Prevention of Exotic Species Introductions to the San Francisco Bay Estuary: A Total Maximum Daily Load Report to U.S. EPA

California Regional Water Quality Control Board
San Francisco Bay Region

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Executive Summary

Background

Exotic species are one of the greatest threats to the integrity of the San Francisco Estuary ecosystem, perhaps as great as any pollutant regulated under the Clean Water Act (CWA), and currently they continue to be discharged into the estuary, primarily in ships' ballast water. Ongoing introductions of exotic species, including pathogens, to the San Francisco Estuary threaten the ecology, economy, and public health of the San Francisco Bay Region.

Treating exotic species as pollutants is consistent with the existing regulatory framework of the CWA. One of the principles of water quality control is biological control. EPA regulates biological pollutants such as pathogens under various programs of the CWA. Exotic species meet the definition of "pollutant" at Section 502 of the CWA, for the reason that they are "biological materials…discharged into water," and they impair or threaten to impair the full range of designated beneficial uses of waterbodies in the San Francisco Estuary.

An exotic species is defined as any species that is not native to a particular ecosystem, including its seeds, eggs, spores, or other biological material capable of propagating that species. Synonyms for exotic species include non-native species, nonindigenous species, and alien species.

Problem Statement

When an exotic species is introduced into a new ecosystem, there is potential for significant disruption of the balance among existing native and naturalized species, especially if the exotic species competes with native species for resources, preys on native species, and/or no predators are able to control the population of the exotic species. *When an exotic species does or is likely to cause economic or environmental harm, or harm to human health, it is known as an "invasive species." Yet another synonym for such an organism occurring in or near waters is "aquatic nuisance species[1]," or ANS, as defined in the National Invasive Species Act (NISA).* Competition with and predation by invasive species affects 49 percent of endangered or threatened species in the U.S. (Wilcove et al., 1998). About 42 percent of the species listed as endangered or threatened under the Endangered Species Act of 1973 are at risk primarily because of exotic species. Controlling the impacts of exotic species already introduced, is costing Americans in excess of $123 billion per year, mostly from agricultural pests, but the costs of ANS have topped $5 billion per year and are rising (Pimentel et al., 1999).

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[1] An "aquatic nuisance species" is defined in the National Invasive Species Act, 1996, as a non-indigenous (or exotic) species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters.

Source Assessment

The main source of exotic species introductions in the San Francisco Estuary is probably via ships' ballast water. Ballast-mediated introductions such as the zebra mussel in the U.S. Great Lakes and toxic dinoflagellates in Australia have had tremendous ecological and economic impacts. Water-borne diseases such as cholera and hepatitis can be transported with ballast water (Knight, 1999; Harvell et al., 1999). Exterior surfaces of vessels are a documented vector, particularly in parts of the Earth where distinct species assemblages are relatively close together, such as between Australia and Southeast Asia. While the ship vector is probably the greatest point source, there are other sources of exotic species to aquatic ecosystems, which include various aquaculture facilities (shellfish or fish) as point sources. Nonpoint sources of exotic species include bait and fish stocking, and unintentional and/or intentional introductions by individuals, such as dumping of aquariums or water gardens into surface waters, and organisms that escape from or are released from the live food market.

A review of existing international, national, and state control programs to address exotic species introductions via the ship vector reveals a lack of progress on treatment technology to address ballast water discharges. The current regulatory scheme for ballast water under NISA, adopted in 1996, has not initiated an effective technology-based regulatory program for eliminating exotic species introductions through this vector, and a recent California state law leaves significant gaps in closing the door to introductions (see Sections 1.2.3 through 1.2.7). As a result, the existing water quality control program does not adequately protect beneficial uses of the San Francisco Estuary and other waters of the United States. Ample evidence exists that ballast water discharges contain viable exotic organisms and pathogens, and yet no program has moved forward to develop and implement technology and technology-based standards commensurate with other municipal and industrial discharges regulated under the National Pollutant Discharge Elimination System (NPDES).

TMDL and Allocations

The TMDL program is not the preferred program to address prevention of the introduction of exotic species. If the TMDL program were the only available tool to address the ship vector challenge, this nation would institute preventive measures as a last resort when damages have already been incurred, instead of anticipating and preventing the permanent changes that exotic species introductions bring. This TMDL is being proposed for the San Francisco Estuary because it has been so invaded (Section 2), and an objective review of current prevention programs (Sections 1.2.2 – 1.2.6) shows that more invasions are inevitable (Section 1.2.7).

Traditionally, the TMDL process is applied to chemicals on a mass basis, designed to meet a concentration standard in ambient waters, sediments, or tissue. As such, the chemistry-based concepts in typical TMDLs present some difficulties in their transference to the exotic species issue. Also, because exotic species in ballast water has only recently been well characterized and management practices are only recently developed, this TMDL is being proposed in advance of implementation of technological controls. For these two reasons, this TMDL is different than chemical TMDLs in that it is based on a narrative water quality objective, a mostly qualitative analysis of assimilative capacity, and is being proposed in advance of implementation of technology-based controls. Rather than follow a period of technology development and implementation, this TMDL is intended to hasten one.

Because of the significant risks, the working hypothesis is that a water quality-based endpoint to achieve the estuary's water quality standards is *no exotic species introductions*. In other words, an acceptable total maximum daily load (TMDL) of exotic organisms or species is "zero." Based on the worst-case examples documented worldwide, the San Francisco Estuary does not have a capacity to assimilate exotic organisms in a general sense.

Wasteload allocations are given to point sources. Point sources of exotic species to the estuary include ships and aquaculture facilities. Specific point source categories are ballast water, exteriors of ships and other vessels, and registered aquaculture facilities. Load allocations are given to nonpoint sources. Nonpoint sources of exotic species to the estuary include introduction along with bait, individuals dumping aquariums or outdoor water gardens into fresh or estuarine waters, and intentional introductions. Zero allocations are given to all of these potential point and nonpoint sources.

Implementation Issues and Options

Because of the nature of the maritime industry, implementation of this TMDL should be undertaken at a national level. A successful regulatory program for exotic species and the ship vector will require a coordinated nationwide approach, building on an emerging international organization around the issue (including IMO guidelines and NISA regulations), and will need to be easy to understand by ships' masters from all maritime nations, and easy to implement by the U.S. Coast Guard, the enforcement agency recognized by ship masters around the world. The maritime industry recognizes the problem of exotic species and the ship vector, and has participated cooperatively in the various stakeholder forums. Throughout discussions, workshops, meetings, and conferences on this issue over the last year, representatives of the shipping and port interests have emphasized the need for a consistent, nationwide program (see Box 1, Section 1). Among other concerns, the ports and shippers do not want piecemeal requirements to deter global trade from certain locations, nor to burden ship masters, operators, and agents with confusing requirements on top of all the other regulations with which they must already comply. For these reasons, while legislation in states like California and Washington send an important message that the current national program is not adequately protective, they do not present the ideal solution for the problem, because of inevitable inconsistencies between state programs and resulting confusion to the maritime industry.

After technology-based controls are implemented on ships or in ports it may be necessary for the Regional Board to revisit this TMDL process, in case various monitoring programs under the National Invasive Species Act (NISA) and California AB 703 demonstrate that introductions of exotic species are still occurring. Until that time, it is premature to set zero discharge effluent limits due to the necessity of ballast water operations and the uncertainties associated with what technology-based controls will achieve. In addition, the Regional Board is precluded from taking regulatory action by the new state law, AB 703, which sunsets on January 1, 2004. If, at that time, the national and state programs continue to be inadequately protective of beneficial uses of the San Francisco Estuary, allowing viable exotic organisms and pathogens to be discharged to the estuary, then regulatory action will be considered by the Regional Board consistent with the direction outlined in this TMDL report.

1. Background

1.1 Description of the TMDL process

The San Francisco Estuary is a valuable natural resource in the State of California. Water quality standards are set and enforced by the State of California to protect the designated uses of its water bodies. When states and local communities identify problems in meeting water quality standards, a Total Maximum Daily Load (TMDL) can be a part of a plan to address the water quality problems. The purpose of this TMDL is to identify the control measures for introductions of exotic species through discharges to surface waters and additional information needed to meet water quality standards set for waterbodies of the San Francisco Estuary and to guide the implementation of control measures and monitoring programs.

Section 303(d) of the of the Clean Water Act (CWA) requires states to identify waters where the effluent limitations required under the National Pollutant Discharge Elimination System (NPDES) or any other enforceable limits have been implemented and adopted water quality standards are still not attained. The states must also rank these impaired water bodies by priority, taking into account the severity of the pollution and the uses to be made of the waters. Lists of prioritized impaired water bodies are known as the “303(d)” lists and must be submitted to the U.S. Environmental Protection Agency (EPA) every two years.

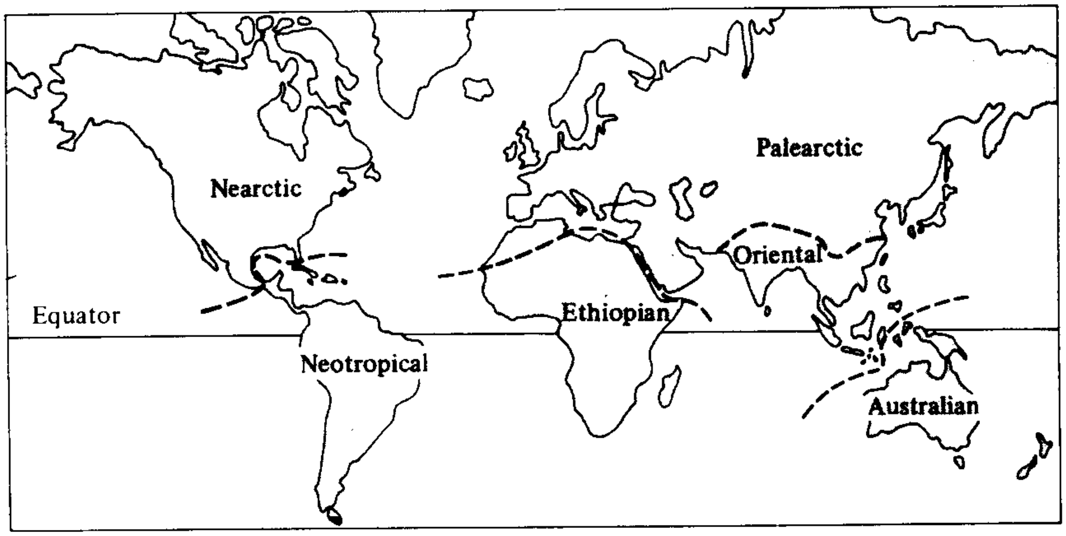
A TMDL represents the total loading rate of a pollutant that can be discharged to a waterbody and still meet the applicable water quality standards. The TMDL approach is usually developed for controlling chemical constituents after implementation of technology-based limits on point sources. The TMDL can be expressed as the total mass or quantity of a pollutant that can enter the water body within a unit of time. In most cases, the TMDL determines the allowable loading capacity for a constituent and divides it among the various contributors in the watershed as wasteload (i.e., point source discharge) and load (i.e., nonpoint source) allocations. The TMDL also accounts for natural background sources and provides a margin of safety. For some nonpoint sources it might not be feasible or useful to derive an allocation in mass per time units. In such cases, a percent reduction in pollutant discharge may be proposed.

EPA regulates biological pollutants under various programs of the CWA. The definition of pollutant at Section 502(6) of the CWA includes “biological materials.” Examples include pathogens (bacteria, viruses, and protists like *Giardia* and *Cryptosporidium* that cause gastrointestinal disease), and recently, aquatic nuisance plants and Atlantic salmon in the Pacific Northwest (Oregon and Washington 303(d) lists, 1998). In April 2000, the California Regional Water Quality Control Board, Santa Ana Region (Region 8) is proposing a TMDL for pathogens, a biological pollutant, in Newport Bay as measured by fecal coliforms. Also, the Ninth Circuit Court of Appeals found that live fish and dead fish discharged into Lake Michigan are pollutants within the meaning of the CWA because they are "biological materials." 657 F.Supp. at 1006-07, see also *Association of Pacific Fisheries* v. *Environmental Protection Agency*, 615 F.2d 794 (9th Cir. 1980).

1.1.1 Definition of Exotic Species

A species is a group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms. Under evolution, species differentiate due to physical distances or barriers between habitats. The study of biogeography is the study of patterns of distributions of plants and animals and an attempt to explain how such patterns arose during the geologic past. Biogeographic regions of Earth are separated from one another by a major barrier to the dispersal of plants and animals, such as a narrow isthmus, high mountains, a desert, an ocean, or an oceanic strait (Pianka, 1988). Therefore, the Earth's natural biodiversity has arisen out of the existence of such barriers, and removal of such barriers constitutes a fundamental threat to this remarkable diversity. Figure 1-1 contains the major biogeographical regions of the Earth.

Figure 1-1



The six major biogeographic regions of the world.

An exotic species is defined as any species that is not native to a particular ecosystem, including its seeds, eggs, spores, or other biological material capable of propagating that species. Synonyms for exotic species include non-native species, nonindigenous species, and alien species. When an exotic species is introduced into a new ecosystem, there is potential for significant disruption of the balance among existing native and naturalized species, especially if the exotic species competes with native species for resources and no predators are able to control the population of the exotic species. When an exotic species does or is likely to cause economic or environmental harm, or harm to human health, it is known as an “invasive species.” Yet another synonym for such an organism occurring in or near waters is “aquatic nuisance species[2],” or ANS, as defined in the National Invasive Species Act (NISA). Competition with and predation by invasive species affects 49 percent of endangered or threatened species in the U.S. (Wilcove et al., 1998). About 42 percent of the species listed as endangered or threatened under the Endangered Species Act of 1973 are at risk primarily because of exotic species (Pimentel et al., 1999).

Although the effects of many exotic species introductions remain unmeasured, it is clear that some “invasive” exotic species, or ANS, are having significant economic and ecological impacts as well as human-health consequences. Today, the main method we eliminate major barriers between biogeographic regions of the Earth is moving species via ships on their exteriors or in their ballast water (SERC, 2000). Ballast-mediated introductions such as the zebra mussel in the U.S. Great Lakes and toxic dinoflagellates in Australia have had tremendous ecological and economic impacts. Water-borne diseases such as cholera and hepatitis can be transported with ballast water (Knight, 1999; Harvell et al., 1999). While the ship vector is probably the greatest source, there are other sources of exotic species to aquatic ecosystems, which include the aquaculture and baitfish industries, dumping of aquariums into surface waters, and intentional introductions.

1.1.2 Interpretation of TMDL for Exotic Species

Exotic species are biological pollutants, and unlike chemical or conventional pollutants, waters of the state do not have capacity to “assimilate” them without changing the species abundance and diversity of the waters, which is a change to the biological integrity of the system. Although not all exotic species are deleterious (Elston, 1997), the worst-case examples, described in Section 2, provide a strong argument that waters of the state cannot assimilate random introductions of exotic organisms. As biological pollutants found to be impairing the San Francisco Estuary, exotic species are assigned a Total Maximum Daily Load of zero, to be allocated among all potential sources in the Estuary, as summarized in Section 4.

Treating exotic species as pollutants is consistent with the existing regulatory framework of the Clean Water Act. One of the principles of water quality control is biological control (Metcalf and Eddy, 1972). For instance, where water supplies, recreational beaches, livestock, or other water contact sports may be affected, the bacterial content of receiving waters is regulated, as sometimes measured by the number of coliform organisms. Effluent limits based on these bacterial measurements are established for point source discharges in NPDES permits, and sewage effluents are disinfected to achieve these limits. Implicit in this disinfection is removal of pathogenic organisms that can harm aquatic life and wildlife, such as fish, shellfish and wildlife pathogens.

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[2] An “aquatic nuisance species” is defined in the National Invasive Species Act, 1996, as a non-indigenous (or exotic) species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters.

Moreover, TMDLs are currently in the process of being established for pathogens, a biological pollutant, for waterbodies throughout the State of California.

There are similarities in aquatic ecosystem effects by both biological pollutants and chemical pollutants. When a biological pollutant such as exotic species is introduced (i.e., discharged) into a receiving water, the biological community reacts in a manner similar to that from a chemical pollutant. A biological indicator such as the Index of Biological Integrity (IBI) can be quantitatively lowered, demonstrating an adverse impact, by both (1) the introduction of an exotic species that lowers biodiversity by competing with or preying upon native organisms; and (2) the discharge of a pollutant that exhibits a toxic effect on the most sensitive organisms, lowering the abundance and/or diversity of the aquatic community. Discharges of chemical and biological pollutants both represent threats to beneficial uses of water, and historically both have been addressed through issuance of NPDES permits to point sources.

Exotic species, as biological pollutants, are treated differently than chemical pollutants in this TMDL context. Exotic species or individual exotic organisms are pollutants to the San Francisco Estuary because (1) they are biological materials, as defined under Section 502(6) under the Clean Water Act; (2) their introduction and establishment in the pelagic or benthic ecosystems of the estuary violate the narrative water quality objective for population and community ecology in Chapter 3 of the San Francisco Bay Water Quality Control Plan (Basin Plan); and (3) their introduction into the estuarine ecosystem threatens to impair virtually every beneficial use designated for the waterbodies of the San Francisco Estuary, due to the documented impacts over the broad range of ecology, economy and public health (Carlton and Geller, 1993; Carlton 1996).

Unlike chemical pollutants, exotic species that are established do not dissipate over time, but rather multiply and exert permanent adverse impacts on the native biota and other beneficial uses of the estuary that range from imperceptible to dramatic. And, unlike chemical pollutants, experts are not able to effectively predict which exotic species will become established in a given receiving ecosystem, and therefore what an acceptable loading rate would be (Carlton, 1996). Therefore, due to the severity of the worst-case invasions documented worldwide (Harbison and Volovik, 1994; Mills et al., 1993; Alpine and Cloern, 1992), and our limited ability to predict whether a given exotic species in a discharge will become an ANS in the San Francisco Estuary, this TMDL establishes a qualitative goal of “zero” for exotic species.

The TMDL process is being used by the Regional Board to place exotic species on the same level as other pollutants regulated by the CWA, and underscores the need for a national program of technology development and implementation, conducted in partnership with the maritime industry, the engineering community, and biological experts. For example, the invasion of *Potamocorbula amurensis* in the 1980s has created a mechanism in the San Francisco Estuary ecosystem to concentrate selenium in the food chain at a much greater rate than ever before, adversely affecting higher trophic organisms such as diving ducks (Luoma and Linville, 1997). Meanwhile, since 1992, the oil refineries in the region have spent approximately $45 million in selenium removal technology capital improvements to reduce the impact of their discharges on biota. This amount does not include money spent on research and development, and subsequent operations and maintenance, such as hazardous waste disposal costs (Tang, 2000). The discharge of *Potamocorbula amurensis* through ballast water, and its subsequent establishment and dominance in the estuary, have effectively undone a substantial portion of the oil refineries' investment in pollution control by elevating the bioconcentration factor for selenium in the main estuarine portions of the San Francisco Estuary, which include Lower and South San Francisco Bays, San Pablo Bay, Carquinez Strait, and portions of Suisun Bay.

This TMDL differs from other chemical-based TMDLs for another key reason – rather than following a period of technology development and implementation, it will hasten one. The typical sequence under the CWA for a pollutant such as nitrate, for instance, was technology-based limits under NPDES permits in the 1970s, water quality-based limits under NPDES permits in the 1980s, and finally, if these measures did not lead to accomplishment of the ambient water quality objective, a TMDL, or mass-based approach.

The major ongoing source of exotic species discharges to San Francisco Bay is associated with ships' ballast water. However, the current regulatory scheme for ballast water under the National Invasive Species Act (NISA) of 1996 has not initiated an effective technology-based regulatory program for eliminating exotic species introductions through this vector (see Sections 1.2.3, 1.2.4, and 1.2.6). A quick review of NISA reveals that ballast management is short-hand for ship-vector management, so activities to address any mode of transfer associated with the ship vector, such as bio-fouling of a vessel's exterior surfaces, are included in this TMDL (Northeast-Midwest Institute, 2000).

National legislation to address ballast water discharges was first enacted in 1990 (National Aquatic Nuisance Prevention and Control Act or NANPCA), but technology implementation for ballast water treatment has not progressed beyond open ocean exchange, which is flawed from two perspectives: (1) short-term and long-term structural stability of many ships may not be adequate to conduct such exchanges, especially in stormy conditions (Lloyd's Register, 2000); and (2) ballast water tanks are not efficiently designed for complete exchange of water and sediments, which is necessary for abating the risk of introductions (Oemcke, 1999). Indeed, researchers have demonstrated that the removal efficiencies of open ocean exchange, when conducted correctly, are likely in the range of 70-90%, and will at best *slow* the rate of exotic species introductions (Dames and Moore, 1999). Since 1990, many new ANS have been established in the Great Lakes system, where open ocean exchange requirements have been mandatory since 1993. Research and development of existing water treatment technologies for addressing ballast water is in its nascent stages, and the U.S. Coast Guard, the lead agency for NISA, has not yet approved any treatments for ballast water other than open ocean exchange (Everett, 2000), which is unable to achieve necessary reductions of viable biological organisms to prevent future introductions of exotic species (ENRC, 1997; Cohen 1998).

A TMDL is required when effluent limits or other pollution control requirements do not address water quality problems. At this time, ten years after legislation was first enacted to address this issue, the "pollution control requirements" of NISA only *request* that ships undergo open ocean exchange, except in the Great Lakes and Hudson River (USCG, 1999). This level of control is inadequate to prevent future introductions of exotic species, and a TMDL of zero is therefore proposed to initiate an effective technology-based regulatory program. Such a program could evolve through development of a National Effluent Guideline for Ballast Water under Section 402 of the CWA, or an equivalent level of protection under another existing statute such as NISA.

At first glance, there appears to be a potential disconnect between a qualitative zero-TMDL goal and a technology-based approach, where a quantitative zero is almost never achievable. However, our nation has already addressed a similar challenge in controlling biological pollutants in drinking water delivered to homes and businesses, under the national Safe Drinking Water Act. Our nation desires a TMDL of "zero" for pathogens in tap water, but our system of measuring compliance considers the performance of the best available treatment technology. Since instances of water-borne disease are now very rare, there is general acceptance of our national treatment-based standards for drinking water, without employing expensive research-level analyses to continually check for the presence of viruses and other microorganisms. The national treatment standard for viruses in drinking water, established in place of maximum contaminant levels or MCLs, is "4-log-kill" or 99.99% removal of viruses. For the protozoan cyst *Giardia*, the treatment standard for drinking water is 3-log kill or 99.9% removal (Pontius, 1990). In some cases a handful of non-native organisms has the potential to initiate a biological invasion of the estuary, and for this reason, a numeric target of multiple-log kill, based on treatment or best management practices, may be the desired standard for exotic species.

Using this example from EPA's drinking water regulation, a qualitative TMDL of zero can be rectified with treatment technology that does not achieve an absolute quantitative goal of zero by creating the appropriate regulatory incentives to improve technology performance over a reasonably rapid period of time.

1.1.3 Exotic Species Control

Exotic species control is usually divided into three categories: (1) prevention of introductions (for species not yet introduced); (2) control of spread (for species that have recently been introduced and have not become ubiquitous); and (3) minimization of impacts at sensitive locations (for species that have become ubiquitous and impact sensitive species or interfere with infrastructure). Depending on the exotic species of concern, management efforts are targeted into one of the three categories. In the San Francisco Estuary, an example of an ANS not yet introduced is the zebra mussel, and personnel at agricultural inspection stations currently inspect boats on trailers coming into the state to ensure that they are not carrying zebra mussels. An example of a species for which controlling spread appears practical at this time is the Atlantic *Spartina alterniflora* cordgrass plant that has been identified in several salt marshes around the Estuary. It has not yet invaded all salt marshes in the Estuary, so management efforts are targeted at incipient populations to keep it from dominating the many wetland restoration sites around the Estuary. The Chinese mitten crab and green crab provide two examples of species that are already ubiquitous in the San Francisco Bay Region. Control programs for the crabs focus on sensitive areas of impact such as water diversion and fish salvage facilities for the mitten crabs, and commercial shellfish beds for the green crabs.

1.1.3.1 PROPOSED TMDL APPROACH: PREVENTION OF INTRODUCTIONS

As described in Section 4.1, this TMDL recognizes the practical consideration that eradication of ANS already introduced through ballast water, historic aquaculture, or other sources is virtually impossible. Typically, budgets for exotic species control get spent on controlling spread or minimizing impacts of existing invasions. Therefore, since introductions are basically permanent, and the existing management regime described in Section 1.2 is not preventing introductions, the TMDL is proposed to assist in filling that gap, creating a national funding mechanism exclusively focused on treatment of ballast water from ships. In addition, the Clean Water Act has historically focused on point source discharges such as ballast water discharges from vessels, so implementation of a TMDL for exotic species would logically result in NPDES permits and the development and implementation of a national effluent guideline for ballast water discharges.

1.1.4 Limitations of TMDL Program to Control Exotic Species

This technical TMDL report outlines a possible strategy for using CWA authorities to address the vexing problem of exotic species transfer via ships and other identified sources such as aquaculture, the bait trade, the aquarium trade, and intentional introductions. The case study of exotic species in San Francisco Bay has received international attention due to the dramatically high percentage of non-native species that are dominant in the estuary’s various aquatic habitats (Cohen and Carlton, 1995; Thompson et al., 1999), and the finding that the shipping vector is probably responsible for most of the recent documented introductions (Cohen and Carlton, 1995; Cohen, 1998). Faced with such a convincing weight of evidence that exotic species have impaired beneficial uses of the estuary as much as any other pollutant, the Regional Board listed exotic species on the 303(d) list as a high priority, triggering the requirement to establish a TMDL for exotic species, focusing on the major vector: discharges from ships.

The TMDL program is not the preferred program to address prevention of the introduction of exotic species. If the TMDL program were the only available tool to address the ship vector challenge, this nation would institute preventive measures as a last resort when damages have already been incurred, instead of anticipating and preventing the permanent changes that exotic species introductions bring. This TMDL is being proposed for the San Francisco Estuary because it has been so invaded (Section 2), and an objective review of current prevention programs (Sections 1.2.2 – 1.2.5) shows that more invasions are inevitable (Section 1.2.7).

The major problem with using TMDLs as the program for addressing exotic species impairments is that it does not provide incentives to protect waterbodies that are presently *not impaired*, which is the most important goal of preventing exotic species introductions and preserving what remains of the nation’s natural biological heritage. For example, the TMDL for the San Francisco Estuary does not provide an incentive to ships ballasting in the estuary to institute pollution prevention controls (i.e., treatment on the uptake) to protect the resources of the ships’ destination, such as Prince William Sound (Alaska), the Columbia River, or Puget Sound. It merely sets an allowable load of zero for this estuarine system, but does nothing to protect other estuaries from foreign ballast discharges, or even discharges of San Francisco Bay waters that contain deleterious ANS such as the Amur River clam (*Potamocorbula amurensis*), the Chinese mitten crab (*Eriocheir sinensis*), and the European shorecrab, or green crab (*Carcinus maenas*).

If exotic species TMDLs for specific waterbodies were the sole regulatory driver for ballast water treatment technology implementation, then the technology would get implemented only in areas that are listed as impaired. Such a program would direct protections onto discharges to the impaired waterbodies, focused only on end-of-pipe treatment, making a premature, *de facto* determination that port-based (shore-based or barge-based) facilities are the long-term technological solution to the problem. This conclusion ignores that ship-based facilities, despite concerns about reliability and equipment maintenance, exhibit the important characteristics of pollution prevention (i.e., screening on the uptake and disposal of species at their point of origin). Another factor is that the maritime industry may be willing to let more politically active areas such as San Francisco Bay, Puget Sound, Vancouver B.C., Australia, New Zealand, and the Great Lakes institute port-based controls, passing the costs on to these regions, and avoid their responsibility to address the problem in how their ships are designed. In addition, we presently do not have enough information to determine if ship-based facilities incorporated into design of new ships is the most cost-effective solution to the problem, and the TMDL approach would not provide incentives to direct that research. Ultimately, the TMDL program can only provide protections for the waterbodies that are listed as impaired. And perhaps most importantly, unlike chemical pollutants, exotic species exert permanent changes in those waterbodies that are invaded, so there is no hope to use the TMDL process to reverse such damages in “unimpaired” waterbodies.

Another limitation of using TMDL for exotic species is that there is not consensus among various interested parties, including EPA, on whether exotic species are a pollutant, or merely “pollution,” or a stressor, the latter of which would not trigger a TMDL process. The Regional Board moved ahead with its 303(d) listing process in February 1998, with a goal of challenging the local port and maritime industries to surpass the pace of the current national program administered by the U.S. Coast Guard (see Section 1.2.4). On May 12, 1999, EPA approved the State of California’s 303(d) list, which included exotic species as a pollutant impairing waterbodies of the San Francisco Estuary. Previously, on November 8, 1998, an EPA staff report interpreted exotic species as a stressor on the ecosystem, but not necessarily a pollutant (Smith and Karkoski, 1998). Presently, there is no official position on this interpretation from EPA Headquarters (Carlson and Charleton, pers.comm., 2000).

As EPA considers its official national position on determining whether exotic species are a pollutant, this TMDL is intended to bring attention to a class of common point source discharges that do not meet CWA standards, and provide some discussion on how CWA authorities could be used to address this complex issue. As discussed above in Section 1.1.2 and below in Section 8, the NPDES program could be initiated to drive technology development and implementation for ballast water treatment. After all, this was a successful regulatory tool for bringing municipal and industrial discharges in the San Francisco Bay Region to their present improved performance, and as the District of Columbia Circuit Court of Appeals recently indicated, “the cornerstone of the Clean Water Act’s pollution control scheme is the National Pollutant Discharge Elimination System (NPDES) permit program…” (*Natural Resources Defense Council, Inc. vs. EPA* 822 F.2d 104, 108 [D.C. Cir. 1987]).

1.1.5 Phased Approach to TMDL

EPA has described a phased approach to TMDL development for situations where data and information needed to determine the TMDL and associated allocations are limited. The phased approach is essential to developing a TMDL for exotic species in San Francisco Bay.

As discussed above and demonstrated in the Problem Statement (Section 2), there may never be adequate scientific information to determine a quantitative assimilative capacity for exotic species in San Francisco Bay, because of our limited abilities to predict (1) which organisms will become ANS in new environments; and (2) the maximum number of specific organisms that can be discharged without inoculating the estuary. We are also hampered in such a quantitative analysis because of lack of broad taxonomic expertise necessary to identify both exotic and native species.

Indeed, the National Science Foundation has developed its recent program “PEET: Partnerships for Enhancing Expertise in Taxonomy” to address the potential “extinction” of professional taxonomists, who as a group are aging and retiring without being replaced (PEET website). New taxonomists are not emerging because of the recent lack of jobs and funding in taxonomy and systematics. The loss of biological diversity has been accompanied by a loss in the expertise necessary for identifying and inventorying the biota of the Earth. Retirement of taxonomic specialists, shifts in academic recruitment and staffing, and reductions in graduate training all conspire to diminish the knowledge that is needed to answer what the National Science Board has labeled a global crisis ("Loss of Biological Diversity: A Global Crisis Requiring International Solutions," NSB 89-171). Introducing exotic species into new environments has been shown to contribute to this global crisis (Wilcove, et al., 1998).

In addition, ballast water management approaches described in Section 5 (Linkage Analysis) have not been fully implemented, nor their effectiveness in controlling exotic species introductions fully ascertained, so it is premature to impose a standard that may or may not be achievable. Nonetheless, the Source Assessment (Section 4) clearly identifies substantial ongoing sources, and the Linkage Analysis (Section 5) demonstrates the importance of controlling these ongoing sources. In accordance with EPA guidance, this phased TMDL contains a monitoring and review plan (Section 8).

TMDLs must include specific information to be approved by U.S. EPA Region 9. This information can be summarized by in the following seven elements:

1. **Plan to meet State Water Quality Standards**: The TMDL includes a study and a plan for the specific water and pollutants that must be addressed to ensure that applicable water quality standards are attained.

2. **Describe quantified water quality goals, targets, or endpoints**: The TMDL must establish numeric endpoints for the water quality standards, including beneficial uses to be protected, as a result of implementing the TMDL. This often requires an interpretation that clearly describes the linkage(s) between factors impacting water quality standards.

3. **Analyze/account for all sources of pollutants**: All significant pollutant sources are described, including the magnitude and location of sources.

4. **Identify pollution reduction goals**: the TMDL plan includes pollutant reduction targets for all point and nonpoint sources of pollution.

5. **Describe the linkage between water quality endpoints and pollutants of concern**: The TMDL must explain the relationship between the numeric targets and the pollutants of concern. That is, would the recommended pollutant load allocations exceed the loading capacity of the receiving water?

6. **Develop margin of safety that considers uncertainties, seasonal variations, and critical conditions**: The TMDL must describe any uncertainties regarding the ability of the plan to meet water quality standards. The plan must consider these issues in its recommended pollution reduction goals.

7. **Include an appropriate level of public involvement in the TMDL process**: This is usually achieved by publishing public notice of the TMDL, circulating the TMDL for public comment, and holding public meetings in local communities. Public involvement must be documented in the states' TMDL submittal to EPA Region 9.

Section 1.1 Key Points:

- **A TMDL is a plan to meet water quality standards.**
- **A TMDL is required when effluent limits or other pollution control requirements don't fix water quality problems.**
- **"Other pollution control requirements" includes the existing national regime for ballast water management, administered by the U.S. Coast Guard.**
- **A description of the maximum pollutant load a waterbody can handle is fundamental to TMDL development.**
- **EPA regulates biological pollutants.**
- **One of the principles of water quality control is biological control.**
- **The Regional Board listed exotic species as a pollutant impairing the waterbodies of the San Francisco Estuary.**
- **EPA approved the Regional Board's impaired waterbodies list.**
- **The ship vector is the largest on-going source of exotic species to the Estuary.**
- **The TMDL program is not the preferred program to address prevention of the introduction of exotic species, for several reasons.**
- **Rather than follow a period of technology development and implementation, this TMDL is intended to hasten one.**
- **Quantitative assimilative capacity determinations for exotic species are elusive because of limited abilities to predict what species will become nuisances, and the lack of broad taxonomic expertise necessary to identify both native and exotic species.**
- **EPA allows development of a phased TMDL when more information is needed.**
- **EPA has specific guidance for what has to be in a TMDL.**

1.2 Current Federal and State Programs to Control Exotic Species in Vessel Discharges

1.2.1 Regional Water Quality Control Board Authorities

The California Regional Water Quality Control Board, San Francisco Bay Region (Regional Board), administers the Clean Water Act, under its federally designated authority. The Regional Board consists of nine governor-appointed members who serve five years terms. Science information is gathered and policy is developed for the Regional Board by its civil service employees (staff), currently numbering approximately 100 in the San Francisco Bay Region. The Regional Board has adopted a Water Quality Control Plan (Basin Plan) that specifies water quality standards for the San Francisco Bay watershed, and implementation measures to enforce those standards.

Those measures that go beyond the scope of the current Basin Plan must be adopted by the Regional Board after the appropriate Basin Planning process. In the State of

California, this requires that the proposed Basin Plan first presented to the Regional Board in a publicly noticed hearing. Public comments are taken, and sixty days later staff present responses to comments and relevant revisions to the proposed amendment. The Regional Board then votes on adoption, and if the amendment is adopted, it is sent to the State Water Resources Control Board (State Board) for approval. The State Board, consisting of five governor-appointed members, votes on approval of the proposed amendment. If the State Board approves the amendment, it is sent to the Office of Administrative Law (OAL) to determine whether the amendment is consistent with California law. After OAL approval, the final step in adoption of a Basin Plan amendment is EPA approval.

The entire Basin Plan amendment process can take one to three years to proceed through all steps. However, EPA has authority to promulgate its own regulations if the State process is not meeting the requirements of the Clean Water Act in a reasonable amount of time. EPA has already taken such measures in California, the most notable being setting numeric criteria for water quality in the California Toxics Rule. EPA has also signaled its intention to promulgate the measures proposed in this TMDL if necessary.

To date, the Clean Water Act has not been used explicitly to control introductions of exotic species to waters of the United States. In the 1970s, the National Pollutant Discharge Elimination System (NPDES) regulations were written to exempt ballast water discharges from NPDES permits, on the basis that they were considered to have minimal impacts. The importance of vessels and global trade in the transport of exotic organisms between coastal ecosystems was not understood until the 1980s, when dramatic examples of deleterious aquatic invasions came to light.

1.2.2 International Maritime Organization (IMO) Voluntary Guidelines

On November 27, 1997, the IMO’s Marine Environmental Protection Committee (MEPC) adopted Resolution A.868(20), “Guidelines for the Control and Management of Ships’ Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens.” The IMO recommends that all maritime nations of the world adopt and use these voluntary guidelines. Included in these guidelines is a standard IMO ballast water reporting form that is used by the USCG in the national program, described below.

On the issue of exotic species introductions, the IMO has endured criticism on the pace of achieving a protective regime. In response to this criticism, the IMO reminds that the main purpose of IMO is to adopt international treaties, which are intended to apply to as many ships as possible. Unanimity of this kind inevitably takes time - it depends on the speed with which Governments act, as well as IMO - and it can only be achieved at all by ensuring that the regulations adopted are very widely acceptable and this can take time (IMO, 2000).

From June 28 to July 2, 1999, the IMO’s MEPC held its 43rd meeting at the IMO headquarters at the Albert Embankment, London, England. The committee's chairman, Mike Julian, said the ballast water issue was the MEPC's top priority. And yet, by the end of the week, there had not been enough progress to move to holding the diplomatic conference necessary to bring in a new convention. According to a press account of the meeting, there was a widely held feeling that failure to agree on mandatory ballast water management regulations would lead to increased unilateral national and regional action to control the spread of invasive species (Singapore Shipping Times, 1999).

The IMO has been an effective organization in addressing oil pollution, but as indicated above, consensus and solutions to the exotic species issue have been elusive. As far as pollution is concerned, the indications are that there has been a remarkable improvement in the amount of pollution caused by ships during the last two decades. This is partly due to the tightening of controls through IMO conventions such as the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and partly to the introduction of better methods of controlling the disposal of wastes. According to a study carried out by the United States National Academy of Sciences, oil pollution from ships fell by about 60% during the1980s while the number of oil spills has also been greatly reduced (IMO, 2000).

