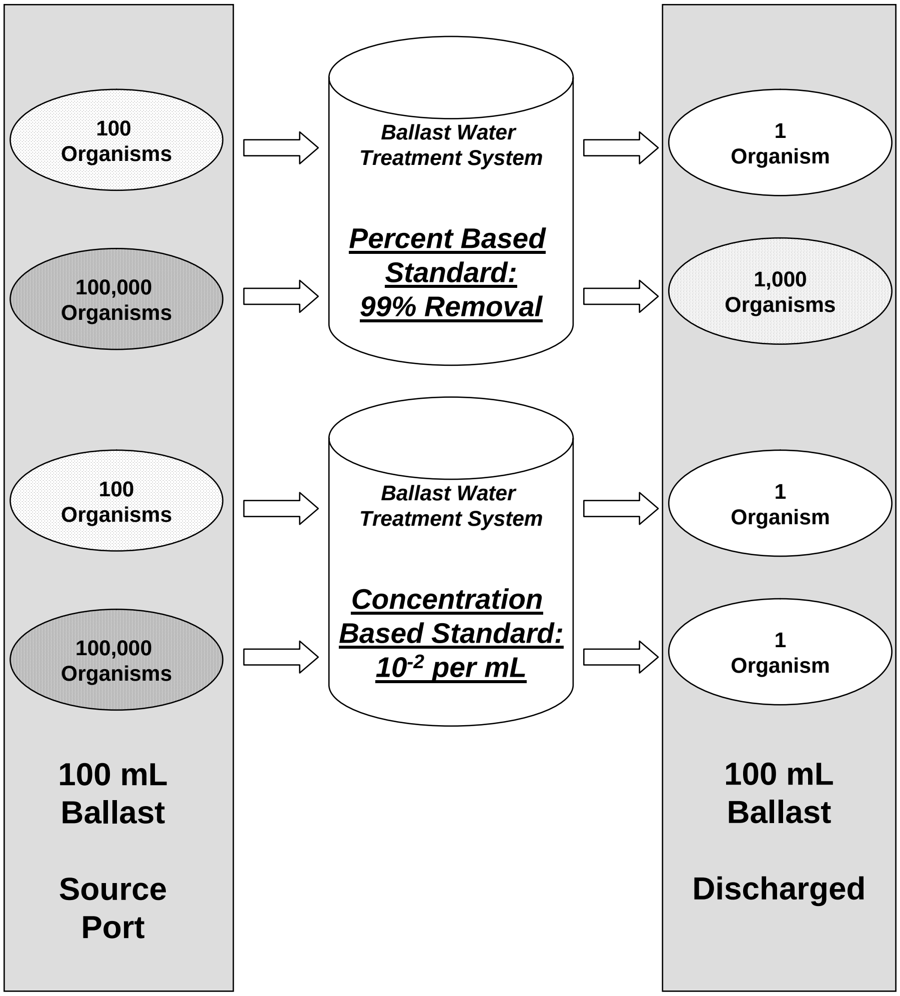

Figure VII-1. Illustrations of percent based (upper half) and concentration-based (lower half) standards.

Note: For percent based standards, the number of organism discharges is highly dependent upon the density of organisms at the source port. Thus, adoption of a percent based standard can result in widely varying numbers of organisms that are discharged.

The Panel agreed that at a minimum, reductions achieved by California's performance standards should improve upon the current status quo, and decrease the discharge of viable ballast organisms to a level below quantities observed following proper ballast water exchange. To better understand and consider this minimal threshold, data on organism concentrations in both unmanaged and properly exchanged ballast were examined. As part of a nearly identical information gathering effort during the development of IMO performance standards, ballast water data from a variety of studies around the world were gathered and standardized by Dr. Gregory Ruiz, director of the Smithsonian Environmental Research Center, Marine Invasions Laboratory (MEPC 49/2/1 2003) (Appendix A). Dr. Ruiz provided a summary of this data, with organism concentrations converted from the biological classifications originally presented by the Marine Environment Protection Committee, to size classes as considered by the advisory panel. Based on his research on the efficacy of ballast water exchange, Dr. Ruiz also noted that exchanged ballast water results in an average tenfold reduction in organism concentrations (Minton et al. 2005) (Figure VII-2 and Table V-1, columns 2 and 3).

Beyond the minimal threshold of ballast water exchange, there was no scientific evidence that could direct the selection of standards to establish a predictable level of protectiveness. The inability of science to pinpoint precise performance standards beyond ballast water exchange stems from a central information gap: the relationship between the numbers of organisms exposed to a location (i.e. port, region, or state) and the resultant likelihood of a non-native organism becoming established. Aside from the logical observation that zero organism discharge would equate to no risk, and that increasing numbers of organisms would equate to increasing risk, the shape of this "dose-response" curve is unknown (Ruiz and Carlton 2003) (Figure VII-3). Thus, a specific invasion risk cannot be approximated for a particular quantity of organisms discharged (MEPC 49/2/1 2003). Consequently, it is not possible to conclusively determine how much more stringent standards must be in comparison to exchange for adequate protection. It is also not possible to perform a risk-benefit analysis whereby performance standards may be selected that maximize protection, while minimizing time and financial investment needed to develop a ballast water treatment system sophisticated enough to meet it.

Given the lack of knowledge of the actual dose-response curve, the selection of standards becomes somewhat arbitrary above the efficacy of ballast water exchange. Faced with this dilemma during deliberations over the designation of an IMO standard, two groups of technical experts (biological, engineering, environmental) recommended standards based on their best scientific judgment. The International Study Group on Ballast Water and Other Ship Vectors recommended a minimum 100-fold (10^2) improvement over exchange for both zooplankton and phytoplankton (0.4 zooplankton

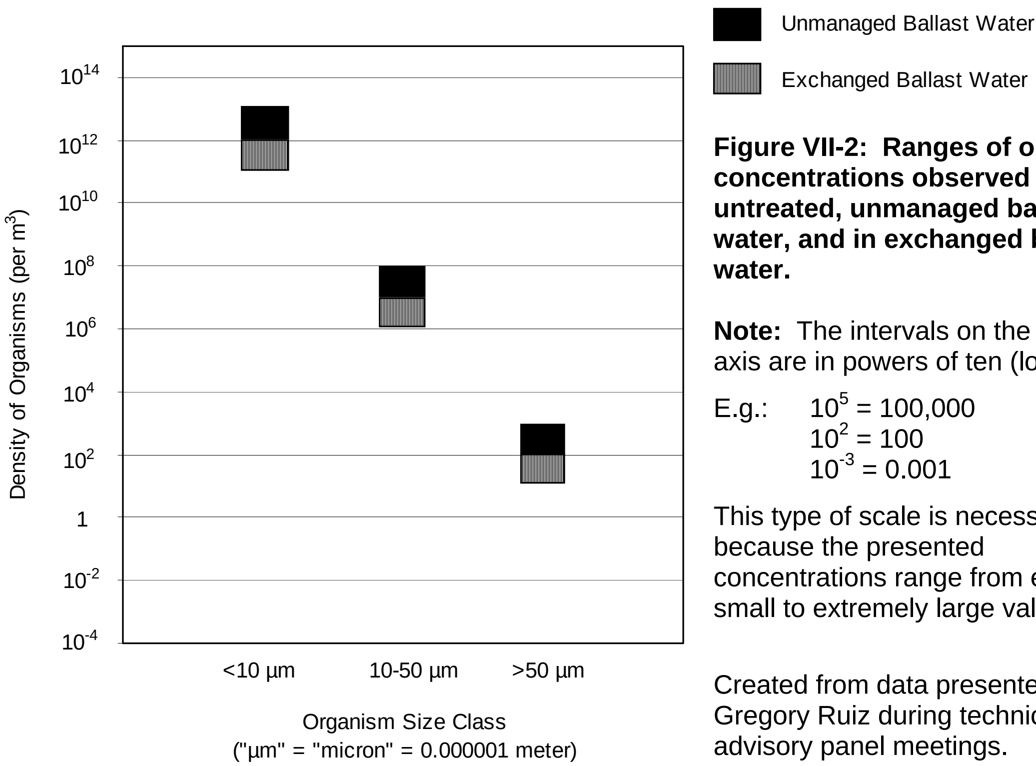

Figure VII-2: Ranges of organism concentrations observed in untreated, unmanaged ballast water, and in exchanged ballast water.

Note: The intervals on the vertical axis are in powers of ten (log scale).

E.g.: $10^5 = 100{,}000$
$10^2 = 100$
$10^{-3} = 0.001$

This type of scale is necessary because the presented concentrations range from extremely small to extremely large values.

Created from data presented by Dr. Gregory Ruiz during technical advisory panel meetings.

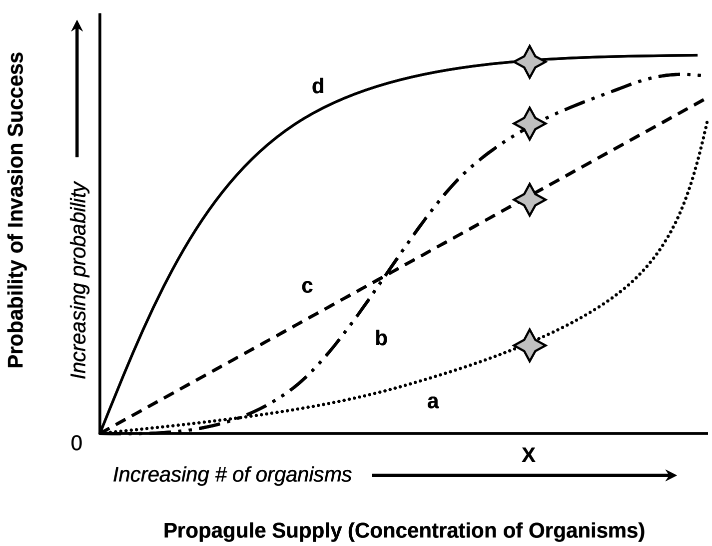

Figure VII-3: Hypothetical dose-response relationship curves. The true shape of the relationship is unknown. Note that depending on the shape of the curve (a-d), an organism concentration of X can result in widely different probabilities for invasion success, as denoted by the gray stars. Hence, without knowledge of the shape of the curve, it is not possible to accurately predict the probability of invasion success for a given organism concentration.

Modified from Ruiz G.M. and J.T. Carlton 2003. Invasion vectors: a conceptual framework for management. In: Invasive Species, Vectors and Management Strategies. Ruiz G.M. and J.T. Carlton (Eds). Washington D.C.: Island Press. 459-504.

per m^3, 0.0133 phytoplankton per mL)(MEPC 49/2/21 2003). Based on information from the international study group and from a workshop organized by the USCG (MEPC 49/INF.31 2003), the United States recommended at least a 1000-fold (10^3) improvement over exchange for zooplankton (0.01 per m^3), a standard similar to the SGBOSV for phytoplankton (0.01 per mL), and human health-based standards for indicator bacteria (BWM/CONF/14 2004).

The dose-response curve does include a single known point: zero exposure to NIS would present no invasion risk. Based on this logic, the only potential standard that is unarguably “biologically protective” would be zero viable organism discharge. Since the ability to measure a complete absence of organisms is beyond the detection limits of modern sampling equipment, such a standard could be practically applied as a zero “detectable” organism discharge. In practice, confirmation that a treatment technology achieves and continues to maintain a zero detectable discharge target would translate to actual discharge levels that register at the lowest detection limits possible using the best sampling equipment and methodologies available.

Some vessels do not need to discharge ballast water due to their operational procedures or because of vessel design. Clearly, such vessels meet a zero target, and are preferable for both the industry and regulators. For those vessels that must discharge ballast water, however, the current and future ability of ballast treatment technologies to meet such a zero detectable standard presents a technical challenge. Prototype technologies show some potential for achieving a near zero discharge for larger ballast organisms but it is not clear if or when they will be able to reach a zero detectable target, or if a similar target is possible for smaller organisms (Section VIII, “Best Available Treatment Technologies”). As noted earlier, the evaluation methodologies will also need to be advanced. For example, a treatment technology that kills organisms but does not remove them from a tank will require evaluation beyond simple counts, and current methods for discerning some living and dead ballast organisms are not well developed. These hurdles, however, should not preclude the adoption of treatment standards that will serve to drive technologies and evaluation methodologies to meet them.

Dr. Andrew Cohen of the San Francisco Estuary Institute suggested a “natural invasion rate” as a basis for a standard. The goal of such a standard would be to reduce ballast discharges of organisms to a concentration that results in an invasion rate near those that would have been observed in the absence of human forces. Dr Cohen estimated that this rate is 50 species each million years (Table V-1 column 8). However, this approach is based on numerous assumptions that create a high level of uncertainty for its application to performance standards that will have regulatory impacts. The rate is based upon unpublished estimates of natural invasions for a limited number of organism groups, in a single region, during a relatively narrow time period (2-5 million years). There is no evidence how the rate might vary if extrapolated to the large number of unaddressed organisms, to other geographic areas or other prehistoric periods. The conversion from a “natural invasion rate” to a discharge standard (a concentration of organisms) was based on an assumption that the “dose-response” curve was linear (Figure VII-3, curve c), though the true shape of the curve is unknown. The proposed approach had been neither published nor peer reviewed and was thus not known or widely accepted by the scientific community.

Though limited, the guidance provided by the scientific data provides a range, albeit an extremely wide range, within which performance standards could be selected. At a minimum, standards should significantly reduce organism discharge observed following a proper ballast water exchange. At a maximum, the most “biologically protective” standard would be zero discharge. Beyond these limits, the best available science could not conclusively indicate where a performance standard should fall.

As discussed earlier, this problem was mirrored in the recommendations presented to the IMO by internationally recognized scientific experts in the field. When obligated to select specific standards in the absence of strong scientific guidance, these groups chose 100-fold and 1000-fold improvements over ballast water exchange, based on the non-specific rationale that standards should be biologically protective, should greatly reduce organism concentrations to levels much lower than unexchanged ballast, and should challenge developing technologies.

VIII. BEST AVAILABLE TREATMENT TECHNOLOGIES

Commission staff compiled and evaluated information on alternative treatment technologies designed to remove or inactivate organisms entrained in ballast water. The following summarizes that effort.

Treatment technologies must be effective under variable water quality conditions (temperature, salinity, nutrients, suspended solids, etc.), and must be designed to operate so as to minimize or prevent impairment of the water quality conditions of the receiving waters. Treatment technologies must also be effective under conditions such as high flow-rates, large volumes, and ballast water residence times (time water is held in tanks). They must be capable of inactivating a diversity of organisms ranging from microscopic bacteria and viruses to free-swimming plankton visible to the naked eye. Effective treatment technology is further complicated by the variability of vessel types, shipping routes and port geography. Because of these difficulties, the identification of a single treatment technology for all NIS, ships, and port conditions is unlikely. Rather a suite of treatment technologies will undoubtedly need to be developed to treat ballast water. Two general approaches are currently under development to attempt to meet these challenges: shipboard (onboard operational vessels), and shoreside (treatment occurs at a shore based facility following transfer from a vessel).