1.2.3 Invasive Species Executive Order

On February 3, 1999, President William Clinton signed Executive Order 13112, “Invasive Species.” The Executive Order established the Invasive Species Council, including the Secretary of State, the Secretary of the Treasury, the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Transportation, and the Administrator of the Environmental Protection Agency. It is co-chaired by Interior, Agriculture, and Commerce. The Executive Order directs federal agencies to identify actions under their relevant programs and authorities that can affect the status of invasive species, and use them, subject to the availability of appropriations and within the Administration’s budgetary limits.

The Clean Water Act, administered by the U.S. Environmental Protection Agency, qualifies as a relevant program that would directly affect the status of invasive species, if implemented in a manner recommended in this TMDL report.

1.2.4 National Invasive Species Act

On November 29, 1990, largely in response to the zebra mussel invasion of the Great Lakes and Mississippi River, Congress enacted the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA), which was reauthorized and amended as the National Invasive Species Act (NISA) on October 26, 1996.

NISA recognizes that ballast water is the most significant source of exotic species introductions, but also recognizes and provides funding for education and control of other sources, including aquaculture, bait and fish stocking, and unintentional introductions such as dumping aquariums into receiving waters.

The U.S. Coast Guard (USCG) adopted regulations for implementing the ballast water provisions of NISA in May 1999. In California waters, the USCG regulations implementing the national program *request* regulated vessels to avoid ballast uptake in polluted or infested areas, exchange their ballast water in the open ocean, and *require* them to submit a standard International Maritime Organization (IMO) reporting form. Regulated vessels under NISA include all vessels, U.S. and foreign, carrying ballast water into the waters of the United States after operating beyond the economic exclusion zone, except specific exempted vessels, including crude oil tankers in the coastwise trade and military vessels already regulated under Section 312(n) of the CWA (Uniform National Discharge Standards for Vessels of the Armed Forces). All ships calling in the Great Lakes or in the Hudson River upstream of the George Washington Bridge are required to exchange ballast water in the open ocean.

A key provision of the USCG's regulations is the safety exemption in Section 151.2030. If the ship's master determines that conducting an open ocean exchange is unsafe due to adverse weather, vessel design limitations, equipment failure, or any other extraordinary conditions, the master, operator, or person-in-charge of a vessel is not required to perform a ballast water management practice. While safety of the crew is of utmost importance, this exemption allows foreign ballast water to be discharged into our nation's marine and estuarine waters without any removal of organisms.

The National Ballast Information Clearinghouse (NBIC) and associated National Ballast Survey, administered by the Smithsonian Environmental Research Center (SERC) for the USCG, have been established under the NISA to assess vessel reporting rates. Assessment of vessel reporting rates is the USCG's first step in assessing the efficacy of the NISA program for preventing introductions of exotic species through ballast water. This first step is clearly a positive step towards preventing exotic species introductions, but as discussed in Section 1.2.7, this system of reporting has no associated methods of verification, and does not abate the risk of introductions.

NISA has authorities that can lead to requirements more stringent than the current USCG voluntary regulations. For instance, Section 1101(f) states, "the Secretary shall make the guidelines mandatory if either reporting or compliance with the voluntary system is inadequate." Therefore the statute indicates Congress's intent to develop a program that ensures high compliance, the scope of which includes all ship operations whether or not associated with ballasting, and all ships operating in the United States, whether or not in domestic voyages.

Under NANPCA, the Aquatic Nuisance Species Task Force (ANSTF) was established in Section 1201, and Section 1201(c) specifies an *ex-officio* representative from the San Francisco Bay-Delta Estuary Program.

The ANSTF carries out the national Aquatic Nuisance Species Program, the elements of which include prevention, monitoring, control, research, education, technical assistance, implementation, and reports to Congress. Congress authorized an average of $22 million per year, from 1997-2002, to fund the program. Under NISA authorities, all of the nonpoint sources identified in this TMDL report are being addressed either through education (with Sea Grant) or cooperative efforts with federal and state quarantine agencies, discussed in Sections 4.5 and 4.6.

The ANSTF established a Ballast Water and Shipping Committee (BWSC), and they recently met on March 1, 2000, setting important directions for ballast water discharge standards development under NISA authorities, in light of recent state activity described below in Sections 1.2.5 and 1.2.6 (see Box 1).

The Regional Board has determined that the current voluntary national program for ballast water does not adequately prevent introductions of exotic species to the estuary (see Section 1.2.7, below). Moreover, the open ocean exchange program has been mandatory in the Great Lakes since 1993, and introductions of ANS have occurred since that time (Grigorovich and MacIsaac, 2000; Jensen et al., 2000).

1.2.5 California Assembly Bill 703 (Lempert)

On October 10, 1999, Governor Gray Davis signed into law Assembly Bill 703 (AB 703), which initiated a regulatory program for ballast water in the State of California. Implementation of AB 703 began on January 1, 2000, and is led by the California State Lands Commission, Marine Facilities Division, in consultation with other state and federal agencies, including the State Water Resources Control Board (State Board). All California state agencies are prohibited from imposing different ballast water requirements prior to its sunset date of January 1, 2004 unless mandated by federal law.

The California law essentially makes the USCG program mandatory in the state, similar to the Great Lakes and Hudson River, with some additional requirements. The state adopted the IMO's Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges" as state operating policy. This program requires all vessels that enter the waters of the United States from outside the Economic Exclusion Zone (EEZ – 200 nautical miles from shore) to manage ballast water according to

BOX 1: RECENT ACTIVITY OF THE BALLAST WATER AND SHIPPING COMMITTEE OF THE AQUATIC NUISANCE SPECIES TASK FORCE (ANSTF)

At the March 1, 2000 meeting the BWSC decided to form an ad-hoc Standards Working Group. After reviewing the existing technical information on the efficacies of ballast water exchange and ballast treatment systems, the group will either propose a draft set of standards for ballast treatment systems, or recommend specific research that will be required before such standards can be developed. The draft produced by the workgroup is intended to prompt and focus subsequent discussions within the full Committee on the nature of the standards to be recommended by the BWSC.

The Committee designated the USCG as the lead agency for the workgroup. To date, representatives of the USCG, EPA, and the USFWS have been identified, while Navy and NOAA are in the process of determining the appropriate people. USCG staff is assembling existing technical information on ballast exchange and treatment systems, and developing a summary for use by the workgroup. An initial meeting / conference call will be scheduled for the workgroup in April, 2000 (and announced to the full workgroup), during which the schedule and tasks will be developed. The initial intent is to produce a draft standard out of the Committee by August, 2000.

By coincidence, the Great Lakes Commission (GLC) has submitted a grant proposal to the EPA for funds to support the production of a briefing paper and public forum on standards for ballast water management. If funded, the GLC project will start in September, 2000. It is anticipated that the draft standard developed by BWSC Standards Workgroup will serve as a valuable basis for further discussion and development through the GLC schedule of activities (McKeown, 2000).

prescribed measures. These measures are intended to prevent the introduction and spread of ANS into any of the state's rivers, estuaries, bays, or coastal areas.

All vessels must perform at least one of the following management practices to prevent the release of exotic species into state waters:

- Exchange ballast water in areas not less than 200 nautical miles from any shore and in waters more than 2,000 meters deep before entering the waters of the state;
- Retain ballast water on board the vessel;
- Use an alternative method approved by the state;
- Discharge ballast water to an approved facility; or
- Exchange ballast water in an area agreed to by the state.

The State Lands Commission will conduct inspections in cooperation with the USCG, take samples of ballast water and sediment, examine documents and assess vessels' compliance with the program. Vessel operators must provide certain information required by NISA to the State Lands Commission, in addition to providing it to the USCG as required by NISA.

The law also directs the state to conduct three studies and report the findings to the legislature:

- By December 31, 2002, complete an evaluation of alternatives to managing ballast water, including treatment (lead agency: State Water Resources Control Board);
- By December 31, 2002, complete a study of baseline conditions in coastal and estuarine waters, including an inventory of the location of exotic species (lead agency: Calif. Dept. of Fish and Game, Office of Spill Prevention and Response); and
- By September 1, 2002, complete an evaluation of the effectiveness of the program in reducing exotic species introductions (lead agency: State Lands Commission).

To fund the new state program, the State Lands Commission is authorized to levy an appropriate and reasonable fee on vessels, not to exceed $1,000 per vessel voyage, and to deposit these revenues into a dedicated Exotic Species Control Fund.

AB 703 includes greater surveillance, monitoring, and technology evaluation than the national program, but falls short of protecting the San Francisco Estuary from future introductions of exotic species from ballast water. The shortcomings of the new law, from the perspective of preventing introductions, can be summarized as follows:

- Domestic voyages are exempt. Since open ocean exchange does not eliminate risks of introductions (90% efficiency at best, if executed correctly), a vessel calling in this estuary coming from Los Angeles can still harbor organisms that may have originated from a foreign port, and the San Francisco Bay remains a

potential source of the ANS Amur River clam and Chinese mitten crab to other estuaries of the west coast;
- A ship's master may elect to forego exchange procedures if s/he determines that it is unsafe to do so, allowing untreated foreign ballast water to be discharged in the estuary;
- The techniques for verifying that a ballast water exchange has occurred are rudimentary (e.g., salinity testing), increasing the opportunity for false reporting;
- The requirements to address ballast water treatment consist only of a State Board report with limited funding (approximately $300,000 over two years), which is not the level of commitment necessary to implement a nationwide, technology-based approach to ballast water treatment.

The new law will generate new information that is important for implementing elements of this TMDL. Because it continues to rely on open ocean exchange as a solution to the problem, and it does not apply to ships on domestic voyages, it will not prevent future introductions of exotic species.

1.2.6 Other States' Legislation

This TMDL report repeatedly emphasizes a nationwide approach to addressing the ship vector for exotic species. As the EPA and USCG consider nationwide approaches to technology development and implementation, states other than California are proposing legislation to improve protection of their waters from the ongoing, untreated discharges from the maritime industry.

At the time of this TMDL technical report, the state of Michigan is actively engaged in a legislative process to elevate the issue of exotic species and the ship vector above the current level of the international and national programs. At the time of this report, the proposed law is undergoing review and revision, so it is premature to list the elements of the Michigan bill, since they are subject to change. In Michigan and other Great Lakes states, the national program is already mandatory, but invasions continue, and the state is considering more stringent requirements such as mandatory treatment of ballast water (McCracken, 2000).

The State of Washington passed House Bill 2466 on March 6, 2000, and the Governor signed it on March 24, 2000. The new state law contains provisions that go beyond provisions of both the national and California programs, and begin to address issues raised in this TMDL report, such as the need for ballast water treatment, and the need to establish standards for ballast water discharges, which would "set the bar" for an intensive period of treatment technology development and implementation. For these reasons, the elements of the new law are discussed below, as examples of regulatory initiatives that will improve upon the national program and implement elements of this TMDL. However, unlike California, the Washington program is not fee-supported, and therefore relies on the voluntary partnership and efforts of the shipping and port industries, which are not guaranteed under the new law.

A number of elements of the Washington's new state law add value to the national program, including:

- 50 nautical-mile requirement for ballast exchange, better suited for Pacific coast bathymetry (as opposed to the 200-mile, 2000-meter depth requirement in the Coast Guard regulations);
- Regulation of domestic voyages (except Columbia River and local British Columbia waters);
- July 2002 treatment requirement for unexchanged ballast water;
- Placement of ballast water treatment on an equal policy level as open ocean exchange;
- Use of Coast Guard / IMO report forms;
- Ballast water monitoring;
- Development of a mobile pilot treatment system; and
- Development of ballast water discharge standards.

The national program focuses on managing ballast water only originating in foreign ports, and establishes a 200-mile requirement for open ocean exchange. Some estuaries on the Pacific coast such as San Francisco Bay contain ANS, and the national program, described above under Section 1.2.4, does not yet provide incentive to protect other ports from the spread of these species. Establishing a ballast water exchange zone less than 200 miles off the Pacific coast will provide greater flexibility for ships on domestic voyages to conduct exchanges and will reduce the risk of spreading exotic species throughout the coastal region. The relatively narrow continental shelf of the Pacific coast allows for an open ocean ecosystem much closer than 200 miles offshore.

Currently, the national program sends a message to industry that open ocean exchange is the preferred method of ballast water management, despite the concerns over vessel structure integrity and organismal removal efficiency. At the time of this report, the USCG has approved no other alternative ballast water management methods. By establishing July 2002 as a date for prohibition of untreated or unexchanged ballast water discharges, Washington's new law appropriately places ballast water treatment on the same policy level as ballast water exchange.

The national program allows exemptions for open ocean exchange when there is risk to the safety of the crew, for instance due to stormy seas. The North Pacific Ocean is known for its frequent inclement weather, and therefore a significant percentage of ships calling at U.S. ports along the Pacific coast will not conduct exchange, particularly in winter. Establishing the July 2002 date for implementation of alternative ballast water management for unexchanged ballast water will close a large loophole for ANS introductions along the Pacific coast. This firm date will also provide greater incentive for government, industry, and academia to work together to test and implement ballast water treatment methods.

Maritime industry representatives repeatedly state their recognition of the ballast water problem, but emphasize that to be successful, regulatory reporting requirements must be streamlined and easy to understand. Washington's new law requires the use of standard IMO ballast water reporting forms, which will not add a reporting burden to shippers.

The new law also requires ballast water monitoring for each vessel, allowing some flexibility for a random sampling program, in order to monitor the effectiveness of state and national programs to control ANS introductions.

The new law establishes a cooperative program between the shipping industry, public ports, and the Washington Department of Fish and Wildlife (WDFW) to develop a mobile pilot treatment system for ballast water. This system is to be designed to be compatible among smaller and larger commercial ports, in order to maintain a level playing field among the different ports of the state. As written, the law contains no funding provisions or schedule for such a pilot project, so it is unclear when or if it will be implemented. To date, pilot treatment and monitoring programs have struggled to obtain funds in the manner specified in this law. This example underscores the need for EPA to establish a national program with adequate funding to develop a national effluent guideline for ballast water, and consistent, environmentally based requirements for the maritime industry.

The new law establishes a stakeholder process to support the WDFW in an effort to establish discharge standards for ballast water, consistent with the national program and the Clean Water Act. This process could generate information that would improve the national program, and form the basis for discharge standards that would be enforceable in NPDES permits recommended in this TMDL proposal. The law will enable the department to convene experts and stakeholders on determining the appropriate cost-effective, scientifically verifiable methods that utilize easily measured indices or check for species that indicate the potential presence of ANS or pathogenic species. There is much value in this element of Washington's new law, but without a specified funding mechanism or schedule, we have no guarantee that the information will be generated, which could support development of the nationwide program that is truly needed.

1.2.7 Why Additional Regulatory Action is Warranted

The protections offered by national and California legislation do not go far enough to prevent the permanent impacts of exotic species introductions. Recent legislation in California makes the national program mandatory, requiring ballast water exchange if the ship's master determines it is safe to do so. This recent law has been viewed as an improvement in protection for California's waters, but experience in the Great Lakes region indicates that mandatory exchange requirements do not prevent exotic species introductions via ships. Therefore, from the perspective of abating the risks of point source discharges on beneficial uses, the national and state programs fall short of providing adequate protection. As such, additional regulatory action is warranted that would require ships to treat ballast water, either on the uptake, during the ship's voyage, or during discharge; or preferably, avoid the need to discharge ballast water altogether.

In addition, other vectors associated with ships should be addressed, perhaps through development and implementation of best management practices. Fouling organisms on hulls, on anchor chains, and within sea chests can be transported and introduced into new ecosystems. The risk of introductions to the San Francisco Estuary is probably not as high as with ballast water, due to the exterior stresses and duration associated with a transoceanic voyage. The issue of hull fouling is especially of concern in certain biogeographical regions of the Earth such as Australia, which are located near other biogeographical regions in Southeast Asia, Central Asia, and Africa (see Figure 1-1). Along the Pacific coast, the threat of introductions from organisms on the exteriors of ships may not be as great as in Australia, where certain introductions have been positively traced to ship exteriors (ENRC, 1997).

The recent legislation in the state of Washington represents several steps of progress toward a nationwide approach that could be successful in ushering in ballast water treatment and standards for treatment. The law has several good ideas without secure sources of funding, such as development of discharge standards, and a mobile pilot treatment system. If the EPA would commit to developing a national effluent guideline for ballast water, and the necessary funding that accompanies such a commitment, the public would have a better guarantee that treatment and standards will be developed, ultimately leading to proper protection of the beneficial uses of their waters from the adverse effects of exotic species and pathogens in ballast water discharges. Anything short of a national program will be very difficult to implement, due to the maritime industry’s long history of resisting state regulation (e.g., Intertanko v. State of Washington decision, March 2000).

A successful regulatory program for exotic species and the ship vector will require a coordinated nationwide approach, building on an emerging international organization around the issue (including IMO guidelines and NISA regulations), and will need to be easy to understand by ships’ masters from all maritime nations, and easy to implement by the U.S. Coast Guard, the enforcement agency recognized by ship masters around the world. The maritime industry recognizes the problem of exotic species and the ship vector, and has participated cooperatively in the various stakeholder forums mentioned below in Section 1.2.8. Throughout discussions, workshops, meetings, and conferences on this issue over the last year, representatives of the shipping and port interests have emphasized the need for a consistent, nationwide program (see Box 1, above). Among other concerns, the ports and shippers do not want piecemeal requirements to deter global trade from certain locations, nor to burden ship masters, operators, and agents with confusing requirements on top of all the other regulations with which they must already comply. For these reasons, while legislation in states like California and Washington send an important message that the current national program is not adequately protective, they do not present the ideal solution for the problem, because of inevitable inconsistencies between state programs and resulting confusion to the maritime industry.

Additional regulatory action on ballast water is warranted because the existing regime under NISA, which encourages open ocean exchange, is not preventing ANS introductions. The Great Lakes have had mandatory open ocean exchange requirements for seven years, and continue to be invaded by ANS, such as the spiny fishhook flea

(*Cercopagis pengoi*) in 1998, which is spreading across Lake Ontario and some lakes in upper New York state (Grigorovich and MacIsaac, 2000).

Duluth-Superior Harbor, on Lake Superior, provides an example why the current management regime is not effective, falling short of the central goal of the CWA to protect biological integrity. Since the national law was passed, several new ANS have been added to the list of introductions in this part of the Great Lakes while other existing ANS populations have grown and expanded, such as the zebra mussel and Eurasian ruffe (an invasive fish from ballast water discharges that competes with commercial fisheries).

Since open ocean exchange requirements became mandatory in the Great Lakes in 1993, there have been several new arrivals in Duluth-Superior Harbor that are ANS, exhibiting adverse impacts on aquatic life, fisheries, and infrastructure. Examples include round gobies (*Neogobius melanostomus*) in 1995, threespine stickleback (*Gasterosteus aculeatus*) in 1994, and the rusty crayfish (*Orconectes rusticus*) in 1999 (Jensen et al., 2000).

Actual data being compiled under the USCG's regulatory program underscore the limitations of a voluntary regime to address invasions of exotic species (see Table 4-1). According to the first six months of the National Ballast Survey (July-Dec. 1999), administered by SERC for the USCG, approximately 43% of ships calling at ports inside the Golden Gate Bridge that discharged ballast water (58 out of 134) *did not* exchange ballast water in the open ocean (SERC, 2000). Their reported discharge comprised only 17% of the total volume of reported ballast water discharged, so about 83% of the reported volume of ballast water originating in foreign ports was exchanged on the high seas. Despite this lower volume, researchers from the Great Lakes emphasize that there is no correlation between overall ballast water volume and rate of species introductions (Mills et al., 1993). Because the USCG regulations were adopted less than a year ago, the USCG expects the percentage of vessels exchanging ballast water on the high seas to increase as the maritime industry incorporates the practices into its routines, and especially in the state of California, where 1999 legislation essentially makes the USCG program mandatory for all state waters. Nevertheless, compliance with the USCG regulations in the Great Lakes exceeds 97%, and introductions are ongoing (Gerrity, 1999).

1.2.8 Recent Activity of the Regional Board on Exotic Species

It is the slow pace of technological development and implementation under the current pollution control program for vessels and exotic species, NISA, which provided the impetus for the Board's decision to proceed with a TMDL for exotic species.

A separate stakeholder process for this exotic species TMDL has not been established, since a number of stakeholder processes are already underway, and regulatory action by the Regional Board is precluded until 2004. In early 1999, a draft workplan was developed for this TMDL and Board staff participated in stakeholder meetings and forums (Pacific Ballast Water Group, International Zebra Mussel/Aquatic Nuisance Species Conferences, Coastal Committee of the Western Regional Panel of the Aquatic

Nuisance Species Task Force, and the UC Sea Grant Ballast Outreach Advisory Team) to discuss the proposed TMDL approach as well as other legislative and regulatory initiatives in California and elsewhere.

In conjunction with a terminal development project permit in July 1999, the Regional Board directed staff to work with the Port of Oakland, the largest commercial port in Northern California, to determine the feasibility of treating ballast water discharges to this estuary. A steering committee was formed in October 1999, consisting of representatives of the Port, the Board, Center for Marine Conservation, and the Pacific Merchant Shipping Association. This steering committee organized the "Vessels and Varmints Workshop," to be held at Regional Board offices on May 11, 2000, to describe the most current information on ballast water treatment technology and treatment standards.

In California, Assembly Bill 703 (Lempert) became state law in October 1999, which made Coast Guard voluntary standards under the National Invasive Species Act (NISA) mandatory and set up a fee-supported regulatory program, administered by the State Lands Commission. After several meetings and coordination with the State Lands Commission and the State Department of Fish and Game, the Regional Board was updated on the dynamic regulatory landscape in September 1999.

In December 1999, the Northeast-Midwest Institute, a non-profit organization that contributed to the NISA legislation, convened stakeholders in a forum at Washington, D.C., entitled "The NISA Ballast Management Program: Opportunities to Add Value Through Partnerships." Although staff from California state agencies did not attend, staff of the Port of Oakland did attend, and recommendations of this forum are referenced throughout this TMDL technical report, in order to reflect a reasonable range of stakeholder opinions on this complex issue. Attachment 1 was created by the Northeast-Midwest Institute as a result of this stakeholder forum, and contains a comprehensive comparison of ballast water management programs under IMO, NISA, Great Lakes, and California AB 703.

Throughout these discussions, two clearly identified goals have been articulated before the Regional Board:

i) Focus regulatory efforts on discharges to the San Francisco Estuary that may contain exotic organisms, such as ballast water and exterior surfaces of vessels; and
ii) Prevent the introduction of new exotic species to the San Francisco Estuary. Controlling the spread of exotic species already established in the estuary is <u>not</u> a goal of this TMDL.

This TMDL report addresses these goals by incorporating stakeholder recommendations with the best available science and technology to derive early source reduction actions and long term monitoring strategies to close information gaps. It also relies on numerous laws and organizations to carry out their funded mandates to prevent introductions from vectors besides vessels.

In 1998, the State Board committed to delivering two technical TMDL reports per year from each region as deliverables for TMDL grant funding. This report fulfills one of the deliverables due from the San Francisco Bay Region in April 2000. A technical TMDL report contains all of the elements of a TMDL without an implementation plan. However, because the issue is international in scope and requires a consistent national approach, this report also includes a discussion of implementation issues for EPA’s consideration (Section 8). Due to the recent state legislation (AB 703), the Regional Board is unable to initiate a Basin Planning process to adopt and implement this TMDL until 2004. As such, the Regional Board is delivering this report to EPA to meet a grant commitment, but also to emphasize that action is warranted on a national scale to prevent additional waterbodies from becoming impaired due to exotic species introduced through the ship vector.

Section 1.2 Key Points:

- **Water quality law in the San Francisco Bay region is administered by the Regional Water Quality Control Board (Regional Board)**
- **The Regional Board is supported by a staff of approximately 100, mostly engineers, geologists, biologists, and chemists.**
- **The Regional Board defines water quality standards in its Basin Plan, and has authority to enforce those standards.**
- **Implementation items may require Basin Plan amendments, which can take up to three years to fully adopt.**
- **To date, the Clean Water Act has not been used explicitly to control introductions of exotic species to waters of the United States.**
- **A draft workplan for an exotic species TMDL was presented to the Regional Board in July 1999.**
- **In 1999 - 2000, staff participated in a number of stakeholder forums to refine the TMDL approach described in the draft workplan.**
- **In 1997, the International Maritime Organization (IMO) established voluntary guidelines for ballast water management and encourages all maritime nations of the world to adopt and use these voluntary guidelines.**
- **National legislation on the ship-vector for exotic species was enacted in 1990, and updated in 1996 as the National Invasive Species Act (NISA).**
- **The U.S. Coast Guard is the lead federal agency implementing NISA, and developed regulations that became effective on July 1, 1999, which are voluntary in the State of California.**
- **Existing forums under NISA are making progress toward recommendations for ballast water discharge standards for alternatives to ballast water exchange.**
- **California State Assembly Bill 703, enacted October 10, 1999, made the voluntary elements of the national program mandatory for all ships calling in California ports that originate outside the Economic Exclusion Zone (EEZ), and specifies authorities for the State Lands Commission, the California Dept. of Fish and Game, and the State Water Resources Control Board. AB 703 prohibits the Regional Board from amending the Basin Plan until after the law sunsets on January 1, 2004.**
- **Washington State House Bill 2466, enacted March 24, 2000, made the voluntary elements of the national program mandatory for all ships calling in Washington ports that originate outside Washington, British Columbia, and the Columbia River. The new law recognizes a 50-mile limit for open-ocean exchange, mandates that all ballast water be treated or exchanged by July 2002, establishes a mobile pilot treatment system, and authorizes the state's Department of Fish and Wildlife to develop ballast water discharge standards.**
- **Michigan is considering legislation that would have more stringent requirements than the current national program.**
- **The protections offered by national and state legislation do not go far enough to prevent the permanent impacts of exotic species introductions, so a TMDL of zero is proposed.**
- **This TMDL fulfills a deliverable obligation that the State Water Resources Control Board has to the United States Environmental Protection Agency.**

2. Problem Statement

Ongoing, Untreated Discharges of Exotic Species and Pathogens in Ballast Water Threaten the Region's Ecology, Economy, and Public Health, Even When a Ballast Water Exchange with Mid-Ocean Waters Has Occurred.

With over 230 established exotic species, many of them dominant in their range, the San Francisco Estuary is one of the most invaded estuaries in the world (Cohen and Carlton, 1995). Moreover, the introduction of exotic species into the estuary is currently accelerating, with experts estimating that a new exotic species has been established every 14 weeks since 1961 (Cohen, 1998). Ships' ballast water is probably the most important mechanism transporting exotic marine and freshwater organisms around the world today. In recent years, ballast water discharges have introduced the Amur River clam (*Potamocorbula amurensis*), the New Zealand sea slug (*Philine auriformis*), two or three species of Black Sea jellyfish, over a dozen species of Asian zooplankton, possibly the Chinese mitten crab (*Eriocheir sinensis*), and scores of other exotic organisms that have become established in the estuary (Cohen, 1998). It is unknown how many unidentified native species may have become extinct in the wake of this remarkable invasion. Unless preventative measures are taken, the rate may accelerate further if the amount of foreign ballast water arriving in the estuary rises with projected port expansions and further globalization of trade.

Although the San Francisco Estuary provides an alarming example of exotic species impacts, ballast water invasions in other parts of the world are reminders that the impacts can be relatively much worse, threatening the ecology, economy and public health in a region.

Other countries are battling exotic species in their waters, sometimes those originating from North American shores. One of the most devastating invasions has been documented in the Black Sea, where the Atlantic comb jelly, native to the mid-Atlantic bight, has virtually eliminated the crustacean zooplankton community, contributing to the decline of the region's fisheries and the economy that is based on them (Harbison and Volvik, 1992; Travis, 1993; Bright, 1999). A Japanese sea star has devastated shellfisheries in Tasmania and the associated elements of the economy (Seastar Ecology Group, 1996).

Public health is at risk from untreated ballast water discharges, even when the ballast water is exchanged on the high seas. Cholera (*Vibrio cholerae*) is transported with ballast water, including ships that report "no ballast on board" (NOBOB), which have unpumpable ballast water and sediments and associated organisms that can be re-suspended when water is taken in (McCarthy and Khambaty, 1994; Knight, 1999). An epidemic strain of cholera from South America was apparently discharged with ballast water into waters of the Gulf Coast of the United States, where it was discovered in fish and shellfish (MMWR, 1993; Federal Register, 1998). It may have been ballast water that originally transported the strain from Asia to South America, triggering an epidemic in 1991 that resulted in over one million reported cases and 10,000 deaths (Tauxe, 1995; Ditchfield, 1993).

Other public health threats in ballast water discharges include toxic algal blooms, including those referred to as "red tides." In some parts of the world there have been new or increasingly frequent outbreaks of toxic red tides caused by microscopic organisms called dinoflagellates. These dinoflagellates produce neurotoxins that accumulate in shellfish, causing illness and sometimes death in the people that eat them (Culotta, 1992). Recent studies have shown that in some of these regions toxic dinoflagellates were introduced in the sediments transported with ballast water (Hallegraeff et al., 1989, 1990, 1991; Hallegraeff and Bolch, 1992; Hallegraeff 1993). *Pfiesteria piscicida*, another neurotoxin-producing dinoflagellate that could be transported with ballast, has caused large fish kills on the east coast of the United States and memory loss and learning problems in some people exposed to contaminated waters in North Carolina (Culotta, 1992; Mlot, 1997). Additionally, there are increases in reports worldwide of various marine diseases that affect species such as marine mammals, commercially important fisheries and shellfish, and coral, which is probably exacerbated by ongoing transport of ballast water around the world (Harvell et al., 1999).

2.1 Waterbody name and location

The San Francisco Estuary is a natural embayment in the Central Coast of California that has been described as "one of the most impacted estuaries" in the National Estuaries Program (Nichols, Cloern, Luoma, and Peterson 1986). The impacts date back 150 years to the California Gold Rush, when hydraulic mining and dredging substantially altered the bathymetry and geochemical cycles of the estuarine system (Kelley, 1989). While still rebounding from those historic perturbations, the estuary is now being impacted by a surrounding metropolitan population of approximately eight million people, burgeoning residential, agricultural, and industrial development, natural weathering processes throughout its drainage basin, and a booming global shipping trade that has been accompanied by an increased rate of exotic species introductions (Cohen, 1998).

The San Francisco Estuary includes several waterbodies identified in the San Francisco Water Quality Control Plan (Basin Plan), all of which are included as impaired by exotic species on the 1998 California 303(d) list. These waterbodies include Central San Francisco Bay, Lower San Francisco Bay, South San Francisco Bay, Richardson Bay, San Pablo Bay, Carquinez Strait, Suisun Bay, and the Sacramento/San Joaquin Delta (see Figure 1).

The estuarine system is divided into two major hydrographic regions, the northern reach and the southern reach, that are linked by the central bay to the Pacific Ocean (Basin Plan, 1995). The northern reach is seasonally well flushed by fluvial discharges, because more than half of California's freshwater discharges through Sacramento and San Joaquin Rivers to the Delta. Approximately 90% of this flow occurs between November and April. This freshwater discharge replaces the volume of the northern reach every 1-60 days, depending on flow conditions. In contrast, direct fluvial discharges to the southern reach (South Bay) are negligible, because it is cut off from Central Valley drainage by the Diablo Range; the water replacement time in the lagoon-like South Bay ranges from 120 to 160 days or more (Cheng, et al. 1993; Walters et al., 1985; Smith 1987).

2.1.1 Exotic Species Impacts on Designated Beneficial Uses of San Francisco Estuary

The Bay supports a variety of beneficial uses defined in the Basin Plan (Basin Plan, Table 2-1, 1995). As stated in the California 303(d) list, approved May 1999, exotic species introductions result in disruption of native species, bioaccumulation of elements like mercury and selenium in the food chain, and reduction in food availability for native species; rare, threatened and endangered species; and commercially important species.

The beneficial uses primarily threatened by exotic species introductions relate to aquatic life, and include estuarine habitat (EST), marine habitat (MAR), ocean, commercial, and sport fishing (COMM), shellfish harvesting (SHELL), fish migration (MIGR), fish spawning (SPAWN), cold freshwater habitat (COLD), warm freshwater habitat (WARM), wildlife habitat (WILD), and preservation of rare and endangered species (RARE).

When exotic species proliferate due to lack of predation or competition, they often exhibit explosive growth rates and can coat or foul elements of infrastructure, such as intake pipes, pumps, piers, pilings, and buoys. Examples of ANS that have exhibited these fouling characteristics include the zebra mussel (*Dreissena polymorpha*) in the Great Lakes and Mississippi River Basins, and the Asian freshwater adhesive mussel (*Limnoperna fortunei*) from mainland China, which invaded Japan’s Ibi River in 1990 (Magara, 1999), and the Rio de la Plata and Parana’ rivers of Argentina in 1991 (Darrigran et al., 2000). Zebra mussels are estimated to cost the invaded regions of the U.S. approximately $3 billion annually, and rising, to mitigate the effects of this remarkable invasion (Pimentel et al., 1999). Therefore, indirect impacts can result to other beneficial uses of state waters from exotic species, notably from bio-fouling of infrastructure, and these uses include agricultural supply (AGR), industrial service supply (IND), municipal and domestic supply (MUN), navigation (NAV), industrial process supply (PRO), and noncontact water recreation (REC2), also known as aesthetic enjoyment of waters.

Water contact recreation (REC1) is threatened by the pathogens and toxic dinoflagellates that have been documented to be contained in ballast water discharges from transoceanic voyages (McCarthy and Khambaty, 1994; Hallegraeff, 1998; Whitby, 1998, Knight, 1999).

Table 2-1

Beneficial uses of waterbodies of the San Francisco Estuary defined in the Basin Plan. Beneficial uses that are most likely to be impaired by future exotic species introductions are boldfaced, and example(s) provided.

Beneficial Use	Abbreviation	Exotic Species carried by Ships that can Impact Use (example)
Agricultural Supply	**AGR**	**Zebra mussel**
Cold freshwater habitat	**COLD**	**Round goby**
Ocean, commercial and sport fishing	**COMM**	**Round goby, Shrimp virus**
Estuarine habitat	**EST**	**Amur River clam (*Potamocorbula*)**
Freshwater replenishment	FRSH	
Groundwater recharge	GWR	
Industrial service supply	**IND**	**Zebra mussel**
Marine habitat	**MAR**	**Japanese shore crab**
Fish migration	**MIGR**	**Chinese mitten crab**
Municipal and domestic supply	**MUN**	**Zebra mussel**
Navigation	**NAV**	**Zebra mussel**
Industrial process supply	**PRO**	**Zebra mussel**
Preservation of rare and endangered species	**RARE**	**Chinese mitten crab**
Water contact recreation	**REC1**	**Cholera, Other pathogens, Toxic dinoflagellates**
Noncontact water recreation	**REC2**	**Zebra mussel**
Shellfish harvesting	**SHELL**	**Green crab, Cholera, Toxic dinoflagellates, Invertebrate pathogens**
Fish spawning	**SPWN**	**Fish pathogens, Chinese mitten crab (increased siltation from burrowing into banks)**
Warm freshwater habitat	**WARM**	**Asian swamp eel**
Wildlife habitat	**WILD**	**Pathogens to wildlife**

2.2 Water Quality and 303(d) status

There are three regulatory triggers for the finding of impairment in San Francisco Bay due to exotic species: (1) disruption of the natural benthos, (2) changing pollutant availability in the food chain, and (3) disruption of food availability to native species. These findings led the Regional Board to list Bay waters as impaired in accordance with CWA Section 303(d).

The California 303(d) report, dated May 1999, specifies the source of exotic species introductions to be ballast water discharges. While there are other potential sources of exotic species introductions, ballast water appears to be the most significant in the San Francisco Estuary based on recent introductions documented by Cohen and Carlton in 1995 (See Tables 4-2 and 4-3 and Figure 4-3). Ballast water discharges, currently unregulated under the Clean Water Act, pose risks not only to the Estuary's ecology as documented in the 303(d) list, but also economy and infrastructure, and public health.

2.2.1 Exotic Species Impacts on Ecology

Ecological impacts of exotic species in the San Francisco Estuary are the basis for the original decision to put exotic species on the 303(d) list, for the three reasons listed above. The ecological impacts of the *Potamocorbula* invasion are as dramatic as any documented in the literature, and provided the impetus for the Board's 303(d) listing decision. It provides a good example of the potential broad range of impacts that one or more exotic species can exert on an ecosystem. Since it was first discovered in Suisun Bay in 1986, it has proliferated to the point of covering the main estuarine portions of the estuary, excluding native organisms, and depleting the phytoplankton bloom to the detriment of other organisms that need it for food (Carlton et al., 1990; Nichols et al., 1990; Alpine and Cloern, 1992; Kimmerer et al., 1994; Orsi, 1995). It also concentrates selenium in the food chain at a higher rate than the native organisms, and this has led to greater concentrations of selenium in higher organisms such as diving ducks (Luoma and Linville, 1997). These are the impacts of *Potamocorbula* that are understood based on a handful of scientific studies – many more subtle and adverse effects on native, sensitive, and commercially important species may be occurring, but we do not have the committed tools, agencies, or funding to understand the full range of impacts of exotic species invasions like *Potamocorbula* in the San Francisco Estuary.

The recent invasion of the Chinese mitten crab (*Eriocheir sinensis*) in 1992 may have been from intentional introduction or through ballast water (Cohen, 1998). Like *Potamocorbula,* this species has a wide range of existing and potential impacts that cover the spectrum of ecology, economy, and public health. The high fecundity of this species has enabled it to reproduce in massive numbers, overwhelming the fish salvage and water diversion facilities of the state and federal water projects in 1998 (Wynn et al., 1999). The impacts of this invasion included mortality of endangered species of fish, displacement of native organisms, and competition with native organisms for food. The swarming numbers of crabs are arguably an adverse aesthetic impact (noncontact water recreation beneficial use – REC2). The economic cost of abating the impacts of the mitten crab at the water facilities was high, but its tendency to burrow and weaken levees and streambanks may lead to economic impacts throughout California related to stabilization efforts that could be astronomical. Such impacts are being recorded in San Francisquito Creek in South San Francisco Bay, but monetary estimates are not presently available (Napolitano, 2000). Finally, the mitten crab is also a potential threat to public health. In Asia, the mitten crab is a host organism for the Oriental lung fluke parasite, which fortunately has not been recorded yet in California.

2.2.1.1 DISRUPTION OF NATURAL BENTHOS

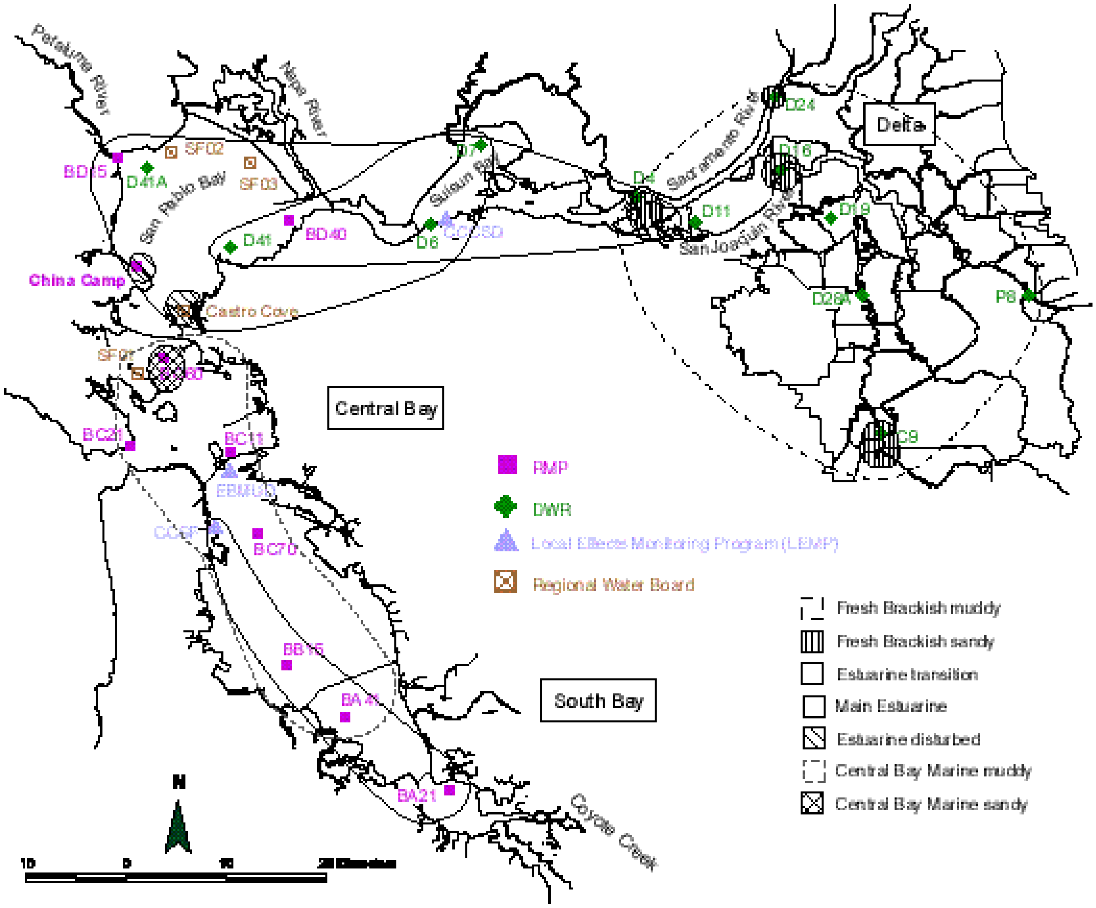
The bottom-dwelling invertebrates of the San Francisco Estuary, known collectively as the benthos, have been substantially altered by numerous exotic species introductions such as *Potamocorbula*.

Using data from the 1995 study by Cohen and Carlton, and benthic community analyses from several other studies, the San Francisco Estuary Institute conducted a Benthic Pilot Study in 1999 as part of the San Francisco Estuary Regional Monitoring Program. The study determined that the benthos of San Francisco Estuary can be divided into seven distinct assemblages (Figure 2-1). Although the original study purpose was to establish reference conditions for benthic organisms as a way of evaluating impacts of waste discharges, the compositions of benthic assemblages that were generated in the study are largely exotic species in some parts of the estuary (Thompson et al., 1999).

Data from the Benthic Pilot Study reveal the consequences of random exotic species introductions in the estuary. Almost all benthic samples collected in the Bay between 1986 and 1997 contained exotic species. Only three samples from a Central Bay sandy site, Red Rock near the Richmond-San Rafael Bridge, contained no exotic species. That site is located mid-channel with very dynamic hydrology and has very sandy sediments and low species diversity and abundance. Table 2-2 lists the 60 exotic species that are found in the benthos of San Francisco Estuary (Thompson et al., 1999).

Subsequent to the Benthic Pilot Study, staff of the San Francisco Estuary Institute and EPA Region IX assessed the contribution of exotic species to the benthos in each of the seven species assemblages. The main estuarine and estuarine transition assemblages had the highest proportions of exotic species diversity and abundance, and the Central Bay sandy assemblage had the lowest incidence of invasions (Figure 2-2). The latter represents only one site, atypical of the estuary's predominantly muddy substrate, and should not be broadly interpreted. The high density of exotic species in the estuarine assemblages reflects to a large degree the presence of *Potamocorbula*. This single introduced exotic species accounted for about 43% of the total abundances in those assemblages (Table 2-3). It is important to note, however, that even without *Potamocorbula*, exotic species constituted almost 50% of the individuals. The abundance of *Potamocorbula* was greatly reduced (0.2%) in the "disturbed" estuarine sub-assemblage, while the total abundance of other exotic species again constituted about 50% of the total individuals.

Figure 2-1
Distribution of Macrobenthic Assemblages in San Francisco Estuary based on the Benthic Pilot Study (Thompson et al., 1999)[3]



In addition to over 230 confirmed exotic species in the estuary, Cohen and Carlton identified 123 species that are "cryptogenic," for which there is not information to determine if the species are native or exotic. If these cryptogenic species are assumed to be exotic species, then the percent of species diversity and abundance of exotic organisms in the assemblages goes up in most cases, especially for the assemblages that cover a larger area of the estuary, as depicted in Figure 2-1 (Table 2-3). While inclusion of these ambiguous species changed the percentages, they did not change the overall spatial pattern of invasion, which seems to favor the estuarine and fresh-brackish portions of the estuary.

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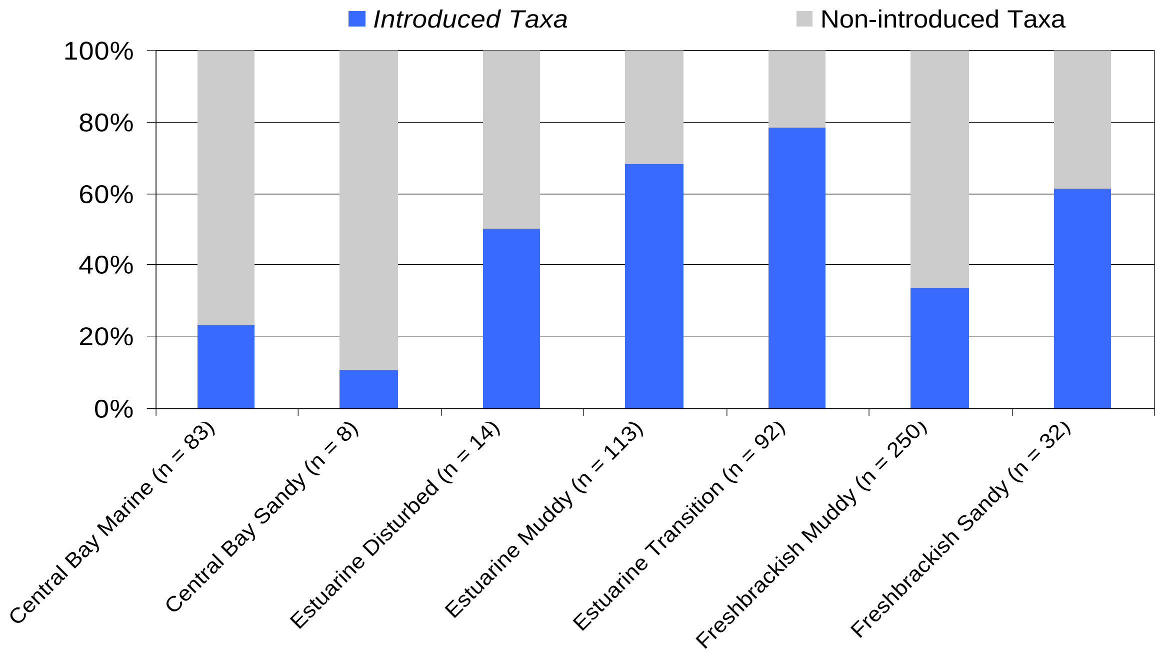
[3] San Francisco Estuary Institute, Regional Monitoring Program for Trace Substances (RMP). Overlapping distributions indicate that the benthos at some sites changed related to changes in freshwater flow and salinity.

Figure 2-2

Percent of Introduced Taxa in the Macrobenthos of the San Francisco Estuary (1994-1997)



Percent of Total Abundance of Introduced Taxa in the San Francisco Estuary (1994-1997)

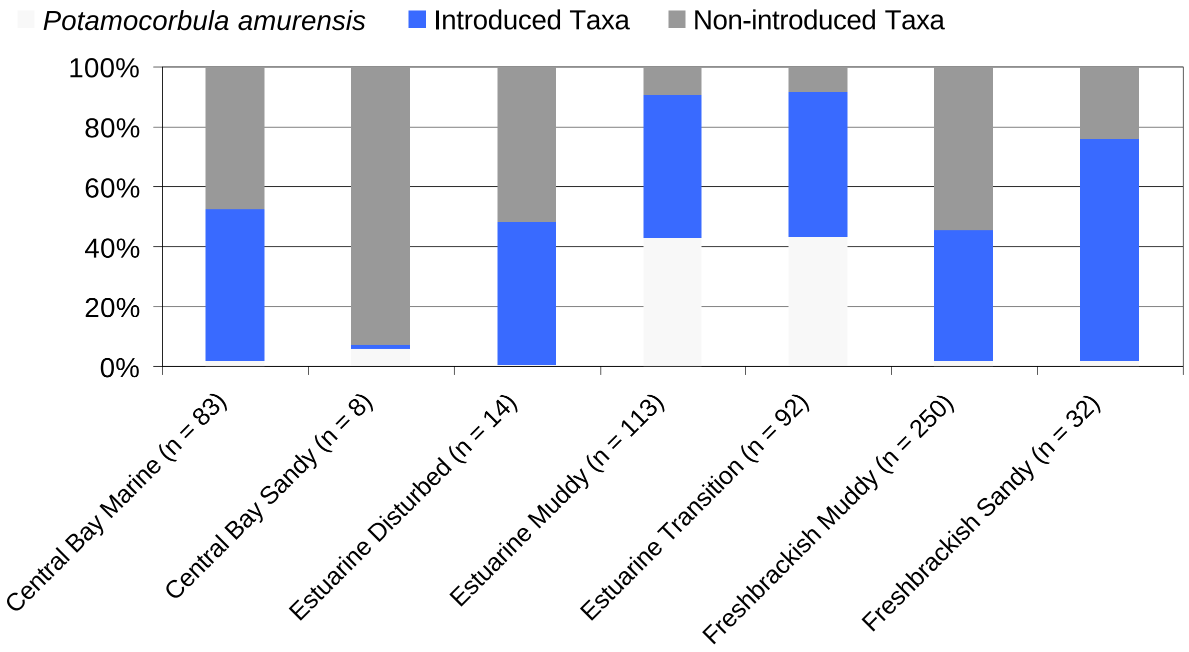


Table 2-2
Nonindigenous species collected from the eight benthic studies from the Regional Monitoring Program Benthic Pilot Study (Thompson et al., 1999). The nonindigenous species were identified from Cohen and Carlton (1995).

NON-INDIGENOUS TAXON	YEAR OF INTRODUCTION	NON-INDIGENOUS TAXON	YEAR OF INTRODUCTION
Acanthomysis aspera	1992	*Melita nitida*	1938
Acanthomysis bowmani	1992	*Molgula manhattensis*	1950
Ampelisca abdita	1954	*Monopylephorus evertus*	1996
Ampithoe valida	1941	*Munna sp. A*	1900
Balanus improvisus	1900	*Musculista senhousia*	1946
Boccardiella ligerica	1954	*Mya arenaria*	1900
Bowerbankia gracilis	1963	*Nippoleucon hinumensis*	1986
Branchiura sowerbyi	1963	*Okenia plana*	1950
Caprella mutica	1976	*Palaemon macrodactylus*	1957
Corbicula fluminea	1945	*Paranais frici*	1961
Corophium acherusicum	1912	*Parapleustes derzhavini*	1904
Corophium alienense	1973	*Philine auriformis*	1992
Corophium heteroceratum	1986	*Polydora ligni*	1933
Corophium insidiosum	1931	*Potamocorbula amurensis*	1986
Crepidula convexa	1900	*Potamothrix bavaricus*	1965
Crepidula plana	1901	*Pseudopolydora kempi*	1972
Diadumene leucolena	1936	*Pseudopolydora paucibranchiata*	1973
Eusarsiella zostericola	1953	*Rhithropanopeus harrisii*	1937
Ficopomatus enigmaticus	1920	*Sabaco elongatus*	1950
Gammarus daiberi	1983	*Schizoporella unicornis?*	1963
Gemma gemma	1900	*Sinelobus stanfordi*	1943
Grandidierella japonica	1966	*Stenothoe valida*	1941
Heteromastus filiformis	1936	*Streblospio benedicti*	1932
Ilyanassa obsolete	1907	*Synidotea laevidorsalis*	1900
Jassa marmorata	1977	*Tenellia adspersa*	1953
Macoma petalum	1988	*Theora lubrica*	1982
Manayunkia speciosa	1963	*Tubificoides brownae*	1961
Marenzelleria viridis	1991	*Tubificoides wasselli*	1961
Marphysa sanguinea	1969	*Urosalpinx cinerea*	1900
Melanoides tuberculata	1988	*Venerupis philippinarum*	1946

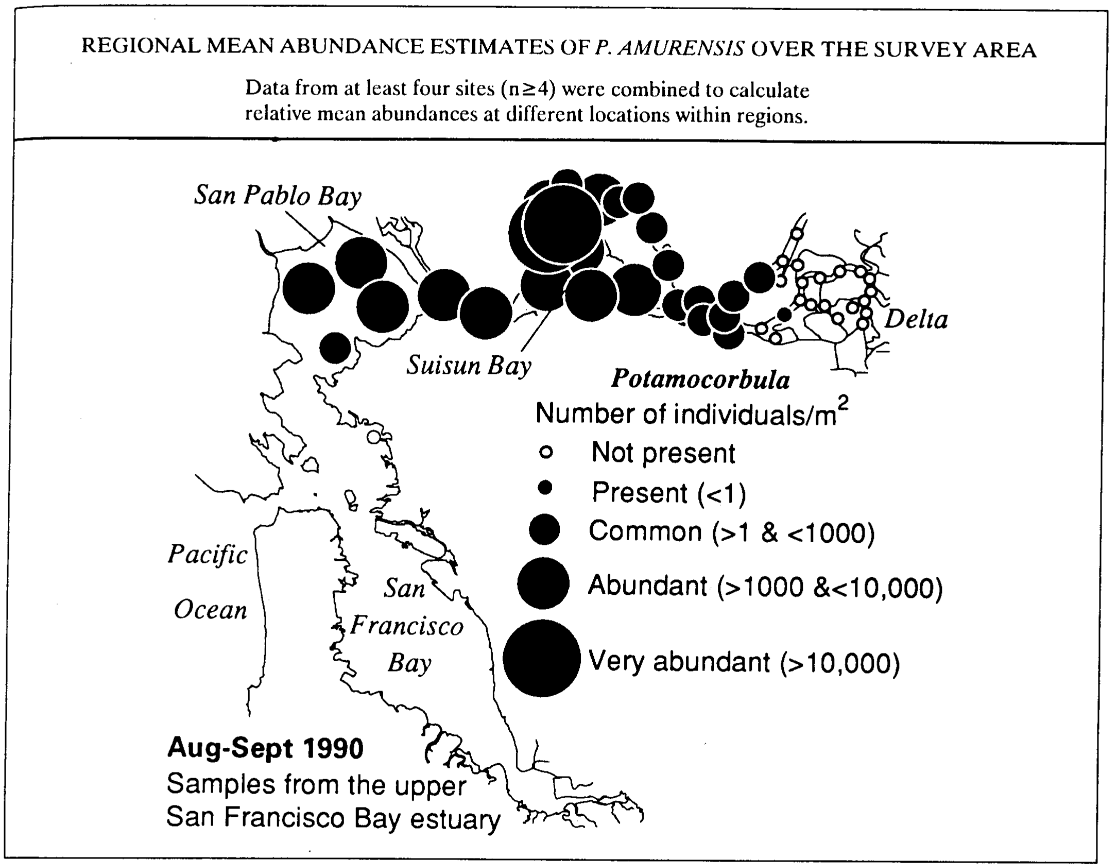
Table 2-3
Mean (Range) Percent of Exotic Species and Total Abundances in the Macrobenthic Assemblages in the San Francisco Bay-Delta. Data: RMP Benthic Pilot Study (1994 – 1997)

Macrobenthic Assemblage	**Percent Exotic Species**		**Percent Exotic Abundances**		**Percent *Potamocorbula* Abundance**
	Known[1]	**with Cryptogenics[2]**	**Known**	**with Cryptogenics**	%
Central Bay Marine Muddy n=81	23.3 (7.3 – 53.3)	32.5 (8.0 – 60.0)	52.8 (1.7 – 96.6)	64.8 (2.1 – 97.3)	1.7
Central Bay Marine Sandy n=8	10.7 (0 – 20.0)	22.6 (0.0 – 50.0)	7.2 (0 – 24.2)	25.6 (0.0 – 68.0)	6.2
Main Estuarine n=113	68.4 (22.7 – 100)	68.5 (20.0 – 100)	91.0 (1.1 – 100)	91.3 (1.1 – 100)	43
“Disturbed” Estuarine n=14	50.2 (23.1 – 73.3)	52.3 (30.8 – 73.3)	48.4 (0.13 – 97.6)	62.4 (8.9 – 100)	0.2
Estuarine Transition n=92	78.7 (37.5 – 100)	81.7 (37.5 – 100)	91.7 (25.3 – 100)	92.4 (25.3 – 100)	43.4
Fresh-Brackish Muddy n=250	33.6 (12.5 – 75.0)	50.4 (15.4 – 87.5)	45.8 (0.2 – 98.2)	60.2 (0.2 – 98.2)	1.6
Fresh-Brackish Sandy n=32	58.4 (20.00 – 100)	76.2 (25.0 – 100)	70.3 (12.5 – 100)	79.7 (35.8 – 100)	1.6

[1] From Cohen & Carlton, 1995, Table 1
[2] From Cohen & Carlton, 1995, Table 1 and Table 2

Four years after the first individual *Potamocorbula* clam was identified by a biology class from Diablo Valley College in Concord, the Interagency Ecological Studies Program sponsored a study of the spatial extent of the invasion in a technical report. Figure 2-3, below, is reproduced from that report, and graphically shows the dramatic abundances of individual *Potamocorbula* clams in the northern portion of the estuary, which routinely exceed densities of 10,000 individuals per square meter (Hymanson, 1991).

Figure 2-3[4]


REGIONAL MEAN ABUNDANCE ESTIMATES OF *P. AMURENSIS* OVER THE SURVEY AREA

Data from at least four sites ($n \geq 4$) were combined to calculate relative mean abundances at different locations within regions.

2.2.1.2 INCREASED BIOACCUMULATION OF POLLUTANTS

Much emphasis of exotic species impacts is placed on their displacement of native organisms, but exotic species can change the pathways of contaminant bioaccumulation in ecosystem food webs in instances where an exotic species becomes prey for higher trophic organisms. The case of *Potamocorbula* was studied by the U.S. Geological Survey because of the remarkable abundances of this organism and the resultant impact on the diets of higher trophic organisms, and its presence in a part of the estuary that is impaired by the bioaccumulative element selenium.

The USGS studies of selenium and the benthic food web conducted during the early 1990s determined that *Potamocorbula* accumulates selenium in its tissues at higher concentrations than any other benthic organism that is ingested by diving ducks such as scaups and scoters (Luoma et al., 1996). Because of its high relative abundance, its introduction into the estuary therefore increased the bioaccumulation factor (BAF) for selenium in the food web. Meanwhile, enforcement orders on oil refineries in the region

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[4] Source: Hymanson, 1991. *Results of a Spatially Intensive Survey for* Potamocorbula amurensis *in the Upper San Francisco Bay Estuary.* Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Technical Report No. 30, October 1991.

in the early 1990s required research, development, and implementation of selenium removal technology, resulting in substantial selenium mass reductions and $45 million in capital investments. The research and operations and maintenance costs are not currently available, but are probably on the same order-of-magnitude as the capital costs (Tang, 2000). This case study illustrates how an exotic species can reverse successful pollutant reduction efforts by altering fundamental components of the conceptual food web model – in this case the BAF for the northern estuary. Although the selenium source has been reduced, the diving ducks may be exposed to more selenium than before due to *Potamocorbula*'s ability to concentrate selenium more efficiently than other benthic organisms.

The mud snail *Illynassa obsoleta* was introduced to the San Francisco Estuary, probably around 1907 along with oysters, which were then raised and harvested in Bay waters (Cohen and Carlton, 1995). In South San Francisco Bay, this species is a major prey species for the endangered California clapper rail (*Rallus longirostris obsoletus*). Studies by the U.S. Fish and Wildlife Service indicate that this species bioaccumulates mercury, selenium, and silver at higher rates than other prey species of the clapper rail (Schwarzbach, 2000). The introduced mud snail provides yet another example of how an introduced species can increase the concentration of contaminants in the food web, effectively canceling some of the reductions of these pollutants that may have been achieved through pollution prevention or treatment.

2.2.1.3 INTRODUCTION OF MARINE DISEASES

In the past few decades, there has been a worldwide increase in the reports of diseases affecting marine organisms. Diseases affecting benthic marine species such as corals and seagrasses have larger impacts by altering habitat and ecosystem function. Evidence is mounting that diseases that are detected are new. Most new diseases occur by host shifts and not by the emergence of new microorganisms. Economically and ecologically important species such as shellfish, coral, and marine mammals have been studied more extensively and have exhibited increases in disease that are not evident in the geologic record, suggesting anthropogenic influences such as ballast water transport and aquaculture, as well as pollution from sewage and stormwater runoff. Epidemics must also be affecting less apparent species, many of which may be disappearing without notice (Harvell et al., 1999).

Human activities have greatly enhanced global transport of agents of marine disease. In terms of introducing marine diseases, aquaculture is the most commonly identified vector, and it has been suggested that most mass mortalities of bivalve mollusks have resulted from transfer of infected stocks (Farley, 1992). Due to economic concerns, spread of shrimp viral diseases has been well documented. For instance, the infectious hypodermal and hematopoietic necrosis virus, which appears to have its origin in the Indo-Pacific region, now occurs throughout the world causing catastrophic epidemics in aquaculture facilities. The vector for transport of this devastating shrimp virus is not limited to transfer of aquacultural materials – its host range appears to include a wild species of shrimp and its spread was partially responsible for halting the Mexican commercial fishery for a few years, causing significant economic impacts (Harvell et al., 1999). This example demonstrates how a marine disease, transferred in aquacultural materials, can escape into the local ecosystem, and its global transport enhanced by ballast water uptake and discharge. These processes are too random to control after-the-fact, and provide another compelling argument for routine disinfection of ballast water discharges.

2.2.2 Exotic Species Impacts on Economy and Infrastructure

Certain exotic species, especially fouling organisms such as the zebra mussel (*Dreissena polymorpha*) and the Asian freshwater adhesive mussel (*Limnoperna fortunei*), can cause economic and infrastructure impacts that are difficult to anticipate, but once they are introduced, the economic effects can be permanent and substantial. Such economic impacts are being repeated at locations throughout the world, emphasizing the fact that Americans have a choice to pay now for preventive measures, or pay more later for abating the tremendous economic impact of permanent invasions. Zebra mussels, quagga mussels, and other fouling organisms such as *Limnoperna fortunei* and *Perna perna* have not yet invaded west coast states. There is still time to prevent these potentially devastating invasions through consistent, nationwide institution of control measures for ballast water that go beyond open ocean exchange.

The zebra mussel has become a major problem in the Great Lakes and Mississippi River Basins by clogging water systems, intakes, and discharge pipes for cities, factories, and power plants, resulting in an annual price-tag of over $3 billion and rising (Pimentel et al., 1999). It also fouls boat hulls, fouls buoys until they actually sink (creating a navigation hazard), and accumulates in immense numbers on recreational beaches, creating an offensive odor (OTA, 1993; Cohen, 1998). Many of the largest water systems in California appear vulnerable to invasion by the zebra mussel, and the resulting costs could be substantial (Cohen and Weinstein, 1998). The economic impacts of the zebra mussel precipitated the national legislation in 1990.

Commercial fisheries are not as extensive in the San Francisco Estuary as other regions of the United States such as the Pacific Northwest, the Great Lakes, and the Gulf of Mexico. The estuary supports a herring fishery for exports to Japan, and a bay shrimp bait fishery (Rugg, 2000). Similarly, sport fishing is not as extensive as other regions of the nation, such as the Great Lakes, where it is a $1 billion industry. Therefore, since the local economy is not as dependent on fisheries as other areas, the economic impacts of their decline from exotic species are not expected to be as great as other areas of the world, such as the Black Sea, where the destruction of fisheries from an exotic species invasion had a widespread economic impact (Travis, 1993; Harbison and Volvik, 1994).

2.2.3 Exotic Species Impacts on Public Health

Ballast water discharges to the San Francisco Estuary have not been characterized for pathogens and toxic dinoflagellates such as red tide organisms or *Pfiesteria piscicida* (Cohen, 1998). However, many studies demonstrate that pathogens and dinoflagellates are commonly detected in ballast water, even from transoceanic voyages (Cohen, 1998).

Canadian studies conducted in the winter of 1997 on ships arriving mainly from Europe found that ballast water discharges commonly violated water quality standards, with 50 percent of the ships carrying ballast water contaminated with fecal coliforms. Ships arriving in the summer, or from Asian ports, would be likely to have substantially higher rates of contamination (Whitby, 1998).

The limited information available on pathogen content of ballast water strongly suggests that discharges of ballast water violate effluent limitations that are placed on sewage treatment plants in the San Francisco Bay Region. A recent pathogen survey of ships in the Great Lakes trade revealed that 88 percent of ships sampled (n=27) had detectable fecal coliform, typically in the range of 10-200 MPN/100ml, with a few samples exceeding Basin Plan ambient criteria for water contact (90th percentile of 400 MPN/100ml). Additionally, these discharges would not comply with the effluent limit for the San Mateo Wastewater Treatment Plant, for instance, which discharges into the Bay's deep channel near water recreation areas, and is a maximum of 200 MPN/100ml. Since most ballast water discharges occur in shallow port areas, the applicable effluent limit would probably be consistent with municipal dischargers that receive less than 10:1 dilution at their outfalls, based on *total* coliform, which tends to be about four times higher than fecal coliform in the same water samples. To protect public health and prevent outbreaks of wildlife disease in slough areas, "shallow water" dischargers such as San Jose/Santa Clara and Fairfield-Suisun must meet a five sample median limit for total coliform of 23 MPN/100ml and a maximum of 240 MPN/100ml. Ballast water discharges in the Great Lakes survey would violate such a limit over half the time.

In the Great Lakes pathogen survey, about 75% of the samples were from residual water in "empty," or NOBOB tanks, and 25% were from full ballast tanks. Eleven ships were surveyed for specific pathogenic organisms. Cholera was detected in 15% of ships, enterovirus was in 18% of ships, *Giardia* was in 18% of ships, and hepatitis A and *Cryptosporidium* were in 9% of ships sampled. The eleven ships in this particular study were also sampled for fecal *Streptococcus, Salmonella typha*, *Clostridium*, and pathogenic *E. coli* 0157-H7, which were not detected in this limited survey. Pathogens to shellfish, fish, and wildlife were not analyzed in this survey (Knight, 1999).

In August 1997, a red tide was reported and confirmed in the Berkeley Marina, in Central San Francisco Bay near the Golden Gate. Throughout the marina, the water color was a deep reddish brown, and the phytoplankton community was almost entirely composed of the dinoflagellate *Gymnodinium sanguineum* (=*splendens*), a species known from tropical and subtropical coastal waters around the world. Noxious odors developed and organisms that had been growing on the sides of the floats and pilings sloughed off. The observations at Berkeley Marina raised concerns about potential impacts to fish and other organisms, and on people who worked in contact with the water or were exposed to the noxious odors. Reddish water was also reported in Oakland Outer Harbor and boat operators reported streaks of red water in the open bay waters. By September 1997, Berkeley's Aquatic Park, a brackish-water lagoon connected to the Bay through culverts and tide-gates, contained red water. City employees removed 50-75 dead fish, including striped bass and halibut, from the lagoon soon thereafter. Possible causes of the observed kills of near-surface invertebrates in Berkeley Marina and fish in Aquatic Park may have been direct toxic effects from the red tide, low oxygen levels associated with decay of the bloom, or night-time respiration by the dense dinoflagellate concentrations. It is not definitively known if this toxic bloom in San Francisco Bay resulted from warmer waters associated with El Nino, or if this dinoflagellate was discharged in ballast water. Subsequent surveys in late fall 1997 confirmed that the dock fouling communities returned to normal after the algae bloom, but many questions remain about the source of the 1997 red tide in San Francisco Bay (Cole and Cohen, 1998).

Oceans and estuaries have been identified as incubators and conveyors of human diseases (Harvell et al., 1999). Many potentially pathogenic organisms, including *Aeromonas*, *Clostridium*, *Klebsiella*, *Legionella*, *Listeria*, *Pseudomonas*, and *Vibrio*, are naturally active in estuaries and oceans, and some can persist in dormant, non-culturable but viable states (Colwell and Spira, 1992). While cholera provides a compelling case for the need to disinfect ballast water discharges, described below, there are other microorganisms in ballast water not yet studied that may pose equal or greater risk. According to local public health experts, other strains of *Vibrio* could be transported in ballast water. Examples include *V. vulnificus* (can cause sepsis/shock), *V. bronchosepticum* (causes pulmonary dysfunction), and *V. aeromonas*, a self-limiting diarrheal illness (Baxter, 2000). Enteric viruses generally survive longer in fresh and marine water than coliform bacteria, which are commonly monitored for testing water quality, so in instances where fecal coliforms are not detected in samples, a public health risk may still be present (Harvell et al., 1999).

As mentioned above, *Vibrio cholerae*, the cholera-causing bacterium, has been detected in ballast water and correlative analyses have suggested that *V. cholerae* detected in the Gulf of Mexico may have come in ballast water from Lima, Peru (MMWR, 1993; McCarthy and Khambaty, 1994). An average of 0-5 cases of cholera are reported in the U.S. annually (CDC, 2000). In the San Francisco Bay Area, one case of cholera was treated at the Stanford Medical Center in April 1996, contracted by a merchant marine on an aircraft carrier at the Alameda Naval Air Station, inbound from Bremerton, WA, that dropped his hammer into bilge water and subsequently retrieved it. Since cholera has a six-day incubation period, and the merchant marine had not been out of the country for over a month, the exposure to this disease was probably from the bilge water (Benjamin and Frank, Alameda Co. Public Health Dept., 2000; CDC *V. cholerae* case #1996-3).

Recent studies on *V. cholerae* are generating information that is vital to abating the public health risks associated with ballast water discharges. *V. cholerae* provides an example of an organism that is commonly picked up in ballast water, ideally equipped to survive oceanic journeys in ballast tanks, and readily transferred from port to port. The latest studies suggest that *V. cholerae* has a viable non-culturable “resting” state, and show that it can grow as a biofilm on the sides and structural elements of ballast tanks (Schoolnik and Yildiz, 1999). This cholera biofilm is highly resistant to chlorine, and certainly resistant to a simple ballast water exchange, which does not generate the shear stresses necessary to discharge the entire biofilm layer into the mid-ocean.

Molecular fingerprinting of *V. cholerae* has provided evidence of genetic similarity between epidemics that are separated by large geographic distances, with the only plausible explanation being ballast-mediation, based on review of actual shipping traffic. The evidence to-date is considered correlative and circumstantial, but it raises serious concerns about the efficacy of current management practices in abating transfer of dangerous microorganisms via ships, especially considering the tendency of these organisms to form resistant biofilms on ballast tank surfaces. For instance, it is posited that the current Lima, Peru cholera epidemic may have originated in Indonesia based on these lines of evidence, as well as the subsequent outbreak of cholera in Mobile Bay, Alabama (MMWR, 1993; McCarty and Khambaty, 1994). Another recent study showed genetic similarity in cholera between an outbreak in Veracruz, Mexico, and organisms from the Danube River in Europe, and identification of shipping voyages that occurred concurrently (Schoolnik, 2000).

Many of the microorganisms of concern in ballast water are “exotic pathogens,” and qualify as exotic species under the definitions in this TMDL, but there are also pathogens endemic to the United States that should be noted. For instance, there is a strain of *V. cholerae* endemic to the Gulf of Mexico region, and most of the 91 cases in the United States between 1973 and 1993 are attributable to this organism. The genetic studies can distinguish biotypes and serotypes of cholera organisms based on production of enzymes, cholera toxin gene patterns, and presence of associated viruses. The reason why a cholera epidemic is not occurring in the United States due to ballast water discharges is that cholera cannot get a start like it did in Latin America where there is limited sewage treatment (Schoolnik, 2000).

The specter of biofilms on the inside walls and structural elements of ballast tanks poses a number of public health and treatment challenges. Chlorine is inactivated by *V. cholerae* biofilms, and the biofilms are resistant to oxidative agents (Schoolnik and Yildiz, 1999). Technology development for abating public health risks of ballast water discharges must consider this mode of organismal transfer.

In summary, there is much evidence, including from San Francisco Bay, that potential impacts to public health from ballast water discharges are substantial. Also, ongoing ballast water discharges to this Estuary would not meet the effluent limits that the Regional Board sets for municipal discharges to protect both public health and fish and wildlife from harmful pathogens. For these reasons, a TMDL is proposed that would lead to permitting on a nationwide level, and a system of accountability for ballast water discharges that is on the same level as municipal and industrial dischargers in the San Francisco Bay Region.

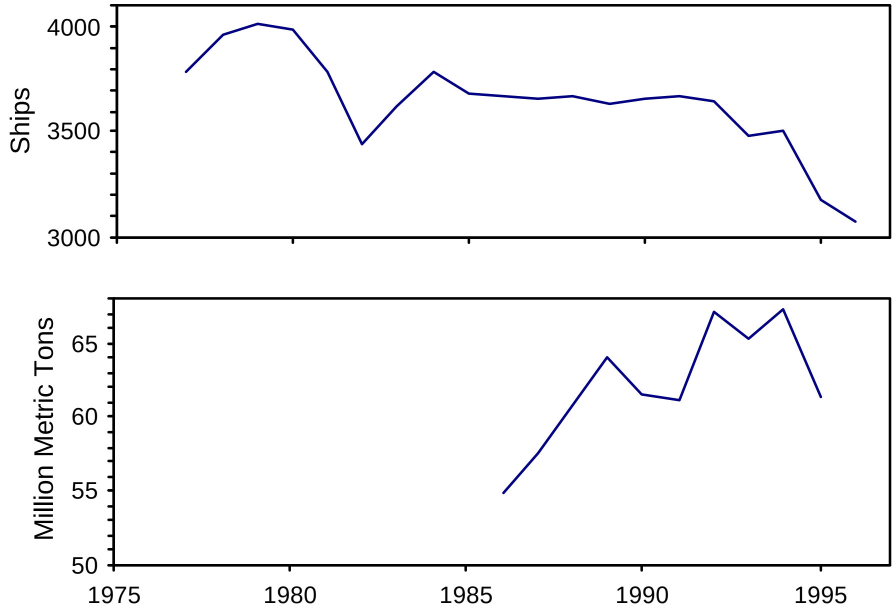
2.3 Increasing Global Trade

Ballast water invasions, toxic red tides, and marine diseases are clearly on the increase, and concurrently, the pressure to increase global trade is being applied. Over 80% of global trade occurs via shipping, and all signs indicate that there will be future growth. Therefore, part of the problem with exotic species introductions in the estuary is a theoretical increase in the probability of more invasions, unless comprehensive regulatory actions are taken to arrest the upward trend, graphically shown in Figure 4-3.

While the number of ships arriving in the estuary has been gradually declining, the sizes of the ships and the amount of cargo they handle have been increasing (Figure 2-4). For example, the 1996 update of the Bay Area Seaport Plan reported that the number of vessel calling at Bay Area ports fell from 2,597 to 2,299 ships between 1988 and 1993, while the quantity of cargo handled rose from 18 to 20 million metric tons (20 to 22 million short tons) (Seaport Plan, 1996). The shipping and cargo study conducted for the Seaport Plan projects substantial further increases (Manalytics, 1988). The total tonnage of cargo exported is projected to grow from less than 6 million metric tons in 1980 to over 36 million metric tons in 2020 (Figure 2-5), primarily due to increases in containerized cargo (growing from 2.5 to 22.4 million metric tons, and accounting for 64% of the total increase) and petroleum products (growing from 0.7 to 8.8 million metric tons, accounting for 26% of the increase). Imports are projected to increase from 7 to almost 25 million metric tons between 1980 and 2020, with containerized cargo (growing from 1.3 to 7.5 million metric tons) and petroleum products (growing from 4 to 12 million metric tons) again being the main contributors, together accounting for nearly 80% of the total increase.