A number of candidate treatment technologies have been identified as possible solutions to preventing or reducing the introduction of NIS via ballast water discharge (National Research Council 1996, SWRCB 2002, GloBallast 2004). Many borrow from the wastewater treatment industry and include mechanical, physical, and chemical processes. They range from filtration and cyclonic separation to ultraviolet irradiation (UV), ultrasound, electro-ionization, deoxygenation, heat, ozone, and chemical biocides. The evaluation of treatment possibilities is at an early stage and no alternative treatments have been yet approved by state, regional, or federal regulatory authorities. Shipboard treatment systems to date have generally combined one or more type of treatment to address the different sizes of organisms found in ballast water. Most of these systems have been tested only in laboratories. A select few have been installed onboard operational vessels. Several promising shipboard treatment systems are in the conceptual or experimental testing stages.

One such system installed onboard a large passenger vessel and a container ship treats ballast water with a two-step process. A cyclonic separation chamber first disposes of larger particles and organisms, before exposing the remaining ballast water to ultraviolet irradiation for the treatment of smaller organisms. Structural modifications were necessary onboard both vessels to resolve operational issues before either system could be tested for effectiveness (Wright 2004, Matson Navigation 2005). The system removed organisms to a greater extent than unmanaged ballast water on both vessels, but did not meet the proposed IMO standards for every size class of organisms. The number of microbial and zooplankton organisms decreased over time during three different evaluation voyages (Welschmeyer et al. 2004). UV exposure produced near instantaneous effects on phytoplankton with no signs of viable recovery during the experiments.

Another promising treatment system utilizes ozone gas to treat ballast water that contains NIS. The system was installed on a tank vessel in 2000 and studies were carried out to: determine the efficacy of the system to remove coastal organisms compared to ballast water exchange; assess possible environmental risks of discharging ozone-treated ballast water; and to obtain operational experience with the system in order to implement future system improvements.

This work represented a “proof of concept” phase for the ozone treatment system, and as such, the results are limited to a few trials from one port system. This study indicates that ozonation can remove many coastal organisms and may compare favorably with ballast water exchange. The experiments suggest possible residual toxicity from bromine over time. It suggested that bromine was the ozone-producing oxidant responsible for organism mortality and that it may persist at toxic concentrations in ballast water for 1-2 days following treatment (Cooper et al. 2002). Further testing for residual effects of bromine, crew safety, corrosion, vessel modification, and costs is ongoing.

Other treatment technologies are undergoing shipboard testing with promising initial results. The first of these treats ballast water by de-oxygenation. This system uses low-sulfur inert gas to displace oxygen in ballast tanks creating a hypoxic (low oxygen concentration) environment that significantly decreases the survival of NIS. This system also claims an added benefit of reducing corrosion within ballast water tanks under certain operating conditions. A full-scale system has been installed on a bulk carrier and studies designed to evaluate the efficacy of this system as well as operational issues are scheduled to begin in mid-2006.

Another technology uses chlorine dioxide to treat NIS in ballast water. Chlorine dioxide has been effectively used for over 50-years in industrial and municipal applications. Initial studies of this treatment technology were carried out in 2002. Results show this technology effectively treats zooplankton, phytoplankton, and some microorganisms. Further research is needed, and the Commission is contracting with Matson Navigation Corp., to assist in the installation and evaluation of the chlorine dioxide treatment system onboard an integrated tug barge. Installation of the system was completed in October 2005 and testing will begin in early to mid-2006.

One more technology combines mechanical filtration and UV to treat NIS in ballast water. The filtration is provided by an auto-backflush disc filtration unit fitted with 100 µm disks, though the vendor claims the system can be fitted with 50 µm disks. Disinfection is accomplished with a medium pressure cross-flow/inline UV system. The system was installed on a large passenger vessel in 2004. Preliminary testing began in 2004, but results have not been made available.

Additional alternative technologies have been installed and tested onboard vessels. The Global Ballast Water Management Programme (GloBallast), a program that assists developing countries to implement measures to control the introduction of NIS, maintains a research and development directory. The directory lists alternative treatment technologies that have been installed and tested onboard vessels, but results from these studies are not available and little or no commercial application has occurred.

Before any type of shipboard treatment system can be made commercially available, more shipboard evaluations will be necessary. All ship-based treatment systems must be engineered to conform to a vessel's structure, ensure crew safety, and must be able to withstand the vibrations and movements induced by the vessel's engine or rough seas. Additionally, numerous biological parameters must be measured to evaluate effectiveness, and consistent, reproducible testing protocols need to be established.

While shipboard treatment systems are attractive because they allow more flexibility to manage ballast water during normal operations, there continues to be interest in the shoreside treatment of ballast water. However, utilization of shore-based treatment for ballast water poses several challenges. Current wastewater treatment plants are not equipped to treat saline water (SWRCB 2002, Moore pers com.). Municipal facilities will need to be modified for the purposes of treating ballast, or new facilities will have to be established. The acquisition and development of new ballast water treatment facilities will be difficult and costly in California port areas. Additionally, onshore treatment is not feasible for vessels that must take on or discharge ballast water while underway. Regardless, shore based ballast water treatment should be considered for unique terminals, those with limited but dedicated vessel calls, and as an option for older vessels nearing the end of their service life. To date only limited feasibility studies have been conducted for the onshore treatment option.

One such study was conducted by URS/Dames & Moore (2000), commissioned by the California Association of Port Authorities (CAPA). The study was to conceptually assess the technical and operational feasibility of onshore ballast water treatment at public port facilities. The study looked at four conceptual onshore ballast water treatment facilities with four different treatment capacities. The study report describes the initial requirements of land for each facility, construction and operation costs, as well as vessel and wharf retrofitting for onshore transfers and ballast water storage. The report concluded that, if standards used in existing wastewater facilities are adopted and costs are not a factor, shore-side treatment is feasible in California. Since costs are a factor, the report recommends that more thorough studies be conducted to better estimate costs for onshore treatment (URS/Dames & Moore 2000).

Another study was prepared for the Port of Seattle and in association with the Washington Department of Fish and Wildlife, under the Pacific Ballast Water Treatment Pilot Project. It assessed the technical feasibility and associated capitol costs of transferring ballast water to and from vessels through fixed shoreside, truck-mounted, and barge-mounted ballast transfer services. Six vessel types that frequent Puget Sound ports were examined. Five vessel surveys were conducted to identify the level and costs of modifications required to assist ballast water transfer. Modification costs calculated for each vessel type assumed that universal deck connections are installed, and that modifications to allow transfer would result in minimal impact to normal operations. The study concluded that in all cases, vessels would require modifications to their existing ballast system in order to be able to transfer ballast with minimal impact to current operations. The study concluded that while it is technically feasible to transfer ballast to and from ships through a transfer service, assessing the full economic feasibility requires additional study (The Glosten Associates 2002).

Finally, a study of the feasibility of shoreside treatment of ballast water at a cruise ship terminal in San Francisco is currently being sponsored by Bluewater Network, San Diego BayKeepers, Surfrider Foundation, and The Sierra Club. The objectives of this study are to assess the technical, environmental, and economic feasibility and benefits of shoreside ballast water treatment and re-use for cruise ships (Bluewater Network 2005). The project is expected to be complete in late 2005, early 2006.

As further studies are completed and revised, more information is expected to become available regarding the application of alternative treatment technologies. It is argued that the development of performance standards will help to facilitate the further development of technologies. Continued research and development will likely be necessary once performance standards are in place to verify if technologies meet or exceed those standards. Standards and technology will need to be dynamic because ballast water management is in its infancy.

IX. ECONOMIC ACHIEVABILITY

Establishment of performance standards requires the consideration of related economic impacts. There are many ways to evaluate the current and projected economic impacts of performance standards. Areas considered were the substantial costs associated with the control and or eradication of NIS, potential losses to California's ocean economy as a result of NIS introductions, the costs of treatment technologies, as well as effects to the overall economic health of the maritime industry as a result of adopting performance standards.

Once a problematic NIS becomes established, eradication efforts are generally unsuccessful, and costs associated with attempting to control problematic species are extremely high. The US has suffered major economic losses as a result of controlling NIS (aquatic and terrestrial). Estimated economic damage associated with NIS, including control measures are nearly $120 billion a year, with at least $1 billion spent annually on controlling just six aquatic species (Pimental 2004). Nationwide, $1 billion dollars per year was spent in the early 80's to control and mitigate damage caused by the Asian clam (*Potamocorbula amurensi*s) (Lovell and Stone 2005; Pimental 2004). The cost to control and conduct research on the Chinese mitten crab (*Eriocheir siensis*) was $1 million in 2000-2001 (Carlton 2001). The rate of new introductions is increasing (Cohen & Carlton 1998, Ruiz & Carlton 2003); which suggests that economic impacts will likely increase as well.

California has the largest ocean economy in the U.S., ranking number one for both employment and gross state product (Kildow and Colgan 2005). California's natural resources also contribute significantly to the coastal economy. For example, in 2000 total landings of fish were over 500 million pounds, bringing in nearly $140 million. Squid, the top revenue-generating species in 2002, brought in $16.5 million. The fishing industry directly contributed more than $400 million to California's economy in 2000 (Kildow and Colgan 2005). NIS presents a threat to these and other components of California commercial fisheries, as well as to aquaculture, sport fisheries, and recreational fisheries.

The realized and potential cost of NIS introductions, and the limited effectiveness of current ballast water management options (e.g. mid-ocean exchange) (Section III, “The Need for Performance Standards”), has led to increased attention and research on alternative ballast water treatment technologies. The use of these technologies will involve economic investment on the part of ship owners, and likely relieve the economic impacts of control and eradication of NIS. The cost of these alternative treatment technologies warrants review when considering the development of performance standards.

As described in Section VIII, general information on prototype shipboard technologies is limited. The few studies available provide a glimpse at the potential cost of implementing alternatives to mid-ocean exchange (Table IX-1), but only reflect costs associated with research and development. While other studies have been completed beyond those listed in Table IX-1 (see GloBallast at http://globallast.imo.org), results from those studies have not been widely reported and no commercial applications have been developed.

Table IX-1 shows cost information for a subset of treatment technologies that have been installed onboard operational vessels. The costs listed are only representative of technologies installed under research and development conditions, and are expected to decrease as they become commercially available. Equipment costs are for the purchase of the technology or system. The installation costs include but are not limited to labor and materials, which varied depending on the geographic location where the work was performed. For example, shipyard labor costs in China are generally much lower than labor costs here in the United States. Operational costs are associated with the long-term use and maintenance of the system. Because all technologies are still in the research and development stage, costs for testing are included.

Table IX-1 – Cost information for specific vessels with systems installed (in thousands)
The following technologies are still in the R&D stage, as such, costs will likely be reduced once commercial applications are developed.

Technology/Vessel	Equipment Cost	Installation (Labor/materials)	Operation costs	Testing (Per voyage)
Hydrocyclone + UV				
Container Vessel	$200	$220	$6	$67
Passenger Vessel	$105	$15	$20	NA
Passenger Vessel	$135	$65	$15	$67
Passenger Vessel	$128	$19	NA	NA
100 µm Filter + UV				
Passenger Vessel	$173	NA	$20	$63
Chlorine Dioxide				
Integrated Tug-Barge	$237	$157	$75	$80
Deoxygenation				
Integrated Tug-Barge	$300	$50	$12	$100
Container Vessel	$290	$170	$12	$100

NA – data were not available

In addition to the vessel-specific technology applications listed above, Commission staff consulted with technology developers in order to compile generic cost estimates for the retrofit or new build for different vessel types (e.g. bulk carrier, tank vessel, container vessel). According to the technology developers, estimates provided are strongly linked to vessel-specific characteristics and associated engineering issues and technology. For example, the cost of any given system is highly dependent on ballast water capacity, ballast pump rates, normal operational needs, and available space. Therefore, the estimates provided to retrofit were extremely coarse. For example, the estimated costs to retrofit ranged from $200,000 for a bulk carrier to $5 million for a tank vessel (Gallopo pers. com., Perlich pers. com.). Developers were unable to provide estimates for technologies that might be installed onboard newly built vessels.

While ship-based treatment of ballast water is considered the most flexible method to control NIS, Commission staff compiled and considered available economic information for onshore treatment of ballast water. The URS/Dames & Moore (2000) report described key findings that though shore-side treatment may be technically feasible, it will require heavy financial investment. Several assumptions used in the report (e.g. generic vessel-type, minimal vessel delays, all right-of-ways available, treatment to waste-water standards) will likely increase the costs. The Port of San Francisco alone would face capital costs of at least $16.6 million for onshore treatment. The piping (from berth to treatment facility) would be $6.4 million and storage tanks would cost $6.3 million. If the eleven major port-complexes located in California were to be fit with shore-side treatment capabilities, capital costs would range from $7.6 million to $49.7 million per port. Annual operation and maintenance of the facilities would cost between $142,000 and $223,000 for each port in California (URS Corporation/Dames & Moore 2000).

A major cost associated with shore-side treatment is associated with the transfer of ballast water from a vessel to shore or to a storage unit. A study by The Glosten Associates (2002) demonstrates that these costs are highly dependent on vessel-specific characteristics. For example, the costs to retrofit vessels with transfer systems ranged from over $100,000 for a bulk carrier to nearly $2 million for a tank vessel (The Glosten Associates 2002). These estimates apply only to mechanical connection between a vessel and a hypothetical shoreside facility, and do not include the cost associated with constructing or maintaining a shore-side facility.

More detailed studies are recommended to assess the economic achievability of shore-side treatment (URS/Dames and Moore 2000; The Glosten Associates 2002). The two completed studies make several major assumptions that greatly simplify the complex operational realities of ports and the vessels that visit them. Many important site-specific details that would result in significantly varying costs were not addressed. For instance, the operating costs of transferring ballast water to shore should consider the costs for vessel delays, which may be significant. Additionally, studies state that mobile transfer services will be required for shore-side treatment to be feasible, yet neither study addresses this issue or incorporated these services into their cost estimates.

Based on the limited information available for both shore-based and ship-based treatment of ballast water, it is difficult to clarify the economic achievability for any particular type of treatment. So far, available cost estimates suggest the capital costs of shore-side treatment will exceed the capital costs for shipboard treatment.

While further studies are needed regarding costs of alternative treatment technologies, the industry's ability to pay for these technologies warrants consideration. Since, information regarding specific company revenues and net earnings was not available, Commission staff considered the overall economic trends of the maritime industry.

All data sources suggest that the maritime industry has been growing steadily over the past decade. The Port of Los Angeles was ranked as the top U.S. international freight gateway in 2003 (U.S. Bureau of Transportation 2005). Two of the top five U.S. ports, ranked by dollar value of foreign trade in 2003, were located in California (Navigation Data Center 2004). According to figures from the ports of Oakland and Long Beach, tons of cargo transported since 1990 has been increasing through 2003 (Port of Oakland 2005; Port of Long Beach 2005). Data from the US Maritime Administration and the US Army Corps of Engineers show a steady increase in cargo imports and exports from 1992 through 2001 (Figure IX-1). The overall economic status of the maritime industry in California appears to be in good condition.