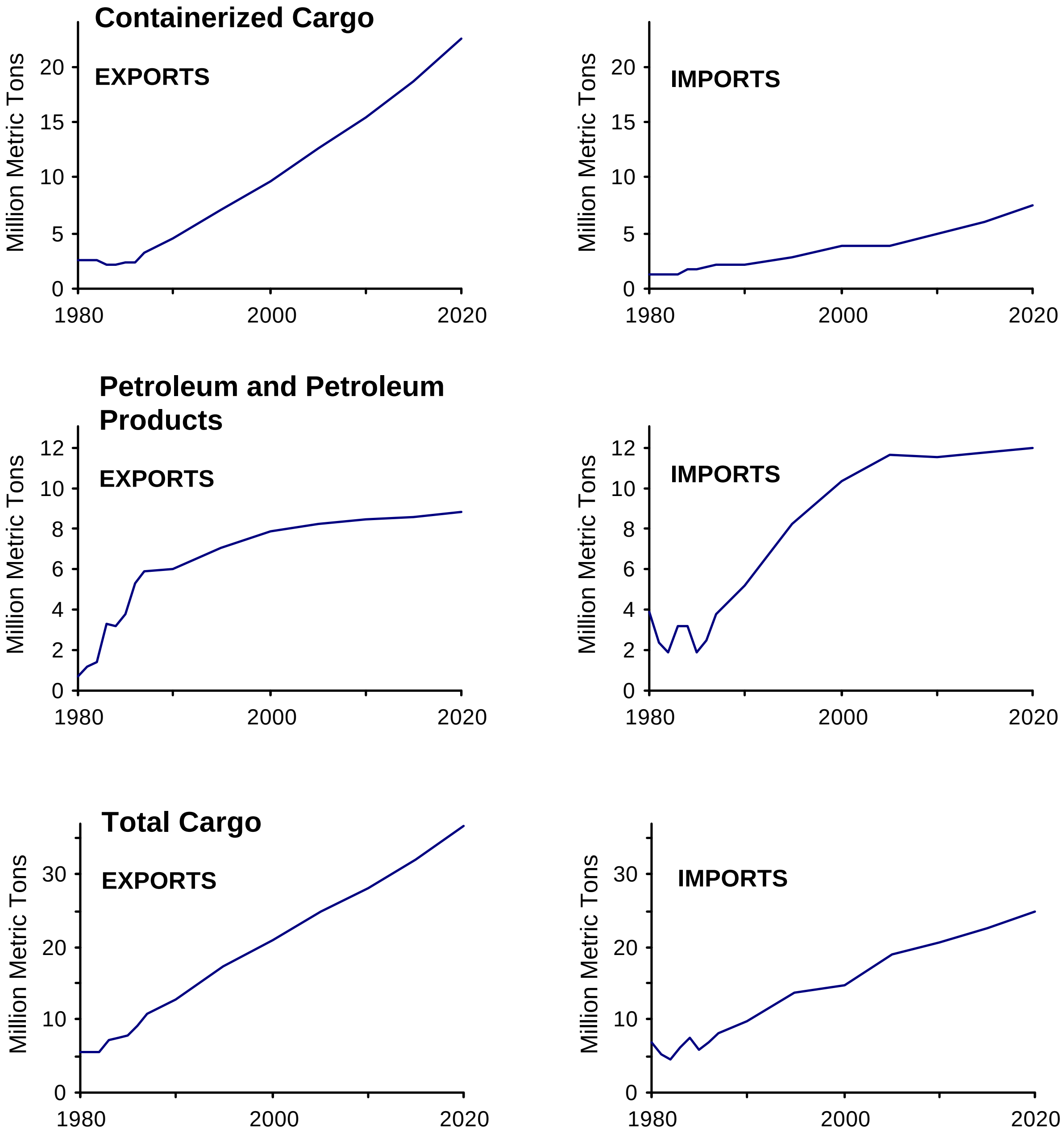
As Figure 2-5 shows, growth in exports is projected to exceed growth in imports. This projection is positive from an economic standpoint, but it raises concerns for untreated ballast water discharges. Ships that export more than they import bring in ballast water from other foreign and domestic ports. Ships that carry cargo one-way, such as oil tankers shipping crude oil from Alaska to the Bay Area, will discharge foreign ballast water in the ports where they load cargo for export. Recent studies of Prince William Sound in Alaska, where crude oil is exported, show that 14 exotic species (13 crustaceans and one fish) are being carried by tankers and being discharged into the sound, associated with San Francisco Estuary, Long Beach, and other port areas that receive shipments of crude oil from Alaska. Fortunately, for now, evidence indicates that these species have not established resident populations, but the area has only begun to be studied in the last couple of years. At least 15 exotic species have already been established in Prince William Sound, but they are different than the ones identified in the tanker study, and many of them were introduced along with aquaculture (Sonnevil, 2000).

Figure 2-4
Trend of Ship Arrivals and Cargo Tonnage at San Francisco Estuary Ports



From Cohen, 1998, Ship data from Marine Exchange 1997. Cargo data from US Army Corps 1996.

Figure 2-5
Export and Import of Cargo Tonnage through San Francisco Bay Area Ports



From Cohen, 1998, Based on data from Manalytics 1988. 1980-87 is actual cargo tonnage; figures to 2020 are projections.

Section 2 Key Points:

- **With over 230 established exotic species, many of them dominant in their range (e.g., *Potamocorbula amurensis*), San Francisco Bay is one of the most invaded estuaries in the world.**
- **Examples from this estuary and from throughout the world demonstrate that exotic species and pathogens transported in ballast water, if discharged to a specific region, threaten the ecology, economy, and public health of that region.**
- **The potential ecological impacts of exotic species introductions are very broad, including displacement of native organisms, competition with native organisms for food, increasing bioaccumulation of contaminants in the food web, and increases in marine diseases that can also have economic impacts to aquaculture and fishing.**
- **Public health impacts of ballast water discharges are not well studied, but many pathogens are known to survive in seawater, and much evidence exists that implicates ballast water as a vector of water-borne disease worldwide.**
- **Toxic algal blooms are increasing globally, and such organisms are transported in ballast water every day.**
- **Ballast water that has been studied would not meet coliform effluent limits placed on municipal dischargers to protect people that swim and sail in the Bay.**
- **Open ocean exchange does nothing to abate the risk to public health of pathogenic organisms that form biofilms on the inside of ballast tanks.**
- **Global Trade is increasing, and channels to ports are being deepened, both of which will lead to greater volumes of ballast water discharges to this estuary.**
- **The San Francisco Estuary is a potential source of invasive exotic species to other ports along the Pacific coast as well as other nations.**
- **Almost every beneficial use of the Estuary and its tributaries are threatened by exotic species introductions, including endangered species and water supply to agriculture and cities throughout the State.**
- **There is still time to institute controls on ballast water, consistent with**

3. Numeric Target

The lack of available data on predictability of harmful invasions precludes the development of a complex, quantitative TMDL for exotic species. However, the narrative water quality objective, discussed below, is clearly violated by ongoing discharges of exotic species, especially from vessels, and the Regional Board has designated exotic species as a high priority pollutant under Section 303(d). This qualitative assessment of impacts from exotic species, based on extensive scientific investigations by Cohen and Carlton (1995), Nichols et al. (1990), Alpine and Cloern (1992), Luoma and Linville (1997), Kimmerer et al. (1994), Orsi (1995), and Thompson et al. (1999) provide a foundation for a numeric target of zero viable exotic organisms in discharges. Because technology-based limits have not been developed and implemented for ballast water, a zero-TMDL is proposed that will mandate nationwide technology development and implementation with zero as the appropriate target.

Because of the significant risks, the working hypothesis is that a water quality-based endpoint to achieve the estuary's water quality standards is *no exotic species introductions*. In other words, an acceptable total maximum daily load (TMDL) of exotic organisms or species is "zero." Based on the worst-case examples documented worldwide, the San Francisco Estuary does not have a capacity to assimilate exotic organisms in a general sense. Technically, this estuarine ecosystem may have a range of abilities to assimilate, or otherwise adapt to, various exotic species introductions. However, the Amur River clam (*Potamacorbula amurensis*) provides us with a sobering example of a species that was not assimilated, but conversely, changed the fundamental trophic structure of the San Francisco Estuary ecosystem by annually depleting the spring phytoplankton bloom, beginning in the late 1980's (Nichols et al., 1990; Alpine and Cloern, 1992, Kimmerer et al., 1994).

The Chinese Mitten Crab (*Eriocheir sinensis*) is another example of an organism that cannot be assimilated by this ecosystem, but rather, exerts irreversible changes on the ecosystem that are only beginning to be quantitatively assessed. This species was first identified in South San Francisco Bay in 1992, and may have been introduced via ballast water or intentionally introduced because of its economic value in southeastern Asia. In September 1998, hundreds of thousands of individuals of this recently introduced species clogged water intake systems of the state and federal water supply aqueducts and compromised the functioning of fish screens designed to protect endangered fish species. The mitten crab invasion has negatively impacted fish salvage operations at these facilities, causing high mortality of fish in collection and transport apparatuses (Wynn et al., 1999). The density of individuals was so high during the adult fall migration in 1998 that state and federal water officials expressed alarm at their potential impact on water deliveries. This recent incident shows how an exotic species can threaten beneficial uses such as municipal domestic and agricultural supply (MUN, AGR) and preservation of rare and endangered species (RARE).

At this time, we do not know whether implementation of technology-based limits on ballast water discharges will lead to attainment of water quality standards for water bodies of the San Francisco Estuary. Under the CWA statute at Sections 301(b)(1)(A) and 303(d), a TMDL is required when a water body does not meet water quality standards and point sources requiring NPDES permits with technology-based effluent limits have still not solved the problem. Based on the current federal regulations, the vessels cannot be issued NPDES permits because they are exempt. Therefore, the TMDL is required, and the zero load will be "allocated" to non-NPDES sources of exotic organisms.

3.1 Narrative Water Quality Objective

Chapter 3 of the San Francisco Bay Basin Plan contains both numeric and narrative water quality objectives, required to protect beneficial uses of the region's waterbodies, including those of the San Francisco Estuary.

On the 1998 303(d) list for the State of California, the Regional Board found that exotic species are impairing beneficial uses of the waterbodies of the San Francisco Estuary by (1) disrupting the natural benthos; (2) changing pollutant availability in the food chain; and (3) disrupting food availability to native species.

The three adverse effects cited in the 303(d) list constitute violations of the narrative water quality objective for *population and community ecology*, on page 3-3 of the Basin Plan. The narrative objective states that:

> *…the health and life characteristics of aquatic organisms in waters affected by controllable water quality factors shall not differ significantly from those for the same waters in areas unaffected by controllable water quality factors.*

As point sources of exotic species and pathogens, vessel discharges are examples of controllable water quality factors. Studies by Nichols et al. (1990), Cohen and Carlton (1995), Luoma and Linville (1997), and Kimmerer et al. (1994), among others, have demonstrated that the health and life characteristics of aquatic organisms in San Francisco Bay, including phytoplankton, zooplankton, fish, and diving ducks, have been significantly altered by the ballast-mediated invasion of the Amur River clam, *Potamocorbula amurensis*. This clam species provides one of the worst-case invasions of ANS in the United States.

As discussed in Section 4, other point sources include various aquaculture facilities (fish or shellfish) and are also controllable water quality factors. Potential nonpoint sources such as sport or subsistence fishing (introductions through bait), and other unintentional introductions such as aquarium dumping and escapes from the live food market, represent additional controllable water quality factors, but the ability to regulate such activities with the resources of the Regional Board is very limited. Fortunately, prevention of exotic species introductions via these sources are a mandate of the ANSTF under NISA, and is being carried out through various educational and regulatory efforts. Intentional introductions of aquatic nuisance species (ANS) are against numerous laws such as the Lacey Act that are presently enforced by various agencies discussed in Section 4.6.

The state water quality standard for the waterbodies of the San Francisco Estuary includes all designated beneficial uses, numeric or narrative water quality objectives to protect the uses, and antidegradation, or maintenance of existing water quality at a minimum. The finding under 303(d) that the Estuary is impaired due to exotic species, based on the narrative objective above, is based mostly on the data collected on the Amur River clam and the Chinese mitten crab. With over 230 exotic species, other impairments are likely, but there are limited data because the impairment determinations entail a lot of research. For instance, information collected on ballast water in the Great Lakes imply that discharges to this estuary could impair water contact recreation (REC1) near discharge locations (Section 2.2.3), but no data collection efforts on this issue have been initiated to date. Table 3-1 below contains a summary of beneficial uses that are impaired due to exotic species introductions.

Antidegradation requirements of state water quality standards have been established to ensure that waterbodies with high water quality are not degraded to the point where they marginally meet a numeric or narrative objective. A numeric target of zero exotic species introductions implements the state’s antidegradation requirements, set forth in State Board Resolution No. 68-16. Of the three elements of the water quality standard, this TMDL would most directly implement the antidegradation requirement, establishing that any further exotic species introductions would further degrade the waterbodies of the San Francisco Estuary, in violation of the water quality standard. The analysis in Section 2 shows that the effects of any single introduction can range from subtle to catastrophic. Exotic pathogens such as cholera may exhibit temporary impacts, but certain exotic species can permanently change the structure of the estuarine ecosystem.

3.2 Selected Numeric Target for Completing the TMDL

To achieve the narrative objective for population and community ecology, described above, the numeric target is 0 (zero) viable exotic organisms, or species, in discharges. A numeric target of zero means that at the end of the implementation period, there must be no ongoing sources of viable exotic species in discharges to the San Francisco Estuary. The goal has been set at zero because no amount of new exotic species can be deemed as acceptable in the estuary, due to our current inability to predict which exotic species will successfully invade the system, and which species will exhibit characteristics of ANS.

Unlike most TMDLs, the exotic species TMDL for the San Francisco Estuary *precedes* a period of technology development and implementation. The implementation will be phased, and zero wasteload allocations and load allocations can be adjusted as appropriate to reflect best available technology as information becomes available, for instance in the December 2002 report from the State Board. The Regional Board is open to reviewing the implementation plan at the time the state law, AB 703, sunsets on January 1, 2004. A possible review of the numeric target would have to be based on findings of future studies on appropriate threshold levels for best available technology.

Significant reductions in discharges of viable exotic organisms must be achieved before the numeric target can be reconsidered.

Table 3-1
Beneficial Uses of the San Francisco Bay Estuary that have been Impaired by Exotic Species Introductions
(Beneficial uses that have been impaired by exotic species are boldfaced)

Beneficial Use	Abbreviation	Exotic Species
Agricultural Supply	AGR	
Cold freshwater habitat	COLD	
Ocean, commercial and sport fishing	COMM	
Estuarine habitat	**EST**	**Amur River clam (*Potamocorbula*)**
Freshwater replenishment	FRSH	
Groundwater recharge	GWR	
Industrial service supply	IND	
Marine habitat	MAR	
Fish migration	**MIGR**	**Chinese mitten crab**
Municipal and domestic supply	MUN	
Navigation	NAV	
Industrial process supply	PRO	
Preservation of rare and endangered species	**RARE**	**Chinese mitten crab**
Water contact recreation	**REC1**	**Cholera, Other pathogens, Toxic dinoflagellates (threatened – more site-specific data needed)**
Noncontact water recreation	**REC2**	**Chinese mitten crab (swarming appearance during migration – subjective impairment)**
Shellfish harvesting	SHELL	Green Crab has arguably impaired aquaculture in other bays of the Region.
Fish spawning	**SPWN**	**Chinese mitten crab (increased siltation from burrowing into banks)**
Warm freshwater habitat	WARM	
Wildlife habitat	WILD	

At first glance, there appears to be a potential disconnect between a qualitative zero-TMDL goal and a technology-based approach, where a quantitative zero is almost never achievable. However, our nation has already addressed a similar challenge in controlling biological pollutants in drinking water delivered to homes and businesses, under the national Safe Drinking Water Act. Our nation desires a TMDL of “zero” for pathogens in tap water, but our system of measuring compliance considers the performance of the best available treatment technology. Since instances of water-borne disease are now very rare, there is general acceptance of our national treatment-based standards for drinking water, without employing expensive research-level analyses to continually check for the presence of viruses and other microorganisms. The national treatment standard for viruses in drinking water, established in place of maximum contaminant levels or MCLs, is “4-log-kill” or 99.99% removal of viruses. For the protozoan cyst *Giardia*, the treatment standard for drinking water is 3-log kill or 99.9% removal (Pontius, 1990). In some cases a handful of non-native organisms has the potential to initiate a biological invasion of the estuary, and for this reason, a future numeric target of multiple-log kill, based on treatment or best management practices, may be the desired standard for exotic species.

Using this example from EPA’s drinking water regulation, a qualitative TMDL of zero can be rectified with treatment technology that does not achieve an absolute quantitative goal of zero by creating the appropriate regulatory incentives to improve technology performance over a reasonably rapid period of time. Examples of regulatory structures are discussed in Section 8, Implementation Issues.

4. Source Assessment

Because of the dynamics and mobility of biological populations, it is very difficult to draw a cause-and-effect linkage between sources and extant exotic species populations. In some cases where there are no economic factors, for instance *Potamocorbula*, ballast water seems to be the only plausible explanation for introductions to the San Francisco Estuary from its native range in estuaries of Northeast Asia (Amur River delta). In the case of the Chinese mitten crab, a person may have intentionally introduced the species into this ecosystem, because of the economic value of this organism in Southeast Asia as a delicacy. However, decapod larvae of crab species are known to survive transoceanic voyages in ballast tanks, so ballast water cannot be ruled out as a potential source (Carlton and Cohen, 1997; Cohen, 1998). Other potential sources of exotics introductions include aquaculture, bait, dumping of organisms from aquaria, and intentional introductions, but evidence from this estuary and studies of ballast water, summarized in Section 4.2, point to ballast water as a much more significant source.

In this section of the report, different sources of exotic species introductions are discussed, and ballast water is identified as the most probable ongoing source of exotic species to the San Francisco Estuary. Potential source areas in the San Francisco Bay Region are identified based on the different sources, in order to identify the locations of areas that may be most beneficial to conduct monitoring to detect incipient invasions or otherwise show success in preventing new introductions (see maps in Attachment 2 and Figures 4-5 and 4-6).

Table 4-9 contains the preliminary source assessment summary for this TMDL. As shown in the table, actions are proposed only for vessel point sources, because existing education and control programs are in place for the nonpoint sources, although they could be expanded by the implementing agencies, as appropriate. There are no registered aquaculture facilities in the San Francisco Bay Estuary, so no actions are proposed for this point source category, which has been otherwise shown to be a significant source of exotic species introductions in the Great Lakes and Pacific Northwest.

4.1 Past Exotic Species Introductions

Past exotic species introductions are <u>not</u> considered a nonpoint load to be reduced under CWA authorities. Once introduced, an aquatic nuisance species is extremely difficult to eliminate, and controlling spread of exotic species already introduced is not an element of this TMDL. From a practical standpoint, exotic species introductions are permanent, and the best use of resources in discharge management is to focus on prevention of introductions. In the TMDL lexicon, past exotic species introductions could be interpreted as a nonpoint load, but this would be erroneous, because the individual exotic organisms (pollutants) are not being actively discharged from a nonpoint source such as a person dumping his/her aquarium, but are progeny of the biological pollutants that were previously discharged.

4.2 Ballast Water

4.2.1 Characteristics of Ballast Water Discharges

Ballast water is carried by ships to provide stability and adjust a vessel's trim for optimal steering and propulsion. The use of ballast water varies among vessel types, among port systems, and according to cargo and sea conditions. Ballast water often originates from ports and other coastal regions, which are rich in planktonic organisms. It is variously released at sea, along coastlines, and in port systems. As a result, a diverse mix of organisms is transported and released around the world with the ballast water of ships. As noted by the Smithsonian Environmental Research Center (SERC), ballast water appears to be the most important vector for marine species transfer throughout the world. The transfer of organisms in ballast water has resulted in the unintentional introduction of tens to hundreds of freshwater and marine species to the U.S. and elsewhere (Carlton and Geller, 1993; NRC, 1995; Carlton and Cohen, 1998). Furthermore, the rate of new invasions from ballast water has increased in recent years (Mills et al., 1993; Carlton and Cohen, 1998).

A ship carrying little or no cargo rides high in the water. This may make the ship vulnerable to being knocked over by high waves and winds, increase the potential for "slamming" the bow or stern when riding over large waves, or raise the propeller so that it is insufficiently covered by water. So, at the start of a voyage a ship may take on a large quantity of water - of whatever water the ship is floating in, fresh water if in a river port, or salt water if in the sea - in order to lower the ship to a safer and more efficient position in the water. At the end of the voyage the ship will then discharge this ballast water into a new port or coastal region (perhaps thousands of miles from its source) before loading cargo. Ballast water is also loaded or discharged for other purposes, including adjusting the ship's trim, improving maneuverability, increasing propulsion efficiency, reducing hull stress, raising the ship to pass over shallow areas (reducing draft), and lowering it to get under bridges or cranes (reducing air draft).

Ballast water enters a ship through intakes located below the water line, typically about 10 to 25 feet down. These intakes are typically covered with grates or strainer plates with openings of about half an inch or larger, although corrosion can further enlarge these openings and the plates sometimes fall off (Marine Board, 1996). The function of the strainer plates is to prevent damage to the ship's pumps from objects that might otherwise be drawn in, although when present and in good condition they would incidentally serve to prevent the introduction of large organisms into ballast tanks. Depending on the level of the tank relative to the water surface, water may be taken on or discharged either by low-head centrifugal pumping or by gravitational flow. Ballast water is generally carried in several different compartments on board ship, often in tanks set aside for that purpose (called "segregated" or "dedicated" ballast tanks), although bulk carriers and tankers may carry ballast water in their cargo holds ("unsegregated" tanks). Some individual ships can carry tens of millions of gallons of ballast water (see Section 5.2).

While the majority of ballast water discharges occur in port as cargo is loaded on the vessel, as noted above, ballast water discharges are made during the voyage to make adjustments as appropriate. As such, berths at ports are considered to be the main "point source" areas in the estuary for ballast water discharges and exotic species introductions, but it is recognized that a "line source" of ballast water exists in the shipping lanes of the San Francisco Estuary, from outside the Golden Gate into the Bay, and throughout the deep channels of the estuary that lead to commercial ports and private terminals as far inland as Redwood City, Sacramento, and Stockton.

4.2.2 Locations of Ballast Water Discharges

The San Francisco Marine Exchange (SFMX) publishes the Golden Gate Atlas every two years, which contains detailed information on the anchorages and ports of the San Francisco Estuary and the Sacramento/San Joaquin Delta. Attachment 2 contains maps of all the estuary's port and terminal areas, copied from the 1998 Golden Gate Atlas. Over one hundred individual berths are denoted on these maps, which convey the spatial extent of specific ballast water discharge locations in the estuary. These locations should be reviewed to determine representative monitoring locations to detect incipient invasions or otherwise demonstrate the success of control efforts. Two facilities are indicated on these maps that do not have berths, including the SFMX and the California Maritime Academy (CMA) in Vallejo. The major commercial ports of the estuary are listed in Table 4-10, dry docks with NPDES permits are in Table 4-11, military terminals of the region are listed in Table 4-12, and private terminals of the region are listed in Table 4-13.

Attachment 2 also contains some of the shipping traffic data collected by the SFMX in 1999, including arrivals by port, and arrivals by ship type. Not counting the bay anchorages, the Port of Oakland has about one-half the shipping traffic that comes in the Golden Gate. Of the 3,192 ships that entered the Golden Gate in 1999, about 55% were container ships, 22% were tankers, and 12% were bulk carriers. The SFMX's annual report, "Golden Gate Ship Traffic," contains more specific information as well, including arrivals by specific berth, by last port of call, by flag, and the ten most active shipping agencies of a given two year period. In 1999, the most active berth in the estuary was the Chevron Longwharf in Richmond (412 calls), followed by Berth 23 in the Port of Oakland (246 calls). The Port of Los Angeles/Long Beach is the most common last port of call, at 1,505 ships, and the most common flag is United States at about 24% of the total. In both 1998 and 1999, Inchcape Shipping was by far the most active agency in the Golden Gate, representing 22% of all ships.

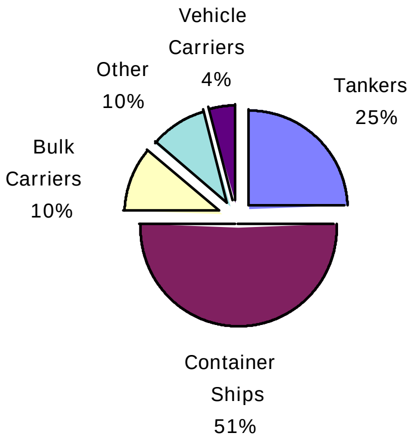
One important piece of information that the SFMX does not collect is ballast water discharge information. Table 5-1 in Section 5, Linkage Analysis, contains ballast water discharge information that has been reported to the USCG by U.S. and foreign ships entering U.S. waters from outside the EEZ. This information is not any more specific than the general area (e.g., Golden Gate as represented by "SFCMS" in the table), so specific port locations of discharges are not available.

4.2.3 Shipping Traffic Patterns in the San Francisco Estuary

Since adoption of the NISA regulations in 1999, SERC has begun to tabulate shipping traffic and ballast water discharge volume data for the ports of the United States, as described in Section 1.2.4. At the time of this report, SERC has not generated the second quarterly report, so shipping data are not available to further characterize traffic and discharge patterns in the San Francisco Estuary at this time.

In a technical report written for the California Urban Water Agencies at the end of 1998, the San Francisco Estuary Institute compiled information and estimates on ballast water discharged into the estuary, based on limited available information (Cohen, 1998). The information presented here is intended to allow a sense of the scale of discharges, and the Regional Board will continue to track shipping information as it becomes available through efforts of the U.S. Coast Guard and SERC, the Port of Oakland, the Port of Stockton, and the California State Lands Commission under AB 703.

Figure 4-1
Arrivals in the San Francisco
Estuary by Type of Ship

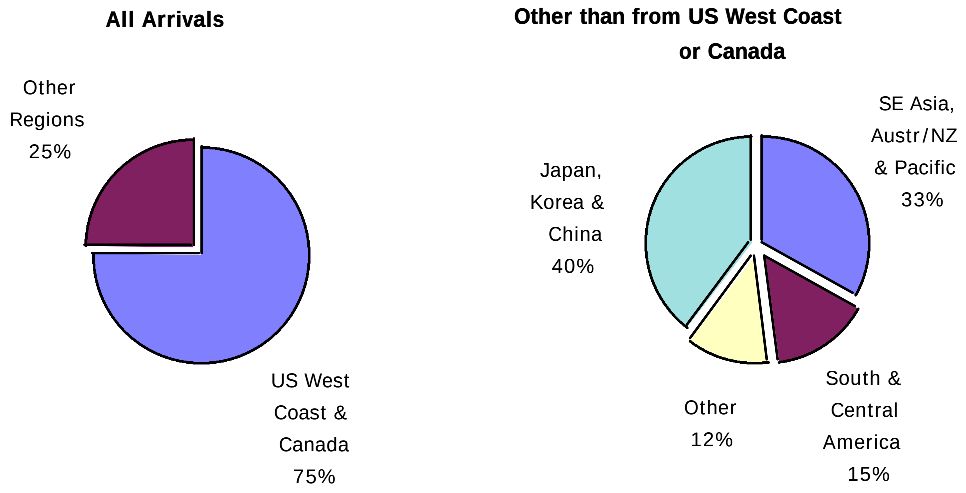


from data for 1996 (Marine Exchange 1997; Cohen 1998)

About half the commercial ships that arrive in the Estuary are container ships, a quarter are tankers, and a tenth are bulk carriers (Figure 4-1). Three-quarters of the ships arrive from ports on the North American west coast, and most of the remainder from elsewhere on the Pacific Rim (Figure 4-2).

Attachment 2 contains summaries of 1995-1999 shipping traffic data collected by the San Francisco Marine Exchange. The patterns shown in the graph for 1996 data also hold for 1999 data.

Figure 4-2
Arrivals in the San Francisco Estuary by Last Port of Call



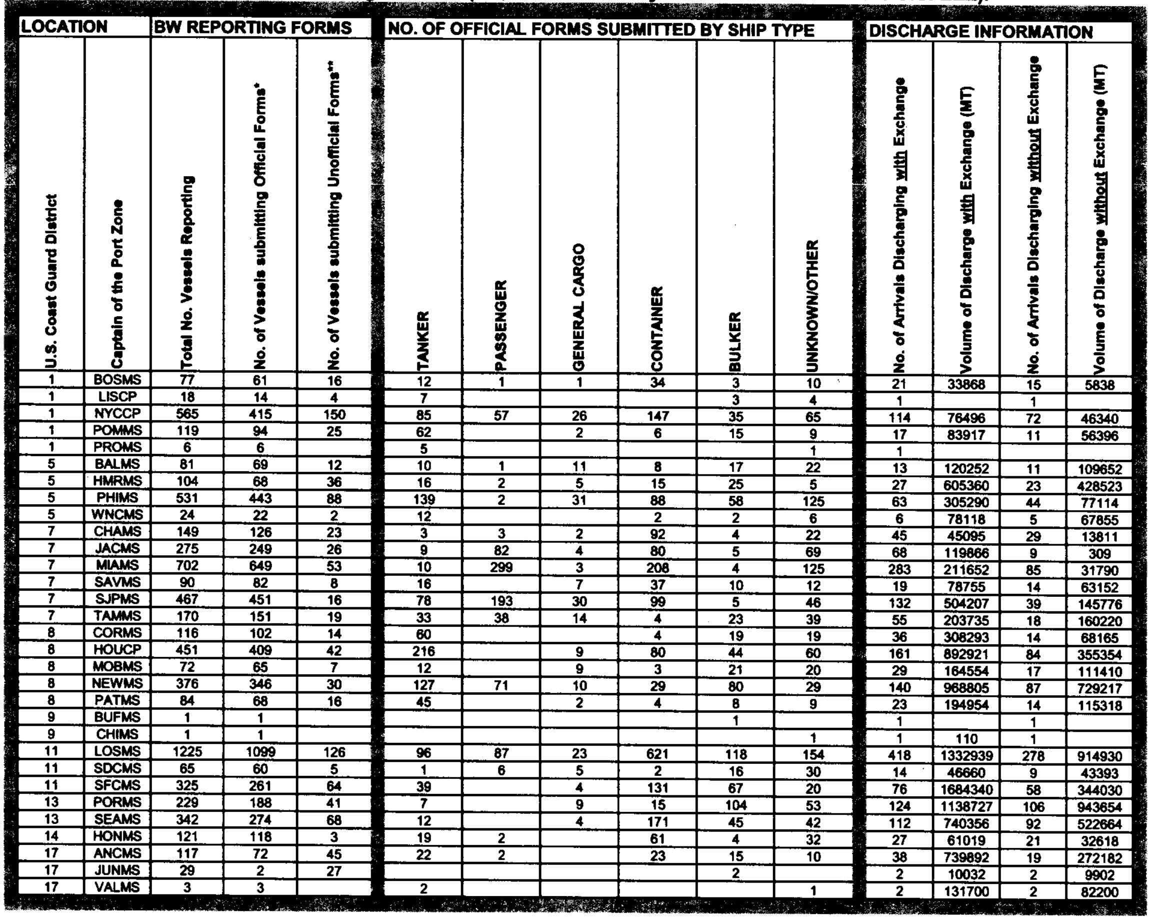
From Cohen, 1998, from data for 1996 (Marine Exchange 1997)

Presently, ballast water discharges occur at commercial ports, some private terminals, and some military terminals. These areas are therefore recommended for monitoring to detect incipient invasions and otherwise ascertain the success of the current federal and state programs.

Actual data being compiled under the USCG's regulatory program underscore the limitations of a voluntary regime to address invasions of exotic species (see Table 4-1). According to the first six months of the National Ballast Survey (July-Dec. 1999), administered by SERC for the USCG, approximately 43% of ships calling at ports inside the Golden Gate Bridge that discharged ballast water (58 out of 134) *did not* exchange ballast water in the open ocean (SERC, 2000). Their reported discharge comprised only 17% of the total volume of reported ballast water discharged, so about 83% of the reported volume of ballast water originating in foreign ports was exchanged on the high seas. Despite this lower volume, researchers from the Great Lakes emphasize that there is no correlation between overall ballast water volume and rate of species introductions (Mills et al., 1993). Because the USCG regulations were adopted less than a year ago, the USCG expects the percentage of vessels exchanging ballast water on the high seas to increase as the maritime industry incorporates the practices into its routines, and especially in the state of California, where 1999 legislation essentially makes the USCG program mandatory for all state waters. Nevertheless, compliance with the USCG regulations in the Great Lakes exceeds 97%, and introductions are ongoing (Gerrity, 1999).

Table 4-1
National Ballast Survey Data According to Port Areas
(Golden Gate Traffic: see the SFCMS row)

Ballast Water Reporting Forms from the National Ballast Survey. Data collected between July 1, 1999 and Dec. 31, 1999.
All reporting forms correspond to foreign arrivals (i.e., submissions by arrivals from outside the U.S. EEZ).



LOCATION		BW REPORTING FORMS			NO. OF OFFICIAL FORMS SUBMITTED BY SHIP TYPE						DISCHARGE INFORMATION			
U.S. Coast Guard District	Captain of the Port Zone	Total No. Vessels Reporting	No. of Vessels submitting Official Forms*	No. of Vessels submitting Unofficial Forms**	TANKER	PASSENGER	GENERAL CARGO	CONTAINER	BULKER	UNKNOWN/OTHER	No. of Arrivals Discharging with Exchange	Volume of Discharge with Exchange (MT)	No. of Arrivals Discharging without Exchange	Volume of Discharge without Exchange (MT)
1	BOSMS	77	61	16	12	1	1	34	3	10	21	33868	15	5838
1	LISCP	18	14	4	7				3	4	1		1	
1	NYCCP	565	415	150	85	57	26	147	35	65	114	76496	72	46340
1	POMMS	119	94	25	62		2	6	15	9	17	83917	11	56396
1	PROMS	6	6		5					1	1			
5	BALMS	81	69	12	10	1	11	8	17	22	13	120252	11	109652
5	HMRMS	104	68	36	16	2	5	15	25	5	27	605360	23	428523
5	PHIMS	531	443	88	139	2	31	88	58	125	63	305290	44	77114
5	WNCMS	24	22	2	12			2	2	6	6	78118	5	67855
7	CHAMS	149	126	23	3	3	2	92	4	22	45	45095	29	13811
7	JACMS	275	249	26	9	82	4	80	5	69	68	119866	9	309
7	MIAMS	702	649	53	10	299	3	208	4	125	283	211652	85	31790
7	SAVMS	90	82	8	16		7	37	10	12	19	78755	14	63152
7	SJPMS	467	451	16	78	193	30	99	5	46	132	504207	39	145776
7	TAMMS	170	151	19	33	38	14	4	23	39	55	203735	18	160220
8	CORMS	116	102	14	60			4	19	19	36	308293	14	68165
8	HOUCP	451	409	42	216		9	80	44	60	161	892921	84	355354
8	MOBMS	72	65	7	12		9	3	21	20	29	164554	17	111410
8	NEWMS	376	346	30	127	71	10	29	80	29	140	968805	87	729217
8	PATMS	84	68	16	45		2	4	8	9	23	194954	14	115318
9	BUFMS	1	1						1		1		1	
9	CHIMS	1	1							1	1	110	1	
11	LOSMS	1225	1099	126	96	87	23	621	118	154	418	1332939	278	914930
11	SDCMS	65	60	5	1	6	5	2	16	30	14	46660	9	43393
11	SFCMS	325	261	64	39		4	131	67	20	76	1684340	58	344030
13	PORMS	229	188	41	7		9	15	104	53	124	1138727	106	943654
13	SEAMS	342	274	68	12		4	171	45	42	112	740356	92	522664
14	HONMS	121	118	3	19	2		61	4	32	27	61019	21	32618
17	ANCMS	117	72	45	22	2		23	15	10	38	739892	19	272182
17	JUNMS	29	2	27					2		2	10032	2	9902
17	VALMS	3	3		2					1	2	131700	2	82200

* "Official forms" include the North American Ballast Water Reportingt Form and the IMO version of this form submitted by ships arriving from outside U.S. EEZ.

** "Unofficial forms" are foreign arrival forms that do not meet the criteria of the North American or IMO Ballast Water Management forms and that contain unuseable data.
In cases where useful data can be extracted, the information is treated as if reported in an Official BWM FORM.

Note: there were approximately 1800 vessels reporting during this period that were domestic arrivals and that were not included in this table.
Additionally, approximately 200 forms either did not include port of arrival and/or date of arrival or were unreadable and thus were excluded from analysis.

4.2.4 Exotic Species Introduced via Ballast Water Discharges

Today, ballast water is the main source of exotic species introductions in the San Francisco Estuary. For 27 exotic species established in the Estuary, ballast water appears to be the only likely mechanism for their introduction into Pacific Coast waters (Table 4-2); these account for 12 percent of the 234 exotic species known from the Estuary. Another 60 species are possible introductions (Table 4-3), for a total of 87 clear or possible ballast water introductions, or 37 percent of the total introductions. Many of the introductions in the early part of the twentieth century were associated with an aquaculture industry for oysters that no longer exists (Cohen and Carlton, 1995). Figure

4-3, below, graphically displays the trend of exotic species introductions via ballast water for the species listed in Table 4-2, showing an accelerated invasion rate in this highly invaded estuary, with ballast water as the principal source.

Table 4-2
Exotic Organisms in the San Francisco Estuary Introduced to the Pacific Coast via Ballast Water Discharges

For organisms in this table, there appears to be no other reasonably likely mechanism to account for their introduction to the Pacific Coast other than through ballast water discharges. We include in the category of ballast water transport the possibility of transport in other parts of ships' seawater systems, such as sea chests or pipes. Data updated from Cohen & Carlton 1995 and Cohen 1996.