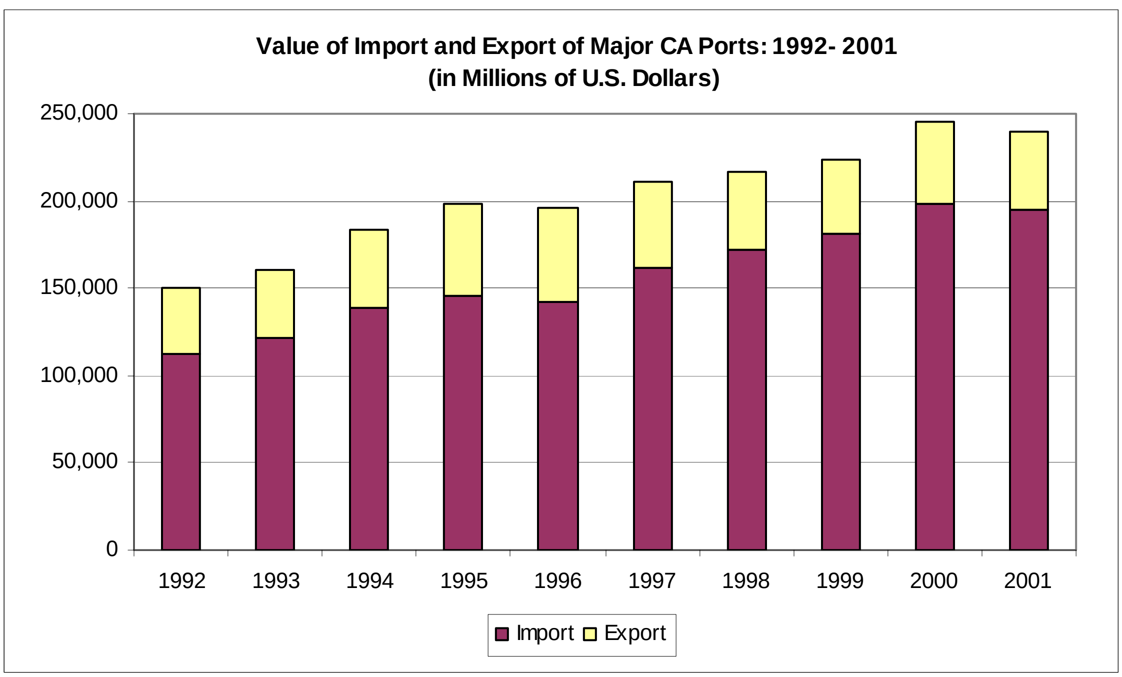

Figure IX-1: Major California ports, 1992-2001 values of imports and exports

From: Kildow and Colgan, 2005

Regardless of the economic condition of the maritime industry, experts suggest that, when compared to the major costs to control and or eradicate NIS, the costs to treat ballast water are minimal. Although a thorough analysis was not performed, the continued economic impacts of controlling NIS will likely exceed the capital and operational costs of ballast water treatment (Gotsch pers. com., Costello pers. com.).

It is clear that damages from NIS are extremely costly in the US. Treating ballast water with alternative treatment technologies will help to prevent further introductions that would also lower control and eradication costs. Unfortunately, the actual economic impacts from treating ballast water will remain unclear until further research is conducted. The shipping industry appears to be healthy and therefore, it should be able to tolerate the costs of ballast water treatment within reasonable economic limits.

X. CONCLUSIONS AND RECOMMENDATIONS

Consideration of Panel Recommendations

Majority Panel Report - The Majority Panel Report recommended standards and an implementation schedule, summarized in Tables X-1 and X-2. The standards recommended are more stringent than any other national and international standards proposed for ballast water treatment (e.g. IMO, SB 363). It appears that these interim standards will be protective of state waters and more feasible than the ultimate goal of zero discharge standards for all size classes of organisms at this time. However, the best available science could not conclusively indicate if these conclusions are correct. Furthermore, these standards come with several logistical challenges, which will need to be addressed.

The Majority Panel Report recommendation that systems meet a zero-detection standard for all organisms >50 µm in size by 2009 may not be feasible because treatment technologies are still in their infancy. The Majority Panel Report describes studies, which show filtration systems can eliminate organisms of this size. While advances in manufacturing technology enable these filtration systems to remove particles greater than 50 µm, and engineering designs allow these systems to be small and simple to operate, the filtration technologies that have undergone evaluation were not designed to meet specific performance standards. Furthermore, limited shipboard studies have been conducted and no data are currently available on the efficacy of these systems under normal conditions onboard a vessel. Therefore, while these technologies show promise, the Commission cannot assure that these filtration systems will prove feasible and effective across a wide array of vessel types and environmental conditions during the time allotted in the recommendations.

It may be difficult to verify if systems meet the recommended standards due to the limitations of sampling methodologies to measure zero or very small organism concentrations in any size class, and to determine if they are living or dead. While it is possible to count zooplankton in the largest size class (>50 µm), current methods for the live/dead determination are coarse. For protists and phytoplankton, primarily in the middle size class (10-50 µm), methods that can determine both quantity and live/dead status are still being developed. Likewise, while methods for counting colonies (colony forming units) of human health pathogens are developed, methods for counting individual, non-specific bacteria and virus cells in the smallest size class (<10 µm) have not been fully developed. While these limitations should not preclude the Legislature from adopting the performance standards, they must be considered. As treatment technologies are developed to meet these standards, evaluation methods, sampling protocols and technology to test treatment systems for effectiveness will also need to be developed.

Minority Panel Report - Representatives of the shipping industry submitted a Minority Panel Report. The Report recommended standards that align with either the IMO Convention or future USCG standards in order to maintain international and/or national consistency (Table X-1). These Panel members felt that adopting standards consistent with other national and international programs would help to propel the development of technologies more effectively. The Report acknowledges that although the IMO convention standards may not be as stringent, they would facilitate technologies to meet stricter standards more quickly.

The shipping industry operates in a worldwide market, and vessels operating for any single company generally visit a number of countries. Consequently, the industry favors international or national consistency of treatment performance standards, over a patchwork of varying standards across states or nations. In practice, any single vessel will be forced to meet the standards of the strictest nation/region it visits. The performance standards recommended by the Majority Panel Report would be the most stringent of any adopted or proposed elsewhere, and the industry contends that it would be unreasonable to expect special investment for the adoption of an individual state's standards. Shipping industry representatives on the Panel therefore advocate that California's standards align with the standards adopted at the IMO Convention. Alternatively, they advocate that the standards align with the anticipated January 2006 release of USGS proposed federal standards.

Reports submitted as part of the IMO Convention suggest that the standards adopted by IMO would only be a marginal improvement on current management practices of ballast water exchange for the largest organisms (>50 μm) and may be similar to unmanaged ballast water for the smaller organisms (<50 μm) (Table V-1, MEPC 49/2/1 2003) (Section VII "Scientific Considerations"). Furthermore, the timeframe during which the USCG will propose to adopt U.S. federal performance standards is uncertain. The stated legislative intent of the Marine Invasive Species Act is to move California expeditiously toward the elimination of the discharge of NIS. As such, Commission staff does not believe the standards adopted by IMO or a reliance on uncertain future federal action meets this intent.

Minority Panel Position Letter - A minority position letter was submitted by The Ocean Conservancy. The position letter encourages the adoption of interim standards outlined in the Majority Panel Report as a starting point with an approach that permits the improvement of the standards that is consistent with improving technology over time (Table X-1). The Ocean Conservancy advocates setting a specific date for achieving a zero discharge standard with benchmarks for reviewing the feasibility of zero as the date approaches. Although the achievability of a zero discharge standard may not be possible at this time, Commission staff does agree with setting a specific date for achieving a zero discharge standard with specific timelines to review technological and economic feasibility as the date approaches, as well as further scientific research.