Organism		Probable Native Region	First Record on the Pacific Coast
Polychaete Worm	*Boccardiella ligerica*	Europe	1935
Korean Shrimp	*Palaemon macrodactylus*	Asia	1957
Chameleon Goby	*Tridentiger trigonocephalus*	Asia	1960
Yellowfin Goby	*Acanthogobius flavimanus*	Asia	1963
Asian Semele Clam	*Theora fragilis*	Asia	1968-69
Amphipod	*Corophium alienense*	unknown	1973
Mysid Shrimp	*Deltamysis holmquistae*	unknown	1977
Copepod	*Sinocalanus doerrii*	China	1978
Copepod	*Limnoithona sinensis*	China	1979
Copepod	*Oithona davisae*	Japan	1979
Cumacean	*Nippoleucon hinumensis*	Japan	1979
Shimofuri Goby	*Tridentiger bifasciatus*	Japan	1985
Asian Clam	*Potamocorbula amurensis*	Asia	1986
Copepod	*Pseudodiaptomus marinus*	Asia	1986
Amphipod	*Corophium heteroceratum*	China	1986
Foraminifer	*Trochammina hadai*	Japan	1986
Copepod	*Pseudodiaptomus forbesi*	China	1987
Polychaete Worm	*Potamilla* sp.	unknown	1989
Polychaete Worm	*Marenzelleria viridis*	Atlantic	1991
Opisthobranch	*Philine auriformis*	NZ, Australia	1992
Nebaliad	*Epinebalia* sp.	unknown	1992
Mysid Shrimp	*Acanthomysis aspera*	Japan	1992
Copepod	*Acartiella sinensis*	China	1993
Copepod	*Limnoithona tetraspina*	China	1993
Copepod	*Tortanus dextrilobatus*	China, Korea	1993
Mysid Shrimp	*Acanthomysis bowmani*	unknown	1993
Shôkihaze Goby	*Tridentiger barbatus*	Asia	1997

Table 4-3
Exotic Organisms in the San Francisco Estuary Possibly Introduced to the Pacific Coast via Ballast Water Discharges

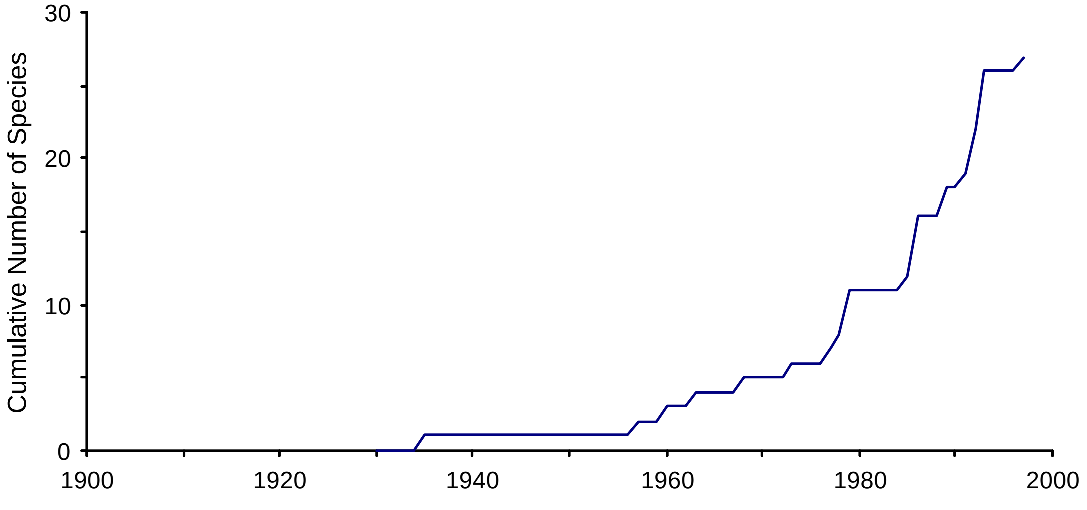
For organisms in this table there are other reasonably likely mechanisms, in addition to ballast water discharges, that could account for their introduction to the Pacific Coast. Data updated from Cohen & Carlton 1995 and Cohen 1996.

Organism		Probable Native Region	First Record on the Pacific Coast
False Angelwing Clam	*Petricolaria pholadiformis*	Atlantic	1927
Polychaete Worm	*Polydora ligni*	Atlantic	1932
Polychaete Worm	*Streblospio benedicti*	Atlantic	1932
Sea Squirt	*Styela clava*	Asia	1933
Anemone	*Diadumene leucolena*	Atlantic	1936
Polychaete Worm	*Heteromastus filiformis*	Atlantic	1936
Mud Crab	*Rhithropanopeus harrisii*	Atlantic	1937
Amphipod	*Melita nitida*	Atlantic	1938
Anemone	*Diadumene franciscana*	unknown	<1940
Amphipod	*Stenothoe valida*	unknown	<1941
Amphipod	*Ampithoe valida*	Atlantic	1941
Amphipod	*Jassa marmorata*	Atlantic	1941
Tanaid	?*Sinelobus* sp.	unknown	1943
Mediterranean Mussel	*Mytilus galloprovincialis*	Mediterranean	1947
Sea Squirt	*Molgula manhattensis*	Atlantic	1949
Hydroid	*Cordylophora caspia*	Black Sea	<1950
Oligochaete Worm	*Branchiura sowerbyi*	Asia	1950
Polychaete Worm	*Pseudopolydora paucibranchiata*	Pacific	1950
Nudibranch	*Okenia plana*	Japan	1950-60
Polychaete Worm	*Sabaco elongates*	Atlantic	1950s
Polychaete Worm	*Pseudopolydora kempi*	unknown	1951
Bryozoan	*Alcyonidium polyoum*	Atlantic	1951-52
Bryozoan	*Conopeum ?tenuissimum*	Atlantic	1951-52
Nudibranch	*Tenellia adspersa*	Europe	1953
Ostracod	*Eusarsiella zostericola*	Atlantic	1953
Amphipod	*Ampelisca abdita*	Atlantic	1954
Jellyfish	*Corymorpha* sp.	Atlantic	1955-56
Oligochaete Worm	*Limnodrilus monothecus*	Atlantic	1960
Polychaete Worm	*Manayunkia speciosa*	Eastern North America	1961
Oligochaete Worm	*Paranais frici*	Black Sea	1961-62
Oligochaete Worm	*Tubificoides apectinatus*	Atlantic	1961-62
Oligochaete Worm	*Tubificoides brownae*	Atlantic	1961-62
Oligochaete Worm	*Tubificoides wasselli*	Atlantic	1961-62
Nudibranch	*Eubranchus misakiensis*	Japan	1962
Seaweed	*Polysiphonia denudata*	Atlantic	1963-64
Oligochaete Worm	*Potamothrix bavaricus*	Eurasia	<1965
Amphipod	*Grandidierella japonica*	Japan	1966
Polychaete Worm	*Marphysa sanguinea*	Atlantic	1969
Jellyfish	*Blackfordia virginica*	Black Sea	1970
Nudibranch	*Sakuraeolis enosimensis*	Japan	1972

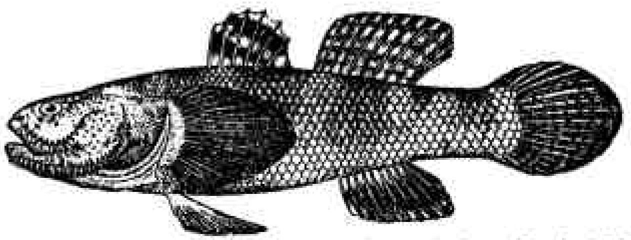
Table 4-3 Continued.

Organism		Probable Native Region	First Record on the Pacific Coast
Skeleton Shrimp	*Caprella mutica*	Asia	1973-77
Nudibranch	*Catriona rickettsi*	unknown	1974
Anemone	*Diadumene ?cincta*	Europe	<1975
Nudibranch	*Boonea bisuturalis*	Atlantic	1977
Isopod	*Dynoides dentisinus*	Japan, Korea	1977
Isopod	*Ianiropsis serricaudis*	Japan	1977
Isopod	*Eurylana arcuata*	NZ or Chile	1978
Jellyfish	*Cladonema uchidai*	Japan	1979
Nudibranch	*Cuthona perca*	unknown	1979
Amphipod	*Gammarus daiberi*	Atlantic	1983
Sea Squirt	*Ascidia* sp.	unknown	1983
Sea Squirt	*Ascidia zara*	Japan	1984
Sea Squirt	*Ciona savignyi*	Japan	1985
Isopod	*Munna* sp.	unknown	1989
Jellyfish	*Maeotias inexspectata*	Black Sea	1992
Mitten Crab	*Eriocheir sinensis*	China, Korea	1992
Isopod	*Paranthura* sp.	unknown	1993
Amphipod	*Melita* sp.	unknown	1993
Amphipod	*Paradexamine* sp.	unknown	1993
Isopod	*Sphaeroma walkeri*	Indian Ocean	1994

Figure 4-3
Ballast Water Invasions in the San Francisco Estuary



Exotic species established in the San Francisco Estuary, for which there is clear evidence of introduction to the Pacific Coast via ballast water. Tallied by the date of the first Pacific Coast record.



Source: Jordan and Snyder 1902.

The sh^kihaze goby has recently been found in the estuary.

Figure 4-4. Recent Arrival in the San Francisco Estuary from Ballast Water. Gobioid fishes such as this species, found in the estuary in 1997, have caused ecological and economic damages in the Great Lakes. There, the round goby has adversely affected commercial and sport fishing. The impacts of the sh^kihaze goby in the San Francisco Estuary have not yet been ascertained.

Ballast water discharges to the estuary occur in commercial ports, private terminals, military terminals, drydocks, and, to a lesser extent, the ship channels that connect them. If a terminal only imports goods or materials, then no ballast water discharges occur except perhaps minor discharges for adjustments. Attachment 2, page 130, contains 1999 data for ship arrivals by berth. This is currently the most comprehensive list of terminals available in the San Francisco Bay Region (and the two commercial ports of the Central Valley Region). This list will be updated in the future as more information becomes available, particularly through the SERC and State Lands efforts, which will generate ballast water discharge information.

A few terminals in the region only import goods, and therefore do not receive ballast water discharges in port. For instance, the USS Posco terminal in Pittsburg currently receives 25-28 annual imports of steel from South Korea, with no associated ballast water discharges. The C&H Sugar terminal near Carquinez Bridge receives 21-26 sugar shipments per year, with no ballast water discharges. The Dow Chemical terminal in Pittsburg receives 5-6 shipments of caustic soda from Vancouver, Canada, or Freeport, Texas, and does not export any products. Therefore, just because ships are arriving at terminals does not automatically make them a source of exotic species introductions. The nature of the shipping traffic at every terminal must be considered before conclusions are made about site-specific control measures. However, terminals such as these, if engaged in one-way traffic, are sources of San Francisco Estuary ballast water to the waters of the ship’s destination, which should be of concern, due to the documented ANS in this bay.

4.2.5 Biological Content of Ballast Water

The following information was compiled in the 1998 report by the San Francisco Estuary Institute (Cohen, 1998), demonstrating that ballast water can contain the full range of organisms from viruses to schools of small fish. It has long been recognized that marine and freshwater organisms can be transported in the water carried by ships. As early as 1897 biologists had shown that marine plankton (organisms that drift within the water column, most of which are microscopic or nearly microscopic) can pass through pumps into a ship's seawater system and survive. In 1908, it was reported that an Asian diatom had been introduced to the North Sea in ballast water (Carlton, 1985), and the invasion of northern Europe by the Chinese mitten crab was believed to result from a pre-1912 ballast water introduction (Cohen and Carlton, 1997). Not until the 1970s, however, did scientists begin directly sampling the organisms in ballast water. Numerous studies have since shown that ballast tanks typically contain many species of animals, plants, protozoans, bacteria and viruses, sometimes in considerable abundance (Tables 4-4 to 4-6). However, the organisms in the ballast water of ships arriving in the San Francisco Estuary have never been sampled (Cohen, 1998).

Many planktonic organisms can survive relatively long voyages drifting in the ballast water carried in ships, to be discharged into coastal waters at the end of the voyage. Other organisms may settle out within a ballast tank as juveniles or adults, living in sediments accumulated on the bottom of the tank or attaching to the sides or bottoms of tanks or to the insides of pipes or other components of the ballast system. Some planktonic organisms produce cysts or spores or other resting stages, which may be tolerant of extreme environmental conditions and capable of remaining dormant for weeks or months. Notable among these are some toxic species of dinoflagellates, whose viable cysts have been found in ballast sediments in enormous numbers (Hallegraeff et al., 1990; Hallegraeff and Bolch, 1991 and 1992). These resting stages may release planktonic forms back into the ship's ballast water prior to discharge, or may themselves be introduced into the environment with discharged sediments.

The density of organisms reported from ballast water and ballast sediments varies greatly (Table 4-6). Several studies have reported dramatic declines in the number and diversity of organisms over the duration of a voyage (Table 4-7). Although in some studies these declines occurred in conjunction with substantial changes in temperature or reductions in dissolved oxygen (Carlton, 1985), in other cases declines occurred even when environmental variables remained stable at non-stressful levels (Wonham et al., 1996). In such cases the declines may be due to depletion of food resources, since there is no light in ballast tanks that would allow phytoplankton to photosynthesize. A few live organisms have been collected from ballast water or ballast sediments after periods of up to a year (Table 4-8). Such long-term survival might be due in part to the presence of resting stages (spores, cysts or diapause eggs) of diatoms, dinoflagellates, protozoans and copepods (Carlton, 1985; Hallegraeff and Bolch, 1991), or to the long-term persistence of protozoan and invertebrate communities in ballast tank sediments (Smith et al., 1996).

Even with large declines, substantial numbers and considerable diversity of living organisms may remain in ballast tanks after voyages of 10-20 days. It appears that densities on the order of 0.1-1 relatively large (>80 µm, or >0.003 inch) planktonic organisms per gallon, and greater densities of smaller organisms, may frequently be present in ballast water at the conclusion of a transoceanic voyage. Given the large capacity of ship's ballast water pumps[5], a single deballasting ship may thus discharge into the environment millions of exotic phytoplankton and invertebrate zooplankton per hour, and larger numbers of protists, bacteria and viruses.

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[5] Typical ships' pumping capacities are 0.3-0.5 million gal/hr for general cargo and container ships, 1.3-2.6 million gal/hr for bulk freighters and ore carriers, and 1.3-5 million gal/hr for tankers (Marine Board 1996).

Table 4-4 - Investigations of Ballast Tank Biota

Includes both reported observations and systematic studies. Numbers of species given are minimum numbers based on conservative counts from reported data, and may differ from the original authors' counts. The numbered studies refer to data reported in Table 5-3.

	Study Site and Period	Sampling Regime and Results
1	Australia 1973	Plankton sampled in 1 ship from Japan included polychaetes, copepods, amphipods, ostracods and chaetognaths (Medcof 1975).
2	Australia 1976-78	Plankton and fish in 23 woodchip carriers from 13 Japanese ports included 61 species; most common were copepods, molluscs, larvaceans and barnacles. Sediments from 9 woodchip carriers from 7 Japanese ports yielded 32 crustaceans and polychaetes (Williams *et al.* 1988).
3	Montreal and St. Lawrence River 1980	Plankton samples from 46 ships that had ballasted outside the northwest Atlantic included 132 phytoplankton, 7 protist and 35 invertebrate species (Bio-Environmental Services 1981).
4	North Atlantic 1981	Plankton sampled from a variety of ships and routes included 3 protist, 24 invertebrate and 1 fish species (Carlton *et al.* 1982).
	Australia 1981	Identified 4 fish and reported mysids in ballast water of a domestic bulk carrier (Middleton 1982).
5	Coos Bay, OR 1986-91	Plankton samples from 159 woodchip carriers from 25 Japanese ports included 402 species in 24 animal, plant and protist phyla, with the most common being copepods, diatoms, polychaetes, barnacles, molluscs and flatworms (Carlton & Geller 1993; Pierce *et al.* 1997).
6	Australia 1987-93	Sediment from ballasted cargo holds in 12 Japanese woodchip carriers arriving in Tasmania in 1987-88 yielded 56 phytoplankton species, including abundant diatoms in 4 ships and dinoflagellates cysts in 7 ships (Hallegraeff *et al.* 1990). Sediments from 31 out of 83 mainly Japanese woodchip, wheat and ore carriers arriving in Australia in 1987-89 (including the 12 already mentioned) contained dinoflagellate cysts, with toxic species in 4 ships (Hallegraeff & Bolch 1991). 343 ships were sampled by 1990, with sampling continuing through at least 1993 (Hallegraeff & Bolch 1992).
7	Great Lakes and upper St. Lawrence River 1990-91	Plankton samples from 86 ships included 110 species of zooplankton in 11 phyla, mainly copepods, cladocerans and rotifers; and 100 species of bacteria, phytoplankton and protists, mainly diatoms and dinoflagellates including 21 bloom-forming, red tide and/or toxic species (Locke *et al.* 1991, 1993; Subba Rao *et al.* 1994).
	Japan 1991	Ballast water and sediments sampled in ships at 17 Japanese ports by the Japanese Assoc. for the Prevention of Marine Accidents. Results not published (noted in Kelly 1992).
8	Washington state 1991	Samples from 6 Japanese woodchip carriers arriving at Tacoma and Port Angeles in 1991 yielded 21 species of phytoplankton and protists from incubated sediments; and at least 8 orders of organisms in ballast water from 3 ships (Kelly 1992, 1993).

Table 4-4 Continued. Investigations of Ballast Tank Biota

Study Site and Period		Sampling Regime and Results
	Gulf of Mexico 1991-92	Ballast water samples in 5 of 19 ships yielded *Vibrio cholerae*, which genetic analysis found to be identical to the strain responsible for the 1991 South American cholera epidemic and found in oysters in Mobile Bay, Alabama (McCarthy & Khambaty 1994).
	Germany 1992-95	Plankton sampled in 189 ships, along with organisms in sediment, fouling organisms on tank walls, and larger crabs and fish where possible, included over 350 species, mainly unicellular algae, copepods, other crustaceans and molluscs (Gollasch *et al.*, in press).
9	Chesapeake Bay 1993-94	Plankton net, whole and bottom water samples in 70 ships from foreign ports yielded 275 plant, protist & animal species; and 4 species in sediment from 5 ships (Smith *et al.* 1996).
10	Hong Kong 1994-95	Plankton samples from 5 ships from both sides of the North Pacific included 82 species of invertebrates and protists, with copepods being the most common (Chu *et al.* 1997).
11	Scotland 1994-95	Plankton sampled from 32 ships and sediment from 24 ships yielded dinoflagellates, diatoms and other organisms. This study is ongoing (Macdonald, in press).
12	Baltimore, MD 1995	Plankton samples from 1 coal carrier from Israel yielded 23 species of dinoflagellates and invertebrates, numerically dominated by copepods, bivalves, polychaetes and gastropods (Wonham *et al.* 1996).
	New Zealand 1995-97	Plankton and bottom water samples from tanks with foreign ballast water in 50 container ships, bulk carriers and break bulk carriers arriving at Lyttelton and Nelson yielded live phytoplankton in 80% of tanks, dominated by diatoms, heterotrophic flagellates and dinoflagellates, and live invertebrates in 83% of tanks with arthropods, molluscs and annelids occurring most frequently (Hay *et al.* 1997).
13	Valdez, AK 1996	Plankton from 16 domestic and 1 foreign oil tanker included 68 taxa (Ruiz & Hines 1997).
	Israel 1996	Cultured ballast water and sediment samples from 17 ships yielded at least 198 heterotrophs (reported as flagellate, pseudopodial and cilate forms), plus diatoms, cnidarians, turbellarians, nematodes, rotifers, gastrotrichs, polychaetes and copepods (Galil & Hülsmann 1997).
	various sites	Studies are under way or being undertaken in Chesapeake Bay, Long Island Sound, the Port of Morehead City in North Carolina, the Port of Long Beach in California, the Port of Honolulu in Hawaii, the Gulf of St. Lawrence, British Columbia, Sweden and Wales (Gauthier & Steel 1996; Walton & Crowder, 1998; Eldredge 1998; J Carlton, pers. comm.).

Table 4-5 - Organisms Collected in Ballast Tanks

Number of distinct taxa (=minimum number of species, conservatively counted) of living organisms reported in ballast tanks. In some cases the numbers listed are my counts based on the species data reported in the cited works, and may differ from the original authors' counts. In most cases the actual number of species in the ballast tanks were probably much higher than the reported numbers. The level of taxonomic effort applied to different organism groups varies greatly, making comparions between groups and between studies difficult.

Study[1]	1	2a	2b	3	4	5	6a	6b	7	8	9	10	11	12	13
Number of Ships	1	23	9	46	n.a.	159	12	100	86	6	70	5	32	1	16
Type of Sample[2]	P	P	S	P	P	P	S	S	P	S, P	P	P	S, P	P	P
Vascular Plants	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Bacteria	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Cyanophytes	–	–	–	15	–	–	–	–	1	–	1	–	–	–	1
Chlorophytes	–	–	–	26	–	2	–	–	1	2	1	–	2	–	–
Rhodophytes	–	–	–	2	–	2	–	–	–	–	1	–	–	–	–
Phaeophytes	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Chrysophytes	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–
Xanthophytes	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–
Cryptophytes	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–
Diatoms	–	–	–	57	–	128	42	15	61	16	17	13	25	–	3
Dinoflagellates	–	–	–	20	–	4	14	51	30	3	25	5	32	6	2
Flagellates	–	–	–	3	–	–	–	–	2	2	–	–	–	–	–
Foraminifers	–	–	–	–	–	3	–	–	–	–	1	3	1	–	1
Radiolarians	–	–	–	–	–	2	–	–	–	–	2	2	–	–	–
Ciliates	–	–	–	7	3	37	–	–	3	–	53	3	2	–	1
Cnidarians	–	1	–	–	–	25	–	–	1	–	7	4	–	–	1
Ctenophores	–	–	–	–	–	–	–	–	–	–	4	–	–	–	1
Platyhelminthes	–	1	–	–	1	33	–	–	1	–	3	2	–	1	1
Nemerteans	–	–	–	–	–	1	–	–	–	–	1	–	–	–	1
Nematodes	–	–	–	1	1	1	–	–	1	–	3	2	1	–	–
Rotifers	–	–	–	3	1	1	–	–	10	–	5	–	–	–	–
Gastrotrichs	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
Annelids	1	1	4	2	2	43	–	–	10	1	26	4	–	1	10
Sipunculids	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–
Molluscs	–	–	–	2	1	19	–	–	2	2	8	3	–	2	3
Arthropods	4	54	28	27	17	73	–	–	81	3	97	39	–	13	34
Tardigrades	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Bryozoans	–	–	–	–	–	3	–	–	1	–	1	–	–	–	1
Echinoderms	–	–	–	–	–	6	–	–	1	–	4	–	–	–	2
Phoronids	–	–	–	–	–	1	–	–	–	–	1	–	–	–	1
Chaetognaths	1	1	–	2	–	3	–	–	1	–	9	1	–	–	1
Hemichordates	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Urochordates	–	1	–	–	–	6	–	–	–	–	2	1	–	–	1
Cephalochordates	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Fish	–	2	–	–	1	2	–	–	–	1	6	–	–	–	1
TOTAL	6	61	32	176	28	398	56	66	210	30	279	82	63	23	67

1 Studies are those reported in: (1) Medcof 1975; (2a,b) Williams *et al.* 1988; (3) Bio-Environmental Services 1981; (4) Carlton *et al.* 1982; (5) Carlton & Geller 1993, Pierce *et al.* 1997; (6a) Hallegraeff *et al.* 1990; (6b) Hallegraeff & Bolch 1992; (7) Locke *et al.* 1991, 1993, Subba Rao *et al.* 1994; (8) Kelly 1992, 1993; (9) Smith *et al.* 1996; (10) Chu *et al.* 1997; (11) Macdonald, in press; (12) Wonham *et al.* 1996; (13) Ruiz & Hines 1997. See Table 5-1 for information on these studies.

2 Sample types are: P=plankton (mainly by plankton net, sometimes including whole water samples, and sometimes including sampling of larger fauna with nets at surface or in near-empty cargo holds); S=sediment.

Table 4-6 - Densities of Organisms Collected in Ballast Tanks

These studies reflect ballast water of various ages, and in some cases may reflect mixtures of older and freshly-loaded ballast water. Generally, in a given ballast tank, the density of organisms declines with time (see Table 5-5).

Study	Mesh Size of Collecting Device	Range, Maximum or Mean Density of Organisms (individuals per 1,000 gallons)
Bio-Environmental Services 1981	80 µm	diatoms max = 270,000 annelids max = 650 dinoflagellates max = 1,600 molluscs max = 4,600 other algae max = 860,000 cladocerans max = 3,000,000 ciliates max = 6,600 copepods max = 260,000 rotifers max = 670,000 barnacles max = 3,100 nematodes max = 14,000
Carlton *et al.* 1982	153 µm	polychaetes max = 80 copepods max =18,000 mollusks max = 40 barnacles max = 1,200
Wang 1990	80 µm	crustaceans range = 300 to 3,500
Hallegraeff & Bolch 1992	20 µm	in tank-bottom sediments: dinoflagellate cysts max = 85 billion toxic dinoflagellate cysts max = 57 billion
Carlton & Geller 1993	80 µm	polychaetes >750 copepods >5,700 mollusks >750 barnacles >750
Locke *et al.* 1993	41 µm	total living and dead individuals of: zooplankton range = 80 to >260,000 a rotifer max = 200,000 a water flea max = 130,000 copepods max = 80,000
Subba Rao *et al.* 1994	sedimented whole-water samples	for individual species of: diatoms max = 11 billion ciliates max = 39 million dinoflagellates max = 14 million copepods max = 1.5 million flagellates max = 60 billion bacteria & autotrophic plankton max = 10 trillion
Smith *et al.* 1996	80 µm	organisms except bacteria & viruses range = 0 to 68,000 in non-exchanged tanks mean = 3,400 in exchanged tanks mean = 160
Wonham *et al.* 1996	80 µm	on a 17 day voyage: at start at end in cargo hold zooplankton 30,000 300 phytoplankton 7,000 40 in deck tanks zooplankton 10,000 0.4 phytoplanton 4,000 0
Chu *et al.* 1997	80 µm	Copepods max = about 4,000
Ruiz & Hines 1997	80 µm	all organisms range = 5,700 to 62,000 mean = 26,000 diatoms range = 0 to 5,500 mean = 3,600 dinoflagellates range = 0 to 1,200 mean = 240 annelids range = 2 to 4,700 mean = 1,200 molluscs range = 5 to 18,000 mean = 2,600 copepods range = 70 to 38,000 mean = 14,000 barnacles range = 50 to 16,000 mean = 2,700

Table 4-7. Decline of Biota with Age of Ballast Water

Carlton *et al.* 1982	A series of studies conducted on research and commercial ships found the following: *Study KB2*–No apparent decline in zooplankton density or diversity after 15 and 18 days with little change in ballast water temperature. *Study KB3*–Zooplankton density dropped 100-fold and diversity dropped from 7 to 1 species in 13 days with a large (19°C) increase in ballast water temperature. *Study KB-IS*–Zooplankton density remained stable over 7 days of relatively constant temperature, then dropped about 40-fold over 14 days when temperature rose and fell through an estimated 6-8°C. Diversity dropped from 11 to 3 species over the 21 day period. *Study TA-I*–Net zooplankton density dropped about 60-fold over 64 days, diversity dropped from 12 to 1 species over 95 days. Rotifers were present at the start of the voyage but gone by day 31; microflagellates and ciliates were present through day 64 but gone by day 95. Ballast water temperature varied over 22°C during the 95 days. *Study TA-II*–Zooplankton density dropped about 20-fold and diversity dropped from 8 to 5 species over 30 days. Ballast water temperature varied over a 14°C range. *Study TA-III*–Zooplankton density dropped about 20-fold and diversity dropped from 4 to 2 species over 31 days. Ballast water temperature varied over a 15°C range. *Study MRI*–Zooplankton demsity dropped 100-fold and diversity dropped from 12 to 2 species over 12 days. A period of elevated temperature and low dissolved oxygen occurred.
Williams *et al.* 1988	In ships arriving in Australia from Japan, the number of species declined with age of ballast water; the trend suggested few if any species would survive 24 days.
Wonham *et al.* 1996	On a coal carrier in ballast from Israel to Baltimore, plankton density dropped about 100-fold in 16 days in a ballasted cargo hold (4.5 million gallons). In smaller deck tanks (0.5 million gallons), zooplankton density dropped >10,000-fold in 15 days, phytoplankton dropped 1,000-fold in 4 days. In 16 days the number of species dropped from 38 to 23 in the cargo hold, and from 36 to 3 in the deck tanks, while temperature, salinity and dissolved oxygen remained nearly constant.
Smith *et al.* 1996	In ships arriving in Chesapeake Bay, there were higher densities of organisms in ballast water less than 14 days old than in water 14-24 days old, but this could be due to differences in water sources. The oldest ballast water containing an organism (one copepod) was 41 days old.
Gollasch *et al.*, in press	On a container ship bound from Singapore to Bremerhaven, the density of planktonic diatoms and dinoflagellates dropped >90% in 9 days, and zooplankton density dropped 90% in 4 days. Diatom species dropped from 30 to 4 in 23 days, dinoflagellates from 13 to 0 in 14 days, and zooplankton from 24 to 4 in 23 days. While bound from Colombo to Bremerhaven, zooplankton in one tank dropped from 16 to 4 species in 14 days, but one surviving species increased greatly in abundance.
Chu *et al.* 1997	In ships arriving in Hong Kong, the number of species declined with the age of ballast water, but about 5-10 species were present in one-year-old ballast water.
Hay *et al.* 1997	No "free-swimming" phytoplankton were found in ballast water more than one month old.
Ruiz & Hines 1997	In ships arriving in Prince William Sound from the U. S. west coast, the density of annelids and molluscs but not of total organisms was lower in ships with older ballast water. Sampling of 4-6 day old ballast water showed no overall decline in abundance over 48 hours.

Table 4-8
Longest Records of Persistence of Organisms in Ballast Water or Sediments

months:	1 2 6 12	Reference
Diatoms	---	Chu *et al.* 1997
Dinoflagellates	---------------------------	Hallegraeff *et al.* 1990
Protozoans	---	Chu *et al.* 1997
Microflagellates	---------	Carlton *et al.* 1982
Ciliates	---------	Carlton *et al.* 1982
Flatworms (Turbellaria)	----	Carlton *et al.* 1982
Nematodes	---------	Carlton *et al.* 1982
Polychaete larvae	----	Carlton *et al.* 1982
Bivalve larvae	----	Carlton *et al.* 1982
Barnacle larvae	----	Carlton *et al.* 1982
Cladocerans	----	Carlton *et al.* 1982
Copepods (Calanoida)	---	Chu *et al.* 1997
Copepods (Cyclopoida)	---	Chu *et al.* 1997
Copepods (Harpacticoida)	---	Chu *et al.* 1997
Mites (Hydracarina)	----	Carlton *et al.* 1982

Tables 4-4 through 4-8, originally produced for the 1998 San Francisco Estuary Institute report (Cohen, 1998), demonstrate the broad range of organisms that can survive for weeks to months in ballast tanks, and the variability among organisms of their survivability. Because of our inability to predict which organisms will become established, and the precise mechanisms of establishment, this information brings emphasis to the need for ballast water management that renders a very wide range of organisms, originating in coastal or freshwater aquatic ecosystems, unviable prior to discharge.

4.3 Exterior Surfaces of Vessels

The exterior surfaces of vessels can be also be a vector for exotic species introductions. This vector tends to be a source of exotic organisms that settle on surfaces, attach, grow, and release gametes into solution to propagate the species. Examples include species of kelp, barnacles, mussels, and numerous microorganisms, including pathogenic organisms that form biofilms. Vessel exterior surfaces were a more important source of introductions in the early part of the 20th century – today this vector is of decreasing importance as a source of introductions to the San Francisco Estuary (Cohen, 1998). In addition to a vessel's hull, species can adhere to other surfaces such as the sea chest and the anchor chain.

4.3.1 Hull Fouling

The issue of hull fouling has long been crucial to ship owners, for many reasons other than introduction of exotic organisms. Fouling causes an increase in surface roughness and greater frictional resistance. Studies have shown that a slime layer of only 1 mm thickness can cause a 15% loss in ship speed (ENRC, 1997). Such a significant loss in speed translates to large monetary losses in fuel consumption and inability to meet schedules. Hence, a significant economic incentive already exists to encourage ship owners and operators to keep their hulls clean.

Exotic organisms can attach themselves to the hulls of ships and survive long journeys. The risk posed to the San Francisco Estuary by hull fouling of large ships, fishing vessels, and recreational craft has not been characterized. In Australia, for example, two exotic species of concern, the Japanese kelp and Sabella worm, are believed to have been translocated either as larvae in ballast water or as fouling organisms on hulls. Japanese kelp has spread along the coastline of Tasmania due primarily to vessel hull transport and ocean currents. Among other effects, it excludes many native flora and fauna and threatens mussel and oyster farming (ENRC, 1997).

In a 1997 technical report, the Environment and Natural Resources Committee of the Parliament of Victoria, Australia, concluded that “the risk of translocation of exotic marine species via hull fouling may be as great as that associated with ballast water discharge.” The Committee also concluded that the biological waste from hull cleaning operations is at least as serious a pollutant as chemical waste. Therefore, efforts to collect information on ballast water discharges at the source areas of the San Francisco Estuary should be complemented, at least initially, by an effort to characterize the risk associated with hull fouling on various seagoing vessels.

Exotic species introductions via ship exterior surfaces may be more common in biogeographic regions such as Australia and New Zealand, which are located relatively closer to distinct biogeographic regions characterized by different species assemblages (see Figure 1-1). The risk of introductions to the San Francisco Estuary is probably not as high as with ballast water, due to the exterior stresses and duration associated with a transoceanic voyage. Along the Pacific coast, the threat of introductions from organisms on the exteriors of ships may not be as great as in Australia and New Zealand, where certain introductions have been positively traced to ship exteriors (ENRC, 1997).As Figure 1-1 conveys, the San Francisco Estuary and the whole Pacific coast of North America are relatively isolated from other biogeographic regions by large oceanic distances. The stresses on the outer ship surfaces from a trans-Pacific journey reduce the probability of an introduction via this vector, while the relatively quiescent ballast tanks are ever-increasingly important with faster and more abundant ships.

Anti-fouling paints are used on the hulls of ships to prevent the build-up of fouling organisms, and currently represent the most effective way of preventing hull fouling. However, the active constituents in these paints are highly toxic to marine life, and are the subject of pollution prevention efforts worldwide. Research is ongoing into alternative anti-fouling paints that have the “no-stick” effect of teflon, but they are not yet ready for implementation. The most effective paints contain tri(n-butyl)tin (TBT) dispersed throughout the paint, which is eventually released at the paint surface to inhibit settlement of organisms. Prior to the mid-1970’s, copper oxide-based paints were used. The more effective TBT paints provide about five years of fouling protection, while copper oxide paints only last 2-3 years, and may cause corrosion to aluminum hulls.

Both TBT and copper have been designated pollutants of concern by the Regional Board, and various recent regulations have discouraged the use of TBT in marine paints. Best management practices implemented at estuary shipyards have discouraged the discharge of hull cleaning operations directly into the estuary, in order to reduce discharges of toxic metals such as TBT and copper. Explicit restriction of in-water hull cleaning would serve to lower TBT and copper discharges, and also prevent introduction of exotic organisms. To a certain extent, until suitable alternatives are developed to TBT, having a small area affected by TBT paints may be a trade-off for introducing exotic species that spread everywhere and wreak widespread havoc. At this time, without hull fouling information specific to this estuary, the magnitude of the trade-off is unknown.

The Australian Quarantine and Inspection Service (AQIS) is the lead agency of Australia addressing the issue of exotic species introductions. A recent AQIS survey of 21 merchant vessels in Tasmania, including 5 different vessel types, showed that a total of 65 different species representing eight animal phyla and five plant divisions were present on 17 of the 21 vessels surveyed. Four species were identified as exotic to Tasmanian waters. All four species were identified on domestic vessels, indicating the importance of domestic voyages as a vector of exotic species introductions (AQIS, 1999). The three factors with a statistically significant influence on the vessels' degree of fouling were (1) age of antifouling paint, (2) mean voyage duration, and (3) mean voyage speed. Older paint, shorter voyages, and slower vessels were the conditions that favored fouling of the hull, as would be expected.

In the San Francisco Estuary, potential sources of hull fouling discharges of exotic species include boatyards, marinas, drydocks, commercial ports, military terminals, and private terminals. Any facilities that remove organisms from vessels need to make sure that hull cleaning wastes are not disposed in the estuary. Such practices would be consistent with the best management practices currently in effect that restrict discharges of pollutants such as TBT from vessel maintenance facilities.

Figure 4-5 contains a map of some boatyards and marinas currently under regulation by the Regional Board for reasons other than exotic species introductions, and the sites are tabulated in Table 4-14. This is not a comprehensive list, and can be amended if a comprehensive program is initiated to review hull fouling as a source of exotic species introductions. Given the issues described above, this is not the highest priority for controlling exotic species introductions at this time.

4.4 Aquaculture

The main vector today for exotic species introductions not associated with ships is aquaculture (Gunderson, 2000). However, according to the California Department of Fish and Game (CDFG), there are no registered aquaculture facilities in the San Francisco Estuary. Table 4-16 contains a list of all registered aquaculture facilities in the San Francisco Bay Region, which are all located around Tomales Bay, except for two facilities near Half Moon Bay on the Pacific Ocean. All of these facilities culture shellfish such as oysters, mussels, abalone, and clams.

Tomales Bay and the Pacific Ocean along the San Mateo coast are not listed as impaired by exotic species, although any statewide efforts to monitor aquaculture as a source would be advised of these locations. Currently, CDFG officials carefully track the compliance of aquaculture facilities in accordance with Division 12 of the Fish and Game Code, 15000 et seq., to protect against escape of cultured organisms or associated "by-catch" (Holbrook, 2000). As such, a control program is in place and no further control measures are recommended in this TMDL report.

Many exotic species introductions in the early 20th century were probably associated with aquacultural operations (Cohen and Carlton, 1995). With shellfish harvesting (SHELL) as a designated beneficial use, restoration of aquaculture in the San Francisco Estuary is a long-term goal of the Regional Board. In the 21st century, as toxic and bioaccumulative pollutant levels subside and pathogen sources are reduced, shellfish harvesting and shellfish or fish aquaculture may be restored to the estuary. As this occurs, controls should be put in place, consistent with existing CDFG regulations, to ensure that such facilities will not be a source of exotic species introductions.

4.5 Bait and Fish Stocking

In California, a large quantity of live organisms is imported for use as bait, especially during years when demand exceeds the state's aquacultural and natural supply of bait. Examples include golden shiner minnows, centrarchids, and water dogs (salamanders). Additionally, salmonids are imported for stocking fee-fishing ponds, and CDFG wardens routinely inspect these organisms for disease, so that the facilities can be certified as "disease free." In the Great Lakes, home of a $1 billion sport fishing industry, live bait (especially baitfish) has been implicated as a significant vector for spreading or introducing exotic species. Certain ANS are thought to be spread by the bait vector, such as aquatic macrophytes like *Hydrilla verticillata* and two species of exotic crayfish.

Bait and fish stocking may be more important as a vector for spreading existing invasions as opposed to initiating new invasions. As pointed out in Section 1.2.8, the focus of this TMDL is on preventing introductions, and not controlling the spread of existing introductions. A comprehensive two-year study underway in the Great Lakes region by a network of Sea Grant offices is examining the risk of transporting ANS and other by-catch species in live baitfish and stocked fish. Analysis for ANS in 212 live baitfish samples from retail outlets in five Great Lakes states show that (1) no samples contained ANS, but a sample from Ohio contained an alewife and a goldfish (neither are designated ANS in Ohio), (2) by-catch bait species contamination ranged from 10-50% depending on the state, and (3) no samples contained any plant material. Angler surveys indicate that leftover bait is frequently dumped in the water. Characterization of operations showed that most public and private fish stocking agencies and businesses are taking actions that eliminate or reduce risk of ANS spread (Jensen et al., 2000). This study implies that these industries are "cleaner" than may have been expected, and for the issue of preventing new introductions in the San Francisco Estuary, it is probably a minor nonpoint source compared to ballast water.