Table X-1: Summary of Advisory Panel recommendations on performance standards by organism size class.

Organism Size Class (Units)	Majority Panel Recommendations	Minority Panel Recommendations	Minority Panel Position [3]
> 50 μm ($/m^3$)	No detectable living organisms	10 organisms	No detectable living organisms
10 - 50 μm (/mL)	10^{-2} organisms	10 organisms	10^{-2} organisms
< 10 μm (/100 mL)	10^3 for bacteria 10^4 for viruses Public health protective limits [1]	Public health protective limits [2]	10^3 bacteria 10^4 viruses Public health protective limits [1]

[1] 126 colony-forming-units per 100 milliliters of Escherichia coli, 33 colony-forming-units per 100 milliliters of Intestinal enterococci, 1 colony-forming-unit per 100 milliliters or 1 colony-forming-unit per gram of wet zoological samples for Toxicogenic Vibrio cholerae (serotypes 01 and 0139)

[2] 250 colony-forming-units per 100 milliliters of Escherichia coli, 100 colony-forming-units per 100 milliliters of Intestinal enterococci, 1 colony-forming-unit per 100 milliliters or 1 colony-forming-unit per gram of wet zoological samples for Toxicogenic Vibrio cholerae (serotypes 01 and 0139)

[3] The Ocean Conservancy supports the Majority Panel Report's long-term standard of zero, however advocates setting a date for achieving a zero discharge standard with benchmarks for reviewing the feasibility of zero as the date approaches.

Table X-2: Recommended implementation schedule for interim performance standards. Newly constructed vessels built by timeframes indicated in the middle column must meet standards once placed in active service. Older (existing) vessels must meet standards by deadlines indicated in the last column.

Ballast water capacity of vessel	Standards apply to new vessels in this size class constructed on or after	Standards apply to all other vessels in this size class beginning in
< 1500 metric tons	2009	2016
1500 – 5000 metric tons	2009	2014
> 5000 metric tons	2012	2016

Commission Recommendations and Rationale

Commission staff considered the majority and minority positions submitted by the Panel in addition to reviewing the most current research and data available. As described throughout this report, there are many information gaps, which affect the selection and implementation schedule of performance standards for California. There is no strong scientific evidence that argues for a specific level of treatment. Additionally, questions remain regarding the effectiveness and economic achievability of technologies. Regardless, the Commission believes that by setting technology forcing standards and mandating the review of treatment technologies as they relate to the implementation schedule, the intent of the Act to move the state expeditiously toward the elimination of NIS can be accomplished.

Commission staff used the Panel recommendations and rationale, as well as other information in creating its final recommendations to the Legislature:

1. The State of California should adopt the Interim Performance Standards put forward by the Majority Panel Report.

No single approach (i.e., biological, technical, economic, uniformity) provides certainty regarding the determination of performance standards. Though limited, the scientific data provides an extremely wide range, within which performance standards could be selected. At a minimum, standards should reduce the number of organisms discharged below those observed following a proper ballast water exchange and should function without introducing chemical or physical constituents into the treated ballast water that may result in an adverse water quality impact on the receiving waters. At a maximum, a standard should dictate a zero discharge of organisms in ballast water. Beyond these limits, and contrary to the statements made in the Majority Panel Report, the best available science could not conclusively indicate where a performance standard should fall. As discussed in Section VII, Scientific Considerations, the Majority Panel's rationale for recommending these standards is questionable. However, the proposed standards encompass several other desirable characteristics: they are significantly better than ballast water exchange, they are in-line with the best professional judgment from the scientific experts participating in the IMO Convention, and they do approach a protective zero discharge standard. As such, the proposed interim standards do meet the intent of the Act.

Clearly, the fewer organisms that are discharged from a vessel, the lower the risk that an invasion will occur. The question remains, “How much better than exchange is protective enough?” An ideal standard would maximize biological protection, facilitate the rapid development and installation of effective technologies, and minimize the economic burden placed on the shipping industry. Current information regarding biological protection, technological feasibility, and economic achievability is ambiguous at best.

Despite the many unknowns, Commission staff believes the codification of performance standards is essential to move technology development forward. Stakeholders have argued that the lack of movement on technology development is a direct result of no clear set of standards. Industry has contended that it needs “a target” to aim for. Standards are clearly needed sooner rather than later, to act as a catalyst.

Though the Commission agrees that national consistency regarding performance standards is preferable to a patchwork of rules, the protection of California waters from NIS is critical. Commission staff does not believe that the IMO standards would adequately protect California waters. A small percentage of vessels would meet the >50 µm IMO standard simply through ballast water exchange, and some could meet it even without exchanging ballast water. The IMO standards therefore, could not be considered performance standards that are significantly better than ballast water exchange.

The Commission supports nationally implemented standards that are protective of California waters and believes that adoption of the standards recommended in the report can help lead the national standards into becoming as protective as possible. The USCG has been working on this ballast water issue for several years and may release their proposed standards in early 2006 in the form of a rulemaking package, but the actual numeric standards are not available for consideration at this time. Additionally, several pieces of federal legislation were introduced in 2005. The passage and implementation of this legislation is not assured. Therefore, Commission recommends that the State of California adopt the Majority Panel Report recommendations on concentration-based, organism size class interim performance standards.

2. The State of California should adopt the Implementation Schedule proposed by Majority Panel Report and adopted in the IMO Convention for the interim standards.

The implementation schedule for compliance with any adopted performance standards is important for the success of any law or rule. In 2004, California ports received over 14000 vessel calls by nearly 2000 different vessels. Since July of 2001, over 5000 different vessels have operated in State waters. Depending on the nature of effective emerging technologies, installation of some systems may only be possible in shipyards. Currently, the demand for shipyard services exceeds supply, and scheduling typically occurs years in advance. Therefore, implementation timeframes must be appropriate not only in terms of the speed of technological development, but also shipyard availability for the retro-fit of existing vessels and construction of new vessels.

Based on Commission data, the majority of vessels (>4400) operating in California since July 1, 2001 have ballast water capacities exceeding 5000 metric tons (MT). A sizable percentage of these vessels are over 10-years old and will presumably be nearing the end of their operational lifespan by the time a treatment system would be required to be installed. The vast majority of vessels will have approximately ten years to identify appropriate technologies, schedule necessary shipyard time, and install technology (Figure X-1). The Commission recommends the State of California support the adoption of the implementation schedule proposed in the Majority Panel Report and adopted in the IMO Convention.

3. Adopt the Final Performance Standard of zero detectable for all organism size classes by 2020.

The Advisory Panel and Commission support the long-term standard of zero detectable discharge of living organisms. Based on the operational lifespan of vessels, the availability of shipyard access, and expected technological advancements, establishing a final zero discharge standard for all vessels by 2020 is likely feasible.