Because individuals can fish just about anywhere in the estuary, for sport or subsistence fishing, the bait vector is considered to be a potential nonpoint load of exotic species recognized in this TMDL, which cannot be easily regulated using CWA authorities. A recent study of fishing pressure in the San Francisco Bay Region, conducted by the California Department of Health Services (DHS) for a fish consumption study, generated a list of the sites around the estuary where the most fishing activity occurs (Calif. DHS et al., 1999). The top 14 sites are indicated on Figure 4-6 and listed in Table 4-15. For the purposes of monitoring incipient invasions or otherwise demonstrating the lack of a source of introductions, the locations in Figure 4-6 could be used as sites in the monitoring network.

Representatives in the Great Lakes point out that effective education strategies will be the most important element in preventing spread of exotic species due to angling. Laws in the Fish and Game Code, implemented by CDFG, already restrict introduction of species and disease into state waters (Fish and Game Code Sections 2270-2272; 5050; 6300-6306; 6400; 15005; 15102; 15200-15202; 15500-15506; 15600-15601; California Code of Regulations Title 14, Sections 135, 171, 236, 238, and 671). Section 671 contains the state’s list of detrimental species also known as a “black list.” Bait and fish stocking are currently regulated by CDFG, addressed in the national education program by the ANSTF, and no further actions are recommended in this TMDL.

4.6 Intentional or Unintentional Introductions

A potentially major “nonpoint” source of ANS introductions is when individuals bring pests or diseases intentionally or unintentionally from foreign countries, via air and sea traffic. The potential vectors for such introductions include the growing live food market, dumping or flooding of aquariums and water gardens, intentional release of organisms into the aquatic environment, and many others. These potential sources of exotic species introductions are recognized in this TMDL as nonpoint loads, which cannot be easily regulated using CWA authorities.

Keeping harmful exotic species out of the United States is not a new issue. The Lacey Act (at 18 USC 42) was originally passed in 1900, and amended in 1981. The U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (APHIS), the California Department of Forestry and Agriculture (CDFA), and CDFG implement the Lacey Act and the correlating state laws (e.g., Fish and Game Code Sections referenced above). The Act and its regulations (at 50 CFR 16.11 to 16.13) prohibit the “importation, transportation or acquisition” of certain organisms listed as injurious, authorizing the Secretary of the Interior to add any wild mammals, wild birds, reptiles, amphibians, fishes, mollusks or crustaceans, or their offspring or eggs, that are determined “to be injurious to human beings, to the interests of agriculture, horticulture, forestry or to wildlife or the wildlife resources of the United States.” The aquatic species on the prohibited list are: live or dead fish in the salmon family, live walking catfish or their eggs (family Clariidae), live mitten crabs or their eggs (genus *Eriocheir*), or the zebra mussel *Dreissena polymorpha*. The regulations (at 50 CFR 16.13(a)(1)) further prohibit the release of any imported fish, mollusk, crustacean or their progeny or eggs without prior written permission from the State wildlife conservation agency that has jurisdiction over the area of release. The Act also (at 16 USC 3371-3378) makes it an offense to "import, export, transport, sell, receive, acquire or purchase" or possess any animal that is "taken, possessed transported or sold" in violation of any law, treaty, or regulation of the United States, any Indian tribal law, or any State law or regulation, or any foreign law.

Control of pests and diseases entering the country has long been a concern of agriculture, and thanks to efforts of the ANSTF and others, aquatic nuisance species (ANS) have been added onto "black lists" for pest inspectors to review. APHIS operates agricultural inspection facilities in the San Francisco Bay Region to ensure that agricultural products being imported into or exported from the United States do not harbor harmful animal and plant pests. APHIS Plant Protection and Quarantine Officers conduct inspections. Ships, aircraft, cargo, baggage, and passengers entering the region from foreign countries are subject to inspection for prohibited agricultural materials that could harbor foreign animal or plant pests and diseases. Commodities that are determined to be a threat to U.S. agriculture are either refused entry or treated under APHIS supervision. APHIS also regulates the proper storage and disposal of garbage from international vessels. Some APHIS inspectors travel overseas at the exporter's expense to supervise agricultural commodity inspections and treatments in foreign countries. This pre-inspection expedites imports and reduces the risk of importing pests and disease.

The CDFA's Plant Health and Pest Prevention Services division stations pest exclusion biologists at the ports of San Francisco, San Pedro, and San Diego. They are responsible for inspecting second port-of-call foreign and domestic vessels, crew quarters, passenger baggage, and cargo shipments for the pests that may be detrimental to California agriculture. These biologists enforce vessel garbage regulations, issue permits to remove food stores, and may seal vessel stores where high pest food risk items are contained on board, to prevent crew members from taking these food items ashore while on leave. Port staff also issue and administer compliance agreements for catering facilities, vessel dry docks, and vessel garbage handling facilities and monitor them as needed. They supervise treatments of commodities found to be infested with agricultural pests. There is an existing cooperative network that includes port staff, shipping representatives, U.S. Customs, USDA, CDFA, County Agricultural Commissioners, and agricultural officials from other states.

While there are concerns that the existing programs under APHIS and CDFA are not preventing intentional introductions, for instance the Chinese mitten crab, a control program with implementing agencies is in place and no further actions are recommended in this TMDL.

Table 4-9

San Francisco Estuary Exotic Species TMDL Preliminary Source Assessment

Vector	Source Locations	Control Measures	Control Program	Lead Agency(ies)	TMDL Action Proposed?	Source Magnitude/Priority
Ballast Water	Commercial Ports, Private Terminals, Military Terminals	Ballast Water Management (e.g., Exchange) and Treatment	NISA AB 703	U.S. Coast Guard State Lands Commission	YES – National Effluent Guideline for Ballast Water	HIGH
Vessel Exterior Surfaces	All of the above plus: Boatyards Marinas	Routine Maintenance, Inspections	Indirect: Boatyard, Drydock, and Marina BMPs	RWQCB (for permitted facilities under statewide Industrial Permit)	YES – Ongoing RWQCB program for boatyard and dry dock BMPs	MEDIUM - LOW
Aquaculture	NONE	N/A	N/A	Calif. Dept. of Fish and Game	NO	LOW
Bait & Fish Stocking	Fee-Fishing Ponds, Piers, Certain Shore Areas, Throughout Estuary	Inspections	Fish & Game Code, Public Education	Calif. Dept. of Fish and Game, ANS Task Force, Sea Grant Education Programs	NO	LOW
Intentional Introductions	Ubiquitous	Inspections	Lacey Act, Fish & Game Code	USDA APHIS, CDFA, CDFG, etc.	NO	MEDIUM
Unintentional Introductions	Ubiquitous	Inspections	Public Education	USDA APHIS, CDFA, CDFG, Sea Grant, etc.	NO	MEDIUM

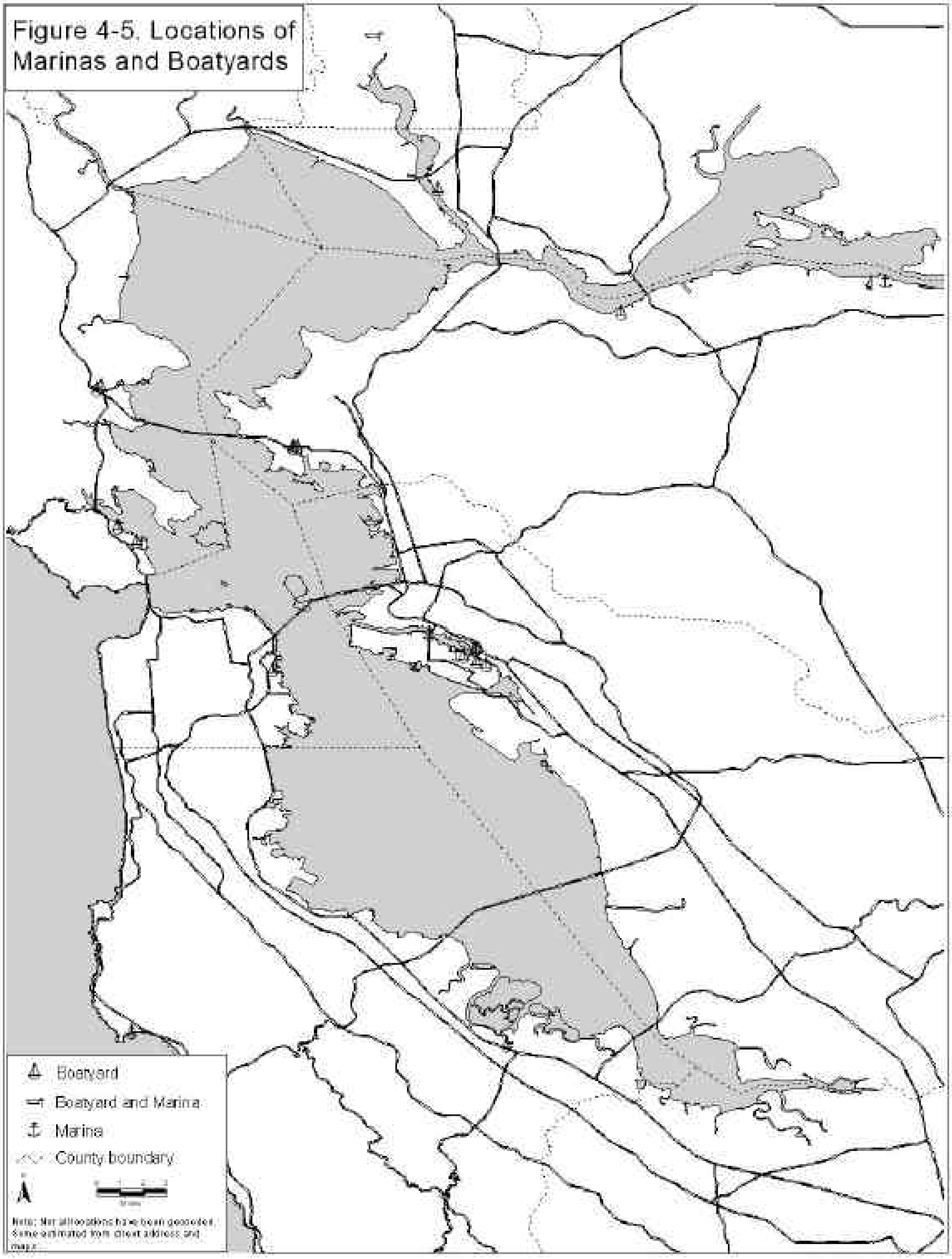

Figure 4-5. Locations of Marinas and Boatyards

Note: Not all locations have been geocoded. Some estimated from street address and maps.

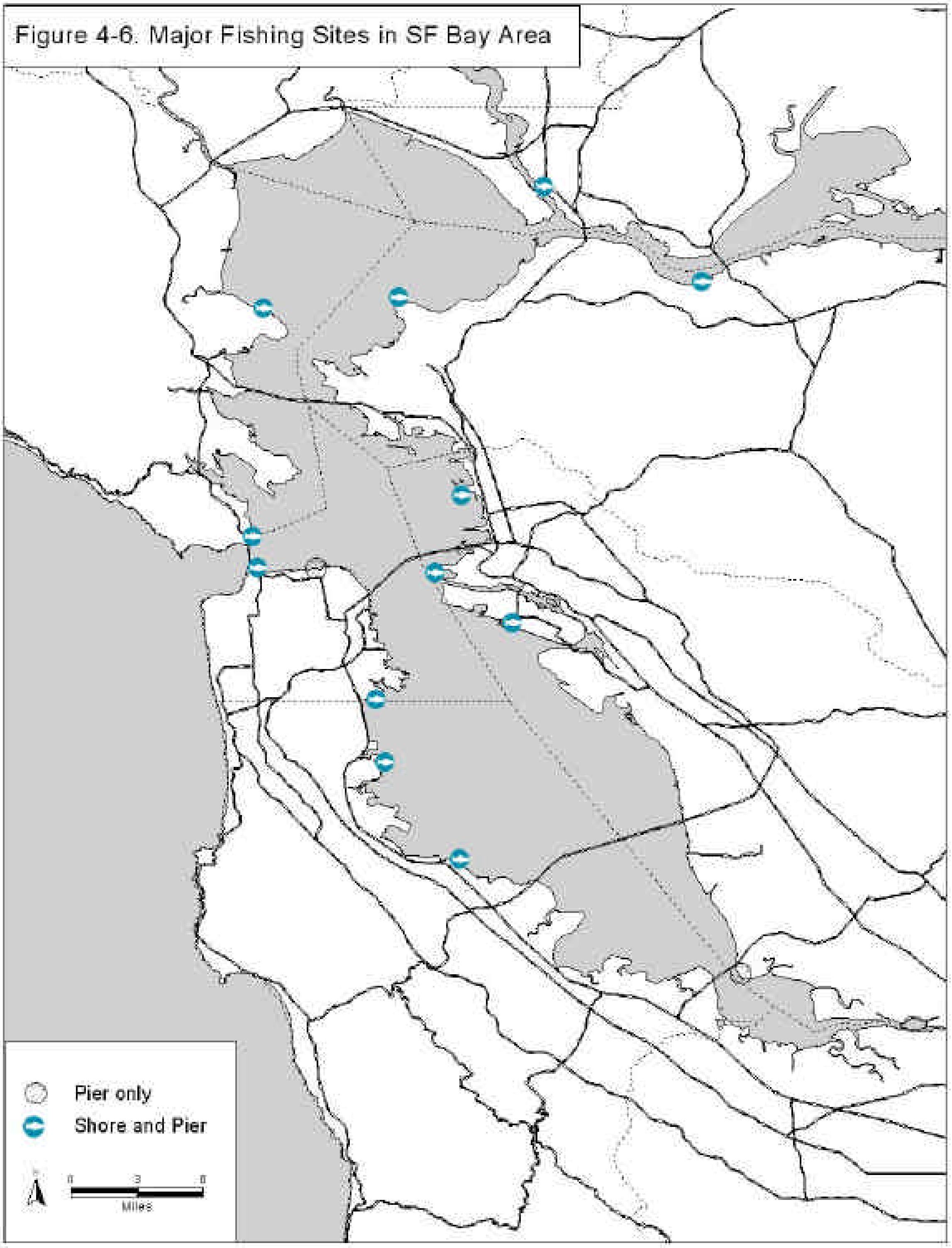

Figure 4-6. Major Fishing Sites in SF Bay Area

Table 4-10
Major Commercial Ports of the San Francisco Estuary (including Central Valley)

NAME	CITY	1999 ARRIVALS
Port of Oakland	Oakland	1,822
Port of Redwood City	Redwood City	31
Port of Richmond	Richmond	549
Port of Sacramento	Sacramento	85
Port of San Francisco	San Francisco	253
Port of Stockton	Stockton	111
TOTAL		2,851

Table 4-11
Permitted Drydock Facilities of the San Francisco Bay Region (NPDES)

NAME	ADDRESS	CITY	GENERAL TRAFFIC INFO.
Bay Ship & Yacht	2900 Main St	Alameda	Various ships, including Ferries
Astoria Metals-Hunters Point	Hunters Pt, Bldg 367	San Francisco	Fishing vessels, and other various vessels
SF Drydock, Inc.	foot of 20th St	San Francisco	Passenger ships and other vessels

Table 4-12
Military Terminals of the San Francisco Bay Region

FACILITY NAME	STATUS	CITY
Alameda Naval Air Station	Active (Merchant Marine Ships)	Alameda
Concord Naval Weapons Sta.	Active (22 ships, 1999)	Concord
Fleet Industrial Supply, Oakland	Transferred to Port of Oakland	Oakland
Fleet Industrial Supply, Alameda	Transferred to City of Alameda, but potential future turning basin for Port of Oakland	Alameda
Hunter's Point	Astoria Metals	San Francisco
Mare Island	Closed	Vallejo
Pt Molate	Closed	Richmond
Pt Ozol Fuel Facility	Active (2 ships, 1999)	Martinez
Treasure Island	Closed	San Francisco

Table 4-13
Private Terminals of the San Francisco Bay Region

NAME	CITY or PORT	1999 ARRIVALS
Schnitzer Steel	Oakland	12
GP Gypsum	Antioch	16
Benicia Industries & Coke	Benicia	42
Exxon	Benicia	124
Shell (Equilon)	Martinez	94
TOSCO, Amorco	Martinez	4
TOSCO, Avon	Martinez	52
Wickland Oil, Martinez	Martinez	94
Bay Bulk	Pittsburg	19
Diablo Services	Pittsburg	11
Dow Chemical	Pittsburg	4
U.S. Steel Posco	Pittsburg	26
C & H Sugar	Crockett	29
TOSCO, Rodeo	Rodeo	65
Wickland Oil, Selby	Crockett	81
Time Oil (Terminal 8)	Richmond	23
Levin Richmond (Terminal 9)	Richmond	46
Texaco (Terminal 10)	Richmond	18
Castrol (Terminal 11)	Richmond	0
TOSCO, Richmond (Terminal 13)	Richmond	53
ARCO (Terminal 14)	Richmond	32
All Other North Bay Terminals (not including Commercial Ports)		685
TOTAL		1,530

Table 4-14
Some Boatyards and Marinas of the San Francisco Bay Region

NAME	ADDRESS	CITY
Mariner Boatyard	2415 Mariner Square Dr	Alameda
Nelson's Marine	2241 Clement Ave	Alameda
Oceanic Boatworks	1899 Dennison St	Oakland
Stone Boatyard	2517 Blanding Ave	Alameda
Svenson's Boat Works	1851 Clement Ave	Alameda
Bay Ship & Yacht	310 W Cutting Blvd	Richmond
Eagle Marine	245 N Court St	Martinez
Sanfordwood Boatyard	530 W Cutting Blvd	Richmond
Richmond Boatworks	616 W Cutting Blvd	Richmond
Bayside Boatworks	2360 Marinship Way	Sausalito
Marin City Boatworks	60 Bay St	San Rafael
New Wave Marine	2350 Marinship Way	Sausalito
Roland's Boat Repair	145 Third St	San Rafael
Anchor Marine	262 Princeton Ave	Half Moon Bay
Yacht Masters	1 Harbor Way	Vallejo
South Bay Boatworks	1450 Maple	Redwood City
Brittish Marine	9 Embarcadero Cove	Oakland
San Francisco Boatworks	835 China Basin	San Francisco
Richardson Bay Boatwork	2300 Marinship Way	Sausalito
Berkeley Marine	1 Spinnaker Way	Berkeley
Napa Valley Marina	1200 Milton Rd	Napa
Grand Marina	2099 Grand St	Alameda
Sausalito Boat Harbor	501 Humboldt (lower)	Sausalito
Harris Yacht Harbor	100 Trojan Rd	Bay Point
Port Sonoma Marina	270 Sears Point Rd	Petaluma

Table 4-15
Major Fishing Sites of the San Francisco Bay Region

Site Name	County	Fishing Type
Alameda	Alameda	Shore and Pier
Port View Park	Alameda	Shore and Pier
Berkeley Pier	Alameda	Shore and Pier
Pt. Pinole Reg. Park	Contra Costa	Shore and Pier
McNear's	Marin	Shore and Pier
Fort Baker	Marin	Shore and Pier
Candlestick	San Francisco	Shore and Pier
SF Muni Pier	San Francisco	Pier only
Oyster Point	San Mateo	Shore and Pier
Coyote Point	San Mateo	Shore and Pier
Dumbarton Br. Pier	Alameda	Pier only
Martinez	Contra Costa	Shore and Pier
Vallejo Shore and Pier	Solano	Shore and Pier
Fort Point	San Francisco	Shore and Pier

Table 4-16
Registered Aquaculture Facilities in the San Francisco Bay Region, Calif. Dept. of Fish and Game

Site Name	County	Waterbody	No. of Acres	Type	Products
Bay Bottom Beds	Marin	Tomales Bay	5	Commercial Production	Pacific Oysters
Cove Mussel Co.	Marin	Tomales Bay	10	Commercial Production	Bay Mussels, Pacific and European Oysters
Hog Island Oyster Co.	Marin	Tomales Bay	138.2	Commercial Production	Littleneck Clams, Bay Mussels, Pacific, European, Eastern, and Native Oysters
Intertidal Aquariums	Marin	Tomales Bay	25	Commercial Production	Pacific and European Oysters, Manila Clams, Bay Mussels
Pt. Reyes Oyster Co.	Marin	Tomales Bay	48.4	Research & Development	Bay Mussels, Oysters and Clams
Spenger's Restaurant	Marin	Tomales Bay	1	Commercial Production	Bay Mussels, Pacific, European, and Eastern Oysters
Tomales Bay Shellfish Farms	Marin	Tomales Bay	156	Commercial Production	Pacific and European Oysters
Johnson Oyster Co.	Marin	Tomales Bay	1060	Commercial Production	Rock Scallop, Bay Mussels, and Pacific Oysters
Abalone Acres	Marin	Tomales Bay	?	Research & Development	Red Abalone
Liquid Earth Abalone	Marin	Tomales Bay	0	Research & Development	Red Abalone
Marshall Boat Works	Marin	Tomales Bay	1	Research & Development	Abalone, Mussel, Scallops, Clams, Prawns
Princeton Abalone	San Mateo	Princeton Harbor, Pacific Ocean	1	Research & Development	Red Abalone
Pacific Offshore Farms	San Mateo	Pillar Point Harbor, Pacific Ocean	1	Research & Development	Red Abalone

5. Linkage Analysis

TMDLs developed for chemical pollutants include an analysis of a waterbody's loading capacity (or assimilative capacity) based on an analysis of existing loads and specified numeric target(s). The loading capacity must be linked to the sources and numeric target(s). In Section 5.1, this concept is applied to exotic species, recognizing a numeric target of zero viable exotic organisms in discharges and reiterating the case that the estuarine ecosystem cannot assimilate the worst-case exotic species.

Section 5.2 describes the assumption that implementation of control measures would lead to the achievement of the water quality standard, with respect to exotic species, the shipping vector, and the narrative water quality objective for population and community ecology in the Basin Plan, and also the role of monitoring to check that assumption.

5.1 Determination of Loading Capacity

As discussed in Section 3, the assimilative capacity of the San Francisco Estuary, based on worst-case exotic species that have not yet been introduced to the ecosystem, is zero. For example, the estuary does not have capacity to assimilate an ANS such as the zebra mussel, which would cause widespread ecological and economic damage both in the estuary and upstream in the rivers and water projects of the State. Discharge and subsequent establishment of an exotic species that would exert such impacts would violate the Estuary's water quality standard by impairing uses, violating the narrative water quality objective for population and community ecology, and degrading the estuarine ecosystem by lowering diversity and abundance of native organisms. The following conceptual equations illustrate the linkages between identified sources, relative probabilities of exotic species introductions from these sources (as indicated by + signs), the numeric target for discharges, and the assimilative capacity of the San Francisco Estuary for worst-case exotic species, or "aquatic nuisance species."

Point Source Loads (+++) = Ballast Water (++) + Vessel Exterior Surfaces (+) + Aquaculture (zero – no registered sources)

Nonpoint Source Loads (+) = Bait and Fish Stocking (+) + Unintentional Introductions (Aquaria, Accidental Releases or Escapes)(+) + Intentional Introductions (Illegal Fishery Establishment)(+)

Numeric Target for all Sources = zero viable exotic organisms per discharge

Assimilative Capacity (zero nuisance exotic organisms in San Francisco Estuary) = Sum of Numeric Targets (zero viable exotic organisms per discharge)

5.2 Achievement of the Water Quality Standard

The water quality standard, including the narrative water quality objective for population and community ecology, will be achieved relative to exotic species when exotic species introductions to the San Francisco Estuary have ceased. Because technology development and implementation have not occurred, it is too soon to know whether ballast water treatment technology will lead to achievement of the water quality standard, which would be verified by periodic monitoring of the estuary.

Monitoring of the Great Lakes ecosystem has shown that a mandatory ballast water exchange program, in effect since 1993, is not preventing introductions (Section 1.2.4). Therefore, for the purposes of this TMDL report, it is assumed that the new mandatory open ocean exchange requirements in California will not prevent further introductions, although it may slow the current accelerated rate of introductions. This assumption is also based on reported removal efficiencies of less than 90% and the fact that a ship's master can claim a full exemption for safety, no questions asked, leading to zero treatment. As shown in Table 4-1, approximately one-third to one-half of all ships calling in the United States are presently not exchanging their ballast in the open ocean, perhaps due to concerns about long-term structural integrity of ships.

As technologies are developed and implemented, review of monitoring information for new exotic species introductions will allow the Regional Board to decide if technology combined with management procedures is preventing introductions. Technology on ships, barges, or on-shore will be designed to achieve technology-based standards, or limits, to be determined in the various stakeholder processes now getting underway in the Great Lakes and State of Washington.

Although it is unknown whether ballast water treatment will lead to attainment of the standard, it is a reasonable prediction that a national program of technology development, implementation and monitoring will make considerable progress toward attaining that goal. This prediction is based on extensive experience of EPA in establishing national effluent guidelines for industries and publicly-owned treatment works (POTWs), and the significant improvements in various waters around the country, including San Francisco Estuary. Prior to secondary and tertiary treatment plants in the San Francisco Bay Region in the 1970s, it was not safe for the public to swim in estuarine waters due to biological pollution. Implementation of technology to control microorganisms, the most difficult biological pollutant to neutralize, resulted in attainment of the water contact recreation (REC1) use during dry weather conditions throughout the estuary by the 1980s. Generally speaking, technology-forcing regulation has been a successful tool for abating biological pollutants in ambient waters, but also in public water supply. Treatment technology developed and implemented under the Safe Drinking Water Act has led to effective protection of public water supplies from biological pollutants.

A TMDL is considered after technology-based limits do not achieve water quality standards. A technology-based process has not been officially initiated for ballast water discharges, although Section 8.4.2 describes some technologies that have begun testing through encouragement under NISA. As described in Section 8.5, “Challenges and Information Gaps,” there are issues unique to ballast water that must be addressed before ballast water treatment can be feasibly implemented. These issues are not easily solved, and require a concerted national effort to ensure that creative solutions are explored and the most cost-effective and biologically effective technologies implemented. Given these uncertainties, the fact that a technology-based approach has not been initiated and funded at the national level, and limitations set by state statute (AB 703), a regulatory TMDL is not proposed by the Regional Board at this time.

At the close of the first period of technology development and implementation, estimated to be early 2004 (end of AB 703 law), the Regional Board will review the most current monitoring information from the estuary and the pace of treatment technology development under NISA, and determine whether to revisit the TMDL process, or allow the nascent technology-based management regime to continue, with a commitment to revisit the issue periodically.

6. TMDL, Load Allocations, and Wasteload Allocations

Because of the significant risks, the working hypothesis is that a water quality-based endpoint to achieve the estuary's water quality standards is *no exotic species introductions*. In other words, an acceptable total maximum daily load (TMDL) of exotic organisms or species is "zero." Based on the worst-case examples documented worldwide, the San Francisco Estuary does not have a capacity to assimilate exotic organisms in a general sense.

Wasteload allocations are given to point sources. Point sources of exotic species to the estuary include ships and aquaculture facilities. Specific point source categories are ballast water, exteriors of ships and other vessels, and registered aquaculture facilities. Because of the biogeographic location of the San Francisco Estuary, graphically indicated in Figure 1-1, only ballast water is considered a major source of exotic species introductions. Unlike areas such as Australia that are relatively near distinct biogeographic regions with different species assemblages, recreational traffic and hull fouling are not expected to be a major source of introductions to this estuary. Similarly, because there are no registered aquaculture facilities in the estuary, this is not considered a major point source. Nevertheless, zero allocations are given to all of these potential point sources. If water quality in the estuary improves to the point of supporting aquaculture facilities, for instance, control programs will have to be in place to ensure that exotic species do not escape from such facilities.

Load allocations are given to nonpoint sources. Nonpoint sources of exotic species to the estuary include introduction along with bait, individuals dumping aquariums or outdoor water gardens into fresh or estuarine waters, and intentional introductions. Zero allocations are given to all of these potential nonpoint sources.

TMDL (zero) = Point Source Loads (wasteload allocation = zero) + Nonpoint Source Loads (load allocation = zero) + Margin of Safety (implicit)

7. Margin of Safety

For any pollutant, TMDLs contain a substantial amount of uncertainty, and therefore, must contain a margin of safety. The TMDL must describe any uncertainties regarding the ability of the plan to meet water quality standards. The plan must consider these issues in its recommended pollution reduction goals.

The qualitative goal of zero introductions *implicitly* contains a margin of safety. As ballast water management and treatment systems are implemented over the next few years, and the percent removal of organisms improved, technology-based discharge standards will be established that will approach, but never achieve, a quantitative zero. The State Board will be reviewing and summarizing technologies in a report required under AB 703, with a due date of December 2002.

Review of the TMDL process in 2004 may suggest a different TMDL target based on the types of standards developed and technologies implemented for ballast water treatment. For instance, the proposed TMDL target in the Newport Bay pathogen TMDL is based on fecal coliform, 5-Sample/30-days Geometric Mean less than 200 organisms/100 mL, and not more than 10% of the samples exceed 400 organisms/ 100 mL for any 30-day period, to be achieved no later than December 31, 2013. It is premature to determine whether a quantitative non-zero target, tied to technology and prevention of introductions, is warranted.

8. Implementation Issues

Because the problem of exotic species in ballast water is not unique to the San Francisco Bay Region, it is imperative that emerging technologies be coordinated and implemented on a national scale, preferably by the U.S. Environmental Protection Agency (EPA), in close coordination with the U.S. Coast Guard (USCG). The USCG has recently initiated technology discussions under its authority under NISA, and this process could potentially meet the intent of a TMDL/Basin Plan/NPDES scheme to develop and implement ballast water treatment technology.

Numerous laws prevent the intentional introduction of exotic species in both aquatic and terrestrial habitats, such as the federal Lacey Act of 1900 that was amended in 1981. However, laws and regulations currently in effect do not explicitly require characterization, abatement or treatment of ship ballast water and exterior surfaces. Provisions of the CWA and the state Porter-Cologne Water Quality Control Act (California Water Code or CWC) could apply to the introduction of exotic species from ship hulls or in ballast water releases, as a waste discharge of a biological pollutant. Ballast water and hull fouling constitute a “waste” as defined by the CWC at Section 13050.

In addition, ballast water discharges from ships need to be brought into compliance with effluent standards in effect to protect public health. As described in Section 2.2.3, ongoing ballast water discharges to this estuary would not comply with bacterial limits placed on municipal dischargers in the region. Certain microorganisms in these discharges, whether “exotic” to the San Francisco Estuary or not, pose a threat to public health, particularly to those that engage in water contact recreation in areas proximate to terminals and shipping channels. At a minimum, any discharge to the San Francisco Estuary must eventually comply with established effluent limits to protect public health.

Public health protection is a useful starting point for initiation of a nationwide ballast water treatment program. EPA has experience in setting standards and approving alternative technologies for treatment of drinking water under the Safe Drinking Water Act and treatment of municipal wastewater under the CWA. Since public health protection is based on biological pollutants such as exotic species, future technologies and standards for ballast water treatment will be similar to those already in effect for drinking water and wastewater treatment plants, adapted to the circumstances of the ballast water challenge. Moreover, the microorganisms that are treatment targets for public health protection represent the most difficult “biological pollutants” to remove from discharges. In other words, if these discharges are treated to achieve standards for public health protection, it is likely that all exotic organisms will be concurrently removed, creating a much more reliable scheme for prevention of exotic species introductions through ballast water.

The regulatory structure to be developed to control ballast water discharges could be patterned after the successful CWA approach with technology-based limits in NPDES permits for industrial wastewater treatment facilities [see 40 CFR 125.3(a)(2)(i) and (iii) to (v)]. For example, in the first six months of the ballast water program under the CWA, a technical panel with appropriate stakeholder representation could establish best practicable technology currently available (BPT) for abatement of risks associated with ballast water and hull fouling discharges. Open ocean exchange procedures, described in Section 8.4.1, would likely emerge as an element of BPT as a result of this process.

Concurrent with the determination of BPT, a federal agency such as EPA should initiate a multi-year program to define the best available technology economically achievable (BAT) for abating risk from ballast water discharges. This multi-year effort would include extensive engineering feasibility analyses and comparative evaluations. As with industrial wastewater treatment and industry-specific effluent guidelines, EPA could coordinate a national effort which would identify a number of feasible options for treatment that emerge from intensive engineering investigations. This effort would culminate in the development of a national effluent guideline for ballast water discharges, estimated to take no less than five years, based on recent experience with other national effluent guidelines (Carlson and Charleton, 2000). It is not appropriate for the Regional Board to be the lead agency on this national issue, but rather it should participate as a stakeholder and implementing agency.

Currently, regulations are being developed to address sewage discharges from military vessels under CWA Section 312(n). Regulatory mechanisms to address ballast water discharges from mobile sources such as commercial ships could be patterned after the Section 312(n) approaches, if determined to be feasible and effective.

8.1 Basin Planning

When this TMDL was originally proposed to the Regional Board in July 1999, a Basin Plan amendment was proposed as the first element of implementation. Table 4-1 of the Basin Plan, Discharge Prohibitions, could be amended to add a prohibition for the discharge of viable exotic organisms into the waters of the state, in order to meet the narrative water quality standard for population and community ecology.

With the adoption of AB 703 in October 1999, the Regional Board is not permitted to add regulatory requirements for shipping related to exotic species until the law sunsets on January 1, 2004, unless mandated by federal law. At that time, a Basin Plan amendment could be planned, based on information that is compiled between now and then. Until that time, a number of activities are underway that will generate information pertinent to the decision to amend the Basin Plan. Activities of USCG, ANSTF, SERC, the State Lands Commission, the California Dept. of Fish and Game, the State Board (Dec. 2002 technology report), and the states of Michigan and Washington will generate information on (1) the effectiveness of the existing management programs; (2) the biology of ballast-mediated invasions and the characteristics of specific ballast water discharges; and (3) the technology that may be feasibly implemented on ballast water to control introductions of exotic organisms and protect public health.

In the meantime, there is unprecedented activity nationwide on the issue of ballast water management. In the past few months, the USCG and ANSTF have been active and assembling committees to discuss (1) alternatives to open ocean exchange that could be approved, such as treatment; (2) techniques to verify that treatment or an exchange of ballast water has occurred; and (3) discharge standards. The State of Washington passed legislation that requires development of a discharge standard (see Section 1.2.6), to be developed in cooperation with industry, government, and interested parties, including the Pacific Ballast Water Group, of which the Regional Board is a member. These committees have appropriate stakeholder representation and these processes will generate information that will inform future regulatory decisions by the Regional Board.

8.2 NPDES Permitting Issues

The National Pollutant Discharge Elimination System (NPDES) permits under the CWA are the mechanism by which capital-intensive technologies are implemented to meet specified schedules to achieve water quality standards. This has been accomplished in the San Francisco Bay Region for municipal and industrial dischargers to address conventional pollutants such as bacteria and oxygen demand, as well as toxic pollutants such as selenium in oil refinery discharges.

8.2.1 Ballast Water

NPDES permits could be used as the mechanism to implement ballast water treatment technology to achieve a zero-TMDL goal for exotic species. NPDES permits could be issued to individual ships as point sources, or take advantage of other organizational structures in place to reduce reporting and regulatory burdens. It may make sense to permit shipping companies or shipping agencies for ballast water management plans for a group of ships. Alternatively, ports could be permitted and held responsible for the discharges from ships that call at their berths. In discussions on this matter, it is pointed out that agencies already handle a number of regulatory matters for individual ships. From a regulatory standpoint, it could be simpler to hold land-based entities such as ports responsible for the pace and scope of ballast water treatment technology implementation. This TMDL report does not advocate any specific approach – it merely brings attention to an existing mechanism by which capital-intensive treatment technologies get funded and implemented in a reasonable timeframe.

For other programs such as industrial storm water, general NPDES permits are adopted statewide, and affected entities file notices to comply with such general permits. Permits are issued where there is the most control over the operation. The decision on how to use NPDES permits for ballast water discharges should be based on the best level to maintain the most control, and most efficient way of regulating. If you go too high up in the organization of responsibilities, you can lose the accountability, for instance for regular maintenance of treatment equipment. Some responsible party for the permit holder takes responsibility for the accuracy of the monitoring and compliance. Any NPDES permits should be issued at the level that makes the most sense in terms of accountability and efficiency.

A potential conflict exists between the CWA statute and its implementing regulations at 40 CFR 122.3(a) that does not require vessels to have permits for discharges under the National Pollutant Discharge Elimination System (NPDES) of point source pollution permitting. As described below under Section 1.2.1, the federal and state statutes define these discharges as point sources of pollution, but the regulations authored by the EPA presently may not allow the regulating system to impose any accountability or control on them. On January 13, 1999, a coalition of scientists and diverse groups formally petitioned the EPA Administrator to repeal the regulations set forth at 40 CFR 122.3(a), on the grounds that any vessel exclusion is illegal and runs counter to case law (Johnston, 1999). Eighteen representatives to Congress from the Bay Area jointly signed a bipartisan letter dated February 11, 1999, urging the Administrator to repeal the vessel discharge regulation at 40 CFR 122.3(a), on the basis that the regulation was drafted at a time when this exotic species vector was poorly understood. EPA responded on April 6, 1999, committing to a staff report on regulatory options by September 1999.

EPA completed the analysis of regulatory options on-time, but EPA management has withheld the public release of this analysis. No further analysis is provided in this report, and when the EPA report becomes available, it should be referenced for potential regulatory structures under NPDES permits.

The permitting system under the California Water Code, “waste discharge requirements” or WDRs, could be used to regulate vessel discharges to waters of the state. However, it is desirable to implement such surface water discharges under the federal NPDES program for two reasons. First, all surface water discharges in California are presently regulated under the NPDES program, and any permitting program for ballast water should be consistent with this approach. Second, states’ authority to regulate interstate and international commerce is legally controversial – the recent *INTERTANKO* decision (March 2000) ruled that the State of Washington could not institute worker safety requirements on ships that are more stringent than federal requirements. For this reason, use of the federal permitting system may be more legally defensible.