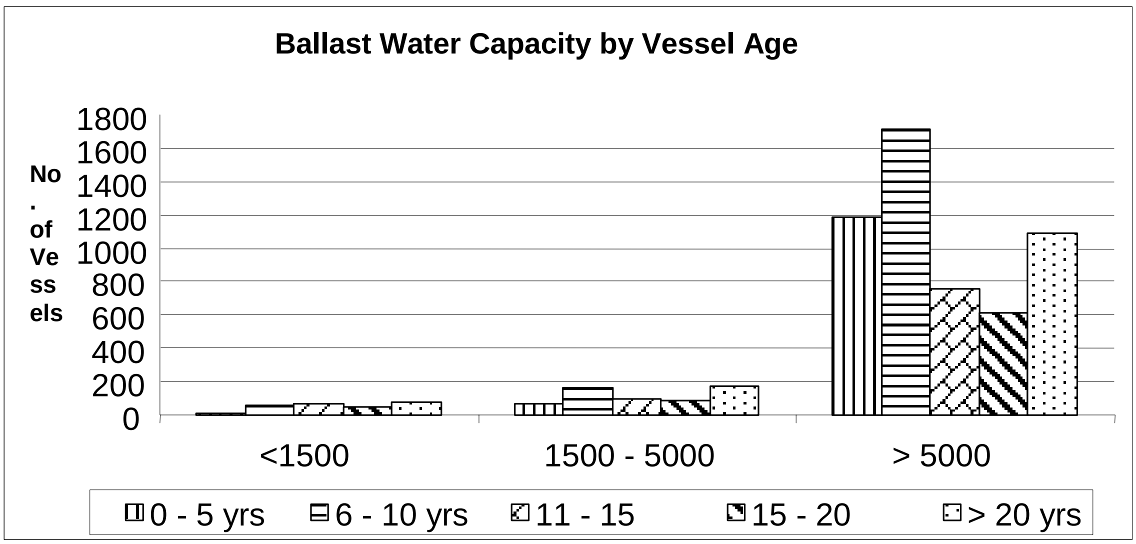

Figure X-1: Ballast water capacity by vessel age
Source: California State Lands Commission-Marine Invasive Species Program database

4. The State of California should mandate an initial and periodic review of treatment technologies and management practices.

The Commission recommends periodic reviews of treatment technologies and management options to determine whether appropriate technologies or management options are able to achieve or exceed the proposed interim and final standards. Assessment of technologies should consider biological effectiveness, safety, environmental soundness, potential water quality impacts and consideration of methods to minimize or prevent such outcomes, practicability, and cost effectiveness. Marine Environment Protection Committee 53/2/2 provides an appropriate template for these reviews.

The first review should be conducted no later than January 1, 2008, one year before the first implementation date of January 1, 2009. Another review, regarding the feasibility of the final zero standard, should be conducted no later January 1, 2019. These reviews would inform the State of California as to whether sufficient technology is available to meet the adopted standards and allow time to modify the schedule if necessary.

This review should consider systems that are commercially available or technologies that are close to being available. The following questions need to be asked: Are components widely available (geographic limitations, availability of replacement parts)? Can the system be used on any vessel or are there constraints related to ballast water capacity (flow rates, time to process ballast water) and operations (voyage duration, temperature and humidity impacts on system)? Is the infrastructure related to ballast water treatment available (sufficient manufacturing, shipyard capacity) for new ships and retrofit of existing vessels?

In addition to the initial review, review of existing and upcoming technologies and management practices should be conducted every three years beginning January 1, 2011. If, as a result of these reviews, technologies are identified that exceed established performance standards, strengthening of those standards should be accomplished.

The reviews should also examine whether industry is making good faith efforts to comply with the standards. If not, the State may want to consider alternative requirements or forms of support for technology development and implementation.

5. The State of California should support the "Grandfathering" of vessels with existing experimental treatment technologies that has been approved by the Commission and/or the USCG.

The implementation schedule recommended by the Panel addresses the retrofitting of existing vessels as well as standards required for future vessel construction. Another important, though very small group of vessels that should be considered, are those whose owners have elected to install prototype treatment technologies in advance of established performance standards. The IMO Convention addresses these vessels (Regulation D-4), by giving a 5-year extension to vessels that participate in an approved program to test promising ballast water treatment technology prior to the date that standards become effective. Under this scenario, a vessel with ballast water capacity greater than 5000 MT that had an experimental treatment system installed in advance of the adoption of California performance standards would be allowed to use that system until 2021. At which time it must comply with the adopted performance standards. In general, these vessels' owners have worked closely with state, federal, and international entities, adding to our understanding of ballast water treatment technology onboard operational vessels.

6. The State of California should support the establishment of a testing and evaluation center that provides the industry, developers, and regulators an opportunity to take promising technologies to working prototypes.
Mandating performance standards must take into account the certification, and subsequent verification of treatment technologies. The current State program does not have the expertise, equipment, facilities, or financial resources necessary for the testing and certification of treatment technologies. This infrastructure would substantially improve the effective implementation of performance standards and the ongoing evaluation of technologies once approved.

The USCG has recently established a testing and evaluation center in Key West, Florida. However, this single facility will only be able to consider three or four systems annually, once testing and verification protocols are established. Discussions between Commission staff and USCG have identified the need for additional testing and evaluation centers. The Commission staff has proposed the establishment of a center in the San Francisco Bay area that would compliment the USCG's Florida facility. A San Francisco-based facility could offer a testing scenario under rigorous conditions that are widely different from those of Key West. Complementary California and Key West facilities could subject technologies to an array of environmental conditions that may be more reflective of the range of conditions vessels encounter during the course of international trade. The budget to establish such a facility, including capitol start-up cost, personnel, operating expenses and equipment is estimated at approximately $10 million over three years. To date, funding for such a center has not been identified.

7. The State of California should appropriate additional funding and personnel to expand biological surveys to assess the effectiveness of the State's Program. The only way to evaluate the effectiveness of performance standards or other management measures is through long-term biological monitoring. Such work is essential in determining how to change and enhance the Program to more effectively reduce invasions in California. As mandated by the Act, the California Department of Fish and Game administers a statewide monitoring program for NIS within California's estuaries and along its coast.

Under the existing study plan, each monitoring site will be revisited about every 3 years, allowing for at least two sampling events at each site before the sunset date of the program (established in the Act). This monitoring schedule was dictated by time and resource limitations, and will provide only limited data with which to assess whether any new introductions have occurred. The sheer size of the California coastline and the lag time involved for new species to become established necessitates monitoring over a much longer time horizon. It's easy to 'miss' a species on any one visit to a site. The more visits, the greater likelihood that a complete inventory is developed and new introductions are spotted.

One of the resource limitations of these studies has been the availability of taxonomists to do the species identification work. Currently, there are a limited number of taxonomists familiar with the wide variety of species being collected in the surveys. Moreover, because many of the species are introduced from other regions, they may never have been seen by taxonomists working locally. More detailed taxonomic analysis, including genetic identification, would help to resolve the very important questions regarding an organism's pathway of introduction and region of origin. Genetic identification can more accurately determine whether a species is new to this continent or just new to the area of California where it is currently found. With such information it will be easier to assess if the introduction is from a ship vector, which would mean that existing control programs have not been fully effective, or may show that there are other sources of introduction that need to be addressed through other regulatory means.

At a minimum, it is critical that financial resources continue that allow the CDFG to continue its present efforts for the long term, at the very least through the end of the implementation dates established by this report. The Commission recommends that the CDFG be provided additional funding and personnel to expand the frequency and geographic coverage of surveys for a more complete data timeline.

8. The State of California should consider incentives to promote continued technology development.

Technology developers and the shipping industry are unlikely to continue development of technologies that exceed established standards. California should consider various incentive programs (fee reduction, tax credits, etc.) to continue technology development even after technologies are able to meet the adopted performance standards. Positive inducements that are financially advantageous for the shipping industry could serve the advancement of technologies towards the ultimate standard of zero discharge.

9. The Legislature should remove the sunset date in the enabling legislation.

The Marine Invasive Species Act of 2003 includes a sunset date of January 1, 2010; which is well before many of the implementation dates recommended in this report. Continuation of the Marine Invasive Species Program will be necessary to ensure the development of technologies and the proper implementation of the standards in the field.

XI. LITERATURE CITED

Assembly Bill 433. State of California Assembly Bill. 2003 Regular Session. Passed September 24, 2003.

Battelle. 2003. United States Coast Guard. Programmatic environmental assessment for ballast water management program for U.S. Waters. USCG-2003-14273-3. 38 pp.

Bluewater Network. 2005. Request for proposals: Study of the Feasibility of Shore-side Treatment of Ballast Water at the new cruise ship terminal at Piers 30-32 in San Francisco. Accessed October 18, 2005. Website: http://www.bluewaternetwork.org/campaign_ss_cruises.shtml

California Regional Water Quality Control Board. 2000. Prevention of Exotic Species Introductions to the SF Bay Estuary: A TMDL report to the US EPA. San Francisco Bay Region.

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

Carlton, J.T. 2001. Introduced Species in U.S. coastal waters: Environmental impacts and management Priorities. Pew Oceans Commission. Arlington, VA. 28 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. San Francisco Estuary Institute, Richmond, CA. 81 pp.

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

Cooper et al. 2002. Full-scale Ozone Ballast Water Treatment for Removal of Marine Invasive Species. Proof of Concept study for the Nutech Ozone Treatment System.

Costello, C. (personal communication, 9/7/2005)

Dickman, M. and Zhang F. 1999. Mid-ocean exchange of container vessel ballast water. 2: Effects of vessel type in the transport of diatoms and dinoflagellates from Manzanillo, Mexico, to Hong Kong, China. Marine Ecology Progress Series. (176) 253-262.

Fofonoff, P.W., G.M. Ruiz, B. Steves, and J. Carlton. 2003. In ships or on ships? Mechanisms of transfer and invasion for nonnative species to the coasts of North America. *In* Invasive Species, vectors and management strategies. G.M. Ruiz and J.T. Carlton eds. Island Press, Washington D.C. 152-181 Pp.

Fraenkel, A. (personal communication, 11/14/2005)

Gallopo, C. (personal communication, 6/15/2005)

Global Ballast Water Management Program (GLOBALLAST). 2004. Ballast Water Treatment R & D Directory. 2nd Edition. International Maritime Organization. London. <http://globallast.IMO.org>

Glosten Associates, 2002. Ballast Water Transfer Study: Technical Feasibility with associated capital costs. Port of Seattle, Washington.

Gotsch, C. (personal communication, 6/2005)

H. R. 1591. April 13, 2005. National Aquatic Invasive Species Act of 2005. Introduced.

International Maritime Organization (IMO). 2005. International Convention for the Control and Management of Ships' Ballast Water and Sediments. London.

International Conference on Ballast Water Management for Ships. 2004. Considerations of the Draft International Convention for the Control and Management of Ships' Ballast Water and Sediments. BWM/CONF/14.

Kildow, J. and C. Colgan. 2005. California's Ocean Economy. A Report to the Resources Agency, State of California. Prepared by The National Ocean Economics Program. pp. 167

Lovell, Sabrina J. and Susan F. Stone. 2005. The Economic Impacts of Aquatic Invasive Species: A Review of Literature. National Center for Environmental Economics.

Marine Environment Protection Committee (MEPC). 2004. International Maritme Organization. Recommendations for the conduct of the review of the status of the ballast water management technologies set by Regulation D-5 of the Ballast Water Management Convention. MEPC 53/2/2.

Marine Environment Protection Committee (MEPC). 2003. International Maritme Organization. Comments on draft regulation E-2. Concentrations of organisms delivered in ships' ballast water in the absence of any treatment: Establishing a baseline for consideration of treatment efficacy. MEPC 49/2/1.

Marine Environment Protection Committee (MEPC). 2003. International Maritime Organization. Summary of an International Workshop on Ballast Water Discharge Standards. MEPC 49/INF.31.

Matson Navigation Company, Inc. 2005. M/V R.J. Pfeiffer Ballast Water Treatment System Final Summary Report: Prepared for the California State Lands Commission.

Minton, Mark S., Emma Verling, A.Whitman Miller, and Gregory M. Ruiz. 2005. Reducing propagule supply and coastal invasions via ships: effects of emerging strategies. Frontiers in Ecology. 3(304-308).

Moore, S. (personal communication, 9/12/2005)

National Research Council. 1996. Stemming the Tide: Controlling Introductions of Nonindigenous species by ship's ballast water. National Academy Press, Washington D.C. 141 pp.

Navigation Data Center. 2004. U.S. Army Corps of Engineers. The U.S. Waterway System – Transportation Facts. Accessed June 6, 2005. Website: http://www.iwr.usace.army.mil/ndc/factcard/fc04/factcard.pdf

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

Perlich, T. (personal communication, 6/2005)

Pimentel, D., R. Zuniga, and D. Morrison. 2004. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics. *In Press.*

Port of Long Beach. 2005. Port Statistics. Container Trade in Yearly TEU Totals (1994 – 2004). Accessed June 12, 2005. Website: http://www.polb.com/about/port_stats/yearly_teus.asp

Port of Oakland. 2005. Container Statistics. Port of Oakland TEU Activity (1992-2004). Accessed June 12, 2005. W`ebsite: http://www.portofoakland.com/maritime/facts_cargo.asp

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

S. 363. February 10, 2005. Ballast Water Management Act of 2005. Introduced.

SB 895. Oregon State Senate Bill, 71st Oregon Legislative Assembly 2001 Regular Session. Section 2(3)(a). Accessed 11/15/2005. Website: http://www.leg.state.or.us/01reg/measures/sb0800.dir/sb0895.en.html

S. 770. April 13, 2005. National Aquatic Invasive Species Act of 2005. Introduced.

S. 1224. June 9, 2005. National Oceans Protection Act of 2005. Introduced.

SHB 2466. State of Washington Substitute House Bill, 56th Legislature 2000 Regular Session. Passed March 6, 2000. RCW 77.120.030.

SB 332. State of Michigan 93rd Legislature 2005 Regular Session. Passed June 6, 2005.

State Water Resources Control Board (SWRCB). 2002. Evaluation of Ballast Water Treatment Technology for Control of Nonindigenous Aquatic Organisms.

United States Bureau of Transportation. Department of Transportation. 2005. Accessed June 20, 2005. Website: http://www.bts.gov/

United States Coast Guard. 2001. Report to Congress on the voluntary national guidelines for ballast water management. Washington D.C.

URS Corporation/Dames and Moore. 2000. Feasibility of Onshore Ballast Water Treatment at California Ports. A study conducted on behalf of the California Association of Port Authorities. San Francisco.

Washington Department of Fish and Wildlife. 2003. Washington State ballast water program. Accessed 12 June 2005. WAC 220-77-095. Website: http://www.wdfw.wa.gov/fish/nuisance/ballast.htm

Welschmeyer, N., S. Bollens, S. Avent, E. Landrau, T. Voss, and R. Fairey. 2004. Onboard Testing of Ballast Treatment Efficacy: Summary Report. Prepared for the California State Water Resources Control Board and California State Lands Commission.

Wright, G. 2004. Final Summary Report. West Coast Demonstration Project. Prepared for the California State Lands Commission.

XII. APPENDICES

APPENDIX A

MAJORITY REPORT AND RECOMENDATIONS OF THE CALIFORNIA ADVISORY PANEL ON BALLAST WATER PERFORMANCE STANDARDS

APPENDIX B

MINORITY REPORT AND RECOMENDATIONS OF THE CALIFORNIA ADVISORY PANEL ON BALLAST WATER PERFORMANCE STANDARDS

APPENDIX C

MINORITY POSITION LETTER
SUBMITTED BY
THE OCEAN CONSERVANCY