If certain regulatory barriers are removed at 40 CFR 122.3(a), the Clean Water Act’s NPDES permitting program could be applied to the ballast water and/or hull fouling discharges from ships. A diverse array of individuals and organizations are in favor of implementing the NPDES permit program due to its success in reducing pollutant discharges from cities and industries, and its associated proven enforcement mechanisms.

A successful model exists under the NPDES program that could be implemented based on the interaction of the state permitting authority (the Regional Board) and ports. In terms of the NPDES program, commercial ports are analogous to municipal sewage treatment plants, with shipping companies similar to industrial users of the municipal collection system. States and the EPA do not have the resources to permit every industry that discharges to a sanitary sewer, so the industrial pretreatment program was established and delegated to cities to implement. The cities remain responsible for the effluent that enters waters of the state, and design their industrial permitting programs to meet their “end-of-pipe” requirements. Some sanitation districts in California regulate over 500 industries under this program. The industrial pretreatment program has reduced industrial pollution of waters of this region by over 90% on a mass basis since its inception in 1983 (Wu, 2000).

Hypothetically, if ports took responsibility for a centralized collection and treatment system for ballast water, one NPDES permit could be issued for such a facility and the port would tailor requirements for its shipping companies to meet its “end-of-pipe” requirements. These “end-of-pipe” requirements could be water quality-based (e.g., viable organisms per volume discharged) or treatment-based, as with drinking water requirements in our nation. Alternatively, if on-board treatment systems were implemented by shipping companies, an NPDES permit for the port could detail the port’s responsibilities to provide assurance to the Board that these treatment systems are operational and meeting treatment standards. In either scenario, the permit would function as a memorandum of understanding between the Regional Board and the port - a clear statement of the procedures and responsibilities of each entity, as well as what is expected of the myriad ships that enter and exit the ports daily. Presently, existing law does not authorize the second scenario.

8.2.2 Other Point Sources

Besides ballast water, point sources identified in this TMDL report include exterior surfaces of vessels and aquaculture. For exterior surfaces of ships, any permitting structure used for ballast water discharges from larger commercial and military vessels could contain provisions for monitoring and abating the risks of fouling organisms. Industry practices already exist that address hull fouling, because of the economic incentives referenced in Section 4.3.1. For instance, Lloyd’s Register of Shipping, a reputable ship classification organization, requires as a condition of classification that ships go into dry dock a minimum of two times per five years (Jenkins, 2000). Additionally, ferries in the San Francisco Bay go into dry dock once per year to clean the hulls and other exterior surfaces (Dirk, 2000). Fouling of smaller vessels and recreational craft is currently addressed in marinas and boatyards around the estuary. In the early 1990s, the Regional Board adopted a general NPDES permit for discharges of cleaning waste from boatyards, focused on toxic pollutants contained in boat paint, encouraging best management practices to route process wastes into the sanitary sewer. The five-year permit expired, and these cases were transferred to the statewide general industrial storm water NPDES permit. Currently, Regional Board staff are inspecting these facilities and adding new facilities to the general NPDES permit. This exiting regulatory activity will address hull fouling of smaller craft in the San Francisco Estuary.

At this time, there are no registered aquacultural facilities in the San Francisco Estuary, according to the CDFG. Therefore, no permitting structures are recommended in this report. Facilities such as fish hatcheries are permitted by other Regional Boards in the state, and such regulatory structures could be applied if aquaculture were initiated in the watershed of the San Francisco Bay Region that drains to San Francisco Bay.

8.3 Discharge Standards for Ballast Water and Exotic Species

Ballast water discharges contain the two threats of exotic species introductions and pathogens. Standards should be developed that reflect a management or treatment technique's efficacy at basically eliminating both of these risks.

All parties, including industry, government, and environmental interests, agree that ballast water transport of exotic species is a problem. All parties recently reached agreement at an "Exotics Policy" summit in the Great Lakes in September 1999 that the United States should establish discharge standards for ballast water. This sentiment was echoed at a ballast water standards workshop in the Auatic Nuisance Species Conference in Toronto in February 2000. The Ballast Water Steering Committee of the ANSTF has formed a standards subcommittee to develop ideas for standards, under the direction of the USCG (see Section 1, Box 1). The State of Washington adopted a new law on March 24, 2000, calling for establishment of discharge standards for ballast water (see Section 1.2.7).

Discharge standards can be technology-based or risk-based (also called water quality-based). Technology-based limits can be based on certain measurements like total suspended solids (TSS) for municipal and industrial discharges, or can be simple treatment-based standards, such as filtration for surface water sources of drinking water (Surface Water Treatment Rule). Risk-based standards would involve characterization of discharges for specific exotic organisms of concern, such as the zebra mussel or *Pfiesteria piscicida*.

8.3.1 Technology-Based Standards

Under Section 312(n) of the Clean Water Act, EPA and the Department of Defense are cooperatively working on uniform discharge standards for armed forces vessels. Phase I of the process is complete, and the team have identified 25 discharges from vessels that need standards, including ballast water. Phase II is the standard-setting phase.

The Section 312(n) process is considering several criteria for setting standards, including environmental effects, feasibility of controlling discharges, impact on the armed forces, and cost. For the various discharges, the sequence of analysis is:

I. Identify technologies
II. Narrow technologies to vessels of armed forces
III. Set standard based on best available technology
IV. Check to see if it protects the environment
V. Recongnize that different vessels have different standards (existing vs. new)
VI. Adopt standard.

The 312(n) process is described to convey the idea that a technology-based standard gets set first, and then a process is in place to make sure that the environment is protected (risk-based). The same sequence should apply to ballast water discharges to the San Francisco Estuary, or any other waters of the United States.

8.3.2 Risk-Based Standards

Risk-based, or water quality-based, standards evaluate environmental effects of the discharge. The risk-based approach is troublesome even with chemicals, due to natural variability and uncertainty. Agricultural protection programs, referenced in Section 4, use a risk-based approach. As noted earlier, we do not have the predictive tools to know which organisms will successfully invade the estuary, and how many of them are necessary to instigate the introduction. The native temperature, salinity, and latitude ranges of ANS are not proven as effective predictors of future invasions.

Other nations of the world, particularly Australia, are considering ballast water management schemes other than the approach of implementing technology first. A risk-based approach considers the origin of recent invasive species to identify potential new invaders. Seventy percent of Great Lakes invaders are from the Black, Azov, and Caspian Seas, including the infamous zebra mussel, but less than 2% of the ships that call at the Great Lakes originate from these locations. This fact calls attention to secondary and tertiary shipping routes as vectors, for instance from the Baltic Sea.

Australia has adopted a “black list” approach that identifies species most likely to cause harm. This risk-based approach identifies potential source regions, physiological limits (temp., salinity, etc.), and determines the risk that species would be carried alive or as a resting stage to Australia in ballast water. A comprehensive procedure, a Decision Support System, has been initiated by AQIS, and is salinity and temperature driven, assuming no evolutionary response of species to new environments. It is a species-by-species approach that is time-consuming and expensive. Specific port berths have been characterized for exotic species throughout Australia, and risk factors are assigned to ships on domestic voyages based on the ports and berths where they take on ballast water. This approach has its merits, for instance in controlling the spread of the Chinese mitten crab from this estuary to other estuaries of the West Coast. But such an approach is vulnerable to overlooking unforeseen ANS that may not be pests in other locations where they are native or introduced.

Given the merits of both approaches, it seems that a combination of technology-based and risk-based approaches to ballast water discharges is warranted.

8.4 Ballast Water Management

Ballast water management is taken very seriously by the shipping industry, for the purposes of maintaining ship stability and trim, structural integrity, and minimizing ballast sediments to maximize cargo capacity. In the last three years, ballast water management for prevention of introduction of exotic species and pathogens has begun to make progress toward the goal of zero introductions.

As of the year 2000, the U.S. Coast Guard has begun to take an active role in evaluation of ballast water management schemes that are alternatives to the open ocean exchange recommended in the May 1999 NISA regulations. They point out that in designing management or treatment systems for ballast water, several characteristics of ballast water discharges need to be considered. First, the volume of water requiring treatment on a vessel is of concern. The ballast capacity of commercial vessels varies from 1,000,000 gallons to over 20,000,000 gallons, representing the difference between a passenger vessel and a bulk ore carrier. Clearly, even vessels that carry relatively little ballast water actually carry a substantial volume. Table 8-1 contains a summary of average ballast water volumes carried by different types of ships.

Second, the rate at which ships are designed and built to pump that water is of concern. As with total volume, the pumping rates vary greatly depending on ship size and the purpose of the ballast movement. At the low end, military and Roll-on Roll-off vessels moving ballast to manage stability, trim and heel may pump at rates of 50 – 500 m3/hr (13,000 – 130,000 gals/hr), while at the upper end, tankers and bulk carriers may pump ballast to replace cargo at rates of 5,000 – 20,000 m3/hr (1,300,000 – 5,300,000 gals/hr). As with total ballast water capacity, the rate at which ballast water is loaded and discharged is an operational challenge.

Ballast water treatment systems, whether shipboard, land-based, or operated from barges or trailers, need to be designed and constructed to meet these basic operational characteristics. Numerous other operational considerations, related to ship design and structure, trade routes, and industry manning practices, will also influence the practicality of specific treatment system technologies. These are reviewed at some length in a recent report by Darren Oemcke and published cooperatively by the Ports Corporation of Queensland (PCQ) and the Cooperative Research Centre for the Ecologically Sustainable Development of the Great Barrier Reef (James Cook University). This report “The treatment of ships ballast water” is available for downloading from the PCQ Web-site at http://www.pcq.com.au/pdf/pauline2.pdf.

Table 8-1 - Average Ballast Water Carried by Ships

Average amount of ballast water (in gallons per ship) in ships arriving at United States and San Francisco Estuary ports from foreign ports.

Ship Type	U. S. Average	Estuary Average
— Ships in Ballast —		
Bulk Carriers	3,800,000	1,670,000
Container Ships	not applicable [1]	not applicable [1]
Tankers	3,170,000	2,370,000
All 3 Ship Types	2,720,000	1,840,000
— Ships in Cargo —		
Bulk Carriers	–	1,670,000
Container Ships	1,380,000	1,380,000
Tankers	–	640,000
All 3 Ship Types	–	1,380,000
— All Ships —		
Bulk Carriers	3,000,000	1,670,000 [2]
Container Ships	1,380,000	1,380,000 [2]
Tankers	900,000	1,000,000 [2]
All 3 Ship Types	1,580,000	1,410,000 [2]
— Unpumpable Ballast —		
Bulk Carriers	18,000	–
Container Ships	38,000	–
Tankers	22,700	–
All 3 Ship Types	24,500	–

Source: Carlton *et al.* 1995, page 77

[1] Container ships rarely sail without cargo, and thus do not normally arrive "in ballast."

[2] The quantities of ballast water discharged by these types of ships entering the Estuary, calculated from data in US Coast Guard 1996, are:

Bulk Carriers	1,730,000 gallons
Container Ships	1,270,000 gallons
Tankers	2,760,000 gallons
All 3 Ship Types	1,520,000 gallons

The substantial difference in tanker data from the two studies is primarily due to Carlton *et al.* including data only for the relatively small tankers that call at the Port of San Francisco, and excluding the large tankers that call at the Estuary's oil refinery terminals.

The approaches to preventing the transfer of exotic species via ballast water can be broadly grouped according to whether the water is managed, for example through replacement, holding, or selective acquisition; or treated in some fashion, for example by heating, filtering, irradiating, or oxidizing. In reality, the eventually successful, and practical, approaches to preventing ballast-mediated introductions will almost certainly entail combinations of management and treatment actions. Below is a summary of the existing efforts currently known to the U.S. Coast Guard, to develop ballast water management and treatment systems for preventing introductions of exotic species. This is not an exhaustive list, and other efforts certainly exist. New systems seem to be proposed at every new technical conference.

8.4.1 Open Ocean Exchange

Ships' ballast water is already carefully managed – just not, in most cases, to prevent introductions of exotic species. As discussed in Section 1.2, the international, national, and state programs presently encourage ships' masters to exchange their ballast water for mid-ocean water while en route on the high seas. Below are some different techniques for open ocean exchange, which is considered a ballast water management approach, and not a treatment approach.

8.4.1.1 FLOW-THROUGH EXCHANGE

Flow-through exchange occurs when ballast water is flushed out by pumping in the mid-ocean water at the bottom of the tank and continuously overflowing the tank from the top, over the deck, until three full volumes of water have been changed. This method is employed to minimize the number of organisms remaining in the tank. It is thought to be more effective at removing organisms than the empty/refill method based on some studies, and it may be less stressful to the hull.

With most current ballast system configurations, this is potentially safer than empty/refill, but not absolutely so, and it's effectiveness is compromised by problems related to incomplete mixing and unpumpable volumes within the physically complex ballast tanks. Several improvements have been suggested, most involving changes in the design of the ballast plumbing. Some of these are:

The Brazilian Dilution Method – so named because it was first advanced by engineers with the Brazilian corporation Petrobras. This approach rearranges the intake and outlet plumbing to increase mixing efficiency and avoid safety problems associated with manually opening and closing deck manholes, and large volumes of water flowing over the decks. Accessory stripping pumps are often advocated to reduce the residual volume. There have been several subsequent variations of this design approach put forward by other naval architects and marine engineers.

Swish & Spit – This has lately been proposed as a solution to the NOBOB problem in the Great Lakes, where vessels entering the Lake system from foreign waters may have a considerable volume of unpumpable water and accumulated sediment in their ballast tanks. The idea is, to sequentially and rapidly pump aboard and discharge small quantities of mid-ocean water. This will tend to resuspend sediments, which will then be discharged, and to replace fresh or brackish residual water with high salinity mid-ocean water. Preventing the accumulation of sediment in the tanks will also reduce the accumulation of resistant algal cysts and resting stages of undesirable organisms. A version of this is already employed as a good ship-husbandry practice, because rapid replacement of turbid ballast water from riverine or enclosed coastal ports with clearer ocean water prevents the build-up of a heavy sediment load that reduces cargo capacity (Everett, 2000).

8.4.1.2 EMPTY/REFILL EXCHANGE

Empty/Refill Exchange occurs when ballast water taken on in ports, estuarine or territorial waters is pumped out until the tank is empty, then refilling it with mid-ocean water. Under the USCG regulations, masters and operators are advised to pump out as close to 100 percent of the ballast water as is safe to do so.

Even under calm seas, this often results in unacceptable stress and strain conditions, for which there are not easy engineering solutions. Under heavy seas, this is simply not possible because of loss of trim and stability. There is also the problem of "unpumpable" residual ballast volumes and sediments, which prevent the complete replacement of water (and organisms). Some newer builds have been designed with improved ballast water systems that minimize (but don't completely negate) both the safety and efficiency problems. New builds for FedNav in Canada, for instance, are being designed with such improved sequential exchange capabilities (Everett, 2000).

8.4.1.3 HOLDING BALLAST WATER

This method has been touted as the "gold bullet" for the ballast water discharge problem, but certain ships such as bulk carriers engaged in one-way cargo trade would never be able to accomplish a zero-discharge. It is considered a specialized practice most applicable to newer container ships, the most common ship in the San Francisco Estuary. These vessels are now sometimes designed to relocate "locked in" ballast water within the ship during loading and unloading operations, thus reducing the need to discharge and take on ballast (Everett, 2000).

8.4.2 Ballast Water Treatment Technology

Control of ballast water discharges is an emerging category of technology. The increasing awareness of the problem of organism transfer via ships' ballast has encouraged research into existing and potential water treatment technologies which could be used to treat ballast water. At this time, it is not clear whether ship-based or port-based (including shore-based or barge-based) treatment would be the most effective approach. Nations leading such research include Australia, the United Kingdom, Canada, the United States of America, and New Zealand.

The following examples, provided by the U.S. Coast Guard, are meant to provide a picture of the breadth of approaches currently being investigated through shore or ship-based trials. This is not an exhaustive list, it merely represents the efforts which the USCG has been able to find; in most cases these are private concerns that have taken the initiative to inform the USCG about their activities. The numbers used are all provisional. These are all ongoing R&D efforts, and as such are subject to significant changes over time. For the same reason, treatment efficiencies are not specified, even though many of these efforts have conducted biological effectiveness tests.

Treatment systems, with a few exceptions, are almost all component-based, with primary, secondary, and perhaps tertiary stages. A frequent approach is physical separation (primary) followed by a physical biocide such as U.V. or ultrasound (secondary). Some concepts include provision for a subsequent chemical biocide (tertiary).

Hydrocyclonic separation coupled with U.V. irradiation - Hyde Marine / OptiMarin is currently installing a system on the P/V Regal Princess, for sea testing during the coming summer cruise season in Alaska/BC waters. This system will be tested at a flow rate of 200 m3/hr. The U.V. component is being adapted from production packages already used to kill bacteria and algae in injection seawater on ocean drilling rigs.

Maritime Solutions, Inc / Enviro Voraxial Technology is gearing up to test at the University of Maryland's Chesapeake Bay Laboratory. Flow rates for the initial tests with a 2" lab system will be 6-23m3/hr, although 8" (1,300 m3/hr) and 16" (11,000 m3/hr) are either already manufactured or in design. In preliminary tests, MSI reports that the 2" model removed over 90% of suspended sands, and that the design target for the 8" is 95-99%. At the ANS Conference in Toronto in February 2000, this group announced that they would also test a patented, natural derivative biocide (CutleriteTM) for use as a secondary or tertiary treatment. A product of black walnut trees, this allelopathic agent is reputed to be highly effective, and to have a rapid decay rate.

Velox Technology is currently testing its system in Vancouver, B.C. in collaboration with the Department of Fisheries and Oceans Canada. The flow rate for these laboratory tests is about 12 m3/hr, although rates of 80 – 340 m3/hr are reported for previous physical tests.

Filtration - The Northeast Midwest Institute's Great Lakes Ballast Water Treatment Demonstration Project, a collaboration involving many commercial and academic partners, has tested a system based on a self-cleaning filter on a barge in Duluth-Superior Harbor, Minnesota. They have reported good results down to a pore size of 50 microns at a flow rate of 340 m3/hr.

The Singapore Environmental Technology Institute is continuing to test a system based on a combination of self-cleaning and media filters. At flow rates of 50 m3/hr, they reported good removal efficiencies down to a pore six of 10 microns.

Filtration / Separation coupled with pressure & oxygen change - Browning Transport Management is gearing up to test their system in collaboration with Old Dominion University, in Virginia. Their dockside laboratory tests will be run at a flow rate of 70 m3/hr.

Heat - BHP Transport / Australian Quarantine and Inspection Service used engine waste-heat to raise ballast water to 38^{o}C on the M/V "Iron Whyalla", a bulk ore carrier operating between Japan and Australia, and demonstrated good effectiveness against all zooplankton and most phytoplankton.

Ozone - Nutech O3, Inc. of McLean, Virginia, is gearing up to test their ozone treatment system on a commercial vessel (probably a tanker – negotiations in progress) in summer 2000. This will be a tank-based treatment, and thus independent of flow rate. They report good results in shore-based trials using Chesapeake Bay bulk water samples.

A number of other systems have been proposed, based on a variety of approaches (ozone, gas supersaturation, heat, U.V., glutaraldehyde), but to the knowledge of the USCG these have not progressed to the point of testing actual engineered treatment systems.

The National Ballast Clearinghouse (link in USCG Ballast Water Management Homepage: http://www.uscg.mil/hq/g-m/mso4/first.htm) is developing a Ballast Water and Aquatic Invasions Research Directory (BWAIRD). This on-going, actively updated, directory will be accessible through the Clearinghouse Web site in the near future. One major topic of the directory will be ballast water management and treatment. The BWAIRD should greatly expand and update this list.

8.5 Challenges and Information Gaps

Technology-forcing regulation under the CWA is never simple. Establishment of a national effluent guideline for an industry that is especially controversial can take longer than eight years (Carlson and Charleton, 2000). There is no existing “black box” that can be readily applied to discharges of ballast water from ships. And a closer look at some of the details of the ballast water issue reveal a host of technical challenges to overcome. However, the potential costs of a national ballast water program should always be weighed against the potential costs of ongoing ANS invasions (already topping $5 billion annually) and the incalculable cost of the loss of biodiversity. In such an equation, a technology-based program does not appear cost-prohibitive, but much more attention is needed to cost out various ship-based or port-based treatment solutions to ballast water discharges.

8.5.1 Ballast Water Sampling – How Representative?

The techniques used to sample ballast water for organismal and chemical content are not straightforward. The equipment list for the New Zealand program is 1 ½ pages long, including various pumps for different types of tanks, transformers, hoses, tool box, tape, filters, buckets, rope, stationery, clothing, plankton and seine nets, and pH/salinity meters (Cawthron Institute, 1997).

Even if a sample is successfully brought up through the deck of a ship, it may not represent the full range of water quality in the tank. Ballast tanks are not homogeneous completely-mixed reactors, but are characterized by various geometries with structural elements and corners where sediments accumulate. Each time water is emptied from a tank, it is similar to the tide going out – organisms burrow into the sediment for refuge much like that at an ocean beach.

The low-head ballast water pumps, typically located over 10 feet below the water line, send and retrieve water through a bell-shaped structure faced down on the tank floor. The area near the inlet is typically devoid of sediments due to the high velocities at the inlet, and the problems in the interior of the tank, with respect to exotic species, are far-removed from the inlet/outlet area, rendering exchange procedures less effective. For example, the sediments that could harbor resting stages of ANS accumulate in areas behind structural elements far from the inlet/outlet. In addition, the biofilms of potentially dangerous microorganisms that form on the structural elements and tank walls are located too far from the inlet/outlet to be physically removed by the high flows.

8.5.2 Verification Techniques for Exchange or Treatment

Currently the national program relies on ship masters' reporting of ballast water discharge locations and volumes, and whether or not an open ocean exchange has been carried out. The only technique the USCG presently uses is salinity. This technique can verify that a ship inbound from a fresh/brackish water port has exchanged its ballast water with mid-ocean water, but does nothing to verify the master's word from a ship inbound from a salt water port, such as Osaka, Japan. The current lack of verification tools for the national and state ballast water programs renders the programs relatively weak in the category of public accountability.

Recognizing the importance of accurate verification techniques, the USCG has recently convened a committee under the ANSTF to study alternative techniques, such as inspecting pumping and engine records (as Australians have done) and using biological measurements such as copepods or bioluminescence. Alternatives to salinity testing are all in the developmental phase.

8.5.3 Retrofitting Ships and Design of New Ships

Ships are typically very crowded with equipment. A typical ship has very little room to install new equipment and piping, let alone space enough to transport the new equipment to its intended location. Sewage package plants and oil/water separators have been installed on ships to comply with MARPOL requirements, and they are typically wedged into very small spaces. In addition, the high-flow, low-head pumps that move ballast water are located well below the water line, unable to move water up and out of a ship for treatment purposes. Given these substantial constraints, costs of retrofitting ships to accommodate on-board or on-shore treatment options are expected to be fairly high.

One of the most important changes that could occur quickly is the way ships are designed, and what technologies are incorporated into those designs. In the next two years, review of ship design standards to abate exotic species introductions should be a top priority for the EPA and the USCG. This is one of the recommendations that came out of the NISA workshop that generated the table included as Attachment 1.

8.5.4 Monitoring Issues

8.5.4.1 BIOLOGICAL SAMPLING OF AMBIENT WATERS

In order to evaluate the efficacy of the existing and future national and state programs, ambient monitoring of the organisms of the estuary is critical. This point has been made throughout this TMDL report, and the maps in Section 4 and Attachment 2 provide spatial information on potential portals of entry for exotic species in the estuary.

AB 703 contains provisions for the California Department of Fish and Game to conduct field surveys and biological studies in areas of the state that are not well characterized. Although San Francisco Estuary is frequently identified as one of the most-studied estuaries in the nation, monitoring needs to be ongoing here as well, in order to evaluate the effectiveness of existing or future programs for ballast water control. Any patterns of invasion detected in such ambient monitoring will need to be analyzed relative to temporal sequence, source regions, and invasion pathways.

8.5.4.2 BIOLOGICAL SAMPLING OF BALLAST WATER AND OTHER SHIP VECTORS

It is surprising that very little information is available, outside of the scientific literature referenced in Sections 2 and 4, regarding the biological content of ballast water. No sampling has occurred in this estuary (Cohen, 1999). However, the process of elimination has revealed ballast water as the only plausible source of species recently introduced to this estuary (Tables 4-2 and 4-3).

To inform management decisions, a regular ballast water sampling program is needed to develop data on organisms being discharged to the San Francisco Estuary, and the characteristics of the ballast water. This would provide data for risk assessments and for analysis of the comparative risk of different introduction pathways; baseline information against which to measure ballast water exchange and treatment efforts; and data needed to design effective treatment systems. This could potentially include collection and identification of:

- Invertebrate plankton by direct examination
- Culturing invertebrate plankton to adult stage (necessary to identify many larval forms)
- Phytoplankton, including potentially toxic forms such as some dinoflagellates
- Bacteria, including various species of *Vibrio*
- Viruses
- Organisms in ballast sediment
- Larger organisms such as fish.

The ballast water sampling program could include analysis of other contaminants such as:

- Fecal coliforms

- Trace contaminants including metals and organics (derived from source water or tank coatings).

The program could also include analysis of ballast water characteristics that would affect treatment processes, such as:

- Turbidity, color, total suspended solids, and particle size distribution (which affects chemical biocide or UV disinfection)
- Organism sizes (which affects filtration processes)
- Iron and calcium content (whose precipitation could affect UV disinfection)
- pH, alkalinity, etc. (can affect various treatment processes).

Sampling programs could also assess the importance of two other ship vectors:

- Hull fouling (by diver or in-drydock surveys)
- Anchor chains, sea chests, and other exterior surfaces (in-drydock surveys).

8.5.5 Ballast Water Discharges and Shipping Traffic

As noted in Section 4.2.3, new information on ballast water discharge locations and volumes in the San Francisco Estuary is currently not available. Some attempts at estimating these volumes were made in the San Francisco Estuary Institute report of 1998. To accomplish the TMDL, a systematic program needs to be coordinated based on existing efforts of SERC to collect data on vessels from foreign ports, and the Port of Stockton and Port of Oakland efforts to supplement this data with data from domestic voyages. Currently the data is based on reports submitted by ship masters to the USCG. Some effort should be made to make actual measurements and compare them to the reported levels. Moreover, the biological content and water quality of these discharges must be characterized to enable the EPA, USCG, and the Regional Board to determine the best decision on a comprehensive approach to managing discharges from ships that currently threaten all the beneficial uses of the estuary.

To address exotic species, we can look to successful regulatory and technical tools that exist in our regulation of sewage, industrial wastewater, and drinking water. As a result of these tools, pollution and water-borne disease have been significantly reduced in this nation, with costs and controversy along the way. It is reasonable for us to explore the ability of these existing tools to stem the rising tide of harmful exotic species in our waters – it is consistent with their original intent.

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List of Acronyms

ANS- Aquatic Nuisance Species
ANSTF or ANS Task Force- Aquatic Nuisance Species Task Force
DFO- Department of Fisheries and Oceans Canada
EPA- United States Environmental Protection Agency
IMO- International Maritime Organization
NANPCA- Nonindigenous Prevention and Control Act of 1990 (P.L. 101-646)
NIS- Nonindigenous Invasive Species
NISA-National Invasive Species Act of 1996 (P.L 104-332)
NOAA- National Oceanic and Atmospheric Administration
PBWG- Pacific Ballast Water Group
PMSA- Pacific Merchant Shipping Association
SERC- Smithsonian Environmental Research Center
SFMX- San Francisco Marine Exchange
UN- United Nations
USCG- United States Coast Guard
USFWS- United States Fish and Wildlife Service
USGS- United States Geological Survey

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Attachment 1 – A Comparison of Ballast Management Program Provisions

A COMPARISON OF BALLAST MANAGEMENT PROGRAM PROVISIONS - IMO, US Nat'l and GL Programs, and CA Program (from Northeast Midwest Institute, 2000)

	IMO[1]	US National Program	GL Program	CA
PRIMARY BALLAST WATER MANAGEMENT				
Voluntary?	X	X (conditional after 2 yrs.)	X (for 2-yrs only)	NA
Mandatory?	O	X (potential after 2 yrs)	X	X
Safety exemption?	X	X (no strings attached)	X (strings attached)	X
Other exemptions?	X	X[2]	O	X[2]
Applicable to domestic intrabasin/coastal voyages?	O	O	Ltd	O
Applicable to construction of new ships?	O	O	O	O
Applicable to construction of existing ships?	O	O	O	O
Alternative treatment methods allowed?	X	X	X	X
Standards for alternative treatment?	O	Ltd	Ltd	Ltd
Responsive to unique regional needs?	O	Ltd	X	X
Process for approving/removing treatments?	O	Ltd	Ltd	Ltd
Requirements on groups besides shipping such as ports and recreational boaters?	O	O	O	O
Compatible with National and International programs?	X	X	X	X
1 Current Assembly Resolution 2 TAPS trade exemptions				

	IMO	US National Program	GL Program	CA
ADDITIONAL MANAGEMENT MEASURES (BMP's)				
Applicable to ballast water?	X	X	X	X
Applicable to residuals/NOBOB's?	Ltd	Ltd	Ltd	X
Applicable to sediment disposal?	X	X	X	X
Applicable to ship vectors other than ballast tanks?	O	X	O	X
Ballast management plan requirement/guideline?	O	X	X	X
Fees to support program?	O	O	O	X
Incentives for alternative treatment?	O	O	O	X
REPORTING				
Reporting of ballast management activity for voyages from outside the EEZ?	O	X	X	X
Reporting of ballast management activity for coastal voyages?	O	O	O	Ltd
Uses IMO standard/compatible form?	X	X	X	X

	IMO	US National Program	GL Program	CA
VERIFICATION/ENFORCEMENT				
Verification that all ships are reporting primary ballast management activity?	O	X[1]	X	X
Sampling to verify management activity?	O	X[2]	X	X
Other methods (e.g. Newcastle) to verify management activity?	O	X[3]	X[3]	X
Penalty for non-reporting?	NA	O	X	X
Penalties for non-compliance with management requirements?	O	X (potential after 2 yrs)	X	X
Electronic submission of form?	NA	X	X	X
Dedicated enforcement entity?	O	X	O	X
RESEARCH				
Demonstration of alternatives to BWE?	O	Ltd	Ltd	X
Assessment of efficacy of BWE?	O	Ltd	Ltd	X[4]
Assessment of rate of introductions (and baseline)?	O	Ltd (NOAA/FWS)	Ltd (NOAA)	X
Research on species transport/survivability?	O	Ltd	O	X
Development of standards for alternative treatment?	O	X	X	X
1 Compare to customs and MARAD information 2 Beginning in January 3 Compare to Logbook [4] Deadline for this is December 31, 2002				

	IMO	US National Program	GL Program	CA
DATA ANALYSIS				
Comprehensive evaluation of reporting data from ships coming from outside the EEZ?	O	X	X	X
Comprehensive evaluation of reporting data from ships engaging in coastal trade?	O	O	O	?
Comprehensive evaluation of monitoring data?	O	X	X	X
Evaluation of regional shipping patterns?	O	Ltd[1]	Ltd[1]	X
Evaluation of national shipping patterns?	O	Ltd[1]	NA	NA
Evaluation of regional baseline ecological data?	O	Ltd (NOAA, FWS)	Ltd (NOAA)	X
Data base for ballast research?	NA	X	NA	NA
OUTREACH TO AND FEEDBACK FROM STAKEHOLDERS				
Outreach program for mariners?	O	X	X	X
Outreach program for public?	O	Ltd	Ltd	X
Opportunities for stakeholders to give feedback to the program?	O	Ltd	Ltd	X
[1] Does not include coastal voyages				

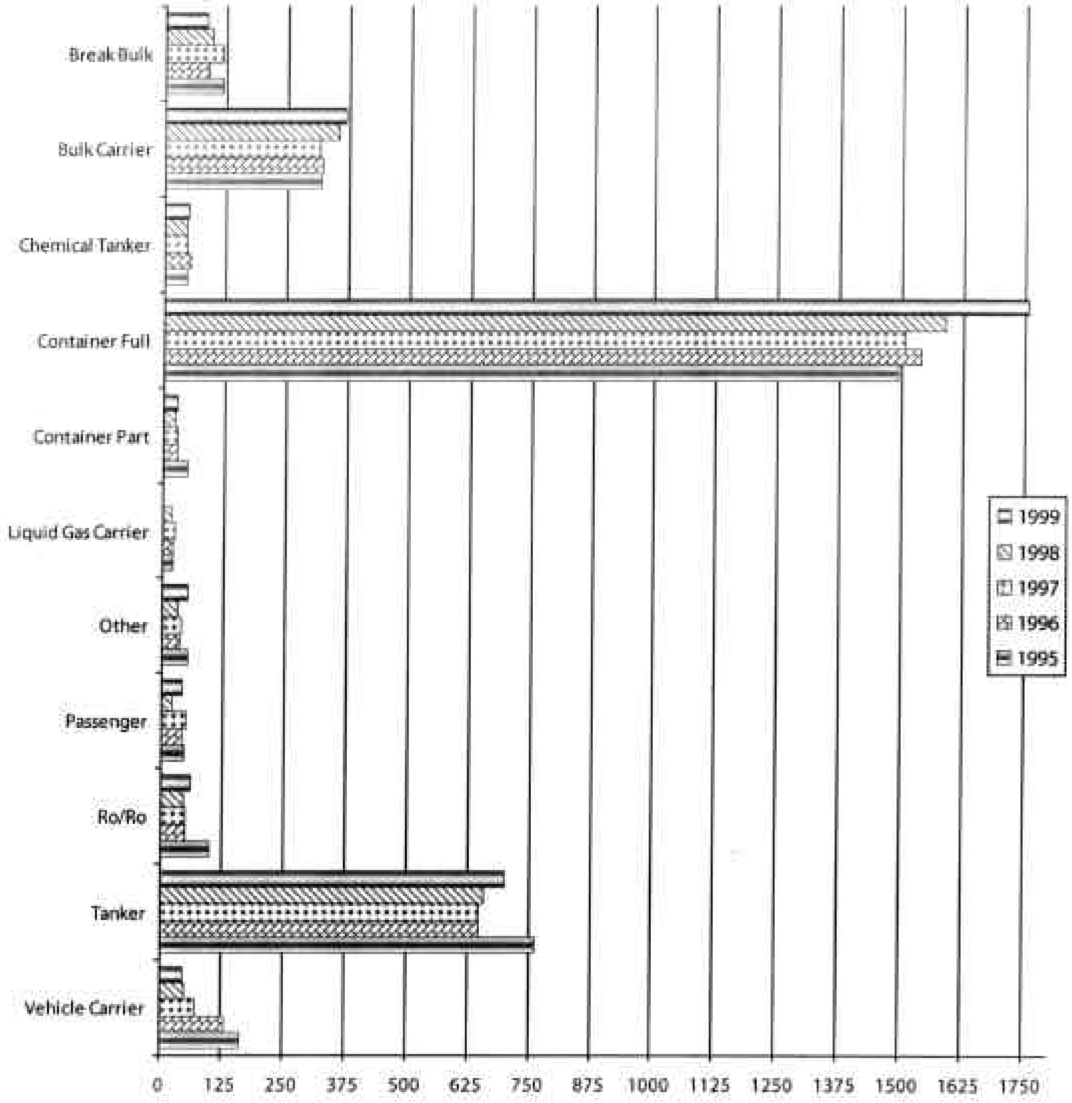
	IMO	US National Program	GL Program	CA
PROGRAM EVALUATION				
Review of compliance?	O	X	O	X
Review of treatment effectiveness - How effective are the treatment methods used?	O	X	O	X
Review of program scope and compliance - How many ships are participating?	O	X	O	X
Review of overall program effectiveness - How effective is the program at preventing invasions?	O	X	O	X
Ability to revise program after evaluation?	O	X	O	O
Provide for a cost-benefit analysis of program?	O	O	O	X
FINANCIAL INCENTIVES/REQUIREMENTS				
Funding provided for research?	O	X	O	X
Funding provided for ship construction?	O	O	O	O
Funding provided for technology innovation?	O	X	O	O
Incentives for installing treatment technology?	O	O	O	Ltd

Attachment 2 – San Francisco Estuary Shipping Traffic and Maps of Ports and Terminals

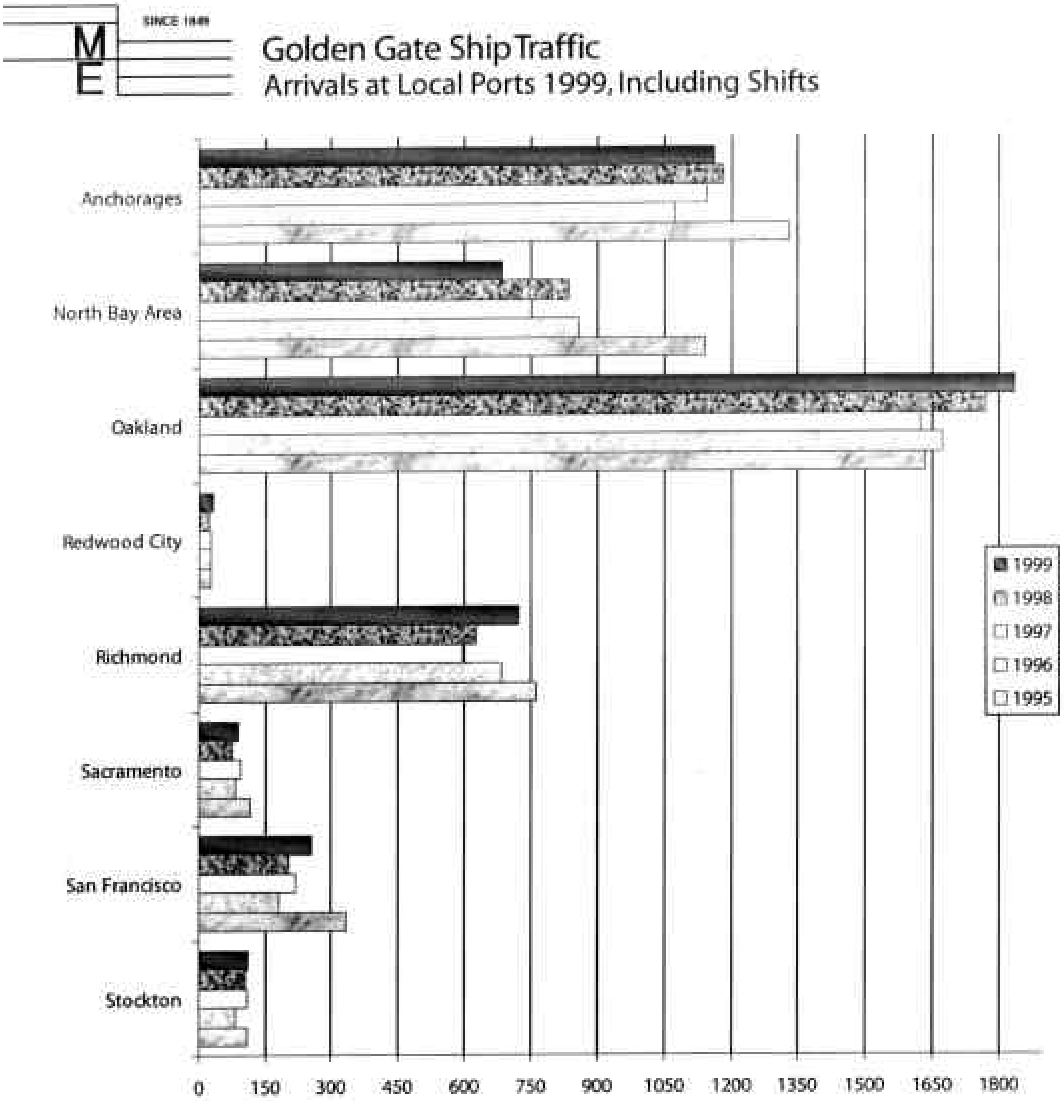
From the San Francisco Marine Exchange's

Annual Ship Traffic Report
And
Biennial Golden Gate Atlas

Golden Gate Ship Traffic
Arrivals by Type 1999



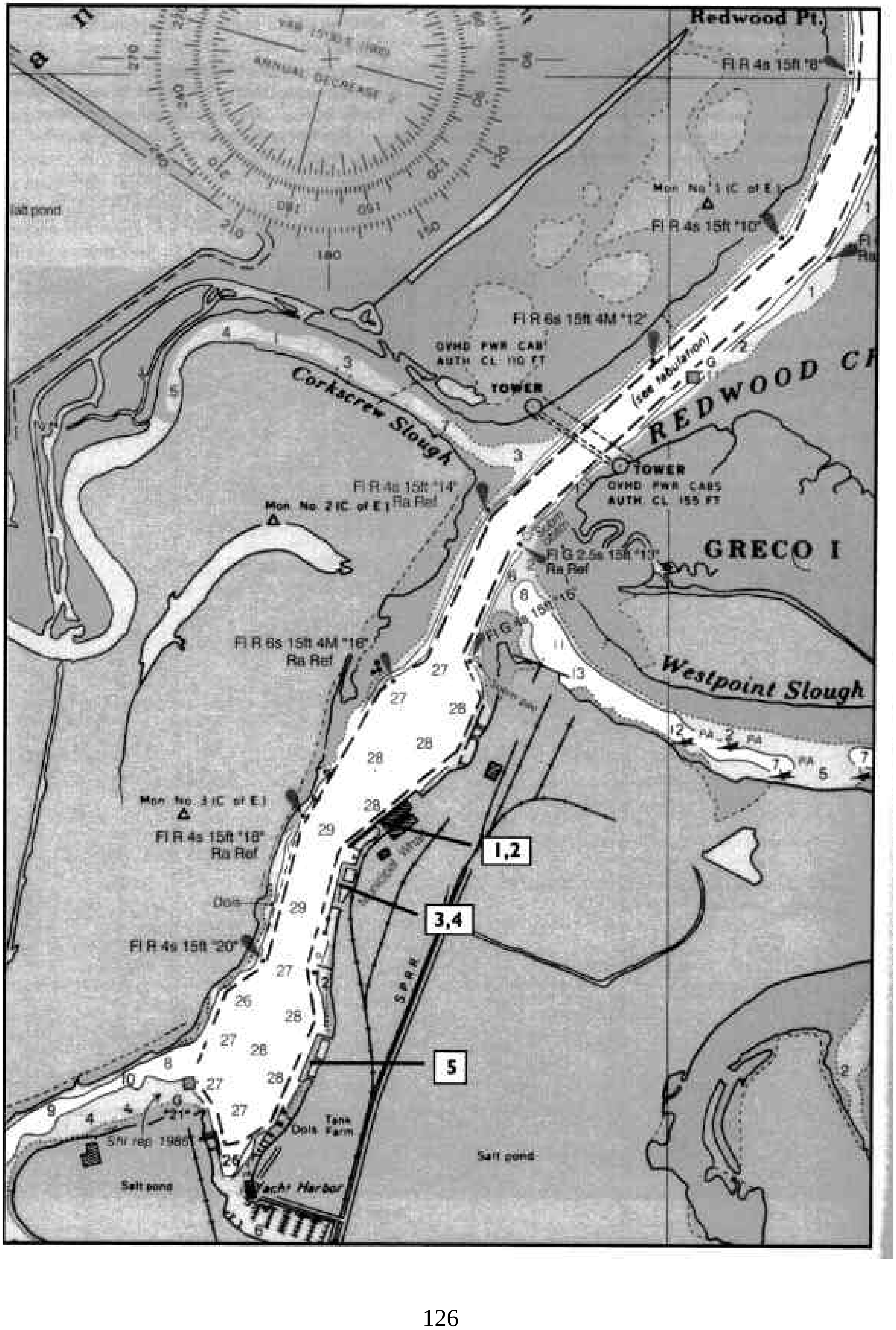
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Break Bulk	13	5	9	5	7	7	5	7	6	7	6	9	85
Bulk Carrier	42	22	27	33	38	25	30	31	31	22	38	27	368
Chemical Tanker	3	5	4	4	8	0	7	5	2	4	6	1	49
Container, Full	139	137	145	144	149	154	145	157	149	145	143	149	1,756
Container, Part	2	2	1	5	1	1	2	1	1	4	2	4	27
Liquid Gas Carrier	1	1	3	3	4	2	2	0	2	1	1	1	20
Other	0	1	3	7	4	3	4	4	3	4	0	3	52
Passenger	1	0	1	3	8	5	6	6	9	2	0	3	44
Roll-on/Roll-off	6	5	5	7	4	5	7	6	5	5	3	2	60
Tanker	46	37	56	70	66	56	74	67	61	52	63	53	701
Vehicle Carrier	2	5	4	5	5	3	4	3	3	3	4	4	45
Totals	**255**	**223**	**258**	**286**	**294**	**261**	**286**	**287**	**272**	**249**	**266**	**256**	**3,192**



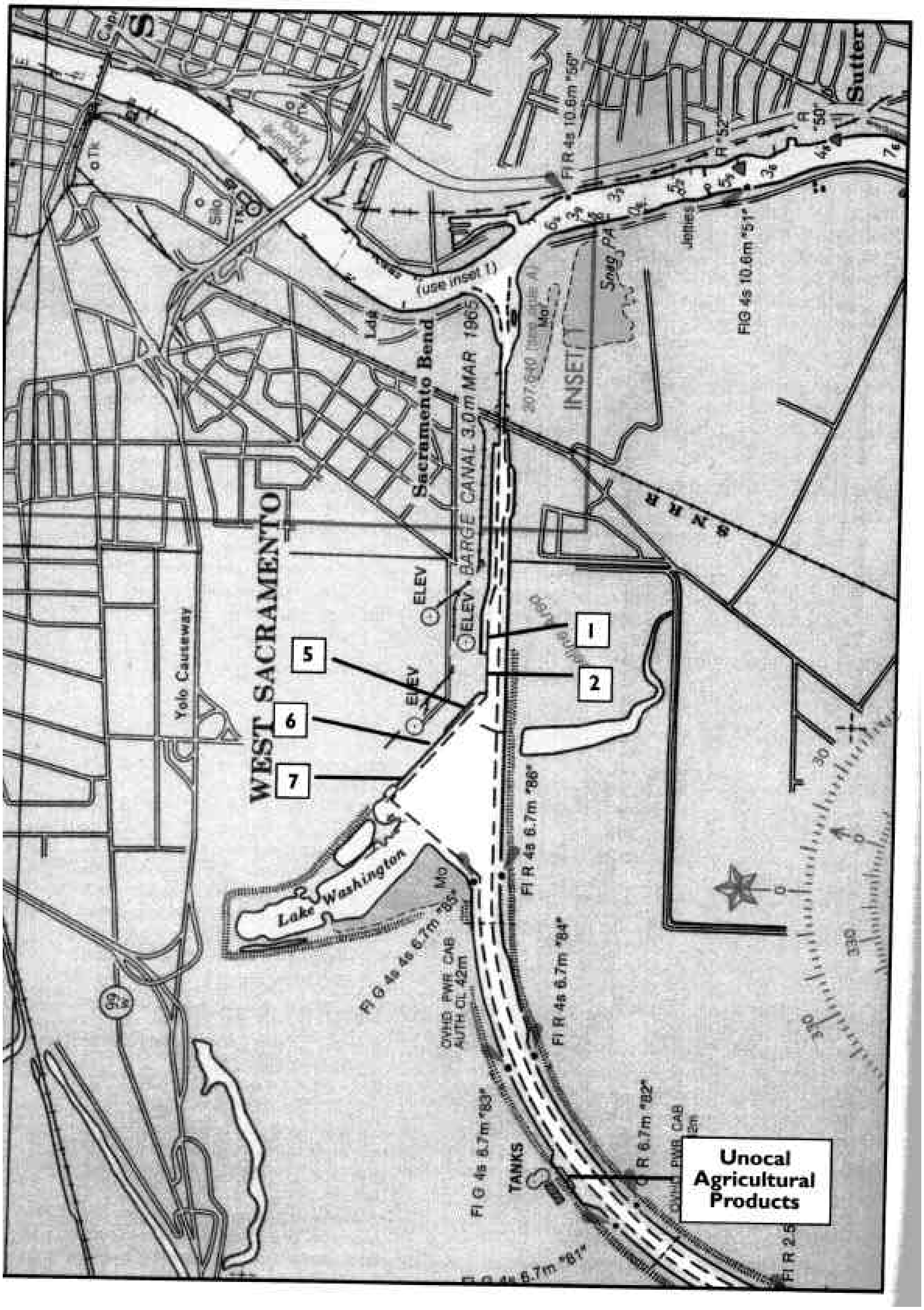
Golden Gate Ship Traffic
Arrivals at Local Ports 1999, Including Shifts

Port	**Arrivals**
Anchorages	1,161
North Bay Area	685
Oakland	1,834
Redwood City	31
Richmond	721
Sacramento	85
San Francisco	253
Stockton	111
Total	**4,881**

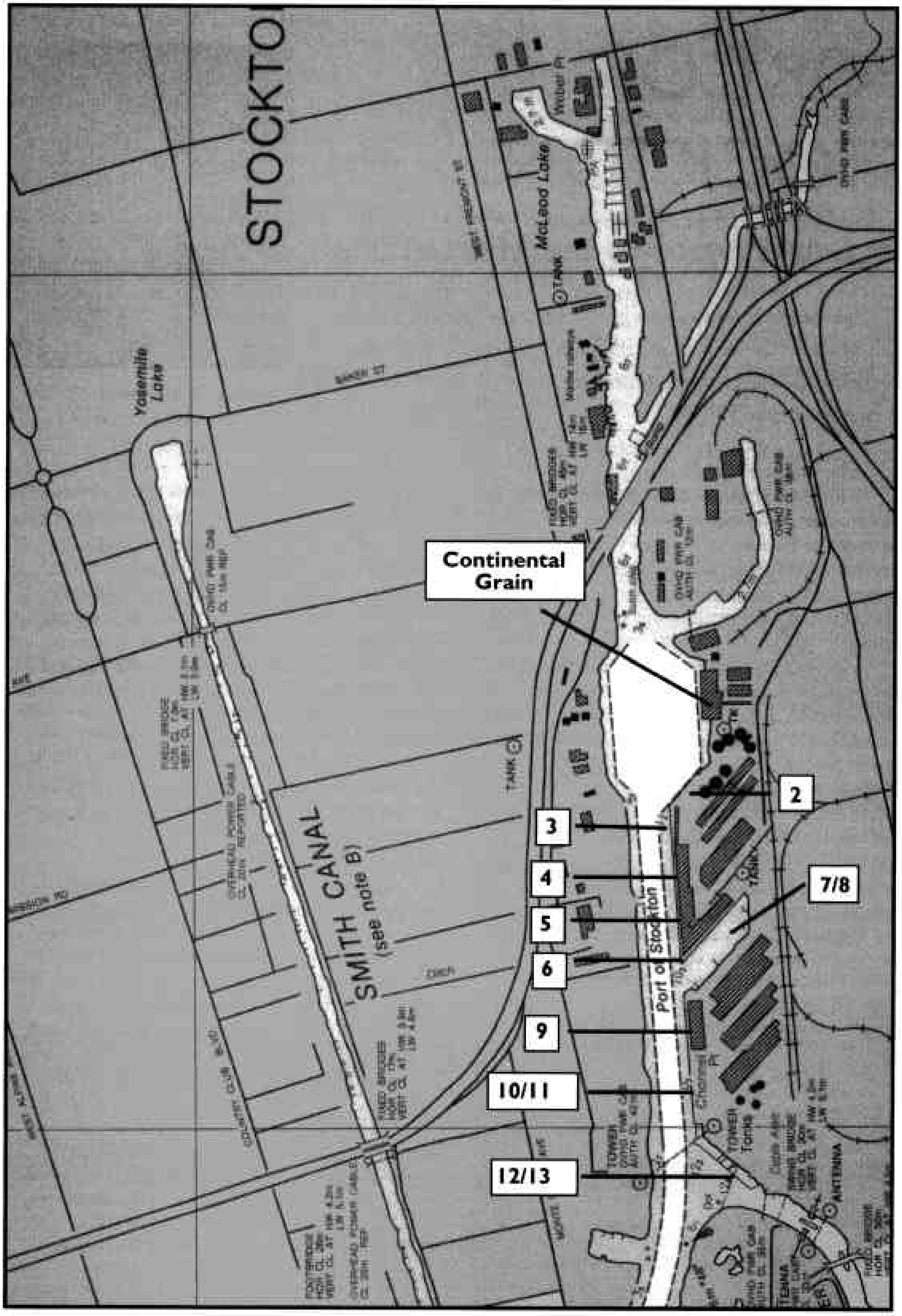
PORT OF REDWOOD CITY Berths



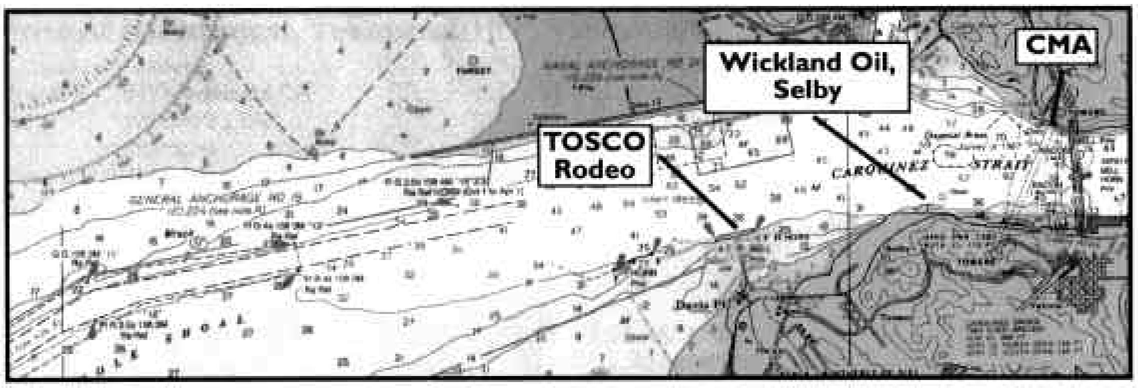
PORT OF SACRAMENTO Berths

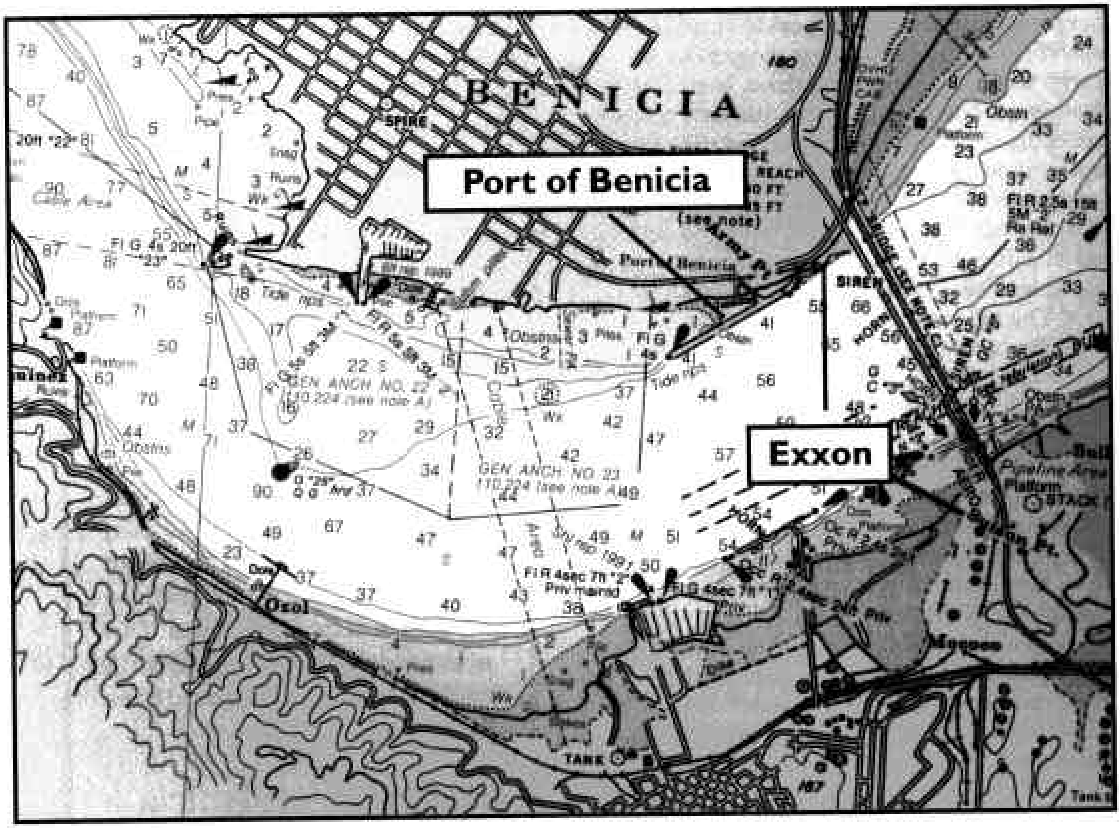


PORT OF STOCKTON Berths

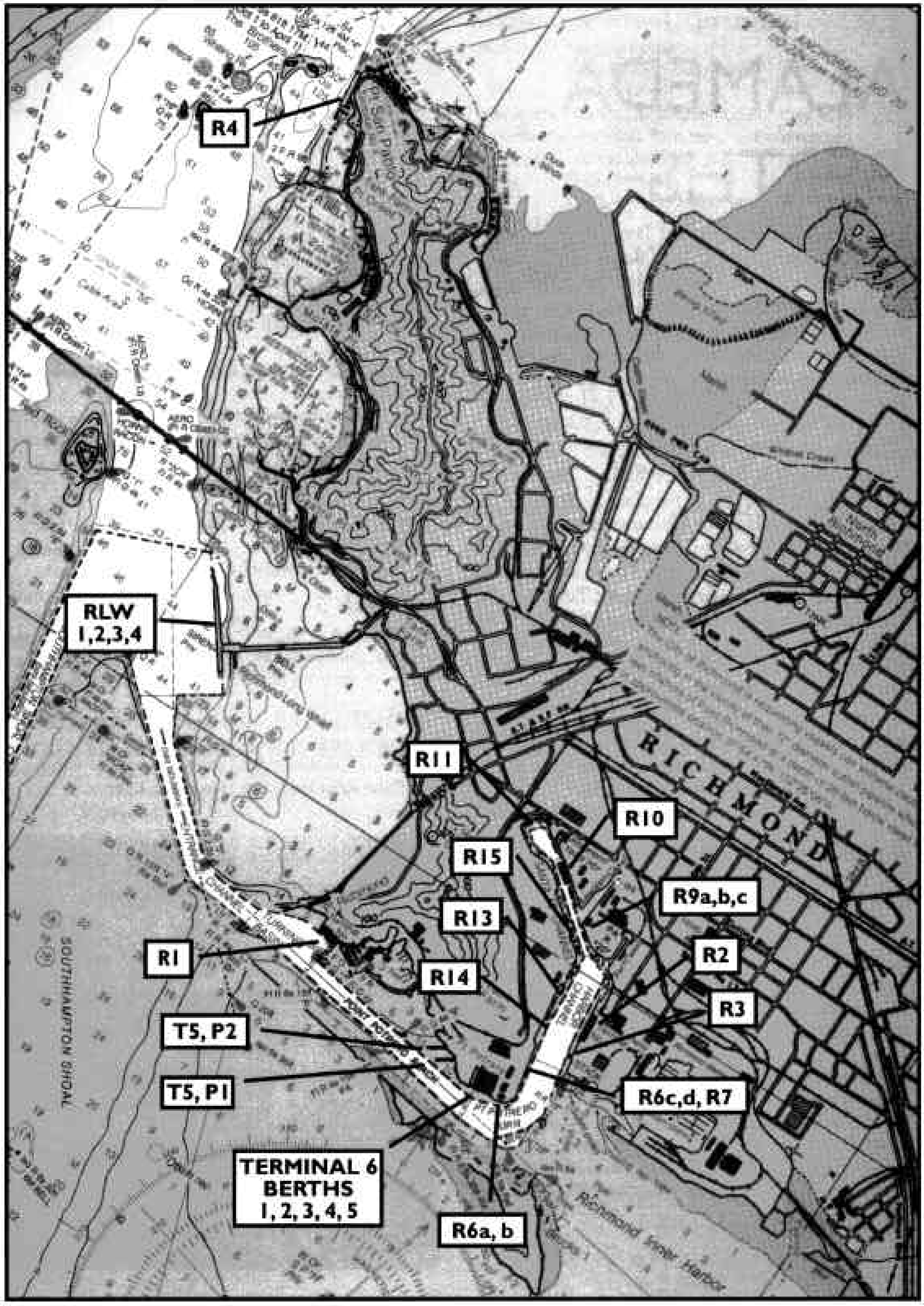


NORTH BAY AREA PORTS and TERMINALS

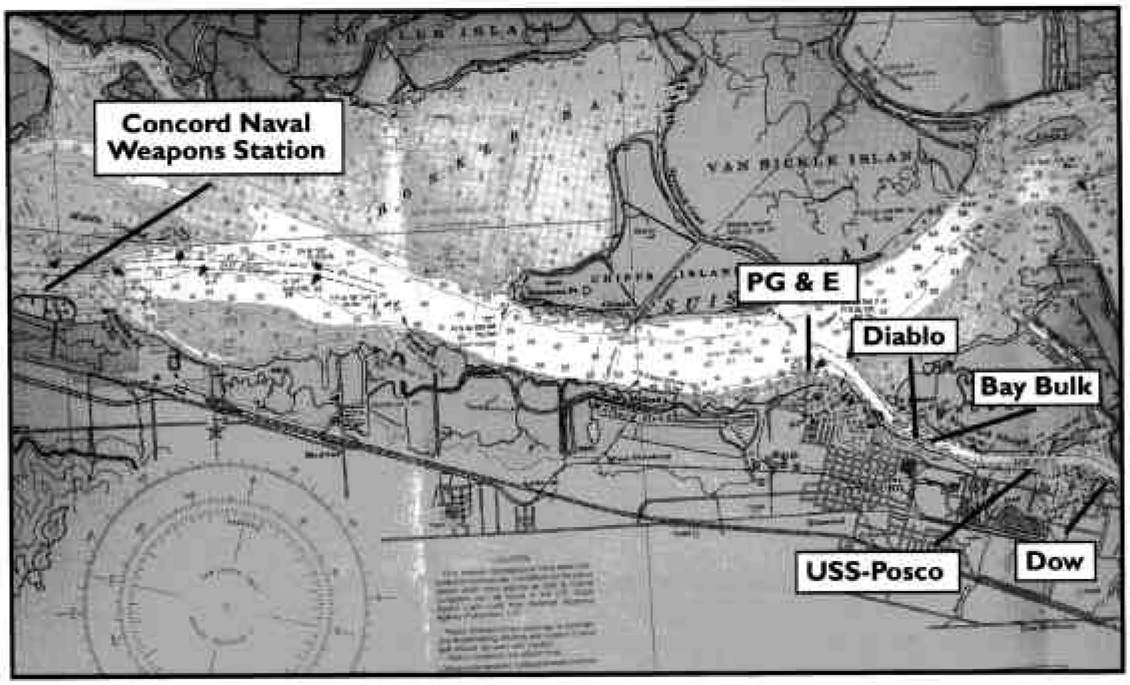


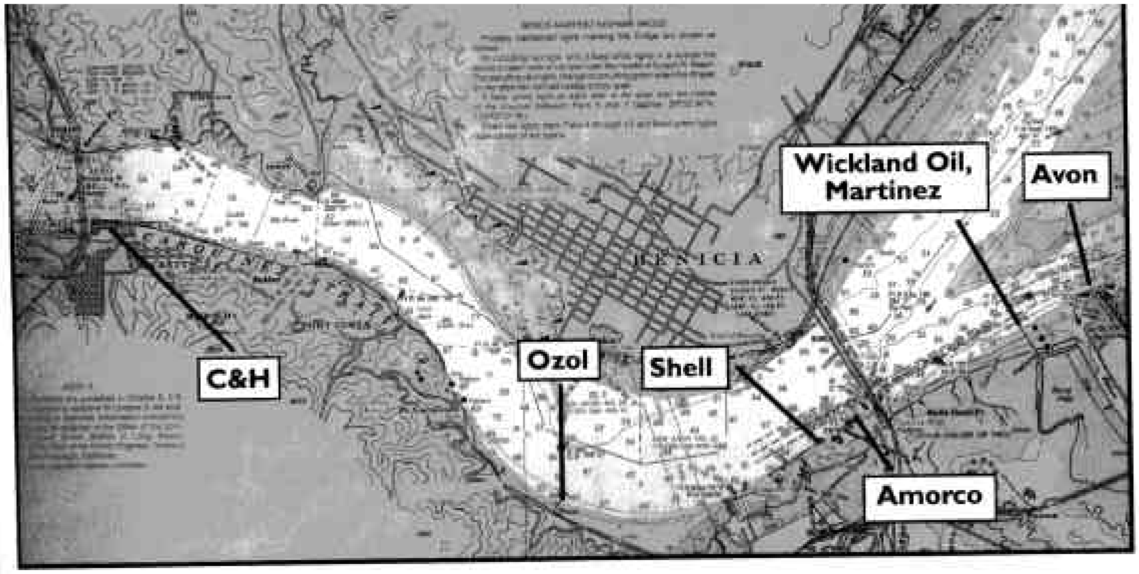


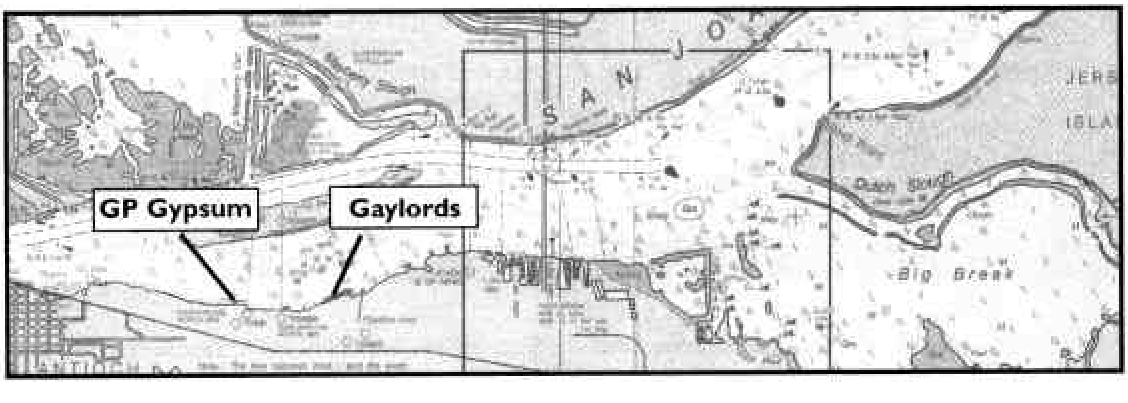
PORT OF RICHMOND Berths



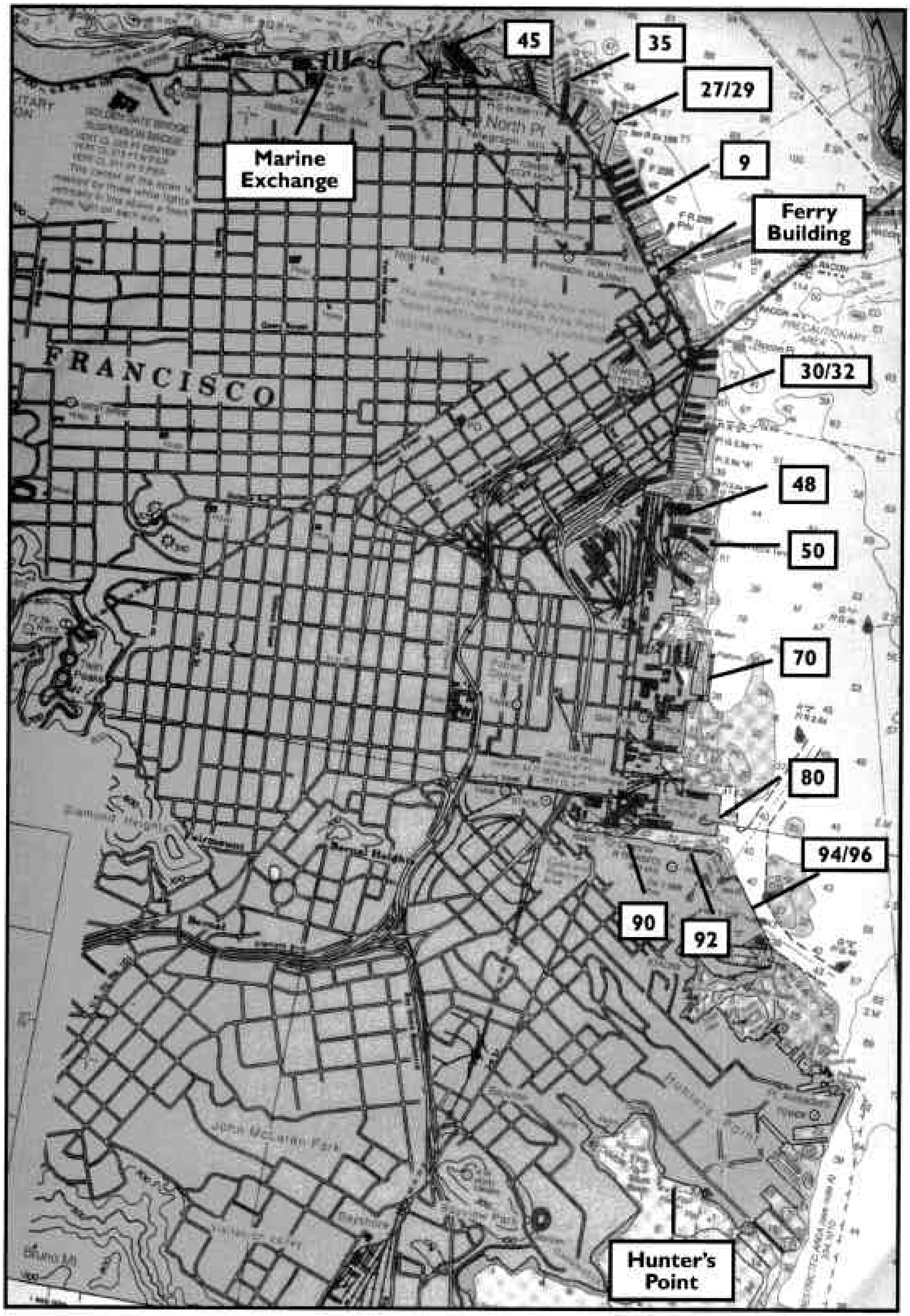
TERMINALS OF CARQUINEZ STRAIT, SUISUN BAY, and SAC./S.JOAQ. RIVERS



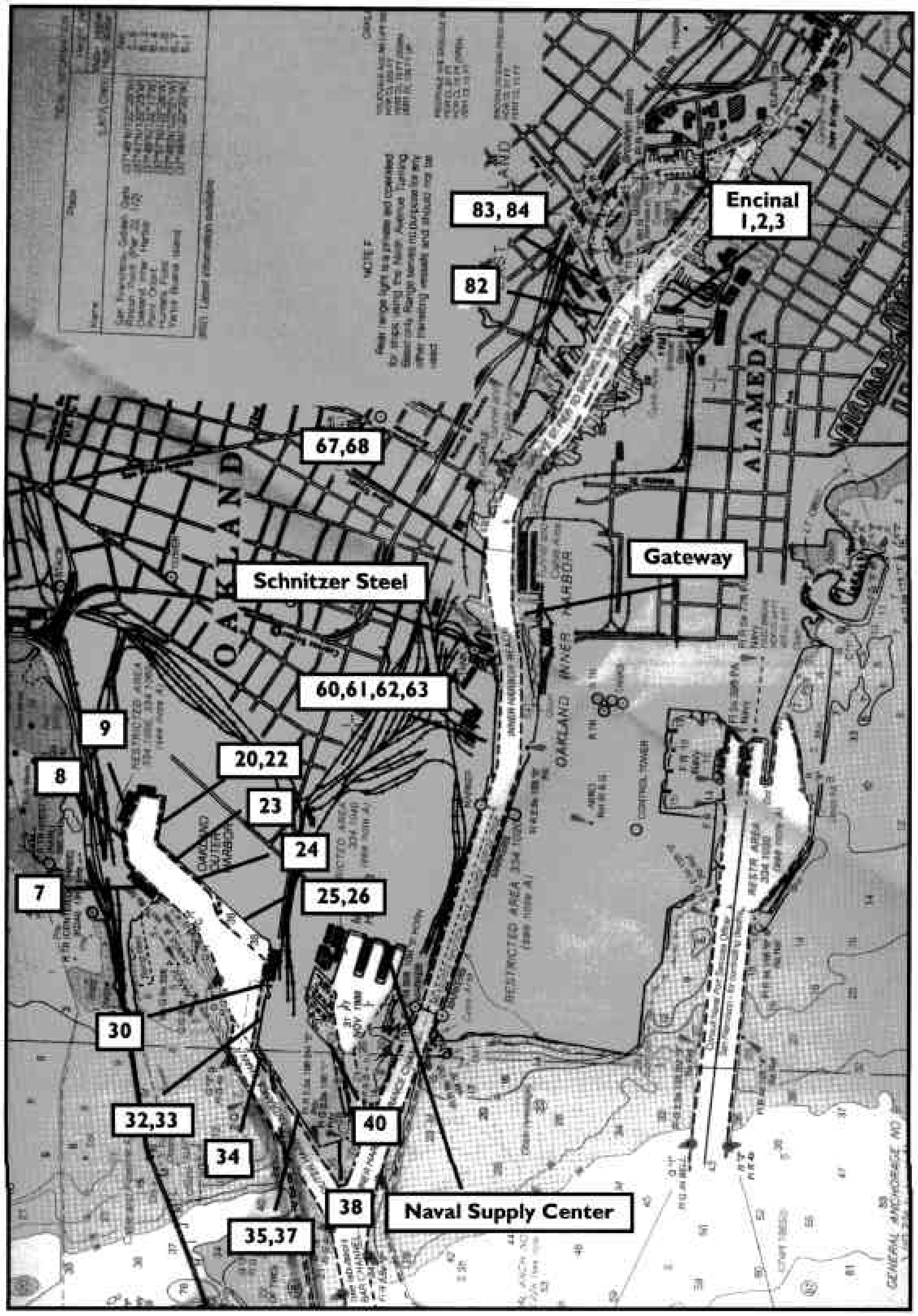




PORT OF SAN FRANCISCO Berths



PORT OF OAKLAND and ALAMEDA Berths



ARRIVALS BY BERTH, 1999

Port Area	Berth	Arrivals
Anchorages		**1161**
	No. 5	11
	No. 7	75
	No. 8	276
	No. 9	779
	No. 14	2
	No. 19	1
	No. 23	15
	New York Point	2
Oakland		**1834**
	7	55
	20	111
	22	61
	23	246
	24	139
	25	49
	25/26	45
	26	11
	30	140
	32	43
	32/33	30
	33	54
	34	1
	35	172
	36	6
	37	131
	60	69
	60/61	1
	61	75
	62	122
	63	29
	67	114
	68	102
	82	15
	83	1
	Schnitzer Steel	12
North Bay Area		**685**
Antioch		**16**
	GP Gypsum	16
Benicia		**166**
	Coke	7
	Benicia Industries	35
	Exxon	124
Concord Naval Weapons Station		**22**

Port Area	Berth	Arrivals
Martinez		**246**
	Equilon	94
	Ozol Oil	2
	TOSCO, Amorco	4
	TOSCO, Avon	52
	Shore Terminal	94
Pittsburg		**60**
	Bay Bulk	19
	Diablo Services	11
	Dow Chemical	4
	U.S. Steel (POSCO)	26
San Pablo Bay		**175**
	Crockett	29
	TOSCO, Rodeo	65
	Shore Terminal, Selby	81
Redwood City		**31**
Richmond		**721**
	R2 (California Oils)	23
	R3 (RT 3)	78
	R4 (Paktank and PM Ag)	15
	R5 (MSRC)	1
	R6 (Pasha)	2
	R7 (Pasha)	5
	R8 (Time Oil)	23
	R9 (Levin Richmond)	46
	R10 (Texaco)	18
	R13 (Unocal)	53
	R14 (ARCO)	32
	R15 (Gold Bond)	13
	Chevron Longwharf	412
Sacramento		**85**
San Francisco		**253**
	15	1
	27	1
	30	4
	32	3
	35	42
	50	2
	70	1
	80	148
	92	28
	94	1
	96	6
	AAA	1
	San Francisco Dry Dock	15
Stockton		**111**
SAN FRANCISCO ESTUARY TOTAL		**5566**

Source: San Francisco Marine Exchange, 2000